Hunter-gatherer and Environmental Relations during the Mesolithic of Atlantic Europe.

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Hunter-gatherer and Environmental Relations during the Mesolithic of Atlantic Europe.

Volume I

Submitted for the award of the
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Durham University

The Department of Archaeology.

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Abstract

Environmental change is a major concern for society today. This concern extends the flooding of people's homes, the reduction of biodiversity due to habitat loss, and the threat to economic prosperity where it is dependent upon the exploitation of wild resources. In terms of past climate change there has been significant amounts of research conducted into the Pleistocene to Holocene transition. This project explores the evidence for environmental change, of a less severe yet potentially disruptive amplitude, and its influence on the behaviour and decisions of Mesolithic hunter-gatherers on the Atlantic façade of Europe. The archaeological record is reviewed with a particular focus on the 8.2K cal bp event and the 2nd half of the 5th millennium cal BC. The resulting datasets are interrogated utilising a multiproxy approach and consideration is given to that which is archaeologically visible and that which is not. The limitations of the archaeological record are addressed through the development of new methodologies and interpretative frameworks. The findings are significant, as the severity of the 8.2k cal bp event at northern latitudes is confirmed, although this falls short of being able to assert a total abandonment at higher latitudes. During the 5th millennium cal BC, a period of instability related to more energetic shoreline conditions has been identified and this is very likely a regional phenomenon. The period of instability is accompanied by changes in hunter-gatherer behaviour, and this includes changes in the spatial organisation of settlement, and adjustments to procurement strategies. The overall situation is that environmental change is the norm during the Mesolithic of the Atlantic façade, almost certainly due to its highly moderated climate. The adaptability of hunter-gatherer societies in response to the changes brought about by fluctuations in the moderating mechanisms is strongly attested. In many ways not much has changed, as flooded homes, reductions in biodiversity and changes in the resources available for exploitation are all observed.

Acknowledgements

This multidisciplinary work has only been possible due to the effort and support of an extended group of people whose contribution must be acknowledged.

Firstly, my supervisory team of Professor Mike Church and Professor Peter Rowley-Conwy who have accompanied me on my journey, in one formal capacity or another since October 2012, when I started my undergraduate studies. A better combination for providing support and challenge cannot be imagined. The journey has been a most enjoyable one for me and I hope the experience has not left them too scarred.

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Finally, my thanks to the Directors of Arts and Humanities Research Council (Northern Bridge) and their team without whose support which this project could not have taken place. Their support and understanding in response to the Covid-19 pandemic was greatly appreciated.

If I have unintentionally omitted anyone then please accept my sincere apologies.

Malcolm J. Evans, January 2021.

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This Thesis is dedicated to my wife and soulmate.

Mrs E. C. Evans MEnvSci (Hons)

For her support and understanding in the face of personal adversity.

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1 Introduction.

1.1 Background

For those who have known me for a long time I suspect the choice of subject matter for this research was an all but an inevitable one. A lifelong obsession with rock pooling, angling and wildlife photography permits me to feel a certain level of empathy with our hunter-gathering predecessors. Whilst my personal efforts lack the motivation of securing the livelihoods of myself and my dependents certain aspects of the activities involved are shared. The execution of the activities involved have not changed much, an understanding of the behaviour and characteristics of one's target is required, whether stalking or ambushing are the method best employed for a given target. These modern hobbies demand, if success is to be achieved, an understanding of when and where to seek the quarry, and these are not unrelated. There is a well-known saying within the angling fraternity that there are three key aspects that must be considered: location, location, and location. As anyone who takes their angling seriously knows all too well, the above oversimplifies the matter as the location is factored by time of day, season of the year, and the weather conditions, both preceding and prevailing. It is a stark reality, based upon personal experience, that after booking a week on a Scottish salmon (*Salmo salar*) or Canadian steelhead (*Oncorhynchus mykiss*) river for a year hence, the prognosis for success is often all too clear weeks before, and at times months before arrival at the river. These observations can equally be extended to photographing migratory birds. A sense of doom prior to departing upon a scheduled trip can of course be avoided. This is achieved by simply avoiding all weather reports for the period between booking and arrival, ignorance certainly can be bliss, so to say. The blissful state being further assured, in the case of salmon angling, by avoiding the reports of how skilled and therefore successful fellow anglers have been during the previous seven years. Fortunately, neither my own continued existence nor that of my family were dependent upon the success of such enterprises.

This naturally brings forth a question of…..what if one's livelihood or existence depended upon the arrival of a seasonal resource at a given location when you expect it to be there? What if, as has been observed in relation to Atlantic salmon, longer term trends of uncertainty and decline in the number of fish running, and similarly the stamp of those fish that do run, are operating? This clearly highlights, at least to the author, the fact that an idealised seasonal round, where at a specific point in the year a hunter-gatherer group arrives at a favoured location for the focused exploitation of a resource, is one that may actually be atypical. Certainly, the seasonal round for the Nootka of Vancouver Island in Canada appears to take the form of a well-defined seasonal round of three primary nodes (Jewitt, 1824). The question must be asked as to whether such an ideal form of seasonal round ever existed within the Mesolithic of Atlantic Europe, and especially at more northerly latitudes. There is justification for tabling such a fundamental question, and that is the fact that Atlantic Europe experiences a very moderated climatic regime at a given latitude due to the influence of the gulf stream, and the north easterly trajectories of the cyclonic weather systems. The climate, weather and marine conditions are therefore subject to fluctuations in these mechanisms, certainly at the century and decadal scale as well as the scenarios represented by exceptional years such as the winter of 1963-1964, and the exceptionally warm summers of 1976 and 2018. Therefore, what is often portrayed as a somewhat utopian mobile existence probably requires constant adjustment to both the nodes visited within a seasonal movement network and the approaches adopted on how and what is exploited at each node visited. This question is not without consequences for archaeologists as it has implications for how often individual sites were visited and were the activities performed there always the same? In 2013 the opportunity to explore aspects of the above fortuitously arose.

The research agenda that underpins this thesis was first formulated during 2013 to 2016 during undergraduate and masters study. A detailed analysis of the mollusc assemblage from the later of the middens on the Isle of Lewis in Scotland's Western Isles was conducted by the author. The results identified that specific subsistence practices were undertaken, and that these exhibited some unique characteristics within the context of Scotland and the Mesolithic of the Atlantic façade as a whole (Evans, 2015). Subsequently, a qualitative and cursory examination of the mollusc assemblage from the earlier midden on Lewis indicated that the manner of mollusc exploitation may have differed between what were spatially and temporally adjacent sites. It was clear that such changes during the terminal Mesolithic may have significance in the consideration of the events that followed, particularly at higher latitudes. During 2016 an analysis of the mammalian and avian assemblages from these two sites was conducted by the author for a masters dissertation (Evans, 2016). Significant changes are observed, both in terms of the exploitation of vertebrates in general, and particularly birds. A view that changes in resource exploitation were occurring on the Isle of Lewis during the terminal Mesolithic was developed. That change was occurring is of course a valuable observation, but of greater value is understanding why. The changes observed could stem from various root causes, the three that most readily spring to mind being a change in seasonality, a change in the environment, or an unrelated change in the people's behaviour. The latter point requires further qualification as a change in people's behaviour could result from innovation, or a change in preferences in the absence of environmental drivers. All the above root causes may or may not be due to external human influences ranging from the selective adoption of ideas to a more extensive acculturation. Of course, such changes in human behaviour can also result from the replacement of one population by another. Clearly further research was justified as the character of the changes needed to be more fully explored and the question of why any change occurred pursued. It was also clear that if substantiated the observed changes in resource exploitation could be a glimpse of a wider regional phenomena. Fortunately, a lifelong interest in the hunter-gatherers of earlier prehistory and the obsessions referred to earlier, resulted in the whole exercise being thoroughly enjoyable and satisfying one.

1.2 The Conceptual Development of an Idea

It was during the period of 2014 to 2016 that certain aspects that would influence this research crystallised for the author. The first was that the climatic regime of the Holocene was in fact anything but a stable trajectory of amelioration since the end of the last glacial. This in turn highlighted that whilst the Pleistocene-Holocene transition is well researched, as is to a lesser degree the 8.2K cal bp climatic event, there is very little understanding of how climatic and environmental changes impacted or influenced the lives of the hunter-gatherers of the region; especially those phenomena of shorter chronological duration and lower amplitude. As Colin Ballantyne (2004) succinctly summarises the matter: "A particularly interesting question is how sensitive the Mesolithic economy was to environmental change and whether, when adverse changes occurred, populations responded by adaption or migration". It also became clear that if such changes were to be sought a baseline from a known event would be very useful. Clearly a review of what the archaeological record tells us about the response of hunter-gatherers to the 8.2K bp events, which is best summarised as a 'double whammy' from both the climatic cooling event (Ullman *et al*, 2016) and the tsunami that resulted from the Storegga Slide (Weninger *et al*, 2008). Such a review will provide a useful calibration point as well as being informative in its own right.

The second was the methodological challenges became apparent, and particularly those associated with methodologies deployed within the published literature. Therefore, the project's scope, at least in the author's mind, included facing up to these challenges and seeking alternatives or mitigation where, and if, they could be found. A quick review of the characteristics of the six sites from the Western Isles encouragingly suggested that they exhibited many of the attributes required to support the proposed research agenda. It was also during this period that the author became cognisant of just how much modern populations are dependent upon the exploitation of local coastal, as well as marine resources in general. In some parts of the world this dependency operates at a subsistence level, but even within Atlantic Europe the dependency exists if economic contributions and therefore social stability are to be maintained. The most recognisable examples of such dependences are fishing for crustaceans, and the harvesting of various species of mollusc for export. There is, even today, an obligate dependency on stability in the environment and this often manifests itself in relatively remote areas with limited levels of, or potential for, industrial alternatives. Can past changes in the environment and the impact on prehistoric communities be leveraged to assess vulnerabilities of certain communities today? In theory yes, but first it is necessary to establish a means by which these dynamics and interrelations can be discerned within the archaeological record, a proposition that can be best characterised as 'easier said than done'. Whilst the budget and timeframe for the project prevented a consideration or evaluation of the modern scenarios and prognoses, taking the first step of establishing whether such variations and associations could be discerned within the archaeological record appeared to be a sensible one.

The existing and initial analyses permitted the overall aims of the project to be distilled and these can be summarised as follows. Firstly, to elucidate the nature of the Mesolithic of the remote Scottish Islands and to understand their context within the Atlantic façade. To explore to what extent, if any, can we see Tipping *et al* (2012)'s 'times of crisis' in the behaviour of the Mesolithic Hunter-gatherers of Atlantic Europe, and what are the implications for the interpretation of the archaeology of the region. This can be alternatively defined as furthering our understanding of the dynamics of hunter-gatherer – environmental relationships during the Mesolithic.

1.3 Down the rabbit hole and back again: Questions questions and more questions

During the earlier analyses of the mollusc and vertebrate remains questions kept arising, and as is often the case, further investigation results in the number of questions multiplying. Further research and analysis during the earliest stages of this project compounded the situation. Some of the questions appeared quite daunting and threatened to constrain progress. An example selection such questions is provided below, and hopefully this will furnish the reader with some sense of the flavour of the questions that arose:

a) Does the procurement of limpets from the high-shore and the low-shore actually mean anything archaeologically? What is the high-shore and conversely the low-shore? Does limpet conicity meaningfully delineate between the two?

b) What does the length of a limpet really tell us; likewise, its age at death? Specifically, what does the assertion of the mean values for the each of the above really tell us?

c) Are shell-middens (more precisely, the samples we subject to detailed analysis) a truly time averaged accumulation with a very small percentage of material surviving the ravages of taphonomy and diagenesis, or do at least some components reflect far more closely what was deposited?

d) Can we tell what humans used molluscs for? Are all size classes of a given mollusc taxon used for the same purpose? Therefore, how should we analyse and interpret changes in population structures?

e) Can the size of organisms (or year classes) be used to determine seasonality of occupation?

f) In terms of faunal exploitation how can environmental changes be separated from changes in season of occupation or human cultural practices?

g) How can, if at all, environmental change be linked with changes in deposition on the middens?

h) Can any synthesised picture be generated, given that the various environmental proxies respond to different stimuli, with different amplitudes of input required to generate a discernible output response? They also exhibit different lag durations between the input stimuli occurring and the output response being observed.

i) Can sedentary year round occupation be delineated from multiple seasonal occupations if the hunter-gatherers are nimble in their choices of when to visit and what to do when they get there?

j) Are the statistical inference tests commonly deployed asking the correct question or even the question they are presumed to be asking?

The above can be considered as quite fundamental in nature and arguably are hiding in plain site within the published literature. The above, along with many more that might be considered as ‘subplots’, went into the melting pot. It is appropriate here to clarify that whilst it was the intent to reuse published methodologies where their utility had been demonstrated, it was never the intention of this project to simply apply the suite of established methodologies and produce the standard output associated with each. This is rooted in the conviction that such an approach results in siloed statements that are difficult to integrate and that each piece of analysis is generally focused on producing the standard outputs and not addressing a given project's aims. Consideration of all the relevant information, shaped by the above, suggested a research strategy consisting of five phases.

Phase 1: Data gathering.

During this phase the zooarchaeology of the assemblages from the Western Isles and West Voe was completed. This was also complemented by a survey of published assemblages from the Atlantic facade to determine the species exploited during different phases of occupation. An extensive literature review was conducted against the life traits and ecological profiles of the different taxa identified during the review. A review was also conducted of the published results relating to other environmental proxy records such as palynology and ice core data. The objectives of this phase were to establish what is present in the assemblages, and what has been published and how was the data obtained. To obtain a more inclusive view of the methods and particularly quantification units employed, and therefore cognisance of the magnitude of any synthesis challenge to be developed.

Phase 2: Data exploration.

The data obtained during phase 1 was explored using a data mining philosophy; that is different questions were asked of the assemblages based upon what was present. The questions were put to the assemblages in different forms both to evaluate methodologies, as well as to test candidate hypotheses that drop out of preliminary findings. The objective of this phase was to identify specific lines of analytical enquiry that will serve the research questions as well as the aims and objectives of the project. It is also during this phase that published methodologies were evaluated 'bottom up' based upon the ecological and biological information collected during phase 1.

Phase 3: Targeted Analysis.

In some cases, the data exploration phase produced relevant, usable, and reliable datasets that can be carried forward into the data synthesis phase. In other cases, a specific line of enquiry was identified that was then carried out against the identified research question. Such instances took the form of further laboratory analysis or reanalysis or reinterpretation of published datasets.

Phase 4: Data Synthesis.

This phase sought to bring the various datasets together and through a defined interpretive framework, formulate answers to the research questions in order to address the project's aims and objectives.

Phase 5: Writing up the results and conclusions reached.

1.4 The Aims, Objectives and Research Agenda of this Project.

1.4.1 Aims

The aims of this project as already stated are to elucidate the nature of the Mesolithic of the remote Scottish Islands and to understand their context within the Atlantic façade, coupled with furthering our understanding the dynamics of hunter-gatherer – environmental relationships during the Mesolithic. The scope is geographically limited to that of the Atlantic façade for two reasons. Firstly, the new assemblages are from the Atlantic façade, secondly as demonstrated in chapter 5, the Atlantic façade and the Scottish sites provide for an excellent opportunity to pursue the aims of the project. The scope is taxonomically restricted to mammals, birds, molluscs, crabs and fish. Botanical remains and other arthropods are not considered in any detail. Of course, consideration of these aspects would further improve our understanding, but the specific skills required could not be acquired in a timely fashion, and neither was their sufficient time to execute the analysis.

1.4.2 Objectives

Prior to defining the objectives, it is appropriate to provide further context by highlighting a couple of specific challenges relating to the comparative analysis of zooarchaeological assemblages, and likewise their synthesis. The key issue is that the data within the published literature is likely to exploit the full gamut of quantification units posing a significant, and it might be argued insurmountable, challenge to comparative analysis. Numerous methods and units exist, and all have acknowledged strengths and weaknesses and therefore their own community of advocates and detractors. It is therefore necessary to define a set of project objectives that address these specific elements as well as support the delivery of the project's aims.

1. To provide the first description and interpretation of resource exploitation during the Mesolithic of the Western Isles and Shetland.

   The Mesolithic occupation of the remote Scottish island groups is a relatively recent discovery, when the excavations at Northon on the Isle of Harris (Gregory *et al,* 2005; Simpson *et al, Eds.*, 2006) and West Voe in Shetland (Melton and Nicholson, 2004, 2007). This project will describe the exploitation of resources from new sites as well as extending the data available for Northton and West Voe. In doing so the first description and interpretation of the subsistence strategies during the Mesolithic of these remote archipelagos will be provided.

2. To obtain a more comprehensive view of resource exploitation during the Mesolithic of Atlantic Europe.

   Understanding the full spectrum of resources exploited and how this varies spatially and temporally is a key step in understanding two key aspects of the archaeological record. Firstly, such information can provide a view on geographical distribution of different subsistence strategies, additionally it can reveal the extent to which stability or volatility in the deployment of the strategies is observed temporally. The stability or volatility of hunter-gatherer behaviour in turn can be considered as proxy for variation in environmental conditions within the region.

3. To improve the information yield obtained from faunal remains.

   The published literature leverages a limited number of the characteristics of the organisms exploited at different sites and these take the form of a set of standard analyses and are not (usually) specifically designed to answer questions regarding the dynamics of human – environmental interactions. A more complete, (although a healthy dose of pragmatism requires this to fall short of being exhaustive), bottom up review is required to build a database that captures those life history traits, physiological characteristics and habitat preferences that are relevant to the interpretation of the faunal assemblages of the region. The data captured supports another key requirement of understanding the specific procurement opportunities or challenges a taxon presents, as well as the scale of exploitation that can be sustained.

4. To define a method by which the appropriate questions to ask of an assemblage are identified and the optimal way of articulating the question is determined.

   To critically appraise the methodologies deployed within the published literature, seeking either confirmation of their utility within this project or, using the information compiled into the faunal database, define refinements or alternatives that will better support the aims of the project. A further aspect is the consideration of the quantification units available and those that should or can be utilised. This in turn determines which quantitative analytical methods may be legitimately deployed.

1.4.3 Specific Research Questions

The stated aims and objectives of the project are served by seeking answers to several key research questions. The process is to a degree iterative as it is not until the composition (and other characteristics such as population structures) of the assemblages is known that decisions can be made on whether a given site can contribute to the answer to a particular question. Whilst overall the suite of research questions remained stable, the number and form of the research questions were on occasion refined. Most of the revisions were highlighted during phases one and two as understanding the assemblages and published data developed. Such refinement might simply be driven by consideration of the sample sizes available, once preservation states have been factored in. Likewise, some analytical methods attract a significant monetary investment, and it is prudent to await the results from cheaper forms of analysis before deciding whether there is sufficient justification for making such an investment. The final point is one of analytical mind set. Research questions will change, either because the results obtained at a particular point in the project suggest the data to answer a question is unlikely to be sufficient, or the results obtained suggest a new research question that has more merit; usually in the form of a better prognosis for obtaining an informative outcome. The final list of research questions that are addressed in this thesis are provided below.

1) How does faunal exploitation vary over time within the Atlantic façade, is continuity or change the norm?
2) Can the influences of the 8.2K bp climatic event and mega-tsunami be observed in the archaeological record and what magnitude of influence on human groups can be inferred; what does this say about the resilience of the strategies deployed?
3) How does the exploitation of faunal resources in the remote Scottish Islands compare to that of mainland and elsewhere within the Atlantic façade?
4) What was the relationship of the occupants of the remote Scottish Islands and the mainland?
5) What were the season(s) of occupation in the remote Scottish Islands?
6) Can the small otoliths, usually encountered in the assemblages of the region, be leveraged to understand seasonality of occupation and the variation of conditions in the marine environment?
7) Were conditions within the marine environment around the remote Scottish islands stable during the second half of the 5th millennium BC.
8) Is there change in the substance strategies utilised on the Scottish Islands during the terminal Mesolithic?
9) Is there evidence for environmental change during the second half of the 5th millennium BC and can this be associated with any changes in hunter-gatherer behaviour during the terminal Mesolithic?

In summary, this project will attempt to respond, at least in a modest capacity, to two challenges that have been set:

> “The resolution of research is not adequate to quantify the role of marine material and whether it changed through time” (Wickham-Jones, 2007, p.90).
>
> “…….suggests (even demands) that we should be able to explore phases of Holocene climate change, abrupt or gradual, and the human response to such change (Tipping *et al*, 2012, p.18)

1.5 Thesis Structure.

It is becoming more popular for doctoral theses to be presented around a core of *circa* five 'standalone papers'. Having reviewed several such examples this approach was explicitly rejected by the author due to a firmly held conviction that the nature of the research centres around integration and synthesis, that goes beyond a corralling of often diverse findings in a concluding chapter. The research philosophy is explicitly to avoid producing a series of siloed research outcomes, as is all too frequently encountered. Whilst a thesis may spawn a number of research papers it is the firmly held belief of the author that a doctoral thesis is probably a researcher's last opportunity to present a fully integrated outcome whilst free from the shackles of the publishing process, and that it is an opportunity that should not be passed up lightly. The final approach adopted is a hybrid one, clearly certain chapters may form the basis of a publication; in other cases, the constraints around journal article publication require the content of multiple chapters to be combined with a refined and targeted scope. Volume 1 contains the main chapters and volume 2 the supplementary information (SI-) that supports each chapter. To aid the reader a guide to the chapters is now provided.

Chapter 1: Introduction.

The background to the thesis, its origins, and original objectives. The scope, research strategy, aims, objectives and specific research questions are defined.

Chapter 2: Hunter-gatherers and their Environment: How, What, Where and When.

This chapter defines key terms including that of hunter-gatherer. The concept of environmental change is defined. The codification regimes that result from seminal works are evaluated and the terminology and codification going forward are defined. The range of hunter-gatherer behaviour and therefore their plasticity is reviewed to provide a baseline for potential site interpretation.

Chapter 3: The Visible and the Invisible.

Much of past human activity is not (or is rarely) preserved in the archaeological record and yet these aspects may be more critical to a society than those that do. A number of environmental change scenarios are defined, and a detailed review is conducted against the ethnographic record of two anthropologically very different hunter-gatherer societies. The resulting datasets are utilised to assess the implication of the defined environmental changes not only on those aspects that preserve in the archaeological record, but those that do not.

Chapter 4: Methodological Considerations when Analysing Shell-middens.

This chapter considers extant theoretical approaches and their implementation within the published literature. The approach is to strip back the existing approaches to their core so that the strengths and limitations can be better understood, and in the case of limitations suitable mitigations defined. The methodological strategy for the project is defined based upon the results obtained from the review and then this is executed in subsequent chapters to analyse and interpret both the new assemblages and published assemblages.

Chapter 5: The Mesolithic of Atlantic Europe.

The definition of Atlantic Europe in this project is made. Data is presented from published assemblages and changes either temporally or spatially are identified. Specific sites are identified as suitable for further consideration in subsequent chapters. Two periods are specifically targeted, the first being the period immediately prior to and following the 8.2K cal bp events, and the second the latter half of the 5th millennium cal BC prior to the Neolithicisation of Britain and northern Europe.

Chapter 6: The Zooarchaeology of the Remote Scottish Islands.

This section presents the analysis of the assemblages from seven sites. Four from the north west coast of the Isle of Lewis, two from the southern extreme of the Isle of Lewis and one from the Shetland Isles. In accordance with the strategy defined in chapter 4 published methods are deployed in conjunction with new methods. Initial interpretations of each site are provided based upon the results obtained in earlier chapters.

Chapter 7: The 8.2K cal bp event.

This section explores the archaeological record of the 8.2K cal bp climatic event and the Storegga Slide tsunami utilising the data from chapters 3, 5 and 6. The response of hunter-gatherers to the events is evaluated and the most parsimonious scenario defined.

Chapter 8: Change in the 5th Millennium cal BC.

Using the data from chapters 2, 5 and 6 the case for environmental change and the nature of any such change is determined. Hunter-gatherer responses to environmental change are considered both in terms of the new sites and, where the published data permits, at the wider sub-regional level of northern Atlantic Europe.

Chapter 9: Review and Conclusions.

The conclusions reached in earlier chapters will be summarised and the success of the project and its approach evaluated.

1.6 The End of the Beginning.

Two aspects require clarification, the first is related to the objectives of the project, or rather, objectives this project explicitly does not have. The other item is of a more administrative nature.

The literature reviewed (and not simply that cited) during this and previous projects appears to disproportionately reflect a pursuit of sedentary behaviour during the Mesolithic of Western Europe and particularly within north-western Europe; to the point that sedentism appears to take on the status of a 'holy grail'. As will be discussed in subsequent chapters the search for sedentism appears to generate some interesting approaches to data categorisation and analysis; and a significant degree of flexibility in setting the ‘height of the bar’ against which sedentary behaviour is assessed. Why sedentism should be positioned, as it were, on some sort of pedestal is unclear until a characteristic with which it is invariably associated - social complexity - is brought into the equation. Why social complexity and the hierarchical, is deemed desirable is probably rooted in the evolutionary perspective. That is socially complex hunter-gatherers are more evolved hunter-gatherers and it is likely that some do not want to be told their hunter-gathering forebears were not, or failed to, ‘evolve’. This is a fundamental misconception of the nature of the mobile and egalitarian; certainly, establishing that the hunter-gatherers of England were highly mobile and egalitarian, would not cause the author any consternation or offence whatsoever, even though their haplogroup is U5a. The project considers the possibility of hunter-gatherer groups that can be categorised as highly mobile and egalitarian, as well as those that are less mobile and more hierarchical, but only to assess the nature of relationships with the environment. This project does not seek either category but simply accepts and embraces either, where and when they are encountered.

This project is of an interdisciplinary nature and may be read by individuals who are specialists in one aspect but have little exposure to others. Where appropriate, citations are provided to well respected textbooks where the basics of an aspect, for example the maturation of the mammalian skeleton, may be obtained.

2 Hunter-gatherers: What, when, how and where?

2.1 Hunter-Gatherer Plasticity

2.1.1 Introduction.

This chapter discusses the variety of human societies that are corralled by the term hunter-gatherer, which in some sources is termed hunter-fishers-gatherers. The objective is to clarify the use of key terminology and interpretative frameworks and how these are utilised within this project. Without an understanding of the archaeological nature of certain types of site that result from certain organisational configurations, it is difficult to seek evidence for local environmental changes.

2.2 What is a hunter-gatherer?

'What is a Hunter-gatherer?' may appear rather fundamental but it is worth clarifying. A hunter-gatherer society cannot be defined as one that utilises wild resources in contrast to those societies that do not, and this is emphasised when the exploitation marine resources, especially fish, are considered. The primary definition is based upon what they do not possess or exploit, namely domesticated animals, or plants, other than the dog (*Canis familiaris*). This definition is necessary because agricultural societies, and more recently industrial societies, have always exploited non-domesticated animals and plants (Milner *et al*, 2007; Barrett *et al*, 2004; Yamazaki and Oda, 2009; Dupont *et al*, 2007; Alvarez-Fernandez, 2015; Montgomery *et al*, 2013) and still do so extensively today (Bharucha and Pretty, 2010). The key point is that beyond the above requirement for an absence of domesticates no other criteria exist. In various areas of the world prior to European contact, population size (excluding the empires), social stratification, richness of ritual, territorial ownership, do not delineate hunter-gatherers from the early agriculturists. The temporal qualification given above is necessary as European contact caused severe disturbance in most areas of the world, not only to hunter-gatherers, but also the large empires, who it must be said, fared less well than their hunter-gathering contemporaries and neighbours. As discussed in chapter 3, such disruption includes: the over exploitation of natural resources, the introduction of new technologies, and territorial pressure. The most visible form of the latter is the creation of the 'Indian reservations' in North America.

2.3 The Diversity of Hunter-Gatherer Societies.

2.3.1 Which Pigeonholes are the Correct Pigeonholes?

The basis of classifying societies has a long history of which the very basics are the Victorian (cf. Nilsson, 1868; Westropp, 1872) views of hunter-gatherers. Which can be paraphrased as primitive and as 'corks bobbing on the environmental sea'. Such ideas were not inconsistent with the later classification regimes introduced by Service (1962; 1975) and Steward (1955). Constructs such as those of Service and Steward were complemented, although not necessarily through a convergence of standpoints, by the classifications of hunter-gatherer societies which are typified by those offered by Binford (1980) and Woodburn, (1968; 1982). Rowley-Conwy and Piper (2016) and Renouf (1984) review the different perspectives within the discipline and bring into sharp relief the positions of Elman Service, Julian Steward, Lewis Binford and James Woodburn and the theoretical tensions they collectively generate. The way forward proposed is to consider Saxe-Goldstein hypothesis that links mortuary behaviour and therefore cemeteries to territorial ownership and therefore a level of social complexity (Rowley-Conwy and Piper, 2016). This requires systematic and spatially constrained inhumation of humans (cemeteries) to be identified. The only limitation is that it places a requirement on all societies in all prehistoric periods, to consider the terrestrial environment as a more 'special' place than the marine one for putting group members to rest. Nevertheless, the approach offered by Rowley-Conwy and Piper (2016) does offer an encouraging way forward.

During this project, a number of aspects crystallised for the author as a consequence of deconstructing the two continuums offered by Binford (1980) and Woodburn (1982) and considering them in relation to groups that extensively exploit marine resources in temperate environments. The aspects that must be considered are the key concepts of immediate return, delayed return, logistical procurement, encounter based procurement and finally storage. These are all decoupled from each other in the analysis presented in table C2-1. The key observations are as follows:

1. Immediate return: can be procured without specialised equipment and consumed in the immediate future with little processing.
2. Delayed return: can be procured only after substantial investment of resources and time to construct the equipment needed.
3. Encounter Procurement: acquired whilst navigating the ecosystem without specific targeting. Specialised equipment and skills may still be required, however.
4. Logistical Procurement: acquired by targeting the resource in suitable locations and are unlikely to be encountered unless targeted. Specialist knowledge and skills maybe required but this is taxon dependant.
5. Storage: Is storage possible? The effort and other resources required to store effectively will be considered in chapter 3.

Table C2-1: Some key resources types often encountered in the Mesolithic shell-middens of Atlantic Europe considered in relation to the categorisation provided in the main text. All resources can be leveraged in an immediate return manner. Five resources must be considered as delayed return due to the equipment required. Most resources require a logistical approach to procurement although encounter based procurement may occur as exceptions, usually this relates to rare or exotic species. Birds are more likely to be acquired on an encounter basis as they may become ensnared in fishing nets or hooked on baited lines. *** the method recorded by the column is the optimal way to achieve success. ** Some unintended success may result from the methods utilised to targeted other resources. * the method defined by the column is not the optimal one, but it may result in rare but highly valued species. All resources have the potential to be stored at least for several weeks.

Exploited Resource	Biotope	Distribution Influences	Immediate	Delayed	Encounter	Logistical	Storage
Epifaunal Gastropods	Rocky Shore	Wave exposure. Dessication threat. Salinity. Tidal Range Position.	Y	N	*	***	P
Epifaunal Bivalves	Rocky Shore	Wave exposure. Dessication threat. Salinity. Tidal Range Position.	Y	N	*	***	P
Infanual Bivalves	Sandy Beach	Wave exposure. Salinity. Sediment. Tidal Range Position.	Y	N	*	***	P
Fish	Variable	Substrate. Bathymetry. Submarine topography. Salinity.	Y	Y	*	***	P
Birds	Variable	Food supply. Preferred roosting locations.	Y	Y	**	***	P
Bird Eggs	Colonies	Nesting environment. (Grassland, gravel, trees, cliffs).	Y	N		***	P
Seals	Colonies	Low lying Rock platforms, raised sand banks.	Y	Y	**	***	P
Whales	Windfall	Currents influence where dead or sick whales enter the coastal zone.	Y	Y	***	*	P
Crabs intertidal	Rocky Shore	Wave exposure. Salinity.	Y	N	***	*	P
Crabs infralittoral-sublittoral	Variable.	Bathymetry. Substrate.	Y	Y		***	P
Urchins	Variable.	Wave exposure. Substrate.	Y	N	*	***	P

Table C2-1 does not address the exploitation of plants or fungi. Generally, the lack of visibility of such resources archaeologically renders such an analysis difficult. It is known that some plants, such as acorns, require extensive pre-processing prior to consumption and therefore may not be truly suitable for immediate return exploitation.

Based upon table C2-1, it is clear that when marine resources are being exploited a logistical approach is required and that many of the resources that might be expected to contribute most to the economy, such as fish and marine mammals are also delayed return as Woodburn (1982, p.432-433) includes the construction of equipment such as spears, nets and traps as delayed return activity. Woodburn (1982) has an explicit, but unquantified, viewpoint on what constitutes simple equipment as used by the immediate return groups. However, as will be highlighted in later chapters the level of investment in raw materials, and especially effort, is a function of the raw material to be worked and the technocomplex available to work it. Binford (1980) contrasts logistical acquisition with encounter based acquisition. Binford (1980)'s foragers as a group move to 'map onto resources' after which resources are acquired on an encounter basis. Can acquisition ever be truly encounter based? The foraging must occur in locations and during seasons with a pre-existing knowledge of what will be available, and where in the landscape conditions will permit it to prosper. Encounter basis acquisition is probably therefore an analytical failure to discern the vast knowledge the hunter-gatherers utilise to find their resources. Nomadic behaviour is also probably an analytical failure in terms of resolving the vast knowledge and skill utilised to decide where to go next. There is one area where the basic constructs of Binford (1980) and Woodburn (1982) provide a more appropriate framework, and that is trade.

The author sees little or no difference between trade and other mechanisms of acquisition, other than it maps more readily to the construct of logistical versus encounter based acquisition. Trade is either logistical or encounter based (chapter 3). In the former specific trade missions occur and these are undertaken with a specific group to acquire specific resources including prestige goods or the intangible prestige of the elite. In the latter, resources diffuse through a network of small mobile groups and when two groups (nodes) meet trade may occur if both have something the other desires. There is a significant amount of latency in such a network, but major ceremonies or windfall events can (temporarily) spatially collapse part of the network eliminating latency, whilst increasing the levels of direct interaction between groups; the resulting trade remains acquisition by encounter.

The nuances of the anthropological theory are not really a concern for this project other than the final aspect that crystallised as presented in table C2-2. Using the data from Groom *et al*, (2019, table 4, p.14) the effort required to construct the cordage required to manufacture a fishing line of 10m in length and a fishing net of length 5m, height 3 m and a square mesh size of 3cm can be estimated (table C2-2). The fishing line requires 0.78 person days to construct, including acquisition of raw materials, but excluding the effort of hook manufacture, leader manufacture and either of lure construction or bait acquisition. The net requires greater than 78 person days (of 12 hours) effort, excluding the time to combine the cordage together to form the net; the manufacture of net floats and sinkers are also additional effort. The *chaine operatoire,* elapsed time and man hours required to construct either a dugout canoe, plank canoe, skin canoe, or bark canoe just reemphasises the point (chapter 3). Encounter based acquisition does of course occur whether it be a stranded cetacean or pinniped, a curious seal approaching a canoe, or finding a large common whelk (*Buccinum undatum*) whilst foraging for the usual intertidal epifaunal molluscs. However, as stated in chapter 1 success will be very limited if a hunter-gatherer simply chooses a random point on the shore, at a random time of day, and a random day in the month, in a random month of the year, and casts out their baited line. Neither can a hunter-gatherer forage on a rocky shore and expect to encounter infaunal bivalves or visit a sandy shore and encounter epifaunal gastropods. Basically, successful exploitation of marine resources is due to its very nature, unavoidably, logistical. When considering the maritime hunter-gatherers of the Atlantic Europe during Holocene we are not seeking to establish whether they are delayed or immediate return or whether the procurement is logistical, or encounter based. They are delayed return and logistical, they are obliged to be, they really do not have a choice in the matter and asserting a logistical and delayed return behaviour is simply not a research outcome. Binford (1980) and Woodburn (1982) also imbed storage within their definitions, which confuses the issue. Logistical acquisition is not the same as logistical consumption. The storage of subsistence resources needs to be considered separately to whether delayed return or logistical behaviour is operating (see also Rowley-Conwy and Piper, 2016 for a discussion).

What is of interest is how the archaeological sites map onto Binford (1980)'s site typography. As two types of logistical behaviour must be recognised (Binford, 1980). The first is the location type where a task group procures resources, processes them, and then returns them to a residential base camp (ibid). The second is where the entire group moves to the resource being logistically targeted (ibid); that is the residential camp, and the location are one and the same. Understanding which of these two models the archaeological sites fit is of interest. A distinct signature that advocates a particular season of occupation at a site is typically taken as an indicator of highly mobile societies, but this may not be the case if the site reflects the activity of a task group as suggested for Ertebølle Culture in Denmark (Rowley-Conwy, 1999 and references therein), whereas it probably is if the site is a result of the logistical movement of the entire group.

Table C2-2: Manufacturing times for example nets and the Antrea net. Manufacturing times from the mean for the experienced individual 1 in Groom *et al*, (2019, table 4 p.14). Dimensions of the Antrea net from Miettinen *et al* (2008). 12 hour person day utilised. The estimate is only for manufacturing the cordage and not the actual assembly of the net. The cordage requirement does not include knots or looping, although this could be material for small mesh sizes. The Antrea (fodder fish) data is discussed in chapter 6 and is specified to target small and juvenile gadidae.

Net	Length (m)	Height (m)	Mesh (m)	Perimeter (m)	Vertical Strands	Horizontal Strands	Cordage (m)	Cordage (Km)	Manufacture Time (Person Days)
Fishing Line	10	N/A	N/A	N/A	N/A	N/A	10	0.01	0.78
Example 1	5	3	0.03	16	166	99	1009	1.01	78
Example 2	5	3	0.06	16	83	49	510	0.51	40
Antrea	27	1.5	0.06	57	449	24	1378.5	1.38	107
Antrea (fodder fish)	27	1.5	0.02	57	1349	74	4078.5	4.0785	316.93

The final dimension in which hunter-gatherers are measured is that of social complexity. As discussed above Rowley-Conwy and Piper (2016) review the usual methods and highlight the ambiguities and suggest the use of funerary behaviour. There is another approach which could be dovetailed with the approach advocated above. This is evidence for labour investment in activities where is appears unlikely that the undertaking would be practicable for a small highly mobile group. Does a task require significant amounts of labour and does the activity suggest control over, or at least an 'ability to motivate' labour? A case in point is the Antrea net (table C2-2) preserved in Finland and dated to 8,600-8,400 cal BC (Miettinen *et al*, 2008). The manufacture of the net using a more realistic figure of around 6 person hours per day would require a team of five for around two months. The group would lose the foraging or hunting or fishing capability of five people for an extended period. The implications of packing away and setting up the manufacturing process (over and above the workload associated with camp set up and departure), if residential moves were frequent, have not been factored in. Winter evenings are possibly an opportunity for undertaking such activities assuming the light levels in the dwelling were sufficient to execute the task. Such an undertaking raises the questions of at what level was the ownership of the net assigned and how was the bounty it produced allocated?

2.3.2 Human - Environment Relations.

The relationship between humans and the environment, is a topic that attracts significant research, political and public attention today. The relationship is a dynamic one and the field of study encompasses the entire period of hominin existence, seeking answers to such fundamental questions as the role of climate and environment in hominin evolution. As already discussed, the view of hunter-gatherer environmental relations has moved on considerably from that held by the Victorians, especially in relation to the capability of hunter-gatherers to alter the environment to their advantage.

Hunter-gatherers have adapted to different ecosystems and in doing so have developed sophisticated solutions to the specific challenges posed. There is also unequivocal evidence that hunter-gatherers have altered their environment through niche construction, in certain cases the environmental change is unintended and simply part of the feedback loop between organism and environment observed in biology (Laland and Brown, 2006). In other cases, the niche construction is deliberate in terms of an envisaged outcome; an outcome that alters the environment to the hunter-gatherer's advantage (table C2-3) (Smith, 2011; Rowley-Conwy and Layton, 2011). One point that should be made is that the time depth of some of the examples in table C2-3 is debated within the literature, and in some cases is attributed to European influences or pressures resulting from colonisation; at least by some authorities. This aspect is not of material interest to this project and will not be pursued further. The key point is that when required innovative solutions can be developed and deployed in response to external stimuli. Several archaeological examples of such niche construction have also been proposed for Atlantic Europe and key examples are provided in table C2-4. Two key factors are highlighted here. The first is that analysis and interpretation of the archaeological record should not place unjustified constraints on the solutions hunter-gatherers may adopt. The second is that without a demonstrable output the majority of the archaeological examples simply cannot be demonstrated to be anything other than unintentional or a consequence of natural phenomena.

Table C2-3: Well known examples of intentional niche construction activity taken from the ethnographic record.

Example Culture	Example Region	Output	Description Sources	Time Depth	Intended/ Consequental
Gunditjmara	Australia	An increased abundance in mature eels high in body fat available compared to what would occur without the niche being constructed.	Hydro engineering with dams and channels extends the size of the habitat available for elvers to mature into eels. Secondary benefits such as attracting water fowl and hydrophilic plants. Builth (2006).	Claimed to be radiocarbon dated to *circa* 4000 cal BC. Unable to find any citations even on the Australian government sites.	Intended
Evenk	Siberia	Over population of elk, some of which must occupy more accessible areas and therefore are easier to hunt.	Culling of the main predator of elk, the grey wolf (*Canis lupus*) Grøn and Turov (2007).	Unclear	Intended
Owens Valley Paiute	North America	Increased abundance of various root crops compared to the area that would be irrigated by natural means. Fish can be obtained from two locations in two seasons they would not ordinarily be available in. Patches of seed bearing species such as sunflower develop at the end of the irrigation zone.	Hydro engineering with channels and ditches up to 6.5km in length extends the area receiving levels water required for germination and maturing. Lawton *et al* (1976) Smith (2011). NB. As the cited sources stress the irrigation approach is not agriculture or incipient agriculture.	Debated. Pre-European dates qualitatively and indirectly argued for by Lawton *et al* (1976)	Intended
Ju/'hoansi (!Kung)	Africa (Kalahari) Australia	Accelerated grass growth attracting game. Reduction in the search component of procurement effort.	Grassland burning. Jones (1969). Smith (2011).	Early Prehistoric dates probably.	Intended
Native Californian Groups Eastern North American Groups	North America	Increased production of acorns.	Forest burning for selective reasons. Dodds (2002). Mason (2000)	Probable.	Intended
British Columbia	North America	Disruption of natural succession to preserve specific taxa in terms of abundance.	Forest burning to sustain the abundance of pine. Suttles (1987).	Probable	Intended
Forest Burning	Various	New growth attracts game into areas where more visible. Reduced search time, increased hit rate.	Forest burning to stimulate growth and attract game and encourage fruit baring shrubs. Dodds (2002) Lewis and Ferguson (1988).	Probable.	Intended
North West Pacific Coast	North America	Four fold increase in yield? Reduction in the search component of the procurement cost.	Clam gardens. Some evidence that such structures may not have been focused on clams but other classes too. Groesbeck, *et al*, 2014. 98.Caldwell *et al* (2012)	Unclear. Dating extremely difficult.	Intended
North West Pacific Coast	North America	Extended production zone and hence greater yield of root crops and rhizome producers.	Extension of the area suitable for the growth of saltmarsh tubers and rhizomes. Smith (2011).	Unclear. Dating extremely difficult.	Intended
Nukak	South American rain forest	Increased number of stands or wild orchards. Reduction in the search component of the procurement cost.	Seed broadcast sowing. Seed discard after processing results in wild orchards. (Smith, 2011).	Probable	Intended
Hopi	Central Plains and East Coast of North America	Reduction in the search component of the procurement cost.	Relocation of berry and nut producing species. Smith, (2011),	Unclear	Intended
Various	Various	Coppicing of trees, especially hazel.	Creation of straight thinner trunks useful for artefact manufacture. Increase hazelnut yields. Holst (2010) Pickard and Bonsall (2007).	Mesolithic dates likely	Intended
Various	Various	Greater abundance.	Weeding and tending to eliminate competition. Smith (2011)	Unclear	Intended

Table C2-4: Candidates for niche construction in the Mesolithic of Atlantic Europe.

Example	Locations	Hypothesised Output	Assessment	Demonstrated?	Refined
			Sources	in the Mesolithic	Definition
Reduction in Aboreal Pollen	Western Isles Shetland Ireland	Woodland clearance for raw material. Clearance to encourage game.	Brayshay, and Edwards, 1996; Edwards, 1996, 2004, 2009; Edwards and Sugden, 2003) Dates suggest the 8.2K cal BP event rather than human activity is being detected in Shetland and the Western Isles. Neither archipelago had game to encourage. Clearing a major source of shelter from wind does not make sense.	No	Intentional
Exploitation of specific tree species	Scotland	Changes in the species composition of woodlands.	The use of tree species due to burning properties or selection based upon what is available is not deliberate manipulation. Bishop *et al*, 2014.	No	Consequental
Increases in microcharcoal	Western Isles Shetland Isles	Signature of woodland management using fire to attract game through renewed growth or alter species composition.	(Edwards, 1996, 2004, 2009) Burning down such a critical resource on remote Islands really does not make sense. Burning down a major source of shelter from the wind does not make sense. Can burning be managed in such a windy environment.	No	Intentional
Increases in microcharcoal	Ireland North East England	Signature of woodland management using fire to attract game through renewed growth or alter species composition.	Simmons and Innes, (1987) Innes *et al*, 2013	Possibly	Intentional
Introduction of wild boar	Island of Gotland Ireland Cyprus	Introduction of wild boar into ecosystems where previosuly absent. Source of animal protein.	Warren *et al*, 2014; Vigne *et al*, 2009; Ahlgren *et al*, 2016	Ireland - No Cyprus - Possibly Gotland - Probably	Intentional
Burning reed beds	Northern England	Unclear.	Day (1993).The objective of the activity is unclear.	No	N/A
Introduction of hare	Island of Gotland Western Isles?	The case for the Western Isles is hypthetical given the currently available data.	Ahlgren *et al*, 2016. This project and Hamilton-Dyer, 2006	Gotland - Probably Western Isles - ?	Intentional

2.4 The Nature of Environmental Change.

From the perspective of a group of hunter-gatherers the environment may change in several ways. A key but obvious scenario is that the environment changes around a human group. Examples of such change are shifts temperature, changes in the weather in terms of precipitation or storminess and as discussed in chapter 3 these have implications for the composition and spatial structure of the ecosystem. Another, and again obvious scenario, is when hunter-gatherers move into a new environment which differs from that previously occupied in terms of the characteristics defined above. The third scenario is where the environment is altered by the human group itself, as already discussed this may be intentional or unintentional. The intentional alteration of the environment has already been considered through tables C2-3 and C2-4. The unintentional can be demonstrated through a simple example. There are complex relationships between limpet abundance, growth rates, and size and the organisms they share the immediate environment with (cf. Lewis and Bowman, 1975; Thompson, 1980), the specifics of which need not be presented at this point. However, if the limpet population is over procured in certain areas of the shore barnacles will expand their coverage and deny space for limpet grazing and also settlement of the young spat; in other areas of the intertidal zone the dynamic is between limpets and fucoids (seaweed) or between limpets and mussels. A

Plate C2-1: An area of a rock outcrop in Gairloch Bay north-west Highlands of Scotland. The solid arrows highlight immobilised limpets, and the dashed arrows highlight areas where limpets have become detached. A scale was not available when taken but the two limpets are around 20mm in length. ©M.J.Evans.

scenario is shown in Plate C2-1, where barnacles have expanded to such an extent that the limpets eventually cannot graze and the spaces show where recently limpets have succumbed, presumably to starvation, and detached from the substrate. This example illustrates how fine a balance the hunter-gatherers needed to maintain with their environment if favoured locations are to be revisited regularly, if not frequently.

There is a further variant of this last scenario and that is when the environment changes due to the activities of other human groups whose stakeholding in certain aspects of the ecosystem and environment differs substantially from that of the occupying group, and this might also include territorial pressure. The removal of inland or upland forest will diminish the availability of a critical resource and also potentially disrupt estuarine ecosystems. The over exploitation of particular species to the point where abundance is below some critical level required to support the hunter-gatherer's economy and social institutions, are basic examples (chapter 3).

2.4.1 Seasonal Mobility versus the Mobility of Seasonal Indicators.

The seasonal mobility of hunter-gatherer groups is usually established by utilising the seasonality indicators provided by the faunal and or vegetable remains. The principle is therefore that a change in those indicators reflects a change in the season groups visited a site. The difficulty is that archaeology deals with vast tracts of time during which climatic conditions are variable. Therefore, an assumption that the basis for seasonal interpretation is temporally constant is not always valid. For example, during major colder climatic episodes the latitudes of England and Scotland may become the summer feeding and breeding grounds for geese and swans and the over wintering grounds are shifted to lower latitudes. It is for this reason that multiple proxies must be sought, although the increase in certainty only comes when several proxies are utilised as discussed in chapter 6. The final consideration is storage. Storage, especially if resources are moved between locations, both displaces a seasonal indicator within the calendar year and consequently reduces its precision or renders it near useless.

2.4.2 Ecosystem Diversity.

Hunter-gatherers have occupied a diverse range of ecosystems, all of which pose significant, albeit different, challenges in day to day life. These challenges extend beyond the day to day, to year to year and generation to generation, which requires the environmental change to be considered at various temporal scales. Hunter-gatherers have or remain successful in deserts, tropical rain forest, temperate deciduous and coniferous forests, open grasslands and arctic tundra and ice fields. Binford (1980, p.16) suggests patterns in how hunter-gatherer groups map onto his scheme that relate to latitude, although he also acknowledges anomalous societies, such as the people of Tierra del Fuego.

2.4.3 The question of isolated islands.

There is unequivocal evidence that Hunter-gatherers have colonised remote islands during prehistory (cf. Arnold, 1992; Ahlgren, *et al*, 2016; Vigne *et al*, 2009; Boethius *et al*, 2017). They offer specific challenges for hunter-gatherers and opportunities for archaeologists studying niche construction, marine resource exploitation and environmental change. The first is that in many cases the islands lack the usual terrestrial fauna, which even if not a major component of the diet, are usually a major source of raw materials. The occupants of such Islands are less able to temporarily buffer against a reduction in marine resource availability using terrestrial mammals. The published stable dietary isotope results for humans are to the author's knowledge based upon bulk bone collagen and therefore any such episodes are unlikely to be resolved (cf. Hedges *et al*, 2007; Montgomery *et al*, 2013). Such analysis, if based upon the incremental analysis of dentine might resolve such episodes prior to adulthood (cf. Montgomery *et al*, 2013). The above suggests that changes in marine resource availability is therefore more likely to be resolved by the remains of the marine resources themselves on such islands, as mitigation must occur in the absence of, or with limited access to, terrestrial fauna. Returning to dietary stable isotopes the coastal Mesolithic hunter-gatherers of Atlantic Europe are asserted to exploit marine resources extensively and make little use of terrestrial protein. The published data suggests that three of the individuals from Oronsay are extreme cases within the region (Schulting, *et al*, 2004, figure 2, p.148; Fontanals-Coll *et al*, 2014, fig 6 and 7, pp.547-548); although they are also temporally anomalous with continental Atlantic Europe, which might explain this observation.

2.5 Hunter-gatherer Successes and Failures.

2.5.1 The Hunter-gatherer Diaspora of the Early Holocene.

Hunter-gatherer success abounds. They colonised every land mass it was viable to do so and they occupied every ecosystem where it is possible to exist without industrial age technology and external support. The literature specifically mentions the rapidity with which humans reached arctic Norway at Lagesidbakti between 9,860 and 9,250 cal BC, suggesting the development of a productive marine ecosystem as an enabler (Blankholm, 2004; Bjerck, 2016). What has received less consideration is the possibility that these people were in fact trying to maintain their way of life by tracking the species adapted to the glacial as their range shifted northwards. Which of these scenarios are correct is an important research agenda, but not one that will be pursued by this project. The material observation is that either scenario is a testament to the adaptability of hunter-gatherers in response to climatic and environmental change. Given the colonisation occurs when large glaciers and ice sheets were still contributing huge amounts of fresh water into the coastal ecosystems it seems likely that, due to known salinity tolerances, the hypothesised marine ecosystem is not the same as that we observe later. Unfortunately, the zooarchaeological record for this period in Norway is non-existent (Bjerk, 2007). The greatest testament to hunter-gatherer success is that they successfully navigated the environmental 'vandalism' that accompanied the European diaspora, for at least three centuries.

2.5.2 Hunter-gatherer ‘Failures?’

One aspect that must be highlighted here is of a geographic nature and emphasises that Western and Central Europe are an anomaly when considered in a global context. In every other region hunter-gatherers persisted alongside agriculturalists until at least the point of European contact, and in some cases into the 20th and 21st centuries; this is not the case in Western Europe. Hunter-gathering as an economic solution was lost in north-western Western Europe (other than in arctic settings) by around 3,800 cal BC, and in many of the sub-regions of Europe one or two millennia earlier (Rowley-Conwy, 1984; 2011). Consequently, there is simply no ethnographic or histo-ethnographic records for hunter-gathering within the region, and suitable case studies must be sought from elsewhere. In other words, when studying the Mesolithic of Atlantic Europe archaeologists are from one perspective ‘on their own’. Why are western and central Europe unique in this regard? This is a ‘very big question’ and whilst it is relatively straightforward to hypothesise a myriad of reasons, a more focused research is agenda is required.

2.5.3 Summary.

In this chapter the definition of hunter-gatherer has been confirmed and it is one that only has one constraint. The relevant anthropological frameworks have been reviewed and it has been clarified that certain aspects of categorising the hunter-gatherers of Mesolithic Atlantic Europe very probably constitutes a superfluous exercise. This is because logistical acquisition must be decoupled from logistical consumption. Likewise, delayed return investment in acquisition must be decoupled from delayed consumption. In conclusion the author finds the theoretical constructs of Binford and Woodburn unhelpful when considering groups that extensively exploit marine resources. Another key principle is that placing constraints on the solutions that hunter-gathering societies may adopt when interpreting archaeological sites is not without risk, although it appears that demonstrating actual niche construction within Europe is for the most part extremely difficult. Finally, hunter-gatherers must maintain a fine balance with their environment and therefore interpretations of archaeological sites in terms of duration of occupation and frequency of occupation must be made whilst acknowledging this dynamic; in short, scale is probably everything.

3 Hunter-gatherers and their Environment: The Visible and the Invisible.

3.1 Introduction.

The question of how hunter-gatherers respond to changes in their environmental has attracted much attention. The approaches employed encompass most, if not the entire gamut, of sub-disciplines that make up what is collectively archaeology. This endeavour stimulates consideration of what aspects of human life are archaeologically visible and what are not. The nature of the discipline makes it is easy to forget that the objective is not to understand the archaeological record *per se*, rather the objective is to understand past people's lives; the former is 'only' a means to that end. Therefore, when considering an observed change in the archaeological record the obligation is to consider what people may have been experiencing and that includes those aspects that are archaeologically invisible. A question therefore is to what degree a relationship between the visible and invisible can be established.

Researchers have considered changes in material culture both from the perspective of functional adaption and as a proxy for population density (cf. Mikkelsen *et al*, 1999; Viken, 2018); others have scrutinised settlement patterns both in terms of settlement size and their location within the landscape (cf. Bicho *et al*, 2010; Bjerk, 2016; Indrelid, 1978; Fretheim *et al*, 2016), and often these two approaches are combined. One obvious approach is to consider the nature of faunal record, as at least some of the animal species available for exploitation may change in response to environmental vectors. Examples of such an approach are the change in the composition of zooarchaeological assemblages in Iberia during the Pleistocene to Holocene transition (cf. Clarke, 1983; Gutierrez-Zugasti, 2011, table 1, p.56) or during the Mesolithic – Neolithic transition of Scandinavia (Rowley-Conwy, 1984). Alternatively, some have hypothesised changes in an ecosystem in terms of the resources available that might be inferred from the established changes in the regional or hemispherical environmental proxies. Changes in human behaviour are attributed to the availability and exploitation of such resources, for which there is little archaeological evidence (such as the exploitation of salmon), if any at all (cf. Sutton, 2017; cf. Rowley-Conwy and Zvelebil, 1989, p.52). Broad scale approaches have also been deployed in terms of defining (sometimes hypothesising) changes in the environment and considering the high-level implications these might have for human behaviour on a ballpark scale (Garrow and Sturt, 2010; Wicks and Mithen, 2014; Waddington and Wicks, 2017; Weninger *et al*, 2008; Tipping *et al*, 2012; Orquera *et al*, 2011; Edwards, 2004; van der Schriek *et al*, 2008). In some instances, it can be argued that what is presented is association without demonstrable causation, particularly at a local level; in others we have causation without demonstrable association. The reality is that all the above approaches basically construct models to either support analyses of the available data or highlight data that could be sought and therefore make a positive contribution. Furthermore, they all have merit and contribute to furthering the cause of a better understanding of past lives, potentially the research return can be enhanced if a catholic approach is adopted which seeks to employ multiple approaches.

As discussed in chapter 2 environmental changes occur in one of three ways. The environment changes 'around' a hunter-gatherer society, the hunter-gatherers move into a new environment. In the former scenario there is the special case where the hunter-gatherers change the environment in which they reside, although may be not in ways they envisaged. The strategy is to build upon all the approaches and reach a more nuanced view on what responses specified environmental vectors may solicit from hunter-gatherer societies, and how these responses might manifest themselves in the archaeological record. If the strategy adopted is centred around one approach more than the others, it is at a fundamental level, an extension of the approach utilised in Waddington and Wicks (2017). Using the data obtained from a detailed review of the ethnographic and archaeological data, an integration of the various methodological stances is sought. Such an approach must navigate the fundamental tensions that exist, and are often present within the literature, regarding the relative merits of ethnographic recording and the written accounts it generates (Suttles, 1968, p.62), and the results obtained from archaeological excavation (cf. Munoz, 2011; Sutton, 2017; Tivoli, 2010; Borrero, 1997; Ames, 1991, p.937).

The conflicts that must be addressed are that the ethnographic accounts have been accused of bias, selectivity, and in the case of the earlier examples, a lack of objectivity due to the absence of formal methodologies. The most serious challenge is that even the earliest accounts must postdate European contact and therefore do not reflect the pre-contact status quo (cf. Suttles, 1967, p.62; Yesner, 2004). The perceived limitations of the archaeological record are simply that it preserves but a small fraction of the both the material culture and subsistence economy of past societies, and that even those components that are preserved are subject to bias because of differential preservation, and often recovery (Borrero, 1997, pp.78-79). The other challenge is that these two sources of information operate at diametrically opposed temporal scales (See Binford, 1968 for a discussion). The earlier ethnographic observations usually cover behaviour of a few days or weeks and even when systematic observation is carried out over several years the period of field work each year is very restricted. The archaeological record presents a temporal challenge of different character; the archaeological record is (usually) aggregated and time averaged. Often, for example when analysing faunal assemblages, the paucity of remains results in the analyst implementing an artificial extended time aggregated unit (cf. Boethius, 2017), yet, analysing the result is if it were a single archaeological 'event'.

The challenges of analysing and interpreting the archaeological record is explored in some depth in chapter 4. But prior to defining the methodological approach adopted in this chapter a few illustrative examples highlight the challenges ahead. As will be presented in due course the ethnographic record for Tierra del Fuego ascribes a very limited role for lithic tools, beyond armatures, which are rare. The activities and distribution of the skills required to make scrapers and similar lithic tools does not feature in an anthology of accounts that does discuss just about every other activity. The ethnographic record is clear in that the role of scraper and cutting tool are fulfilled by modified mollusc shells. The archaeological record contradicts the above position with various lithic implements, including scrapers, being common components (cf. Orquera *et al*, 2011, pp.66-67.; Godino *et al*, 2011, p.131; Mena, 1997, pp.52-53), although armatures are rare. It seems likely that the relative abundance and importance of certain resources that resist diagenesis are magnified within the time aggregated archaeological record. A similar conflict exists in relation to the use of perforated teeth (pinniped), presumably for personal adornment (Orquera *et al*, 2011, p.67). The argument of diagenetic, taphonomic, and therefore temporal distortion, seems equally applicable here. This is particularly so as the ethnographic record's description of pinniped procurement and butchery practices suggests that the heads of pinnipeds were usually not returned to the residential camp site. This is also the case for the post cranial skeleton, excluding the bones of the flippers, which is incompatible with the interpretation of Munoz (2011). Munoz (2011) conducts a comprehensive review of skeletal element representation for pinnipeds, and it is interpreted against the remains of guanaco (*Lama guanicoe*), for which skeletal element representation is not provided. Are the guanaco remains tool making blanks or meat baring bones? A similar approach applied to the pinnipeds and red deer from the Oronsay middens would lead to some interesting conclusions. Similar disagreements are noted by Borrero (1997) in relation to the exploitation of birds (see also, Tivoli, 2010) and rodents. The relationship between the remains of pinnipeds and residential locations highlights further the challenges of interpretation and achieving a reconciliation between the ethnographic and the archaeological. The final example is the systematic exploitation and logistical storage of the larvae of the pandora moth (*Coloradia pandora*) as by the Owens Valley Paiute described by Fowler and Walter (1985). Tens of kilogrammes are acquired by each harvester and these are roasted to preserve them as winter provisions. This substantial component of the subsistence economy, which is potentially very sensitive to climatic and environmental change, is of course archaeologically invisible. Clearly, the task ahead is not a straightforward one.

The approach will be to assess impact, corresponding disruption, and possible responses, in two very different hunter-gatherer societies; and this is conducted in response to a set of defined environmental vectors. The assessment is to be based upon the full spectrum of resources (or at least as far as this can be realistically known from documented accounts and excavated sites), and to consider how different components of the economy are inter-related and interdependent. The latter point is key as it is essential to consider the potential for a 'domino effect'. The objective is to qualitatively model the impacts and responses with a consideration of which, if any, will be visible in the archaeological record. The approach is designed to incorporate the components that archaeologically visible and those that (under normal circumstances) are not, as the latter may be indirectly visible. It also incorporates those aspects highlighted by the archaeological record but potentially missed by the ethnography. By understanding the potential archaeological signature of these different relationships, a view is developed on how responses to environmental change may manifest themselves within the archaeological record of Mesolithic Atlantic Europe.

A review of the literature has highlighted two regions populated by hunter-gatherer societies, namely British Columbia in Canada and Patagonia-Tierra del Fuego in Chile. These regions provide evidence for variation in behaviour between distinct groups. Two societies, one from each region, are considered in detail: the first being the Moachat (aka Nootka) of Western Vancouver Island and the second the Yamana (aka Yaghan) of Tierra del Fuego in Chile. In terms of Binford (1980)'s classifications, the former are collectors whilst the latter are foragers; although it is noted that neither is a perfect fit to Binford's definitions. It is important to clarify at this point that the objective is not to conduct an anthropological or even archaeological comparison of these two societies, they are clearly very different. Neither is it the objective to seek an 'archaeological fit' of one of these societies to regions of Atlantic Europe; thus, the risks highlighted by Binford (1968, p.269) regarding applying the ethnographic record to past societies are avoided, as are the dangers of identifying superficial comparative fits between societies as highlighted by Yesner (2004). The objective is to define two model entities, 'type societies', against which specific environmental vectors can be evaluated in terms of risk to the economic system and human responses to the manifestation of such risk. The characteristics and attributes of these societies are rooted in ethnographic observation and the archaeological record. However, an element of what-if reasoning is required; for example, considering a Yamana-like society that uses lithic technology extensively. Likewise, consideration must be given to Yamana-like and Moachat-like societies that utilise canoes made from skins rather than bark or dugouts. In the case of the Moachat, a scenario that envisages plank canoes is also prudent. This approach ensures that these 'type societies' are based upon verifiable data observations, whilst making the debate between ethnographic versus archaeological, in this context, a moot one.

3.2 Methodology.

Both societies are very heavily dependent upon marine resources, the majority of which are acquired whilst afloat. The societies exhibit significant differences in terms of residential mobility, social structure and population density. These two examples therefore constitute close to end points of the continuums that extend from egalitarian to hierarchical and from immediate return to delayed return, but unlike previous studies (cf. Binford, 1980; Woodburn, 1982), in a context of an extensive exploitation of marine resources. Other options exist, for example the Ainu of Japan (cf. Shinichirō, 1960; Watanabe, 1968) and the Chumash of California (cf. Arnold, 1992; Rick *et al*, 2011), but the two selected exist in appropriate climatic regimes and within biotopes that are characteristic of those that are found in higher latitude temperate zones (Suttles, 1967, p.56; Bjerck, 2016). The inclusion of these two societies in a single discussion is not without precedent as Mackie *et al*, (2011, p.90-91) uses the Yamana as a counter point during his discussion of the indigenous people of Coastal British Columbia. But it is useful here to reiterate that the comparison sought is between the two model entities that will be generated. The methodology applied to the ethnographic and archaeological record to generate the required model entities can be summarised as follows:

1) Collate detailed observations relating to subsistence activities and social activities from ethnographic accounts to construct a bottom up analysis that maps resources to key functions and then to key behaviours of a society.
2) Supplement the ethnographic observations with wider observations from within the academic literature, including the archaeological record.
3) Assess the resilience of components of the economy and inter-dependency within the components.
    a. Establish criticality of a resource in terms of its ubiquity within functions.
    b. Establish vulnerability of a resource in terms of the diversity of resources upon which it is dependent.
    c. Considering both bark and skin canoes in the Yamana scenario
    d. Considering dugout, skin and plank canoes in the Moachat scenario
    e. Considering both mollusc shell dominated and lithic dominated technocomplexes.

4) Conduct an impact assessment of the subsistence activities in relation to environmental changes.
    a. Changes in temperature ($3^{O}C$ in average annual temperature) over a generational time scale.
    b. 3 – 4 m rise in relative sea level over a generational timescale.
    c. Changes in storm frequency and associated precipitation on a decadal or generational time frame.
    d. The impact of a tsunami.

5) Consider the implications for social activities and structures of the impacts observed on the subsistence activities.
6) Identify the common features and differences in the results between these two very different types of society.
7) Consider the archaeological visibility of the changes in subsistence and social structures.

3.2.1 When the climatic door is left open.

For the purposes of this analysis a change in regional annual temperature ($3^{O}C$) will be considered in relation to the climate at the location today, applied uniformly throughout the year. The implications of a weakening or disruption in the climatic moderating mechanisms that could result in a much greater local reduction is not considered at this stage. The fact that such a reduction in annual temperature might manifest itself disproportionately throughout the seasons is also not considered here, but it is considered in chapter 7. The major consequences associated with a temperature change are as follows:

- Growth rates of poikilothermic organisms will generally reduce.
- The duration of growing season may contract.
- Fish and mollusc spawning may become less successful if the delta results in a deviation from the optimum range (Carter, 2005; Lambert, 1987; Largen, 1967; Gross and Smythe, 1946).
- The composition of faunal and floral communities may change if the delta drives range shifts, expansions, or contractions.
- The timing of the seasonal (especially vertical) migrations of animals may be altered (Jones *et al*, 2020; Clark, 1983, pp.110-117).
- Humans may require additional clothing made from materials that provide better insulation.
- Human nutritional requirements in terms of calories may increase.
- River flow rates may increase due to reduced transpiration (Moore, 1985), and the salinity of the immediate marine environment may alter beyond the tolerance range of some species.
- Reduction in the altitude of the tree line (cf. Ballantyne, 2004, p.31).

3.2.2 An unsolicited Intrusion.

A rise in sea level (4m) has a number of potential consequences for hunter-gatherer societies.

- The wave exposure levels at a given location may alter with a concomitant alteration in the composition of mollusc communities (Ballantine, 1961b; Ballantyne, 2004; Codignotto and Aguirre, 1993).
- Invertebrates at a given location may become less abundant within the inter-tidal zone and instead occupy the infralittoral or sublittoral (cf. Ballantine, 1961).
- Storm waves will reach the shore with more energy and this may require settlements to be relocated. In some locations, a reverse effect may be observed (Ballantyne, 2004, pp.36-39).
- Tidal Ranges may increase substantially at a local scale dependent upon coastal topography and bathymetry (cf. Shennan and Horton, 2002).
- Low lying areas may be inundated, and settlements may have to relocate (cf. Ballantyne, 2004; Sturt *et al*, 2013).
- The inundation of low lying coastal plains may result in a consequential loss of woodland habitat, or grazing areas (including birds), especially the over wintering areas for terrestrial mammals.
- The locations of bird nesting areas may alter as will the areas where grazers congregate.
- The areas in which pinnipeds haul out or breed may also change.
- The locations where marine fish spawn may also change (cf. Shelton *et al*, 2014).

3.2.3 The problem with frolicsome weather is.

Changes in storm frequency, energy and precipitation levels also have a number of implications for maritime hunter-gatherers, some of which are common to the increase in sea level stated above.

- The wave exposure levels at a given location may increase and alter the composition of the mollusc communities, both taxonomically and morphologically.
- Invertebrates at a given location may become less abundant within the inter-tidal zone and instead occupy the infralittoral and sublittoral.
- Storm waves will reach the shore with more energy and this may require settlements to be relocated.
- The size of trees and the altitude of the tree line may both be reduced.
- The areas in which pinnipeds haul out or breed may also change.
- The locations where marine fish spawn may also change.
- The number of days upon which resources can be pursued whilst afloat will reduce (Garrow and Sturt (2011).
- The number of days upon which resources can be safely procured from the intertidal zone will reduce.
- Windchill will increase and clothing may need to be adjusted.
- Drenching due to precipitation may become more frequent and clothing may need to be adjusted, as might architecture.

- Drying as a storage method will become less important than other mechanisms.
- Post-storm bounties in the form of animals ejected and stranded (particularly invertebrates) may increase.

3.2.4 One very bad day at the office.

Tsunamis are without doubt an environmental input of catastrophic magnitude. A tsunami is simply a wave that propagates the energy that is input into the marine environment by an event. They can result from the calving of large icebergs, the rolling of large icebergs due to differential melting rates, submarine landslides, and seismic events resulting from volcanic and tectonic activity. A tsunami is a wave and subject to the basic laws of wave dynamics as many will have observed in ripple tank experiments as students. That is, they refract, diffract (can turn corners) and the wave height, wavelength and velocity is related to the depth of the water column by Green's law. A tsunami (strictly speaking its interaction with a land mass) is described in terms of a) The run up height which is the altitude above sea level the wave reaches and b) the inundation distance which is how far in land the wave penetrates.

A wave approaching a continental land mass over open ocean will pick up some load as it enters shallow water but will hit the shore more as a wall of water, after which the destructive load it carries will increase rapidly. In environments rich in inlets and fjord environments the narrowing of the geographic feature causes the wave amplitude to increase, inflicting damage at a higher altitude (greater run up height) than if a flat coastline is encountered (Synolakis *et al*, 2006; Fine *et al*, 2005). Flatter geographic scenarios such as low lying coastal planes, including broad estuarine habitats, experience a reduced run up height but a greater inundation distance. The inundation will recede (although this can take several hours) and as the vast volume of water returns to the ocean it carries a destructive load which causes further and substantial damage. For an interesting discussion of the perceptions and stages thereof of survivors of the 2004 Indian Ocean tsunami (mortality > 240,000) see Raholm *et al* (2008). The effects of a tsunami in terms of run up height and inundation distance are very localised, although there is general pattern of a reduction in run up height with distance from the source when the wave is traversing the shallower continental shelf (Synolakis *et al*, 2006; Weninger *et al*, 2008). The situation is rather different where the wave propagates over ocean basins, so despite the general reduction in run up height over 10 to 100s of Km close to the source, the eastern Indian Ocean tsunami of 2004 had a run up height of around 10m on the western margin of the Indian Ocean thousands of km distant (ibid). The key point is that the local geography and bathymetry can result in significant differences in run up height and inundation distance at locations that are in fairly close proximity to each other (ibid). One key and counter intuitive characteristic is that the run up can be as high on the side of a large island that is opposite the source of the wave as it was on the side exposed to the wave front (ibid, p.85). The objective here is, of course, not to model the impact of a tsunami on the northwest pacific coast or Tierra del Fuego (which in any case is a completely different and specialised field), but to consider generally the damage that a tsunami can potentially do to Moachat-like or Yamana-like societies and their environments. From an archaeological perspective the occurrence of a tsunami in the past is identified by specialists in the earth sciences. In suitable locations geologists will identify the traces of such an event, usually in the form of sediment deposits (cf. Synolakis *et al*, 2006;

Weninger *et al*, 2008), although stratigraphic anomalies due to sediment removal may also mark such an event.

3.2.5 When the gods are definitely not smiling.

There is one combination of environmental vectors that can be quickly considered and that is a temperature reduction coupled with an increase in stormy conditions. These are very simply additive increased precipitation, reduced temperature, and increased windchill are a deadly combination. The ability to acquire resources will be constrained whilst the energy requirements of the population would increase. Reduced transpiration due to cooler temperatures coupled with increased precipitation will increase river flows with the consequences discussed above potentially magnified. On a similar theme the hypothesised increase in storm frequency and increase in sea level is basically additive, including increases in tidal range (Ballantyne 2004, pp.37-38; Edwards, 2004, p.67).

The question naturally arises as to what happens if a tsunami is experienced after or during a period where a 4m increase in relative sea-level and 3^{O}C reduction in mean annual temperature are experienced. The temperature reduction is not directly additive with the former two, the challenges associated with this vector remain the same. The temperature reduction may however retard ecosystem recovery following a tsunami. The former two are, however, potentially, and likely to be additive, although the changes in local bathymetry may have a buffering effect in certain locations. In the general case the rise in sea level may permit the tsunami (as observed for waves in general earlier) to make land fall with greater energy and an increased run up height. Generally greater destruction will be experienced especially in low lying areas, the destruction of trees will be added to the losses on low lying plains due to the transgression (Waddington and Wicks, 2017).

3.3 The North-west Pacific Coast of North America.

3.3.1 Background.

The people of the Northwest Pacific of North America provide an excellent opportunity to both explore human relationships with their environment in a coastal setting whilst also establishing one end point of the spectrum in terms of mobility and social complexity. Based upon Suttles (1987) the populations that had direct access to the coastal margin, either directly or via the various inlets and estuaries in the area, are represented by 22 language groups (figure C3-1). Suttles (1987, p.31-40) highlights that whilst the economic systems of the extended area can be generally characterised as based upon seasonally abundant marine resources, there is actually significant variety in the biotopes exploited by particular groups and therefore also in the detail of their economic systems. This in turn results in nuances in social behaviour, such as in the way potlatch demonstrations of wealth distribution were conducted (Ibid, pp.42-43). The situation can be summarised as a mosaic of biotopes within a general theme which are inhabited by human groups who collectively produce a corresponding mosaic of behaviours, again within a general theme.

The Moachat were socially stratified with elites, commoners, slaves and vassal tribes. Suttles (1987, p.5, p.7; 1967, pp.65-67) considers them to be one of the two most stratified societies in the extended region as stratification was also evident within the elite class and visible during potlatch. The indigenous people have been extensively researched and one particular group, led by Maquinna, that occupied Friendly Cove (figure C3-2) are considered to be the group exhibiting the greatest level of dependence on marine resources (McMillan, 1969, p.4). A number of works present detailed views of the Moachat and these combine ethnographic research with the observations made within contemporary accounts from the late 18th and 19th centuries, most also reference Jewitt (1815; 1824)'s account. The approach here is to consider this one specific and detailed account from the early 19th century and to complement this with other examples from the wider region where appropriate. This minimises the influence of European contact and particularly subsequent political developments such as the creation of 'Indian reservations'. The approach also mitigates (but does not eliminate) the distortion the adoption of modern trading and technology can generate, and offers more direct time depth than ethnographic accounts from indigenous elders taken in the first half of the 20th century. Jewitt (1824)'s account will be directly utilised extensively, for not only does it provide direct observation of different economic and social practices, but also facilitates an analysis of the interdependency of economic activities on each other. This was combined with the information available from relatively recent excavations at Cooptee (McMillan, 1969), which in general agrees well with the ethnographic account; further highlighting the importance of mollusc shell tools.

As will be discussed, the environment is very productive and offers great variety in terms of marine resources, as well as terrestrial animals and plants. For its latitude (just slightly less the Isles of Scilly in the United Kingdom) the climate is moderated[3] due to the Japanese current bringing warm waters into the region. Suttles (1967, p.58), observes that frost free winters with temperatures above 0°C are common, although harsh winters with extended periods of some weeks with temperatures of *circa* -18°C are not unknown, they are however infrequent. The other key feature of climate in the region is very high-levels of precipitation and this varies quite significantly within the extended region, and even between one side of Vancouver Island and the other (Suttles, 1987, p.32). The climatic regime is also confirmed in Jewitt (1824, p.202)'s account and Ingraham (1789, p.159). The modern annual sea surface temperatures are provided in figure C3-3.

3.3.2 Results

The detailed observations from the ethnographic and archaeological record are provided in SI-Chapter3-1 and the key findings are now summarised.

The data available for the Moachat and the wider north-east pacific (SI–Chapter 3) permits a general definition of a complex hunter-gathering society to be made. Such a society exhibits the following characteristics.

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[3] This a relative statement for the Pacific climate is not particularly moderated by the standards of the Atlantic.

a) Low levels of residential mobility between fixed locations with substantial residential architecture, which can also be considered monumental.
b) The majority of critical resources are acquired relatively close to the residential bases.
c) The vast majority of subsistence resources are acquired whilst afloat in a canoe.
d) Resource acquisition is seasonally logistic.
e) The environment appears to offer more than enough resources to meet basic subsistence requirements of the population.
f) Social organisation is stratified and organised into base units of extended kinship households that occupy a single dwelling within the village.
g) Social practices result in excessive utilisation of resources that can decouple logistical acquisition from a matching logistical consumption profile.
h) The social practices demand a far greater level of procurement and stored surplus than subsistence actually requires.
i) Trading can be considered as logistical procurement through specific missions to acquire specific prestige resources or simply, the less tangible, prestige of the elites.
j) The need to generate such large surpluses and maintain social structures results in key resources being critical points of potential failure; this relates not only in relation to the resources to be consumed, but also the resources required to procure them.

The literature examined attests that the Moachat (and the people of the north-west Pacific coast in general) exploited a very diverse portfolio of resources (although most were of secondary or even tertiary importance) and did so employing storage techniques in a logistical (*sensu* Binford, 1980) and delayed return (*sensu* Woodburn, 1982) manner (Tables C3-1). It is reasonable to conclude that these communities would be very resilient to environmental changes and catastrophic environmental events. A more detailed consideration of the evidence suggests the opposite may be true. Of course, annual variation in the abundance and or timing of seasonally available resources are problems that must be overcome and indeed were. Based upon Jewitt (1824)'s account resource consumption was not aligned with the logistics of storage. That is consumption was not based upon a managed budget derived from the stored resources available. Consumption was often excessive and wasteful increasing exposure to fluctuations in seasonally abundant resources (Jewitt, 1824, pp.143-144, pp.161-162; Suttles, 1967, p.64). Both Jewitt (1824, p.161) and Suttles (1967, p.58-59) highlight that periods of deprivation occurred, and these were linked to failures or delayed timing of the spring fishing, whaling and (sometimes combined with) prolonged periods of stormy weather (Jewitt, 1824, p.53, pp.161-162; Drucker, 1951, pp.36-37, cited in Suttles, 1987, p.39; Suttles, 1967, p.58-59 and quotations therein). These periods of deprivation, particularly in the spring, appear at times to be not so much due to whether sufficient stored resources had been available, but rather the fact that all the resources were consumed (to the point of excess) in large social events prior to leaving the winter village at Cooptee (Jewitt, p.144; Suttles, 1967, p.64). As defined earlier one approach to considering the risk level is to look at the roles and interrelationships between resources. This considers whether a particular resource is required to procure another or even itself. In this analysis a tentative relationship between the winter 'sprat' fishing and spring salmon and halibut/cod fishing has been made. This was conducted and the results are provided in a cross table (Table C3-2). The Moachat rely on the storage of surplus in a form that it can be consumed or traded. Table C3-3 presents a cross table of the contribution of different resources to the viability of the system. Table C3-4 maps certain key social functions to the resources to highlight the resources that enable such functions. The data presented highlights some key aspects. The following statements relate to not only the direct dependences defined in the tables but also the indirect dependencies that exist between the tables.

1) There is all but a total dependence upon bark.
2) There is a total dependence upon wood, both full tree trunks and smaller branches or flexible twigs. Unsurprising as the Moachat appear to have rejected the use of ceramics.
3) Active whaling exhibits a recursive relationship for the harpoon material, and the very strong sinew leader.
4) Active whaling is dependent upon seals (*Phoca vituline***;** *Mirounga angustirostris*), maybe also sea cow (*Hydrodamalis gigas*) and sea lion (*Eumetopias jubatus; Zalophus californianus; Callorhinus ursinus*) for skin bladder floats.
5) Whale bone and tendon are critical and enabling resources.
6) Whale flesh and oil are critical resources.
7) Forage fish, particularly herring (*Clupea pallasii*) are a critical resource.
8) Salmon are a critical resource and are available for all but 2 months of the year.
9) Terrestrial mammals have little subsistence value but are key within the social functions.
10) Mollusc shells (*Mytilus californianus*) are a surprising key component of the technological solutions for whaling and other hunting activities, as well as skin processing.
11) Sea mammal oil is probably a dietary necessity and is ubiquitous in the consumption practices associated with just about all subsistence resources.
12) Any resilience that might naturally be ascribed to a logistical storage approach is probably, at least in part, illusionary due to the resource consumption profile determined by cultural practices. This includes the need to acquire prestige goods such as dentalium shell as well as moose (*Alces alces*) and beaver (*Castor canadensis*) hides through trade.

Prior to discussing the implication of the above results, it is necessary to briefly discuss the nature of anadromous salmonids as a resource. Although the Moachat possessed a very diverse economy, it was very heavily biased towards the exploitation of whales plus marine and anadromous fish; particularly the exploitation of the annual salmon runs and herring migrations. The information considered so far emphasises the dependency the Moachat had on the abundance of this resource, both from the actual fish, but also the spawn. The time depth of this dependency appears to be restricted within the wider region; appearing to have developed within the last 500 years; prior to which the key resource was herring (Boethius, 2018, p.104-105 and references therein); McMillan *et al*, 2008). The evidence for intensive exploitation of salmon is either weak or absent from the earlier archaeological record.

Five species of salmon migrate to and from the rivers of British Columbia and there is also a run of steelhead, the anadromous form of the rainbow trout. As Suttles (1987, p.38-39) observes, it is difficult to assess the actual numbers of returning salmon during historic or prehistoric times (Atlantic or Pacific) as most modern fisheries (North-west America, Scotland, Norway etc) have been subjected to sustained commercial fishing pressure, which in more recent periods has been extended to the pelagic stage of the life cycle. This has a detrimental effect on stocks and therefore also the size of the run. As mitigation, both from an ecological and a commercial perspective, most fisheries are now hatchery driven to lesser or greater extent. A quick review of the situation of Canada’s Frazer river suggests a typical annual run of the anadromous salmonids will be around 50 million (Hawkshaw *et al*, 2019).

Rowley-Conwy and ZveleBil (1989) conducted a similar analysis of the salmon run of the rivers Dee and Clwyd in Wales. The records for the rivers Tweed, Spey and Tay were consulted during this project (data not presented) and the outcome was similar to the findings for the Clwyd and Dee; it is simply not possible to estimate what the 'natural' run level is and therefore how this may have varied due to environmental change in the past. It is possible to concur with Rowley-Conwy and Zvelebil (1989, p.44) that the level of reduction in salmon runs since the second half of the 20th century, due to a myriad of causes, would if it occurred in prehistory, constitute a collapse of the resource. The key point here is that the difference in the size of the salmon runs between European rivers and the major rivers of the north east Pacific is measured in orders of magnitude. Today, a run on the Fraser of less than 5,000,000 sockeye salmon is considered something of a disaster, whereas the disaster threshold for pink salmon is less than 10,000,000 (Hawkshaw *et al*, 2019), but this may simply reflect the level of run required to support the extensive commercial and leisure fisheries. The crisis in stocks is currently attributed to fishing pressure both within the river and at sea, combined with increasing temperatures and fluctuating sea surface salinity (SSS) levels (ibid). The available data suggests that the rivers of the western coast of Vancouver Island do not attract a run of the larger sockeye (*Oncorhynchus nerka*), chinook (*O. tshawytscha*) or pink (*O. gorbuscha*) salmon. The runs available in this subregion are those of the steelhead, and smaller coho (*O. ksutch*) and chum (*O. keta*) salmon. It should also be noted that the natural ecology of the pink salmon is a two year life cycle with the run occurring biennially and that the runs of region have aligned in this respect (Suttles, 1987, p.34-35); the sockeye has a four yearly peak. This cyclic behaviour is not strongly evidenced for pink salmon in the data available from the Frasor River (Hawkshaw *et al*, 2019), although this is possibly an artefact of modern hatchery and juvenile release management.

The key enablers of a stable stock are twofold. Firstly, the adults must be able to reach the spawning grounds and the main reason for this being inhibited is excessively high or low temperatures (Carter, 2005), lack of flow in the rivers, or access being blocked by landslips or similar (Cecco, 2019; Durran, 2019). Flow rate is basically influenced by precipitation levels factored by transpiration levels; the latter being temperature driven. Landslips are a real risk as recent events attest. Driven by considerations of conservation and commercial fishing, a major exercise was instigated on the Frazer River in June 2019 as a landslide blocked the path of millions of salmon migrating up the river (Cecco, 2019; Durran, 2019). Clearly such an event on one of the smaller rivers could render a Moachat fishing station dysfunctional, and possibly compromise the social standing of its owner. The full impact of such an event, in terms the size of the run, would exhibit a time lag of between 2 and 5 years depending upon the species. Landslips of this type will be linked to river flow levels, precipitation, and land use. Secondly, the temperatures must be in the optimal range for embryo development and hatching (Carter, 2005). Based upon the data published by Carter (2005) it would seem the risk to salmon breeding is more likely to come from a temperature increase rather than a temperature decrease.

Sutton (2017) proposes a model where the anadromous salmonids that colonised the streams and rivers that formed in response to the progression of deglaciation were the 'magnet' resource that pulled humans into North America. This is a difficult position to sustain as the archaeological record simply does not support extensive exploitation of salmon during the period in question. In terms of resources being available in a seasonally abundant manner it is unclear why the terrestrial megafauna combined with the extant bison (*Bison bison*) would fail to generate a sufficiently magnetic attraction. Notably, the extensive exploitation of forage fish such as herring and smelt (Osmeridae) does exhibit great antiquity

(Moss *et al*, 2016; Palmer *et al*, 2018). Sutton (2017)'s approach is that of hypothesising an environmental vector, in this case the probable post-glacial colonisation of the rivers by salmon. A causal link to a change in human behaviour such as an extension in geographic range is then asserted; in the absence of any evidence and at odds with the evidence that does exist. The 'absence of evidence not being evidence of absence' concept is often deployed in scenarios such as this. Unfortunately, it cannot be considered an axiom, as its appropriateness depends upon the context. If deployed indiscriminately, in the worst case is assumes the nature of a factoid and in the best case a critical reality check for interpretive frameworks. The key test is what does the other evidence from a site comprise of, and therefore what are the taphonomic and diagenetic likelihoods of absence despite presence. With a better understanding of salmon, it is now possible to return to the Moachat.

What is clear is that the Moachat are potentially very vulnerable to environmental changes. Any change that resulted in deforestation or a significant reduction in the abundance of pine would be catastrophic. Suttles (1987, p.32, p.35) notes that in the Coast Salish area the abundance of pine appears to be maintained through controlled burning to prevent succession to climax forest. Jewitt (1824) makes no reference to Maquinna's group engaging in such niche construction activity. The Moachat's approach to building appears to have been sensitive to the issue as their building approach is based upon almost total reuse of their building materials (Jewitt, 1824; Ames, 1991, p.939); although the practicalities of recreating their substantial architecture during each visit must also be a key influence in this regard. But the exposure extends beyond their architecture as their huge storage and cooking tubs require this resource (Jewitt, 1824). This resource also provides the canoes (ibid) and without these the majority of the procurement activity could not take place, and neither could their seasonal movements. The canoes also appear to be imbedded within the social system in terms of whaling ritual (ibid, pp.154-155) and, in some instances burial (McMillan, 1969). Specific canoes also appear to have been deployed for war. What is also clear is that without tree bark the Moachat would lack nets and line for fishing and would be reduced to scavenging dead or almost dead whales. They would also be totally reliant on pelts for clothing, as bark is the raw material for cloth production. It is also of note that Jewitt (1824, p.160) had to walk for 5km to obtain firewood as supplies immediately around Cooptee had been exhausted.

The Moachat, as with any hunter-gatherers exhibiting logistical behaviour, are vulnerable to fluctuations or failures in seasonally abundant resources. The key exposures are the salmon migrations and the migration patterns of herring and halibut (*Hippoglossus stenolepis*). Prior to the 20th century the anadromous and marine fish stocks should not have been materially influenced by anthropogenic exploitation at sea. In the case of the salmonids their habit of returning to their river of birth makes variation in marine currents due to changes in weather patterns less of an issue. This is less true for the herring and halibut who will adjust their migrations in such circumstances.

The stage has now been reached where the environmental scenarios defined in the methodology can be applied to a complex hunter-gathering group similar to the people of the North West Pacific coast. Some alternative scenarios are required such as a scenario where cloth is not utilised greatly or at all, and clothing is based more upon animal skins. Likewise, a generalisation of a hunter-gatherer group such as this must consider the possibility of canoes being constructed in different ways as exemplified by the bark canoes of the Yamana, the plank canoes of the Chumash, and the skin craft of the Aleutian Islanders. This is necessary because the canoe is such a critical technological solution for the societies employing a marine resource based economy.

3.3.2.1 Temperature Reduction

A reduction in annual temperature of around 3^{O}C within the region will without doubt increase the frequency and durations of incidents of frost or snow cover, which are noted by their rarity by many observers (cf. Suttles, 1967, p.58). The Moachat already employ significant cultural buffering in the form of clothing and there seems little reason to assume that this could not be scaled in response. The shared plank houses will also provide adequate protection due to the amassed thermal output of the occupants. In general, such a reduction in temperature should not cause any great disruption to the marine mammal populations exploited, as their geographic range incorporates temperature differentials of this magnitude. Any event (admittedly unlikely in this scenario) which did materially reduce the accessibility of marine mammal resources might result in an increase in the faunal record of the candle fish (*Thaleichthys pacificus*). The Kwakiutl to the north rely heavily on this resource for oil due to the relative lack of marine mammals in their territory (Suttles, 1967, p.63). The limited dependence on terrestrial mammals basically mitigates against risk in population reductions or increased seasonal migrations. As many terrestrial mammals seasonally migrate in terms of altitude it is possible that terrestrial mammals would be at low altitude for a greater part of the year and therefore more accessible (cf. Jones *et al*, 2020). In general, however, the terrestrial mammals present have natural ranges that incorporate temperature differentials of this magnitude (see Rosvold *et al*, 2013 for a discussion). An increase in the demand for clothing could see the dependence upon terrestrial mammals increase, either by an increased investment in terrestrial hunting and trapping or through logistical trade (see chapter2). The trapping approach results in large clusters of large boulders where one might not usually expect them within the forest. The archaeological visibility of traps is open to discussion, but if any methodological challenges were overcome an increase in such sites might be evident. The remains of terrestrial mammals may also become more abundant within the zooarchaeological record, as might the armatures appropriate for their acquisition. Whilst the Moachat employ both drying and smoking for preservation, their primary method is boiling using pyrolithics. The incidence of fire fractured stones can be expected to increase within assemblages simply due to basic physics (Newton’s law of cooling) as more energy will be required to achieve and maintain the required temperatures.

Given the region’s climate today, the primary risk to anadromous salmonoids would result from temperature increases (see the data tables in Carter 2005). Increased temperatures will increase transpiration in the surrounding forests and therefore may also reduce the flow levels in the rivers. The same datasets (Carter, 2005) indicate that a reduction in temperatures that would either significantly inhibit migration, spawning and hatching are outside of the temperature delta being considered here. There might be a small reduction in the success of spawning and hatching for chinook; but this species does not appear to be the one the Moachat exploit through mass extraction at the entry points to their spawning streams. The location and construction of the fish weirs may require adjustment if the flow levels increase due to reduced transpiration in the surrounding forests, which in turn may lead to increased occurrences of land slips. The timing of the salmon runs may, on average, be delayed by some weeks. The timing of herring spawning is, both in the autumn and spring, temperature dependant (Lambert, 1987) and therefore some variation in the timing of these events can be expected. An environmental change such as considered here, whilst they can appear as events to archaeologists, will occur over decadal to generational timescales and therefore adjustments to the seasonal procurement activities can be made. As noted above, Jewitt (1824) reports having to walk 5km to locate firewood at

Cooptee; in a scenario where more wood is burnt due to lower temperatures, supply may become an issue. The response anticipated from a general Moachat-like society is provided in table C3-5.

3.3.2.2 Energetic Weather

An increase in the frequency, duration, and severity of stormy weather (and precipitation) is a more serious proposition for the Moachat. Their autumn and winter occupations of Tashees and Cooptee, deeper within Friendly Cove not only place them close to seasonally available resources, but also offer shelter from the autumn and winter storms; clearly exposure to storms, and the inhibiting effect they have on resource acquisition whilst afloat, were a concern for the Moachat. As discussed above events or regimes such as this inhibit, whaling, pinniped hunting, line fishing, rake fishing and have been documented as causing hardship or even deprivation. Such events increase the exposure level of all shorelines and as wave exposure is a material factor in both where herring spawn (Shelton *et al*, 2014, pp.239-240) and the success of spawning (ibid), some variation might be expected. The variation will potentially change where the herring spawn (ibid, p.240-242) and the new locations which are now sufficiently sheltered will have to be incorporated into the subsistence strategy. Such an adjustment by the herring will be necessary if stocks are to be maintained as wave exposure is a material factor in the success of incubation and hatching (ibid). The community of bivalve molluscs at the usual gathering locations may alter in response to increases in wave exposure and concomitant changes in substrate characteristics (cf. Aneiros *et al*, 2014, pp.82-83; Rufino *et al,* 2010), and new locations that now have the correct composition will need to be found, alternatively the species composition of the zooarchaeological record may change. Harvesting salmon in weir traps will also require adjustment, in terms of location, due to changes in the wave exposure at different locations; combined with increased river flow rates due to increased precipitation, which in turn increases the risk of land slips.

A possible mitigation will be an increase in the exploitation, through hunting or trapping, of terrestrial mammals which would be evident in the archaeological record in the manner already discussed. This may also be accompanied by an increase in the exploitation of birds which would be visible in the zooarchaeological record and an increase in the abundance of arrowhead artefacts and possibly gorge snares in the form of the bone terminal tackle component.

There is also an architectural consideration as Jewitt (1824, p.69) observes that the large heavy planks that form the rooves of long houses are not actually secured to the framework. He also observes that during severe storms the males had to climb onto the rooves to weigh them down with their combined body mass, even if the result is a total drenching. There appears little doubt that as hunter-gatherer's go, the Moachat are about as logistic as it is possible to get, in terms of resource acquisition and storage. The constraints this scenario places on procurement activity may drive a shift to a more logistically managed consumption regime if deprivation or hardship are not to become routine. This would potentially have implications for social practices, including potlatch, and in general the way their hierarchical structures are reinforced and maintained. Reductions in wealth may become evident in the grave goods (especially dentalium) which can be substantial, even though much of the deceased's wealth was burnt during what can best be described as a wake (ibid, pp.155-156; pp.147-148). The response anticipated from a general Moachat-like society is provided in table C3-6.

3.3.2.3 RSL Rise

An increase in sea level of 3 to 4 m will result in the relocation of sites over time. Some sites will be moved due to the impending threat of inundation in absolute terms or an increase in tidal range. Those that are not at threat from inundation may shift to avoid temporary flooding and damage from storm waves. The substantial architecture should result in clearly visible (post-holes) signatures of such moves whether they are an out and out rebuild at a new location or beyond (further from the shore) the earlier boundaries of the settlement; creep in the location of the long houses over time should also be visible. Such archaeological visibility will only occur where the original settlement remains at least in part above the high water mark. Some implications for subsistence are worthy of consideration. The locations for mollusc gathering will potentially change, as will the locations where the herring spawn. Such change maybe driven simply by changes in the water column changing where habitats at the correct depth occur (Rufino *et al*, 2010). Additionally, the increase in the water column will change the energy of the waves at a location and this will also change the species composition of molluscs at a given location (Aneiros *et al*, 2014). Where clam gardens and stone fish traps[4] are being deployed temporal variation in their location relative to the low water mark and spatial distribution may signify such a change in sea level, and may constitute a response aimed at sustaining a known acquisition point. The implication of a change in exposure level at a given location on herring spawning activity has already been discussed. The locations where pinnipeds haul out generally and where their pupping nurseries are located may also change. These changes will occur on a generational time scale and therefore incremental adjustments, such as the creep in dwelling locations described above, can be made. The proximity of wood supplies will change if low lying coastal planes are inundated. The main consequence will probably be an increase in the journey time to acquire wood and bark of the desired type and size. The response anticipated from a general Moachat-like society is provided in table C3-7.

3.3.2.4 A Tsunami.

Finally, consideration of a tsunami and the implications it brings. It goes without saying that a tsunami of any magnitude is a catastrophic event that results in a significant mortality rate in the vicinity, whether human, faunal and floral. The question therefore is not so much the immediate impact but the recovery. Canoeists in the channels between islands will be killed, as will those present at the villages. Only those well in land and at an altitude above the local run up height will avoid the attentions of the wave. In the case of the Moachat these are locations they do not habitually frequent on a day to day basis; the felling of trees for canoes or dwellings, checking traps for terrestrial prey and the collection of yama berries (*Amelanchier alnifolia*), being adhoc or seasonal exceptions. The dwellings, canoes, tools and weapons will be destroyed as will any stored provisions and importantly, amassed wealth. What awaits the survivors can now be considered.

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[4] McMillan, (1966, p.56) describes similar structures as ‘canoe skids’; areas cleared of rocks to haul out canoes.

The dwellings will be destroyed, and at the site being occupied at the time, the planking will be smashed and or deposited over a very wide area, at all sites this will be true of the substantial frameworks. Canoes will also be destroyed, if any of the large more robust examples do survive it is unclear how easily they will be located as they will have been deposited over a very large area and maybe some significant distance inland. The molluscs beds will either have been swept away or smothered by sediment, both scenarios being lethal. The majority of pinnipeds and sea otters (*Enhydra lutris*) caught in shallower water or hauled out, will have been killed. If the timing was inopportune the pinniped pups will have been killed or herring spawning beds destroyed. The smaller salmon rivers maybe blocked by sediment. The carcasses of whales, unfortunate enough to have been caught in relatively shallow water, will be present along with the carcasses of other mammals, which might be considered a temporary boon. Trees close to the shore will have been destroyed and low lying forested planes will also have been destroyed; the same can be stated for berry bearing bushes and shrubs.

In the immediate aftermath, subsistence resources would be quite abundant as would the skins, tissues and bones of the marine mammals utilised as raw materials. The same can be said in relation to trees many of which would be available without the effort to fell them being necessary. The question now becomes one of the responses. Presumably, the people would seek to re-establish the pre-wave situation, but first the immediate priorities must be addressed in the context of a greatly reduced capacity for work in terms of available labour; although this is accompanied by a reduced number of people to feed.

- Shelter must be established through the creation of dwellings (on a smaller scale due to the reduced availability of manual labour resources?)
- If canoes have been lost, then they must be replaced if critical resources are to be obtained and seasonal abundances exploited when they arrive. Presumably, these will be initially of the smaller variety due to limited availability of labour.
- Raw materials for tools, weapons, clothing and storage must be acquired, which (at least initially) might be relatively easy as stated above; notwithstanding limitations on labour.
- New weapons and tools must be constructed so that subsistence activities can recommence.
- Subsistence activities must recommence if the survivors are to obtain adequate nutrition, and unless the diet changes dramatically, this includes the acquisition of sea mammal fat and oil.
- Animal skins will be required for clothing as the *chaine operatoire* for cloth production is complex and very time and labour consuming.
- Subsistence must also seek to address generating a surplus if seasonal down turns are to be negotiated, albeit by a smaller population.
- Fishing weirs will need to be reconstructed.

A key point here is the season in which such a catastrophe is experienced. At the end of winter, through to early summer enough time will exist to get things up and running again and prepare for the following winter. If the timing is mid-summer to mid-autumn, then the challenge of surviving the winter will be a serious one. The point at which the group would seek to fundamentally relocate from the area is unclear. The medium term outlook is no less daunting.

The marine mammal resources will have been severely depleted and how long it will take for the populations to recover is unclear. Dead salmon and other marine fish will have been deposited far and wide, often some distance in land. The key point is that spawning success will be reduced, and this will have consequences for the salmon run in two to five years hence. Trading and potlatch are key elements of the Moachat's way of life, and it is likely that the groups they trade with will have been affected to a similar degree and maybe fared even worse. Generating a sufficiently large surplus to permit trade to acquire the prestige goods (such as *Dentalium spp*.) and engage in potlatch, may not be possible for some time and this is not without possible ramifications. The response anticipated from a general Moachat-like society is provided in table C3-8.

3.3.2.5 Aggregated Scenarios.

A temperature reduction coupled with an increase in stormy conditions are additive as described above. The Moachat's ability to travel and carryout activities outside would be severely constrained. It is difficult to envisage how the strategy of maintaining the integrity of the long house rooves using human body mass could continue. Reduced transpiration due to cooler temperatures coupled with increased precipitation will increase river flows with the consequences outlined above potentially magnified. Additional exploitation of terrestrial resources is another possible response both for subsistence and to manufacture warm clothing, especially if the ability to travel for trade is constrained; assuming of course enough surplus can be generated to trade with. Without adjustments to social practices hardship may be experienced and the abundance of less favoured resources may be observed in the archaeological record.

The question naturally arises as to what happens if a tsunami is experienced after or during a period where a 4m increase in relative sea-level and 3^{O}C reduction in mean annual temperature are experienced. The aggregated impact may be archaeologically visible in terms of reduce village size, reductions in the sizes of plank houses, and changes in the composition of the zooarchaeological assemblages. It also seems likely that some villages or areas will be abandoned and that presence of prestige items in general and in burial contexts will be reduced.

A reduction in subsistence and wealth generation, whether for the reasons associated with the catastrophic scenario above, or a more subtle climatic vector over decades could have far reaching effects. Wilkinson *et al* (2007) modelled various levels of reduction in precipitation over a five year period and its effects on the societies dependent upon rainfed agriculture in Northern Mesopotamia. The results, whilst not directly applicable to a group of complex hunter-gatherers, do highlight some important considerations. The model suggests that the people in Northern Mesopotamia would not starve due to reduced agricultural yield, but societal breakdown would occur due to failures in the social system and in particular the inability to fulfil reciprocal obligations. In terms of the complex hunter-gatherers the situation is possibly analogous, especially in the multiple vector scenario. In the absence of a significant surplus and the capacity to continue Potlatch, social structures are going to become stressed and possibly unsustainable. Management of resources to ensure the people did not suffer deprivation would receive greater attention. A more planned and budgeted logistical approach would be required and the possibility of strategic mergers with other linguistically affiliated groups cannot be ruled out and neither can an abandonment of the sites or sub-region. If nothing else the survivors may no longer 'trust' the area they live in.

3.3.3 Interim Summary

In general, a Moachat-like society should be able to adjust and adapt to any of the scenarios evaluated here, except a tsunami where the challenge is not adaption but recovery. Where adjustment is possible the likely signatures will be manifest in the location of sites, a possible increase in off-site archaeology, task camps, and changes in the composition of assemblages both generally and in burial contexts. A key observation is that the resources procured far exceed that required to feed the society and provision it with raw materials. Related to this is that this type of society is not amassing surpluses in one season in order to scrape through leaner seasons. At each of the seasonal camps more than sufficient resource can be procured and each location provides a new and substantial source of input (sea mammals, salmon and herring spawn at Yuquot, salmon and yama berry at Tashees, and herring at Cooptee).

It is not beyond reason to conclude that in terms of the acquisition of subsistence and raw materials, substantial levels of storage are not actually required. The social structures and the practices that maintain them are what drive the levels of procurement observed (see also Suttles, 1987). It is this latter factor that would appear to limit whether a society of this type can make the adjustments necessary to embrace the scenarios evaluated. This can be summarised in the following manner: does the behaviour of people giving resource to those they felt responsible for, even when low on resource themselves continue (Jewitt, 1824, pp.63-64), or is the situation more like that experienced by Chinook people, where the elites never experienced famine as they took resource from lower classes (Ray, 1938, p.56, cited in Suttles, 1987, p.49)?

Two final points must be covered prior to proceeding to the other group of focus. Firstly, a Moachat type society is at risk in any scenario that results in widespread deforestation. It is impossible to envisage how such a society could survive due to the dependence on wood and bark. This is not unrelated to the second point which is external pressures on the territorial size. The fairly substantial Moachat group considered here actually exploit a relatively small territorial area as they extract their resources so intensively from the marine environment. But territorial pressure that is accompanied by deforestation would be a serious situation for such a society and their way of life.

3.4 The Yamana of Tierra del Fuego.

3.4.1 Background

By way of contrast to the north-west Pacific the indigenous people of southern Patagonia and Tierra del Fuego are now considered (figure C3-4). Tierra del Fuego is a very diverse area that is made up of numerous islands, fjords and glaciers and generally can be characterised as mountainous and heavily forested, predominantly with Magellan's beech (*Nothofagus betuloides*) with some areas of moorland on the more southernly islands (McCulloch *et al*, 1997). In the Eastern part of the region there are open plains (ibid). Annual precipitation between 200 mm in the north of the region with an annual average temperature of $7^{O}C$ (ibid). In the south of the region occupied by the Yamana annual precipitation is between 3000 mm in the west and 500mm in the east (ibid). The average annual air temperature is between $5^{O}C$ and $6^{O}C$ (ibid). The sea surface temperatures today for a location in the Beagle Channel and one in the Magellan Straight are provided in figure C3-5. The latitudinal displacement from the equator is roughly the same as Manchester in the United Kingdom.

As with British Columbia there is a mosaic of biotopes within this extended region and this results in differences in the economic and technical solutions and therefore behaviour of human groups. This variability can be characterised through three specific communities. The Selk'nam of northern Tierra del Fuego had an economy based upon terrestrial hunting, particularly of the guanaco; a medium sized camelid related to the lama (*Lama glama*) and the alpaca (*Vicugna pacos*) (Borrero 1997). The Yamana of the Beagle Channel and the islands south of it had an economy based upon the exploitation of marine resources, particularly sea mammals and sea birds (ibid), whilst the Haush occupy the south-eastern part of Tierra del Fuego north of the Beagle Channel and combine marine resources with the seasonal exploitation of the guanaco (ibid). In this extended region there is a mosaic of biotopes set within an overall environmental gradient in terms of precipitation and wind. Mena, (1997, p.53) notes that the zones characterised by the maritime adaption are basically coterminous with the regions of dense forest. Orquera *et al* (2011) go so far as to suggest the full littoral adaption was not possible until the region became forested around 6,700 ^{14}Cyrs ago. The environmental gradient also drives a trend in architecture. The more wind resistant conical huts are constructed from substantial trunks and have an internal base diameter of around 3.6m ($10m^2$) with depression around 0.5m deep excavated in the centre to protect the fire from wind (Gusinde, 1961, p.21, p.24). The domed hut has similar dimensions but was often extended into a double-family oval shape during winter and the long axis would extend to *circa* 7m ($20m^2$) (ibid, p.20, p.33). Whilst the skin covering is removed, the substantial frameworks are left when the family move on and will be reused either by the same family, or more rarely another, during a future occupation. Even if the framework subsequently collapses, the building materials remain and can be re-erected (Gusinde, 1961, p.34, p.37; Orquera *et al*, 2011, p.63-64). The large ceremonial hut was constructed in the manner of the extended domed hut, but enclosed an area of *circa* $136m^2$ (Gusinde, 1961, pp.676-680; Chapman, 1997, p.94).

In the border zones where these different groups potentially interface Borrero (1997, p.65; fig 43, p.68) highlights the potential difficulties in determining which group generated a given archaeological site; the issue being common forms of material culture such as arrow heads, basket weave (if preserved) and harpoon design (Borrero, 1997, p.65). Gusinde (1961) makes little or no reference to the (or knowledge of by indigenous informants) knapping of lithic tools by the Yamana, and it is hypothesised that items such as lithic arrow heads (the Yamana also used bone), and even bows, are traded from the Selk'nam (Gusinde, 1961, p.143, p.154). Whilst some differences exist (such as the participation of the sexes) the basic approach to the initiation ceremony and its objectives are common for the Yamana and Selk'nam (Chapman, 1997). The separation between the Yamana and Selk'nam does appear to exhibit antiquity within the archaeological record and appears to have developed between 6,000 and 5,000 ^{14}Cyrs bp (Mena, 1997, p.51). This separation was probably enabled by the eustatic increase in sea level associated with the 8.2K cal bp climatic event, which it is asserted finally severed Tierra del Fuego from the mainland by changing both the Beagle Channel and Magellan Strait into the marine thoroughfares later used by European explorers (McCulloch *et al*, 1997, p. 27; Borrero, 1997, p.62).

The focus here is the Yamana due to their evident maritime adaption and dependency upon marine resources. The approach is the same as that adopted for the north-east Pacific. Many metanalyses exist along with archaeological publications and these are complemented by contemporary field accounts. The review will focus on the direct observations available within a specific anthology of contemporary accounts; specifically, the multivolume work by Martin Gusinde (1961), which includes and critiques numerous references to the accounts of various travellers and explorers during the 18th and 19th centuries; as well as detailed observations from his field work. The version (Gusinde, 1961) consulted here is the version translated from German to English by Frieda Schutze. Care is of course required as such observers can make ill-informed interpretations of what they observe, and they may, as pointed out by Borrero (1997, p.79), also be unaware of whether they are observing the Yamana or Haush (ibid). This issue is something that Martin Gusinde was very aware of and he makes significant efforts to address it. Despite the need for caution, there is great potential in the direct and detailed observations of the lives of these indigenous people that are lost in the metanalytical works and are simply invisible within the archaeological record. For example, Mackie *et al* (2011, p.91) make a number of assertions based upon Gusinde (1961) that a detailed review of this source reveals cannot be justified. Gusinde (1961, p.273)'s description of fish weirs places them firmly in the category of an emergency measure, undertaken reluctantly when multiple families were low on resources and unable to relocate. Gusinde (1961, p.260) positions diving down into the water to retrieve marine invertebrates as an atypical behaviour resorted to when their normal collection tools were not working effectively; not surprising given the sea temperatures and potential wind chill. It is true that Gusinde (1961) does suggest the wife, at times, moored the canoe off-shore and then swam to shore; this being a mitigation against the canoe being damaged by rough seas. Mackie *et al* (2011, p.91)'s description of the Yamana's storage of resources is also potentially misleading; the limited scenarios in which this is observed are not related to smoothing out seasonal variations in abundance but preserving 'treats' that are acquired from unpredictable windfall events (Gusinde, 1961, p.338). Gusinde (1961) contains no reference to the Yamana manufacturing or even utilising textiles. The above firstly highlights the risks of utilising second-hand references to ethnographic sources and justifies the approach of a first-hand detailed review of the literature. Gusinde (1961) will be complemented by the broader perspectives provided in the wider literature, that also consider the wider region, and specific data found within the archaeological literature. The detailed data observations are provided in SI-Chapter3-2.

3.4.2 Results

1) Continual access to fire is a basic issue of survival.
2) There is a total dependence upon bark, due to the total dependence upon the canoe.
3) There is a total dependence upon wood, both full tree trunks and smaller branches or flexible twigs.
4) Whale bone is a critical and enabling resource.
5) Marine mammal sinews, especially those of whale, are a critical and enabling resource.
6) Large mussel (*Mytilus edulis* and *Mytilus chilensis*) shells are a critical and enabling resource.
7) Numerically mussels were a major component of the diet, but unimportant in terms of dietary input.
8) Sea mammal oil is probably a dietary and physiological necessity and is drunk very frequently.

9) Certain windfall events are critical for the maintenance of social relations and certain social functions.
10) The limited storage can be described as tactical for the short term rather than logistical.
11) Trade for rare items is diffusive in character and not direct. In procurement terms trade is primarily on an encounter basis (chapter 2).

Prior to discussing the implications of the above results, a discussion is required regarding domestic dogs. The ethnographic record attests that dogs were fully integrated into the Yamana's way of life, sharing their huts and canoes. Gusinde (1961) also highlights that the earliest accounts make no reference to dogs and their remains are also absent from the archaeological record. Zoologists assert that the dogs observed post European contact were of a variety that accompanied the earliest Spanish settlers (Ibid, pp.286-297). Nevertheless, by the 19th century dogs were fully integrated into Yamana's lives and they were the primary method through which otter (*Lontra provocax*) and fox (*Lycalopex spp.*) skins (the flesh was not eaten) were acquired (ibid, pp.246-249). Presumably, alternative approaches were used to acquire these resources, assuming they were exploited at all, prior to dogs becoming available. The availability of domestic dogs to a Yamana-like people is an element of 'what if' analysis that needs to be addressed.

The Yamana exploit a diverse suite of resources of which very few are stored and few, if any, are stored for logistical or delayed return reasons (*sensu stricto*) see tables C3-9. The Yamana do not appear to be at any particular risk from fluctuations in the abundance or timing of seasonal resources. Certain resources are more readily available at certain times of year, for example when concentrations of penguins (spheniscidae) and cormorants (*Phalacrocorax magellanicus*) occur during the breeding season, which also means eggs are available (ibid, p.247); similar observations can be made for pinnipeds. Fish likewise exhibit a seasonal variation in the locations where they are accessible (ibid, p.262-263). The Yamana's nuclear family social unit can generally source sufficient resources from most locations, at any time of year, at least for a short period. This is because the dispersed family units keep local population densities low and the demands placed upon the environment are spread relatively evenly throughout their region. Logistical storage of abundant resources is often seen as a mitigation to resource fluctuations and yet it also imposes dependencies on these same resources; this risk simply does not exist for the Yamana. The resources the Yamana require to procure resources are presented in table C3-10 and the resources required to store are provided in table C3-11. The link between resources and social functions is provided in table C3-12.

The key exposure relates to how frequently, and for how long, episodes of bad weather prohibit travel and constrain certain acquisition tasks; therefore, limiting the amount of resource available at a given location (ibid, p.21-23; pp.306-307). A further exposure exists in terms of the frequency with which the unpredictable windfall events occur; this exposure relates not only to the subsistence resources and raw materials that are made available, but also their role in facilitating larger social gatherings (ibid, p.37, pp.269-272, pp.665-669). These events provide sufficient concentrations of resource to support temporary increases population density and in turn vital social interactions (ibid, pp.640-642), such as exogamic marriages (ibid, pp.422-423). Archaeologically, this would be visible in terms of a reduction in the number of multioccupancy sites; although only when detailed stratigraphic analysis is applied to delineate between large gatherings and an aggregation of small gatherings, or single occupancies over a few years to decades (cf. Orquera *et al*, 2011, p.63). The sites of large social gatherings associated with whale exploitation maybe identifiable by a relatively low abundance (approaching absence?) of pinnipeds and birds in the faunal record as the Yamana's needs are being met by the windfall. There is evidence that by the end of 19th century whale strandings or hunts had become a decadal event heading towards generational (ibid, p.225). Whale strandings were probably once quite common. Figure C3-6 shows the stranding data for the area around the Scotland's Western Isles and clearly strandings are quite common even though the whale population is still very subdued, albeit slowly recovering. The subduing of a weak whale could take days, one recorded an instance of constant attacking by the assembled Yamana taking from 16:00 on a Friday until 22:00 on Saturday (ibid, p.224 and p.227). Whale hunts often resulted in major capsize events and multiple fatalities (ibid, p.226), but these risks were accepted due to the value of a whale. Whale bone is a critical resource for creating the armatures of their various hunting weapons (ibid, p.156-177), but a temporary shortage of whalebone is not catastrophic as both pinnipeds and cormorants can be obtained using clubs (ibid, p.218-221) and in the case of the latter, stealth (ibid, pp.233-234). A lack of whale bone becomes a serious issue when a new canoe is required. It is a vital tool for harvesting the large pieces of bark required in a single piece (ibid, p.111), stitching smaller pieces together is likely to result in a vessel that takes on water faster than it can be baled. Canoe construction also requires a good supply of marine mammal tendon for stitching (ibid, p.118). A specific feature is a dependence upon the shallow rooted medium size trees that exist close to the shore and are used to manufacture the long (up to 4m) weapon and tool handles, (ibid, p.9-12).

The stage has now been reached where the environmental scenarios defined in the methodology can be applied to a hunter-gathering group similar to the Yamana. Likewise, a generalisation of a hunter-gatherer group such as this must consider the possibility of canoes being constructed in different ways as exemplified by the dugout canoes the Moachat, the plank canoes of the Chumash, and the skin craft of the Aleutian Islanders. This is necessary because the canoe is such a critical technological solution for the societies employing a marine resource based economy. Scenarios that include the presence or absence of domestic dogs are also required.

3.4.2.1 Temperature Reduction

A reduction in the mean annual temperature should not be an issue for the resources the Yamana exploit as temperatures would still be well within the range of the species procured based upon their current geographic distributions. Certain poikilothermic resources such as marine molluscs and fish may experience changes in growth rate. A more fundamental issue might be for the Yamana themselves (as they deploy little or no clothing), given they have been observed fending of the onset of hypothermia, through physiological response (Gusinde, 1961, p.52). The Yamana's approach to fire was to keep one burning either in the hut or in the canoe. A fire was only lit afresh following a capsize or a hut collapse (ibid, p.39-40). The materials required for fire starting were normally carried in a leather pouch, the contents, flint and iron pyrites, were not ubiquitous within Yamana's territory and hence were traded (ibid, p.41). Tinder (fungi and bird down) had to be kept dry and were wrapped in the webbing from a large sea bird's foot (ibid).

It is unclear whether the Yamana have any specific physiological adaptions such as a raised rest metabolic rate (RMR) as has been suggested for Neanderthals (Sorenson, 2009; Steegman *et al*, 2002).

The ethnographers note that the Yamana eat a lot and frequently consume marine mammal oil in small quantities and that they quickly become emaciated when denied sufficient resources; their other response to a lack of sustenance is lethargy (Gusinde, 1961 p.307-308). The lethargy could simply be due to 'state of mind' as a consequence of being restricted in their ability to relocate due to the weather; but it could be a response to conserve physiological energy reserves to maintain an elevated RMR. A study was conducted on the Kawésqar of Chilean pacific coast (not the Selk'nam of the Atlantic coast as mis-cited by Sorenson (2009)) indicating that such an adaption did exist (Steegman *et al*, 2002). It is possible that a reduction in temperature of this magnitude would force the Yamana to adopt additional technological buffering in the form of clothing; and this might entail the pursuit of terrestrial mammal skins either through hunting or trade. If the former, a spatial change in the locations of sites maybe observed and it is debateable whether such sites could be distinguished from the mixed economy sites of the Haush. The challenge being that guanaco have a very restricted and localised distribution within the Yamana's territory where it abuts the territory of the Haush. The heavy guanaco cloaks utilised by the Selk'nam would potentially cause issues, especially when wet. In an inherently unstable canoe designed to ride high in the water and over waves rather than cut through them, raising the centre of gravity is probably not the best idea. Archaeologically the effects would not be particularly visible. The presence of domestic dogs would make the skins of otter and fox more accessible (Gusinde, 1961, p.246-249). There might possibly be some change in the relative abundance of species in the archaeological record and it is possible that through range extension or shift, new species may be incorporated into the economy. If the Yamana respond by either extending or shifting their range northwards or eastwards, then the zooarchaeology may remain relatively unchanged but the appearance of sites in new locations should be visible. If such shifts were observed seasonally then the faunal record should provide some indication in the form of juvenile specimens of some taxa. Such shifts would be driven by an increased motivation to reduce exposure to windchill and possibly to source terrestrial skins for clothing. The response anticipated from a general Yamana-like society is provided in table C3-13.

3.4.2.2 Energetic Weather

An increase in the prevalence, severity, and duration of storms, in a region with highly variable and energetic weather systems is a more serious threat to the Yamana. The opportunities for travel would be reduced as would the opportunity for fishing, crabbing and urchin collection all carried out from the canoe using specific tools (Gusinde, 1961). The collection of the vital large mussels would also be inhibited as they are likewise procured from the infralittoral zone. Collection requires calm weather and clear water as it is carried out visually at depths of over 3m. Possible archaeological signatures would be more larger middens with evidence for multiple contemporary huts, with a concomitant reduction in the smaller more ephemeral sites. In this scenario established social practices would result in an increased abundance of large pinnipeds in the assemblages with the entire skeleton represented, rather than a bias towards the bones of the flippers (ibid, p.69). The increase in dwelling signatures will, in part, be due to extended stays resulting in the Yamana building a new hut when an existing hut becomes unhealthy (ibid, p.31). Fish, crab, and urchin remains would probably become less abundant in the faunal assemblages. The size distribution of mussel shells would be skewed left as dependence on smaller intertidal specimens was increased. It is possible that larger male specimens of pinnipeds might be targeted to compensate for the reduced opportunity to hunt. In other words, 'buying in bulk' might be practiced as a tactical measure, not only to secure meat, but the vital supply of sea mammal oil. There may be changes in architecture with the more wind resistant conical hut (Ibid, p.9-12) replacing the domed hut. The conical hut however cannot be scaled to accommodate multiple families (Ibid, pp.9-12) so the number of dwellings per resident family will increase. Site locations are likely to exhibit greater levels of selectivity. Locations offering shelter from winds and rough seas would be more favoured and the sites may occur a bit further back from the shore to mitigate against large or freak waves. Fish weirs (usually an emergency measure) and the exploitation of forage fish may become visible within the archaeological record, although this is predicated on the weir structures being sufficiently robust. A north south or east west patterning of sites that exhibit stronger seasonal signatures may be observed, for example the presence of juvenile birds and pinnipeds. The response anticipated from a general Yamana-like society is provided in table C3-14.

3.4.2.3 RSL Rise.

A 3 to 4m rise in relative sea level would also be a disruption that required adjustments be made. Basically, sites would be distributed differently as the locations where crabs, large mussels and sea urchins are sourced will be too deep for the tools the Yamana utilise. New locations where the nature of the substrate and an appropriate depth coincide, will be used as campsites. The sites previously utilised would be abandoned. The hauling out spots for pinnipeds will change as will the location of their nursery beaches, and this will also influence the location of campsites. The same can be said for the nesting colonies of flightless birds such as the penguin. There are secondary consequences of a transgression of the type defined. That is the increase in the water column will change the energy level of waves arriving at the shore or penetrating inlets and the tidal range may increase at locations still in use (Ballantyne, 2004). What were previously considered as sheltered locations or passages for navigation may no longer be so, and especially so during storms; other very shallow areas may become suitable locations for sourcing invertebrates. The spatial patterning of sites will probably change as described above. Not all changes will be detrimental; in waterways of restricted width the increase in the water column may result in weaker currents making navigation easier. In general site locations may change over time. Low lying coastal planes will be inundated and where these are wooded or forested the trees will die; this will exhibit a heterogenous patterning both spatially and temporally in accordance with the local relief. All the above will occur over several generations (although possibly in the form of a series of rapid pulses) and adjustments can therefore be incremental. As the location of earlier sites will be lost due to inundation, archaeological visibility of these nuanced changes over time is going to be poor, if visible at all. Where pre and post inundation sites are found in close proximity a change in the species exploited may be observed in the zooarchaeological record as the fauna make the adjustments described above; but as stated this is likely to be a very weak signal. The response anticipated from a general Yamana-like society is provided in table C3-15.

3.4.2.4 A Tsunami

Finally, a tsunami and the implications it brings can be considered. It goes without saying that a tsunami of any magnitude is a catastrophic event that results in a significant mortality rate in the vicinity, whether human, faunal and floral. The question therefore is not so much the immediate impact but the recovery. In archipelagos the situation is different to the general case already described above as a load (large trees etc) will be acquired through contact with the first island and this will then impact subsequent islands in addition to the force of the water itself (Synolakis *et al*, p.76). Canoeists in the channels between islands will be killed, likewise those camped on the shore. Only those well in land and at an altitude above the local run up height will avoid the attentions of the wave. In the case of the Yamana these are locations they rarely frequent, and only when bark is required for canoe construction. The dwellings, canoes, tools and weapons will be destroyed and or deposited over a wide area, which may be some distance inland. On the assumption that some fortunate families survive, then what awaits them?

Camp sites will either be buried in debris or will have been swept clean. The materials for constructing huts left by previous occupants will be gone. The mussel (and other mollusc) beds will have either been smashed or smothered by sediment and debris. In some areas, sediment will have been stripped away leaving exposed rock. In the coastal strip exploited by the Yamana the smaller to medium trees with shallow root systems will have been swept away, along with the shrubs that bare berries. The majority of pinnipeds caught in shallower water or hauled out, will have been killed, likewise penguins and cormorants. If the timing was ‘wrong’ the eggs and or chicks will have been killed, likewise pinniped pups. The carcasses of whales, unfortunate to have been caught in relatively shallow water, will be present along with the carcasses of the above.

In the immediate aftermath, subsistence resources would be quite abundant as would the skins, tissues and bones of the mammals used as raw materials. The first requirement is to light a fire and if the pouch with the required materials has been lost then the basic issue of survival manifests itself, due to the lack of iron pyrites and flint within the territory (Gusinde, 1961, p.44-45). If the canoe has been lost, then it must be replaced and if the survivors are fortunate, the island they find themselves on will have a large Magellan beech at its centre to provide bark. It may need to be harvested out of season and the best made of a bad job; maybe by constructing a smaller canoe out of expediency. A smaller canoe may also be mandated as the usual team of three men would not be available and the husband and wife and older children would have to do their best. Shrubs baring berries may also be present in the interior, and if out of season, at least available during a future visit, likewise tree resident fungi. It is not unreasonable to allow the family a maximum window of around one month to get mobile and reequipped, as this is about the maximum time the largest marine mammal carcasses remain in a consumable state, if they can be reached. The Yamana have two advantages that stem from their extreme marine adaption. Firstly, they are not dependent (ignoring a piece of flint) on lithic tool kits that may have been lost; all they need to do is find a few large mussel valves and the odd razor clam valve amongst the carnage and they can basically ‘reboot’. Secondly, they are not dependent on finding terrestrial mammals in the coastal forest zone for raw materials. The coastal forests will of course have been severely damaged and may no longer offer a suitable habitat for the species in question, dictating that longer forays into the terrestrial habitat would be required. The destruction of the smaller shallow rooted trees close to the water’s edge will impede the replacement of harpoon and spear shafts, as well as the tools used to acquire invertebrates. One thing the Yamana do not need to worry about is impressing anyone, it is just not a component of their social system. Once the immediate bounty has been exploited (or it has date expired) and the family are reequipped, medium term considerations come into play.

The marine mammal resources will have been severely depleted and how long it will take for the populations to recover is unclear; the same can be said for the bird population, although those that can fly will probably repopulate more rapidly. Berries, wood (for weapons and tools) and fungi will have to be pursued further into the interior of islands and location (*sensu* Binford, 1980) type sites may become visible archaeologically. The location of surviving molluscs beds must be established, whilst the newly exposed rocks await colonisation by mussels and other epifaunal molluscs. In the archipelago setting, the direction of the tsunami may be material, with any relocation or migration being away from the direction from which the wave arrived; although as already noted this can be very misleading on islands. An open question relates to the relative strengths of two social factors which may conflict with each other. The first is the need to establish social relations, secure future marriages, and assemble teams for large tasks such as bark procurement. The required gatherings will firstly need to attract sufficiently large attendance from what is a reduced and probably more distributed population. A factor related to population level and dispersal is the ability to leverage whales as a resource. A large number of families are required to subdue an injured or sick whale, and this is also true for pulling a whale carcass to shore (Gusinde, 1961, p.224-227). Without the required aggregation of families only whales that are naturally beached can be exploited. The second is maintaining the integrity of local dialect groups whilst meeting the requirements of exogamy. It is likely that the spatial distribution of the surviving families will alter, both due to the need to establish social contacts and finding areas where the immediate depletion in resources is less severe. Spatial contraction may also be necessary to avoid excessive latency in the movement of trade through the network. Parts of the Yamana territory maybe abandoned temporarily. Archaeologically it is likely that the number of sites will reduce in response to a reduced population density and in some areas evidence of occupation may for a period be absent; whether that period is archaeologically visible will depend upon how long the population takes to recover. One fundamental aspect of the tsunami scenario is the physical relief of an area is a key factor on the degree of ecosystem disruption that will occur. The response anticipated from a general Yamana-like society is provided in table C3-16.

3.4.2.5 Aggregated Scenarios

There is one combination of environmental vectors that can be quickly considered and that is a temperature reduction coupled with an increase in stormy conditions. These are very simply additive increased precipitation, reduced temperature, and increased windchill are a deadly combination and the ability of the Yamana to travel and carryout activities outside of the hut would be severely constrained. It is difficult to envisage how the Yamana could continue without mitigation in the form of additional exploitation of terrestrial resources and the use of warm clothing; although as already stated the use of such clothing is not without its downside. Applying thicker coverings of the clay and sea mammal fat over their bodies (Gusinde, 1961, p.51-54, p.67-68) seems unlikely to be an adequate response.

The question naturally arises as to what happens if a tsunami is experienced after or during a period where a 4m increase in relative sea-level and 3^{O}C reduction in mean annual temperature are experienced. The situation is rather different compared to the first society. The major threat will be a drenched family group being unable to start a fire and this is probably a terminal situation in reduced temperatures with increased wind chill. The same level of compounding effects observed in the earlier society does not seem to apply here as the complications associated with social practices are not applicable.

3.4.3 Interim Summary

In general, a Yamana-like society should be able to adjust and adapt to any of the scenarios evaluated here (albeit via some pretty fundamental changes), except a tsunami where the challenge is not adaption but recovery. As noted by Binford (1980, pp.14-15) the Yamana are an anomaly in a behavioural gradient that sees a reduction in residential mobility and increased logistical and delayed return behaviour with increasing latitude. Yet, a Yamana-like society's success is based upon high-levels of mobility as this permits the population to disperse within the environment spreading the demand for resources more evenly and reducing the demand for resources from any given location. The same mobility permits rapid population aggregations to exploit resources a single family could not procure unaided. This mobility also facilitates the required social interaction and performance of vital social ceremonies when windfall resource abundance increases carrying capacity, negating temporarily, the need to disperse. Despite such a variety of marine resources being exploited a common theme emerges in that prolonged occupations exhaust local resources or alternatively drives fauna away from the location after a few hunting trips.

Of particular interest is the absence of any substantial clothing in such a cold, wet and windy environment. Whilst it maybe that this approach is being pushed to it limit of viability at the southern tip of South America, it nevertheless, makes total sense to this author. Anyone involved in outdoor pursuits knows that 'wet cotton kills'. The author suspects that if cloth clothing were employed, the Yamana would simply die of hypothermia. Taking, waterproof or not, clothing into a restricted dwelling space has two disadvantages; firstly, the clothing rarely dries in a single night, and everything else gets wet (pers. obs). Covering their bodies with a mixture of clay and fat (as cross channel swimmers do with the latter) to provide insulation (Gusinde, 1961, p.67-68) is a very honed adaption. Finally, it is possible that trade may need to be conducted in a logistical manner to ensure the resources required for survival are available when needed.

A Yamana-like society appears quite resilient to reductions in particular faunal resources and is not reliant on predictable seasonal abundances. The Yamana themselves are vulnerable to temperature changes because even though they live at a lower latitude than that of northern Scotland their environment is not under any moderating influence. A Yamana-like society is extremely vulnerable to reductions in their mobility due to weather and whilst adaptions can be made, these would be of a fundamental nature involving reduced residential moves and procurement strategies that envisage longer residency periods and the use of locations closer to known resource concentrations. Arguably, these would constitute a fundamental change to the point that the major characteristics of the way of life might be lost.

Finally, as postulated for British Columbia any scenario that results in extensive deforestation would be catastrophic. Territorial intrusion and hence contraction would also be a serious situation, especially if it denies access to the large (and very old) specimens of Magellan's beech from which bark is harvested. Territorial contraction accompanied by deforestation is possibly an extinction event for the sea nomad lifestyle.

3.5 Discussion

This analysis has considered two very different types of hunter-gatherer societies and their vulnerabilities to environmental change. In both cases the loss of key resources has been considered and, in both cases, an 'experiment' has already been conducted, but unfortunately the 'experiment' was poorly conceived and certainly not ethical. Both societies have experienced a drastic reduction in key resources such as pinnipeds, and cetaceans due to the activities of the European whaling fleets, as well as the fur trade for sea otter and fur seal (see Yesner, 2004 for a discussion). The former almost became extinct in the mid-1800s and Stellar's sea cow was regrettably extirpated. There are not even the faintest traces of a silver lining to this very very dark cloud. We can learn little from this 'experiment' as other conditions such as territorial integrity and acculturation (such as the introduction of iron cutting tools) were not held constant or avoided.

The vulnerabilities of these two societies are in many ways very different as might be anticipated. Yet certain common themes have emerged:

- Many of the most critical resources are (under most circumstances) archaeologically invisible. Under normal circumstances only bones, spines, shell and lithics survive. Carbonised plant remains survive but with the exception of the Moachat's use of yama berries, neither society significantly exploits plants for subsistence. Yama berries will only be carbonised by accident as their preparation of drying and pressing does not involve roasting or similar.
- The vast majority of the technologies utilised for both acquisition and storage are also invisible archaeologically. Of the nine key resources that the Moachat utilise in the system that catches whales and stores whale produce, only two are potentially (under normal circumstances) visible archaeologically. The situation is similar (three out of seven) for the Yamana.
- Both these very different societies are heavily dependent upon wood and particularly bark.
- The threat of deforestation, especially when combined with territorial intrusions, is a very real and serious one; whatever its root causes are.
- The importance of the social implications that may result from environmental changes cannot be overstated.

- Off-site butchery results in many key faunal resources being poorly represented or absent from the faunal record; that is unless they are also utilised as a raw material for artefact manufacture.
- Both societies acquire their resources in a predominantly logistical manner.

A number of other elements are highlighted that warrant consideration going forward.

- Large substantial houses and huts are not indicative of sedentism or even low frequencies of residential mobility.
- Pits in houses (pit house) may simply be to protect the fire from wind. The absence or presence of pits may well constitute an environmental proxy.
- The function of certain artefacts would be completely unclear without the ethnography. A key example being the non-hook shaped fishhooks utilised by the Moachat. A very similar artefact is utilised by the Yamana as a gorge hook for snaring birds on land. The Yamana do not use hooks when line fishing.
- The intertidal zone contributes little to the overall subsistence economy in either society, despite both societies generating substantial shell-middens. Most resources are acquired from the infralittoral, sublittoral and open water (Figure C3-7).

Another feature that should be explored is the relationship between group size and the subsistence strategies that are probably viable. In terms of social complexity and group size the Moachat and the Yamana are very close to being at the ends of the continuum of such attributes. It is difficult to envisage a Yamana family having the resources available to support sufficient ‘spare time’ to construct the 110m or more of bark rope required for active whaling. Constructing fishing nets poses a similar challenge for groups of this size as discussed in chapter 2.

3.6 Conclusion.

The interpretation of similar, including very similar, artefact forms require careful consideration as highlighted by the fishhook example. The relationship between certain artefacts forms and the function and objective they enable is highly variable. Similarly, certain procurement activities appear in very different anthropological settings and yet are always invisible archaeologically, as in the case of startling sleeping birds during inclement weather with a torch and then manually despatching them before they can recover and flee. Such an approach was practiced both in British Columbia and in Tierra del Fuego.

Certainly, the data evaluated and the potential for evaluating the experience of hunter-gatherers living with environmental change and events is at first glance rather depressing, as the majority of raw materials and resources that really reflect their lives are basically invisible to the archaeologist, which is hardly a surprise. What the data does provide is a detailed view on the ‘invisible reasons’ why hunter-gatherers might change their behaviour in response to their environment. But all is not lost as some options are available to pursue. These are:

1. A change in taxa exploited, both in terms of composition but also physical attributes.

2. A change in the raw materials exploited.
3. A change in architecture.
4. A change to a seasonal occupation where it is not evidenced before.
5. A change in season of occupation.
6. A loss of seasonality at a site.
7. Evidence for increased duration of occupations.
8. A change in the distribution of sites within the coastal landscape.
9. Abandonment of sites or areas.

With exception of 8.) above it is not unreasonable to propose that the above do not change materially when everything is going well and according to plan. The nuances that change simply due to innovation or individual variability are probably occurring within the archaeologically invisible realm. Conversely, when the above start to change there is also probably even greater change occurring within the invisible realm. As stated above 8.) above does not fit entirely within the stated paradigm as it may change simply due to population expansion. The methodologies employed to identify sedentary behaviour need careful re-evaluation. Arguably an agenda needs to be defined that actively seeks mobility and the variety of forms it takes due to innovative capabilities of hunter-gatherers. Mobility cannot simply be a failure of archaeologists to demonstrate sedentism.

During this review changes to conventional archaeological remains have been considered. In many cases similar changes are observed as a result of the application of quite different environmental vectors. In some cases, it is a combination of changes in the archaeology that reduce the equifinality, but the potential for the archaeological science to contribute must be considered. Stable isotope analyses can elucidate both changes in the resource base and the environmental conditions that might have prevailed in the past. Palynology can inform us about the changes in land cover or use that might be associated with the changes in the archaeology. A challenge is that of chronology, as multiple occupations and periods of non-occupation occur at a temporal scale that is swamped by the uncertainty in radiocarbon chronologies. Related to this is the challenge of associating environmental vectors with archaeological events. These challenges and opportunities are the subject of other chapters.

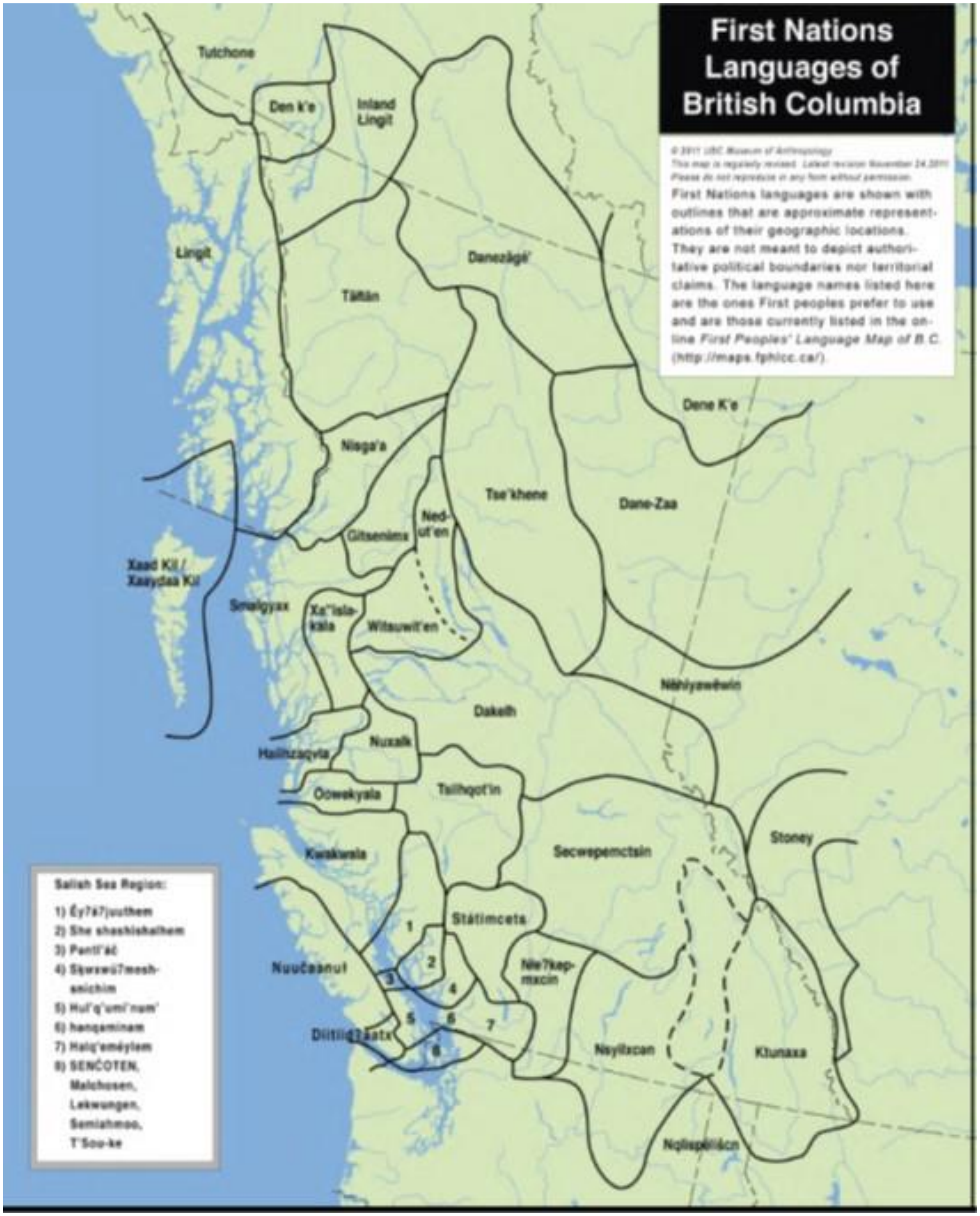
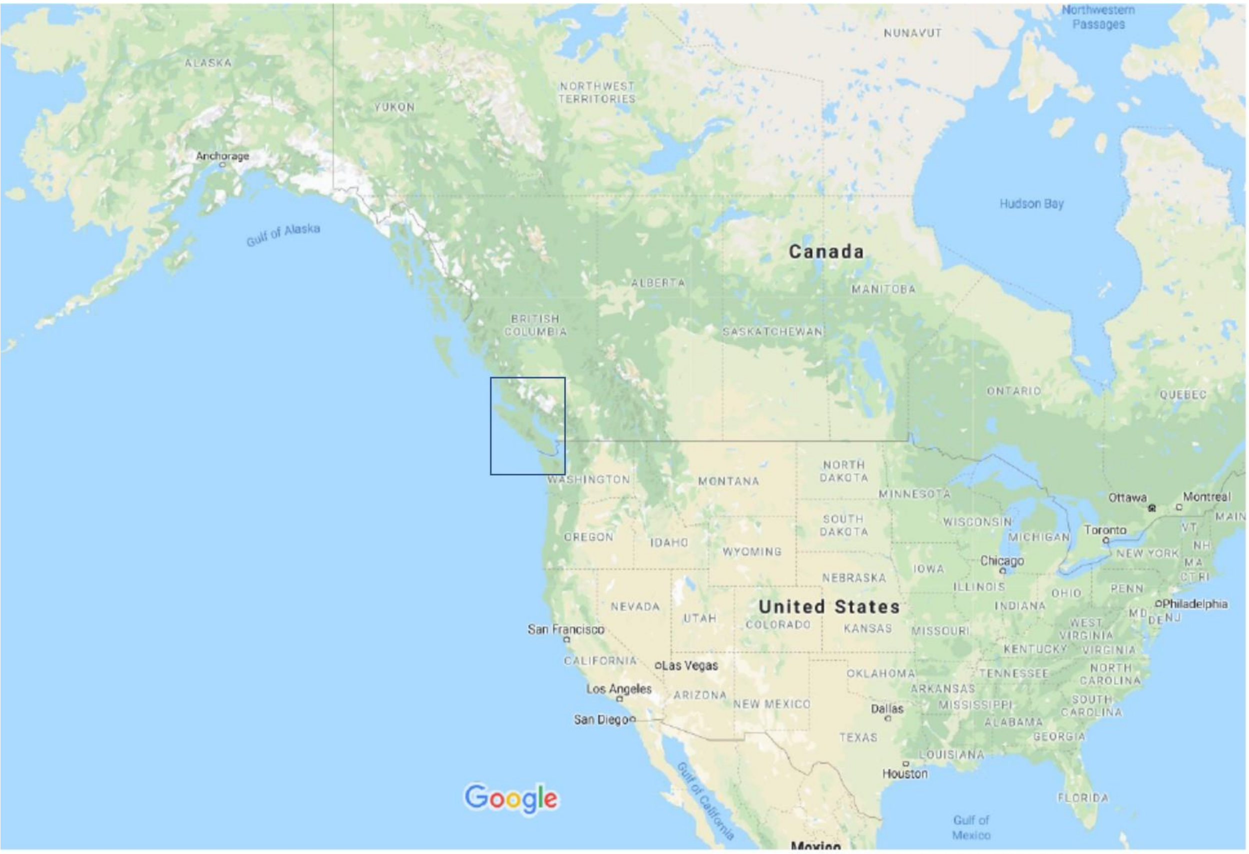


Figure C3-1: Map of Language Groups in British Columba. As discussed in the main text the language groups generally map to the biotopes exploited**.**



Map data ©2020 Google, INEGI 500 km

Figure C3-2A: The location of the area occupied by the complex hunter-gatherers of British Columbia, Canada. The latitudinal displacement from the equator is slightly less than the Scilly Isles in the UK.

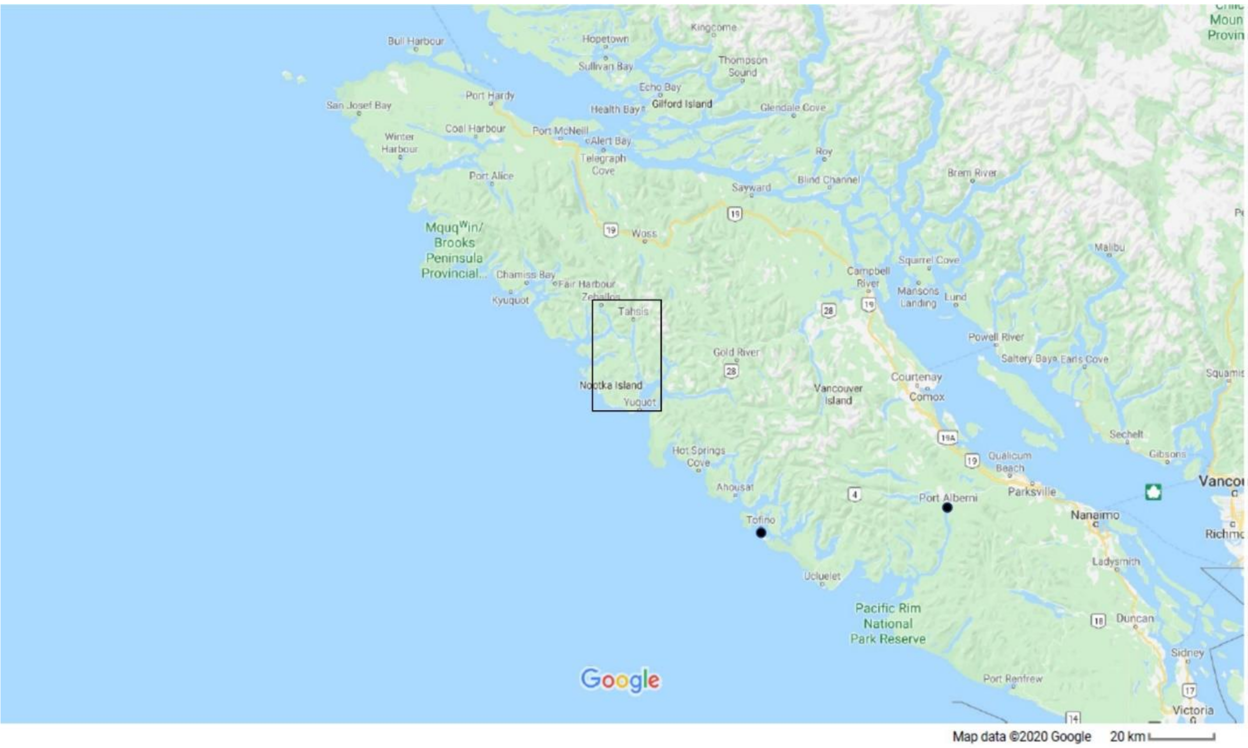


Figure C3-2B: The location of Friendly Cove on Vancouver Island. The black dots show the locations for which modern SST data was obtained.

Figure C3-2C: Friendly Cove and the locations of the three seasonal villages of the Moachat.

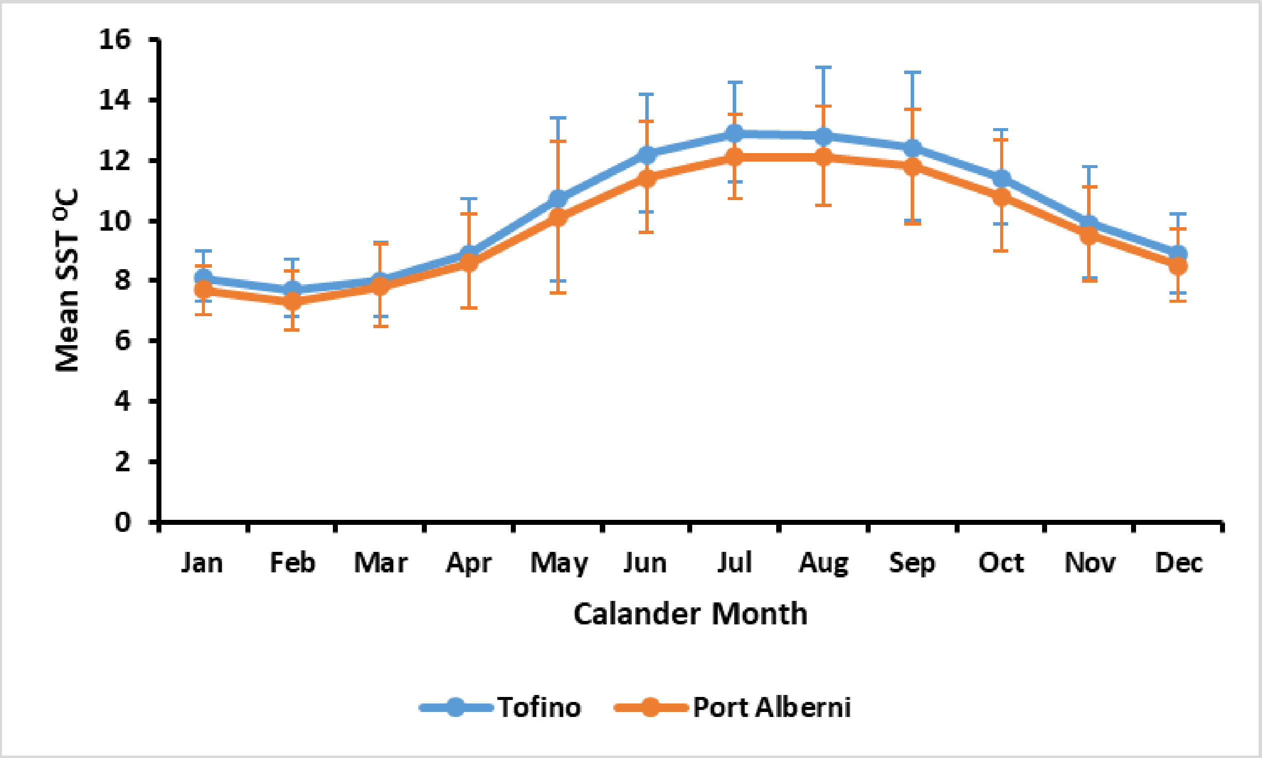


Figure C3-3: Modern mean sea surface temperatures from the locations shown in figure C3-2B. The error bars show the range covered by the lowest mean temperature recorded for a month and likewise the highest, therefore these do not reflect extreme daily temperatures. Temperatures on the open coast are slightly higher than those at the head of major inlets.

Figure C3–4a: The location of Tierra del Fuego. Its latitudinal displacement from the equator is approximately the same as Manchester in the United Kingdom.

Figure C3–4b: The approximate location of the groups referred to in the main text and literature cited therein. Red = Haush, Purple = Selk'nam Lower Black = Yamana Upper black = Kaweskar, Green = Chronos.

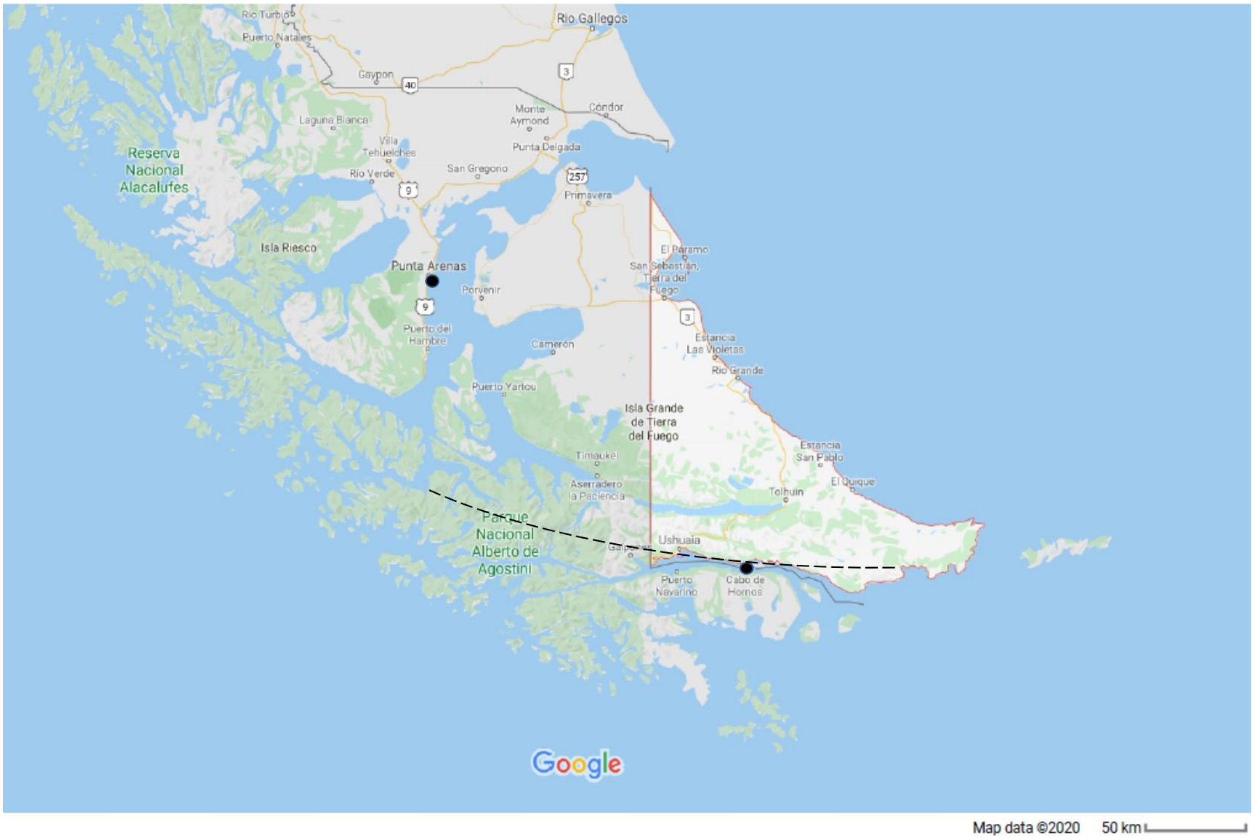


Figure C3–4c: The locations from which SST were taken. The Yamana occupy the region south of the dotted line.

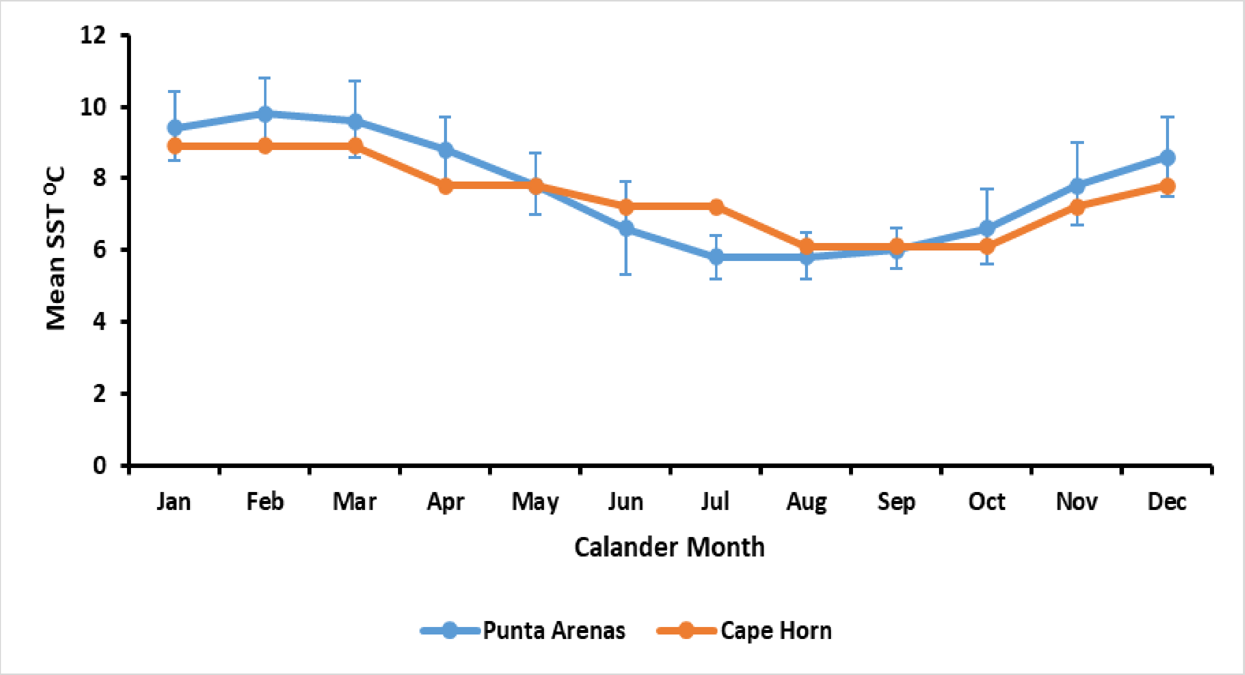


Figure C3–5: Modern mean sea surface temperatures from the locations shown in figure C3-4c. The error bars show the range covered by the lowest mean temperature recorded for a month and likewise the highest, therefore these do not reflect extreme daily temperatures. No range data was available for Cape Horn. Temperatures on the open coast are slightly higher in winter than those within the channels.

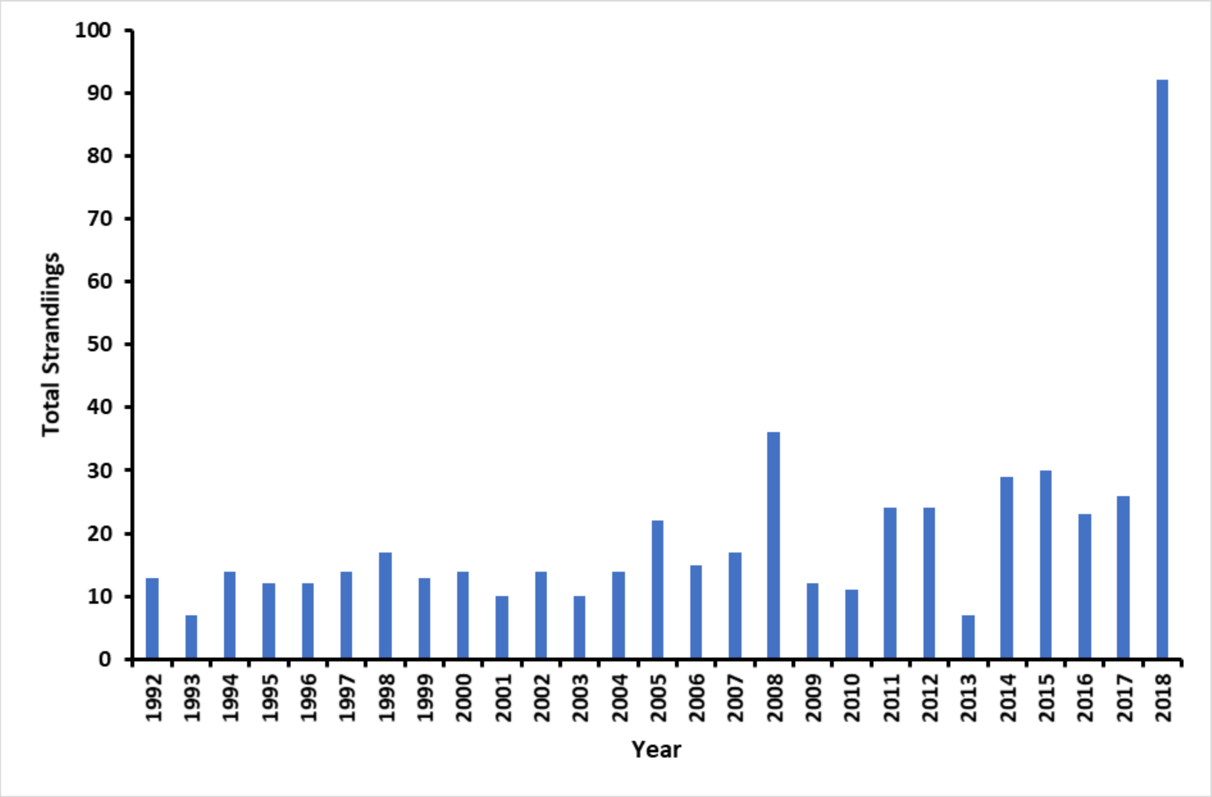


Figure C3-6: Whale strandings on the margins of the Minch (see chapter n for location) and the Atlantic coast of the Western Isles. There appears to be a general upward trend as the whale populations recover following the whaling moratorium in the mid-1980s, following a time lag for the increasing population to reach sexual maturity. The figures for most species in 2018 are consistent with earlier years. There was however a massive level of mortality for Cuvier's Beaked Whale (*Ziphius cavirostris*), especially in August and September, which resulted in the extremely high overall total. The data excludes the standing of dolphins and porpoises, pinnipeds, basking sharks and marine turtles. Nine species were recorded including large species such as the sperm whale (*Physeter macrocephalus*), fin whale (*Balaenoptera physalus*) and humpback whale (*Megaptera novaeangliae*), all of which exceed 50,000kg in weight. Data from the database of the Scottish Marine Mammal Stranding Scheme.

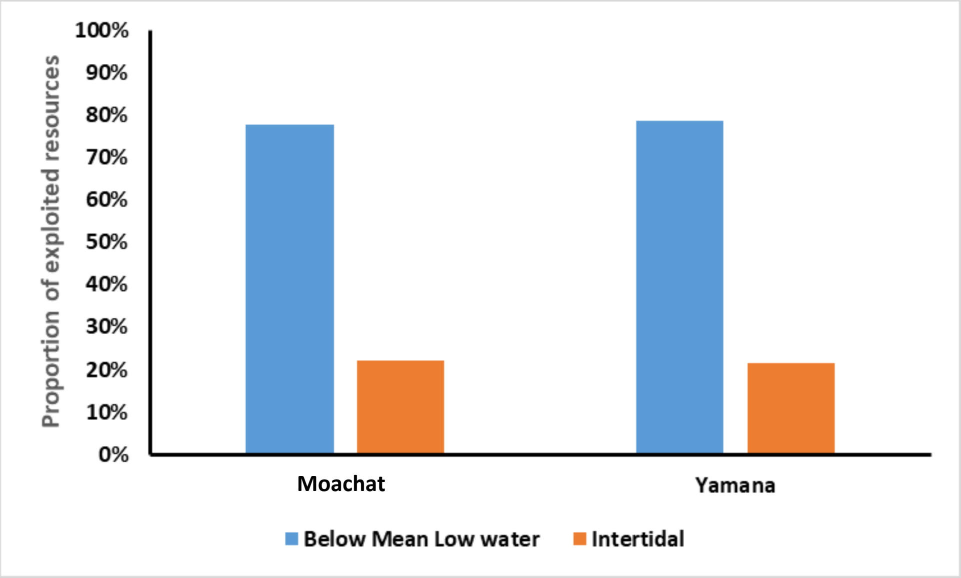


Figure C3-7: Relative proportions of resource species obtained from the intertidal and from the infralittoral, sublittoral and pelagic zones.

Table C3-1: Resources exploited by the Moachat. Highlighted rows are archaeologically visible. Resources highlighted in negative are critical in more than one respect. C=critical for the purpose shown by a column, Y exploited for the purpose shown by the column, S utilised as a status item.

	Seasons	Locations	Season of Focus	Location of Focus	Acquisition	Immediate Consumption	Stored	Raw Material	Purpose	Notes
Mammals										
Deer	Adhoc	Cooptee Sashtees	Adhoc	?	Hunted/Trapped/Traded	Y		Y	Skin Bone	Deer was consumed from time to time.
Moose	Adhoc	Cooptee Sashtees	Adhoc	?	Trapped/Traded	Y		S	Skin	Deer was consumed from time to time.
Lynx/Cougar	Adhoc	Cooptee Sashtees	Adhoc	?	Trapped/Traded			S	Skin	
Wolf	Adhoc	Cooptee Sashtees	Adhoc	?	Trapped/Traded			S	Skin	
Bear	Adhoc	Cooptee Sashtees	Summer/Autumn		Trapped	Y		S	Skin/Bone	ritual cannot be considered a primary source of subsistence
Sea Otter	Adhoc	Yukwat	Spring/Summer	Yukwat	Hunted afloat Clubbed	Y		S	Skin	European contact.
Seal	Adhoc	Yukwat	Spring/Summer	Yukwat	Hunted afloat Clubbed	C	C	C	Skin Bone Tissue	Blubber is stored. Skins for storage and whale floats
Sea Lion	Adhoc	Yukwat	Spring/Summer	Yukwat	Hunted afloat Clubbed	C	C	C	Skin Bone	Blubber is stored. Skins for storage and whale floats
Sea Cow	Adhoc	Yukwat	Spring/Summer	Yukwat	Hunted afloat	Y	Y	?		
Elephant Seal	Adhoc	Yukwat	Summer	Yukwat	Hunted afloat	Y		Y	Skin Bone Tissue	Blubber is stored. Skins for storage and whale floats
Dolphin/Porpoise	Adhoc	Yukwat	Spring/Summer	Yukwat	Hunted afloat	Y	Y	Y	Skin Bone Tissue	
Whale	Spring/Summer	Spring	Spring/Summer	Yukwat	Hunted Scavenged afloat	C	C	C	Bone Tissue	
Birds	All	All	Spring/Summer	Yukwat	Hunted/Trapped/Traded	Y		Y	Bone Feathers	Bones Feathers and quills
Ducks and Geese	Autumn Winter	Cooptee Tashtees			Hunted/Traded	Y		Y	Bone Feathers	Bones Feathers and quills
Fish										
Chinook Salmon	Spring/Summer	Yukwat	Summer	Yukwat	Line fished afloat	C	Y			had developed
Coho Salmon	Spring/Summer	Yukwat Tashees	Summer/Autumn		Line/Trapped/Netted afloat	C	C			had developed
Chum Salmon	Autumn	Tashees	Autumn	Tashees	Trapped/Netted	C	C			
Herring	Winter	Cooptee	Winter	Cooptee	Raked/Netted afloat	C	C			Critical for immediate consumption in winter
Smelt	Winter	Cooptee	Winter	Cooptee	Raked/Netted afloat	Y	Y			
Halibut	Spring/Summer	Yukwat			Line fished afloat	C	Y			Critical for immediate consumption in spring
Cod	Spring/Summer	Yukwat			Line afloat	Y	Y			Critical for immediate consumption in spring
Salmon Spawn	Autumn	Tashees	Autumn	Tashees	Trapped/Netted	C	C			
Herring Spawn	Summer	Yukwat	Summer	Yukwat	Trapped	Y	C			
Invertebrates										
Crabs	Spring/Summer	Yukwat			Littoral Afloat	Y				Not sure how these were acquired
Infaunal Bivalves	Summer	Yukwat			Gathered Littoral	Y	Y	Y	Shell	Tools and Musical Instruments
Mussels	Adhoc	All			Gathered Littoral	Y		C	Shell	Jewitts account implies a food of deprivation
Epifaunal Gastropods	Adhoc	All			Gathered Littoral	Y		S	Shell	Jewitts account implies a food of deprivation
Dentalium	Adhoc	All			Traded			S	Shell	
Plants and Fungi										
Wild Berries	Autumn	Cooptee			Gathered	Y				
Yama Berries	Autumn	Cooptee			Gathered	Y	C			Pressed and dried
Roots	Adhoc	All			Traded	Y				
Critical						9	9			

Table C3-2: Table showing key resources (rows) and the resources required to acquire them or manufacture the system that acquires them (columns). R=raw material, M=used in manufacture. Marine mammals are those that require the greatest suite of resources to acquire them. Whale bone, wood and bark are the resources involved in the acquisition of the most key resources. Highlighted columns are those archaeologically visible.

	Whale Bone	Whale Tissue	Other Bone	Seal Skin	Mollusc Shell	R/R/G	Wood (Trunks) Large/Medium	Wood (Trunks) Small	Bark	Wood (Branches/twigs)	Lithics	Total
Whale Bone	R	R		R	RM		R	R	R		M	8
Whale Blubber	R	R		R	RM		R	R	R		M	8
Whale Tissue	R	R		R	RM		R	R	R		M	8
Whale Flesh	R	R		R	RM		R	R	R		M	8
Whale Oil	R	R		R	RM		R	R	R		M	8
Pinniped Skin	R	R			R		R	R	R		M	7
Seal Blubber	R	R			R		R	R	R		M	7
Seal Oil	R	R			R		R	R	R		M	7
Seal Flesh	R	R			R		R	R	R		M	7
Otter Skin	R	R							R	R	RM	5
Otter Flesh	R	R							R	R	RM	5
Terrestrial Mammal Skin					M	R		R	R	R	RM	6
Terrestrial Mammal Flesh						R		R	R	R	RM	5
Terrestrial Mammal. Bone						R		R	R	R	RM	5
Bird Flesh	R	R							R	R	RM	5
Bird Bone	R	R							R	R	RM	5
Salmon Oil							R	R	R	R	M	5
Salmon spawn						R				R		2
Salmon flesh	R					R	R	R	R	R	M	7
Herring Spawn										R		1
Herring Flesh	R						R	R		R	M	5
Halibut/Cod	R						R		R		M	4
Wild Fruits						R						1
Yama Berries						R						1
Mollusc Flesh										R		1
Mollusc Shell										R		1
R/R/G												0
Wood Trunks (large/Medium)			M								M	2
Wood Trunks (small)			M								M	2
Bark										M	M	2
Wood (Branches/Twigs)											M	1
Lithics			M								M	2
Total	16	13	3	5	10	7	13	15	19	15	25	

Table C3-3: Stored and consumed resources (row)s, Resources used to store (columns). C=utilised to consume, P=utilised to prepare for storage/use, M=used to manufacture the storage vessel, S=used to store the resource. Highlighted rows and columns archaeologically visible.

	Whale Oil	Whale Blubber	Seal Blubber	Seal Skin	Seal Oil	Salmon Oil	Mollusc Shell	R/R/G	Wood (Trunks) Large/Medium	Wood (Trunks) Small	Bark	Wood (Branches/Twigs)	Lithics	Total
Whale Blubber									S				M	2
Whale Flesh	C				C	C							P	4
Whale Oil				S					S				M	3
Seal Skin							P					P	P	3
Seal Blubber									S	S			P	3
Seal Oil				S			M		S	S			M	5
Seal Flesh	C				C	C							P	4
Otter														
Skin							P					P	P	3
Otter														
Flesh	C				C	C							P	4
Terrestrial Mammal Skin.							P					P	P	3
Terrestrial Mammal Flesh	C				C	C							P	4
Bird Flesh	C				C	C							P	4
Salmon Oil				S			M		S				M	4
Salmon spawn	C				C	C	M		S				M	6
Salmon flesh	C				C	C				S		S	M	6
Herring Spawn	C				C	C			S					4
Herring Flesh	C				C	C							M	4
Halibut/Cod	C				C	C				S			P	5
Wild Fruits	C				C	C								3
Yama Berries	C				C	C		S			S	S		6
Mollusc Flesh	C				C	C		S	S		S	S		7
Consumption	13	0	0	0	13	13	0	0	0	0	0	0	0	
Storage	0	0	0	3	0	0	0	2	8	4	2	3	0	
Preparation	0	0	0	0	0	0	3	0	0	0	0	3	10	
Manufacture	0	0	0	0	0	0	3	0	0	0	0	0	7	

Table C3-4: Resource Roles in Social Functions including architecture and canoes. U=Utilised or consumed, R=raw material used, M=used for manufacture of. Potlatch and outward trade utilise all the resources for which a surplus in generated. Highlighted columns and rows should be archaeologically visible.

	Accommodation	Clothing	Status Attire	Status Possession	Potlatch	Outward Trade	Inward Trade	Music / Dancing	Rituals inc Burial	Canoes (Whaling/Social Visits/Relocation)	Medicine	Slaves	Total
Whale Bone			U										1
Whale Blubber					U	U							2
Whale Flesh					U	U							2
Whale Oil					U	U							2
Seal Skin		U			U	U			U				4
Seal Blubber					U	U							2
Seal Oil					U	U							2
Seal Flesh					U	U							2
Otter Skin			U	U	U	U	U		U				6
Otter Flesh					U								1
Terrestrial Mammal Skin		U	U		U		U	M	U				6
Terrestrial Mammal Flesh									U				1
Terrestrial Mammal Bone							U	M					2
Bird Flesh							U						1
Bird Bone							U						1
Feathers		U											1
Salmon Oil					U	U							2
Salmon spawn					U	U							2
Salmon flesh					U	U							2
Halibut/Cod Flesh													0
Herring Spawn					U	U							2
Herring Flesh					U	U							2
Wild Fruits													0
Yama Berries					U	U							2
Mollusc Flesh													0
Dentalium			U	U	U		U		U			U	5
Mollusc Shell								M					
R/R/G													0
Wood Trunks (Large)	R							C		R			3
Wood Trunks (Small)	R									R			2
Bark		R				U					R		3
Wood Branches/Twigs								M					1
Root Crops							U						1
Pigment		R	U		U				U	R			5
Lithics	M						U		R	M			4
Total	3	5	5	2	18	15	8	5	7	4	1	1	

Table C3-5: Potential changes in the archaeological record associated with a Moachat-like society that result from the defined temperature vector.

Nootka Like Society	**Temperature Existing Sites**	**Temperature New Sites**	**Comments**
Sites (Existing)			
Dwellings			
Area/Size			
Positioning	C		More task camps may appear further inland to source terrestrial mammals.
Regional Spatial distribution			
Occupation Duration	C		If seasonal resource timings change then occupation at each location may be adjusted.
Site abandonment/loss			
Site locations			
Seasonal Patterning			
Large ceremonial sites.			
Architecture (Existing)			
Form			
Size			
Raw Material			
Robustness			
Material Culture (Existing)			
Lithic Raw materials			Increase in firecracked stones.
Grave Goods			
Status items			
Armatures form	C		May change to reflect increased pursuit of terrestrial fur animals for clothing.
Armatures material			
Processing Tools (scrapers, awls etc)			
Faunal Community (Existing Sites)			
Mammal Composition/Abundance	P		Increase in terrestrial mammals.
Avian Composition/Abundance			
Fish Composition/Abundance	P		Halibut, cod and herring migrations may change or even move.
Invertebrate Composition/Abundance			
Seasonal spatial patterning	P		Greater seasonal variation in abundance of exploited taxa.
Fish Growth Rate	C		Growth rate reduced.
Invertebrate Growth Rate/Size	C		Growth rate reduced.
Floral Community (Existing Sites)			
Grassland pollen			
Tree pollen	C		Loss of frost intolerant taxa.
Plant macrofossils	C		Loss of frost intolerant taxa.
Microcharcoal	I		Larger fires for warmth.
C = probable change P = possible change R = Reduction I = Increase M=Mitigation	Temperature changes that result from a weakening or hiatus in moderating influences will be more severe and will probably exhibit a relatively greater magnitude in late autumn, winter, and early spring. Late spring, summer and early autumn are more greatly influenced by the frequency of high pressure systems and insolation levels.		

Table C3-6: Potential changes in the archaeological record associated with a Moachat-like society that result from the defined weather system vector.

Nootka Like Society	**Storminess Existing Sites**	**Storminess New Sites**	**Comments**
Sites (Existing)			
Dwellings			
Area/Size			
Positioning	C		Existing sites may incrementally move away from the shore.
Regional Spatial distribution			
Occupation Duration	C		May be adjusted in response to resource yields or resource location changes.
Site abandonment/loss	P		Possible abandonment of outer coastal sites.
Site locations	C		Possibly some inland task camps to increase yield from terrestrial plants, animals marine resources.
Seasonal Patterning			
Large ceremonial sites.			
Architecture (Existing)			
Form	C		Larger and more boulders on the roof.
Size			
Raw Material			
Robustness			
Material Culture (Existing)			
Lithic Raw materials	P		More local resources due to inhibited trade routes.
Grave Goods	C		Reduction due to inhibited trade. Surplus reduced, aligning reduced acquisition with subsistence.
Status items	C		Reduction due to inhibited trade. Surplus reduced, aligning reduced acquisition with subsistence.
Armatures form	P		Forms for terrestrial animals and birds. Increase in arrow head abundance.
Armatures material	P		Less use of marine mammal and possibly more terrestrial mammal.
Processing Tools (scrapers, awls etc)	P		More shell tools.
Faunal Community (Existing Sites)			
Mammal Composition/Abundance	P		More terrestrial species.
Avian Composition/Abundance	C		Change in species due to reduced trade and local exploitation.
Fish Composition/Abundance	R		Reduced abundance due to reduction in fishing days. Task camps if herring spawn locations revised.
Invertebrate Composition/Abundance	I		Increase in exploitation as mitigation. May require task camps at new locations.
Seasonal spatial patterning			
Fish Growth Rate			
Invertebrate Growth Rate/Size			
Floral Community (Existing Sites)			
Grassland pollen			
Tree pollen			
Plant macrofossils			Increased exploitation of plant foods. Less whale oil drives increase in carbohydrate intake.
Microcharcoal			
C = probable change P = possible change R = Reduction I = Increase M=Mitigation	Increased frequency of storms and rough seas is a significant issue. This is highlighted by the fact the Hebridean Whales Cruises lost so many sailing days in July and August 2014 they announced on social media they lacked the financial resources to restart the following spring. Those sailings that could take place were often curtailed, as was my own, from the full 6 hour trans-Minch trip to a 3 hour mainland coastal version. It should also be noted that the species composition and population structures within the intertidal zone will change.		

Table C3-7: Potential changes in the archaeological record associated with a Moachat-like society that result from the defined sea-level vector.

Nootka Like Society	**Sea Level Existing Sites**	**Sea Level New Sites**	**Comments**
Sites (Existing)			
Dwellings			
Area/Size			
Positioning	C		Locally relocated due to threat of inundation or storm wave damage.
Regional Spatial distribution			
Occupation Duration			
Site abandonment/loss	P	M	
Site locations	C		Task camps may be required to exploit new locations for invertebrates, sea mammals, herring spawn.
Seasonal Patterning			
Large ceremonial sites.			
Architecture (Existing)			
Form			
Size			
Raw Material			
Robustness			
Material Culture (Existing)			
Lithic Raw materials			
Grave Goods			
Status items			
Armatures form			
Armatures material			
Processing Tools (scrapers, awls etc)			
Faunal Community (Existing Sites)			
Mammal Composition/Abundance			
Avian Composition/Abundance			
Fish Composition/Abundance			
Invertebrate Composition/Abundance			
Seasonal spatial patterning			
Fish Growth Rate			
Invertebrate Growth Rate/Size			
Floral Community (Existing Sites)			
Grassland pollen			
Tree pollen	R		Loss of coastal woodland and coastal forest plains.
Plant macrofossils			
Microcharcoal			
C = probable change P = possible change R = Reduction I = Increase M=Mitigation	The key challenge with sea level changes for groups that occupation locations close to the shore and therefore at low elevations is whether the pre-event sites remain archaeologically visible. Isostatic readjustments may bring submerged sites back above sea level but with what level of integrity is unclear.		

Table C3-8: Potential changes in the archaeological record associated with a Moachat-like society that result from the defined Tsunami input.

Nootka Like Society	Tsunami Existing Sites	Tsunami New Sites	Comments
Sites (Existing)			
Dwellings	R	R	Number of houses reduced due to reduced population. Resource/labour constraint on rebuild.
Area/Size	R	R	Number of houses reduced due to reduced population. Resource/labour constraint on rebuild.
Positioning	C	C	
Regional Spatial distribution			
Occupation Duration			
Site abandonment/loss	C		Site may be irrecoverable.
Site locations	C	C	Increased exploitation of terrestrial mammals and plant resources.
Seasonal Patterning			
Large ceremonial sites.			
Architecture (Existing)			
Form			
Size	R	R	Reduced population and resource/labour constraint on rebuilds.
Raw Material			
Robustness	R	R	Reduced population and resource/labour constraint on rebuilds.
Material Culture (Existing)			
Lithic Raw materials	C	C	More local resources due to inhibited/lost trade routes.
Grave Goods	R	R	No surplus or vastly reduced. Some items no longer available via trade.
Status items	R	R	Little or no surplus. No longer available via trade. Smaller canoes. Labour shortage for cloth production.
Armatures form	C	C	Increase in forms for bird and terrestrial mammals.
Armatures material	C	C	More terrestrial mammal bone. Alternatives to bark rope due to labour constraint.
Processing Tools (scrapers, awls etc)	C	C	More terrestrial mammal bone or shell.
Faunal Community (Existing Sites)			
Mammal Composition/Abundance	R	R	Less being acquired deposition intensity reduced. Resource base also reduced.
Avian Composition/Abundance	R	R	Less being acquired deposition intensity reduced.
Fish Composition/Abundance	R	R	Less being acquired deposition intensity reduced.
Invertebrate Composition/Abundance	R	R	Less being acquired deposition intensity reduced. Resource base also reduced.
Seasonal spatial patterning			
Fish Growth Rate			
Invertebrate Growth Rate/Size			
Floral Community (Existing Sites)			
Grassland pollen			
Tree pollen	R	R	Loss of coastal woodland and coastal forest plains.
Plant macrofossils	I	I	Greater exploitation as mitigation.
Microcharcoal			
C = probable change P = possible change R = Reduction I = Increase M=Mitigation	A Nootka type society appears to have established trading partners with which a formal trade route exists. Based upon Jewitt (1824)'s account the frequency of trade missions appears to be factored by distance, which can be hundreds of miles. Three prerequisites exist; both parties must have amassed sufficient surplus and wealth, the labour to conduct the trade mission can be allocated, and the trip can be physically made. The mechanism is direct and channelled exchange and not dependent upon diffusion.		

Table C3-9: Resources exploited by the Yamana. Highlighted rows are archaeologically visible. Resources highlighted in negative are critical in more than one respect. C=critical for the purpose shown by a column, Y exploited for the purpose shown by the column, S utilised as a status item, T stored tactically.

Resource	Seasons	Locations	Acquisition	Immediate	Stored	Raw Material	Purpose	Notes
Mammals								
Guanaco	Winter	Isla Navarro	Traded/Hunted	Y		Y	Skin Bone	Instances of bed blanket known. Female preference for skin.
Fox	All	All	Hunted	Y		Y	Skin	
Otter	All	All	Hunted			Y	Skin	Known to be eaten in a crisis.
Seal	All	All	Hunted afloat foot	C	T	C	Skin Bone Tissue	Oil stored. Digestive organs for storage
Sea Lion	All	All	Hunted afloat foot	C	T	C	Skin Bone Tissue	Oil Stored. Digestive organs for storage
Elephant Seal	All	All	Hunted afloat foot	Y	T	C	Skin Bone Tissue	Oil Stored. Digestive organs for storage
Whale	All	Adhoc	Scavenged afloat	C	T	C	Bone Tissue	Blubber stored tactically. Sick and weak whales actively killed
Birds								
Geese	Summer/Autumn	All	Trapped	Y		Y	Bone	Feathers and quills
Cormorant	All	All	Hunted Afloat Foot	C		Y	Bone Skin Tissue	Skin Bone Feathers quills digestive organs for storage
Penguin	Spring/Summer	All	Hunted Afloat Foot	C		Y		Skin Feathers
Albatross	Spring/Summer	All	Hunted Afloat Foot	Y		Y	Bone Skin Tissue	Feathers, bone, webbing
Eggs	Spring/Summer	All	Gathered	Y				
Fish								
Patagonian blenny	Spring/Summer/Autumn	All	Line Spear afloat	Y				Sinew line No hook used
Forage fish	Adhoc	All	Line afloat	Y				Caught with seaweed line No hook used
Herring	Autumn/Winter/Spring	All	Scavenged, Extracted afloat	Y				Beached shoals, also scooped with baskey
Invertebrates								
Mussels (M. edulis)	All	All	Gathered Littoral	Y				
Mussels (M. chilenensis)	Spring/Summer/Autumn	All	Gathered Infralittoral	Y		C	Shell	Cutting, fluid collection
Razor Clam	All	All	Gathered Littoral				Shell	Precision cutting tasks
Voluta spp.	Spring/Summer/Autumn	All	Gathered Infralittoral	Y			Shell	Shell for fluid capture
Epifaunal Gastropods	All	All	Gathered Littoral	Y			Shell	Adornment
Crabs	Spring/Summer/Autumn	All	Gathered Infralittoral	Y				
Urchins	Spring/Summer/Autumn	All	Gathered Infralittoral	Y				
Plants and Fungi								
Fungi	All	All	Gathered	Y		C	Tinder	Many species (circa 10) each ripe in different months - also tinder
Wild Berries	Autumn	All	Gathered	Y				
Roots	Adhoc	All	Traded	Y				
Critical				5	0	6		

Table C3-10: Table showing key resources (rows) and the resources required to acquire them or manufacture the system that acquires them (columns). R=raw material, M=used in manufacture. The in general the use of specific tools for different resources results in complex interdependences as shown in the total column. Whale bone, wood and bark are the resources involved in the acquisition of the most key resources. Highlighted columns are those archaeologically visible.

	Whale Bone	Whale Tissue	Seal Skin	Other Bone	Seal Tissue	Seaweed	Bird Quill	Mollusc Flesh	Mollusc Shell	R/R/G	Wood (Trunks) Large/Medium	Wood (Trunks) Small	Wood Branches Twigs	Bark	Lithics	Total
Whale Bone	RM	R	R	M					M			R		R	M	8
Whale Blubber	RM	R	R	M					M			R		R	M	8
Whale Flesh	RM	R	R	M					M			R		R	M	8
Whale Tissue	RM	R	R	M					M			R		R	M	8
Whale Oil	RM	R	R	M					M			R		R	M	8
Seal Skin	RM	R	R	M	R				M			R		R	M	9
Seal Tissue	RM	R	R	M	R				M			R		R	M	9
Seal Blubber	RM	R	R	M	R				M			R		R	M	9
Seal Oil	RM	R	R	M	R				M			R		R	M	9
Seal Flesh	RM	R	R	M	R				M			R		R	M	9
Otter Skin	R			R					M			R			RM	5
Fox Skin	R			R					M			R			RM	5
Wild Fruits										R						1
Roots													R			
Fungi										R						1
Seaweed																0
Bird Skin	RM	R	R	RM					M			R	R	R	RM	9
Bird Flesh	RM	R	R	RM					M			R	R	R	RM	9
Bird Bone	RM	R	R	RM					M			R	R	R	RM	9
Bird Tissue	RM	R	R	RM					M			R	R	R	RM	9
Feathers	RM	R	R	RM					M			R	R	R	RM	9
Quills	RM	R	R	RM					M			R	R	R	RM	9
Forage Fish	RM	R				R	R	R	M			R		R	M	9
Large Fish	RM	R		RM	R		R	R	M			R		R	M	10
Mussels (M. edulis)										R			R			2
Mussels (M. chilenensis)	RM	R		M					M			R	R	R	M	8
Voluta spp.	RM	R		M					M			R	R	R	M	8
Razor Clam										R						1
Epifaunal Gastropods										R						1
Crab	RM	R		M					M			R	R	R	M	8
Urchin	RM	R		M					M			R	R	R	M	8
Reeds/Rushes/Grasses																0
Wood (Trunks) Large/Medium	R	R		M					M							4
Wood (Trunks) Small	R	R		M					M							4
Wood (Branches Twigs)	R								M							2
Bark	R	R		M					M		R					5
Lithics																0
Total	28	25	16	26	6	1	2		28	5	1	24	12	22	24	

Table C3-11: Stored and consumed resources (row)s, Resources used to store (columns) Storage. C=utilised to consume, P=utilised to prepare for storage/use, M=used to manufacture the storage vessel, S=used to store the resource. Highlighted rows and columns archaeologically visible. Storage is tactical and, in many cases, no different than carrying a supply of drinking water.

	Whale Oil	**Seal Tissue**	**Seal Oil**	**Seaweed**	**Bird Tissue**	**Mollusc Shell**	**Lithics**	**Total**
Whale Blubber	C	SM			S	P	P	5
Whale Flesh	C					P	P	3
Seal Blubber	C	SM				P	P	4
Seal Oil	C	SM				P		3
Seal Flesh	C					P	P	3
Otter Skin						P	P	2
Fox Skin						P	P	2
Fungi	C				S	P	P	4
Wild Fruits	C							1
Roots	C							1
Seaweed						P	P	2
Bird Skin						P	P	2
Bird Flesh	C					P	P	3
Forage Fish	C					P	P	3
Large Fish	C					P	P	3
Crab	C					P	P	3
Urchin	C					P	P	3
Epifaunal Gastropods	C						P	2
Total								
Consumption	14	0	0	0	0	15	15	
Storage	0	3	0	0	2	0	0	
Preparation	0	0	0	0	0	15	15	
Manufacture	0	3	0	0	0	0	0	

Table C3-12: Resource Roles in Social Functions including architecture and canoes. U=Utilised or consumed, R=raw material used, M=used for manufacture of. Material is exchanged on an ad hoc basis either as a trade or gift. Highlighted columns and rows should be archaeologically visible.

	Clothing/Insulation	Adornment	Canoes	Ceramonies inc Burial	Outward Trade Reciprical Giving	Inward Trade Reciprical Receiving	Architecture	Fire	Total
Whale Bone			M		RM		M		3
Whale Blubber	R			U	U				3
Whale Tissue			R		R				2
Whale Flesh				U	U				2
Seal Skin	R	R		U	U		R		5
Seal Blubber	R				U				2
Other Mammal Bone			M		M		M		3
Seal Tissue	M		R		R				3
Terrestrial Mammal Skin	R	R			U	U			4
Seaweed			R						1
Bird Bone	M	MR	M		UMR				4
Bird Feathers								R	1
Bird Tissue		R			R	UR			3
Bird Quill		M							1
Forage Fish				U	U				2
Mollusc Shell	M	M	M		M		M		5
Mollusc Flesh					U				1
Fungi					U			R	2
Wild Fruits					U				1
R/R/G			R		R		R	R	4
Wood (Trunks) Small			R	R	R		R		4
Wood Branches Twigs	M		RM	R			R	R	5
Bark			R	U	R				3
Pigment		U		U	U	R			4
Lithics	M	M			UM	R		R	5
Fire	U	M	M	M					4
Total	10	9	12	9	21	4	7	5	

Table C3-13: Potential changes in the archaeological record associated with a Yamana-like society that result from the defined temperature vector.

Yamana Like Society	**Temperature Existing Sites**	**Temperature New Sites**	**Comments**
Sites (Existing)			
Dwellings	P	P	Possible more evidence for seasonally driven fission and fusion in terms of occupation intensity
Area/Size	P	P	Possible more evidence for seasonally driven fission and fusion in terms of occupation intensity
Positioning	C	C	Task camps may appear further inland to source terrestrial mammals.
Regional Spatial distribution	C	C	May reflect latitudinal variation with season.
Occupation Duration			
Site abandonment/loss	P		Some sites may be abandoned in the colder months. Population distributed less evenly.
Site locations			
Seasonal Patterning	P	C	More seasonally focused sites to reflect mitigation and track faunal patterns.
Large ceremonial sites.			
Architecture (Existing)			
Form	P	P	Use of domed hut versus conical hut may reflect seasonality and not just east west gradient.
Size	P	P	More use of the larger form of the domed hut to permit increased occupants for warmth.
Raw Material			
Robustness	R	R	Domed hut is far less robust in terms of posthole size. Could be mistaken for a switch to tents.
Material Culture (Existing)			
Lithic Raw materials			
Grave Goods			
Status items			
Armatures form	P	P	May change to reflect increased pursuit of terrestrial fur animals for clothing and bedding.
Armatures material			
Processing Tools (scrapers, awls etc)	C	C	
Faunal Community (Existing Sites)			
Mammal Composition/Abundance	P	P	Increase in terrestrial mammals.
Avian Composition/Abundance			
Fish Composition/Abundance			
Invertebrate Composition/Abundance			
Seasonal spatial patterning	P	P	Greater inter-site seasonal variation in abundance of exploited taxa.
Fish Growth Rate	C	C	Growth rate reduced.
Invertebrate Growth Rate/Size	C	C	Growth rate reduced.
Floral Community (Existing Sites)			
Grassland pollen			
Tree pollen			
Plant macrofossils	C	C	Loss of frost intolerant taxa.
Microcharcoal	I	I	Larger fires for warmth.
C = probable change P = possible change R = Reduction I = Increase M=Mitigation	Temperature changes that result from a weakening or hiatus in moderating influences will be more severe and will probably exhibit a relatively greater magnitude in late autumn, winter, and early spring. Late spring, summer and early autumn are more greatly influenced by the frequency of high pressure systems and insolation levels.		

Table C3-14: Potential changes in the archaeological record associated with a Yamana-like society that result from the defined weather system vector.

Yamana Like Society	Storminess Existing Sites	Storminess New Sites	Comments
Sites (Existing)			
Dwellings	I	I	Inhibited travel will result in more concurrent occupations.
Area/Size	I	I	Inhibited travel will result in more concurrent occupations.
Positioning	C	C	Existing sites may incrementally move away from the shore. New sites further from the shore.
Regional Spatial distribution	P	P	Possible reduction of sites in the west and increase in the east. Probably seasonal in nature.
Occupation Duration	I	I	Increased due to inhibited travel.
Site abandonment/loss	P		Some locations will no longer be desirable.
Site locations	C	C	Possibly some inland sites to increase yield from terrestrial plants and animals.
Seasonal Patterning	P	P	May reflect a longitudinal or latitudinal gradient.
Large ceremonial sites.		P	Sheltered locations further into the interior favoured. Less frequent, so larger footprint.
Architecture (Existing)			
Form	C	C	Conical hut favoured.
Size	P	P	Ceremonial huts larger due to reduced frequency of ceremonies and greater attendance.
Raw Material			
Robustness	I	I	Larger post holes. May be mistaken for move to sedentism.
Material Culture (Existing)			
Lithic Raw materials	P	P	More local material (quartz and slate in the Yamana's case) contact network inhibited.
Grave Goods			
Status items			
Armatures form	P	P	Forms for terrestrial animals. Increase in arrow head abundance.
Armatures material	P	P	More use of bone in arrowheads in western sites.
Processing Tools (scrapers, awls etc)			
Faunal Community (Existing Sites)			
Mammal Composition/Abundance	P	MP	More terrestrial species, where available.
Avian Composition/Abundance			
Fish Composition/Abundance	R	M	Reduced abundance due to reduction in fishing days. New sites = mitigation.
Invertebrate Composition/Abundance	R	M	Reduced abundance of infralittoral species due to reduction in fishing days. New sites = mitigation.
Seasonal spatial patterning	P	C	Seasonal latitudinal or longitudinal gradient may be reflected in taxa, e.g. terrestrial mammals.
Fish Growth Rate			
Invertebrate Growth Rate/Size	R	R	More smaller mollusc specimens from the intertidal zone.
Floral Community (Existing Sites)			
Grassland pollen			
Tree pollen			
Plant macrofossils	I	I	Increased exploitation of plant foods. Less mammal oil drives increase in carbohydrate intake.
Microcharcoal			
C = probable change P = possible change R = Reduction I = Increase M=Mitigation	Increased frequency of storms and rough seas is a significant issue. This is highlighted by the fact the Hebridean Whales Cruises lost so many sailing days in July and August 2014 they announced on social media they lacked the financial resources to restart the following spring. Those sailings that could take place were often curtailed, as was my own, from the full 6 hour trans-Minch trip to a 3 hour mainland coastal version. It should also be noted that the species composition and population structures within the intertidal zone will change.		

Table C3-15: Potential changes in the archaeological record associated with a Yamana-like society that result from the defined sea level vector.

Yamana Like Society	**Sea Level Existing Sites**	**Sea Level New Sites**	**Comments**
Sites (Existing)			
Dwellings			
Area/Size			
Positioning	C		Existing sites may incrementally move away from the shore. New sites further from the shore.
Regional Spatial distribution			
Occupation Duration			
Site abandonment/loss	C		Many sites will be lost to inundation.
Site locations	C	M	Change in resources available at existing sites. New sites mitigate subsistence opportunities.
Seasonal Patterning			
Large ceremonial sites.			
Architecture (Existing)			
Form			
Size			
Raw Material			
Robustness			
Material Culture (Existing)			
Lithic Raw materials			
Grave Goods			
Status items			
Armatures form			
Armatures material			
Processing Tools (scrapers, awls etc)			
Faunal Community (Existing Sites)			
Mammal Composition/Abundance	P	M	Changes in faunal locations.
Avian Composition/Abundance	P	M	Changes in faunal locations.
Fish Composition/Abundance	P	M	Changes in faunal locations.
Invertebrate Composition/Abundance	P	M	Only intertidal gathering practicable at some sites.
Seasonal spatial patterning			
Fish Growth Rate			
Invertebrate Growth Rate/Size	P	M	Only intertidal gathering practicable at some sites. New sites = mitigation
Floral Community (Existing Sites)			
Grassland pollen			Possible loss of coastal grass land.
Tree pollen	P	P	Possible loss of forested coastal strip or plain.
Plant macrofossils			
Microcharcoal			
C = probable change P = possible change R = Reduction I = Increase M=Mitigation	The key challenge with sea level changes for groups that occupation locations close to the shore and therefore at low elevations is whether the pre-event sites remain archaeologically visible. Isostatic readjustments may bring submerged sites back above sea level but with what level of integrity is unclear.		

Table C3-16: Potential changes in the archaeological record associated with a Yamana-like society that result from the defined sea level vector.

Yamana Like Society	Tsunami Existing Sites	Tsunami New Sites	Comments
Sites (Existing)			
Dwellings	R	R	Reduced population may result is extended but sparse distribution or concentration might occur.
Area/Size	R	R	Reduced population may result is extended but sparse distribution or concentration might occur.
Positioning	C	C	Task camps may appear further inland to source suitable trees, fruits and fungi.
Regional Spatial distribution	!	!	This is complicated with conflicting drivers. Large areas maybe abandoned.
Occupation Duration			
Site abandonment/loss	C	M	Many existing sites will be swept clean. Sites may also be abandoned.
Site locations	C	M	Mapped onto the distribution of the remaining resources. New sites will seek to mitigate.
Seasonal Patterning			
Large ceremonial sites.	C	R	Reduced population in fewer ceremonies.
Architecture (Existing)			
Form	C	M	Remaining trees will dictate approach. Concentration may see more domed huts.
Size	C	C	Concentration may result in larger multi-occupancy domed huts.
Raw Material			
Robustness	C	C	Concentration may result in larger multi-occupancy domed huts.
Material Culture (Existing)			
Lithic Raw materials	R	R	Diffusion through the reduced contact network reduced unless the network contracts.
Grave Goods			
Status items			
Armatures form			
Armatures material			
Processing Tools (scrapers, awls etc)			
Faunal Community (Existing Sites)			
Mammal Composition/Abundance	C	M	Resources reduced and distribution may be dispersed.
Avian Composition/Abundance	C	M	Resources reduced and distribution may be dispersed.
Fish Composition/Abundance	C	M	
Invertebrate Composition/Abundance	C	M	Resources reduced or even obliterated and distribution may be dispersed.
Seasonal spatial patterning			
Fish Growth Rate			
Invertebrate Growth Rate/Size			
Floral Community (Existing Sites)			
Grassland pollen			
Tree pollen	C	C	Loss of coastal forest belt and plains.
Plant macrofossils			
Microcharcoal			
C = probable change P = possible change R = Reduction I = Increase M=Mitigation	Potentially there will be conflicting drivers. One dispersive to map the reduced population onto new areas of resource concentration. The second accretional, to maintain the distance between the now reduced number of nodes in the contact network thus maintaining social interaction and the diffusion of raw materials through the network. The former reduces collective resilience due to reduced capability to render aid and locate whale strandings, the latter reduces the likelihood of spotting whale strandings and may put pressure on local resources until the ecosystem has fully recovered.		

4 Chapter 4: Methodological Considerations When Analysing Shell-middens.

4.1 Background.

In chapter 3 a number of environmental scenarios were defined and evaluated in terms of what their consequences might be and how these may manifest themselves in the archaeological record, particularly the faunal record, but also to a lesser degree the floral record. To understand the relationship hunter-gatherers had with their environment, and to understand past environmental change from the archaeological record, requires a comparative analysis of faunal assemblages, and an evaluation of how the results of comparisons vary temporally. At first glance this appears to be straightforward, but a closer examination of the literature indicates otherwise and is exemplified by the issues surrounding a matter as fundamental as quantifying faunal remains (cf. Thomas and Mannino, 2017), which 1/5th of the way through the 21st Century many might have thought had been satisfactorily resolved long ago. It is also true that if the premise that changes in the environment can be inferred from the faunal record is accepted, then certain existing interpretive frameworks must come under scrutiny as they assume environmental stability. In this chapter key aspects will be considered, and ways forward sought. It is inevitable that certain issues highlighted will prove unresolvable and in such circumstances the objective is to develop an understanding that means progress can be made with full cognisance of the limitations and risks involved.

4.2 Quantification.

The issues around quantification reside primarily with the units the analyst chooses to utilise and publish, but the skill level of the analyst and quality of the reference collection are also factors. This debate centres around the use of weight, versus the use of number of identified specimens (NISP), versus the minimum number of individuals present (MNI) and the relationship between these units. These matters are discussed comprehensively by the likes of Grayson (1984) and Lyman (2008; 2018). It is necessary to discuss a few key points these authors sensibly raise and the conclusions they reach. The authorities cited, quite correctly, conclude that NISP and MNI are at best ordinal scales. They go on to point out that statistics cannot be utilised on NISP to compare taxonomic abundance as the requirement for independent observations cannot be met, as it is unknown whether specimens have originated from the same individual. Of course, a statistical inference test can be executed against NISP data but what the result is commenting on is an unknown (see below). MNI poses a different challenge because it is a mathematical inequality and that means ratios between two values cannot be legitimately compared. Taken to their logical conclusion the above points are quite restrictive regarding what can and cannot be presented by an analyst. Generating relative abundances is not legitimate for either NISP or MNI and neither is implying them by using bar charts, stacked bar charts or pie charts. Grayson (1984) presents relationships between NISP and MNI and notes correlations. This has been misinterpreted in the literature. Statistical and abundance comparisons have been carried out using a mix of datasets, some quantified in MNI and others in NISP, justified by one of the regressions from one of the graphs presented by Grayson (1984) (cf. Barrett *et al*, 2001). The key point to be taken from Grayson (1984) is that these correlations are site specific, and where deposition environments are variable within a site, specific to a stratigraphic unit (illustrated in SI-Chapter 4-1). As pointed out by Lyman (2008) it is unclear what NISP is actually a proxy for. Whilst NISP is influenced by the number of animals deposited in a stratigraphic unit, it is factored by fragmentation levels, therefore the fraction size interrogated and consequently the robustness of the skeleton of a given species. Comparing NISP from mammals with those from fish (cf. Barrett *et al*, 2001) is therefore not a legitimate approach. Likewise, presenting NISP data from archaeological units of different excavated volumes, durations of occupation, for example sedentary villages versus seasonally frequented camps, is potentially misleading at best. In the former the assemblage will have accumulated over a greater period of time and likewise (unless deposited in a pit) subject to greater levels of footfall both due to the greater elapsed time and a larger population present 24 x 7 x 365. This why the use of NISP between sites and archaeological periods (cf. Best and Mulville, 2016), without any normalisation, is actually an exercise in presence or absence.

Some authorities utilise weight to quantify and compare molluscs. This is probably valid (if normalised by excavated volume: cf. Bailey and Craighead, 2003; SI-Chapter4-3) to compare the quantities of a given taxon between contexts, or even sites, providing each shell has been cleaned to remove sediment and concretion (McCarthy *et al*, 1999, p.94; Claassen, 1998, pp.107). Yet if each shell is to be inspected and cleaned, they may as well be counted. To establish abundance between species the method simply does not work due to variation in robustness (chapter 6).

A final consideration is the anatomical unit utilised to generate MNI and (in some circumstances) NISP. An illustrative example is provided by marine gastropods which are usually quantified in terms of MNI using the apex as the non-repeating element (NRE) to derive it. Andrews *et al* (1985), Sloan (1993) and Jones (1984) utilise the apex for periwinkles (*Littorina littorea*) and the siphonal canal for dog whelk (*Nucella lapillus*). The latter is simply a very robust solid piece of shell and it survives preferentially compared to the apex and therefore the relative abundance of dog whelk to periwinkle is likely to be overstated. Jones, (1991) makes this very observation as a result of dog whelk fracturing experiments.

The above discussion does make for bleak reading as apparently there is not a lot the analyst can legitimately do. The question that arises is whether palaeontology and zooarchaeology have something approaching ‘a complex’ regarding these issues. Ecologists sample ecosystems constantly and the results they obtain are MNI (hopefully ecologists do not generate NISP), that is their sampling informs them that at least this number of individuals were present in the sampled area (cf. Evans and Sanderson, 2017). Presumably, ecologists do not seek 100% sampling efficiency as they wish to avoid self-defeating and unethical local extinctions. Issues analogous to fragmentation, in this case intermittent swarming behaviour and equal species visibility, are factors in the work carried out. Yet ecologists are perfectly content to compare abundances both relatively and absolutely, although usually after applying a data transformation that mitigates against issues such as swarming.

The way forward in this project considers the above and adopts an approach that is relevant given the objectives of a given chapter. In terms of units MNI will be utilised for marine molluscs, crustaceans will be reported in terms of fragments and MNI, whilst vertebrates will be reported both in NISP and MNI. Taking a lead from the ecologists, graphs of relative and absolute abundances will be presented purely because tables listing 1st, 2nd…nth most abundance species by context will make for rather turgid reading, although just such an approach is required in chapter 5. All marine gastropods will be quantified in using the apex as the NRE. Statistics will not be employed against abundance data, except for fragmentation states of marine snails, where the data is simply a record of what is present and nothing more. In chapters 5, 6, 7 and 8 abundances are treated as ordinal data.

4.3 What do the Biometrics Mean?

Zooarchaeologists, the author included, like to gather biometrics and given the success of such approaches in tracking 'big questions' like domestication, it is easy to understand why. Yet there are a number of areas where despite being 20% of the way through the 21st century the meaning and value of commonly collected biometrics is unclear and debated. Two metrics relating to limpets (*Patella spp.*) warrant further consideration as both metrics are considered to contain information regarding environmental conditions and human behaviour. The first is the length (SL_P) of a limpet which is often stated by ecologists to serve as a good proxy for the size of the organism (cf. Baxter, 1982, 1985; Lewis and Bowman, 1975; Blackmore, 1969), it must be noted that Ballantyne (1961a, p.107) concludes length is not a proxy for anything of interest beyond length itself. The ecologists are almost certainly justified in these views because they sample their limpets from discrete locations at specified levels within the tidal range. They also complement the biometric information with a sub-sampling of specimens, within each sampling area, for attributes such as wet flesh weight, dry flesh weight and shell weight. They also capture further biometrics in terms of growth increments per specified unit of time, again at the resolution of sampling area. In summary they have additional contextual data with which to interpret length data. However, what is clear is that when dealing with a time aggregated assemblage that has been selected from the full gamut of habitats available on one or more shores, SL_P must be utilised with care. This because the volume available in a shell for the organism to occupy is three dimensional and is effectively modelled by the standard equation for an elliptically based (of which a circular base is just a variant) cone, and volume is independent of where the apex of the cone is (Denny, 2000; Cabral, 2007).

Bailey and Craighead (2003, p.193) in their analysis of late Pleistocene and early Holocene assemblages state that the lower shore limpets would be favoured as this is where the largest limpets are found. Based upon the data presented it appears that in this context largest means longest (ibid). Possibly this is true in Northern Spain, but at higher latitudes the diametrically opposed position seems to hold. At Sand rock shelter the vast majority of largest limpets are of the very conical type and the vast majority of the flatter limpets are small (Data from Milner, 2009a downloadable archive). Two hypothetical specimens will now be considered (table C4-1). Whilst specimen 2 is longer specimen 1 is larger. A reduction in the mean length will be by default interpreted as a reduction in size and yet that

Table C4-1: Data illustrating that longer limpets are not necessarily larger limpets.

Specimen	**SL_P**	**SW_P**	**SH_P**	**Conicity**	**V_P**
1	35	30	15	2.33	6219
2	38	33	12	3.17	5864

may not be the case (see also Ballantine, 1961a; Campbell, 2008). What is really required is an understanding of how the three dimensions are combining in each specimen and how that is distributed. Within the main text this project will present distributions in terms of SL_P for ease of comparison with published assemblages, but the interpretation of any shifts in length or conicity will be verified against the population structures in terms of volume, the data for which will be presented graphically and as summary statistics in a chapter's SI.

The second biometric (which is very strongly implicated in the above discussion) that needs to be considered is that of limpet conicity which is the ratio of shell's length to its height (SL_P/SH_P). Some authorities calculate and present this ratio as defined, but some present SH_P/SL_P, for comparative purposes converting one form to the other is simply achieved by taking reciprocals. Of more importance is what does this ratio mean and what do shifts in the population structure when expressed in terms of this ratio mean.

Generally, within the archaeological literature the conicity of the limpet assemblages has been utilised to assert whether limpets were collected from high within the tidal range or low within the tidal range (cf. Milner, 2007; 2009a). Whether knowing this is of any material value has been sensibly questioned (ibid). Most authorities have consistently, across the decades, deemed the risk of desiccation during emersion to be the major influence over the conicity of a limpet's shell (Orton, 1928b, 1933; Harley *et al*, 2009; Moore, 1934; Denny, 2000; 2006, p.454; Denny and Blanchette, 2003, Lewis and Bowman, 1975; Cabral, 2007). The matter is further complicated as many of the above authorities have either explicitly, or by inference, denied any real role for shore energy level in limpet conicity, whilst others (Bailey and Craighead, 2003; Finlay *et al*, 2019) have advocated a role for shore energy level; the latter interpreting the conicity of limpets entirely in terms of shore energy level. The interpretation of the available literature is also variable. For example, Denny, (2000) and Ballantine (1961a), amongst others cited above, have both been cited in support of both sides of the debate, which is perplexing as the conclusions these authorities reach is clear. Bailey and Craighead (2003) offered functions for determining shore zonation and shore exposure level from the three biometrics that describe a limpet's shell. These were derived from extant limpet populations in northern Spain. When applied to limpets from north-west Scotland, which experiences a very different level of insolation and therefore desiccation risk, the attribution of shore zone was driven entirely by limpet length. The function for exposure level performed in the same manner with a narrow range of overlap between 30 and 31mm in length. The author (Evans, 2015) concluded that the most conical limpets reside high in the tidal range and the very flattest limpets reside very low within it, but that apart from these morphological extremes, the remaining variation in conicity simply reflects the heterogeneous nature of desiccation risk on a shore (Ballantine, 1961a; and from a slightly different perspective Campbell, 2008). This project considers the primary driver of limpet conicity to be desiccation risk and only diagnostic of position in the tidal range at extreme values. Its analytical value is deemed to reside in the spread of the data, for example, a greater standard deviation in the ratio probably suggests more search effort being expended to acquire the required number of suitably sized specimens.

4.4 Sampling for Biometric Analysis.

4.4.1 Hunter-gatherers as Ecosystem Samplers.

It is probably self-evident, but worth confirming, that whilst going about their business hunter-gatherers have been sampling the environment on our behalf. Of course, such sampling is not of the random type an ecologist would define, and neither is it designed to answer environmental questions. To put it another way, the sampling results our predecessors generate reflect a mixture of cultural filters and according to Southward *et al*, (1995) environmental states and vectors. This has implications for the use of statistical analysis on faunal remains as discussed below. When carrying out such analyses the analyst cannot attempt to understand the natural population from which the sample was created. The situation is not the same as surveying a sample of a city's population for their job types to understand the distribution of job types in the population at large.

Yet certain characteristics of an assemblage can be considered from the point of view of it being a sample taken on behalf of archaeologists. It is well established that the larger the sample taken, or the more frequently smaller samples are taken, the greater the level of biodiversity can be expected, with the biodiversity asymptotically approaching the level where every species it is possible to encounter, however rarely it occurs, is encountered (Hawkins and Hartnoll, 1980; Underwood *et al*, 2008). The same can be said for extreme examples of size or characteristics of a given species. The situation with size relates to the larger size ranges because extremely small examples will not normally feature. An adult limpet suffering from 'severe dwarfism' is unlikely to be selected by a forager. It seems reasonable to expect different assemblage characteristics in different scenarios. Providing environmental conditions are constant these characteristics will form a spectrum bound at one end by archaeological units that relate to a short term occupation and based upon the above reasoning, be expected to exhibit lower biodiversity and a narrower range of sizes. Archaeological units that are made up of many short term occupations can therefore be expected to exhibit larger size ranges and include greater biodiversity; in the latter case whether procurement is logistical or not (see chapter 2). The increased biodiversity results from those species that are obtained on an encounter basis, even if the primary activity is targeting another species in a logistical manner. If the site is visited during multiple seasons, although not necessarily in the same calendar year, greater biodiversity will be present due to seasonal migrations (Underwood *et al*, 2008). The final point that must be made is that the temporal spacing of multiple small scale occupations will also result in greater biodiversity and size ranges as occupations may or may not fall in different stages of the normal climatic cycles and of course the time available for the ecosystem to recover from the previous episode of human exploitation will be longer; something that does not occur if occupation is sedentary or residential moves are infrequent.

4.4.2 Duration of Occupation.

"Cultural Complexity and sedentism amongst hunters/collectors have long been the focus of research amongst Norwegian archaeologists" (Astveit, 2009), and this brings the issue of sedentary behaviour into the discussion. Whereas Ames (1991a) groups semi-sedentary behaviour with sedentary behaviour, here it is classed as a variant of mobility. Sedentism in this project means year round permanent occupation of a site, therefore the Moachat of British Columbia are not sedentary under this definition (chapter 3), although their mobility cannot be classed as high (*sensu* Binford, 1980). How is it possible to delineate between a site that is a result of numerous small scale occupations over a protracted period and a sedentary occupation site? Chapter 3 presented data that confirms that very substantial faunal deposits can arise as a result of numerous small scale and short duration occupations; so arguably in this case, size does indeed not matter. Chapter 3 also provides evidence that significant amounts of lithic artefacts can, especially when the debitage is included, accumulate in technocomplexes in which they play a minor or minimal role (see also Groom *et al*, 2019). Chapter 3 also demonstrates, as acknowledged by Ames (1991b), that substantial dwellings are not exclusive to sedentary societies and can be present at locations occupied for a few days to a couple of months (cf. Mithen and Wicks, 2018). A key point raised in the opening chapter, and reiterated in chapter 3, is that a fixed seasonal round of particular locations visited at specific times of year is an unsatisfactory model that strips highly mobile hunter-gatherers of their vast knowledge, craft and ability to vary their seasonal movements in response to the prevailing conditions. The above discussion raises the question of units of aggregation for archaeological units.

4.4.3 Units of Aggregation.

For the new sites this project aggregates the excavation samples within a context because the spatial relationship between the excavation samples is unknown and their designation is arbitrary. In two instances two contexts were merged based upon the actual zooarchaeology and stratigraphy. In one case two contexts that the excavation team later considered as a single unit have been treated as two separate units, again based upon the zooarchaeology. No further aggregation has been undertaken as this project seeks granularity in the record. In particular, contexts have not been merged in order to create larger zooarchaeological sample sizes, as this may be massaging the data and goes against the desire for granularity and small sample sizes are the price that, at times, must be paid. An alternative approach is utilised by Boethius *et al*, (2017) at the site of Norje Sunnansund in south-eastern Sweden. Boethius (2017) provides a definition of sedentism that is based upon Kent (1989) which includes asymmetric mobility in terms of the time spent at different locations. The author simply does not concur, such definitions are distortions that permit certain theoretical stand points to be sustained. Basically, lowering the bar so that certain ideas and datasets can clear it. Boethius (2017)'s approach is to aggregate the faunal assemblages of an entire site. Boethius *et al* (2017) states that occupation within a radiocarbon PD spread of 1000 years was shorter, but by an unspecified amount. The site is documented as having two phases of around 600 years each (ibid). Given the size of the assemblages and that the two phases are on very different matrixes, one clay overlain by the younger of sand, then aggregation does not appear either warranted or justified. There is really nothing to distinguish this site from one visited many many times over a protracted period. The scale of exploitation of fish, estimated at 46K Kg (ibid) is not large either compared to societies with populations large enough to develop social hierarchy[5]. Why the kill off patterns (which treat this extremely aggregated assemblage as an archaeological event) are based upon a small epiphysis NISP count for a site that is allegedly sedentary,

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[5] A single delivery of salmon to Maquinna's long house was probably *circa* 7.5K kg.

is unclear. Such patterns should be calculated on MNI to avoid double counting. Kill off patterns are very useful when considering managed populations, but how calculating them for wild unmanaged populations informs the debate is also unclear. Potentially the remarkable abilities of the hunter-gatherers to adjust their behaviour in response to the weather and or environmental conditions may be being missed.

The author does not have a solution to the problem of identifying sedentary societies beyond imposing the above mentioned constraints on hunter-gatherers, which is unacceptable. The possibility that a site might be associated with sedentism will be highlighted, but not asserted or advocated.

4.4.4 Sampling from the Assemblage.

The magnitude of the task facing both the excavator and the post-excavation analyst often requires a sampling or sub-sampling approach to be adopted. In terms of this project the decisions required during excavation have been made and this project will deal with what is available as a result. Sub-sampling for analysis from the excavated material has been influenced by two factors. The question that arises is whether the sub-sample is representative of the sample it is taken from. The amount of literature on this topic is vast, and the sample sizes employed highly variable and at times apparently arbitrary (cf. Jones, 1984). The author adopted an approach of running simulations to assess different sample sizes and how well these represented the population they were extracted from. Two simulations were carried out from a pooled population of 3,932 limpets. The first randomly extracted 100 samples of 100 limpets. The second extracted the same percentage of specimens as measured in the largest context of one of the new sites, which resulted in 100 samples of 389 limpets each. In both scenarios the extracted samples were compared to each other and the original assemblage using one-way ANOVA. ANOVA failed to reject H_0 (see below for a definition) despite several samples, when tested against each other, causing the rejection of H_0 at a confidence level (CL) of between 95% and 99%, and in one case 99.99%. The other issue was the fact there were 100 datasets. The test was rerun using only five of the datasets which represented the maximum mean, minimum mean, the 1st quartile mean, the 3rd quartile mean, and the median mean (cross-tables provided in SI-Chapter4-2). On this occasion significance was identified, but only between two datasets rather than the three individual combination testing highlighted. This is because ANOVA is asking the wrong question in the wrong way (see later in this chapter) as it uses the mean of the pooled datasets as well as the mean of each dataset. This is a very sensible thing to do if checking the results of some polling activity carried out by several agents or numerous sampling exercises of the concentration of a chemical in the product of some process. When comparing assemblages of fauna from different archaeological contexts or sites, the pooled mean is meaningless. Samples when compared to the dataset from which they were extracted not infrequently caused H_0 to be rejected at confidence levels of between 95% to 99.9%. The decision was taken to collect biometrics from every specimen in a stratigraphic unit that could yield such measurements and to conduct all statistical testing of datasets on a one to one basis. This decision required the magnitude of the task to be managed and therefore a subset of the excavation samples making up the larger archaeological contexts was utilised, but always in their entirety.

4.4.5 Overcoming Fragmentation

Fragmentation is an ever present problem which directly impacts identification success and therefore NISP, as a NISP requires identification to at least some meaningful taxonomic level. Also, as discussed earlier, a Mesolithic identified specimen that subsequently gets broken after deposition (but prior to excavation where a recent break is easily identified) becomes two or more identified specimens. The exploitation of one taxon for bone marrow extraction will result in an elevated NISP count, relative to those that are not. To summarise the earlier discussion; fragmentation levels are closely related to the NISP values obtained.

The other endeavour where fragmentation is an ever present obstacle is biometric analysis. The most obvious aspect is that if a specimen is broken it may mean that the required biometric cannot be taken. Furthermore, it is unknown, because the biometrics cannot be gathered, whether it is the larger or smaller specimens that are underrepresented in the resulting dataset; a factor Thomas and Mannino (2017) do not consider. The solution to this problem is to find a way that permits the required biometric to be reconstructed from as many of the fragmented specimens as possible. This generally requires the creation of a model in the form of an isometric or allometric relationship between the required biometric and some other biometric which is preserved more frequently. The model must be tested, and accuracy to a level that is consistent with the demands of the research questions being addressed, determined. The approach adopted by this project is to reconstruct all specimens that can be, even if the number from which the required biometric can be obtained is sufficient to support quantitative analysis to a required confidence level. This ensures the chances of the resulting dataset being biased to one size class or another is minimised.

Key objectives of this project include obtaining a better understanding of hunter-gatherer responses to environmental changes, and to confirm the utility of shell-middens as past environmental archives as suggested by Álvarez *et al*, (2011). This mandates an assumption, when devising methodologies and protocols, that the environmental conditions are not constant. Therefore, any modelling must embrace this fundamental condition, and an assumption that modern faunal populations, either in terms structure based upon one or more biometrics, relative abundance, or spatial distribution, reflect archaeological ones, must be managed actively. As a mitigation the models, where sample sizes are sufficient to demonstrate a robust model, are developed from the assemblage itself within a stratigraphic unit. Such models are developed and deployed in chapter 6 so that basic characteristics such as shell length can be reconstructed where actual measurement is not possible. Each model also has its interval of applicability (*sensu* White and Gould, 1965) stated.

In some cases, in order to permit model construction, it will be necessary to supplement the archaeological assemblage with additional observations either from modern specimens or another stratigraphic unit, either to obtain a sufficiently large sample size or adequate coverage in all size classes, as this permits a useable interval of applicability to be stated. At first glance a model based upon such a composite dataset may appear problematic, but it is not. To provide context to this assertion the study of stable isotopes, and DNA (ancient and modern) can be considered. In these disciplines the observations are expressed at deltas against a defined standard or reference, and it is the deltas that are compared between datasets. An analogous approach can be adopted in relation to biometric analysis where the model constitutes a standard and the variation of a stratigraphic unit's assemblage relative to the model can be compared. That comparison can be conducted by using the model to generate outcomes that are compared with the measured values and the distribution of the residuals constitutes the delta against the standard. This approach was implemented, albeit in what can be considered a very embryonic form, in Evans (2015) to assess deviations in limpet conicity between contexts and sites. The standard utilised was generated from the data presented by Ballantine (1961a). Once the delta is understood it can be related to the physiological and ecological characteristics of an organism to infer what is the likely cause of the delta, which maybe environmental, or human behaviour, and of course these may be interrelated as what this project terms eco-behaviour. This is the approach employed in chapters 7 an 8 to compare assemblages and assess changes in population structures.

EQC4-2 $SL_P = 21.1 * AP_P$
$R^2 = 0.90$ N=10. (Norway).

EQC4-1 $SL_P = 9.447 * AP_P$
$R^2 = 0.96$ N=6. (Shetland)

Addressing the matter of understanding whether the captured biometrics are biased by size class due to fragmentation has been dealt with above. There is however an exception, and that is the limpets due to their extreme morphological plasticity to more than one environmental input. Ortea (1986, cited in Bailey and Craighead, 2003, p.187) reconstructed limpet size from apex thickness, but omitted to state how. It was therefore with great interest that the author read the research by Ambrose *et al*, (2016), which provides a method for reconstructing the size of a limpet from the thickness of the shell at the apex. The equations provided simply do not work and for conical specimens produce absurd results. One of the limpets from West Voe should, according to EQC4-1, have a length of 109.6mm; needless to say, it does not (SI-Chapter4-4). The reason for rejecting this approach is provided in SI-Chapter4-4. It is unfortunate that Harris *et al* (2018) utilise EQC4-1 in a nested manner to calculate ages from shell length, with the consequence that despite all the statistics (with multiple redundancy, SI-Chapter4-5), the results are unsafe.

The final consequence of the above observations is that comparing changes in average limpet age and average limpet length (cf. Bailey and Craighead, 2003; Milner *et al*, 2007) is of limited analytical benefit as conicity is ignored. The approach adopted by this project is to consider the distribution of age against length and volume. At the time of writing the author has identified no reliable way (including shell margin thickness) of reconstructing limpet size, and the risk of size bias due to taphonomic factors remains.

4.5 Statistical Inference Testing of Biometrics.

4.5.1 Introduction.

Statistical testing of the results obtained during zooarchaeological analyses is ubiquitous within the literature. It is generally applied to provide support to observed differences between datasets or to assert that no difference exists, and in either case to a desired level of confidence. In this section the use within the discipline, the characteristics of statistical inference testing, and their interpretation, will be reviewed. The review will be targeted at those aspects relevant to zooarchaeological and environmental analysis. This is followed by a statement of this project's approach to the use of and interpretation of statistical inference testing.

4.5.2 A Targeted Review.

4.5.2.1 Background and Terminology

The tests are executed to evaluate a null hypothesis (H_0) that no difference exists. Whilst this is how H_0 is stated within the literature it is not actually correct; H_0 is that no difference can be asserted. The test then either, accepts H_0 or rejects H_0 at a specified confidence level. As before the terminology needs to be nuanced if the output from such tests is to be interpreted and leveraged correctly; the test either rejects H_0 or fails to reject H_0 at a given confidence level (Clarke and Cooke, 2004, pp.433-434). The point is that other than in rare and extreme cases, failing to reject H_0 should be viewed as the data available is insufficient to permit rejection of H_0 at the required confidence level. At this point the term confidence level should be defined. The confidence level is the degree of risk the analyst is willing to accept that H_0 is rejected when it should not be; known as type one error. The ubiquitous value within the literature is a confidence level of 95%, that is a one in twenty chance that a type one error is being made. Where the origin of this value's ubiquity lies is not clear to the author, but it is certainly not some kind of 'magic number'. Thankfully, should the author in the course of this work make a type one error then no one is going to be left stranded on the moon, and neither will tens or hundreds of millions of pounds be lost. Nevertheless, in the more general case, if a result from a project could potentially lead to a reformulation of prehistory and the rewriting of textbooks and lectures, then maybe an acceptable level of risk should be less than one in twenty.

4.5.2.2 Sample Sizes.

The statistical tools researchers utilise have been arrived at through the efforts of some extremely talented mathematicians and statisticians that have involved herculean amounts of calculation effort in periods that often predate the computer. The testing algorithms take into account the sample sizes utilised which is an extremely useful feature. One general characteristic is that the smaller the sample sizes the more extreme the difference between two datasets must be to permit H_0 to be rejected at a given confidence level (Clarke and Cooke, 2004, p.434). This is important and why the earlier definitions of H_0 were nuanced above. An illustrative example arose whilst the author was evaluating certain biometrical traits within modern specimens from two species of a genus of bivalve. The resulting distributions were visually different, and in a manner the relative physiologies and ecologies of the organisms suggested would be the case. However, when evaluating H_0 it could not be rejected. The test used takes the sample sizes into account when determining the critical value, although the test statistic is calculated independently of sample size. With sample sizes of 60 and 120 for each species, H_0 could not be rejected at a confidence level of 95%. Had the distribution been the same but originated from sample sizes of 140 and 280 the test statistic would remain unaltered, but the critical value would be reduced and H_0 could be rejected. As stated, there are strong grounds, based upon physiology, why the distribution should remain constant with increasing sample size. In this case the sample sizes were insufficient (more precisely, the author's efforts collecting modern specimens were inadequate) to reject H_0.

The above discussion naturally leads to a conclusion that bigger samples are better samples. Unfortunately, the actual position is that samples may be too big. In such circumstances H_0 can be rejected on the grounds of very small or nuanced differences in the distribution that may or may not be of archaeological, ecological, or environmental significance. The reason for rejection or failure to reject H_0 must always be established and an informed, reasoned, and rational judgement made and justified on whether rejection of H_0 or failure to reject H_0 is a material outcome. In summary, the archaeological interpretation of statistical inference testing in terms of rejecting or failing to reject H_0 cannot, and must not, be prescriptive. The approach adopted in subsequent chapters is that when population distributions are presented graphically a statement will be made on whether an appropriate inference test has rejected or failed to reject H_0. In particular in chapter 6, where the new assemblages are presented, the statements regarding H_0 should be considered as interim as the detail of whether rejection or failure to reject H_0 is of significance to the archaeology will be pursued in chapters 7 and 8.

4.5.2.3 Is the correct question being asked?

When performing statistical inference tests a question is being asked of the assemblages. Statistical inference testing seeks to establish the grounds upon which two assemblages can be considered different in respect of some attribute. Parametric tests do this by asking the question: 'could these two sample means result from the same normally distributed population?' (see Clarke and Cooke chapter 13 for a discussion). This is rarely the question the author is seeking an answer to, the exception being a comparison of the residuals that result from the application of a model. The author is usually seeking an answer to the question 'are these two sample distributions from the same non-normal distribution?'. The reason for this is straightforward; the assemblages being analysed are a result of human selection. The selection may be in terms of the size or morphological classes retained, processed, utilised, and then discarded. They may also be the size or morphological classes that are acquired during procurement, but then discarded due to being rejected for processing and utilisation. As shown in chapter 6 natural populations of marine molluscs are not normally distributed (if for no other reason than they are extremely fecund) in terms of size and only certain size classes are selected by human foragers. Therefore, seeking an answer as to whether the assemblages originated from the same normal distribution is fairly pointless, and probably totally invalid. The non-normal distributions from which the assemblages derive are proxies for human behaviour factored by the composition of the ecosystem and state of the environment. In this case, in contrast to experimental archaeology conducted against extant faunal populations, the zooarchaeological assemblages are (usually) time aggregated and therefore potentially reflect variation in the environmental state and ecosystem composition, which in turn may have modified human behaviour. A final consequence of the above is that normal distributions of certain characteristics in assemblages and failure to reject H_0 may be of more archaeological interest and significance than might be generally supposed. Due to its importance an earlier assertion will be reiterated at this point. The archaeological interpretation of statistical inference testing in terms of rejecting or failing to reject H_0 cannot, and must not, be prescriptive. It is necessary to clarify at this point that the often discussed issue of how normally distributed the samples need to be, and therefore what type test can be deployed, is not the matter in hand here. This is about the comparative distribution the tests assess the samples against and whether an appropriate question is being posed in an appropriate way.

4.6 Determining Seasonality.

In this work so far, the matter of season of occupation has been referred to often. Unfortunately, determining this basic attribute of a site is in practice often not that easy. What follows is a brief review of the common methods deployed within the literature and those that will be carried forward by this project.

4.6.1 Vertebrates.

The first method to be considered is, at its core, based upon presence or absence of categories of zooarchaeological remains in relation to a taxon’s life cycle and development profile; either the presence of juveniles or the presence of a species in a location it rarely, if ever, frequents outside of a specific season. The presence of habitually pelagic birds is an often deployed example and in the author’s view a sound one. Parks and Barrett (2009) initially attribute the assemblage of auks as evidence of a spring early summer occupation, but then sensibly consider alternative interpretations. The alternative is that the birds were precured at sea in late summer early autumn from boats during the moult when they cannot fly and are therefore vulnerable (ibid). The difficulty is that when approached on the water an auk, moulting or not, does not take off, it dives; the lack of flight does not

Table C4-2: The attributes of certain taxonomic groups for season of death estimation. Y means the required attribute is exhibited and N indicates it is not. For example, the spawning season of saithe ranges from February to May which is excessively wide. Hares and otters have multiple litters throughout most and in some locations the entire year. Some sources in the literature suggest that wild boar (Sus scrofa) have two litters per year some years.

Criteria/Taxon	Deer	Wild Boar	Harbour Seal	Grey Seal	Hare	Otter	Saithe
A temporally constrained birthing season.	Y	Y	Y	Y	N	N	N
Single birthing season	Y	Y	Y	Y	N	N	Y
Well staggered epiphyseal fusion ages	Y	Y	Y	Y	N	N	N
Well staggered dental development ages	Y	Y	N	N	N	N	N
Protracted period to reach adult stature	Y	Y	Y	Y	N	Y	Y

increase vulnerability (Bridge, 2004). Furthermore, the moult does not inhibit diving performance in terms of speed whilst submerged (ibid); it does result in an increase in wing beat rate, but less work is done per beat, so energy consumption is not materially changed (ibid). As stated earlier the author considers the presence of pelagic sea birds, excluding the little auk (*Alle alle*), as a sound spring early summer indicator. Another species that can be utilised in this manner is the mackerel which only frequents north eastern coastal waters during the summer. The arrival of juvenile eels (*Anguilla anguilla*) is also a strong spring early summer indicator. Wild geese, swans and the little auk spend the late spring and summer in the arctic and return to temperate latitudes in the autumn and winter and hence are of utility. Many other taxonomic groups contain suitable species, for instance the ducks, but utility needs to be established at the species level and of course that requires identification at species level, which is regrettably, often far from easy.

Another approach is to consider the mammals. Only certain species are suitable for such an approach as several criteria must be met (table C4-2). Hares (*Lepus spp.*), otters (*Lutra lutra*) and carnivores in general are not suitable for this approach. Table C4-2 also includes an entry for saithe (*Pollachius virens*) a species of fish that has been exploited to determine seasonality within the literature (cf. Mellars and Wilkinson, 1980). Mellars and Wilkinson (1980) used second year fish in their study on the grounds that the variation in size that results from a broad spawning season and environmental variables, is either heavily diluted or even erased by the time the fish are this age.

The generic approach for suitable species is to establish the age of a juvenile and then apply this to the known birthing season and derive a month of death within the calendar year. The age is determined by epiphyseal fusion states of the long bones (cf. Davis, 1987, pp.39-40) or dental development stage using published protocols (cf. Payne, 1973, Grant, 1984). Birthing seasons vary spatially, for example the grey seal births about one month later in the northern North Sea compared to the Atlantic coast of northern Britain. Birthing and spawning seasons also vary with latitude and generally occur later, and within a more constrained window, with increasing latitude. The timing and duration of birthing seasons will also vary during severe and sustained climatic episodes.

4.6.2 Invertebrates.

As a mollusc grows it needs to increase the size of its shell to encompass the increased body size. This is achieved by laying down a new increment of shell at its margin. The size of the increments varies as the lower temperatures and reduced food supply during the winter reduce growth. How frequently such growth lines occur is species dependent and dependent upon habitat, specifically the organism's position within the tidal range (Richardson *et al*, 1979; Henderson and Richardson, 1994; Ekaratne and Crisp, 1981). Deith (1983) undertook a detailed evaluation of application of the methods and results obtained by Richardson *et al*, (1979) to seasonality determination of shell-middens. Whilst Deith (1983) obtained calibration data by sampling extant cockles (*Cerastoderma edule*) from high, medium, and low areas within the tidal zone, the number of times these experienced immersions during the study period was either not recorded or simply not utilised. In Richardson *et al* (1979)'s study correlation between growth lines and elapsed period was specifically related to quantifying this variable. Deith (1983) also noted variability in when cockles started growing following the winter abatement and variability in when growth ceased in the autumn. The latter observation, according (Jensen, 1992), is a characteristic determined by juvenile status and size. The relationship between calendrical date therefore has variability in the slope of the regression in the form of tidal emersions experienced and when the growth period ended, and uncertainty in the intercept due to variability in when the growth period recommenced. A further factor is that cockles obtained from low water spring tide or within the wash zone during such tides may exhibit chaotic growth line frequencies (Richardson *et al*, (1979). Deith (1983)'s approach is understandable as it recognised that with archaeological specimens we do not know where within the intertidal zone a specimen resided, and we do not know what conditions had been during the preceding winter and therefore when growth recommenced. Deith (1983) placed all the above uncertainty into the intercept and offered specific calendar dates plus or minus 10 days for archaeological specimens. This level of accuracy is difficult to justify, if converted into a more justifiable seasonal resolution, no improvement over the use of the proportion of the annual growth represented by the final increment (Bailey and Craighead, 2003) is obtained. Deith (1983)'s modern data does provide a valuable insight into the effects of disturbance such as might be caused by violent storms. Based upon the above analysis this project will utilise proportion of annual growth to estimate season of procurement from limpets and cockles.

4.6.3 Stable Isotope Approaches.

In this section the basic constraints and considerations relating to the use of stable isotopes will be reviewed. Stable isotopes (atoms of the same element that have different atomic masses) offer an alternative method by which season of death, and environmental conditions in general can be established. The basic principle is that the lighter isotope evaporates preferentially in cool temperatures such as those experienced in winter and therefore as a result the seawater is relatively enriched in the heavier isotope. During warmer temperatures, the difference in evaporation rates reduces and the seawater is less enriched in the heavier isotope. Ideal materials from which to analyse oxygen isotope ratios are biogenic carbonates such as those from which the shells of marine molluscs and the otoliths (ear stones) of fish are constructed. The otoliths of fish grow by laying down an additional increment of carbonate as described for mollusc shells above. Therefore, in the case of both fish and molluscs incremental analysis will reflect the seasonal variation in water temperature the organism has experienced during its lifetime and the position of the final increment relative to the annual fluctuation in seawater temperature provides an indication of season of death. Two isotopes of oxygen, ^{18}O and ^{16}O, can be used for such analyses of archaeological materials (cf. Surge and Barret, 2012; Mannino *et al*, 2003; Gutiérrez-Zugasti *et al*, 2015; Deith, 1985; Dias *et al*, 2019; Hufthammer *et al*, 2010).

The basic principles as outlined above are straight forward, but in practice there are a number of material factors must be considered. The two isotopes of oxygen are incorporated into the carbonates in equilibrium with the surrounding water (Campana and Thorold, 2001; Disspain *et al*, 2016). In the case of marine fish (excluding anadromous and catadromous species) this is the seawater whose temperature varies throughout the year. Species that frequent estuaries such as, grey mullet (*Chelon spp.*), flounder (*Platichthys flesus*), and herring (*Clupea harengus*) are not suitable as the isotope composition of freshwater is different to that of seawater. A similar consideration applies to mollusc species that have tolerance to low salinity levels such as the cockle and may also reside in estuaries. The difficulty with estuarine systems is that the flow rate of the river will vary considerably by season and therefore the mix between freshwater and seawater within the estuary and the adjacent coastline will be variable. To this consideration can be added the fact that the isotope ratios in the freshwater will also vary seasonally for the same reason that they do in seawater (cf. Deith, 1985; Hufthammer *et al*, 2010; for a discussion). Similar considerations apply to dietary stable isotope analysis utilising ^{13}C and ^{15}N.

Such analyses are therefore best conducted at sites that are not in close proximity to major river systems, (ideally any river systems at all) as the length of coastline that may be affected by the above mixing of water bodies can be quite extensive. Additional considerations apply to intertidal gastropods as the specimens may have resided in rock pools and the water temperatures in rock pools can reach 30^{o}C. All intertidal gastropods and epifaunal bivalves (that are not rock pool resident) experience and cope with water loss when emersed at low tide and this also influences the isotope ratios. The best candidates for isotope analysis are therefore infaunal bivalves that live low in the intertidal zone and are therefore rarely emersed, or marine fish, that are intolerant of low salinity levels and therefore avoid estuarine habitats or habitats that are heavily influenced by estuarine discharge. This project will therefore execute stable isotope analysis against fish otoliths. The actual reconstruction of past seawater temperature from oxygen isotopes ratios is a very complex and specialised discipline and therefore the approach adopted in this project is look at relative change in isotope ratios and also the magnitude of variation.

4.7 Experimental Archaeology: Exploiting the Results.

Ecological field studies and biological laboratory studies have provided datasets whose value to archaeology is evident in terms of the frequency they are cited not only in this work but also the published archaeological literature in general. Such studies, whilst not conducted with an objective of supporting archaeological research do constitute the core research upon which archaeological research is based. There is an increasing trend for individuals and teams to galvanise the required funding to conduct such core research with explicit archaeological objectives, usually in the guise of experimental archaeology (cf. Ambrose *et al*, 2016; Groom *et al*, 2019; Mellars and Wilkinson, 1980). As with all core research it is necessary to ensure a scope is firmly defined and that the underpinning assumptions are clearly articulated and justifiable. Yet the full potential of such core research is either not realised by, inaccessible to, or unimplementable, by researchers seeking to analyse actual archaeological assemblages. This can be highlighted by considering the three articles cited above.

Ambrose *et al*, (2016) has been discussed at some length above and further comment can be restricted to the fact that the sampling strategy for modern specimens was not designed to deal with time aggregated archaeological assemblages and the data analysis did not stress test its results against an archaeological assemblage. The simple addition of an interval of applicability, as should always accompany any model (White and Gould, 1965) would increase the 'safe' utility of the research outcome. For example, Harris *et al,* (2018) could have limited their use of the regression model to the demonstrated interval of applicability.

Groom *et al*, (2019) conducted research to evaluate various methods of acquiring marine resources using the technologies and raw materials that were probably employed by Mesolithic hunter-gatherers;

subject matter that has resonance with this project as it has the potential to highlight the importance of the 'invisible' as discussed in chapter 3. In fact, Groom *et al* (2019) manage to go one step further and highlight how invisible the tool kit required to manufacture the invisible technologies is. They also provide very useable data in relation to the manufacturing time of the equipment. It is a line of research that should be pursued further to obtain data on success rates during the lunar cycle. Groom *et al* (2019) state that one of the most successful approaches with hand lines was through the visual targeting of fish or crabs. This coupled with the capture of mackerel leads the author to conclude the experiments were conducted during the summer. There are some details that are missing from the paper such as at what time of day, and at what time of year did the fishing take place. The research has excellent potential (SI-Chapter5-6).

The final example considered here is another example of experimental fishing and the results are presented in Mellars and Wilkinson (1980). In this example fishing with modern equipment was utilised to define a size profile by calendar month for saithe which was then utilised to determine the season of occupation at the prehistoric Oronsay middens. The modern experimental fishing is of interest because it took place over a four year period that included the extreme weather of 1976. The data is reproduced in figure C4-1 below. It is not clear when fishing took place and fishing from the shore during day light during very hot sunny weather is an excellent way to avoid catching larger specimens such as those of the second wave in Orkney. The seasonality of the prehistoric fishing at Cnoc Coig is interpreted as autumn and winter using the presence of juvenile grey seal as corroboration (ibid, p.40).

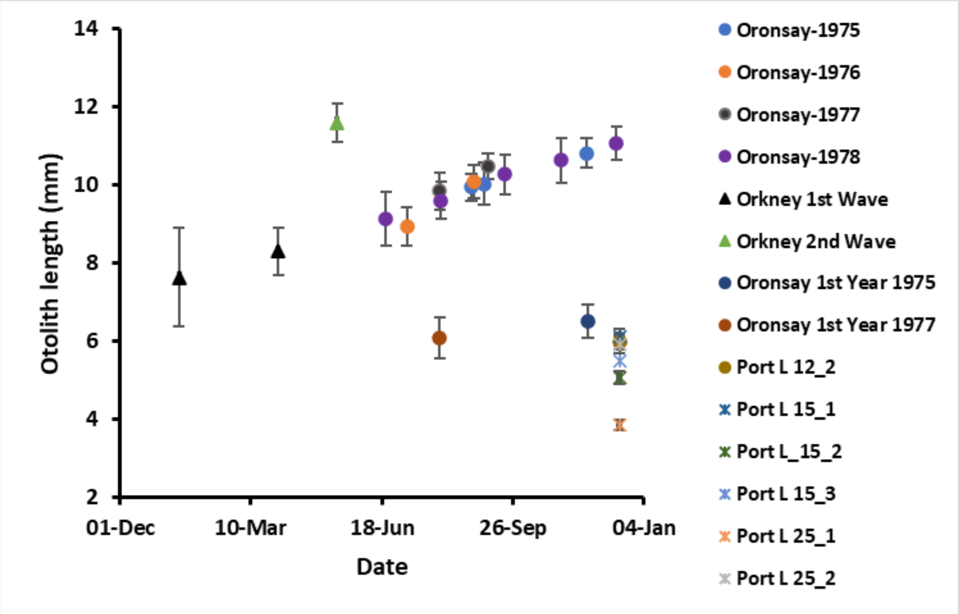

Figure C4-1: The saithe growth profiles. Data for Oronsay from Mellars and Wilkinson (1980, table 2, p.29) and the data for Orkney from Low (1813, pp.193-196). Error bars for Oronsay are 95% confidence level, for Orkney the entire range.

Figure C4-1 also contains historical data from Orkney which raises the possibility that fishing was in the early spring. The alternative interpretation based upon the data from Orkney can be corroborated by the presence of pelagic birds such as the auk family (alcidae) and gannet (*Morus bassanus*) and summer visitors such as the quail (*Coturnix coturnix*) at Cnoc Coig (Nolan, 1986, pp.270-301). The assemblage also contains autumn and winter species such as whooper swan (*Cygnus cygnus*) and greylag goose (*Anser anser*) (ibid); which lends further support to the conclusions reached by Mellars and Wilkinson (1980). The key point is not whether Mellars and Wilkinson (1980) have asserted the correct season for fishing or not, they *probably* did, the question is to what extent the model can be considered portable to other sites. To address the issue of portability this project will calibrate the growth profiles of the saithe otoliths using the stable isotopes of oxygen as described above.

4.8 Scale of Exploitation.

One key aspect regarding the interpretation of shell-middens is the scale of exploitation of molluscs. This is intrinsically bound up in a number of key debates. The first is to what degree were molluscs important to the economy, and it is often assumed very important as the remains can, in larger middens, represent millions of individual animals. This in turn is linked to the question of human impact on the environment in terms of reducing sizes (cf. Mannino and Thomas, 2001), which brings in the question of duration of occupation and frequency of occupation. Milner (2009a) discusses this topic and points out that the (lower) estimate of 150,000 limpets at Sand Rock Shelter could have accumulated in less than 3/5ths of a human generation through the collection of 300 limpets per day for one month per year. This matter can also be brought into focus by considering how much flesh 300 limpets of 30mm in length and of typical conicity, will yield. The answer is quite surprising at only 450g in total (equation from Santini *et al*, 1995, eqn 11, p.554). Whether the beach area could have provided 9,000 limpets, over say 25mm in length, each year is an interesting question. It has always struck the author when visiting a location such as Whitley Bay, with its substantial limpet population, that in the company of ten enthusiastic and committed undergraduates, the extensive shore could be just about cleared of limpets greater than 25mm in length within just a few days to a week. This is of course an experiment that cannot be ethically, and probably legally, carried out. Borges *et al*, (2016) conducted an interesting experiment that simulated harvesting of limpets. This was achieved by removing limpets every three months from two of three study areas. One was the control and the others subjected to high exploitation levels and low exploitation levels respectively. Compared to the control, after 18 months, the high exploitation treatment that removed all limpets greater that 25mm in length resulted in a reduction in the mean length of 7.6mm. The low level exploitation treatment which removed randomly half of the limpets greater than 25mm in length had a lower mean compared to the control by 3.8mm. The experiment seems to suggest that the availability of and yield of flesh from limpets (and probably other gastropods) would be reduced rapidly unless exploitation was either; at a very low level (much lower than in the experiment), or of short duration. It is difficult to envisage a scenario where molluscs of this type could form a significant part of the economy whether as food or bait, unless visits were short, and locations visited infrequently. This final point raises the question of dating periods of occupation and duration of occupation.

4.9 Dating.

Radiocarbon dating was a very welcome introduction to archaeology, but it has become increasing necessary to make ever more complex adjustments and refinements to the raw radiocarbon output (^{14}C assays) to obtain calibrated calendrical dates (PDs). The need to calibrate raw ^{14}C assays is hardly a recent mitigation and neither is the need for a different calibration protocol from materials that in whole or part incorporate carbon that originated in the marine environment. But it is now firmly established that the ΔR required to calibrate such marine sources varies in both time and space which is less than ideal. PDs often appear to offer a period of occupation. The reality is that if there are four non-overlapping ^{14}C assays each reflecting a single year's growth then the resulting, and probably overlapping PDs, cannot be considered to reflect a period of occupation. They provide a statement of uncertainty in when these four events occurred and nothing more. Boethius (2017, p.146) also discusses this issue and the limitations it imposes.

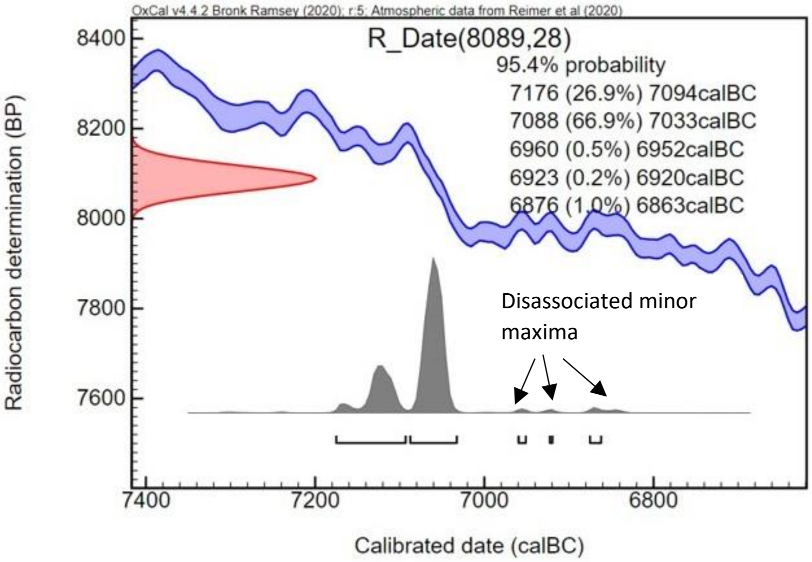

Figure C4-2: Calibrated date from a piece of carbonised hazelnut shell (single years growth) highlighting disassociated minor maxima which significantly extend the elapsed period of uncertainty.

The need to express PDs to a standard is superficially obvious and given the author's background the need to comply with standards is a 'sale that has already been made'; but the key term here is superficially. When trying to understand changes in human behaviour and environmental conditions at a level of granularity sought within this project the standards become an inhibitor, where potentially strict compliance with standards inhibits progress. This will be illustrated by using a ^{14}C assays calibrated as part of this project (figure C4-2). Oxcal 4.4.2 (Bronk-Ramsey, 2009) and the Intcal20 (Reimer *et al*, 2020) terrestrial curve in combination add 170 elapsed years in order add 1% of confidence level. The span of the PD has been increased 118% to obtain the 1.0% increase in confidence level. The calibrated date range for this sample using the Incal13 calibration curve (Reimer *et al*, 2013) and Oxcal 4.4.1 (Bronk-Ramsey, 2009), only two weeks earlier, is 7,166-7043 cal BC at the 95.4% confidence level. Intcal20 whilst adding 170 calendar years to the PD to meet the required confidence level, has significantly reduced the author’s confidence level in knowing when this event occurred, and how that compares to other events. It is also worth noting that of the 35 terrestrial ^{14}C assays calibrated by this project, 100% had an increased range for the PD (most are admittedly small increments), compared to the Intcal13 curve combined with Oxcal 4.4.1. The PDs of materials composed entirely or in part from carbon of a marine origin move significantly when Incal20 and Oxcal 4.4.2 are utilised. The ΔR generated by Ascough *et al*, (2017) utilised in chapter 6 is no longer valid and replacements must be calculated and presumably published. As this project is dealing with hunter-gatherers who exploit marine resources it is worth briefly reviewing the use of ΔR.

Wicks and Mithen (2014) undertook a review of Scottish radiocarbon database and in doing so raised the question of whether there was a hiatus of occupation in and around the 8.2K cal bp climatic event. This aspect will be considered further in chapter 7, but Wicks and Mithen (2014) also recalibrate ^{14}C assays for the humans from the Oronsay middens. This is done using a spatially extensive regional ΔR of 64±46 (Meiklejohn *et al*, 2011) that is an average spatially, but also when considered in terms of temporal variation described earlier. The question is whether the new PDs are better PDs or are they simply an error in the opposite direction to the originals. Given the temporal variation in ΔR which for the Western Isles is 143±54 in the mid-5th millennium BC and 109±55 late in the 5th millennium BC (Ascough *et al*, 2017), these values may be (but only may be) a better option (these ΔR values are based upon the Intcal13 terrestrial and marine curves). Table C5-3 gives the PD for the human remains from Oronsay using the above ΔR values with all other parameters the same as those used by Wicks and Mithen (2014). Table C4-4 provides the same calibration data but based upon Incal20.

Table C4-3: Comparative ^{14}C assay calibrations. Parameters from Wicks and Mithen (2014) and Ascough *et al* (2017) calibrated using Intcal13 and Oxcal 4.4.2.

Site	Laboratory Code	Age ^{14}C years	Error ^{14}C years	Proportion Marine (%)	Wicks and Mithen (2014)ΔR64±46	ΔR 109±55	ΔR 143±54	Alternative Scenario
Caisteal nan Gillean II	OxA-8005	5480	55	50	4270-3940	4334-4003	4337-4042	4334-4003
Cnoc Coig	OxA-8014	5495	55	90	4190-3790	4273-3935	4298-3962	4273-3935
Cnoc Coig	OxA-8019	5615	45	90	4270-3950	4351-4036	4382-4051	4382-4051
Cnoc Coig	OxA-8004	5740	65	90	4430-4030	4569-4168	4569-4218	4569-4218

Table C4-4: Comparative ^{14}C assay calibrations. Parameters from Wicks and Mithen (2014) and Ascough *et al* (2017) calibrated using Intcal20 and Oxcal 4.4.2.

Site	Laboratory Code	Age ^{14}C years	Error ^{14}C years	Proportion Marine (%)	Wicks and Mithen (2014)ΔR64±46	ΔR 109±55	ΔR 143±54	Alternative Scenario
Caisteal nan Gillean II	OxA-8005	5480	55	50	4234-3777	4320-3922	4318-3950	4320-3922
Cnoc Coig	OxA-8014	5495	55	90	3956-3535	4151-3680	4204-3707	4151-3680
Cnoc Coig	OxA-8019	5615	45	90	4071-3640	4256-3823	4312-3888	4312-3888
Cnoc Coig	OxA-8004	5740	65	90	4261-3764	4374-3948	4431-3977	4431-3977

Table C4-3 indicates that if the ΔR utilised by Wicks and Mithen (2014) is closest to the actual value that should be utilised for Oronsay and Colonsay then a possible interpretation is that late in the 5th millennium BC a greater dependence on marine resources developed and this was sustained into the first half of the 4th millennium BC. The alternative scenario can be interpreted as marine protein was very important until the end of the 5th millennium BC and during the late 5th millennium there is evidence for individuals who appear to represent a transition to a terrestrial based diet.

Table C4-4: presents a scenario, where irrespective of the ΔR used, marine resources were not the major source of protein until late in the 5th millennium BC and the flourishing of marine resource exploitation is a characteristic of the first half of the 4th Millenium BC. This is clearly an artefact of using the Intcal20 curve, but the question is 'are interpretations being made that are artefacts of spatially and temporally generalised ΔR' (cf. Finlay *et al*, 2019). As a general observation of principle; given Finlay *et al*, (2019, p.102) are asserting contemporality between the Oronsay and Port Lobh middens it is unclear why they utilise a different ΔR of 73±52 from (Harkness, 1983), rather than the value used by Wicks and Mithen (2014) of 64±46 from Meiklejohn *et al*, 2011). Clearly there is an urgent imperative to establish specific ΔR values for Oronsay and Colonsay and an equally urgent requirement to recalculate and republish every ΔR published for the northern hemisphere. The fact that the publication of Intcal20 generates such an urgent requirement in an uncontrolled manner will be discussed in the final chapter. Thankfully, the standards against which genetic distances and stable isotopes ratios are determined lack this level of volatility.

In summary, chapter 6 will utilise Intcal13 as it is the curve from which the published ΔR values have been calculated. The range of PDs is wide and based upon Incal20 they are getting wider, therefore, when seeking to establish intra and inter site chronologies the project will use faunal stratigraphy or seriation. Strictly speaking this is not the ecological stratigraphy encountered in the form of pollen and mammal assemblage zones, as these are entirely a reflection of the ecosystem. The approach can be considered a hybrid of behavioural stratigraphy and ecological stratigraphy (eco-behaviour).

4.10 Summary.

In this chapter a number of methodological challenges have been explored and the manner in which this project will deal with the challenges has been defined. The methodological strategies that shape the analysis and interpretation presented in subsequent chapters has now been defined. The technical details of the methods and associated protocols will be defined in the relevant sections of the relevant chapters. In the next chapter a review will be conducted of the Mesolithic archaeology of Atlantic Europe, prior to the Mesolithic archaeology of the remote Scottish Islands being presented in chapter 6.

5 The Mesolithic of Atlantic Europe.

5.1 Defining Atlantic Europe in a Project Context

Geographically Atlantic Europe covers a significant range in latitude, from around 37^{O} N in Southern Portugal to 71^{O} in Northern Norway. Likewise, the longitude range is not insignificant extending from 10^{O} West to 25^{O} East. This region therefore includes a very wide range of environmental and climatic profiles which exist within the overarching oceanic climatic regime (*sensu* Belda *et al*, 2014). Certain decisions were required early on to arrive at a coherent definition that would serve the objectives of the project. The immediate question to be answered was: 'Should the definition include the margins of the Irish and North Seas and therefore treat the islands of Ireland and Great Britain as offshore components of this coastal margin?' This definition is a reasonable fit for the early Mesolithic as Britain was not an island and the Irish sea but a narrow channel (figure C5-1). Alternatively, a definition can be made that only those coastlines exposed to the open Atlantic Ocean are considered as Atlantic Europe and the margins of the Irish Sea, North Sea and Eastern half of the English Channel are excluded. The consensus

Figure C5-1: Approximate extent of Doggerland during the early Holocene. Two points of note are that there is a waypoint between Shetland and Norway and the severence of the link between continental Europe and Britain occurred during the 9th millenium cal. bp (Sturt *et al*, 2013). Map copywrite B. J. Coles and S. E. Rouillard.

is that Britain became an island sometime during the 7th millennium BC and therefore this definition is more appropriate from that point onwards. A brief review of the archaeological record and current environmental conditions was undertaken, and it was clear that the latter definition should be adopted (figures C5-2 to 4).

From one angle the definition is self-evident, as in continental Europe there are no Mesolithic shell middens east of Brittany in the English Channel (Gutierrez-Zugasti *et al*, 2011), and it is not possible to consider an archaeological record that simply does not exist. A similar situation is encountered on the channel coast of England as the only known Mesolithic shell-midden is that at Culverwell (Mannino and Thomas (2001; 2002). Therefore, both the coastlines of the eastern English Channel can in principle be omitted from the definition. Culverwell, however, can be considered as a special case as it is basically open to Atlantic influences and was occupied shortly after separation occurred.

The situation in the southern North Sea basin is similar and the absence of Mesolithic coastal midden sites is simply a consequence of the modern coastlines of Normandy, the low countries, and Germany not being coastal during the majority of the Mesolithic period (figure C5-1). This is further compounded by more recent isostatic readjustment in this area being negative and therefore any shell-middens on the East of England will have been lost (submerged and or eroded) due to a combination of this adjustment and rises in eustatic sea level. The south-eastern coastline of the North Sea basin includes northern Denmark, Sweden, and Norway and here due to a positive isostatic readjustment shell-middens and coastal Mesolithic sites are present. This area however has experienced series of significant environmental vectors that are not characteristic of the coastline open to the Atlantic. Firstly, this area is isolated from the open Atlantic and the influences of the AMOC and anticyclonic weather systems is to some degree diluted resulting in a climatic regime that is shifted towards one of a more continental nature (figure C5-2). Secondly, more localised environmental vectors were operating during

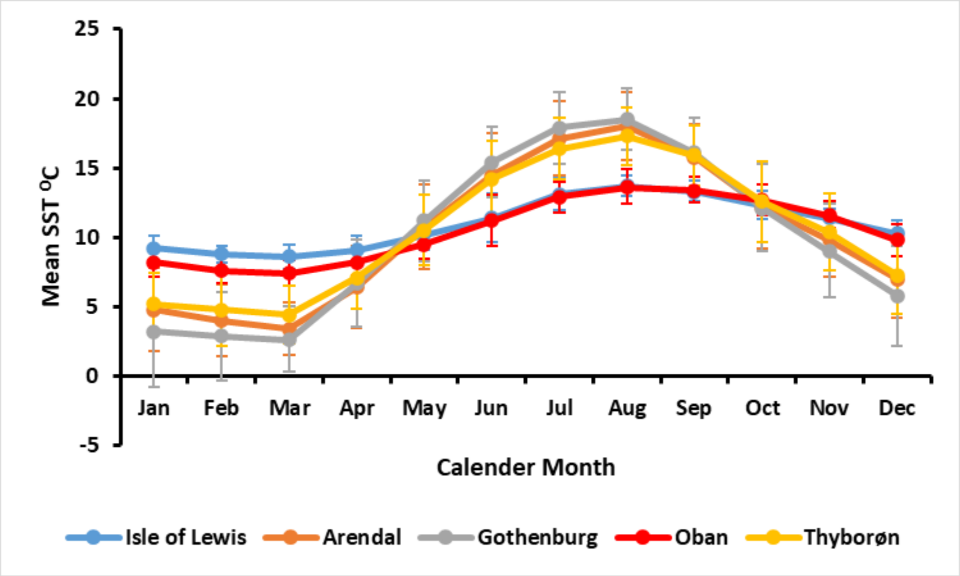

Figure C5-2: Mean sea surface temperatures around the Isle of Lewis (58.52° N), Oban (56.42° N) Arendal (58.46° N) in southern Norway, Gothenburg in western Sweden (57.71° N) and Thyboren (56.7° N) in northern Denmark. Winter temperatures are highly moderated in the Atlantic whilst summer temperatures are constrained. Data from worldseatemperature.org. Error bars reflect maximum and minimum monthly averages which at Gothenburg can be less than 0°C.

the Mesolithic period, and whilst investigating these in detail is beyond the scope of this project a quick review is required to complete the line of reasoning adopted. The Baltic Sea lying within the Baltic Sea basin has relatively low salinity and species of fish usually considered to be freshwater species such the

Figure C5-3: The definition of Atlantic Europe within this project. The definition includes Devon, Cornwall and the Minch. Location of the Storegga slide was obtained from Bondevik *et al*, (2005, fig 1, p.196). The sub-regions are defined as Atlantic Portugal, (including the Muge and Sado middens); Atlantic Spain; Brittany; the Atlantic coast of the Island of Ireland; England and Wales; Atlantic Scotland and Atlantic Norway. The numbers reflect modern SST data points and are associated with locations in SI-Chapter5-3.

pike can be caught there regularly (Pers obs). Since the last glacial maximum (LGM) the area of the Baltic Sea has undergone many transformations which have drastically changed both its salinity and its connectivity with the southern North Sea basin (Morner, 1995). Fish exploitation during the earlier phases of the Mesolithic was based upon freshwater taxa (Boethius, 2016; Boethius *et al*, 2017), which has implications for hunter-gatherer behaviour in the southern half of the North Sea basin also. Rowley-Conwy (1984, pp.312-315) has suggested that influences such as these, especially changes in salinity, may be the driver behind the switch from oyster (*Ostrea edulis*) dominated middens to mussel and cockle dominated ones at the Mesolithic to Neolithic transition. Based upon the data presented by Gross and Smyth (1946) and Nelson (1928) (see also McGonigle *et al*, 2016), a drop in summer temperatures in the Southern North Sea of a few degrees may result in a reduced frequency of oyster spawning and reduced success for spat settlement. The implications for the Atlantic façade are intriguing as the summer temperatures experienced (figure C5-2), would trigger oyster spawning episodically and certainly not annually. Temperature variation in the southern North Sea, if combined with reductions in salinity, would probably be quite serious for oyster yields and sustainable exploitation. The key point is the spawning situation is driven by summer temperatures but that extremely low temperatures such as those experienced during the winter of 1963-1964 can result in the loss of entire oyster beds (Crisp *et al*, 1964).

Untangling the influences of the North Atlantic climatic vectors from the more localised dynamics above simply adds a level complexity that is incompatible with the objective of exploring hunter-gatherer behaviour in response to environmental changes of lower amplitude and shorter periodicity. In summary, for the reasons outlined above the definition of Atlantic Europe adopted by this project, whilst generally intersecting that of Gutierrez-Zugasti *et al* (2011), differs as the North Sea basin is excluded, whilst the Atlantic façade of Norway is included. This definition is, at this stage, broken down into sub-regions based primarily upon modern geopolitical boundaries (figure C5-3).

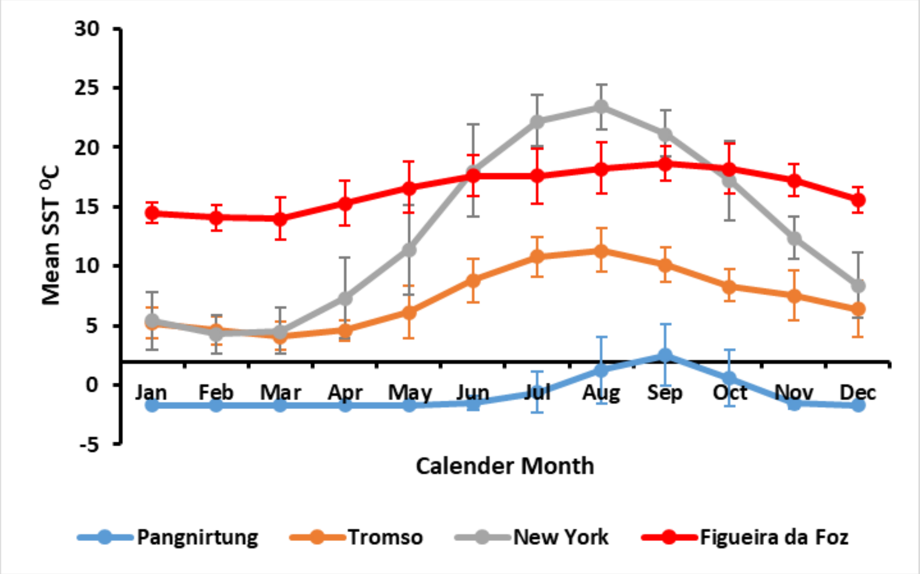

Figure C5-4: Sea surface temperatures at Pangnirtung eastern Canada (66.15^{O} N), Tromso in Norway (69.65^{O} N), Figueira da Foz in Portugal (40.15^{O} N) and New York in the USA (40.71^{O} N). Also compare with the data for Gothenburg and Arendal in figure C5-2. Error bars depict the maximum and minimum monthly means. Data from Seatemperature.org

5.2 Objectives and Methodology

The objectives of this chapter are to identify sites or combinations of sites that yield data suitable for exploring past environmental change. Once data has been collated from the literature it is filtered to identify the sites which provide potential evidence for change in and around the 8.2K cal bp event or during the 5th millennium to early 4th millennium cal BC.

The criteria in ascending order of 'preference' are as follows.

1. Single sites with well-defined chronologies in terms of phasing that is anchored by supporting ^{14}C assays.
2. Sites with at least one terrestrial radiocarbon date which is consistent with any dates on shell are preferred.
3. Spatial groups of sites that collectively have well defined chronologies in terms of phasing anchored by supporting ^{14}C assays, even where individual sites can only be considered as representing a single phase.
4. Sites that offer assemblages in a well stratified sequence, but lacking ^{14}C assays, are considered when, either strong cultural association or biostratigraphy permit a level of chronological positioning to be achieved.
5. Ideally the sites that pass the above filters should offer assemblages that permit clear ordinal ranking of abundances to be defined for the taxonomic classes of mammals, birds, fish, molluscs, and crustaceans. For each class the three most abundant taxa are documented in SI-chapter5.

Generally, the review is limited to the Atlantic façade as defined earlier, but certain other sites that fall outside of that definition have been included as they offer 'outliers' for comparative analysis. Such examples mainly lie in the Irish Sea or northern margins of the North Sea. As discussed in chapter 4 quantification of faunal remains is not without challenges, especially as the published literature utilises a variety of quantification units, including none. Therefore, as stated above and in accordance with conclusions in chapter 4, all abundances are treated as ordinal, which removes the issue of diversity in quantification units. At this stage the results are presented for each sub-region.

The calibration of ^{14}C assays was undertaken with OxCal 4.4.4 and the Incal13 terrestrial and marine curves for the reasons discussed in chapter 4. Chi^2 evaluations to determine whether ^{14}C assays could be combined were not carried out as such mergers smooth the dataset and removes granularity. In some sub-regions the calibration of ^{14}C assays that were based entirely or partially on marine carbon was problematic due to the variability of ΔR values (SI-Chapter5-2.2). Weighted mean ΔR values that were temporally extensive were avoided wherever possible in favour of site or phase specific values. Where local values were unavailable a match was sought based upon chronology and physical location following Bicho *et al*, (2010).

Dietary isotope analyses, where available, are also utilised to support the faunal datasets. Conventionally, scatter plots of ∂^{13}C and ∂^{15}N are utilised to compare results between sites and sub-regions (cf. Fontanals-Coll *et al*, 2014; fig. 5, p.546). This is potentially misleading as the end points for *circa*. 100% marine diet versus *circa*. 100% terrestrial diet are variable, and rightly so. The results from human skeletons must be contextualised against the biosphere through the analysis of contemporary faunal examples. The approach adopted in subsequent chapters is to discuss the $\partial^{13}C$ as a percentage between the end points defined in the relevant publication. The justification for this approach is provided in SI-Chapter5-2.1.

5.3 Results: The Mesolithic Shell Middens of Atlantic Europe.

The results are presented by sub-region in a generally ascending latitudinal sequence. For each sub-region a list of the sites considered suitable for consideration in future chapters is provided in table format. This data is complemented by modern sea surface (SST) temperatures and a map depicting the approximate location of the sites within the sub-region. A detailed (at phase/feature level) list of the ^{14}C assays for each site is provided in the corresponding SI-chapter5 section, as is the summary of faunal composition and site data. The references consulted to build the detailed radiocarbon PDs (and ΔR values) plus the faunal inventories are included in these tables and will not be cited in the main text when discussing the findings.

Certain aspects of this review were common to all sub-regions and can be stated here to avoid repetition. It will not be a surprise to anyone familiar with the discipline that several inhibitors exist to obtaining what might be termed a 'utopian dataset'. Many sites were excavated (*sensu amplo*) long ago without modern protocols and hence certain aspects of the fauna have been missed; to this can be added the fact that in some cases the faunal record was ignored entirely and not even presence or absence data is available. Even when some form of ordinal abundance data is available it has little or no stratigraphic resolution. Many sites have not been scientifically dated and assays taken before the advent of AMS based ^{14}C assays have large uncertainties which quite often render them useless, other than to attribute the date to a given millennium (or more). When ^{14}C assays are available it is often difficult to reconcile the features/layers the material was sourced from to those for which faunal data is available. There is no doubt that the decision process for an excavator to decide what to date whilst excavation is in progress is a difficult and complex one. The challenges regarding ΔR values discussed in chapter 4 were all too evident and another challenge became apparent when dietary mixing is considered both for 14C assay calibration and dietary inferences. Dietary inference can be mitigated for by expressing the carbon value asserted by the source as a percentage of the distance between the end points asserted by the source. The implications for calibrating ^{14}C assays can be mitigated by a ±10% range during the calibration following Wicks and Mithen (2014) (and others), but the price is even more spread in the PDs. A further inhibitor is that of stratigraphical and hence temporal conflation usually driven by a perceived paucity of, and therefore lack of utility, of the remains. Often taxonomic conflation has been carried out, again for the same reasons. A large number of spits are available for each phase at Rocha das Gaivotas and whilst metrics are available by spit, taxonomic composition is not (Dean *et al*, 2012; Dean and Carvalho, 2011).

5.3.1 Atlantic Portugal

The archaeological record of Portugal exhibits great time depth that attests the exploitation of marine resources as far back as the Middle Palaeolithic (Bicho and Haws, 2008; Aruajo, 2016). Portugal is one of the sub-regions of Atlantic Europe that was occupied throughout marine Isotope Stage 2 (MIS2) glacial and therefore did not need to be recolonised by humans during the Holocene. A number of Portuguese midden sites have been published, although rarely as an integrated assemblage detailing all the taxonomic classes defined above. The deposits include those from caves that include marine molluscs in addition to open air shell-midden sites. Modern SST data from two reference points is provided in figure C5-5. The approximate location of the sites is presented in figure C5-6. The sites considered suitable for further consideration are provided in table C5-1. The detailed chronologies are provided in SI-Chapter5-1 as is the faunal and site type data, not only for the sites in table C5-1 but all the sites reviewed.

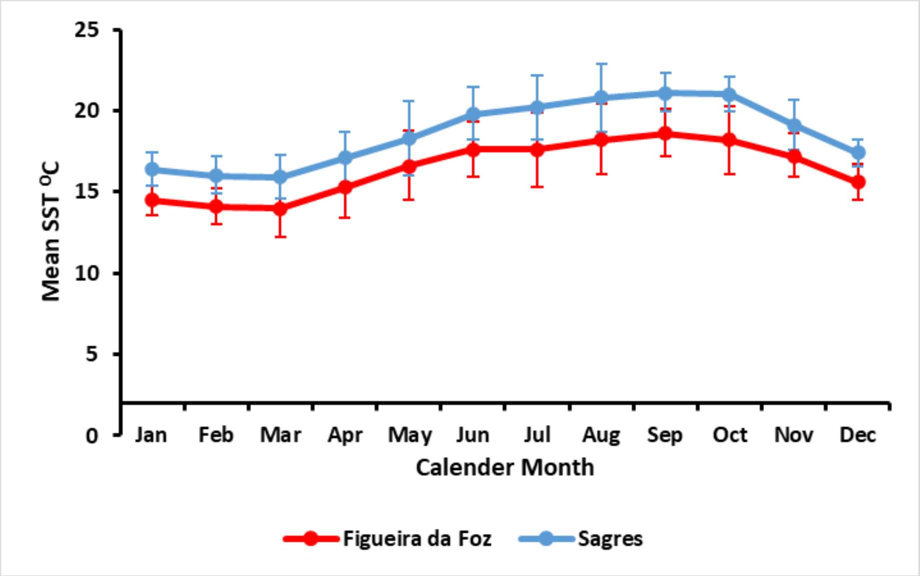

Figure C5-5: Mean sea surface temperature at Figueira da Foz (40.15^{O}N) and Sagres (37.02^{O}N). Error bars reflect maximum and minimum monthly averages. Data from Seatemperature.org

Bicho *et al* (2010) conducted a review of 20 sites and stated that for the vast majority the faunal data is not available as MNI or NISP. Whilst quantification units are not required for an ordinal treatment, such data does permit the taxa classified with equal abundance (often the majority) to be resolved further. Given the insight provided by someone as knowledgeable as Nuno Bicho regarding the sub-region's literature, the decision was made not to pursue the site publications further. The author's own investigations revealed that even the semi-quantitative presence or absence data needs to be treated with caution as, for example, at the site of Vale Frade the molluscs are quantified by weight (Araújo, 2016) and hence the data is of no analytical value (see chapter 4).

Table C5-1: Sites from Portugal that have been selected for consideration in chapters 7 and 8. Data from the sources provided at site level in the detailed faunal tables and chronology tables in SI-Chapter5-1. 1= All phases selected for analysis. 2= Includes a hiatus. 3=Includes two distinct periods of occupation. 4=Only goose barnacle present. Key: Terrestrial mammal (TM), marine mammal (M.Mam), terrestrial bird inc. ducks (TB), marine bird (MB), marine fish (MF), Anadromous/Catadromous fish (A/C), crustaceans (Crust), marine molluscs (M.Mol). Biometrics available (Y). For taxa Y=ordinal or ratio data available, P= presence or absence only known. PD ranges are cal.BC.

Sub-region	Site	PD Range All Phases[1]	Phasing	TM	M. Mam	TB	MB	MF	A/C	Crust.	M. Mol	Biometrics
Portugal	Barranco das Quebradas	6,900	Y								Y	Y
Portugal	Casal Papagaio	7,457-6,856	Y	Y							Y	
Portugal	Magoito	9,134-3,719	Y								Y	
Portugal	Rocha das Gaivotas	7,600-5,400	Y							Y[4]	Y	Y
Portugal	S. Juliao A	7,283-6,240	Y								Y	
Portugal	S. Juliao B	7,452-5,560[2]	Y								Y	
Portugal	S. Juliao C	6,844-3618[3]	Y								Y	
Portugal	S. Juliao D	3,092-2594	Y								Y	
Portugal	Toledo	7,061-6,407	Y	Y		Y		Y			Y	
Portugal	Vale Frade	7,825-6,473	Y	Y		Y		Y			P	
Portugal	Moita de Sebatiao	Chapter 7	Y									
Portugal	Cabeco da Arruda	Chapter 7	Y									
Portugal	Vale Fonte Moca I	Chapter 7	Y									
Portugal	Cabeco da Amoreira	Chapter 7	Y									
Portugal	Pena d'Agua	6,407-6,001	N	P								
Portugal	Formo del Telha	5,721-5,366	Y	P							P	
Portugal	Curral Velho	6,818-6,352	Y								P	
Portugal	Bocas	5,876-5,453	N	P							P	
Portugal	Pena de Mira	7,035-6,461	N								P	
Portugal	Lapa do Picareio	7,580-7,064	N	P							P	
Portugal	Pinhal de Fonte	7,196-6,701	N	P							P	

The situation in Portugal can be summarised as follows. Generally, there is continuity between the late Pleistocene and early Holocene in terms of the terrestrial mammalian resources exploited. Red deer (*Cervus elaphus*) are very important throughout as are wild boar (*Sus scrofa*). The dramatic shift from glacial species to temperate species observed at higher latitudes is not really evidenced. The exploitation of birds is also of interest as it is focused game birds such as the wood pigeon (*Columba palumbus*) and red-legged partridge (*Alectoris rufa*), with minor roles for ducks (anatidae); sea birds are absent. Prior to late in the 7th millennium BC the thermophilic molluscs such as the thick top shell (*Phorcus lineatus*), red-mouthed rock shell (*Stramonita haemastoma*) and oyster feature strongly, after which the former two disappear and the latter becomes less abundant. Recovery of these species appears to commence in the 5th millennium cal BC. Evidence for the exploitation of fish at the coast is poor other than (relatively) at two sites. A total of 143 fish bones are known from Toledo and 70 from Vale Frade. Fishing is focused on various species of sea bream (sparidae) which generally favour warmer estuarine waters, as do mullet, although tope (*Galeorhinus galeus*) is also present. Fish remains are however abundant (for this region?) in the estuarine Muge and Sado middens complexes (Bicho *et al*, 2010).

The PD patterning of the Portuguese sites (SI-Chapter5-1; Bicho *et al*, 2010) does strongly suggest a retreat from the Atlantic coastline into river valleys late in the 7th millennium BC as suggested by Bicho *et al*, (2008; 2010). Sao Juliao is normally given as an exception to this patterning (ibid). Sao Juliao requires further consideration as Phase A clearly predates the 8.2K cal bp event and B has only one date that spans the event and this is an outlier. Phase C just covers the period of the event (with the extreme tail of the 2σ PD), but a short hiatus in occupation between A and B during the event cannot be ruled out. Phases A and B attest a significant role for oysters until late in the 7th millennium BC, but this is greatly reduced during phase C in the 6th millennium BC and whilst only present in small numbers, the thick top shell and red-lipped rock shell reappear, along with the common periwinkle, during the second half of the 5th millennium BC.

Figure C5-6: The approximate location the sites detailed in table C5-1. After Dean *et al*, (2012), Dean and Carvalho (2011), Araújo, (2009; 2016), Bicho *et al* (2010), Soares and Diaz (2006) and Clarke (1983).

There are regional trends in the molluscan assemblages which reflect the nature of the coastlines. In central Portugal, the focus is on infaunal bivalves, especially those that favour estuarine biotopes. In the south the focus is on epifaunal gastropods and bivalves, as might be expected from the rocky shores found there. In the late Pleistocene and early Holocene hares (*Lepus spp*.) appear in the assemblages, although by the Mesolithic these have been superseded by rabbit (*Oryctolagus cuniculus*).

There is some debate as to whether the rabbit remains are anthropogenic and this is discussed at some length by Rowley-Conwy (1992). His conclusion is that in many cases the rabbit remains are the result of anthropogenic action, and It appears that rabbits (small game) did play a significant role in the economy at many sites. This is possibly because they are predictable in their movements to and from their warrens, and hence can be acquired asynchronously with snares (*contra* Dean *et al*, 2012, p.107).

The final source of data to be considered is that of the stable dietary isotope values obtained from human remains. Generally, the contribution of marine protein does not exceed 50% of intake (Fontanals-Coll *et al*, 2014; fig. 5, p.546), and is often much less. It should be noted that a paucity of human remains from the coastal sites limits the above observation to the Sado and Muge midden complexes which are in strongly estuarine environments tens of Km from the coast, and therefore the ^{13}C values must reflect an admixture of seawater and freshwater which may be causing the contribution from marine taxa to be understated (Schulting and Richards, 2001, p.326). Lubell *et al* (1994, p.205) consider the end point for 100% marine diet in this specific environment to be ∂^{13}C 15.0 $^{0}/_{00}$ giving only a 5.0 $^{0}/_{00}$ range to 100% terrestrial diet (ibid). It should also be noted that the influence of freshwater increases from the mid-6th millennium BC (van de Schriek *et al*, 2007; 2008). Whilst the difference between the value for ∂^{13}C generated by ^{14}C assays compared to that obtained by dietary isotope analysis is generally minimal (difference $< 0.50\ ^{0}/_{00}$), the difference can exceed 1.0 $^{0}/_{00}$ and can be as high as 3.4 $^{0}/_{00}$ (Schulting and Richards, 2002, table1, p.1014); therefore when available dietary analyses are preferred by this project.

One data point from the Mesolithic coast is available in Lubel *et al* (1994) and this dates to (6370±70 ^{14}Cyrs) and produced values of ∂^{13}C of 15.3$^{0}/_{00}$ and ∂^{15}N of 16.5$^{0}/_{00}$. The carbon suggests a relatively balanced diet or estuarine influence, and the nitrogen a significant amount of aquatic protein. The isotopic regime in which fauna reside is what the analyses measure and this should not be confused with whether the taxa themselves a marine species are or not, and therefore the implications this has for human acquisition behaviour or technologies.

The final consideration is that it is unclear how the sites fit into a hunter-gatherer settlement system and there is little discussion of this aspect within the literature reviewed by the author. None of the assemblages are particularly large and whether they represent residential camps of mobile bands, extended family units, or the occupation of small task groups is unclear. The exception to the above is probably the Muge and Sado middens which appear to reflect reduced mobility and possibly territoriality based upon the presence of cemeteries (cf. Rowley-Conwy and Piper, 2017).

The archaeology of Mesolithic Atlantic Portugal suggests that whilst the exploitation of marine resources was ubiquitous it was possibly only a supplement to a diverse range of terrestrial birds and mammals. It seems likely that any deterioration in the amount or stability of marine resources could be easily compensated for, other than as source of salt intake. The retraction away from the exposed coast to the interior during the 8.2K cal bp event is therefore intriguing. Significant weaking of the AMOC may have resulted in significant reductions in winter SST during the event (figure C5-4) but it would still have to be considered at least mild. Importantly, Portugal has also highlighted several theoretical matters including those that will be applicable in the other sub-regions.

5.3.2 Atlantic Spain

The archaeological record of Atlantic Spain, as with Portugal, exhibits great time depth and attests the exploitation of marine resources back to the Middle Palaeolithic (cf. Álvarez-Fernández, 2011; Clarke, 1983). The Upper Palaeolithic record from the last glacial is particularly rich and the changes in the faunal record in response to the Pleistocene-Holocene transition has received significant attention as has the Mesolithic to Neolithic transition (Clarke, 1983; Álvarez-Fernández, 2011; 2015; Gutiérrez-Zugasti, 2011a; 2011b; Straus *et al*, 2002; Bailey and Craighead, 2003; Arroyo and Morales, 2009; García-Escárzaga, 2017; Cubas *et al*, 2016). Spain is another of the sub-regions of Atlantic Europe that was occupied by human groups throughout the glacial and therefore did not need to be recolonised by humans during the Holocene. The configuration of the coastline has also undergone significant changes during the Holocene with a low lying forested coastal strip, being lost to eustatic sea level rise (Clarke, 1983). Birds (including marine), marine fish, and marine mammal remains whilst never abundant are quite ubiquitous until the Holocene, after which remains are very rare (Álvarez-Fernández, 2011). The location of the archaeological deposits is very concentrated as shown in figure C5-8, some caves are only 50m from each other (Clarke, 1983, p.25) and many are within 1.5km of each other in clusters. Of more direct relevance to this project is that the published literature provides potential environmental markers for environmental change in the form of the two species of limpet discussed below and the relationship between thick top shell and periwinkles. Those sites with the potential to support the aims of the project are presented in table C5-2. Data relating to a wider range of sites and additional information regarding the sites presented in table C5-2 is available in SI-Chapter5-1. Modern SST are provided in figure C5-7.

The changes in fauna between the Pleistocene and Holocene are observed, as expected. The glacial fauna of woolly mammoth (*Mammuthus primigenius*), bison (*Bison priscus*) horse (*Equus caballus*) and reindeer (*Rangifer tarrandus*), (noting that the latter are not abundant in Spanish sites in general (Morales *et al*, 2004)), disappear during the late Pleistocene to early Holocene. Significantly, at this latitude red deer, roe deer (*Capreolus capreolus*), chamois (*Rupicapra rupicapra*) and ibex (*Capra ibex pyrenaica*) are exploited during the Pleistocene from the Upper Solutrean onwards (Clarke, 1983, p.110), although wild boar and aurochs (*Bos primigenius*) are present only from the early Holocene. Significant changes are observed in the mollusc assemblages with thermophilic species becoming dominant. The edible periwinkle is replaced by the thick top shell, and the common limpet (*Patella vulgata*) is partially displaced by black-footed limpet (*Patella depressa*) (Bailey and Craighead, 2003; Gutierrez-Zugasti, 2011a). Significant weight has been given to the fact that the new species prefer warmer temperatures and the incumbents do not, but this ignores the fact that the incoming taxa occupy different niches. Black-footed limpets out compete the common limpet only at the lowest shore levels and then on shores that are very or extremely exposed in terms of wave energy (Bailey and Craighead, 2003; Ballantine, 1961b, p.9; 1961a; Southward and Orton, 1954, p.13). The thick top shell out competes the edible periwinkle in environments dominated by bare rock whilst it is at a disadvantage in environments that have weed cover (Ballantine, 1961b). The periwinkle is also slightly less tolerant of wave exposure although both species are confined to shores with lower exposure ratings (ibid). Temperature, whilst almost certainly having a role, may not be the only driver. Normal successional cycles on the shore (cf. Ballantine, 1961a; Lewis and Bowman, 1975) may be more material during the Holocene, especially if changes in human behaviour result in greater disruption to those cycles.

Prior to detailed consideration of the mollusc record the other taxonomic classes can be quickly dealt with. Bird assemblages are few and far between and very little information is available other than from two sites. Pico Ramos yielded two tarso-metatarsus from a great auk (*Pinguinus impennis*) and Herriko Barra which yielded a small assemblage dominated by the auk family (alcidae) plus other typically northern marine species (Alorza and Marco, 1993; Zapata *et al*, 2007; SI-Chapter5-1). Both these sites attest that these species were frequenting the area *circa* 5.0K cal BC, although the auks rarely do today. The cormorant family (*Phalacrocorax spp*.) is notable by its absence. The identification of a member of spheniscidae (penguins) by Álvarez-Fernández (2011, table 5, p.337) during the Upper Magdalenian must be treated with 'extreme caution'. The data presented by Alvarez-Fernandez (2011, table 6) clearly show a paucity of fish remains, even at sites where stringent recovery regimes have been applied (cf. Zapata *et al*, 2007), although wrasse are abundant in Mazacullos II level 3.3. The Bay of Biscay lies at or beyond the southern limit of the range of most gadids today, and they may have been absent during warmer climatic periods. The data suggests that the environmental regime late in the 6th millennium BC to early in the 5th millennium BC did permit the species to frequent the area (figure C5-8 for context) (ibid). One interesting observation is that Zapata *et al*, (2007, p.30) report the presence of 'winkles' as the second most abundant mollusc (23%), although nothing more specific. This observation must be treated with caution as discussed in SI-Chapter5-2.3.

The number of sites that could yield useful data across multiple taxonomic classes is limited but the data available for marine molluscs is extensive, and includes biometrics, taxonomic composition, and at some sites with a degree of temporal resolution. Clarke (1971; 1983) makes reference to a 'gigantic' sub-species of limpet (*Patella vulgata sautuola*) which is not recognised today. The fact it reaches a size of 50mm is highlighted, yet this is perfectly within the range of *Patella vulgata* (chapter 6). Limpets of this size will only be acquired in numbers if sites (or the species) are 'rested' frequently or only a few specimens are collected during each visit. Significance has also been attributed to the size reduction of limpets in the Holocene relative to the Pleistocene as an indicator of increased intensification (Gutierrez-Zugasti, 2011a) rather than the environmental causes favoured by Bailey and Craighead (2003). This interesting juxtaposition will be examined further in chapter 7. Sites offering stratigraphic resolution are few, but many of the sites are in very close proximity to each other and therefore the same area of the shore will have been exploited. When sites are clustered to reflect this then temporal sequences can be established.

As highlighted by Fano *et al* (2015), one feature of the archaeology of this sub-region is that the transition from a 'Mesolithic to Neolithic economy' does not appear to exhibit the 'flick of a switch' dynamic asserted for the British Isles and southern Scandinavia (cf. Serjeantson, 2014; Richards and Hedges, 1999; Schulting and Richards, 2002; Rowley-Conwy, 2004). Notably the exploitation of crabs at one of the Spanish Neolithic sites is much greater for all species and especially the, albeit small, marbled crab (*Pachygrapsus marmoratus*) (Gutierrez-Zugasti, 2011b). The stable dietary isotope data from human remains within this sub-region show a greater contribution from protein sourced from the marine environment relative to the Sado and Muge complexes, but still only suggests around or just over, 50% of protein intake is from the marine environment (Fontanals-Coll *et al*, 2014; fig. 5 and 6, pp.546-547). As with Portugal it appears that any fluctuation in marine resources could be easily compensated for with terrestrial resources. Whilst the Neolithic appears around 5,000 cal BC, the

Mesolithic persists in some areas until 4,000 cal BC (Fano *et al*, 2015). This overlap results in difficulty determining the site type. Whether a site is part of a Mesolithic settlement system or a task camp (chapter 2) created by a Neolithic task group (Fano *et al*, 2015, p159; Morales, 2004; Zilhao, 2004),

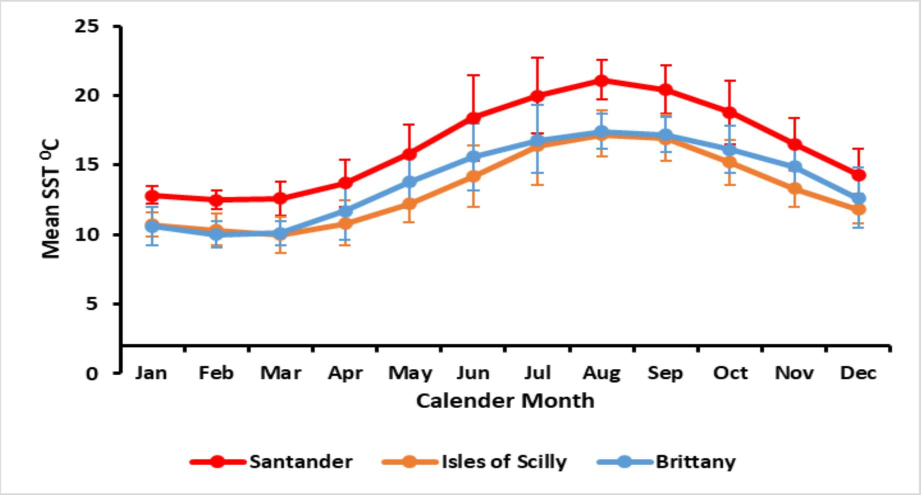

Figure C5-7: Modern SST at Santander (43.46^{O}N) in Cantabrian Spain. Data from the Scilly Isles (49.94^{O}N) and Brittany (47.76^{O}N) defines the generally accepted southern boundary of the range of Atlantic cod (*Gadus morhua*). Error bars reflect maximum and minimum monthly averages. Data from Seatemperature.org

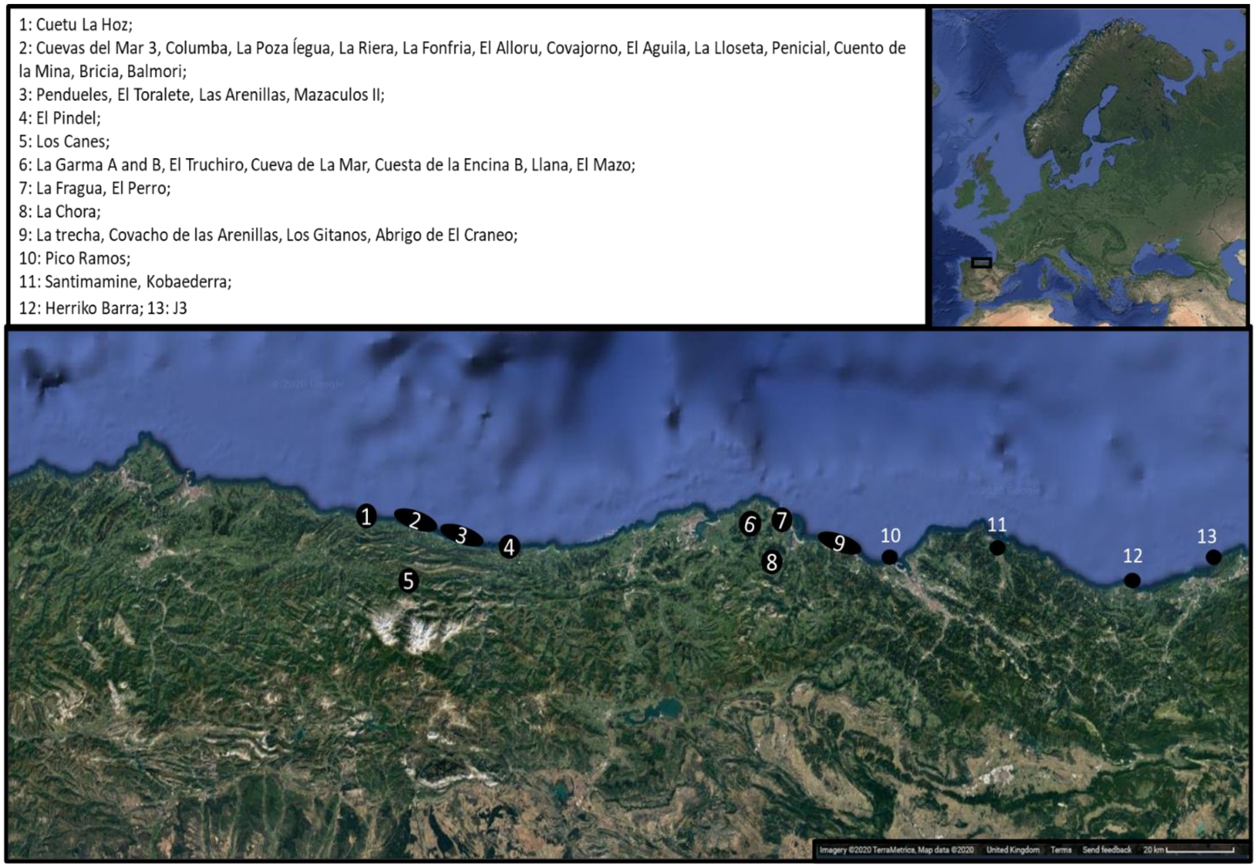
1: Cuetu La Hoz;
2: Cuevas del Mar 3, Columba, La Poza Íegua, La Riera, La Fonfria, El Alloru, Covajorno, El Aguila, La Lloseta, Penicial, Cuento de la Mina, Bricia, Balmori;
3: Pendueles, El Toralete, Las Arenillas, Mazaculos II;
4: El Pindel;
5: Los Canes;
6: La Garma A and B, El Truchiro, Cueva de La Mar, Cuesta de la Encina B, Llana, El Mazo;
7: La Fragua, El Perro;
8: La Chora;
9: La trecha, Covacho de las Arenillas, Los Gitanos, Abrigo de El Craneo;
10: Pico Ramos;
11: Santimamine, Kobaederra;
12: Herriko Barra; 13: J3

Figure C5-8: The location of the Spanish sites detailed in table C5-2. After Guttierez-Zugasti (2011a; 2011b); Clarke (1983); Alvarez-Fernandez (2011; 2015); García-Escárzaga *et al*, (2017).

where ceramics and domesticates might not be expected, is difficult to assess. The evidence for ceramics pre-dates that for domesticates by around 700 years (Zilhao, 2004). It is possible that a complex transition was occurring and a period of ceramically enabled hunter-gatherers, as observed in Denmark, cannot be ruled out; and neither can a ‘negotiated transition’ *sensu* Gron and Sorensen (2018).

Table C5-2: Sites from Spain that have been selected for consideration in chapters 7 and 8. Data from the sources provided at site level in the detailed faunal tables and date tables in SI-Chapter5-1. 1= All phases selected for analysis. 2= Goose barnacle and crab. 3=Crab only. 4= Goose barnacle only. Key as per table C5-1.

Sub-region	**Site**	**PD Range All Phases^1**	**Phasing**	**TM**	**M. Mam**	**TB**	**MB**	**MF**	**A/C**	**Crust.**	**M. Mol**	**Biometrics**
Spain	Cuetu la Hoz	Mesolithic	N								Y	
Spain	Cuevas del Mar 3	Mesolithic	N								Y	
Spain	Columba	Mesolithic	N								Y	
Spain	Poza ÍEgua	7,785-7,457	Y								Y	Y
Spain	La Riera	9,119-4,998	Y	Y					Y		Y	Y
Spain	Les Pedroses	5,300-4408	N								Y	
Spain	Alloru	7,456-6,721	Y								Y	
Spain	Covajorno	Mesolithic	N								Y	
Spain	El Aguila	Mesolithic	N								Y	
Spain	La Arenillas	5.339-4,979	Y								Y	
Spain	Los Canes	6,211-4,546	Y								Y	
Spain	Pendueles	Mesolithic	N								Y	
Spain	El Toralete	Mesolithic	N								Y	
Spain	Mazaculos II	9,303-3,635	Y	Y				Y		Y^2	Y	Y
Spain	El Pindel	Mesolithic	N								Y	
Spain	La Garma A	7,503-5,661	Y								Y	Y
Spain	El Truchiro	Mesolithic	Y								Y	
Spain	La Garma B	Mesolithic	Y								Y	
Spain	El Mar	Mesolithic	N								Y	
Spain	Cuesta de la Encina B	Mesolithic	Y								Y	
Spain	La Chora	5,486-5080	Y							Y^3	Y	Y
Spain	La Fragua	6,491-5,365	Y							Y^2	Y	Y
Spain	El Perro	8,771-8,277	Y								Y	
Spain	La trecha	6,286-3,794	Y							Y^2	Y	Y
Spain	Covacho de las Arenillas	Transition	Y							Y^2	Y	Y
Spain	Abrigo de El Craneo	Mesolithic	N								Y	
Spain	Los Gitanos	4,964-2,584	Y							Y^2	Y	Y
Spain	Pico Ramos	5,207-4,057	Y	Y			Y	Y			Y	
Spain	Santimamine	6,568-4081	Y							Y^3	Y	Y
Spain	Kobaederra	5,313-3,711	Y								Y	Y
Spain	Marizulo	4,346-3,816	Y								Y	
Spain	J3	Mesolithic	Y								Y	
Spain	Herriko Barra	5,205-3,519	Y			Y	Y				?	
Spain	Colombres	Mesolithic	Y	Y							Y	
Spain	Cuento de la Mina	Mesolithic	Y	Y						Y^4	Y	
Spain	Coberizas (Cueva Sabina)	6,503-5,839	Y	Y							Y	
Spain	Balmori	Mesolithic	Y	Y				P			Y	
Spain	Bricia	6,220-5,625	Y	Y				P			Y	
Spain	Penicial	8,532-7,591	Y	Y				Y			Y	
Spain	Fonfria	Mesolithic								Y^4	Y	
Spain	La Llana	Mesolithic	Y							Y^2	Y	Y
Spain	El Mazo	7,061-6,713	Y								Y	
Spain	La Lloseta	4,981-1,637	Y							Y^4	Y	

5.3.3 Atlantic France (Brittany)

As with the two sub-regions considered so far, the archaeology of France exhibits great time depth, but in contrast to Iberia the record pertaining to the exploitation of marine resources is limited to the Holocene and consists of just five Mesolithic sites on the coast of Brittany (Dupont *et al*, 2007; 2009). A number of early Neolithic middens are also known and some of these attest the continuing exploitation of marine resources (Dupont *et al,* 2007). A key point regarding northern France is that during the Pleistocene there is a much greater focus on species adapted to the cold such as bison and reindeer during the glacial and therefore the hunter-gatherers of the region had to adapt to the pursuit of the temperate species as these emerged from southern refugia with the northward spread of woodland. Those sites with the potential to support the aims of the project are presented in table C5-3 and their location defined in figure C5-9. Data relating to a wider range of sites and additional information regarding the sites presented in table C5-3 is available in SI-Chapter5-1. Modern SST are provided in figure C5-7.

The evidence for a Mesolithic coastal occupation is sparse with only four Mesolithic middens and one other site of two phases with shell deposits (locations shown in figure C5-9). The Mesolithic sites also include a number of Mesolithic human burials. The faunal evidence is not available with any real stratigraphic granularity. Mammalian remains are very sparse at all sites, but include wild boar, aurochs, red deer and roe deer in all the middens, and grey seal (*Halichoerus grypus*) is present in two of the middens (SI-chapter5-1). The quantification of bird remains is restricted to two of the middens and exhibits an interesting mix between the typical seabirds found at more northern sites, as well as geese and ducks, and terrestrial birds such as woodcock (*Scolopax rusticola*). The largest avian assemblage is from one of the Neolithic sites and the taxonomic composition is very different, being dominated by the cormorant family, which are absent during the Mesolithic (Tresset, 2005).

Fishing appears to be focused on sea bream with the presence of tope, thornback ray (*Raja clavata*), hake (*Merluccius merluccius*) and pout (*Trisopterus spp.*) also noted. At Beg-an-Dorchenn sharks and rays are most numerous followed by wrasse and then the sea breams. Crustaceans in the form of crabs are present in all the middens with four species confirmed as present. The quantities of crab present at Beg-an-Dorchenn are quite significant when compared to the Mesolithic of northern Spain (Dupont *et al*, 2010; Álvarez-Fernández, 2011; Gutierrez-Zugasti, 2011b). The edible crabs (*Cancer paguras*) at Beg-an-Dorchenn are large with an average carapace width of 136.7mm (Dupont *et al*, 2010).

The middens of Brittany provide assemblages that are an interesting mix of the species that are encountered Spain and Portugal and those encountered further north. The evidence for fishing is stronger in Brittany than further south but still the NISP counts and number of bone fragments in general are very low compared to more northerly middens. This is also the first sub-region in which evidence for the exploitation of sea mammals is more than tenuous and the evidence for terrestrial mammal exploitation is subdued.

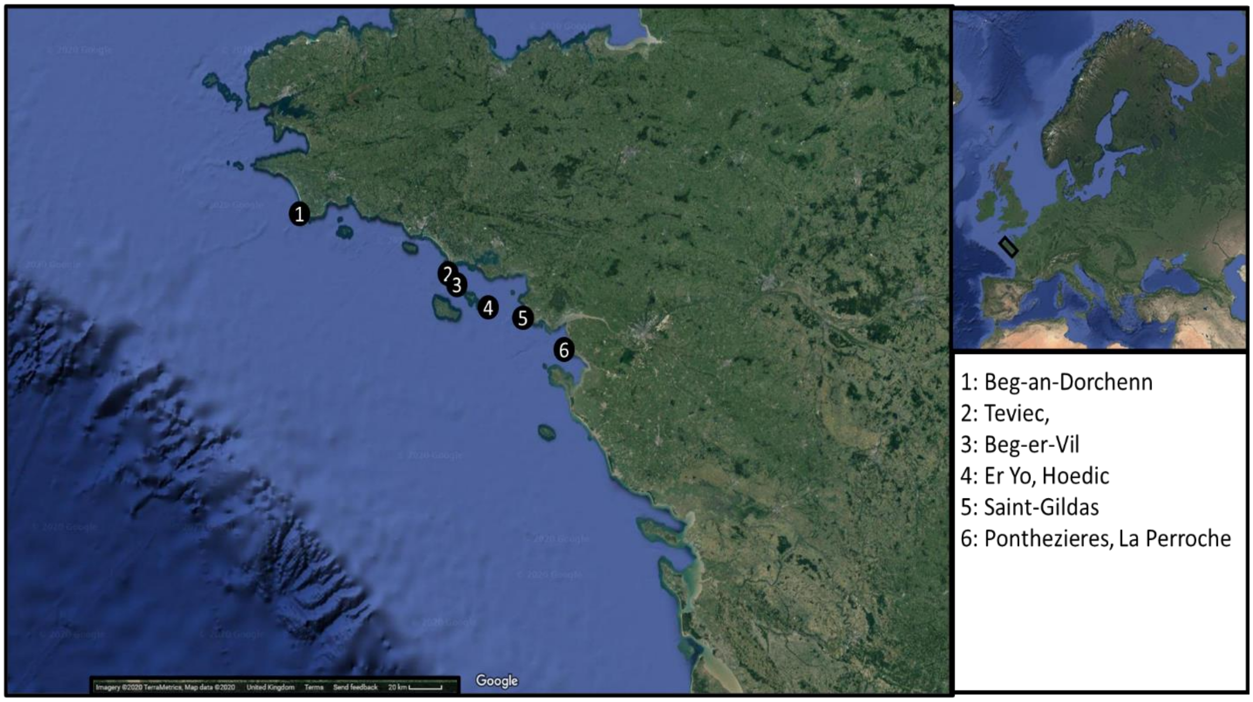

Figure C5-9: The location of the sites detailed in table C5-3. After Dupont *et al* (2009); Dupont and Marchand (2008).

Table C5-3: Sites from France that have been selected for consideration in chapters 7 and 8. Data from the sources provided at site level in the detailed faunal tables and date tables in SI-Chapter5-1. 2= For crabs only. Key as per table C5-1.

Sub-region	**Site**	**PD Range All Phases**^{1}	**Phasing**	**TM**	**M. Mam**	**TB**	**MB**	**MF**	**A/C**	**Crust.**	**M. Mol**	**Biometrics**
Brittany	Saint-Gildas IB	7,046-5,981	N								Y	
Brittany	Saint-Gildas IC	5,801-5,381	N								Y	
Brittany	Beg-an-Dorchenn	6,572-3,380	Y^3	Y			Y	Y		Y	Y	Y^2
Brittany	Hoedic	6,218-3,646	N	P				P		P	Y	
Brittany	Teviec	5,704-4,344	N	P	P	Y	Y	P		P	Y	
Brittany	Beg-er-Vil	6,410-4,528	N	P	P	Y	Y	P		P	Y	
Brittany	Er Yol	2,924-1,262	Y		P	Y	Y				P	
Brittany	Ponthezieres	Neolithic						P		P	Y	
Brittany	La Perroche	Neolithic			P			P			Y	

5.3.4 Atlantic England and Wales

Whilst the archaeological record of England and Wales covers the lower palaeolithic and the later middle palaeolithic, occupation is only evidenced during the inter-glacials (White and Pettitt, 2012, pp.284; pp.381-382). During the glacials and the majority of MIS3 (which barely qualifies as an inter-glacial) the evidence for occupation varies between ephemeral and non-existent. The record for the late Pleistocene is likewise very sparse and for a period of at least 10,000 years, non-existent (ibid, pp.424-426). It is possible that the occupation of what at this time was the north western plateaux of Europe may have been confined to seasonal hunting trips (Pettitt, 2014; Pettitt and White, 2012, pp.430-440). Therefore, this sub-region is the first encountered that required recolonisation by humans and fauna red deer, roe deer, wild boar, aurochs and mountain hare (*Lepus timidus*) adapted to temperate climates. The earliest evidence for red deer and mountain hare being 10,850-13,050 cal BC, which is coincident with the last woolly mammoth (ibid, p.431). It should also be noted that freshwater fish also had to recolonise England and Wales, although initial colonisation was constrained to catadromous and anadromous species such as eel, salmon, sea trout (*Salmo trutta*), shad (*Alosa spp*.), and arctic char (*Salvelinus alpinus*). Relic, and now land locked, populations of the latter exist today in isolated mountain lakes in Wales and the Lake District.

The archaeological record for coastal occupation during the Mesolithic is sparse. Only four shell-middens sites are known, Culverwell, Westward Ho! (that has been intertidal for several decades), which is also notable for circles and lines of pointed wooden stakes (Churchill, 1965, pp.74-75). In North Wales, shell-middens are known but these yield little faunal information. One deposit at Snail Cave is highly turbated and faunal remains cannot be attributed to either the Mesolithic or Neolithic, other than with two exceptions. One duck is directly dated to the Mesolithic and the other, a roe deer, directly dated to the late 4th millennium to early 3rd millennium BC and therefore clearly Neolithic. There is a coastal site

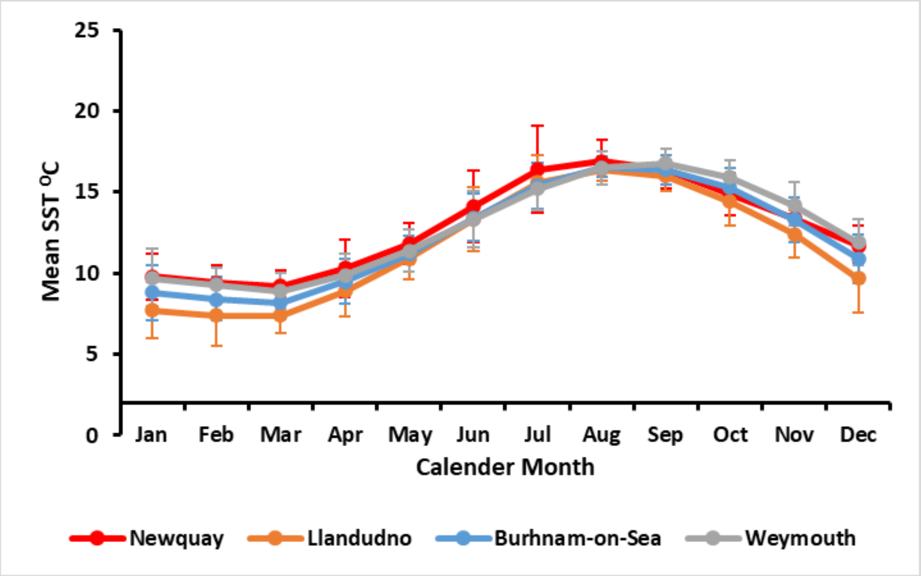

Figure C5-10: Modern SST at Newquay (50.42°N) on Atlantic Cornwall; Burham-on-Sea (51.24°N) in the Bristol Channel; Weymouth on the Channel coast (50.61°N) and Llandudno (eastern Irish Sea (53.32°N). Error bars reflect maximum and minimum monthly averages. Data from Seatemperature.org at Goldcliffe but it lacks a mollusc assemblage. The sites at Nant Hall Road clearly show a switch from epifaunal gastropods and bivalves supported by small amounts of cockle during the Mesolithic, to Neolithic middens that are just about 100% cockle. The location of the sites is provided in figure C5-11 and the modern SST data is provided figure C5-10. The data available from these sites, presented in SI-chapter5-1 along with the detailed PDs for the sites. Table C5-4 details those sites with potential within the project. The stable isotope data from coastal locations within this sub-region is unsurprisingly limited but data from South Wales suggests between 55 and 65% marine protein intake (Schulting and Richards, 2002). The major environmental indicator identified for this region is the thick top shell which is present at Culverwell. A final point is that the literature does not suggest any meaningful impact from the Storegga Slide. Hill *et al* (2014) suggest a run up height of 1 m or less for Atlantic Cornwall and Devon, with the majority of the Irish Sea experiencing none.

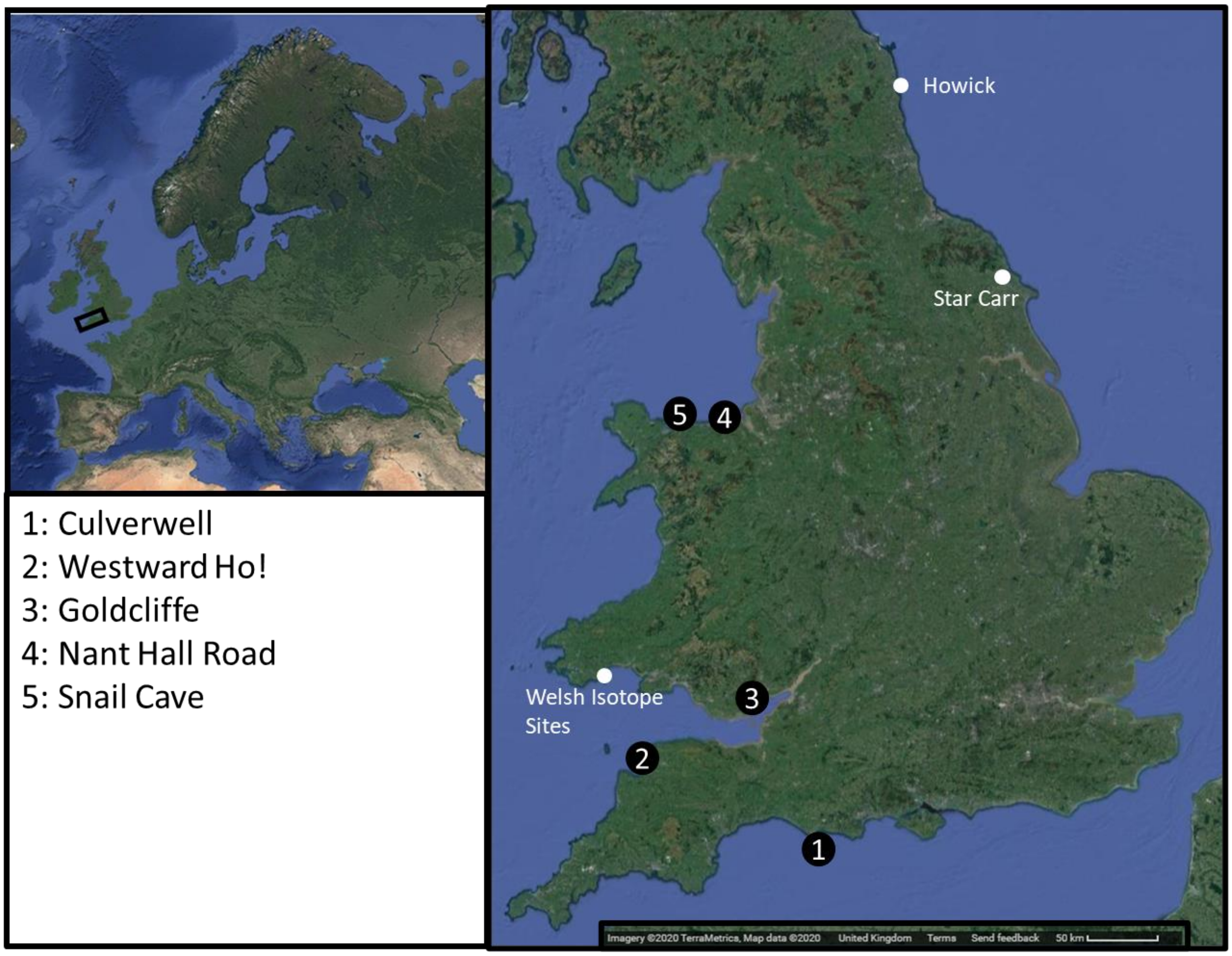

Figure C5-11: The location of the sites detailed in table C5-4 and referred to in subsequent chapters. The locations of Star Carr and Howick are provided for spatial reference only. After Mannino and Thomas 2001; Churchill, 1965; Schulting and Richards, 2002; Milner *et al* (2018, Eds); Waddington *et al*, (2003); Bell, (2007, Ed.); Smith *et al* (2014).

Table C5-4: Sites from England and Wales that have been selected for consideration in chapters 7 and 8. Data from the sources provided at site level in the detailed faunal tables and date tables in SI-Chapter5-1. 2= Identification issues, 3= Includes domesticates. Key as per table C5-1.

Sub-region	Site	PD Range All Phases[1]	Phasing	TM	M. Mam	TB	MB	MF	A/C	Crust.	M. Mol	Biometrics
England and Wales	Culver Island	6,240-4,788	Y	Y							Y	Y
England and Wales	Westward Ho!	7,533-4794	Y	Y[2]							P	
England and Wales	Goldcliff East	5,605-5,316	N	Y				Y	Y			
England and Wales	Nant Hall Road B and C	3,942-3,363	Y	Y[3]							Y	
England and Wales	Nant Hall Road C - F	4,546-3,702	Y	Y							Y	

5.3.5 The Island of Ireland (Ireland henceforth)

There are over 200 shell-middens in Ireland, but the vast majority are not from the Mesolithic period Milner and Woodman (2007). Large oyster middens are known whose dimensions rival those known in Denmark and parts of eastern Scotland, and such middens have often accumulated over extended periods of time and multiple archaeological periods (cf. Sloan, 1993; Milner and Woodman, 2007). The location of the sites reviewed is provided in figure C5-13; the sites offering potential are detailed in table C5-5. Data regarding the sites evaluated and more detail on the selected sites is provided in SI-Chapter5-1. Modern SST data is provided in figure C5-12. The record from the Atlantic coastline is limited to two sites, one of which has yet to be formally published.

Ireland continues to catalyse debate, and often confusion and opacity, regarding the configuration of the ecosystem during the late glacial and early Holocene. This is exemplified by the closely related matters the first of which is the physical connection of the Island to the rest of Europe. Such a connection would have been with Britain which remained connected to Europe until sometime in the 7th millennium BC. The evidence for a late Pleistocene occupation provided by brown bear (*Ursus arctos*) the matter of when humans first visited Ireland is not as open ended as it used to be (Dowd and Carden, 2016), although when substantial residency commenced is. Why is there little or no evidence for species of such economic importance elsewhere such as red deer, roe deer and aurochs (Woodman *et al*, 1997; Edwards and Bradley, 2009) remains unresolved. A key point is therefore the question of when Ireland was last physically linked to Britain and what form did the final connection take. Whilst consensus has grown that there was no land bridge to Ireland after 16,000 years ago (cf. Edwards and Brookes, 2008), this does leave unanswered the question of how mammals such as wild boar and other temperate species either reached Ireland or, having colonised during the Allerod-Bolling inter-stadial, survived the younger dryas. Likewise, the question of why deer and wild cattle did not, looms large (cf. Warren *et al*, 2014). Based upon the evidence from Iberia already presented, deer should have been more suited to surviving the stadial than wild boar. The above matters have been debated widely (Woodman, 1997; 2003; 2004a; Edwards and Bradley, 2009; Edwards and Brookes, 2008; Devoy, 1985; Warren *et al*, 2014) but a satisfactory outcome is still pending. Assuming an impoverished terrestrial mammal fauna, the role of terrestrial mammals in anthropogenic deposits can be expected to deviate from that observed in other sub-regions, which of course has implications for the economy and technocomplex.

The available record is poor in terms of the available faunal data with only two sites, Ferreter's Cove and Mount Sandel, providing welcome exceptions. These two sites do however pose some methodological challenges. Firstly, at Ferriter's Cove the definition of hunter gatherers developed in chapter 2 is breached. The isotopes from human skeletons are consistent with a significant exploitation of marine protein in the diet (*circa* ð^{13}C 14$^{0}/_{00}$) (Schulting, 1999), which is supported by a reasonably sized assemblage of marine fish (McCarthy, 1999), a substantial assemblage of marine molluscs, and a very small assemblage of seabirds. Within the limits of calibrated the PDs the humans, molluscs, charcoal and terrestrial mammals are all roughly contemporary, with some spatial clustering. This is an interesting observation as these PDs include that from a specimen of domestic cattle (*Bos taurus*) (ibid) and polished stone axes are also present (Mandal, 1999). The challenge with Mount Sandel is that it is not coastal.

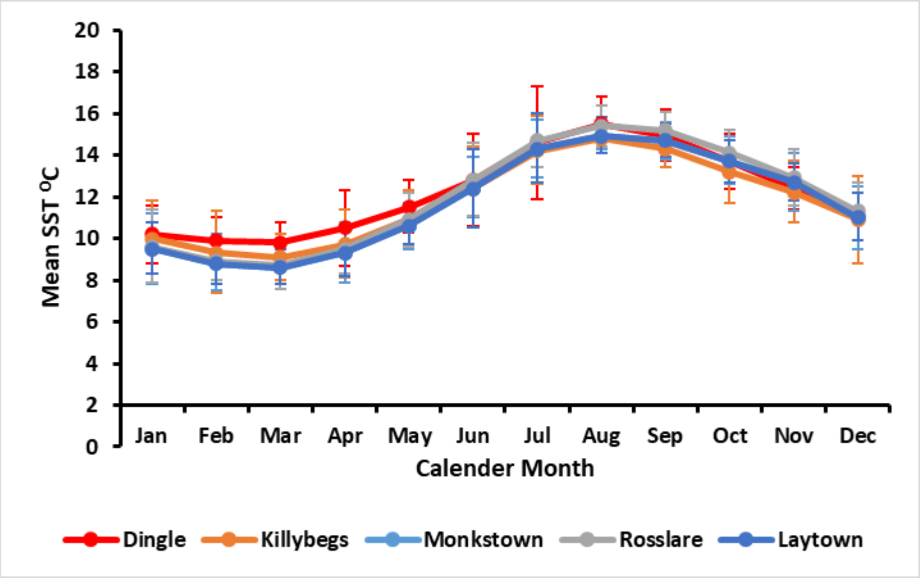

Figure C5-12: Modern SST at Dingle (52.14^{O}N); Killybegs (54.63^{O}N); Monkstown (52.29^{O}N) Rosslare (52.25^{O}N) and Laytown (53.68^{O}N). Error bars reflect maximum and minimum monthly averages. Data from Seatemperature.org

Mount Sandel is a very famous site offering a wealth of archaeological features and material that need not be reprised here (see Woodman, 1985 (ed)). The key point is that the site is quite early (late 9th millennium to mid-8th millennium BC), and it was not in the immediate coastal zone, yet was closer to the contemporary coastline than some Iberian midden sites (Hamilton, 1985; Bailey and Craighead, 2003, figure 3, p.183; Alvarez-Fernandez, 2015). Faunal exploitation focused on catadromous and anadromous fish, plus marine fish species tolerant of low salinity; the bird assemblage is terrestrial and includes woodcock, capercaillie (*Tetrao urogallus*) and some ducks. There is a prominent role for terrestrial mammals (in wild boar and mountain hare). This combination has been encountered already in the middens of Portugal. There is one marked difference between Mount Sandel and the Iberian sites and that is the former lacks marine molluscs or other marine resources such as crustaceans. Based upon the Sado and Muge middens and the sites of La Chora and Los Canes, the biotope should have provided at least marine bivalves, if not within the immediate vicinity of the site, a relatively short distance downstream (Hamilton, 1999; Battarbee *et al*, 1999).

One final point that should be made is that Ireland is the first sub-region where a material manifestation of the Storegga Slide tsunami is asserted (Long *et al*, 2016; Hill *et al*, 2014) with a predicted run up height of 5m on the Atlantic coast (Hill *et al*, 2014). As with parts Western Scotland any tsunami deposits or anomalies will be submerged due to eustatic sea-level rise as asserted for western Scotland by Selby and Smith (2016).

Figure C5-13: The location of the sites referred to in table C5-5. White circles denote sites that are outside the definition of Atlantic Europe but are of contextual interest in subsequent chapters. After Milner and Woodman (2007); Lynch, 2017; Woodman (1985, Ed.); Woodman *et al*, (1999, Eds.) ; Moore, (2003); Liversage *et al* (1967/1968).

Table C5-5: Sites from Ireland that have been selected for consideration in chapters 7 and 8. Data from the sources provided at site level in the detailed faunal tables and date tables in SI-Chapter5-1. 2=Domesticates present. Key as per table C5-1.

Sub-region	Site	Calibrated BC Date Range All Phases[1]	Phasing	TM	M. Mam	TB	MB	MF	A/C	Crust.	M. Mol	Biometrics
Ireland (island of)	Dalkey Island V	4,653-3,714	N	P	P						P	
Ireland (island of)	Dalkey Island II	5,977-5626	N	P	P	P	P	P			Y	
Ireland (island of)	Rockmarshal	4,681-4043	Y	P	P					P	Y	
Ireland (island of)	Baylet	5,486-4,368	Y								Y	
Ireland (island of)	Rough Island	Ceramics	N								Y	
Ireland (island of)	Ferriter's Cove Central	5,056-4,004	Y	Y[2]			P	Y	Y		Y	Y
Ireland (island of)	Ferriter's Cove North	4,717-3715	Y	Y			P	Y			Y	Y
Ireland (island of)	Ferriter's Cove South	5,486-4,235	Y	Y[2]			P	Y			Y	Y
Ireland (island of)	Fanore More Site 1	4,246-3,617	?								Y	
Ireland (island of)	Fanore More Site 2	4,869-4425	?					P		P	Y	
Ireland (island of)	Mount Sandel	8,611-6,485	Y	Y		Y		Y	Y			

5.3.6 Atlantic Scotland

The Mesolithic record in Scotland is extensive and there is some, albeit limited, evidence for late glacial occupation or at least forays into the sub-region (Mithen *et al*, 2015). In Iberia and Brittany, rises in relative sea level can be attributed to eustatic rises due to the absence of or negligible isostatic readjustment. In England, Wales and southern Ireland such changes can be attributed to a combination of eustatic rises in combination with negative isostatic adjustment. Scotland provides a far more variable picture since along with the northern half of Ireland, it was subsumed by the glacial ice sheets (Svendsen *et al*, 2015; Ballantyne and Small, 2019). In certain areas of Scotland relative sea-level change has been entirely due to eustatic change, but in many areas the isostatic readjustment has been strongly positive or negative (Richie, 1985, Smith *et al*, 2012; 2017, Selby and Smith, 2016; Shennan and Horton, 2002; Sturt *et al*, 2013). Clearly this means that the chronology of the archaeologically visible sites will be correspondingly variable.

The Scottish Mesolithic has become synonymous with shell-middens yet they constitute a very small percentage of the hundreds of known Mesolithic sites, which are usually in the form of lithic scatters (Wickham-Jones, 2009). There is also a distinct contrast between the middens on the North Sea coast and those of the Atlantic façade. Many of the North Sea middens are extremely large being hundreds of meters long and containing millions of shells (usually oysters). These middens also tend to be late in date and whilst accumulation may have commenced during the terminal Mesolithic, as in Ireland it continued during later periods (Sloan, 1993). As with other sub-regions many middens were investigated decades ago in the absence of modern excavation and post-excavation rigour; unfortunately, only material culture has been retained in the archives and in some instances these have gone missing. Table C5-6 provides the list of sites that will be pursued further and more detail on all the

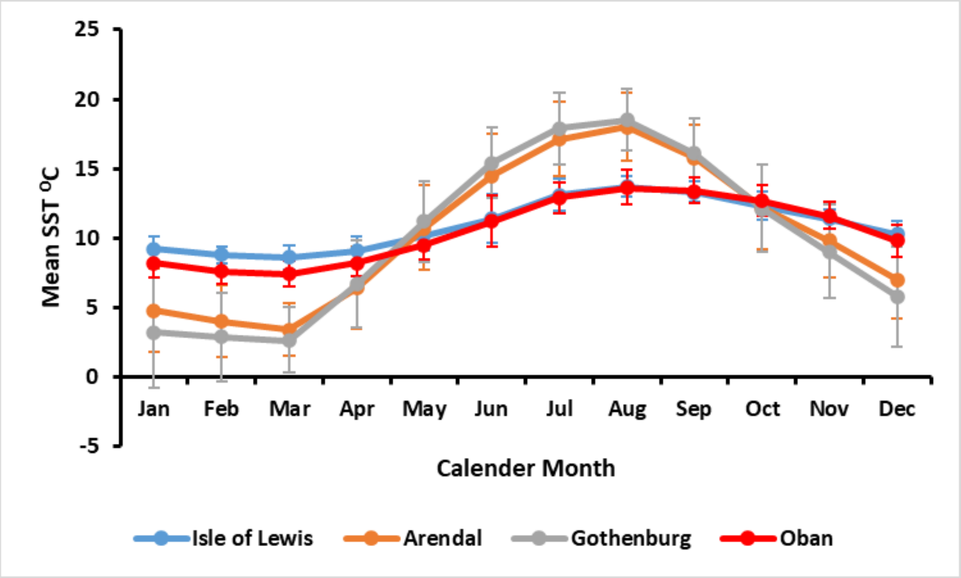

Figure C5-14: Modern SST for north western Scotland. Isle of Lewis 58.52⁰N; Oban 56.42⁰N; Arendal (Norway) 58.46⁰N and Gothenburg (Sweden) 57.71⁰N. Error bars depict maximum and minimum monthly means. Data from Seatemperature.org.

sites reviewed is provided in SI-Chapter5-1. One site Port Lobh has been excluded from further consideration due to a number of issues with the publication (SI-Chapter5-2).

The location of the sites is provided in figure C5-15. Modern SST data is provided in figure C5-14 which clearly indicates how moderated the winter climate is and how constrained the summer climate is. The summer temperatures today make oyster spawning marginal (chapters 7 and 8). The middens of Atlantic Scotland tend to be smaller and dominated by limpets, generally there is also a paucity of material culture and terrestrial mammal remains (Kitchener *et al*, 2004). This viewpoint is inherently biased, not by the researchers, but by diagenesis as the only scenarios in which bone survives is in middens where the marine shells buffer against the acidic soils. Scotland was without doubt disrupted by the Storegga slide with run up heights varying between 3m and 20m (Long *et al*, 2016; Hill *et al*, 2014; Bondevik *et al*, 2005).

Figure C5-15: The location of the sites detailed in table C5-6. After Mellars (1987, Ed); Mithen, (2015); Sloan, (1993); Finlay *et al*, (2019); Russell *et al*, (1995); Hardy and Wickham Jones (2009, Eds.); Saville *et al*, (2012, Eds.); Gregory *et al*, 2005; Wickham-Jones (1990); Connock *et al* (1991-1992); Ashmore and Hall (1997); Myers and Gaurlay (1991).

Table C5-6: Sites from Scotland that have been selected for consideration in chapters 7 and 8. Data from the sources provided at site level in the detailed faunal tables and date tables in SI-Chapter5-1. 2=For Pollachius spp. only, 3=Domesticates present. Key as per table C5-1.

Sub-region	Site	PD Range All Phases[1]	Phasing	TM	M. Mam	TB	MB	MF	A/C	Crust.	M. Mol	Biometrics
Scotland	Risga	5,207-4,555	N	P	P	P	P	P		P	P	
Scotland	Tarradale	6,632-6,005	?								Y	
Scotland	An Corran	6,608-4,229	Y	Y			Y	Y	Y		Y	Y
Scotland	Sand Rock Shelter	7,029-5,221	Y	Y	Y		Y	Y		Y	Y	Y
Scotland	Ulva Cave	6,966-3,657	Y	P				P		Y	Y	Y
Scotland	Carding Mill Bay	4,237-3,372	N	P			P	P	P		P	
Scotland	Macarthur Cave (Lower)	5,728-5,488	N	P		P		P		P	P	
Scotland	Druimvargie	7,570-6,467	N	P		P		?		P	Y	
Scotland	Raschoille	6,648-3,372	Y							P	Y	
Scotland	Morton A	7,522-4,856	N									
Scotland	Morton B	5,606-3,798	N	Y			Y	Y	Y	Y	Y	
Scotland	Cnoc Sligeach	6,075-3,820	Y	Y	Y			Y		?	Y	Y[2]
Scotland	Cnoc Coig	6,527-3,933	Y	Y	Y	Y	Y	Y		Y	Y	Y
Scotland	Caisteal nan Gillean	5,321-4,081	Y	Y	Y			Y		Y	Y	
Scotland	Caisteal nan Gillean II	5,211-3,022	Y	Y	Y			Y		Y	Y	Y[2]
Scotland	Priory Midden	4,881-4,235	Y	Y	Y			Y		Y	Y	Y[2]
Scotland	Inveravon	Multi	Y							Y	Y	
Scotland	Nether Kinneil	Neolithic	Y	Y[3]							Y	Y
Scotland	Brachead	Mesolithic	N								Y	
Scotland	Mumrills	Mesolithic	N								Y	
Scotland	Polmonthill										Y	
Scotland	Muirtown Inverness	4,337-4,045	N								Y	
Scotland	Castle Street Inverness	6,606-5,711	N									
Scotland	Northton	Chapter 6	Y									
Scotland	Teampuil an Bagh	Chapter 6	Y									
Scotland	Traigh na Beirigh 1	Chapter 6	Y									
Scotland	Traigh na Beirigh 2	Chapter 6	Y									
Scotland	Traigh na Beirigh 9	Chapter 6	Y									
Scotland	Pabaigh Mor South	Chapter 6	N									
Scotland	West Voe I	Chapter 6	Y									

5.1.1 Atlantic Norway

One remarkable fact regarding Norway is now soon people colonised arctic Norway (Bjerck, 2007; Blankholm, 2004) presumably utilising the ice free 'marine' channel that opened up prior to the Younger Dryas stadial (Svendsen *et al*, 2015). Almost certainly the easiest way to travel in an environment dominated by deep fjords was by boat as suggested by Bjerck (2016). The colonisation has been hypothesised as being facilitated by the development of a productive marine ecosystem, although no sites containing faunal remains are available in the early Mesolithic (Bjerck, 2007; 2016). It is noted that the earliest colonists' material culture is rooted in the Late Pleistocene Ahrensburg culture of the northern European plain (ibid). It cannot be ruled out that whilst these colonists may have realised that the easiest way to travel was by boat, they may have been tracking the terrestrial mammals that were retreating northwards in response to the Holocene amelioration. Given the amount of fresh melt water that would be entering the coastal area at this point, factors such as salinity and temperature must have resulted in a marine ecosystem, in terms of fish and invertebrates, very different in composition and bio productivity to that which developed later, and which are archaeologically more familiar. It should be noted that Bjerck (2016) focuses on marine mammals in his argument, but a corroborating faunal record is absent due to a lack of preservation (Bjerck, 2007).

The sites considered suitable for further analysis are detailed in table C5-7 and their location in figure C5-17. Further detail and dating for these sites and other reviewed are provided in SI-Chapter5-1. Modern SST are provided in figure C5-16 (see also figure C5-2). Compared to Ireland, England and Scotland there is a much stronger latitudinal trend within the moderated regime.

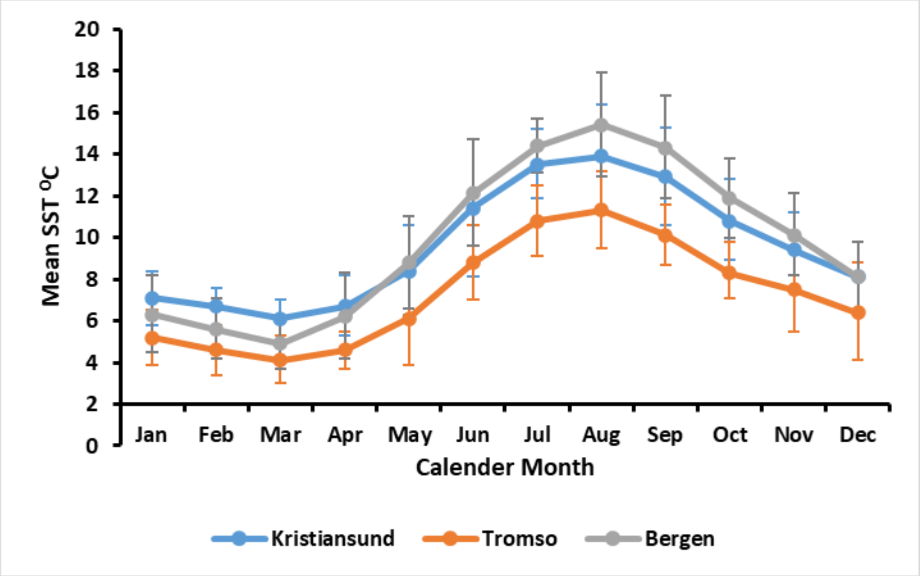

Figure C5-16: Modern SST for Atlantic Norway. Bergen (60.39^{0}N); Kristiansund (63.11^{0}N) and Tromso (69.65^{0}N). Error bars depict maximum and minimum monthly means. Data from Seatemperature.org.

The number of sites is small due to very poor preservation, but some interesting features are present such as the increase in marine mammal exploitation in the Neolithic compared to the

Mesolithic. In general, however terrestrial resources are exploited extensively. This part of Norway also experienced the direct influence of the Storegga Slide and hence can contribute valuable information.

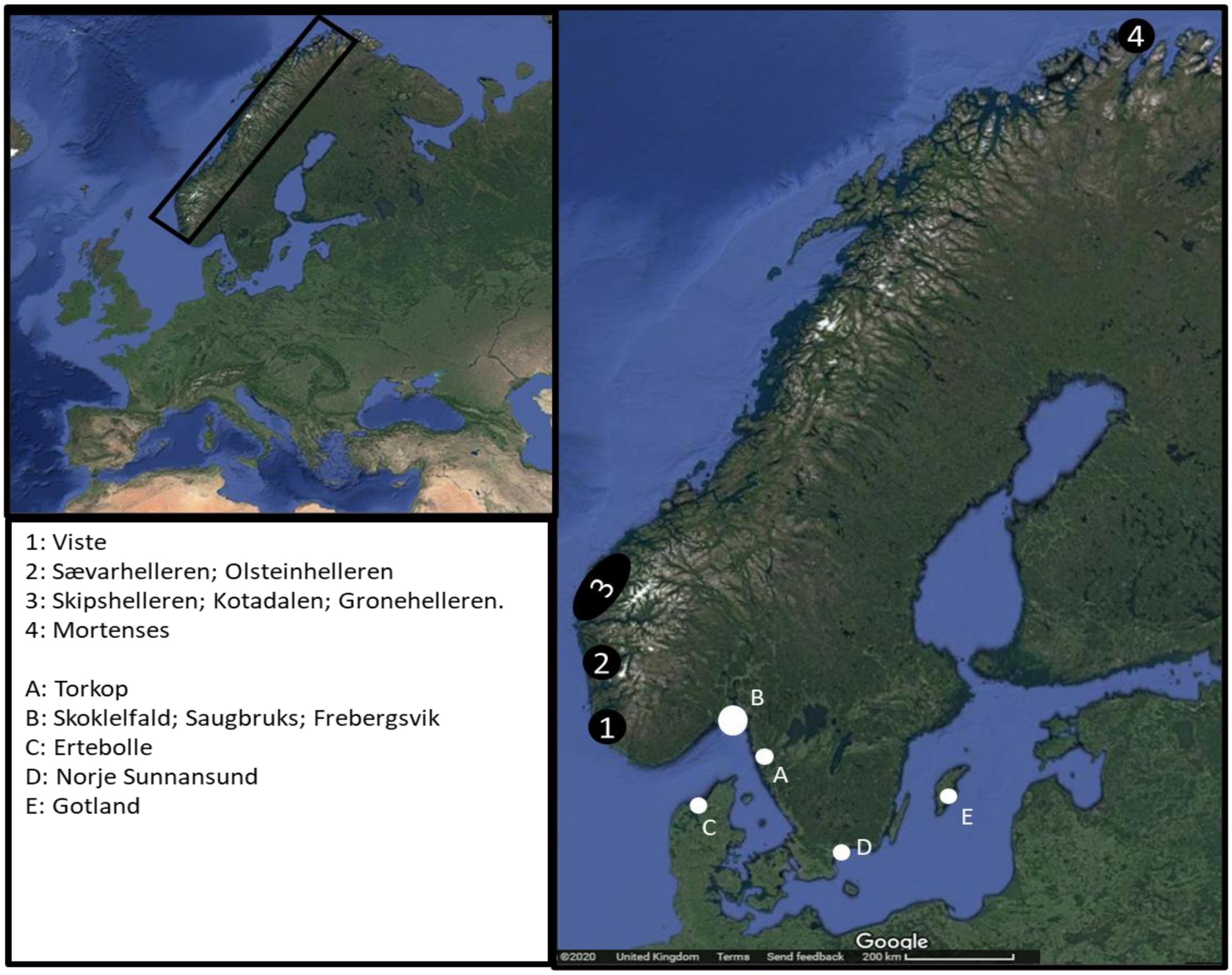

Figure C5-17: The location of the sites detailed in table C5-6. After Bjerck (2007); Boethius (2017); Boethius *et al* (2017); Richie *et al*, 2016. The white markers show the position of other important sites referred to in this or other chapters.

Table C5-7: Sites from Norway that have been selected for consideration in chapters 7 and 8. Data from the sources provided at site level in the detailed faunal tables and date tables in SI-Chapter5-1. Key as per table C5-1.

Sub-region	Site	PD Range All Phases[1]	Phasing	TM	M. Mam	TB	MB	MF	A/C	Crust.	M. Mol	Biometrics
Norway	Sævarhelleren	7,035-5,846	Y	Y				Y	Y		Y	
Norway	Olsteinhelleren	5,621-4,705	Y	Y			Y	Y	Y		Y	
Norway	Gronehelleren		Y	Y	Y			Y			P	
Norway	Kotadalen	6,500-2,900	Y	Y	Y	Y	Y	Y	Y			
Norway	Skipshelleren	5,626-4,690	Y	Y				Y	Y		Y	
Norway	Viste	6,840-5020	Y	Y	Y						Y	
Norway	Mortenses	4,900-4,400	Y	Y	Y		Y	Y			P	

5.4 Summary of Results

The review permits a number of key observations to be made in regard to Atlantic Europe. The marine environment is highly moderated at all latitudes from 37^0N to 70^0N suggesting that the whole of Atlantic Europe should be sensitive to fluctuations in the moderating influences associated with major events such as the 8.2K cal bp cooling event as discussed in chapter 7, with greater sensitivity anticipated in the north. The north is where the consequences of the Storegga Slide tsunami should also be more visible. The exploitation of marine resources also appears to increase with latitude, but this might be an artefact of site visibility due to RSL. Other specific points are:

1) There is evidence for temporal variation in resource exploitation.
2) Three of the individuals from Oronsay have isotope results that are outliers within Atlantic Europe, including those presented from Wales by Schulting (2009).
3) Throughout most of the Atlantic façade terrestrial resources are exploited and within the ±10% error margin associated with dietary proportion calculations any short term or episodic shortfall in marine resource availability, or productivity, can be buffered by terrestrial resources.
4) The exception to 3) above are the remote Scottish archipelagos. Unfortunately, there is no faunal data from the Isle of Man or Orkney.

Adjustments to short term and smaller amplitude fluctuations in marine resources are therefore most likely to be visible in the remote Scottish archipelagos, as buffering with terrestrial resources is either not possible or more difficult. The pursuit of this project's objectives in chapter 8 will focus on the assemblages from the remote islands.

6 The Zooarchaeology of the Remote Scottish Islands.

6.1 Introduction

This chapter will present the zooarchaeological analysis of several sites excavated in the Western Isles between 2010 and 2013 by a team from Durham University led by Prof. Mike Church, plus a further site excavated in Shetland between 2001 and 2005 by a team led by Dr. Nigel Melton of Bradford University. The mollusc assemblage from one of the sites has been previously analysed by the author (Evans, 2015), whilst the avian and mammalian bone assemblages from two of the sites were previously considered by the author (Evans, 2016). This project has reassessed the assemblages and results from the above outputs. Whilst the headline compositions provided by Evans (2015; 2016) remain basically unaltered some nuanced differences exist, and certain biometric models have been refined. A project was instigated to formally publish West Voe and the archived reports, drawings and assemblages became available to the author for a short period. It turned out, that mollusc assemblage still needed to be analysed and published (Evans, forthcoming). This analysis took place in two stints, one in June and one in October 2018 using the already sorted material from the 4R fraction within the archive.

This chapter has three objectives. The first is to describe the use of faunal resources during the Mesolithic and how this varied both spatially and temporally. The second is to generate the datasets that can inform the wider regional investigation of environmental change dealt with in chapters 7 and 8. In achieving the first two objectives a third objective must be met which is to develop the framework and techniques that will implement the strategies defined in chapter 4, thus permitting research questions to be articulated in a manner the assemblages may be able to answer and generally improve information yields.

6.2 Environment and Environmental History

Five of the sites are on the mainland of the Isle of Lewis within the Western Isles archipelago, one is on a near shore island adjacent to the Isle of Lewis and one is on the Mainland within the Shetland archipelago. Conventionally the southern and more mountainous end of the Isle of Lewis is referred to as the Isle of Harris, but from a technical geographic standpoint only a single island land mass exists, the Isle of Lewis. The locations of the sites within the region are provided in figure C5-15. The locations of the sites within their local region are provided in figures within section 6.3. Several PDs are available for each site and these are provided in tables in section 6.3.

6.2.1 The Western Isles.

The Western Isles are an archipelago with a fundamentally north to south orientation, the most southerly major Island is Barra and the most northerly Lewis (See figure C5-15). The archipelago covers a latitudinal range from 56.7 to 58.5° north and therefore is entirely at a much higher latitude than the two societies considered in chapter 3, and therefore the annual variation in daylight hours is correspondingly greater. Today, the climate is highly moderated by the Atlantic Meridional Overturn Current (AMOC; aka the gulf stream) which delivers warm water and the cyclonic weather systems which deliver warm and wet air from the south-west. Winters are mild, with snowfall and frosts rare, the summers are relatively cool. Modern SST are provided in figure C6-1. During the late Pleistocene, the archipelago was, along with the rest of Scotland, covered by ice (Svendsen *et al*, 2015; Ballantyne, 2004; Ballantyne and Small, 2019). The area that is now the islands could be reached by terrestrial fauna or humans that traversed the ice. The other key point is that any pre-Marine Isotope Stage 2 (MIS2) archaeology will have been obliterated and any inhabitation (unikely?) during MIS2 will have occurred on the ice field.

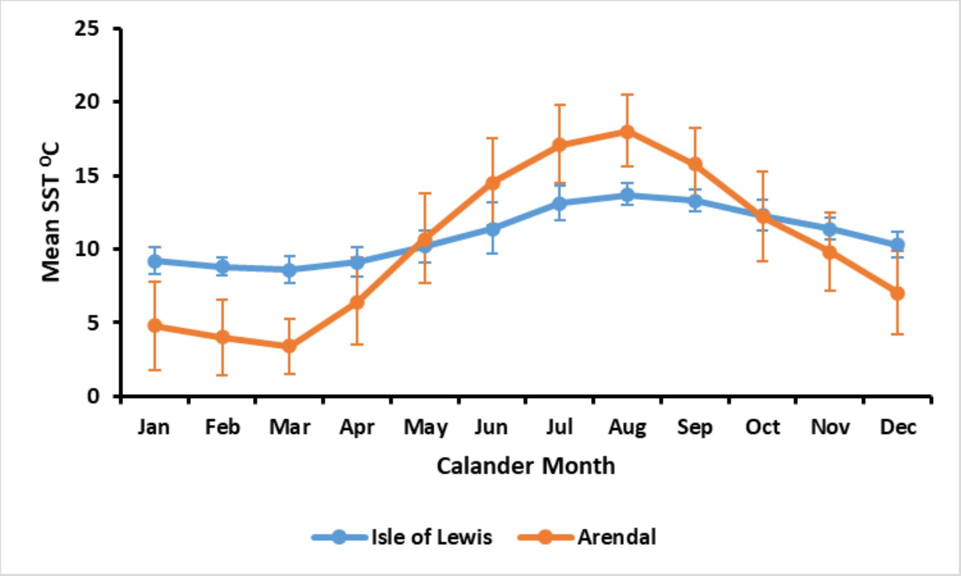

Figure C6-1: A comparison of mean sea surface temperatures between Arendal (Lat. 58.46°N) in Norway. The error bars reflect the maximum and minimum monthly averages the magnitude of which may be exceeded during short term heatwaves or cold snaps. Data from the world sea temperature organisation.

The archipelago is separated from the mainland (including the Isle of Skye) by a relatively deep channel. In the north the channel is known as the Minch, from the Isle of Skye further south the Little Minch, and yet further south, the Sea of the Hebrides separates the Western Isles from the mainland and inner islands such as Coll and Tyree. The separation is narrowest in the Little Minch. The consensus of scientific opinion is that during the period of deglaciation the archipelago was separated from the mainland as sea level rose and the Minch was inundated and that this had occurred by 16,000 cal bp (cf. Ballantyne, 2004, Ballantyne and Small, 2019, Sturt *et al*, 2013); this isolation was maintained during the Younger Dryas stadial. The change in coastline is minimal on the eastern coast due to the steep sided nature of the Minch. On the western coast the islands extended significantly to the west in the form of a low lying coastal plain; also, at this early stage (*circa* 12,000 cal BC) the archipelago was a single landmass (Ashmore, 2004; Sturt *et al*, 2013). Given this early date for separation it appears very unlikely that the mainland's terrestrial ecosystem would have developed sufficiently to permit temperate species to have made their way to the archipelago prior to it becoming physically impossible. If the Islands had any terrestrial mammals at this stage it is probable that they were relic species adapted to arctic and periglacial habitats as observed at Ulva Cave (Bonsall *et al*, 1991) and natural sub-fossils at Inchnadamph (Ashmore, 2004). On the mainland the retreat of the ice sheets resulted in areas of treeless tundra and grasslands that were inhabited by reindeer, arctic fox (*Alopex lagopus*), lemming (*Dicrostonyx torquatus*), horse and possibly (author) mountain hare (Kitchener *et al*, 2004). However, the dates given for when this environment developed appear to be too late relative to the formation of the Minch and the same can be stated in relation to any temporary colonisation of Northern Scotland by temperate species during the Allerod-Bolling interstadial. This is discussed at some length by Serjeantson (1990) who concludes the situation was exactly as described above. The Mesolithic inhabitants would therefore have been unable to exploit the usual terrestrial species: elk (*Alces alces*), red deer, roe deer wild boar without returning to the mainland. The same constraint applies to fur bearing species such as brown bear, wolf (*Canis lupus*), fox (*Vulpes vulpes*) lynx (*Lynx lynx*), pine martin (*Martes martes*) and other mustelids other than the otter (Kitchener *et al*, 2004; Serjeantson, 1990; McCormick and Buckland, 2003; Fairnell and Barrett, 2007). Temperate rodents would also have been absent. Conversely, the inhabitants (especially children) would not have faced the risks posed by the larger predatory species, or venomous snakes. The archipelago would offer any inhabitants a wealth of marine resources, including fish, crustaceans, molluscs, urchins, birds, pinnipeds, and based upon modern data trends, cetaceans as live or dead strandings (figure C6-2). Extremely large examples of the edible crab can also be encountered and the two largest specimens at the Natural History Museum are from north-west Scotland, although both are pathological.

Dinnin, (1996), discusses the terrestrial invertebrate fauna and suggests that non-flying taxa including terrestrial molluscs would have arrived as a consequence of human visits. Some wingless taxa do however exploit air dispersal, for example some spiders (araneae). Although whether the ecosystem would permit colonisation is a different question. Species reliant on the excrement of large herbivores would have encountered a challenging situation, as would species who are obligate decomposers of animal material. Colonisation by invertebrates unable to disperse by air requires further consideration. One class of invertebrates (and amphibians) that would have experienced great difficulty in crossing the Minch 'unaided' are the terrestrial molluscs such as slugs and snails (ibid). For these organisms, tens of kilometres of saltwater are a particular problem, although adhering to the legs of birds and being able to survive passage through the digestive tract of birds are strategies employed by some (Wada *et al*, 2012; Simonova *et al*, 2016). A detailed review at a species level may formalise certain terrestrial invertebrates as proxies for human visits to remote islands, and this is probably a research agenda worth pursuing. The vegetation regime has been studied extensively (Brayshay, and Edwards, 1996, Edwards, 1996, 2004, 2009; Tipping, 2004; Church, 2006; Bishop *et al*, 2013; Bishop *et al*, 2018;) and whilst climatic conditions in northern Scotland would have been suitable for the colonisation by various deciduous and evergreen trees very early in the Holocene due to rapid warming, the spread of such taxa from their glacial refugia takes time in the order of several centuries (Tipping, 2004). Edwards (2004, 2009) characterises the archipelago as having birch (*Betula spp.*) and hazel (*Corylus spp.*) woodland, albeit of a more open nature than that of the Isle of Skye or the mainland. Whether the trees were of the quality hunter-gatherers would seek remains an open question. As noted in chapter 3 the people of the Coast Salish not only preferred the wood from certain trees for certain purposes, they also preferred the wood of that species from certain locations as the workable properties varied by biotope. Another key point from chapter 3 is that hunter-gatherers do not, as a matter of course, fell trees or harvest large branches to obtain firewood, even at the population densities present in British Columbia.

The palynology is unable to inform us on the form the trees took which is a material consideration given the archipelago is known for its frequency of high winds. The now intertidal peat beds (Bronze Age) on the exposed west coast of South Uist[6] contain numerous tree trunks, but these are short and gnarled and are reminiscent of those observed in exposed areas of Cornwall. Assuming the trees exhibited a similar morphology during the Mesolithic they would not meet the criteria applied by the two societies considered in chapter 3 for making spear and harpoon shafts, or the handles of the tools they use for gathering from the infralittoral. Finding suitable members for constructing the frames of canoes or huts may also have been problematic, although it should be noted that the Aleutian Islanders of Alaska ‘got by’ utilising driftwood (Yesner, 2004; Anichtchenko, 2012). Straighter and taller trees may have been heterogeneously distributed where the local topography facilitated their growth and may have been more abundant on the eastern half of the islands which offers more shelter from the prevailing winds. Similar considerations of tree size exist in relation potential yields of fruits and nuts for humans (see Holst, 2010 and McComb, 2009 for a discussion), and bark for rope, nets, and bindings etc (chapter 3).

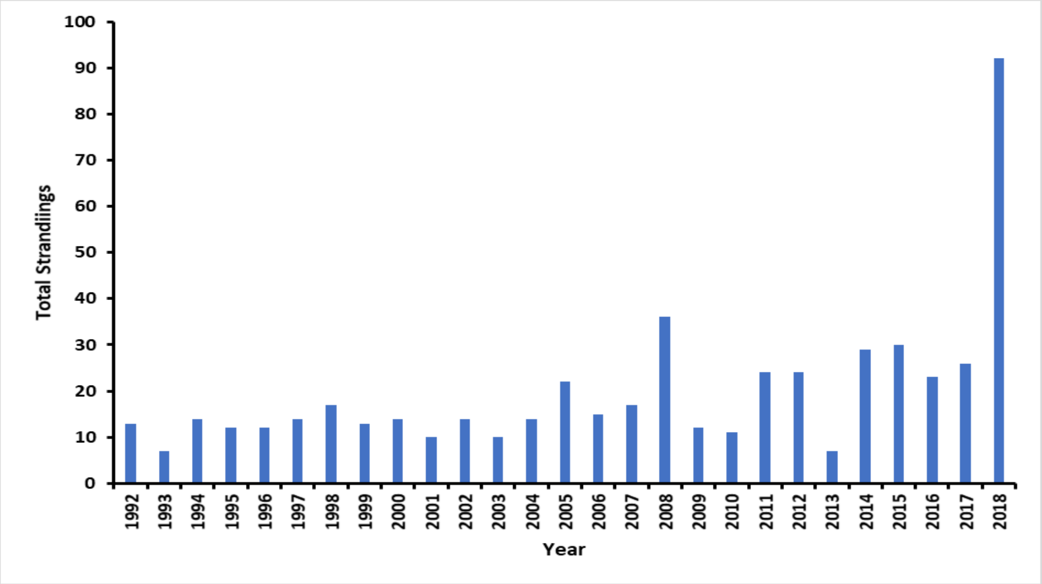

Figure C6-2: Number of whale stranding around the coast of the Western Isles and the mainland margin of the Minch. Strandings are slowly becoming more frequent as the whale population recovers following the implementation of the World Whaling Moratorium in 1982. The extreme number in 2018 is due to a very high number of Cuvier’s Beaked Whale (Ziphius cavirostris) in August and September throughout the region. Data from the Scottish Marine Animal Stranding Scheme (SMASS).

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[6] The author was fortunate enough to be taken to this location on a field trip during the SIPRA symposium (January 2019) where it was communicated that the peat beds had not been intertidal in the 1950s, and that an articulated skeleton of a sheep with an associated lithic assemblage had been recently uncovered.

The archipelago has of course experienced the same changes in eustatic sea level as other regions. This includes the initial transgression that resulted from the deglaciation, and also the increase in eustatic sea level associated with the 8.2K cal bp event (see chapter 7). In Sturt *et al*, (2013)'s model prior to the 8.2K cal bp event the archipelago was made up of two land masses, one the Isle of Lewis and the other what are now the separate islands of the southern half of the archipelago. Based upon the published research the archipelago has not experienced any positive isostatic readjustment (Richie, 1985; Shennan and Horton, 2002). The eastern margins lie on the zero isostatic isobar (Ballantyne, 2004; Smith *et al*, 2017), implying that the western coast has probably experienced a negative isostatic readjustment, albeit of a relatively small magnitude. The possibility that coastal woodland may have been lost, especially from the western coastal margin and between what are now the islands of the Uists, Benbecula and Barra, due to marine transgression was not lost on Edwards and Sugden (2003). The archipelago (at least in some areas) has therefore experienced relative sea level change greater than the eustatic changes associated with these global events. Richie (1985) asserts a change in relative sea level of around 9m for the southern parts of the archipelago, of which the upper estimates for the eustatic rise due to the 8.2K cal bp event accounts for some 4m (see chapter 7). Despite its geographic orientation and position relative to the mainland, the author has little doubt that the effects of the Storegga Slide tsunami (Storegga Slide henceforth) will have impacted both eastern and western coasts where local bathymetry and coastal topography were conducive for it to do so (see chapters, 3 and 7); a view also held by Jordan *et al* (2010), Long *et al*, (2016) and Hill *et al* (2014). Although some consider tsunami deposits or anomalies to be submerged as shown by Smith *et al*, (2012) and Selby and Smith (2016).

When did humans arrive in the Western Isles?

Palynologists such as Kevin Edwards and his collaborators asserted a human occupation at around 8.2K cal bp, based upon disturbances in the palynological record and associated spikes in microcharcoal (Edwards, and Sugden, 2003; Edwards, 2004); suggesting this might be associated with woodland clearance to attract game. This is a difficult argument to accept given the overwhelming evidence is that the archipelago had no terrestrial game to attract. Whilst Tipping (2004) suggests lightning strikes during warmer drier periods as a possible cause, an anthropogenic cause is also possible, even if unintentional, as recent events suggest. During March of 2018 an exceptional high pressure system (anticyclonic) referred to in the media as the 'beast from the East' (Greenfield, 2018) resulted in exceptionally low temperatures and dry conditions throughout Britain. Wildfires occurred within the archipelago which was described as being tinder dry due to the dry winds associated with the weather system (Clinton, 2018). In such a scenario, Mesolithic hunter-gatherers may have built larger campfires than normal, and the odd stray ember could result in increased, but unintended, burning events.

The need to infer a human presence from the palynology has now been eliminated and Kevin Edwards' (and collaborators) tenacity has been rewarded. Archaeological evidence for human habitation has been published and consists of two phases; the first between was dated to 7,050 - 6,700 cal BC and between 6,560 – 6,100 cal BC (Gregory *et al*, 2005).

6.2.2 The Shetland Islands.

It is necessary to explain why this review has relocated from the Western Isles to Shetland clearly skipping the Orkney Isles and Fair Isle. Orkney is famed for its spectacular Neolithic occupation and architecture, but as with Fair Isle, a Mesolithic presence is attested only by artefact finds and at the time of writing no Mesolithic shell-middens, other faunal remains, camps, or structures have been identified. In contrast to the Western Isles and Shetland there also appears to be some uncertainty regarding when Orkney became isolated from the mainland and therefore an island. Whilst Orkney can feature to a degree in subsequent discussions it cannot contribute any data in support of this project's aims and objectives.

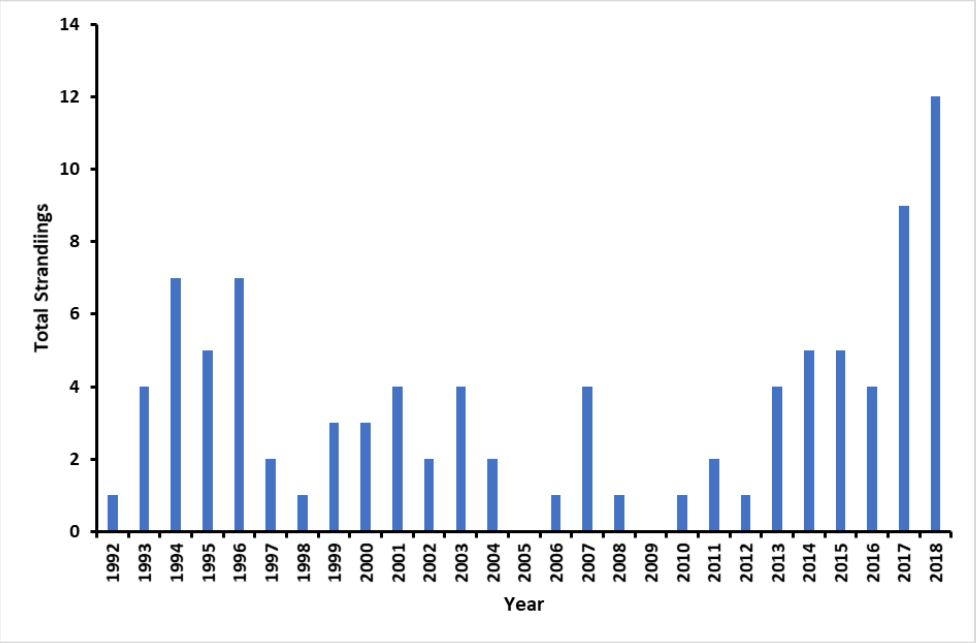


Figure C6-3: Whale stranding around the Shetland Islands. The same comments as made in relation to the Western Isles apply to the high volume recorded in 2018. Data from SMASS.

The Shetland Isles archipelago lies to the north east of the Orkney Isles between latitudes 59.8 and 60.8° north (figure C5-15). Shetland appears to have been isolated from the mainland and Orkney since the deglaciation at the end of Pleistocene (Sturt *et al*, 2013). The probability of terrestrial fauna reaching the archipelago would appear to be just about zero. The faunal resources that were unavailable are exactly as described for the Western Isles above. As with the Western Isles pinnipeds and birds would have been present in addition to fish, urchins, molluscs, and crustaceans; and based upon the recent data trends cetaceans in the form of live or dead strandings (figure C6-3). Invertebrates unable to leverage airborne dispersal will have faced significant challenges with the same mitigations as described earlier available to some species. Given its latitude the climate is highly moderated for the same reasons given for the Western Isles, although slightly more variation is observed in the second half of the year. The modern SST data is shown in figure C6-4.

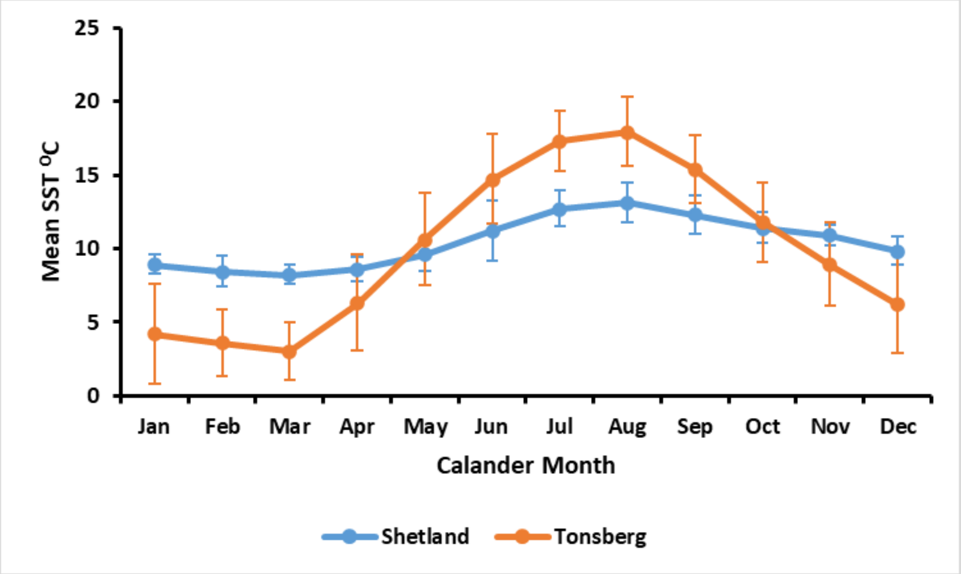


Figure C6-4: A comparison of mean sea surface temperatures between Shetland and Tonsberg (Lat. 59.37°N) in Norway. The error bars reflect the maximum and minimum monthly averages the magnitude of which may be exceeded during short term heatwaves or cold snaps. Data from the world sea temperature organisation.

The situation regarding the vegetation is again similar to that of the Western Isles. The palynology suggests a probable presence of birch, hazel, oak and alder (Edwards, 2009). There is also a reduction in tall herbs and ferns in favour of heath and mire plants between 7,500 and 5,400 ^{14}Cyr bp. Attributing this to grazing by red deer introduced by Mesolithic hunter gatherers appears to push the data beyond reasonable interpretation as observed by Woodman (2004b). Warren *et al* (2014) proposes the introduction of wild boar to Ireland during the Mesolithic and does so at least in conjunction with skeletal assemblages, such as those at Mount Sandel. The capability of hunter-gatherers to conduct such niche construction is without doubt (chapter 2). However, in the absence of evidence such assertions of Mesolithic deer introductions constitute little more than, albeit reasoned, speculation.

In terms of sea level change the situation is again very similar to the Western Isles, with the whole of Shetland lying beyond the zero isostatic readjustment isobar (Ballantyne, 2004; Smith *et al*, 2017). Melton (2009) cites evidence from submerged peat that relative sea-level has risen by 9m since 5,400 ^{14}yr BP. The timing rules out a contribution from the eustatic changes driven by the 8.2K cal bp event. One difference compared to the Western Isles is that the impact of the Storegga Slide is understood and the estimates of the run up height vary between 12m and 20m (Bondevik *et al*, 2005; Blankholm, 2018), depending upon location.

When was Shetland occupied by humans?

Again, it is necessary to repeat the narrative provided for the Western Isles. Occupation was proposed by the palynologists cited earlier based upon pollen disturbances and micro-charcoal. Again, environmental causes need to be explored, especially as the collective knowledge regarding climatic and environment change has improved significantly in the last decade. Nevertheless, the palynologists have been proven correct as in 2001 the first Mesolithic occupation of the Shetland archipelago was identified (Melton and Nicholson, 2004; Melton, 2009). At this stage, the occupation of Shetland can only be archaeologically demonstrated from late in the 5th millennium BC.

6.2.3 Sampling

The taxonomic composition was determined for all samples from all contexts at each site. There is a slight difference in the approach adopted for the two earlier sites on the Toe Head peninsula compared to the later sites on the Cnip Headland. For the former the detailed analysis targeted all the contexts in phases dated to the Mesolithic. The approach to the Lewis sites was to target key contexts as no phasing had been identified. The material in cleaning contexts is unstratified and only included in site level data. As stated in chapter 4 the approach to collecting biometric data was to collect it from all measurable specimens in the excavation samples analysed. A mathematical approach to defining representative sample sizes was not adopted for the reasons discussed in chapter 4.

6.3 The Sites: Their Stratigraphy and Chronology.

The data presented in this chapter relates to new data from the previously published sites of Northton in the Western Isles and West Voe in Shetland. Data is also presented from five previously unpublished sites in the Western Isles. To permit appropriate sizing the maps and Harris matrices are provided at the end of this section.

6.3.1 Northton (NT) NGR(NF 975 912).

NT is located on the Toe Head Peninsula at the extreme southerly limit of the Isle of Lewis in the Western Isles (figure C5-15). This area, whilst not an island geographically, is conventionally referred to as the Isle of Harris. The stratigraphy at NT is complex and includes post-Mesolithic occupations as well as the Mesolithic horizon. The site has been excavated several times, once in the mid-1960s, in 2001 and again in 2010. The PDs permitted several phases to be defined, the quantification of faunal remains was conducted for all phases, but biometrical analysis was restricted to those contexts defined as part of Mesolithic phases. The Harris matrix is provided as figure C6-5 and this maps the contexts from the 2001 excavation onto the 2010 excavation. The faunal data from the earlier excavation (Hamilton-Dyer, 2006) has been combined with that of the new excavations. The principle investigator for the 2010 excavation was also a member of the 2001 excavation team and therefore the context mapping was readily available. The remains have been interpreted by the excavation team as redistributed hearth deposits. The location of the site within the immediate area is shown in figure C6-6 and the PDs are provided in table C6-1.

Table C6-1: Radiocarbon PDs calibrated with Oxcal 4.4.2 (Bronk-Ramsey, 2009) and the Intcal13 curve (Reimer et al, 2013). Dates in bold were calibrated with the chronologically closest available ΔR, which for these ^{14}C assays was that defined for TNB1 in Ascough et al, 2017. The ΔR used for phase 4 of 77±56 is that from Ascough et al, 2017.

Site/Season	Phase	Context	Lab Code	Material	^{14}C Assay	Error	∂^{13}C	Calibrated PD Cal BC	Source
NT 2010	N/A	Neolithic	BM-705	Bone	4411	79	?	3339-2904	Gregory 2006
NT 2010	Phase 3	C.14	SUERC-33736	Hazel nutshell	7470	30	-23.5	6417-6251	Ascough *et al*. 2017
NT 2010	Phase 3	C.14	SUERC-33737	Hazel nutshell	7440	30	-23.3	6391-6241	Ascough *et al*. 2017
NT 2010	Phase 3	C.14	SUERC-34911	Hazel nutshell	7460	40	-25	6416-6241	Ascough *et al*. 2017
NT 2010	Phase 3	C.14	SUERC-34912	Hazel nutshell	7400	40	-21.9	6395-6121	Ascough *et al*. 2017
NT 2010	Phase 3	C.14	SUERC-34913	Limpet shell	5070	35	1.5	**3749-3401**	Ascough *et al*. 2017
NT 2010	Phase 3	C.14	SUERC-34914	Limpet shell	5080	35	0.5	**3757-3448**	Ascough *et al*. 2017
NT 2010	Phase 3	C.14	SUERC-34915	Limpet shell	5105	35	1.4	**3774-3487**	Ascough *et al*. 2017
NT 2010	Phase 3	C.14	SUERC-34916	Limpet shell	5085	35	1.2	**3764-3459**	Ascough *et al*. 2017
NT 2001	Phase 4	C.5 (C.9)	AA-50332	Hazel nutshell	7525	80	-24.4	6560-6226	Gregory *et al*. 2005
NT 2001	Phase 4	C.5 (C.9)	AA-50333	Hazel nutshell	7395	45	-23.7	6396-6104	Gregory *et al*. 2005
NT 2001	Phase 4	C.5 (C.9)	AA-50334	Hazel nutshell	7420	45	-24.1	6403-6220	Gregory *et al*. 2005
NT 2001	Phase 4	C.5 (C.9)	AA-53250	Marine Mollusc	7860	45	1.5	6573-6354	Ascough et al. 2007
NT 2001`	Phase 4	C.5 (C.9)	AA-53251	Marine Mollusc	7880	45	1.1	6586-6372	Ascough et al. 2007
NT 2001	Phase 5	C.7 (C.16/17)	AA-50335	Hazel nutshell	7980	50	-24	7051-6700	Gregory *et al*. 2005
NT 2001	Phase 5	C.7 (C.16/17)	AA-50336	Hazel nutshell	7925	55	-26.3	7032-6659	Gregory *et al*. 2005

6.3.2 Teampuil an Bagh (TB) NGR(NF 9734 9132).

TB is located on the Toe Head Peninsula at the extreme southerly limit of the Isle of Lewis (conventionally Harris) in the Western Isles (figure C5-15). The stratigraphy at TB is complex and includes post-Mesolithic material as well as Mesolithic material. The PDs permitted several phases to be defined, the quantification of faunal remains was conducted for all phases, but biometric analysis was restricted to those contexts defined as belonging to Mesolithic phases. Sites get named in many ways and for diverse reasons, from a methodological point of view the *de facto* situation is that (due to their close physical proximity but temporal separation) TB can arguably be considered as NT 2. The Harris matrix is provided as figure C6-7 and the location of the site within the immediate area is shown in figure C6-6. It is worth noting that a human deciduous maxillary second incisor was recovered from a cleaning context. The tooth did not appear to have been shed naturally as it was firmly attached to bone around its base as it would have been when *in situ*. Unfortunately, being from a general cleaning context it is, *de facto*, unstratified. The available PDs are provided in table C6-2.

Table C6-2: Radiocarbon PDs. Calibration performed with Oxcal 4.4.2 and the Intcal13 curve.

Site/Season	Phase	Context	Lab Code	Material	^{14}C Assay	Error	∂^{13}C	Calibrated PD Cal BC	Source
TB 2011	Phase 3b	C.7	SUERC-38834	Hazel nutshell	6525	30	-27.3	5557-5386	Unpublished
TB 2011	Phase 3b	C.7	SUERC-38838	Hazel nutshell	6735	30	-24.9	5715-5576	Unpublished
TB 2012	Phase 3b	C.7	SUERC-70435	Hazel nutshell	6779	30	-24.5	5722-5635	Unpublished
TB 2011	Phase 2	C.3	SUERC-38832	Hazel nutshell	6750	30	-23.2	5713-5624	Unpublished
TB 2011	Phase 2	C.3	SUERC-38833	Hazel nutshell	6690	30	-23.8	5662-5556	Unpublished

6.3.3 Traigh na Beirigh 2 (TNB2) NGR(NB 1003 3633).

TNB2 is located on the Cnip headland of the Isle of Lewis in the Western Isles (figure C5-15) and unlike the sites from the Toe Head Peninsula is an open air shell-midden. TNB2's stratigraphy is a series of vertically stratified columns that do not mix (within the section) with adjacent columns (Blake *et al*, 2011). The stratigraphy within each column is a generally simple vertical stratification, although a depression and fill are also noted. Quantification has been performed for all samples of all contexts. Biometrical analysis has been focused, but not exclusively, on specific samples of context 5 and context 11. The Harris matrix is provided in figure C6-8 and the location of the site within the immediate area is shown in figure C6-9. This Harris matrix is slightly different to that provided in Evans (2016). The context sheets defined the column containing context 14 as being at the southern end of the section. Inspection of the detailed section drawings revealed this not to be the case, context 14 is north of context 5 and contiguous with it. The context sheet also states that the only reason for assigning a new context number was that it was the start of a new season, which is different to the approach at TNB1 where the context number would be retained and a new sample number assigned. Once the taxonomic composition and biometrics were available it was clear that context 14 and 5 are the same, the former possibly 'run off' from the latter. The data from these contexts were therefore merged as context 5. The available PDs are provided in table C6-3.

Table C6-3: Radiocarbon PDs. Calibration performed with Oxcal 4.4.2 and the Intcal13 curve. The ΔR of 143±54 is that from Ascough *et al*, 2017.

Site/Season	Phase	Context	Lab Code	Material	^{14}C Assay	Error	∂^{13}C	Calibrated PD Cal BC	Source
TNB2 2012	N/A	C.5	SUERC-44850	Hazel nutshell	5700	33	-24.5	4653-4457	Ascough *et al*. 2017
TNB2 2012	N/A	C.5	SUERC-44854	Hazel nutshell	5690	33	-26.1	4615-4453	Ascough *et al*. 2017
TNB2 2012	N/A	C.5	SUERC-44855	Hazel nutshell	5667	33	-24	4591-4399	Ascough *et al*. 2017
TNB2 2012	N/A	C.5	SUERC-44856	Hazel nutshell	5705	33	-26.3	4669-4558	Ascough *et al*. 2017
TNB2 2012	N/A	C.5	SUERC-44857	Limpet shell	5772	33	-0.9	4518-4252	Ascough *et al*. 2017
TNB2 2012	N/A	C.5	SUERC-44858	Limpet shell	5924	33	0.5	4696-4386	Ascough *et al*. 2017
TNB2 2012	N/A	C.5	SUERC-44859	Limpet shell	5704	33	0.1	4452-4176	Ascough *et al*. 2017
TNB2 2012	N/A	C.5	SUERC-44860	Limpet shell	5866	33	0.3	4631-4336	Ascough *et al*. 2017
TNB2 2013	N/A	C.6	SUERC-70443	Hazel nutshell	5748	29	-24	4689-4520	Unpublished
TNB2 2013	N/A	C.6	SUERC-70444	Hazel nutshell	5743	29	-27.1	4687-4517	Unpublished

6.3.4 Pabaigh Mor South (PMS) NGR(NB 1041 3727).

PMS is located on a near shore island that lies off the Cnip headland of the isle of Lewis in the Western Isles (figure C5-15). This was a small scale exploratory sampling exercise with only two contexts defined within a single column. Quantification has been performed for all samples of all contexts. Biometrical analysis has been focused on context 2. The Harris matrix is provided in figure C6-10 and the location of the site within the immediate area is shown in figure C6-9. The available PDs are presented in table C6-4.

Table C6-4: Radiocarbon PDs. Calibration performed with Oxcal 4.4.2 and the Intcal13 curve.

Site/Season	Phase	Context	Lab Code	Material	^{14}C Assay	Error	∂^{13}C	Calibrated PD Cal BC	Source
PMS 2013	N/A	C.2	SUERC-55363	Hazel nutshell	8098	28	-26.3	7166-7043	Unpublished
PMS 2013	N/A	C.2	SUERC-55364	Hazel nutshell	5670	28	-26.1	4578-4449	Unpublished
PMS 2013	N/A	C.2	SUERC-70434	Charcoal	5463	29	-24.1	4356-4260	Unpublished

6.3.5 Traigh na Beirigh 9 (TNB9) NGR(NB 1007 3640).

TNB9 is located on the Cnip headland of the Isle of Lewis in the Western Isles (figure C5-15). TNB9 included a human burial that was inserted into an (possibly only slightly) earlier shell-midden. The excavation centred around the human remains. Compositional data is provided at the site level as the burial has inevitably compromised the stratigraphy of the midden. Only quantification has been carried out and the data presented excludes that of the interface with the overlying more recent layer. A simplified Harris matrix is provided in figure C6-11. The location of the site within the immediate area is shown in figure C6-9 and the available radiocarbon dates in table C6-5.

Table C6-5: Radiocarbon PDs. Calibration performed with Oxcal 4.4.2 and the Intcal13 curve. Dates in bold were calibrated with the chronologically closest available ΔR, which for these ^{14}C assays was that defined for TNB1 in Ascough *et al*, 2017.

Site/Season	Phase	Context	Lab Code	Material	^{14}C Assay	Error	∂^{13}C	Calibrated PD Cal BC	Source
TNB9 2013	N/A	C.6	SUERC-55365	Hazel nutshell	5372	26	-24.7	4330-4071	Unpublished
TNB9 2013	N/A	C.6	SUERC-55366	Hazel nutshell	5297	27	-25.8	4233-4044	Unpublished
TNB9 2013	N/A	C.5	SUERC-56982	Human tooth	5143	33	-15.2	**3932-3688**	Unpublished

6.3.6 Traigh na Beirigh 1 (TNB1) NGR(NB 1002 3628).

TNB1 is located on the Cnip headland of the isle of Lewis in the Western Isles (figure C5-15). TNB1 has simple stratigraphy that can be considered as possibly two columns, each of which contain a simple stratigraphic sequence. Quantification has been performed for all samples of all contexts. Biometrical analysis has been focused, although not exclusively, on specific samples of context 8 and context 14. The Harris matrix is provided in figure C6-12 and the location of the site within the immediate area is shown in figure C6-9. This Harris matrix is different to that employed in Evans (2015; 2016) where contexts 11 and 13 were treated as defined in the context sheets and context registers. A review of the detailed section drawings (Blake *et al*, 2011) revealed that context 11 is only above context 13 in the sense that is higher up a slope and in fact these two thin deposits abut each other, rather than one being above the other stratigraphically. The upper slope context 11 has very small limpets (mean length 27.3mm) the smallest at the site, and the lower slope context much larger ones (mean length 29.3mm) the largest at the site. This pattern is repeated for the crabs, context 11 has far greater number of small fragments but no claws, whilst context 13 has a few larger remains, including the claw elements. In terms of ranking of relative abundances their compositions are the same but differ in the magnitude of the abundance associated with each individual taxon. It was concluded that these are in fact a single context that has experienced some degree of gravitational sorting. The data from context 13 has been merged with that of context 11 as context 11. The available radiocarbon PDs are provided in table c6-6.

Table C6-6: Radiocarbon PDs. Calibration performed with Oxcal 4.4.2 and the Intcal13 curve. Note: Context 1 is a bulk sample of the eroding midden taken prior to excavation commencing and the material dated may have originated from contexts 8, 11 or 14, but to the author's knowledge not the upper interface layer context 5. The ΔR of 109±55 is that from Ascough *et al*, 2017.

Site/Season	Phase	Context	Lab Code	Material	^{14}C Assay	Error	∂^{13}C	Calibrated PD Cal BC	Source
TNB1 2010	N/A	C.1	SUERC-33731	Hazel nutshell	5415	30	-27.4	4331-4233	Ascough *et al*. 2017
TNB1 2010	N/A	C.1	SUERC-33732	Hazel nutshell	5415	30	-26.9	4331-4233	Ascough *et al*. 2017
TNB1 2010	N/A	C.1	SUERC-34902	Hazel nutshell	5355	35	-26	4325-4053	Ascough *et al*. 2017
TNB1 2010	N/A	C.1	SUERC-34903	Hazel nutshell	5280	35	-27.9	4233-3994	Ascough *et al*. 2017
TNB1 2010	N/A	C.1	SUERC-34904	Limpet shell	5560	35	0.7	4272-3964	Ascough *et al*. 2017
TNB1 2010	N/A	C.1	SUERC-34908	Limpet shell	5675	40	1	4387-4053	Ascough *et al*. 2017
TNB1 2010	N/A	C.1	SUERC-34909	Limpet shell	5690	40	1.1	4417-4079	Ascough *et al*. 2017
TNB1 2010	N/A	C.1	SUERC-34910	Limpet shell	5720	35	1.3	4446-4147	Ascough *et al*. 2017
TNB1 2012	N/A	C.14	SUERC-70436	Hazel nutshell	5414	29	-26.4	4388-4235	Unpublished
TNB1 2012	N/A	C.14	SUERC-70437	Charcoal	5388	29	-26.9	4335-4057	Unpublished
TNB1 2012	N/A	C.26	SUERC-70438	Hazel nutshell	5379	29	-27.6	4333-4072	Unpublished
TNB1 2012	N/A	C.26	SUERC-70442	Charcoal	5336	29	-26.9	4260-4051	Unpublished

6.3.7 West Voe (WV) NGR(HU 39181012).

Without doubt the excavation team found themselves with a very challenging site as the stratigraphy at WV is very complex. A significant level of granularity is available due to the use of block and contexts which define excavation samples spatially in both the horizontal and vertical planes. There are two major midden deposits one lying above the other but separated by between 0.5m and 0.8m of archaeologically sterile sand and clearly these reflect two very different types of occupation punctuated by an environmental event (Melton, 2009; Gilmore and Melton, 2011). There is also a lack of stratigraphic consistency for the radiocarbon PDs, which probably is due to periods when the direction and plane of midden accumulation varied as well as possible turbation of an anthropogenic origin. It should also be noted that the PDs obtained from the same species of mollusc are coherent irrespective of stratigraphic position. A draft of the invertebrate report (Evans, forthcoming) from the coming site publication is attached as SI-Gen-1; this is complemented by additional analysis performed by the author more recently.

This project has focused on those contexts that were potentially Mesolithic and this results in the stratigraphic complex involving contexts 412 and 413 being omitted. Their status being akin to the interface layers of contexts 5 at TNB2 and context 3 at TNB1. They almost certainly contain faunal material from the Mesolithic period but also material from more recent periods and identifying which is which is just about impossible. There are two phases within the lower midden, the later of which is likely to be Neolithic. Examination of the section drawings revealed some ambiguity in the status of context 480. The conclusion was that it is not equivalent to 412/413 as implied intermittently within the drawings and is treated here as a separate entity. The data presented for vertebrates was sourced from summary publications (Melton and Nicholson, 2004; 2007; Melton, 2009), and the unpublished data structure reports (Nicholson, 2004; 2005) available within the project archive. The vertebrate assemblages are due to be published by the same specialists who undertook the post excavation analysis between 2004 and 2006 (Nicholson, forthcoming; Worley, forthcoming). The analysis of oyster seasonality is also due as part of the site publication (Milner, forthcoming). The radiocarbon PDs are presented in table C6-7. Correlating the material from the initial small scale 2002 investigation with the more extensive and stratigraphically granular excavations of 2004 and 2005 inevitably attracts a degree uncertainty. The primary context WV3 probably maps to an aggregation of the contexts 436, 466 and 401, whilst WV2 probably maps to contexts 414 and possibly 412/413. Hopefully, this will be clarified in the site publication.

Table C6-7: Radiocarbon PDs. Calibration performed with Oxcal 4.4.2 and the Intcal13 curve. PDs in bold were calibrated with the chronologically closest available ΔR, which for these dates was that defined for TNB1 in Ascough et al, 2017. The cockle and oyster dates have not been included as there is clearly a species specific offset and the ΔR utilised is based upon limpet (Patella spp.).

Site/Season	Phase	Context	Lab Code	Material	^{14}C Assay	Error	∂^{13}C	Calibrated PD Cal BC	Source
WV	1A North	C.401		Limpet Shell	5515	45		**4428-3929**	Melton (2009)
WV	1A South	C.436		Limpet Shell	5730	60		**4486-4102**	Melton (2009)
WV	1B South	C.414		Charcoal	5128	34		4033-3801	Melton (2009)

6.3.8 Summary

The point has now been reached where it is possible to investigate what these Mesolithic people left behind for posterity and hopefully gain some enlightenment on how they lived their lives. In doing so answers are sought to: what resources were exploited and how, in which seasons were the sites occupied and how all of these vary temporally. The sites will be considered in their gross chronological sequence and during the presentation of each site's data, commentary will be made primarily at an intra-site level. The approach is also a layering one where backward reference to the sites already presented will be made. Comparison with other sites from Atlantic Europe and especially the sites from north-western Scotland will be discussed in chapters 7 and 8.

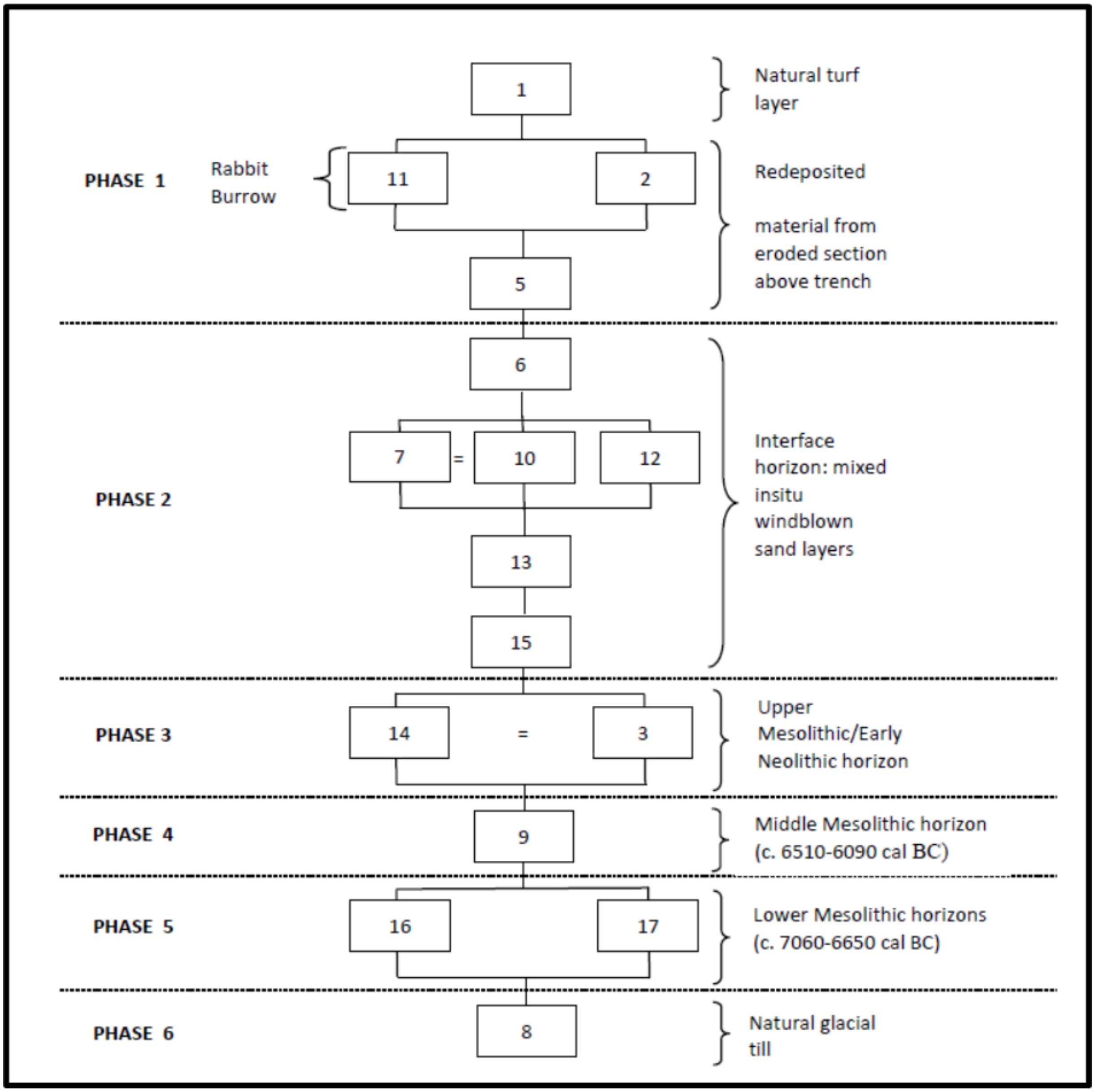


Figure C6-5: Harris Matrix for Northton reproduced from Bishop *et al*, 2011.

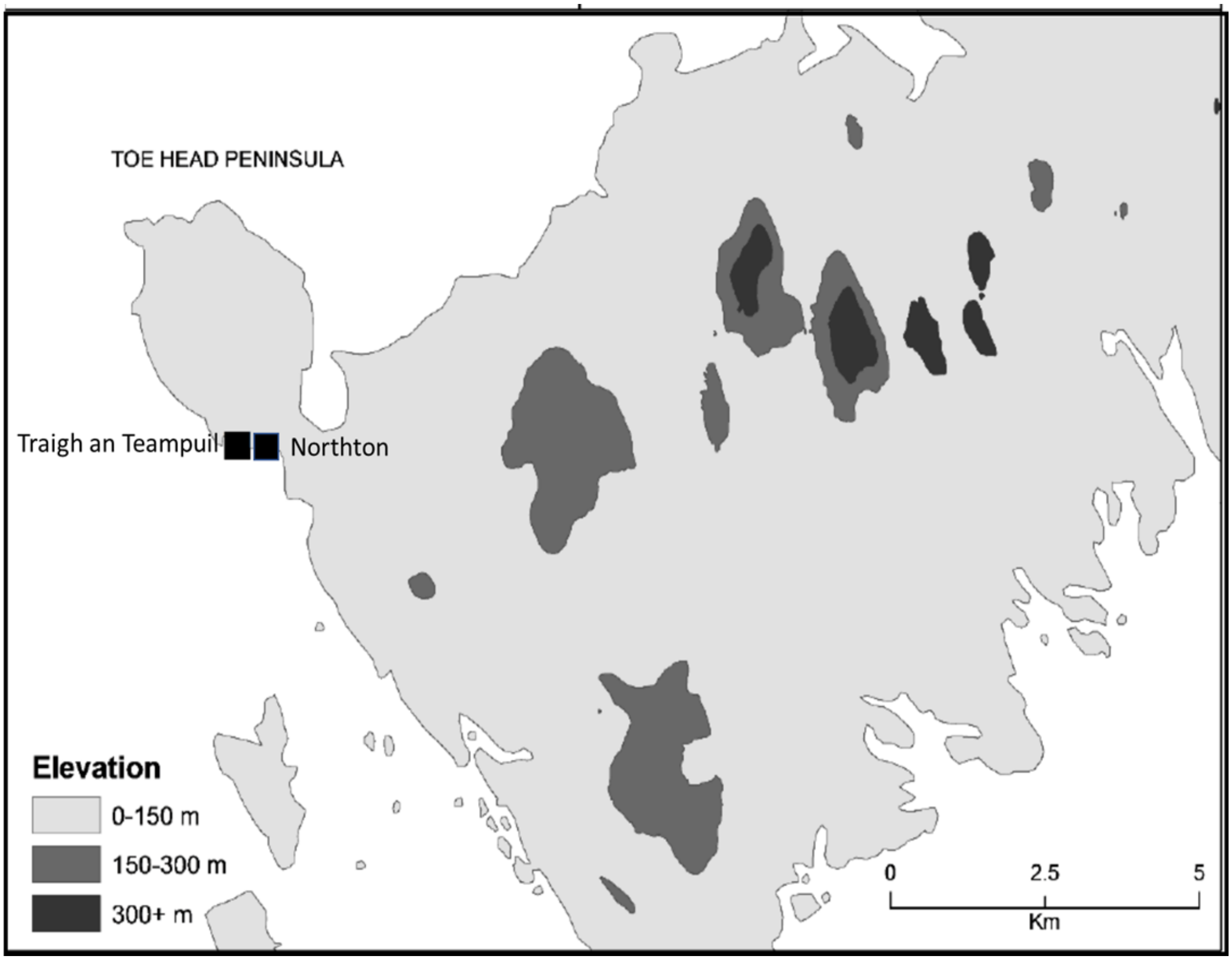


Figure C6-6: Location of Traigh an Teampuill and Northon. Reproduced from Piper and Church (2012) and adapted from Bishop *et al*, 2011.

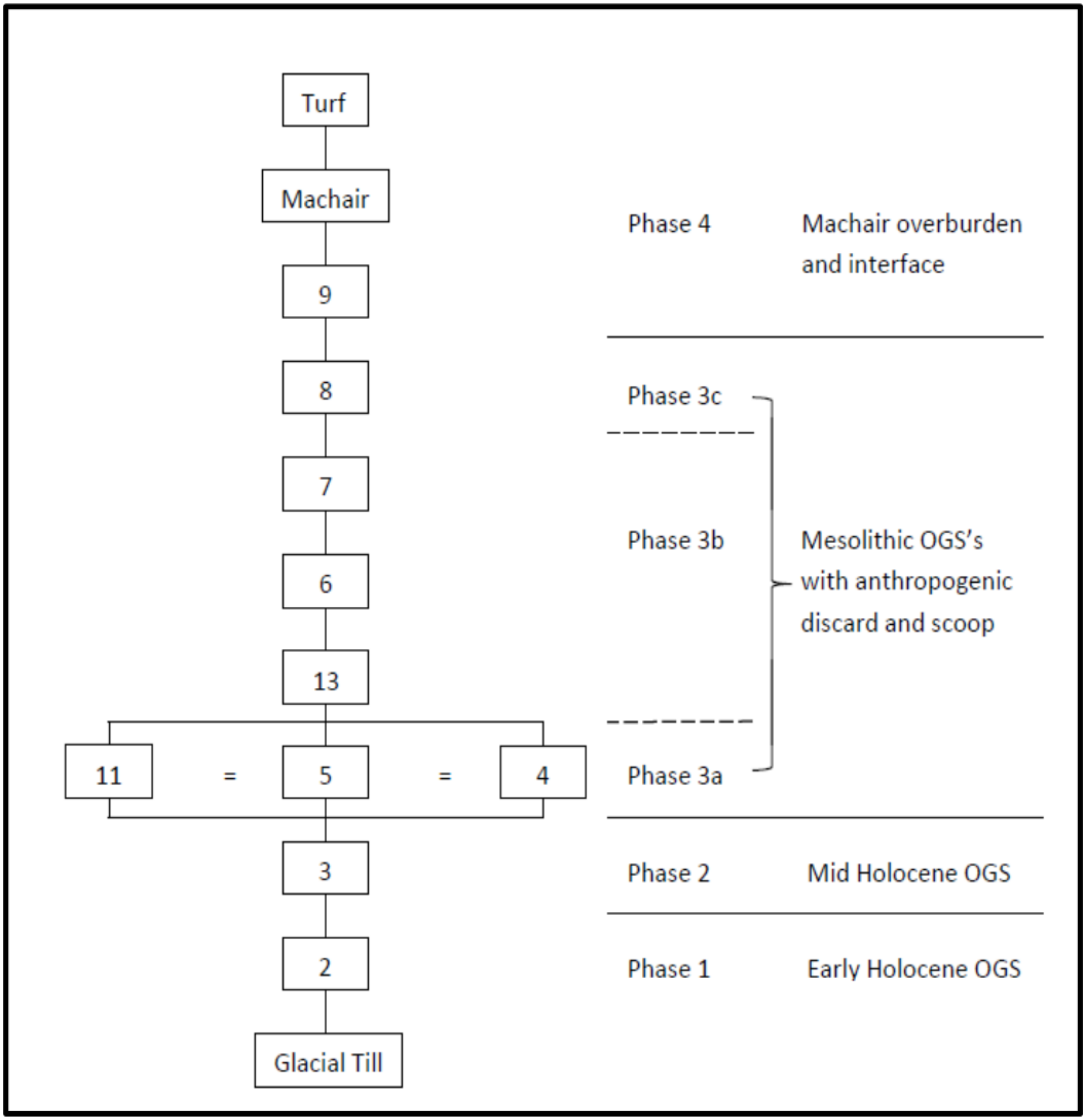


Figure C6-7: Harris Matrix for Traigh an Teampuill. Reproduced from Piper and Church (2012).

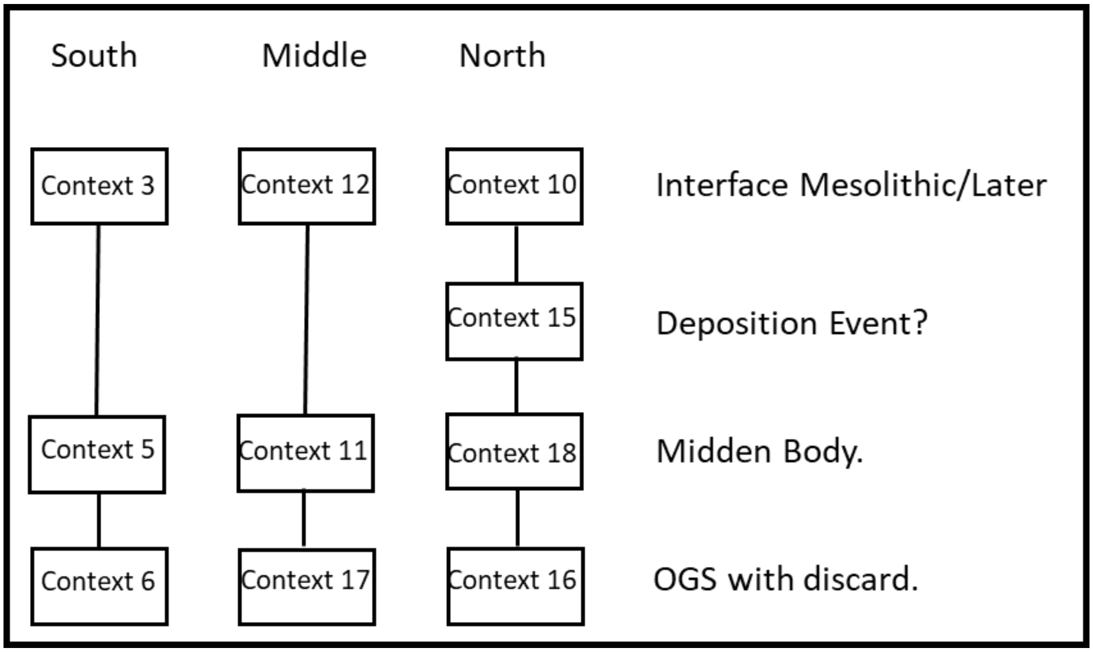


Figure C6-8: Harris Matrix for Traigh na Beirigh 2 after consolidation of contexts 5 and 14.

Figure C6-9: Locations of 1=TNB1, 2=TNB2, 3=TNB9 and 4=PMS. Compiled from Canmore database.

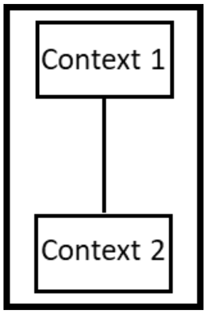


Figure C6-10: Harris Matrix for Pabaigh mor South.

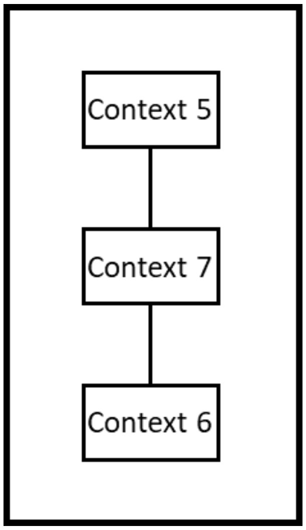


Figure C6-11: Harris Matrix for Traigh na Beirigh 9.

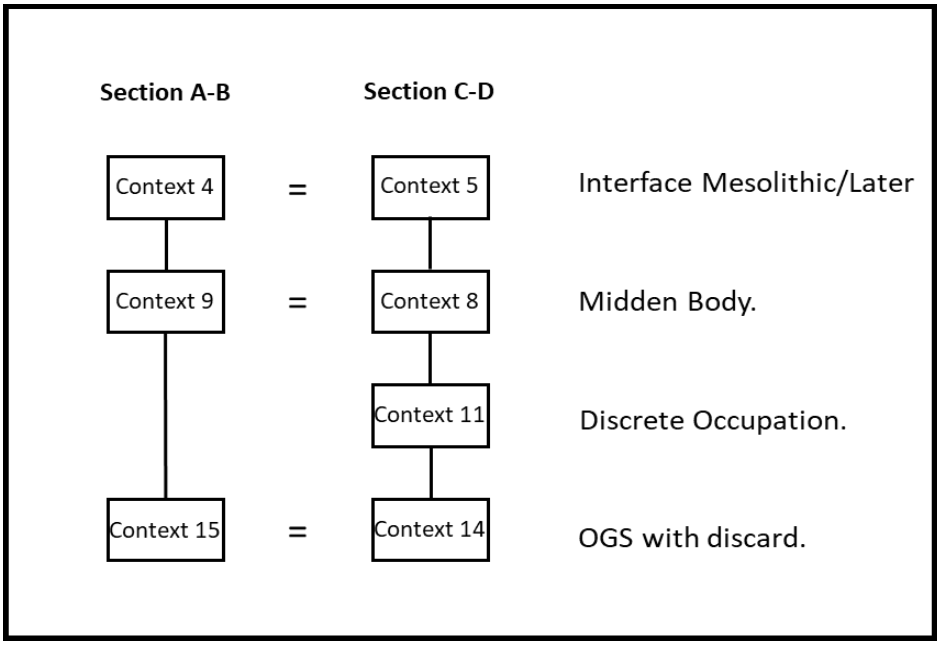


Figure C6-12: Harris Matrix for Traigh na Beirigh 1 after consolidation of contexts 11 and 13.

6.4 Methods

6.4.1 The Composition of the Faunal Assemblages.

As illustrated in chapter 3 a fundamental question regarding the lives of past societies is what species were exploited for subsistence and raw materials, and in what relative proportions of the total; although it should be noted that numerical importance may not equate to dietary importance due to inter-species variation in nutritional value, flesh yield, and utility as a raw material. The composition of the faunal assemblages can also provide information on the prevailing environmental conditions, the seasons of site occupation, site function (*sensu* Binford, 1980) and the biotopes exploited. In chapter 4 certain methodological issues were explored and strategies defined for moving forward with the research objectives of this project and those strategies have been implemented within the methods defined below.

The mollusc assemblages are quantified in terms of the MNI. The detailed methods of quantification are provided in SI-Chapter6-Gen. No quantification of taxonomic composition is provided at site level as it is analytically meaningless; it is an aggregation unit with no archaeological meaning in the vast majority of cases; a notable exception being the contents of a pit known as the Coneybury Anomaly (Gron *et al*, 2018). Identification was carried out using the department's and author's reference collections, complemented by Hayward and Ryland (2012) and the on-line references provided by the National Museum of Wales and Natural History Museum Rotterdam.

The remains of mammals, birds are presented both in terms of NISP and MNI (chapter4). The detailed methodology is defined in SI-Chapter6-8. Identification was carried out using the departments mammalian and avian reference collections. Some specimens of bird, including those of the great auk, where identified using the Natural History Museums avian collection at Tring. Skeletal element abundance is provided based upon a series of zones which are defined in tables C6-8 and C6-9.

Crabs were identified utilising the limited reference collections of the author and the department, as well as Hayward and Ryland (2012) and Crothers and Crothers (2014). Quantification at a taxonomic group level was based upon the chela (claws), and specifically the fixed claw (propodus) and moveable claw (dactylus). In some cases, the presence of a species could be determined from the fragments, but such fragments are not quantifiable in terms of being elements of the claws and are not included in the abundance data, but presence is recorded. The total number of fragments was recorded and NISP was generated from the dactyli and propodi of the chela (claws see plate C6-4). The MNI was generated from these skeletal elements as elsewhere (cf. Gutierrez-Zugasti *et al*, 2016; Pickard and Bonsall, 2009; Dupont *et al*, 2010). The generation of a refined MNI is hampered by intra-individual variation in the size of claws due to crabs exhibiting left or right handedness in terms of size. For some species this is fixed, but the author's data collection at the Natural History Museum in London demonstrated that for some common species it was variable and as with humans one or the other handedness prevailed, but not exclusively. Crabs often lose their limbs, including the claws, to predators or during combat within their own species. All can be replaced but it can take several moults (and therefore potentially years for larger specimens) until the replacement is again full size. Hence using gross size difference is not without risk. For selected species/taxonomic group the number of left hand and right hand dactyli and propodi was counted based upon the element being complete, distal or proximal. The number of complete elements was added to the greater of the proximal or distal fragment. The MNI for a species was then the greater of left hand propodi, left hand dactyli, right hand propodi or right hand dactyli. For the edible crab a refined process was evaluated which used the number of 'teeth' on the propodus and dactylus. The number of complete specimens was added to the number of specimens having three or more teeth present and then the analysis followed that out lined above to generate the MNI. This made little difference to the outcome, increasing the MNI by one in the context with the largest assemblage. The detailed protocols utilised are defined in SI-Chapter6-5.

The analysis of fish remains is restricted to the otoliths (plates C6-5 and C6-6) from the hearing and balance system within a fish's head. The completeness of the otolith was recorded as described later under fragmentation. The number of complete specimens was added to the number of fragments more than 50% complete to generate the minimum number of otoliths (MNO) and the MNI created by dividing the MNO by two. Otoliths can be quite easily sided when complete but when dealing with fragments or eroded specimens this becomes more difficult, hence the approach defined above was deployed. The detailed protocols adopted are provided in SI-Chapter6-6. Identification was conducted using the department's reference collection (larger specimens only) and Harkonen (1986). The relative abundance of otoliths should not be viewed as an alternative to an assessment of the bone assemblage as the otoliths of many species will not be detected in an analysis limited to the >1R fraction; for example, the wrasse family, and all but the largest herring and mackerel. Smaller fractions must be consulted to detect such species, especially those of average size or smaller. The otolith identification carried out here was primarily to support biometric and stable isotope analysis of the genus *Pollachius*.

Relative abundance, whilst very helpful, masks variation in intensity of exploitation. A greater abundance of one taxon will reduce the relative abundance of others, yet this does not mean the latter are being exploited to a lesser degree in absolute terms, when different archaeological units are compared. Yields were therefore calculated in terms of MNI for molluscs and NISP for other classes per excavated litre and this data was utilised to provide a balance and check on the relative abundance results when considering trends (cf. Mannino and Thomas, 2001; Gutierrez-Zugasti, 2009; Bailey and Craighead, 2003). It should be emphasised that this was utilised as a sense check as the compactness of different archaeological units will also influence yields. Whilst table C6-12 reflects all the faunal material present at each site, including that from cleaning contexts, the analysis and therefore results, exclude cleaning contexts as such material is unstratified.

Table C6-8: Skeletal zones for mammals defined in terms of the elements contained. Revised from Evans (2016).

Mammals **Zone**	**Code**	**Element 1**	**Element 2**	**Element 3**	**Element 4**	**Element 5**	**Element 6**
Cranial	C	Skull	Mandible	Axis	Atlas		
Dentition	Dn	Dentition					
Axial	A	Vertebra	Scapula	Pelvis	Clavical	Sternum	Rib
Proximal Forelimb	PFL	Humerus					
Mid-forelimb	MFL	Ulna	Radius				
Proximal Hindlimb	PHL	Femur					
MHL	MHL	Tibia	Fibula				
DL	DL	Metapodial					
Foot	F	Palanx					

Table C6-9: Skeletal zone defined in terms of the elements contained. The elongated necks of birds, in which there is inter-species variation in the number of cervical vertebrae, are considered as cranial as decapitation is likely to occur close to the body. Revised from Evans (2016).

Bird **Zone**	**Code**	**Element 1**	**Element 2**	**Element 3**	**Element 4**	**Element 5**	**Element 6**	**Element 7**	**Element 8**
Cranial	C	Skull	Mandible	Jugal	Quadrate	Premaxilla	Axis	Atlas	Cervical Vertebra
Axial	A	Atlas	Sternum	Coracoid	Synsacrum	Scapula	Pelvis	Rib	Pygostyle
Proximal Forelimb	PFL	Humerus							
Mid-forelimb	MFL	Ulna	Radius						
Distial Forelimb	DFL	Carpo-metacarpus							
Proximal Hindlimb	PHL	Femur							
Mid-Hindlimb	MHL	Tibio-tarsus							
Distial hindlimb	DHL	Tarso-metatarsus							
Foot	F	Phalanx							

6.4.2 Biometric Evaluation.

The size and morphology of individual specimens and the related population structure of size at death can be potentially informative in many analytical spheres: procurement practices, seasonality, age at death and environmental conditions. Additionally, size at death and biometric morphology can be useful during taxonomic identification. The limpets are reported in terms of length, with volume provided in SI-Chapter6-1. Table C6-10 details the measurements captured and calculated for each taxonomic group and the location of the measurements are provided in the plates C6-2 to C6-12 provided at the end of the chapter. Detailed protocols are provided in Si-Chapter6-1.

Table C6-10: Details the biometrics captured by taxon and the and the symbol used to refer to the metric.

	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8
Limpet	Length (SL_P)	Width (SW_P)	Height (SH_P)					
Periwinkle	Shell Height (SH_L)	Shell width (SW_L)	Aperture Height (AH_L)	Aperture Width (AWL)	Aperture Lip Thickness (LT_L)			
Dog Whelk	Shell Height (SH_N)	Shell width (SW_N)	Aperture Height (AH_N)	Aperture Width (AW_N)	Aperture Lip Thickness (LT_N)	Internal Aperture Height (IAH_N)	Internal Aperture Width (IAW_N)	Syphonal Canal Length (SCL_N)
Cockle	Valve Length (SL_C)	Valve Width (SW_C)	Valve Height (SH_C)					
Razor Clam	External Hinge Length (EHL_E)	Lateral Tooth Length (LTL_E)						
Crab	Propodus dorsal length (PL)	Propodus aperture width (PW)	Dactylus dorsal length (DL)	Dactylus proximal width (DW)	Dactylus proximal height (DH)			
Otolith	Length (OL)	Width (OW)						

An objective is to increase the information yield, especially from fragmented specimens to support a more comprehensive interpretation. The solution to reconstructing the shell length at death for razor clam (*Ensis spp.*) was developed in Evans (2015) and was deployed again by this project, but with a slightly revised regression equation based upon an enlarged sample of modern specimens. The ecology and physiology of razor clams permits limited intra species variation in morphology compared to limpets and dog whelks and therefore shell length and shell width have a very strong correlation with the size of the organism (cf. Hernandez-Otero *et al*, 2014; Henderson and Richardson, 1994). The various models evaluated and the basis for model selection are provided in SI-Chapter6-2. The equation utilised is as follows:

EQC6-1 $SL_E = 13.403 * EHL_E^{0.6787}$
Where $EHL_E \geq 15.0\text{mm}$ and $\leq 46.1\text{mm}$ $R^2 = 0.8932$: SE $= \pm 3.9\%$

A series of new measurements were evaluated to reconstruct the size of cockles, periwinkles and dog whelks; the latter, it turned out, very similar to the approach of Palmer, (1990). The dog whelk has two ecomorphes, one elongated and the other squat and these have been associated with sheltered and exposed shores respectively (ibid). Within each ecomorph shell height does reflect the size of the organism, but when comparing members of a mixed assemblage shell height loses its power as a proxy. The exposed shore squat form does not exceed 25mm in length in the areas of Anglesey studied by Palmer (1990), a similar size limitation probably occurs in the western Isles, but it cannot be assumed to have the same value. Understanding the relative abundance of each form is obviously of paleoenvironmental interest (cf. Andrews *et al*, 1985) and comparing the size of specimens potentially informative regarding other factors. Comparing assemblages using shell height, that may have originated in different shore exposure regimes, is doomed to failure. This is an important consideration because an underpinning and fundamental principle of this project is that the environment at a given location cannot be assumed to be constant. The work carried out here (SI-Chapter6-3), Palmer (1990) and Jones, (1984), suggests that aperture height is a better proxy for organism size. The size modelling equations utilised to reconstruct cockles and periwinkles are provided below. The evaluation and selection of models, including the definition of the interval of applicability (*sensu* White and Gould, 1963) are provided for all species in SI-Chapter6-3 and 6-4.

EQC6-2 $SH_L = 1.1392 * AH_L^{1.105}$
Where $AH_L \geq 10\text{mm}$ and $\leq 21.65\text{mm}$ $R^2 = 0.8932$: SE $= \pm 3.6\%$

EQC6-3 $SH_C = 3.2715 * SW_C^{0.8776}$
Where $SW_C \geq 6.12\text{mm}$ and $\leq 19.56\text{mm}$ $R^2 = 0.9649$: SE $= \pm 2.4\%$

The remains of crabs were reviewed and set of measurements defined that could be taken from those skeletal elements likely to preserve in a similar manner to Dupont *et al* (2010). The defined measurements were then captured from reference specimens in the Natural History Museums collections and the small reference collection at Durham University and that of the author. The evaluation of alternative models and basis for model selection are provided in SI-Chapter6-5. The resulting models were utilised to model the size of edible and shore crab in terms of carapace width are provided below.

EQC6-4 $CW_{Cp} = 5.9633 * DL_{Cp}{}^{0.8783}$
Where $DL_{Cp} \geq 6.5\text{mm}$ and $\leq 51.0\text{mm}$ $R^2 = 0.9847$: SE = $\pm 4.8\%$

EQC6-5 $CW_{Cp} = 16.734 * DW_{Cp}$
Where $DW_{Cp} \geq 2.0\text{mm}$ and $\leq 12.0\text{mm}$ $R^2 = 0.9968$: SE = $\pm 3.6\%$

EQC6-6 $CW_{Cp} = 14.512 * PL_{Cp}{}^{0.6955}$
Where $PL_{Cp} \geq 4.1\text{mm}$ and $\leq 36.0\text{mm}$ $R^2 = 0.9404$: SE = $\pm 7.6\%$

EQC6-7 $CW_{Cm} = 7.2631 * DL_{Cm}{}^{0.7447}$
Where $DL_{Cm} \geq 8.3\text{mm}$ and $\leq 25.0\text{mm}$ $R^2 = 0.8725$: SE = $\pm 4.9\%$

EQC6-8 $CW_{Cm} = 23.519 * DW_{Cm}{}^{0.6295}$
Where $DW_{Cm} \geq 2.0\text{mm}$ and $\leq 7.0\text{mm}$ $R^2 = 0.7671$: SE = $\pm 6.4\%$

EQC6-9 $CW_{Cm} = 11.021 * PL_{Cm}{}^{0.6695}$
Where $SW_{Cm} \geq 6.3\text{mm}$ and $\leq 18.8\text{mm}$ $R^2 = 0.7765$: SE = $\pm 7.2\%$

The biometric analysis of fish otoliths was carried out and the lengths of otoliths modelled from the otolith width where length was not available using the equation below.

EQC6-10 $OL = 2.6165 * OW$
Where OW $\geq 1.2\text{mm}$ and $\leq 5.7\text{mm}$ $R^2 = 0.9969$: SE = $\pm 3.4\%$

The weight of fish was based upon the actual otolith length or the modelled length using the equation given by Harkonen (1986, p.102). The details of these evaluations and the resulting models that were deployed are provided in SI-Chapter6-6.

6.4.3 The Presentation and Statistical Analysis of Biometric Data.

When working extensively with the materials described above the analyst can readily visualise the population structure and identify outliers purely in terms of the features measured. Therefore, graphs detailing biometrics of these morphological features have an immediate and direct meaning. It is necessary to recognise that for a non-specialist (in a given taxonomic group) such an approach would take-on a rather abstract nature. Therefore, figures are presented utilising the modelled values of attributes which will hopefully convey a more digestible picture. Razor clam are presented as shell length, cockles are presented as shell height, as are periwinkles. Crabs are presented as carapace width and fish are presented in terms of weight. Fortunately, it has not been necessary to develop multivariate models (beyond that of limpet volume) and therefore the statistical analysis is conducted directly against the values measured for the specific biometric that drives a given model. For razor clams this is external hinge length; cockles, valve width; marine snails, aperture height; and fish otolith width. Crabs are an exception as although each equation uses only one variable, multiple equations driven by different variables are used and therefore statistical analysis for crabs is performed against modelled carapace width as it is against modelled volume for limpets. Testing results are not expressed against a standard confidence level (CL) but the confidence level that H_0 can be rejected at. If rejection is not stated, then the failure to reject is at CL=95%.

6.4.4 Age at Death

Age at death of specimens and the population structure in terms of this variable is also informative. It can provide an insight to seasonality as discussed above. It can also, when combined with size at death, potentially provide an insight on the intensity of exploitation or conversely suggest environmental vectors may be operating. Age at death was estimated by sectioning limpets and cockles and for limpets counting the growth lines in the apex (Plate C6-14). For cockles age was determined by the annuli in the shell perimeter, and this could be compared with the growth increments within the umbo. For mammals, the age at death can be determined by the level of skeletal maturity in the form of the epiphyseal fusion of the long bones (cf. Davis, 1995) and (usually for herbivores) the state of dental development and wear (cf. Payne, 1973; Grant, 1982). Some authorities also look at the bone structure in terms of porosity, but such an approach is not utilised by this project. For avian taxa, skeletal development is more difficult to assess as much of the bone fusion occurs prior to hatching and some of those bones that fuse post-hatching are fragile and are usually detached from each other by the time excavation occurs (Cohen and Serjeantson, 1996); the absence of dentition is also a major limitation.

Molluscs generate growth lines and usually (at temperate or arctic latitudes) these are putatively associated with the growth abatement that accompanies colder temperatures during winter. However, secondary abatement periods do occur due to spawning stress (Orton, 1928a) and or thermal stress and must be considered. The growth profile is also asymptotic, and the growth bands become ever more closely spaced in larger older specimens and this can make their identification challenging. The detailed protocols adopted and a discussion of those rejected are provided in SI-Chapter6-7.

6.4.5 Seasonality

Understanding the seasons during which a site was occupied and therefore the levels of residential mobility is a matter of some importance as discussed in chapters 2, 3 and 4. Determining seasonality has been evaluated in chapter 4 and the main approaches defined. For birds size can also be considered, subject to a firm identification to species level being made, as adult size is achieved relatively quickly so specimens below the normal adult size range can be considered juvenile, unless the species exhibits significant sexual dimorphism. Identification to genus level however is not normally sufficient for this method to be applied, as illustrated by the data collected for the herring gull (*Larus argentatus*) and greater black backed gull (*Larus marinus*) and presented in SI-chapter6-8.

Crabs move into deeper water in the autumn and remain there until spring. Whether crabs can be considered a year round resource or a seasonal one depends upon how they are procured. Residence is also linked to size and therefore age. Larger and older specimens move into deeper water and are rarely encountered (under normal circumstances) within the inter-tidal zone (Bennet, 1985). For example, with the edible crab this relocation occurs when the carapace width reaches 70-80mm (Heraghty, 2013), and for the shore crab (*Carcinus maenas*) specimens over 60mm are mostly found in the infralittoral. The use of creel (lobster pot) type technologies in the sublittoral may enable year round procurement, but sexually mature females do not feed over winter (December to May) reducing the catchable population, hence 85% of the catch in the modern English Channel fishery is obtained between June and November (Bennet, 1995).

Approaches to determining seasonality from the growth lines in molluscs have been reviewed in chapter 4. Within the literature there is a generally valid assumption that the growth abatement occurs during the winter with a growing season of roughly March to November (at temperate latitudes) with some nuancing for different species (cf. Baxter, 1982; Ballantine, 1961a; Lewis and Bowman, 1975, Orton, 1928b; Henderson and Richardson, 1994). For smaller specimens, especially those that are not sexually mature this is a reasonable construct. For some species, such as limpets and razor clam, a difficulty arises with larger sexually mature individuals, as the vast majority of growth occurs within a far more constrained growing period of March to July, after which energy is invested in gonad development (see sources cited above). Spawning stress can result in a period of growth abatement, especially if combined with thermal stress during the summer. The details of these evaluations and the resulting models that were deployed are provided in SI-Chapter6-7.

Season of occupation can also be estimated from the population structures of fish for which either the biometrics of bones or that of the ear stones (otoliths) can be utilised. The question of whether the model of Mellars and Wilkinson (1980) can be ported to other locations has been tabled in chapter 4. Based upon the research of Jones (1991) the width of the otoliths can also be utilised as an alternative to otolith length. The taxonomic composition of the fish assemblage can also indicate seasons during which humans were present (chapter 4). Otolith lengths are modelled from width using equation EQC6-10. Weights are modelled from either measured lengths or modelled lengths using the equations provided in Harkonen, (1986, p.102). The details of the evaluation and selection of the models deployed are provided in SI-Chapter6-6.

6.4.6 Fragmentation

Preservation state helps elucidates how certain resources were utilised or treated. Bone was categorised in terms of burning state; being either carbonised, partially blackened, or calcined. Attempts were made to identify cutmarks, but extensive surface damage due to root acid etching made this problematic and the approach was dropped. One aspect that was very clear during the initial sorting of the assemblage during 2014 and 2015 there was the difference in fragmentation between periwinkles and dog whelks and this was explored further in this project. It was also clear that in many cases where only the length could not be measured the damage to periwinkles was limited to the loss of the protoconch, where the measured minimum length relative to the modelled length was greater than

95%. The loss of the protoconch from otherwise undamaged shells is a damage profile common in specimens within the strand lines on beaches (pers. obs). This pattern of fragmentation is counter intuitive as the dog whelks have far more robust shells in terms of shell thickness (SI-Chapter6-3), which was assessed as the thickness of the outer lip of the aperture (Plate C6-9). Marine mollusc shell was similarly categorised in terms of burning signatures.

For selected taxa fragmentation (periwinkle, dog whelk, razor clam, limpet, edible crab and otoliths), was recorded. The definition of fragmentation utilised for each species is defined in table C6-11. Otoliths were recorded in terms of being normal, carbonised or stained, the latter possibly due to being discarded on the midden within the fish's head and the action of decomposition (cf. Disspain *et al*, 2016). The level of erosion was also classified in terms none/minimal, eroded,loss of surface pattern definition; or very eroded, complete loss of surface morphology, friable and in some cases loss of all but the inner 'skeletal structure' (SI-Chapter6). Fragmentation levels of otoliths were also recorded following Jones, (1991) but with some minor adjustments. Crab remains were defined in terms of fragmentation, which is most easily achieved for the edible crab (*Cancer paguras*) as the number of teeth on the propodus and dactylus is fixed at four throughout life. Other species present a more difficult suite of challenges and therefore only complete, distal, proximal and medial were recorded.

Table C6-11: Definition of fragmentation by taxon.

Taxon	**Fragmentation Metrics**
Razor Clam	% with LTL_E Measurable % EHL_E Measurable.
Periwinkle	% of SL_L, AL_L, SW_L, AW_L combined that can be measured for each specimen.
Dog Whelk	% of SL_N, AL_N, SW_N, AW_N combined that can be measured for each specimen.
Limpet	% of specimens for which SL_P, SW_P, SH_P could all be measured.
Edible Crab	Number of teeth present on each fragment of dactylus or propodus.
Otolith	Proportion <25%, 26%-49%,50%-74%,75%-89%,90%-99%, of length present, plus complete

6.5 Results

The results will be presented for the sites in decreasing age sequence with Northton first and West Voe last. The tables providing detailed summary statistics including sample sizes for the biometric data are provided in SI-Chapter6 to permit the reader to consult them whilst also consulting the main text. Statistical testing outputs are also provided in SI-Chapter6-1,2,3,5,6,7, with CL values provided in the main text. The statistical analysis presented in subsequent subsections is guided by the following general principles. The general shapes of all distributions were established graphically and combined with the values obtained for skew and kurtosis assessed for normality. When approximate normality was evident parametric tests were employed. Where the deviation from normality was material a non-parametric test was utilised.

As already stated, the provision of detailed results at site level has no real archaeological meaning or value. But the assemblages can be characterised, and a sense of scale given, by providing raw counts of different taxonomic groups; this is a statement of the archaeological task and is not a basis for comparative analysis between sites. The assemblages in general are relatively small by the standards of the region. These high-level characteristics are provided in table C6-12.

Table C6-12: Site level summary. The data regarding lithic artefacts was kindly provided by Dr. S. Piper (pers. comm).

Site	Bone Fragments	Crustacean Fragments	Mollusc MNI	Otoliths Fragments	Lithic Artefacts	Bone Artefacts	Worked Shell
Traigh na Beirigh 1	383	3461	26966	927	320		1?
Traigh na Beirigh 2	2164	257	13797	594	342	1	3
Traigh na Beirigh 9	56	n.d.	1412	n.d.	320		
Pabaigh Mor South	90	102	2752	470	13		
Northton (2001 and 2010)	854	0	102	n.d.	809		
Teampuil an Bagh	1234	14	252	n.d.	75	3	
West Voe	5030	35	2339	n.d.	289		5

6.5.1 Northton.

The new assemblages from the 2010 excavations have been combined with the limited amount of Mesolithic material from the 2001 excavations with context matching carried out as defined in the site description. Northton is not a shell-midden but an occupation surface and therefore is a very different kind of deposit to those from the Cnip headland described later in this chapter.

6.5.1.1 The Marine Molluscs

6.5.1.1.1 Composition

The marine mollusc assemblage is interesting for apart from apart from 7 limpets in phase 1, and 2 limpets and one mussel in phase 4, the mollusc assemblage is confined to phase 3 (figure C6-13) and all but one cockle and seven mussels to context 14. The small assemblage is dominated by limpet with a sizeable contribution from cockle, unusual for north-west Scotland. No molluscs are reported from the 2001 excavations which is consistent with the findings of this project in relation to phases 4 and 5. It is unclear why molluscs appear not to feature in these earlier phases as they are represented strongly at other sites that are roughly contemporary (Chapter 5).

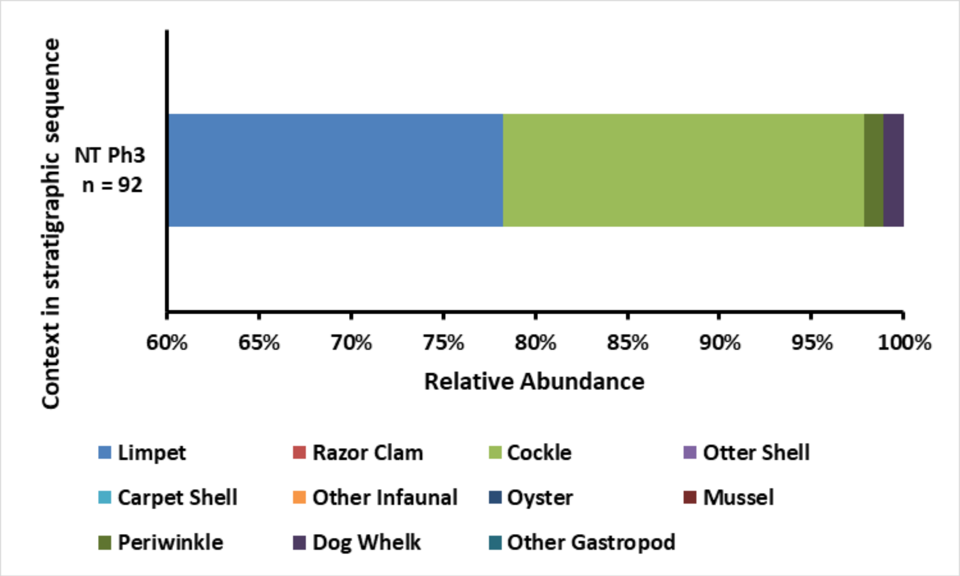


Figure C6-13: Relative abundance of marine molluscs as a percentage of total MNI. 84 of the specimens were in context 14.

6.5.1.1.2 Biometric Analysis

Biometric analysis could not be conducted for limpets as no measurable (even just length) specimens are present. The single dog whelk, which is very large with an aperture height of 23.16mm (shell height 39.41mm, the largest in any of the new assemblages analysed by this project), is complete in every respect suggesting that the animal was probably extracted and eaten. The single periwinkle was in the form of a broken off apex. Biometric analysis of the cockles was conducted, and the results will be presented in chapters 7 and 8 as part of an exercise in comparative growth rate analysis.

6.5.1.2 The Bone Assemblage

6.5.1.2.1 Composition

The total number of bone fragments (excluding fish) identified from the 4R fraction are as follows: phase 3 has 65 (this project), phase 4 has 709 (Hamilton-Dyer, 2006; this project) and phase 5 a meagre 17 (ibid, this project). The fish bone from the 2010 excavation has not been analysed and no otoliths have been identified. The phase 4 fish bone assemblage from the 2001 excavations (763 fragments, NISP 313) is interesting and positive identifications of whiting (*Merlangius merlangius*), cod, herring, three bearded rockling (*Gaidropsarus vulgaris*), wrasse and mackerel have been made (Hamilton-Dyer, 2006). The latter being a summer visitor to the inshore waters of the north east Atlantic. The mammalian and avian assemblages are provided in figures C6-14 and C6-15 respectively. The specimens designated as small mammal or micromammal have been omitted as they are almost certainly intrusive from a later period. The assemblage is small, and identification further hampered by the fact that just about 100% of the bone fragments are calcined. Phases 5 and 4 confirm the presence of mountain hare in the archipelago from early in the 7th millennium BC. Evidence for the exploitation of hares is rare in the Scottish Mesolithic and whether any others within published assemblages can be securely assigned to the Mesolithic is doubtful. Based upon distal humeri phase 4 has a MNI of three, which is surprising given the NISP total is only 38. Otter is also present in these earlier phases, as are seals. Phase 4 contains chunks/slivers of bone from medium/large mammals which may be the waste from tool production. The bird assemblage in phase 4 is diverse and contains the remains of geese/ducks (anseriformes) alongside those of auks, and cormorants which is unusual, as is auks being a minor component. Phase 3, whilst

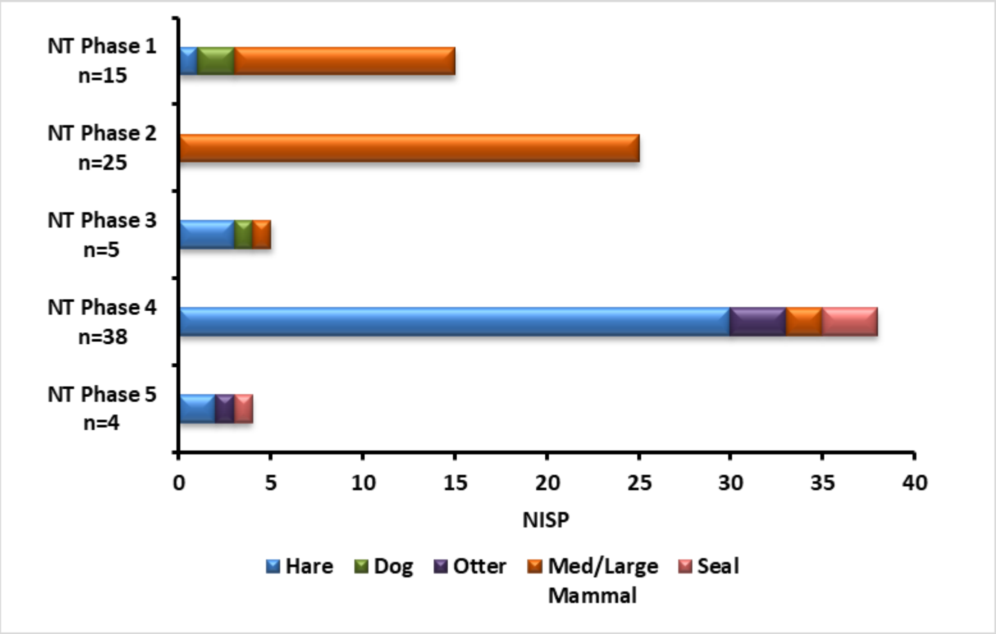


Figure C6-14: Abundance of mammal bone in NISP. All bones from phase 3were found in context 14, except for the medium/large mammal bone which is from context 3.

lacking otter, does contain the remains of dog, which provides a *terminus ante quem* for when dogs accompanied humans on maritime journeys to the archipelago. The desperately small bird assemblage contains only guillemot (*Uria aalge*) with a MNI of one. No fragments of crab were found within the assemblages of any phase and none are recorded on the sample sorting sheets. Phase 3 is slightly problematic for as Ascough *et al*, (2017) observe the ^{14}C assays obtained from the hazelnut fragments and the limpet shells cannot relate to the same period of occupation and the delta is approaching 2,500 ^{14}Cyrs; the hazelnuts sit comfortably with phase4 and the shells are first half of the 4th millennium BC. The question arises as to whether the small bone assemblages should be associated with the hazelnuts or the molluscs. Based upon the skeletal element representation, the hare from phase 3 could be from phase 4. The bird assemblage is not so clear cut as the auk remains in phase 4 are limited to the femur of a great auk, puffin (*Fratercula arctica*), and the shaft of a long bone. Phase 3 contains the remains of a guillemot with two coracoids that articulate perfectly with a sternum. Whilst 78% of the bird bone in phase 4 is burnt none of the bird bone in phase 3 is. Likewise, 95% of the mammal bone is burnt in phase 4 and only one of the three hare bones are burnt in phase 3. Based upon the above, phase 3 is interpreted as a mollusc assemblage in association with the remains of a guillemot, and *possibly* a hare, from the first half of the 4th millennium BC. This scenario should not cause any concern as it has already been encountered at Sao Juliao in Portugal (chapter 5).

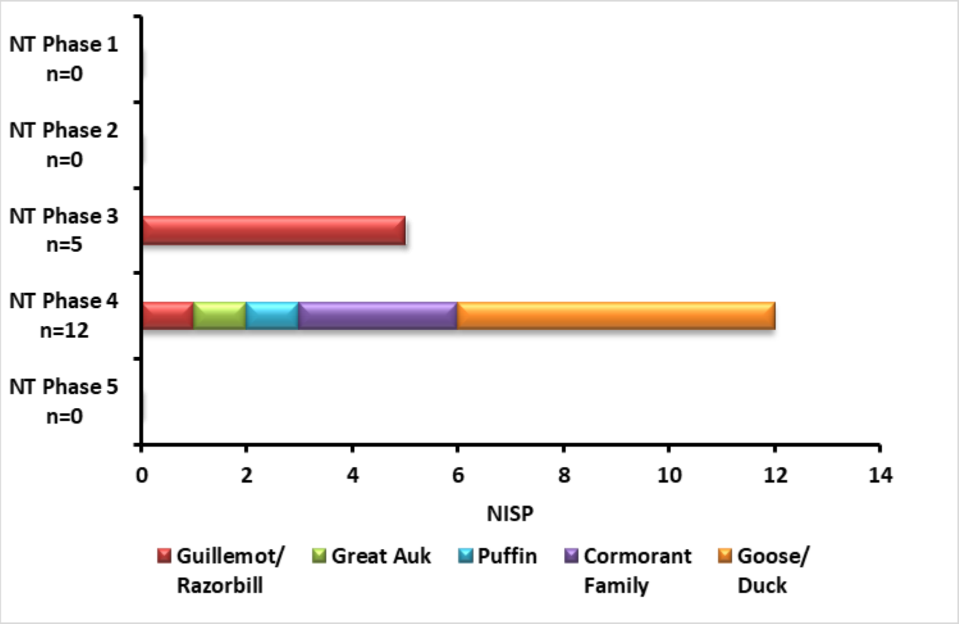


Figure C6-15: The avian assemblage presented as NISP.

6.5.2 Interim Summary.

The assemblages are very small and suggest nothing more than small scale occupations by mobile groups. The remains surviving from phase 5 can do nothing more than confirm the presence of mountain hare early in the 7th millemium BC and that seal and otter were probably exploited. The bird assemblage is non-existent and the fish assemblage not far from it. Late in the 7th millennium BC phase 4 provides a little more insight into the subsistence economy, which includes the exploitation of mountain hare, otter and seal and a diverse range of fish. Tool production on terrestrial mammal blanks also seems likely. The bird assemblage suggests spring summer due to the presence of auks, as speciation of the geese/ducks was not possible and there is size overlap between the largest ducks such as the eider (*Somateria mollissima*) and the smaller geese, and therefore an autumn winter occupation cannot be confidently asserted. The fish assemblage also suggests a spring summer occupation. Phase 3 in the first half of the 4th millennium BC is the first occasion on which any meaningful exploitation of molluscs is observed, possibly combined with the exploitation of hare, seal, and guillemot, along with the presence of dog. The bird assemblage is consistent with that of the Neolithic horizon presented by Finlay (2006), although the presence of molluscs is not. The exploitation of cockle is not typical of the Mesolithic of north-west Scotland and it is possible that this assemblage relates to Neolithic people, who may have been in transit. The earlier tail of the PD range however is within the bounds of those associated with individuals from the first half of the 4th millennium BC who had a hybrid diet as evidenced at TNB9 and Oronsay (Richards and Mellars, 1998) and not the date for the Neolithic horizon.

6.5.3 Teampuill an Bagh.

The site of TB is in close proximity to NT (Plate C6-6) in the Traigh an Teampuill on the Toe Head peninsula and following the confirmation of the Mesolithic occupations at NT and TNB1, became the third Mesolithic site to be identified in the Western Isles. As with Northton the deposit in not a shell-midden but an occupation surface. The excavation team have identified four phases of which phase 3 is further subdivided into three sub-phases. The assemblages consist of marine molluscs, mammal bones, bird bones, fish bone and a small amount of crab (Table C6-13).

Table C6-13: Summary of the faunal assemblage. Preservation in phase 2 is particularly poor which results in a very low NISP count.

Phase	Bone Fragments	Crustacean Fragments	Mollusc MNI	Otoliths Fragments	Bone Artefacts	Worked Shell
Phase 4	1	0	0	n.d.	0	0
Phase 3c	114	0	1	n.d.	0	0
Phase 3b	208	9	186	n.d.	2	0
Phase 3a	622	2	50	n.d.	0	0
Phase 2	190	0	7	n.d.	0	0
Phase 1	0	0	0	n.d.	0	0

6.5.3.1 The Marine Molluscs.

6.5.3.1.1 Composition

The mollusc assemblages are also rather small compared with the numbers of shells encountered in actual shell-midden deposits. The taxonomic composition of the molluscs is provided in figure C6-16. Given the nature of the deposits which include an amount of ash and carbonised material the composition can be interpreted as giving an indication of the role of different taxa in human subsistence. The periwinkle preservation is also good with approaching 80% exhibiting little or no damage (figure C6-18). The other gastropod category varies from others considered by this project in that *Littorina fablis*, *Littorina obtusata*, *Gibbula spp*, and *Lacuna spp*. are absent and the netted dog whelk (*Hina reticulata*) and the habitually sublittoral *Raphitoma spp*. are present.

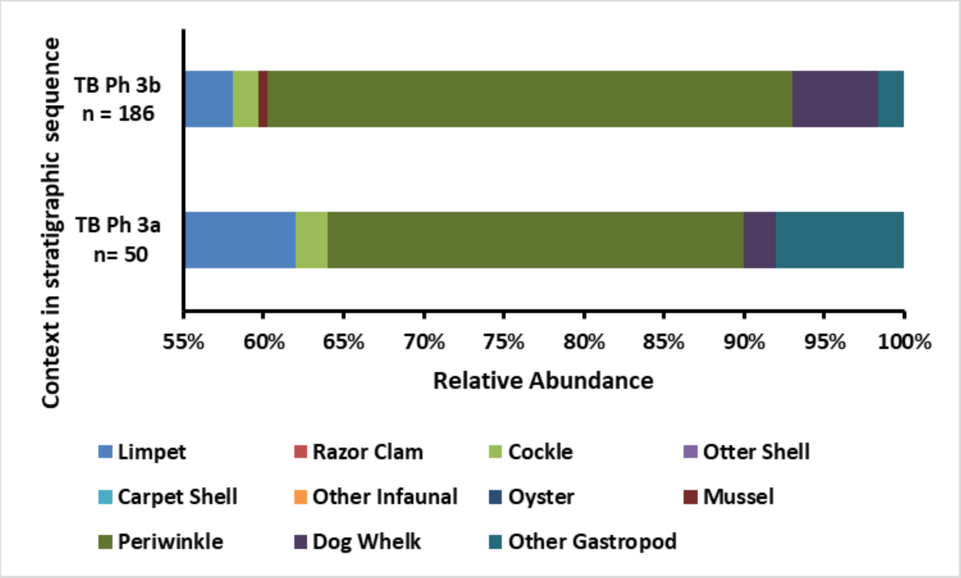


Figure C6-16: The relative abundance of the molluscan taxa as a proportion of total MNI.

6.5.3.1.2 Biometric Analysis

No measurable limpets or dog whelk are present. The periwinkles are rather small and therefore have relatively thin shells even for their species (figure C6-17). The fact that the fragmentation levels are so low further supports the idea that molluscs for human consumption tend not to be smashed (figure C6-18). The two cockles are of a larger size than those at Northton, but smaller than those at the later sites.

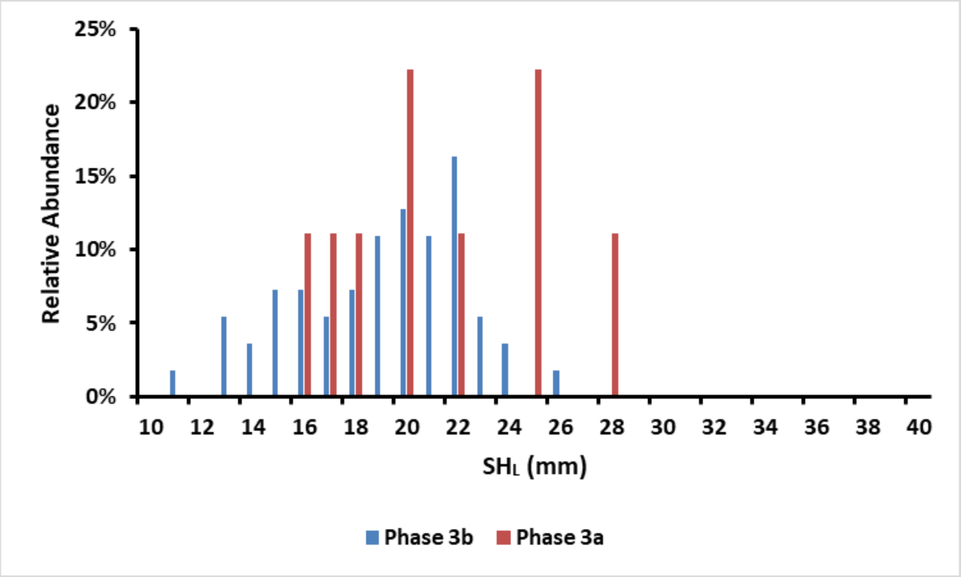


Figure C6-17: The population size structure in terms of SH_L the data presented includes measured length and modelled lengths. Phase 3b n=55 and Phase 3a n=9.

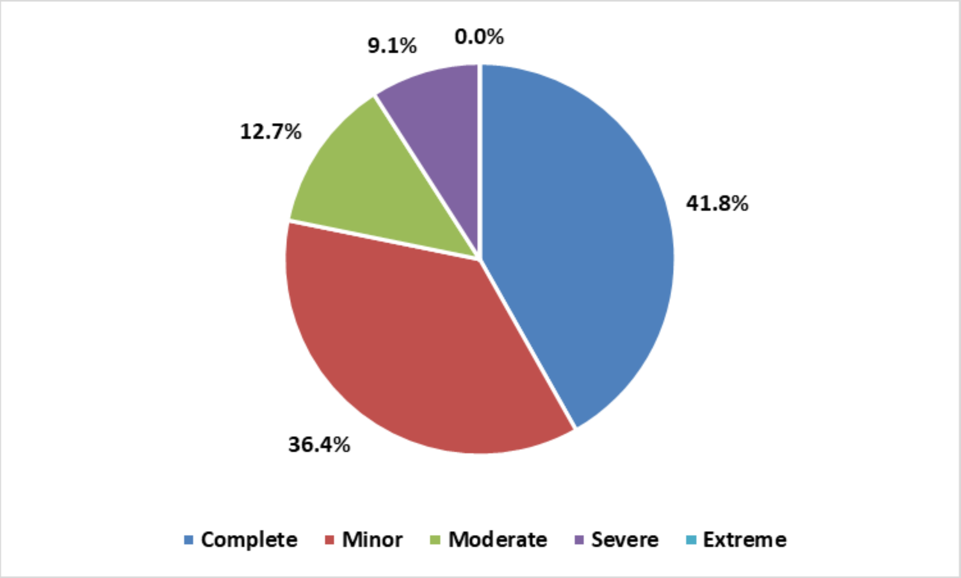


Figure C6-18: Proportion of population that yielded at least 1 of the defined biometric measurements in phase 3b within the defined fragmentation categories. n=55.

6.5.3.2 The Bone Assemblage

6.5.3.2.1 Composition

The bone assemblage is modest, and the mollusc and crab assemblages even more so, but despite the remains being very fragmented, the state of preservation is good. The composition of the mammalian assemblage is provided in figure C6-19 and that of the birds in C6-20.

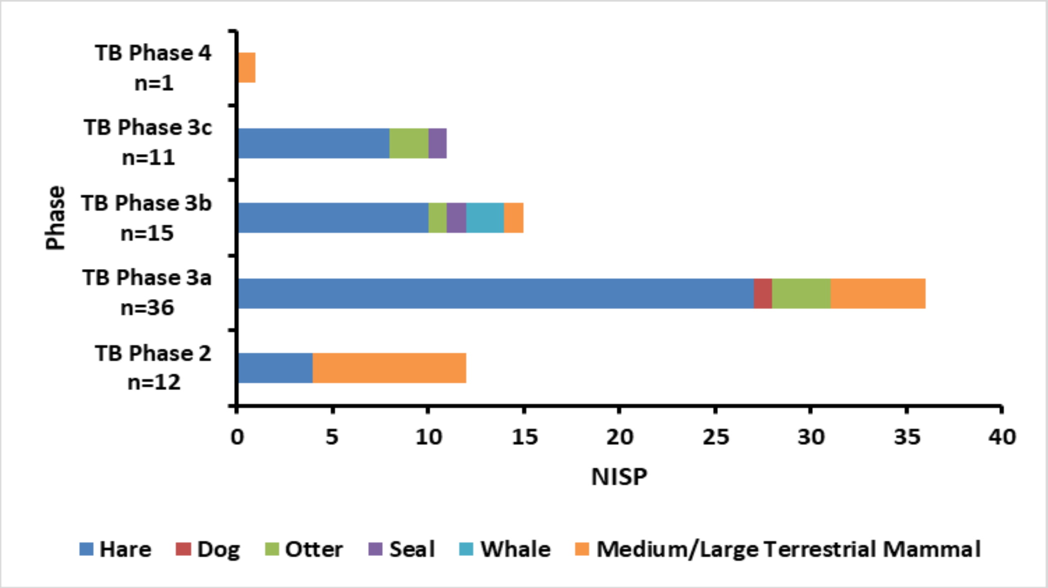


Figure C6-19: The mammal assemblage from Teampuill an Bagh in NISP.

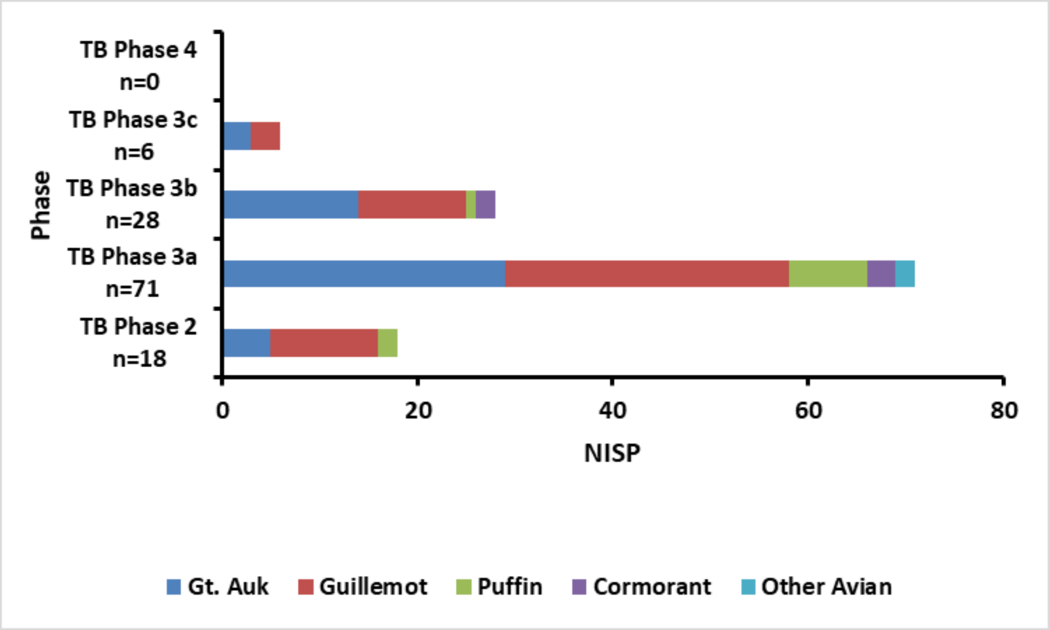


Figure C6-20: The avian assemblage from Teampuill an Bagh in NISP.

The mammalian assemblages are dominated by hare reaffirming the general availability of this resource within the archipelago. Dog is present in 3a but not the later phases. Otter is present throughout, whilst seals and whale are not major components and appear in the later phases. Throughout robust chunks and slivers of terrestrial mammal bone are present, these lack a cortical wall and despite their thickness there is no sign of the curvature and inner surface of the medullary cavity. As surmised for Northton these are probably waste from tool manufacture. Also included in this category are an unworked antler tine from a red deer, and two short sections of bone point which appear to have been made from antler. One section looks as if it was in the process of being shaved down to form a barb, an activity that ended soon after it commenced. The bird assemblage is dominated by the auk family (MNI for great auk in phase 3a is 2 based upon furcula) with a small contribution from the cormorant family, and a couple of fragments of grey heron (*Ardea cinereal*) are present. In contrast to Hamilton-Dyer (2006) the author considers the auks to be a spring summer seasonal indicator.

6.5.4 Interim Summary

The small size of these assemblages must be acknowledged and the difficulty this causes in terms of interpretation likewise. The skeletal element representation provides no evidence for anything other than a single individual of each species (except for great auk) in each phase or sub-phase, this is emphasised by the frequent occurrence of refits of ancient breaks. In one case the ulna of a great auk came in three instalments. A clear contrast to the sites presented in subsequent sections is the lack of dentition, cranial elements and phalanges belonging to hare and in the case of phalanges birds as well. The available material is consistent with a short term stay where a meal was prepared and consumed.

The diverse nature of the assemblage may represent several such discrete occupations where what was available, be it a hare, a cormorant, a razorbill (*Alca torda*), guillemot, or great auk, had to suffice, accompanied by some molluscs and no doubt a combination of vegetables, nuts and fruits. The same pattern would of course result from a stay of a few days, or even a week, if a new meal were procured each day, again based upon what was available. Small groups when in transit may be more likely to acquire subsistence in a more encounter based manner. In either scenario a focused procurement of a resource as reported in chapter 3 is not evidenced and activity was either a brief stopover whilst in transit, or the focus was on something else, fishing perhaps, or one of the myriads of essential but invisible resource types identified in chapter 3.

6.5.5 The Mesolithic Occupation of Toe Head Peninsula.

The area has probably been a thoroughfare throughout the later Mesolithic and probably later periods too. At some point in the 7th millennium BC the Sound of Harris will have formed a relatively sheltered maritime crossing between the Isle of Lewis and the smaller island(s) in the south of the archipelago. It is probably the easiest and safest route for people to travel from the Inner Hebrides, the mainland and east coast of Lewis to the western coast, whether this be for reasons of social interaction, trading, or seasonal relocations. The eastern coast of Toe Head will also provide a campsite, for whatever duration, that offered shelter from the prevailing winds. This route must have been preferred to rounding the Butt of Lewis and then navigating against the prevailing winds and currents, with the ever present risk of being driven out to sea by wind and current and ending up (if lucky) in Orkney or even Shetland. It is clear from chapter 3 that hunter-gatherers are more than capable of understanding these risks and avoiding risky routes when possible, in that example rounding Cape Horn. The richness of the archaeology and its time depth appears to support the importance of the Toe Head area. Before characterising the Mesolithic occupation, the nature phase 3 of NT deposited needs to be revisited.

Traditionally a date in the first half of the 4th millennium BC would be considered Neolithic, but assigning cultural affinity based purely on chronology is fraught with danger. Phase three precedes the Neolithic horizon stratigraphically and the PDs from it do not fall within Northton's Neolithic range. It has also been established at TNB9 and Oronsay (Richards and Mellars, 1998) that individuals existed during the first half of the 4th millennium BC whose diet was a hybrid of the earlier Mesolithic marine dominated diets and later terrestrial diets. It is also established that at Ferriter's Cove in Ireland a community that exploited marine resources quite extensively, also had domestic cows (directly dated) in the late 5th millennium BC (Mcarthy, 1999). Phase three contains no ceramics, and why should it (as observed in chapter 5) if this was a trip to obtain some key, but probably archaeologically invisible resource; why would the task group haul fragile and heavy pots along? Likewise, if conducting a trading mission with valuable resources stored in pots (or a canoe full of tool blanks from terrestrial mammals), it seems sensible to leave them in the canoe or boat whilst making a quick overnight stop. The evidence from the Neolithic horizon (Finlay, 2006) and the Scottish Islands in general (Best and Mulville, 2016) attests the exploitation of seabirds throughout prehistory, the exploitation of molluscs is known to continue throughout prehistoric and historic periods, both in Britain and further afield (cf. Sloan, 1993; Dupont *et al*, 2007; Milner *et al*, 2007; Milner and Woodman, 2007; Alvarez-Fernandez, 2015). Phase 3 will for now remain an enigmatic occupation which resists attempts to assign a cultural label to those who created it.

The Mesolithic occupation of Toe Head stretches back to the very end of 8th millennium BC and continues (but see below) until at least the mid-6th millennium BC and possibly into the first half of the 4th millennium BC. A period that includes the 8.2K cal bp event and the Storegga slide and the data strongly suggests that there was probably a hiatus in occupation between 8.1K cal bp and 7.7K cal bp, when occupation is again attested at TB. The people (and their dogs) appear to have been very mobile and exploited a diverse range of marine resources and the only terrestrial mammal available. Contact with the mainland was probably maintained for all the reasons highlighted in chapter 3, but in this case such contact was an absolute necessity, if the ungulate bones are required for tool manufacture were to be sourced. Skins for clothing are another possible reason for mainland contact, although based upon the observations in chapter 3, the climate on the archipelago probably only demanded a minimal level of provision; that is until *circa* 8.2K cal bp. Whether such contact included the acquisition or trade of the numerous other essential but invisible resources identified in chapter 3 remains a matter for conjecture.

In 2005 Northton provided the first firm evidence for a Mesolithic occupation (Gregory *et al*, 2005) finally putting an end to the frustrations of the palynologists. Prior to moving onto the Cnip headland a final question must be considered. Are the hares a natural population or were they introduced to the archipelago by hunter-gatherers? Anthropogenic faunal introductions to islands have been proposed or demonstrated in numerous settings, the most relevant being the introduction of hare to the Island of Gotland in the Baltic (Ahlgren *et al*, 2016 and references therein) during the Mesolithic. Hares first appear in the Mesolithic of Spain during the early Holocene as they emerged from southern refugia (Clarke, 1983), after which they could migrate into Britain as it was still joined to continental Europe during the Allerod-Bolling interstadial. It is probable that the Minch may have frozen (at least during the winter) during the following Younger Dryas stadial and hence colonisation would have been possible. But given this species waited out the glacial in southern refugia it is necessary to ask: could it survive at these latitudes during the stadial? The position is unclear, but the far less severe 8.2K cal bp climatic event sees the consistent and rapidly increasing effective population size, as determined from mitochondrial DNA diversity, drops temporarily within Europe (Smith, S. *et al*, 2017); suggesting that maybe surviving the stadial would have been something of a challenge. The jury remains out on whether the hares in the Western Isles are the first and earliest case of hunter-gatherer niche construction (*sensu* Rowley-Conwy and Layton, 2011) in Atlantic Europe.

6.5.6 Traigh na Beirigh 2

The results will be presented in this section will focus on columns containing contexts 5 and 11 from the centre of the section. This is not because data from the southern extremities of the midden are not interesting, the very opposite is true, but as no radiocarbon PDs exist for these contexts the possibility of them being later extensions cannot be ruled out, especially as they share certain characteristics with TNB1 especially the contexts in section A-B at that site.

6.5.6.1 The Marine Molluscs

6.5.6.1.1 Composition and Yield.

The taxonomic composition is provided in figure C6-21 and the yield per litre in figure C6-22. The focus is on the main midden contexts (5,11,15,18) as the lowest levels contain very little material and the upper interface layers cannot be securely treated as Mesolithic, although it should be noted that razor clam features strongly in these upper interface layers. The assemblages exhibit an atypical characteristic in terms north-west Scotland in terms of the extensive role played by infaunal bivalves and especially razor clams. Conventionally, since the excavation, context 5 has been considered the main midden, and it does have the greatest abundance of infaunal bivalves, yet in terms of yield per excavated litre (all taxa) context 11 appears to reflect a slightly more intensive period of exploitation.

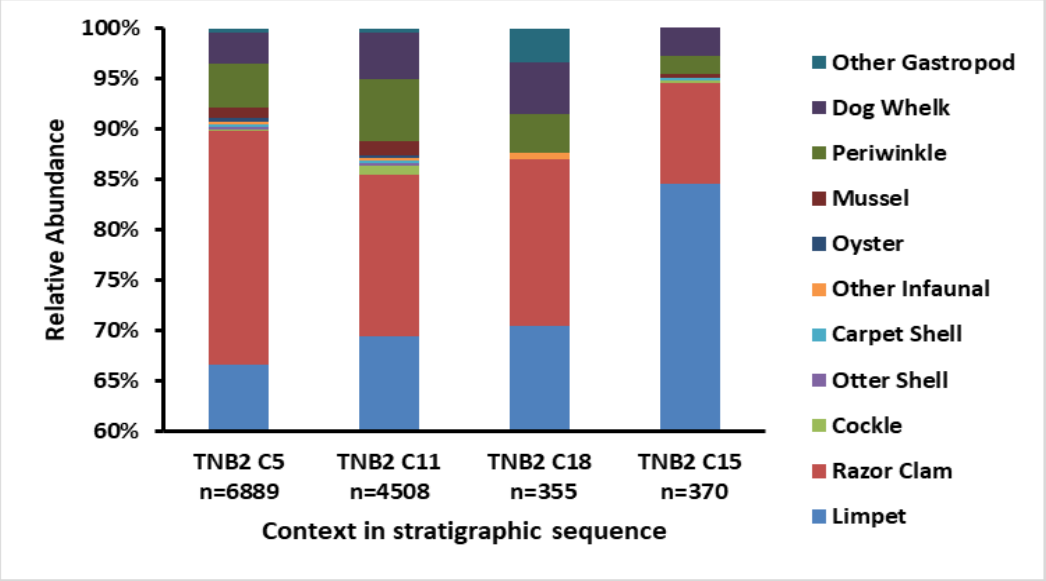


Figure C6-21: The relative abundance of marine molluscs in a sequence going from south to north within the excavated section.

The most abundant species are limpet, razor clam, periwinkle and dog whelks, and if it were not for the presence of razor clam the other three taxa are those which are most abundant in other assemblages from the sub-region (Milner, 2009a; Russell *et al*, 1995; Pickard and Bonsall, 2012). Other respects in which the midden is typical of north-western Scotland is a paucity of oyster and cockle. Mussels are well represented in contexts 5 and 11 given that they do not survive well for taphonomic and diagenetic reasons at other sites (cf. Milner, 2009a). Yet the exploitation of mussels is probably still understated, and they may have made a reasonable contribution to the economy. As will be discussed in due course, compared with some Scottish Mesolithic sites the middens exhibit high levels of biodiversity.

Returning to razor clam, the relative abundance at 24% and 15% is quite remarkable and is atypical of the middens of north-west Scotland and to the author's knowledge within Atlantic Europe. The closest comparison in terms of relative abundance is at La Chora and Marizulo in Cantabrian Spain where the much smaller grooved razor (*Solen marginentus*) contributes around 4% of the assemblage (*Álvarez-Fernández,* 2015) and Toledo in Portugal where it contributes just over 3% (Araújo, 2016). It is also an innovation compared to the earlier sites on Toe Head. It should be noted that relative to limpets, razor clam (and the large infaunal bivalves in general) yield a lot of molluscan flesh. A typical 30mm limpet will yield around 1.35g of flesh, a larger limpet (50mm in length) 7.5g. A smaller razor clam (100mm in length) yields around 9.5g whilst the largest specimens (200mm in length) yield between 80 and 100g. Evans (2015) modelled the relative flesh yields at TNB1 and concluded that balance of flesh yield between limpets and razor clams was heavily in favour of the razor clams, with the median of the 95% confidence level estimate being 70% from razor clams. Unlike the infaunal bivalves usually exploited in Atlantic Europe the razor clams do not tolerate low salinity levels and therefore are not found in estuarine environments (Holme, 1954). Likewise, whilst most of the exploited bivalves burrow to a depth of between 25 and 50mm and can be obtained either through shallow digging or raking, the razor clams burrow to in excess of 0.5m and do so very rapidly (Richardson and Henderson, 1994).

Evidently razor clams required a different approach to procurement, as raking is not an option, and a couple of possibilities exist. Razor clams are found at LWST and the very largest specimens either at ELWST, or in the infralittoral or shallow sublittoral. They can also be obtained as a windfall resource following ejection during violent storms, which given the abundance levels and ubiquity observed in the assemblages seems unlikely. Procurement is limited to one or two days per calendar month, or even one or two days per annum at some locations during the extreme tides associated with the equinoxes (Holme *et al*, 1954). Conversely, availability would be reduced or even non-existent in some locations during the moderated tides associated with the solstices. Visually guided selective acquisition is possible at LWST during the hours of darkness when the animals can be found lying on the surface of the substrate, albeit it for a very limited amount of time (Holme, 1954; Henderson and Richardson, 1994). Digging down into wet sand for half a meter or more during the turn of the tide is onerous, time consuming, and undertaken blind in terms of the size of the prize on offer, and presumably one would therefore take whatever one found, irrespective of its size. Such an approach is understandable given the relative yield of flesh compared to limpet, periwinkles, or dog whelks; yet the razor clams are large and small specimens are rare. Oysters are a ubiquitous but very minor component of the assemblages and this may suggest that access was restricted, probably due to their position within the tidal range. Cockle is all but absent except in context 11, which seems to reflect an (possibly single) episode of collection.

The ‘other gastropod’ category is more abundant in the lowest and highest contexts where composition is dominated by small species such as *Littorina fablis*, *Littorina obtusata*, *Lacuna spp*., and based upon the author’s informal observations of beach sand and sand dunes, probably reflect natural windblown inclusions. Such specimens are generally complete and often retain their colour. Within the main midden contexts, the contributions from these small species are greatly reduced, with specimens of common whelk (*Buccinum undatum*), other buccinidae, and top shells (*Gibbula spp.*) present. The ‘other bivalve’ category simply reflects the odd examples of various bivalves such as (*Mya spp. Donax spp*. and others) that were probably encountered, along with otter shell (*Lutraria lutraria*) and banded carpet shell (*Polititapes rhomboids*) whilst procuring the razor clams.

Excavated litres provide a reasonable guide to yield and therefore potentially exploitation intensity, but precision calculations cannot be justified. Contexts 11 yields more razor clam than the fairly significant drop in relative abundance suggests. The significant reduction in razor clam relative abundance is not supported by the yield data, which suggests only a minor reduction in absolute levels of exploitation occurred. Contexts 5, 18, and 14 probably reflect the same levels of intensity, whilst contexts 11 and 15 reflect episodes of slightly greater intensity. What this data does permit is a verification of whether relative abundance fluctuations are real or just mathematical balancing within the 100% limit. The fluctuation in abundances appear to be a direct result of exploitation levels. The overall yield of these species declines. Trends are difficult to assess as PDs only exist for the column containing context 5, and it is unlikely that, even if ^{14}C assays had been obtained from the other columns, any definitive temporal sequencing would have been unequivocally resolved. There is a clear trend of reducing exploitation of razor clams from context 5 to context 18. Given context 18’s composition in terms of these four species it is suggested that context 5, 11 and 18 represent earlier phases of activity and context 15 is an extension formed at a later date. This will be kept under review as further data is presented.

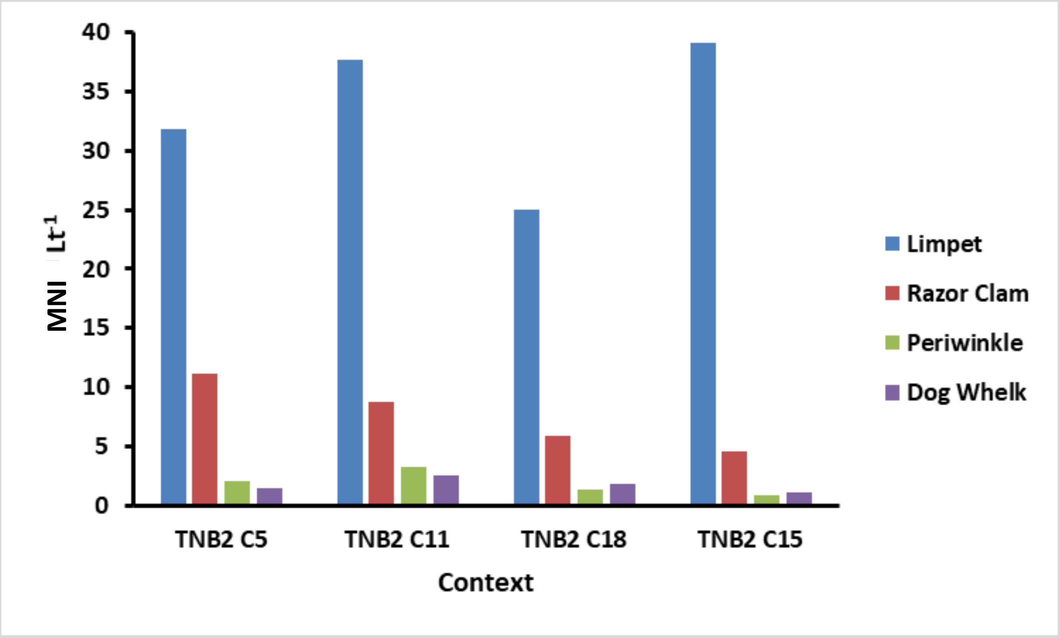


Figure C6-22: Relative yields per excavated litre for selected taxa.

6.5.6.1.2 Biometrics

Biometric analysis was conducted for all the main midden contexts (contexts 5, 11, 18, 15) and SL_P is presented in (figure C6-23); limpet shell volume is also provided in SI-Chapter6-1. Summarised distributions in the form of boxplots are provided here. Descriptive statistics and statistical inference testing outcomes are provided in SI-Chapter6-1 to 4. Given most natural limpet populations are dominated by very small animals and spat (juveniles less than one year old), procured limpet population structures do not reflect natural population structures. However, even if these juvenile specimens (putatively less than 20-25mm in length) are ignored, the procured populations at TNB2 do not reflect natural populations as recorded by various researchers (cf. Baxter, 1982; Blackmore, 1969; Lewis and Bowman, 1975; Thompson, 1980; Ballantine, 1961a). In particular, the mode reflecting limpets greater than 40mm in length is missing. None of the contexts can be considered as a single 'grab everything' that is naturally present event, subject to a minimum length of interest criterion.

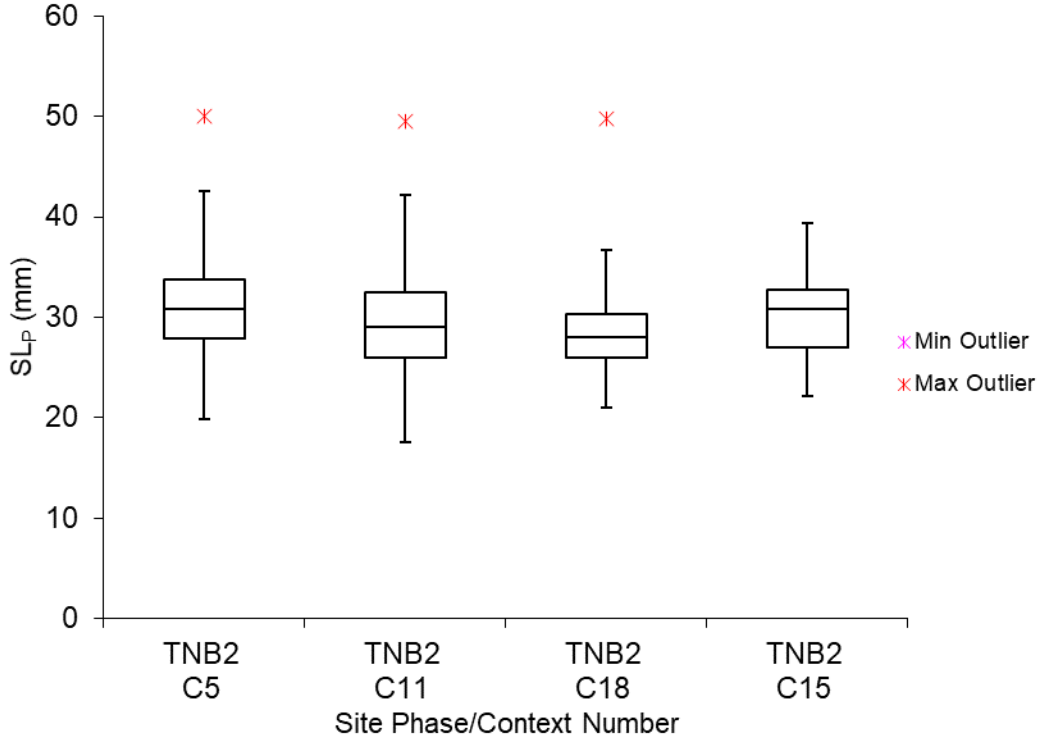


Figure C6-23: The SL_P distribution of the limpets at TNB2 using a conventional boxplot. The horizontal bars within the boxes are the median, the boxes the interquartile range, the whiskers 1.5 x the interquartile range and the stars the minimum and maximum outlier. For context 5 n=1037, context 11 n=549, context 18 n=65 and context 15 n=53.

The longest limpets are found in context 5, reductions occur through contexts 11 and 18 and recovery, to a degree, is observed in context 15, and only materially relative to context 18. H_0 can be rejected when comparing context 5 with 11 (CL=99.99%) and with context 18 (CL=99.9%). The very largest limpets present in contexts 5 and 11 and are not represented well, if at all, in contexts 18 and 15. Clearly the size of the limpets varies between the contexts in terms of the overall amount of flesh each procurement action yields. In terms of volume H_0 is rejected between context 5 and all other contexts at a CL of 99.9%. H_0 is also rejected between contexts 15 and 18 (CL=95%). The restricted range of limpet size in context 15 is consistent with a specific event of short duration as one can only select what is available, time aggregated assemblages are more likely to include extreme sizes as discussed in chapter 4.

The conicity of limpets is presented in figure C6-24. Generally, the majority of specimens fall within the middle range values between 3.5 and 2.5 and suggest a heterogeneous shore configuration in terms of shade, weed cover, rock pools and exposed rocks. Contexts 5 and 11 exhibit values suggesting exploitation of the very lowest (putatively, conicity >3.5) and highest shore zones (putatively, conicity < 2.25). The matter of whether conicity reflects desiccation environment or wave exposure has been discussed in chapter 4 and the conclusion that the primary influence is desiccation regime is utilised here.

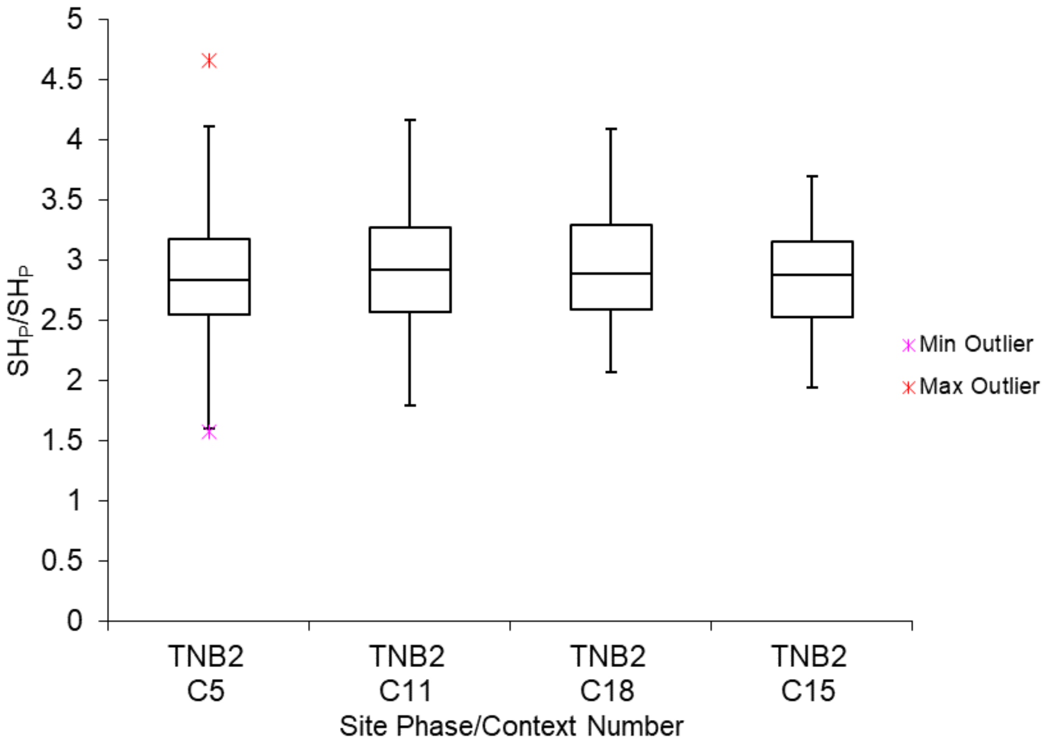


Figure C6-24: The conicity of limpets at TNB2. Generally, the range of values observed reduces with sample size as might be expected. More extreme values can be expected to be encountered the more procurement effort is expended (chapter 4), factored by the lunar cycle. The data suggests acquisition from a variety of environmental settings. Context 5 n=1037, context 11 n=549, context 18 n=65 and context 15 n=53.

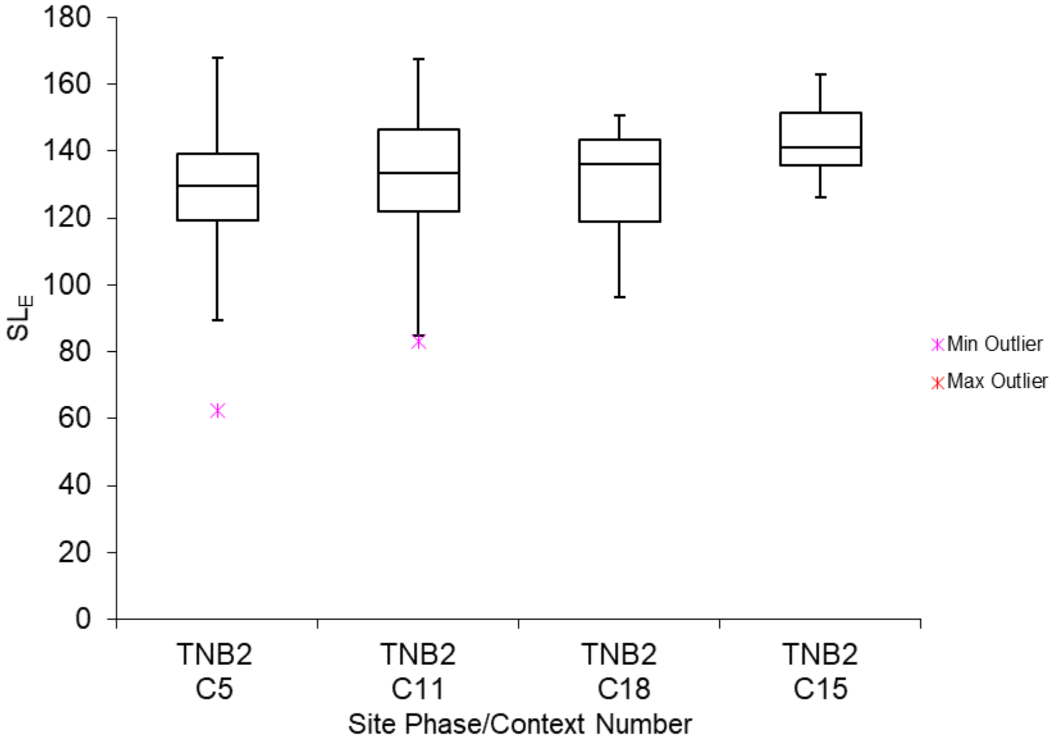


Figure C6-25: The modelled lengths of razor clam. Context 5 n=217, context 11 n=107, context 18 n=17 and context 15 n=10. H_0 can be rejected between all other contexts with Context 15 with CL of at least 95%.

The length of razor clams must be modelled as their extreme morphology and thin brittle shells mean that they do not survive intact. The modelled razor clam lengths are presented in figure C6-25. In contrast to limpets the razor clams are smallest in context 5 whilst context 15 has the largest and most selective population. The sample sizes in contexts 18 and 15 are rather small and therefore interpretation must be handled with caution. Contexts 5 and 11 may reflect multiple acquisitions that occurred at normal spring tides and possibly include more extreme, but less frequent, spring tides. Under such a framework context 15 would be considered to have occurred during one of the more extreme spring tides. Context 18 probably does not include procurement during an extreme spring tide.

An alternative interpretative framework can be applied. Contexts 5, 11 and 18 reflect blind procurement undertaken by digging the razor clams out. This requires significant effort within a limited window of opportunity. In such circumstances the people took whatever they uncovered. In contrast context 15 can be considered as visually selective (or lucky) and reflects procurement from low water spring tide (LWST) in the hours of darkness. It can be shown that differences in fragmentation levels are not responsible for a selective application of the modelling that leads to the results obtained (see below).

A significant proportion of the periwinkles could be measured, and incomplete specimens modelled from the size of the aperture. Figure C6-26 presents the size distributions for contexts 5 and 11. Other contexts yielded too few measurable specimens and although the odd complete one could be included in the regression modelling exercise, providing a population structure is impossible. These populations are significantly different and H_0 can be rejected (CL 95%). The periwinkles in context 11 are larger than those in context 5 and a greater size range is present.

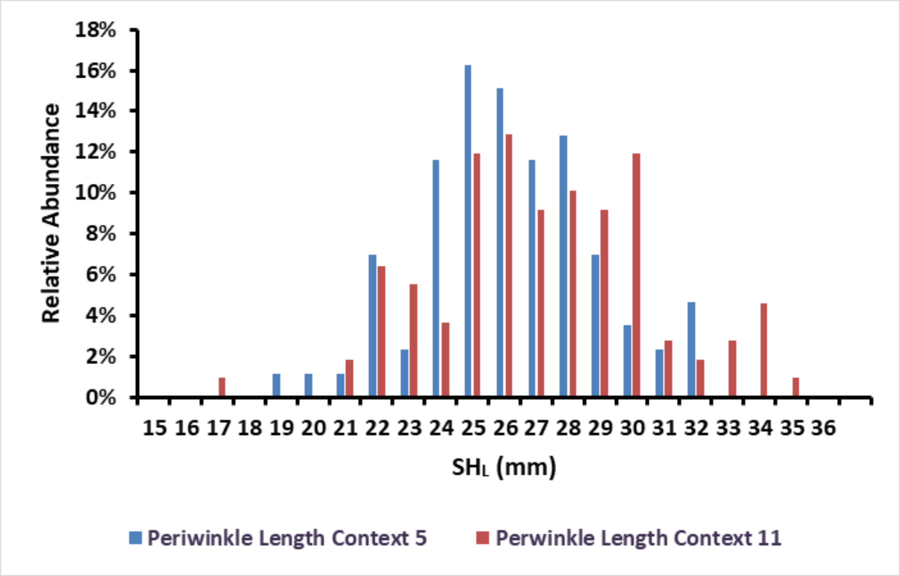


Figure C6-26: The population structure of periwinkles. Sample sizes follow as measured (modelled). Context 5 n=72+(14) Context 11 n=68+(41). H_0 can be rejected at the 99% CL.

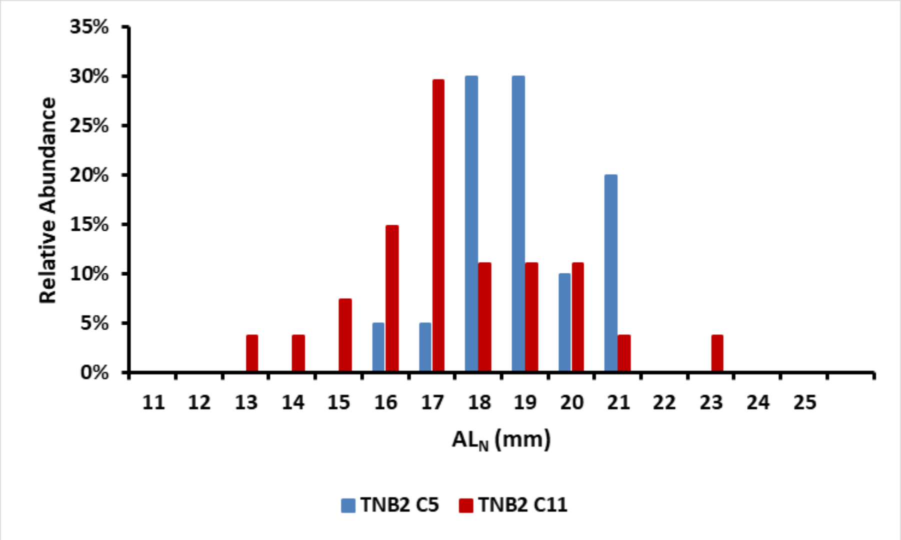


Figure C6-27: The dog whelk population from TNB2. Context 5 n=20 and context 11 n=28. H_0 is rejected at a confidence level of 95%.

Dog whelks are presented in term of the aperture height (figure C6-27) which is more reflective of organism size due to the two different ecomorphs that exist and the material implications this has for overall shell height. Whilst context 11 contains a greater range of sizes, context 5 has the larger specimens. The trend in periwinkle size versus dog whelk size are diametrically opposed, although context 11 exhibits a greater range of sizes for both taxa. This suggests that exploitation of dog whelk is more intensive in context 11. This will be considered further in relation to fragmentation levels.

The fragmentation levels of limpets are presented simply as the ratio between the MNI for a sample/context and the number of measurable specimens. This data and that for razor clam is presented in table C6-14 and for periwinkles and dog whelks in table C6-15. Limpets are less fragmented in context 11 whereas razor clam is more so. The fragmentation levels in context 5 require contextualisation as a very substantial amount of concreted material was present and this was broken up by the author in the laboratory. The recovery levels were very good, and examples of quantifiable bone were rescued along with numerous shells. Recovery of quantifiable shell was very good, but often at the cost of fracture and therefore loss of measurability. Razor clams were more resilient to extraction probably due to the two measurable features being relatively small proportions of the overall organism's length. It should be considered that numerous 'liberated' limpets (and a few marine snails) were also rejected for measurement due to encrustation. Often the encrustation could be removed at the measuring locations, but a reasonable number had to be rejected as cleaning was not effective and the levels of encrustation remaining meant a measurement of sufficient quality could not be obtained. In context 15 the greater level of fragmentation in limpets appears to be genuine. The fragmentation levels of periwinkle and dog whelk warrants a specific discussion.

Table C6-14: Fragmentation of limpet and razor clam as a proportion of MNI.

Context 5	**Complete**	**EHL**	**LTL**	**Delta**
Limpet	20.6%	N/A	N/A	
Razor Clam	0.0%	30.5%	84.5%	54.0%
Context 11	**Complete**	**EHL**	**LTL**	**Delta**
Limpet	28.2%	N/A	N/A	
Razor Clam	0.0%	23.1%	80.3%	57.2%
Context 18	**Complete**	**EHL**	**LTL**	**Delta**
Limpet	26.0%	N/A	N/A	
Razor Clam	0.0%	28.8%	88.1%	59.3%
Context 15	**Complete**	**EHL**	**LTL**	**Delta**
Limpet	16.9%	N/A	N/A	
Razor Clam	0.0%	27.0%	91.9%	64.9%

Table C6-15: A comparison of dog whelk and periwinkle where the shell height is complete as a proportion of MNI.

	Periwinkle	Dog Whelk
TNB2 C5	24.5%	1.4%
TNB2 C11	24.7%	4.0%
TNB2 C18	0.0%	5.6%
TNB2 C15	14.3%	0.0%

Fragmentation levels are very different between these two snails see table C6-12. In contexts 5 and 11 the number of periwinkles with their shell height complete is almost identical and much higher than that observed for dog whelk. The fragmentation was analysed further in terms of the proportion of specimens from which at least one of the defined measurements could be taken (Figure C6-28). The difference between these two snails is startling, especially given that dog whelks have a much more robust shell (SI-Chapter6-3). Deith (1983) suggested that fractured shells were used for bait as bits of shell imbedded in the flesh is not an issue, whereas if consumed it would be, to which the author would add; especially given the thickness of dog whelk shells. These two snails appear to be processed and presumably utilised differently. Based upon this argument the data suggests more use of dog whelks for human consumption in context 11. Other researchers have noted high levels of fragmentation in dog whelk assemblages and offered alternative hypotheses to Deith's (Andrews *et al*, 1985; Russell *et al*, 1995; Gibbons and Gibbons, 2004), including the production of purple dye. It should also be noted that the robustness of dog whelks is evidenced by the fact that isolated but complete apertures survive far more frequently than the more gracile ones of periwinkle (SI-Chapter6-3), a result which is totally consistent with the success rates of crabs cracking dog whelk shells compared to periwinkle shells (Lawton and Hughes, 1985). Further evaluation of these two snails is deferred until later in this chapter after the rest of the data from TNB2 and the other sites has been presented.

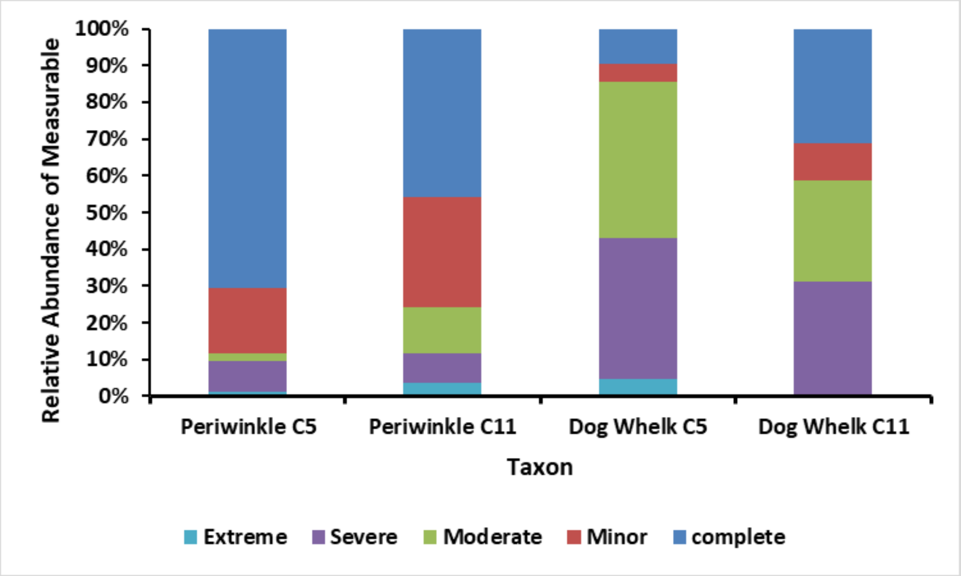


Figure C6-28: The relative fragmentation level of dog whelk and periwinkle as a proportion of those that yielded at least one measurement, that is were not just an isolated apex. The proportion complete therefore does not match table C6-12 as complete here means all measurements could be taken whereas a complete specimen in table C6-12 may appear here as extreme if shell height was the only measurement that could be taken.

6.5.6.2 Interim Summary

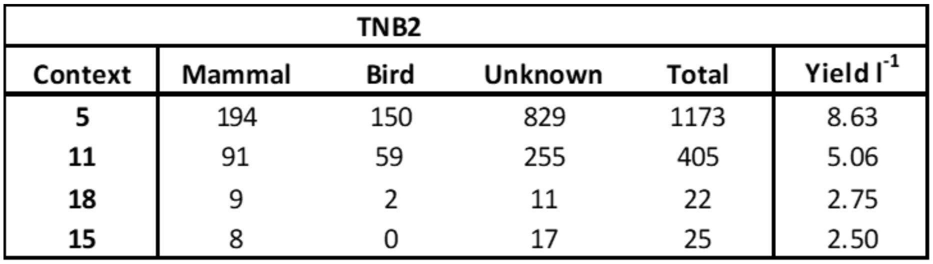
The molluscan assemblage at TNB2 is superficially typical of Atlantic Europe in that all contexts are dominated by limpets. The abundance of razor clam, and infaunal bivalves in general, is unique within the archaeology of Atlantic Scotland, and in relation to razor clam, to the author's knowledge, within Atlantic Europe. There is continuity in that throughout, the razor clams demote periwinkle and dog whelk from their usual 2nd and 3rd positions. There are also definite trends moving from south to north along the section. Limpets get smaller but more abundant. Certain trends exist which suggest a relative chronological sequence within the excavated section. The continuity between contexts 5 and 11 ends with context 18 as mussel disappears and the exploitation dog whelk exceeds periwinkle, a situation that persists in context 15. Contexts 5, 11, and 18 appear to represent an earlier period of occupation within which there is a south to north gradient of reducing contributions from non-limpet taxa. Generally, the razor clams get larger but there is some fluctuation, probably a function of context size. An exception is the increase in the size of dog whelks between contexts 5 and 11 that is accompanied by a reduction in fragmentation, possibly suggesting a change in exploitation of this species, or at least for the larger examples. Context 18 may be from a later period of occupation and the relationship between the two is unclear. The above must be considered tentative, or even speculative if preferred, until the other taxonomic classes have been consulted.

6.5.6.3 The Bone Assemblage

The bone assemblage was evaluated from the 4R fraction and the number of bone fragments by context is provided in table C6-16. Data is presented for the main midden contexts only, as the upper layers cannot be considered as Mesolithic and the lowest layers are all but devoid of bone as they are of molluscs.

6.5.6.3.1 Composition

Table C6-16: Mammal bone classification and yield per excavated litre.



TNB2					
Context	**Mammal**	**Bird**	**Unknown**	**Total**	**Yield l^{-1}**
5	194	150	829	1173	8.63
11	91	59	255	405	5.06
18	9	2	11	22	2.75
15	8	0	17	25	2.50

The assemblage has been reduced to a collection of very small fragments, which proved quite challenging. In most published assemblages the total of fragments belonging to bird, when added to that of mammals either equals, or is very close to, the total number of bone fragments. The taxonomic composition of the assemblage poses specific challenges not usually encountered. Rather than separating the bones from ungulates and carnivores from those of birds, as is the case in most assemblages, this site requires separation (of large quantities unlike NT and TB) of hare from bird, and this results in many diaphysis shaft fragments remaining unclassified. This is discussed in Evans (2016) and the data highlighting the issue is re-presented in SI-chapter6-8. It is not possible to employ a strategy such as that used by McCarthy (1999) at Ferriter's Cove and assume bones with relatively thin walls relative to diameter are avian in origin. It is also notable that when demonstrating the effects of fragmentation on identification Lyman (2008) chooses the example of rabbit tibia versus duck humerus. The taxonomic composition of the mammal assemblage is presented in figure C6-29 and the bird assemblage in figure C6-30.

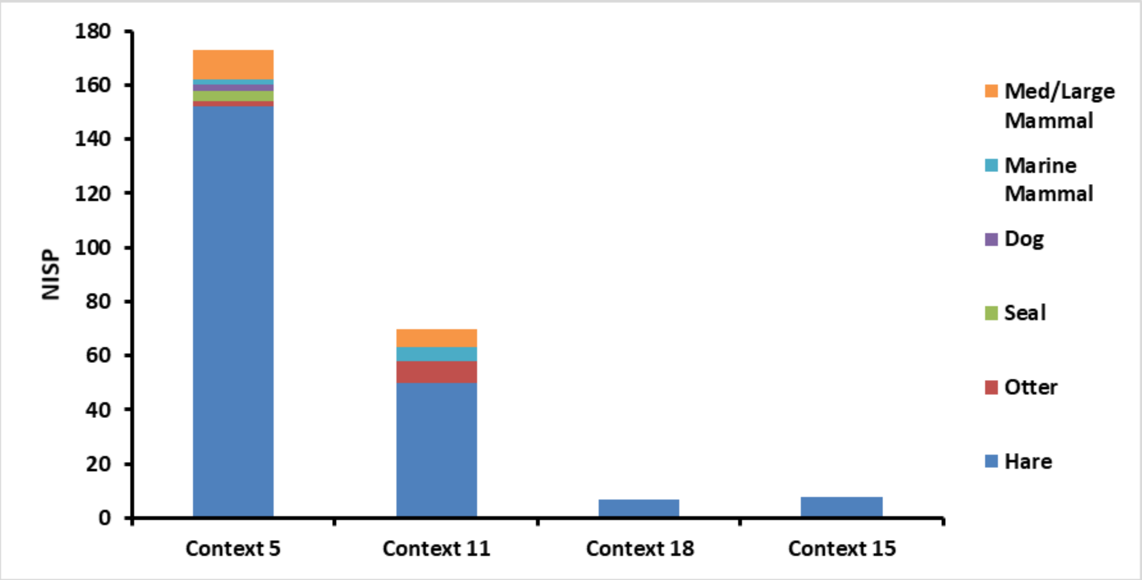


Figure C6-29: Taxonomic composition of TNB2.

The mammal assemblage is not very diverse and dominated by the mountain hare. The implications and unique nature of this level of exploitation of hares has already been discussed in relation to Northton. Some exploitation of otter also seems probable. As with most sites, Oronsay (Mellars, 1979; Mellars and Grigson, 1987) and West Voe (Melton, 2009) being notable exceptions, the evidence for the exploitation of seals and marine mammals is weak. Generally, the remains take the form of unidentifiable chunks of bone, possibly the debris from tool manufacture. The three elements explicitly identified came from the lower half of the forelimb, which is consistent with the butchery practices employed on smaller seals detailed in chapter 3. Meat and blubber were removed from the skeleton at the point of capture and the skin with flippers still attached returned to camp. Similar approaches may have been utilised in north-west Scotland. The pattern in context 5 is repeated in context 11, whereas other contexts are exclusively hare. Contexts 5 and 11, also contain chunks and slivers of robust terrestrial mammal bone, which likely represent debris from longitudinal splitting for tool manufacture. Context 5 contains a phalanx and a proximal portion of a dog's radius. Dr. Kurt Gron kindly offered to process a sample from the radius with a batch of samples he was processing for dietary isotopes. The results (∂^{15}N 15.4$^{0}/_{00}$ (AIR) and ∂^{13}C 12.6$^{0}/_{00}$ (VPDB) are very similar to those obtained from the three earlier humans from Oronsay (Richards and Mellars, 1998), and notably different to the Neolithic dogs from Orkney presented by Jones and Mulville (2016). This dog's protein intake was almost exclusively of marine origin. The radius was not fully fused at death and the radius suggested a dog of medium size, although the legs may have been proportionally longer. If unmanaged by humans, canid weaning naturally starts at around five weeks and is complete at ten weeks, growth is also rapid compared to humans and bone turn over therefore presumably is also. These attributes combined with the weaning period being greatly reduced compared to humans, suggests that any weaning signal in the isotope results is either weak or absent.

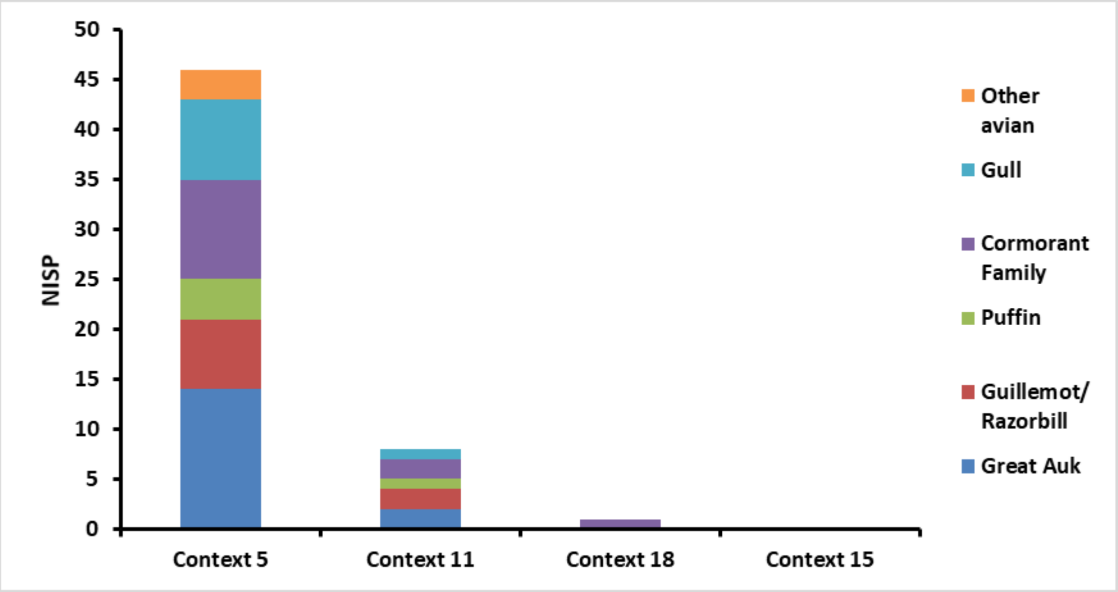


Figure C6-30: The avian assemblage which exhibits a clear trend in terms of the reduction in pelagic species and birds overall.

The avian assemblage is dominated by the auks with a reasonable contribution from the cormorants and gulls. The pattern in context 5 is repeated in context 11, but in context 18 only the remains of non-pelagic species are present. Context 15 had no remains identified as avian. 79% of the assemblage in context 5 is from pursuit diving birds, in context 11 the figure is 88%, and in context 18 100%.

6.5.6.3.2 Preservation

The evidence for burning or heating is minimal for both mammals and birds, and the skeletal elements present suggest that carcass processing may be a contributary reason for this. For both mammals and birds, the complete skeleton is represented (Si-Chapter6-8). If the skeletal element could be identified for a mammal then it could also be speciated. The levels of fragmentation generate a different situation regarding birds, as there are instances where the skeletal element can be identified but identification was not possible even to family level. Whilst all parts of the skeleton are represented there is a difference when the auks are compared to non-auks (Evans, 2016). For the latter the ulnae, humeri and femur are absent. The long bones of birds and beaks are well known to have been put to a variety of uses, as tools, musical instruments, personal adornment, and ritual deposits amongst others (chapter 3; Mannermaa, 2008; Tuck, 1971). The morphology of these bones in the auk family is different as they are compressed into an aerofoil cross-section and they are very short due to the bird's habit of 'flying under water'; cormorants in contrast use their feet to propel themselves whilst submerged. The legs of auks are used only to steer and the muscles of the upper wing are less utilised as the wings are kept straight and rigid rather than flexing as observed in soaring birds such as gulls. The auks probably provide less attractive upper wings and drumsticks when viewed from a culinary perspective. The implication is that the missing bones from non-auks where being put to various uses and therefore did not end up on the midden, whereas the people had no use for the unusually shaped, bones of auks. The axial skeleton is well represented by cervical vertebra, but notably the pelvis and synsacrum are absent for all taxa, which contrasts with the small scale occupation sites on Toe Head.

6.5.6.4 Interim Summary

The assemblages are very fragmented, bordering on pulverised. The mammalian assemblage is dominated by hare and the MNI based upon distal left humeri and calcaneus is four adult and one juvenile in context 5; other contexts yielded MNIs of one. The mammal assemblage also contains chunks and slivers of bone from medium/large mammals (as observed at TB) which are possibly waste from tool production. A bone point (refitted from four fragments) was present in context 5 (plate C6-20), although it is a more gracile example than the examples from TB. The bird assemblage is dominated by pursuit divers that can be acquired deliberately, especially during the nesting season, as described in chapter 3. These birds can also be acquired as a by-product of fishing with nets, or lines. Given the revised chronology of phase 3 at Northton, TNB2 provides a revised and earlier *terminus ante quem* for dogs accompanying humans during maritime journeys in Britain. The data supports a view that the extremely impoverished terrestrial mammalian fauna persisted into the second half of the 5th millennium BC. There is also a general trend of diminishing exploitation of vertebrates (excluding fish) which will be kept under review as further sites are considered.

6.5.6.5 The Crab Assemblage

6.5.6.5.1 Composition

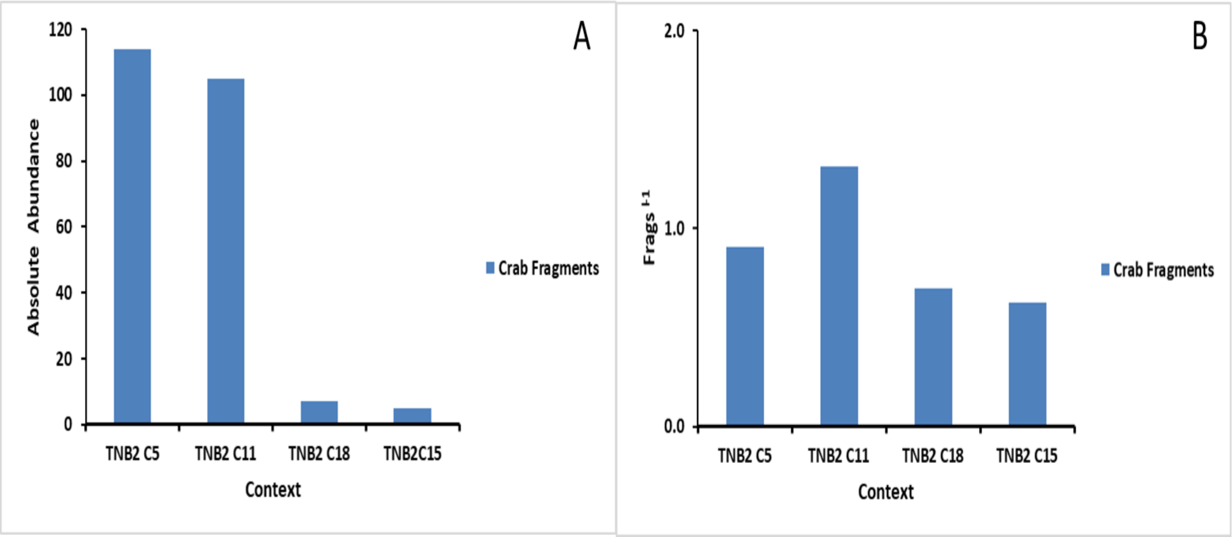


Figure C6-31: A) The number of crab fragments. B) The yield of crab fragments per excavated litre.

The analysis of crabs was conducted against the 4R fraction. Crab remains are not particularly abundant, although far more so than in the 7th millennium on Toe Head, and the yield of fragments per excavated litre only exceeds one in context 11 (figure C6-31).

The first result of note is that whilst all the fragments were examined individually no carapace margins were identified (this observation also applies to the 1R and 2R fractions from C11 examined for otoliths), even for species where the margins are very distinctive such as the edible crab. The fragments

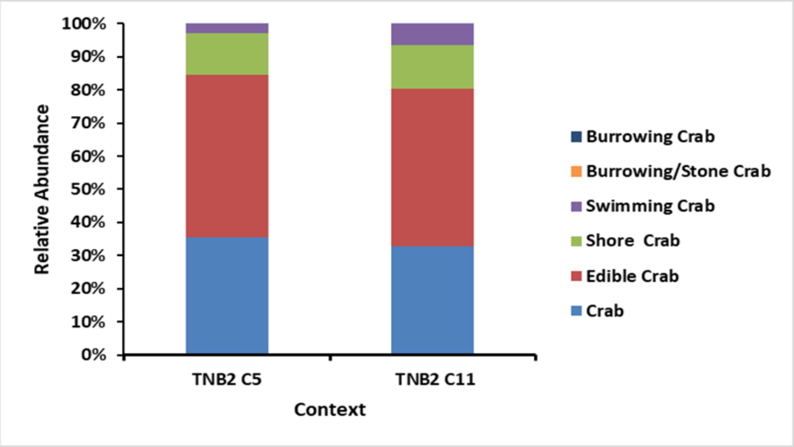


Figure C6-32: Taxonomic Abundance of crabs. Swimming crabs are likely to be Necora puber but Liocarcinus depurator cannot be ruled out for the smaller examples. Crab means no identification was made.

originate from the chela (claws) or other limbs as also observed at MacArthur's Cave (Anderson, 1895, p.228). The assemblages are dominated by the edible crab with non-trivial contributions from the shore crab and swimming crabs (figure C6-32 and table C6-17).

Table C6-17: MNI counts for shore crab, swimming crab and edible crab.

MNI	**TNB2 C5**	**TNB2 C11**
Edible	5	6
Shore	3	2
Swimming	1	1

6.5.6.5.2 Biometric Analysis

Of the five specimens of shore crab whose size could be modelled, four were typical of the inter-tidal zone (carapace width ≤ 60mm) and two are typical of those found below the intertidal zone (figure C6-33). The specimens of edible crab are all larger than would be expected within the intertidal zone (carapace width ≥70mm, Heraghty (2013), and some of the specimens are truly huge (figure C6-34).

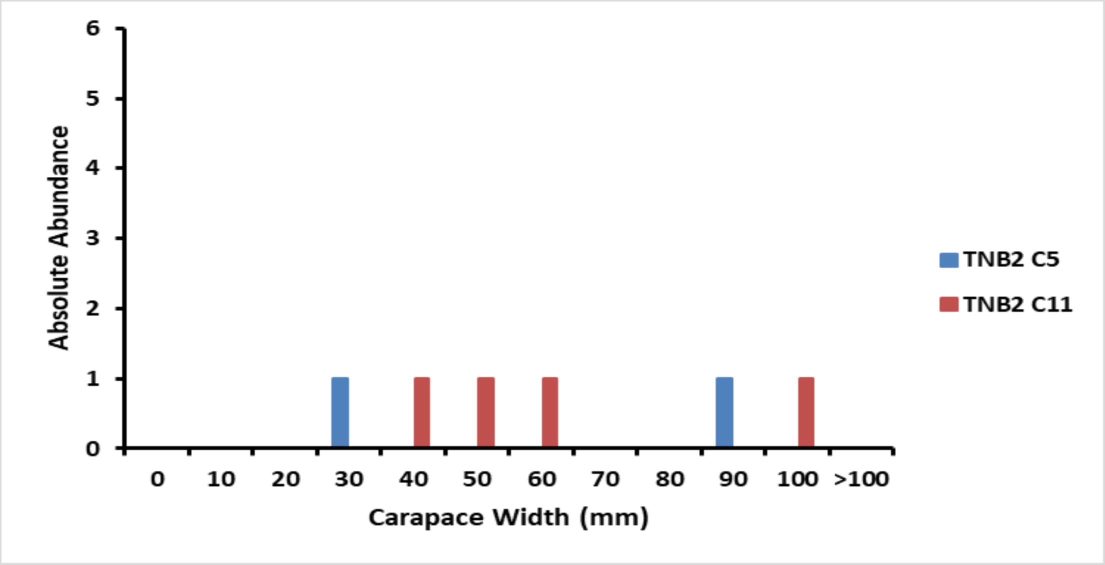


Figure C6-33. Modelled carapace width for shore crab.

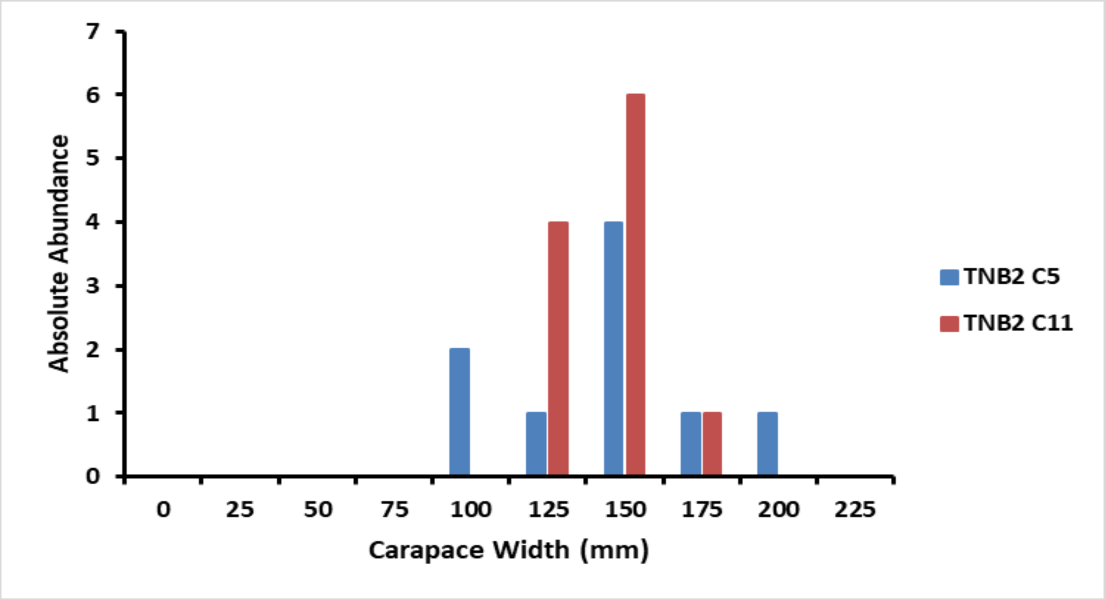


Figure C6-34: Modelled carapace width for edible crab.

6.5.6.6 Interim Summary

Crab exploitation occurred at TNB2 in all contexts. In contexts 5 and 11 the specimens of edible crab are of a size that would not be expected within the intertidal zone under normal circumstances. The shore crab populations reflect specimens whose size suggest acquisition from both the intertidal zone and deeper water. The remains appear to be exclusively from the limbs as no carapace margins were identified. This suggests that the main body of these large edible crabs were taken elsewhere. Another possibility arises given that the people of this region during this period were aceramic. Chapter 3 has highlighted the diverse uses to which mollusc shells and skins were put as containers for liquids, noting that wooden vessels were also utilised in British Columbia. It may be that the strong and light weight nature of the carapace, which is also waterproof, may not have been lost on the Mesolithic inhabitants of north-west Scotland as also proposed by Milner (2009). They would make excellent platters from which to consume a variety of food stuffs, broths, stews, or even process pigments. Chapter 3 also suggests that all that would be needed to carefully remove the carapace is a sharpened mussel or razor clam shell.

6.5.6.7 The Otolith Assemblage

6.5.6.7.1 Composition

Otolith fragments were recovered from the 1R and 2R fractions, to which could be added the isolated specimens (typically 1 or 2) from the 4R. This analysis was restricted to sample 4 of context 5 and sample 13 of context 11. The work here confirms the observations of other researchers in that speciation between many members of gadidae is problematic (Mellars and Wilkinson, 1980; Jones, 1991, Wilkinson n.d., pers. com cited in Jones 1991; Parks, 2009), and especially so when the otoliths are fragmented and relatively few are complete. The size of the assemblage is provided in table C6-18. Whilst certain species can be reliably stated to be present (figure C6-35), the issue of speciation within the *Pollachius* genus and to a lesser extent between cod, whiting, blue whiting (*Micromesistius poutassou*), hake and haddock (*Melanogrammus aeglefinus*) amongst themselves and in relation to *Pollachius spp*. cannot be understated. Over and above the species where a definite presence can be asserted, tentative identifications (data not presented) of fragments suggest that hake, cod, haddock, polar cod (*Boreogadus saida*), and sand goby (*Pomatoschistus minutus*) are probably present at very low

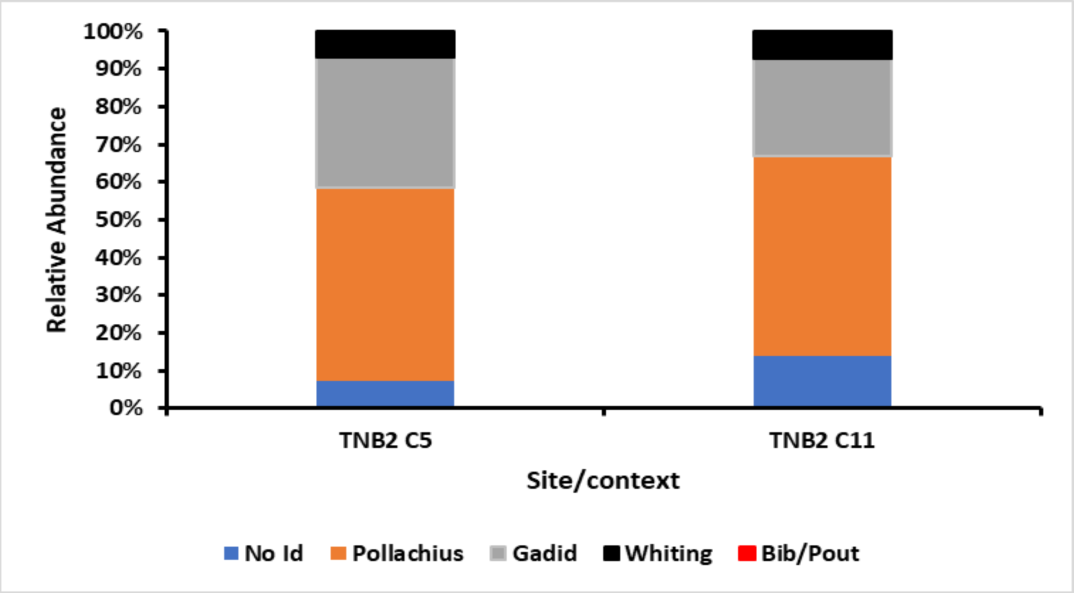


Figure C6-35: Taxonomic composition in terms of relative abundance of otolith fragments. Context 5 n=248, context 11 n=346. Note that as stated in the methods this is not a statement of the composition of the fish assemblage overall.

Table C6-18: Otolith Abundance and yield of fragments.

TNB2	S4 C5	S13 C11
MNO	158	114
MNI	79	57
Yield l-1	3.0	1.4

frequencies or as exotic exceptions. Very few otoliths are complete, and the modelled fish weights are presented. The composition is dominated by saithe/pollack (*Pollachius virens*/*Pollachius pollachius*: *Pollachius* hence forth) and it is likely that the majority of the gadidae also belong to this genus. Whiting (*Merlangius merlangius*) are clearly a non-trivial component.

6.5.6.7.2 Biometric Analysis

The size of the otoliths in context 5 is centred around fish of between 152mm and 195mm in length, weighing between 25g and 63g, the exceptionally large specimen would have weighed *circa* 325g (figure C6-36). Under the classification employed by Parks and Barrett (2009) these fish fall into the lower range of small. In context 11 the distribution is centred around fish of between 125mm and 152mm length, weighing between 17g and 31g, which under the above classification scheme are deemed tiny (ibid). The diminutive size of these fish was such a surprise for the author that verification was sought from other sources using defined lengths to generate weight, and the results agreed within one or two percent. The question arises as to what was being done with fish so small? In context 5, 15.5% of the otolith fragments are carbonised and in context 11, 4.7%. Unfortunately, carbonised otoliths appear to be far more prone to fragmentation than non-carbonised examples. Even if the assemblages from both contexts are pooled only seven specimens can have their length modelled, and the mean length is 7mm (*circa* 46g); the actual samples from each context coincide with their respective modal values in in terms of otolith length and interestingly do not reflect the larger specimens (>60g) in each context. A proportion of the specimens (7.5% in each context) are very eroded and it is possible that these have been through, or were liberated from, the digestive tract of a carnivore, whether mammalian or avian. Dogs were present and possibly some of these small fish were fed to or scavenged by them. The preservation states are provided in figure C6-37 and the fragmentation levels in SI-Chapter6-6. The majority of the fish have not been burned but they may have been boiled or baked.

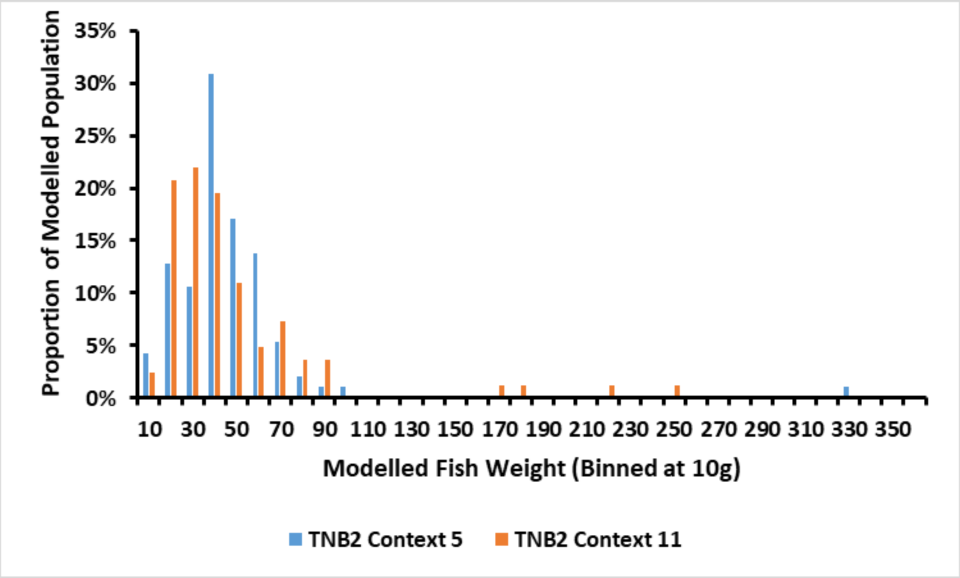


Figure C6-36: Modelled fish weight for all specimens of *Pollachius* for which length could be measured or modelled. Context 5 n=94 context 11 n=122. H_0 cannot be rejected at CL=95%.

Another possibility is that they were involved in some form of fermentation process (see Boethius, 2016 for a discussion) or the production of broth or soup. The final possibility is that they were used to obtain fish oil, although there are other species more suited to this task.

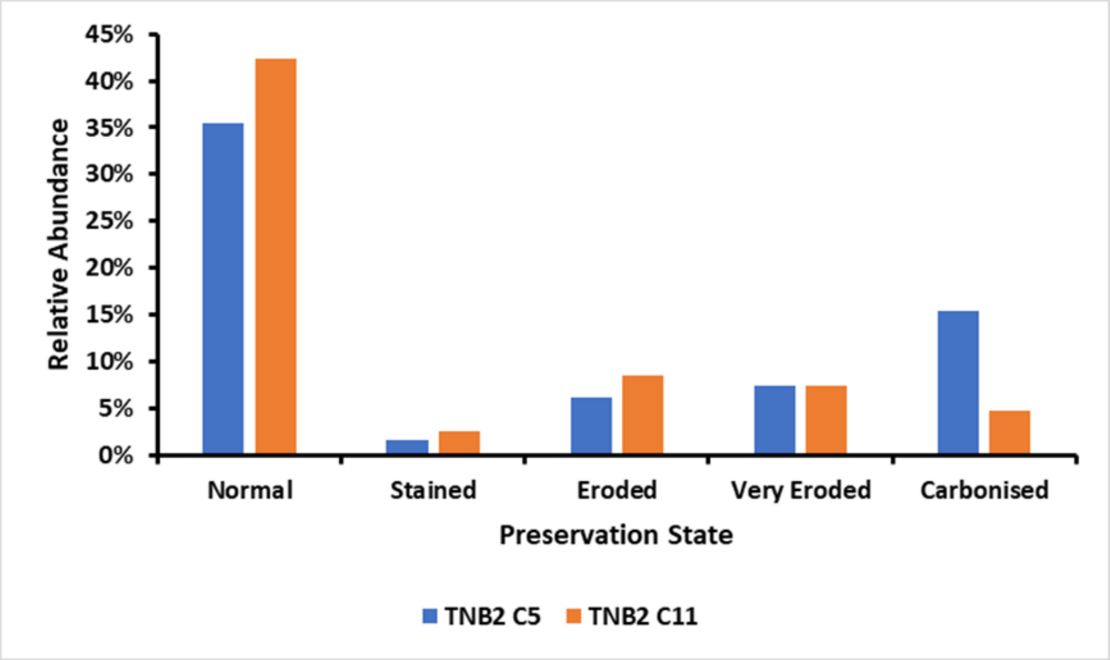


Figure C6-37: Preservation state as a proportion of total otolith fragments.

6.5.6.8 Interim Summary

The otolith assemblages have similar distributions although context 11 has more outliers. The fish are very small and on an individual versus individual level compare unfavourably with razor clam. The length of the fish compared to weight implies that at this stage of their life cycle *Pollachius* are long and thin, which consistent with the author's observations. The question arises as to how these fish were acquired? A mesh size capable of efficiently trapping these fish would require the manufacture of at least two Km of cordage (for a 5m by 3m net, see chapter 3) as a 3cm mesh would be too large, unless the mesh had become blocked by much larger fish. Intertidal traps, either constructed, or leveraging tidal pools, or enhancing natural depressions, is maybe a more viable alternative (chapters 2 and 3). These species do become stranded in large pools (pers. obs.), especially those that form in sand around large rock outcrops. The fish could be encouraged to enter and remain in the traps by baiting them. Of course these fish may not have been the target of the procurement effort, but the discard. The few relatively larger fish may have been discarded following an initial quality assessment, due to having an infected wound, disease, or parasite infestation. Certain parasitic infections of brown and rainbow trout are not evident until the fish is being gutted (pers. obs.). The principle here would be that these small fish were rejected and thrown onto the midden, where dogs could have acquired a proportion. Clearly, if the larger fish were not processed at the site, or at least the processing waste was not deposited at the site, there are implications for site function and the use of space on the headland. This will be considered further when the data from the other sites has been presented.

6.5.6.9 Seasonality and Age at Death.

The mammal assemblages are singularly uninformative. Hare's breed from February until September and have multiple litters. The bone fusion ages for lagomorphs (Rowley-Conwy, 1992; Xin, 1998) mean that a given state of fusion can exist in any month of the year. Lagomorphs have open rooted teeth (Hillson, 1986) that grow continuously through life and therefore dental wear cannot be used for aging purposes, furthermore, (as with otter) the deciduous dentition is lost partially in utero or within a few days of birth. Otters also breed all year round and therefore pose a similar challenge. The bird assemblages however give a firm indication of spring through summer as the auks are pelagic and only come to shore and frequent inshore waters during the nesting season. The size of fish indicated by the otoliths, excluding the rare large examples, are the perfect size for auks and the cormorant family. If large shoals of fish this size were the norm then pursuit diving birds would be attracted, in a similar manner to that reported in chapter 3 in relation to herring. For context 5 the peak in the otolith assemblage (fish lengths 152 – 195mm) would at first glance to suggest occupation during the late autumn to mid-winter, assuming the habits of saithe in the Western Isles were the same as those in modern day Oronsay and Colonsay (Mellars and Wilkinson, 1980). Context 11 therefore appears to be occupied during the early Autumn to early winter. However, fish of the upper end of this size range were available in Orkney until April, and the same observer reports that large numbers of even bigger fish (length 380mm) arrive in shore in May (Low, 1813, pp.194-195); a seasonal pattern not identified by Mellars and Wilkinson (1980) at Oronsay or Colonsay. As highlighted in chapter 4, there are sound reasons to be cautious regarding the inference of seasonality from otoliths and this is pursued in chapter 8. There are no other seasonal indicators, such as geese or swans, or neonate grey seal to support occupation during the autumn or winter. The unfused distal ulna of a seal from either context 5 or 11 is unhelpful as this joint does not start to fuse before the age of five and may not completely fuse until age twelve (Stora, 2000). The size of the element suggests a sub-adult rather than a neonate or juvenile and, in any event, it is impossible to say whether it is from a grey seal or common seal, which is a material factor due to their different birthing seasons.

Seasonality data and age at death was sought from the limpet population using growth increment analysis. Sections were prepared for 30 limpets in the size range (length) 29.5mm to 30.5mm. These were selected at random from sample 26 of context 5 and represent 61% of the available limpets in this size range. Sections were also prepared for limpets ≥40mm in length from sample 26 of context 5 (n=19) and sample 27 of context 11 (n=25) which represent 90% and 100% of the limpets in this size category, respectively.

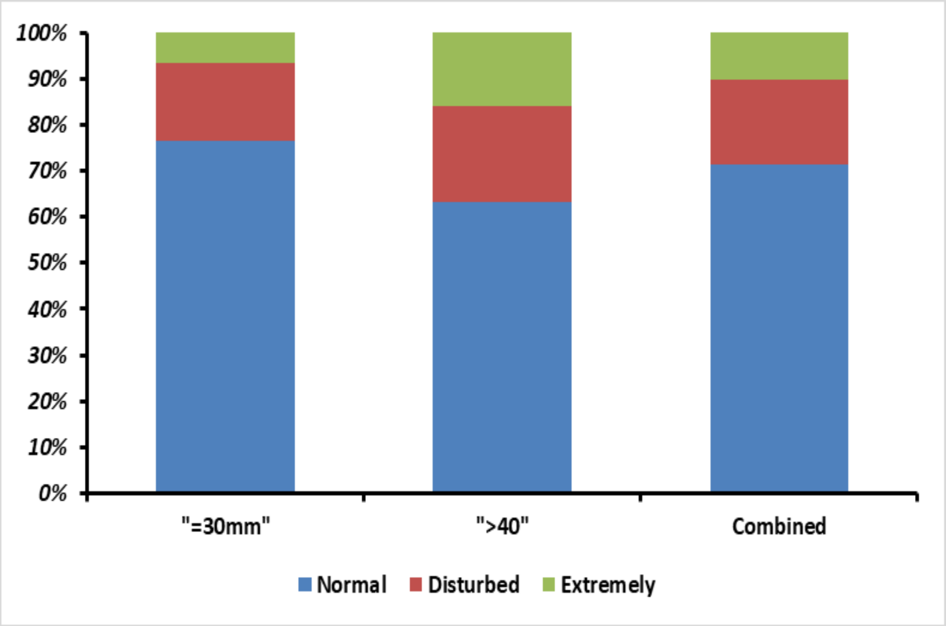


Figure C6-38: Proportion of sampled limpets exhibiting different levels of growth disturbance in context 5. Sample sizes are provided in the main text.

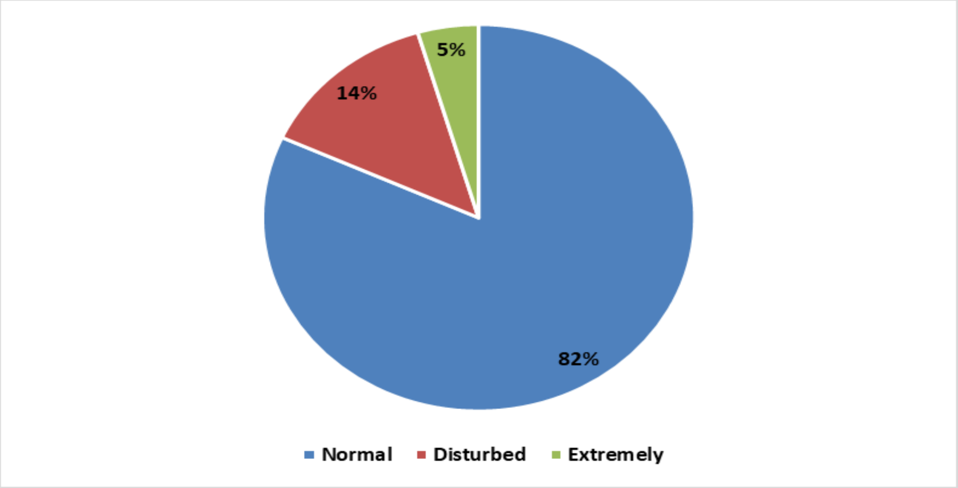


Figure C6-39: Proportion of sampled limpets >40mm in length that exhibited different levels of disturbance in context 11 of TNB2. Sample size is provided in the main text.

Sampling was conducted based upon length rather than volume to ensure a good mix of specimens in terms of conicity. The results were something of a surprise in that a significant number of limpets exhibited growth disturbance, sometimes on more than one occasion. This compromises the analysis of seasonality and age at death as the disturbances result in at best additional non-annual growth lines, and at worst chaotic growth line patterns (C6-Plate-15). This was an unexpected outcome, and an ordinal and qualitative scale of disturbance was created with the categories of not disturbed, minor disturbance, disturbed and extremely disturbed. Examples of the three disturbed categories are provided in plates C6-15 to C6-17. The disturbance of limpet growth is not without interest. Disturbance is more prevalent in the larger size class. Whatever the event or circumstance that results in such growth disturbance it seems self-evident that the older the limpet the more likely it is to have experienced such an event or events. There may also be a form osteological paradox (*sensu* Wood *et al*, 1992) at play. That is the older age class reflects limpets that experienced such an event earlier in life and survived (although some examples from the larger size class experienced disturbance shortly prior to death), whilst those that did not survive would have been unavailable for procurement at a larger size.

Another feature is that some specimens appear to exhibit no growth lines either in the apex or at the shell margin (Plate C6-18). Other than one exception, specimens exhibiting this characteristic were where less conical with higher values (>2.8, most >3.25) of conicity associated with environments posing a low level of desiccation risk. Further research is required into this matter as it maybe that such limpets were resident in rock pools or at ELWST and therefore were experiencing a moderated environment in terms of temperature and rare or no periods of emersion. Such specimens had to be dropped from age at death and seasonality analysis. The prevalence of growth disturbance in context 5 is provided in figure C6-38, the data for C11 in figure C6-39.

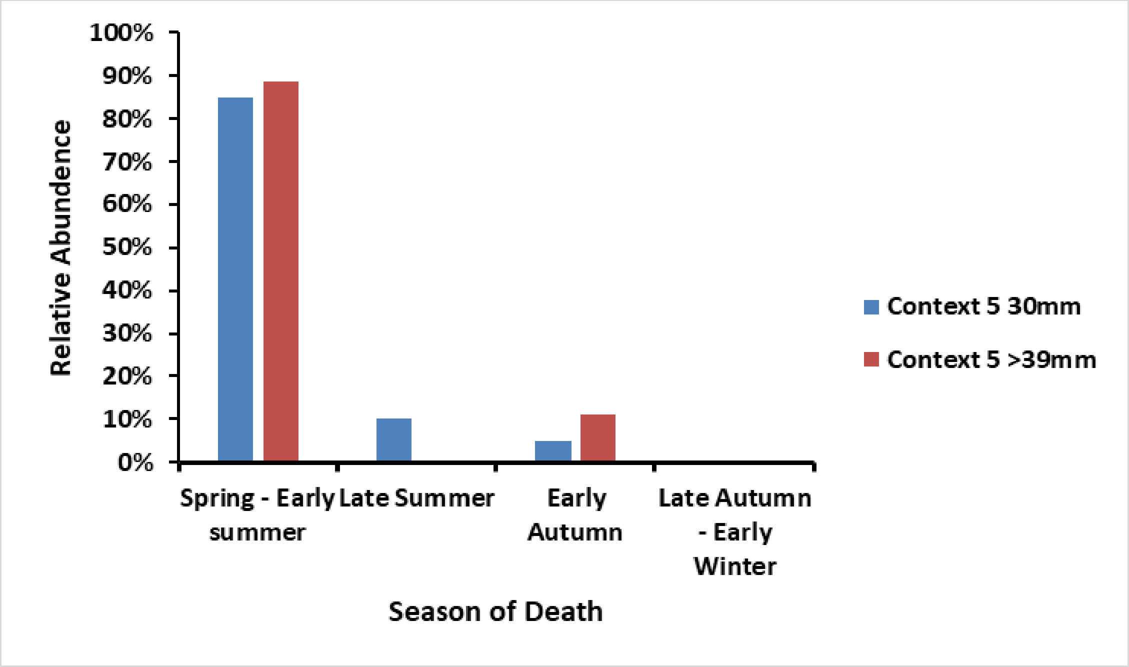


Figure C6-40: Season of death for non-disturbed and limpets with minor disturbance. Context 5 n=35.

The majority of procurement is during spring – early summer (plate C6-13), with some evidence for a presence at the site during the early autumn which is wholly consistent with the bird assemblage (figure C6-40). Cormorants, herons, and gulls would have been available during both seasons, but easier to access during the breeding season. Given that limpets start to develop their gonads from July and are usually spent by March (Orton, 1928; Thompson, 1980), it is possible that the data reflects not so much when the site was visited, but when limpets were more palatable; possibly the seasonality is an artefact of the human pallet. The author has no idea what impact developed gonads have on the palatability of limpets, (or the palatability of limpets in general), and has absolutely no intention of exploring the

Figure C6-41: The year of life in which death occurred for the 30mm length size class at TNB2 context 5.

matter experimentally. This assessment of seasonality must therefore be considered provisional, but the coherence between the limpets and birds is encouraging. As shown in figure C6-41 the age at death is highly variable as observed elsewhere (cf. Ballantine, 1961a) and length versus age is influenced by conicity (Chapter 4; SI-Chapter6-7). This highlights that simple associations of changes in mean age versus mean length at death may be measuring something other than intended as discussed in chapter 4.

6.5.7 Summary.

Significant quantities of data, as is necessary to support the objectives of the project and the underlying principle of canvassing as many proxies as possible, have been presented. The resulting picture is in many aspects a clear one. The entirety of the site reflects a unique profile of mollusc exploitation that is combined with a more typical exploitation of pursuit diving birds, especially the auks. The focus on mountain hare is also another atypical feature of the site, as discussed already in relation to NT and TB. Two marine snails were processed differently and probably utilised for different purposes, although in context 11 more dog whelks may have been consumed. The fragmentation profile of periwinkles is consistent with that observed at TB. These resources were also complemented, at times, by very large edible crabs, that would not typically be found in the intertidal zone. A significant number of fish were also acquired but the size profile is puzzling as the fish are diminutive. Compared to other Mesolithic sites such as Oronsay (Mellars and Wilkinson, 1980) and Sand Rock Shelter (Parks and Barrett, 2009), ‘half the assemblage is missing’. The mode that predominantly relates to first year fish is present but the second mode relating to larger second year (or older) fish is absent. The role and nature of the exploitation of these fish requires further consideration. The exploitation of resources in terms of taxonomic composition and sizes is fairly consistent in contexts 5 and 11, but at the northern extremities change is observed, especially in relation to mammals, birds and the two marine snails. It is possible that the extremities relate to a different period of occupation. There is very limited evidence for the exploitation of marine mammals or otters, which might be due to the way carcasses were processed at the location of capture. This leads to one final observation that appears to suggest a common theme.

The bird remains represent the waste from dressing a bird after which the dressed body along with the humerus (probably still attached), and ulna (other than for auks) are removed elsewhere. The crab assemblage reflects a similar scenario, the midden reflects the removal of the limbs and the main body including the carapace is removed elsewhere. The fish assemblage is lacking the size mode that one would expect to be the target economically and maybe this has also been taken elsewhere. Only hares appear to reflect the deposition of the entire carcass and possibly this is because they were skinned as well as consumed, or they along with the crab claws, and a proportion of the 1st year sized fish, provided the sustenance for the task group procuring and processing the resources.

Between contexts 5 and 11 we observe an increase in limpet abundance accompanied by a reduction in size, razor clam abundance falls but size increases. It is in context 11 that an episode of cockle exploitation occurs, possibly a mitigation measure, as might be increased human consumption of dog whelk. Periwinkle abundance and size increases, as does the abundance of dog whelks, and the size range of both species expands. It is possible that the environment is changing, and this will be considered further in chapter 8. There is a reduction in the exploitation of mammals and birds, although this could be due to contexts 18 and 15 relating to a different season of occupation. In relation to this latter point it should be noted that these contexts contain no seasonal indicators at all in terms of birds or mammals; a situation that will be encountered again later in this chapter.

There are three molluscs valves that have been modified, two that had been pierced and then threaded. Over time the cord appears to have worn through the shell until it structurally failed at the umbo. Shells may have been threaded for any number of reasons, such as to form a pendant, to make castanets to accompany music and dancing (chapter 3) or even as a flasher spoon to attract fish towards a baited area (pers. obs.). The third is an oyster valve with edge modification. The lithic assemblage consists of 342 artefacts, includes 41 quartz cores, 111 quartz flakes and 7 flint flakes (Piper, pers. com). A bone point is also present and chunks of what appear to be (mainly) from medium-large terrestrial ungulates appear to be the waste from the production of such tools. No examples of, the usually ubiquitous, bevel ended stone or bone tools were identified.

The site represents what was probably the refuse heap associated with a seasonally occupied residential camp, but it lacks some attributes that might be expected such as post-consumption food waste and appears to reflect more the initial processing of resources prior to removal. Between around 4,600 cal BC and 4,400 cal BC Mesolithic people (and their dogs) visited the site, usually in the spring and early summer, but now and again during the early autumn. When in residence the people undertook hunting, fishing and to a lesser degree crabbing, whilst gathering other resources such as marine molluscs and urchins. The archipelago offered a rather different environment to that of the mainland and the people adapted their economy in response. It is likely that contact with the mainland was regular, potentially to secure (through hunting or trade), bone and lithic resources for tool manufacture. Contact to maintain alliances, friendships, trade, and mating networks are also likely and strong motivations as highlighted in chapter 3.

6.5.8 Pabaigh Mor South

The assemblage from PMS is from a small scale sampling exercise to characterise the deposit, and therefore interpretation must be tentative. It is included however as in terms of radiocarbon dating it sits on the cusp between TNB2 and TNB1 and may also include a small amount of much older material. There are only two contexts to consider and much of the data to be presented will address only context 2 and hence pie charts will be utilised more extensively than for other sites.

6.5.8.1 Marine Molluscs.

6.5.8.1.1 Composition

The composition of the mollusc assemblage is overwhelmingly dominated by limpet (figure C6-42) at levels inconsistent with TNB2 other than context 15 at the northern extremity. Focusing on context 2 reveals that the second most abundant taxon is dog whelk followed by razor clam and then periwinkle. The greater abundance of dog whelk compared to periwinkle continues the pattern observed in contexts

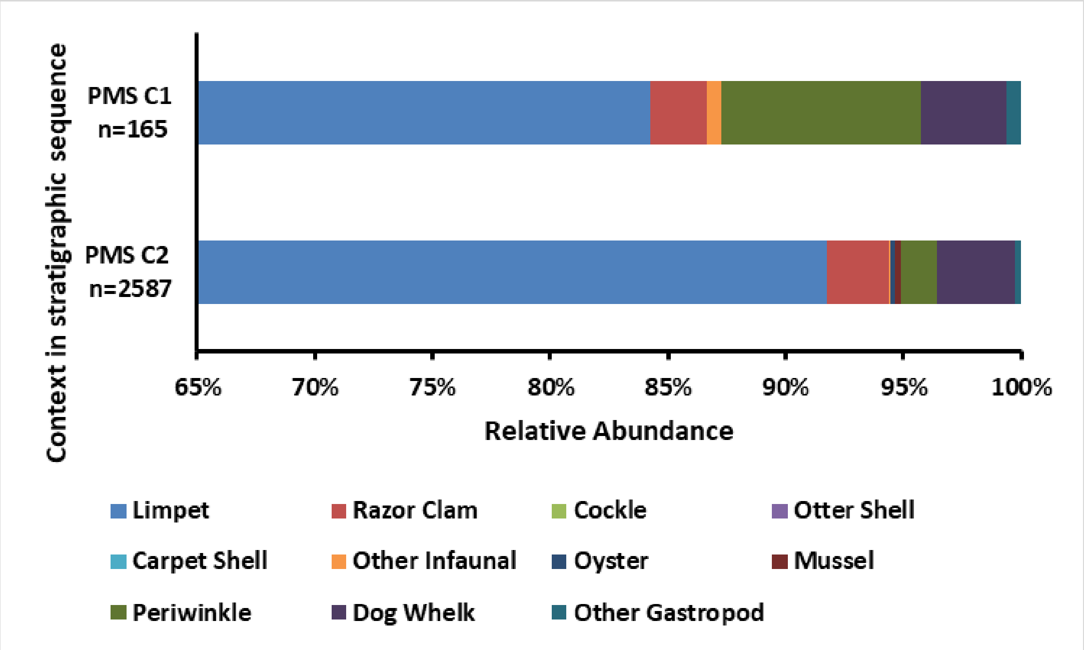


Figure C6-42: Relative abundance of molluscan taxa.

Table C6-19: Fragmentation of limpets and razor clam.

Context 2	Complete	EHL	LTL
Limpet	21.1%	N/A	N/A
Razor Clam	0.0%	26.1%	87.0%

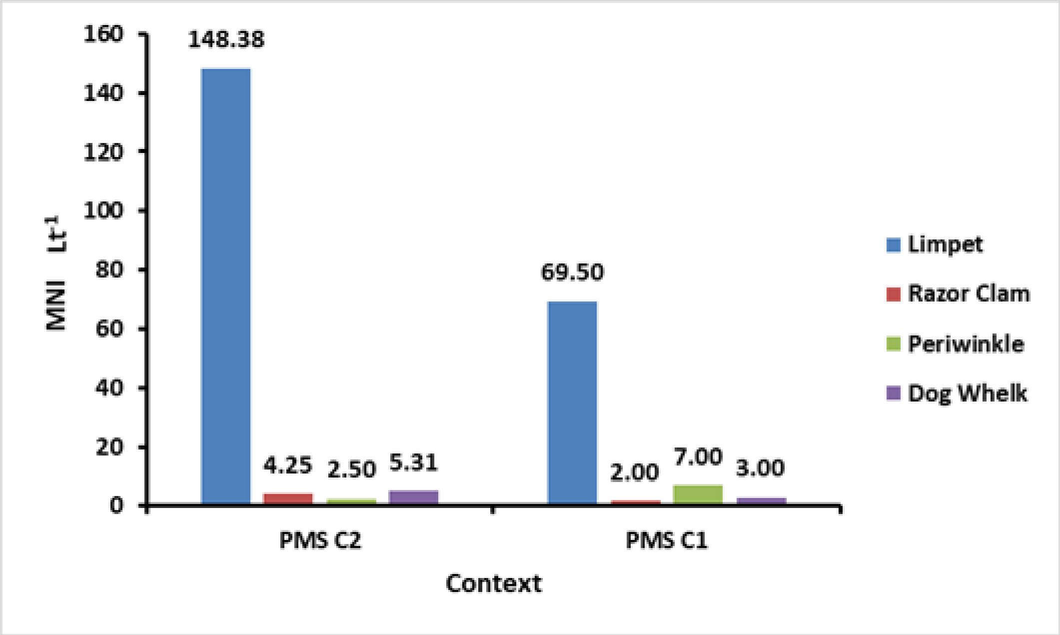


Figure C6-43: Yield of MNI per excavated litre for selected taxa. The high yields compared to earlier sites is restricted to limpet.

18 and 15 of TNB2's northern extremity. The yield of limpet is quite astounding (figure C6-43), and due to this fragmentation will be considered immediately. Whilst fragmentation levels are slightly higher as only 21% of the limpets could be measured (Table C6-19), the key point is that the majority of the non-measurable but quantifiable specimens were small apexes, that had broken off near the top of the limpet. There is a component of the limpet assemblage which is not dissimilar to those on Toe Head where no measurable limpets (even length only) were present. The fragmentation level of razor clam is similar to TNB2. The fragmentation levels for periwinkle and dog whelk are very high with only one complete example of each being present, the vast majority of the remains from these taxa are isolated apexes, repeating the pattern of the limpets. There is no differential in fragmentation between these two marine snails at this site.

6.5.8.1.2 Biometrics

The size distributions of limpet size and conicity are provided in figures C6-44 and C6-45, respectively. The limpets are presented in terms of shell length with volume data provided in SI-Chapter6-1. The limpets are of a good size and the very largest specimens relatively frequent. The conicity distribution is very symmetrical and reflects a spatially comprehensive exploitation of a heterogeneous shore. The size of razor clams is presented in figure C6-46 which depicts a fairly selective exploitation but the largest specimens over 160mm in length are poorly represented as at contexts 18 and 15 of TNB2. It is not possible to present any size data for dog whelk as the fragmentation levels do not permit the size to be modelled. Only four periwinkles have modelled lengths and these range between 24 and 28mm, which is larger than those at TB but still fairly small compared to TNB2.

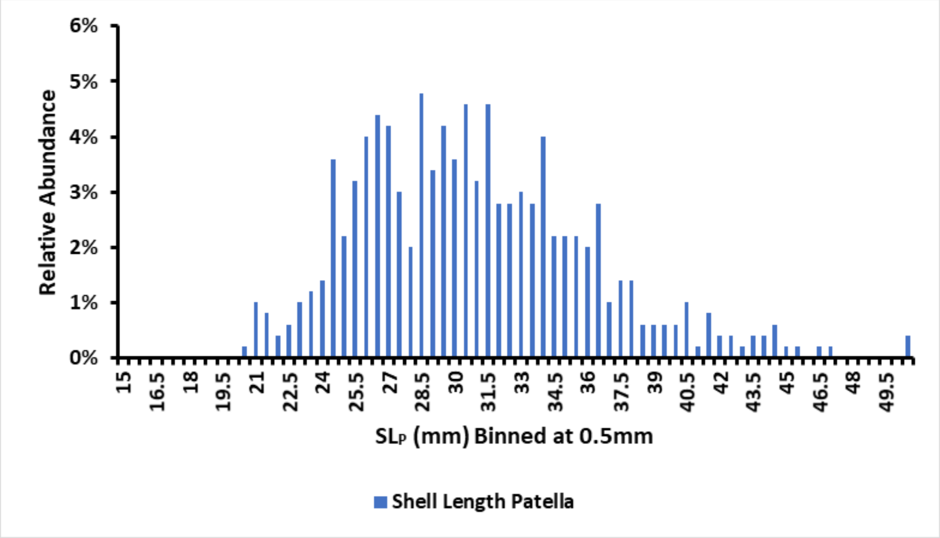


Figure C6-44: Population structure of the measurable limpets in context 2, n=501.

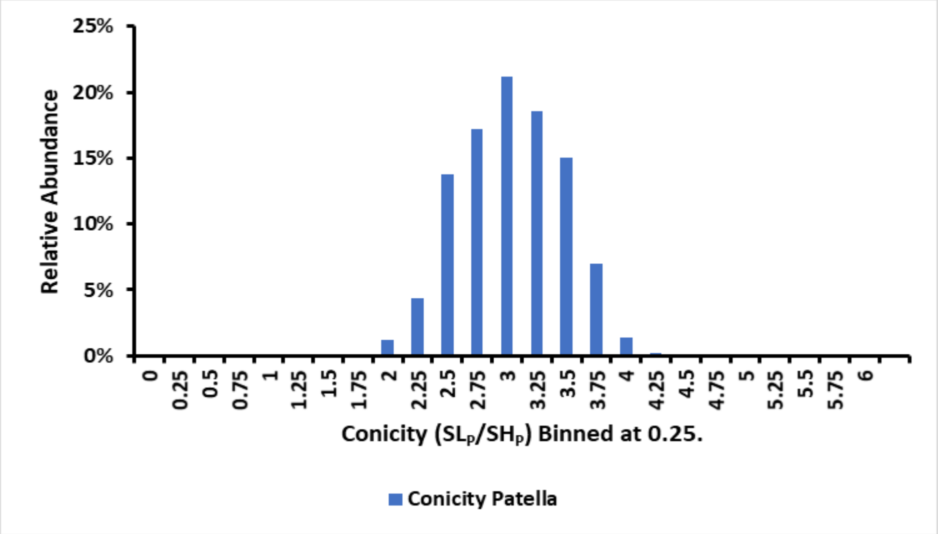


Figure C6-45: Limpet conicity from context 2, n=501.

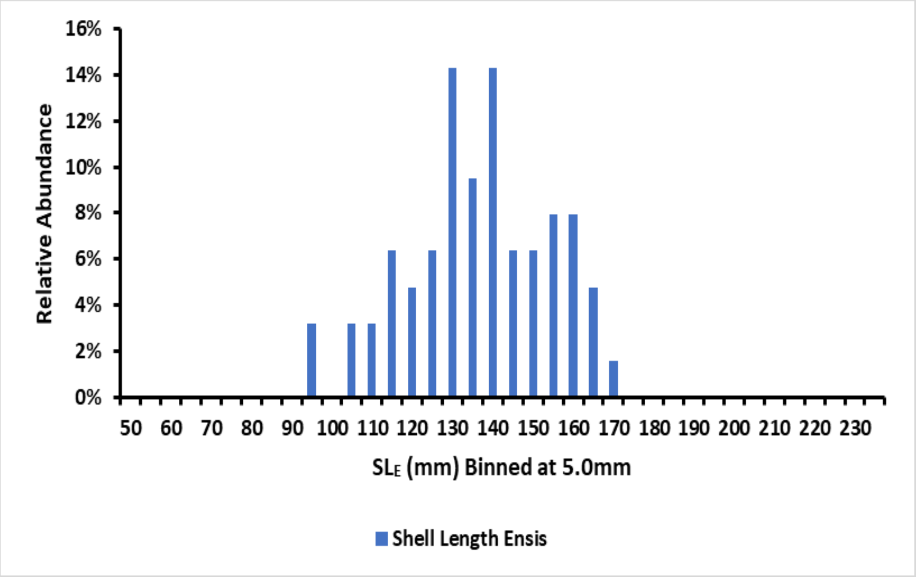


Figure C6-46: Modelled length of razor clam from context 2, n=63.

6.5.8.2 Interim Summary

The mollusc assemblage at PMS contains razor clams of a broad range of sizes that are similar to those in TNB2 (except context 15 which is very selective) and that the very largest examples are poorly represented. The partial recovery in limpet size observed in context 15 of TNB2 is sustained, but at incredibly high yields of MNI. It cannot be ruled out that the large number of highly fragmented limpets may be older and possibly associated with the earlier radiocarbon PD. Further research and excavation are required as possibly this site (and the island in general) contains some of the earliest faunal remains of an anthropogenic origin in Scotland. It is also for this reason that the low relative abundance level of razor clam must be treated with caution, as yields are not excessively low and fragmentation levels are pretty ‘normal’. The fact that dog whelk is the 2nd most abundant taxon is probably genuine and the switch from periwinkle to dog whelk observed at the northern extremity of TNB2 is sustained.

6.5.8.3 The Bone Assemblage

The bone assemblage consists of 72 fragments and is summarised in table C6-20. For its size it is unusually diverse. All but two of the NISP of the mammal assemblage relate to a hare and element composition suggests nothing more than a single individual, which includes a mandible with dentition.

Table C6-20: Classification of the bone assemblage from context 2.

PMS					
Context	**Mammal**	**Bird**	**Unknown**	**Total**	**Yield l^{-1}**
2	14	27	31	72	4.5

There is an incisor of a carnivore which the author has provisionally identified as canid. There is also a component of the sternum of an adult seal.

The bird remains are unusual as the long bones of the wings are present. There is a tibio-tarsus and a humerus from a cormorant, and the humerus of a black headed gull (*Chroicocephalus ridibundus*). There is a left and right sided coracoid, plus a scapula, from a galliform, the size of which suggests a single individual. The specimens are too large to be a quail and the closest match would be a very young willow ptarmigan (*Lagopus lagopus*). Except for the migratory quail the galliformes are weak fliers and yet they appear to have colonised the archipelago by crossing the Minch. There is also a mandible which is tentatively identified as puffin. There are also several fragments of vertebra (non-speciated), one of which appears to have been sliced through. None of the identified specimens are carbonised or calcined, excepting a couple of the unidentified fragments. It seems likely that, with the possible exception of the cormorant and the hare, the assemblage represents natural deaths. It should be stated that a fragment of sheep (*Ovis spp*.) metapodial was present in context 1 above the Mesolithic deposits.

6.5.8.4 The crab assemblage

The crab assemblage consists of 102 fragments which gives a reasonably high yield of 6.4 per litre. The fragments originated from small specimens of shore crab and the modelling of size was not possible. Apparently, crabs did not play a major role at PMS.

6.5.8.5 The Otolith Assemblage

6.5.8.5.1 Composition

The quantity of otoliths given the small volume excavated, is large at 470 fragments generating a MNI of 95 (Table C6-21). As with limpets the yields are the highest of all the sites at 12.7 MNO per litre. This is slightly greater than observed at TNB2 (SI-Chapter6-6).

Table C6-21: The abundance and yield of otoliths fragments in context 2.

PMS	S3 C2
MNO	190
MNI	95
Yield l-1	12.7

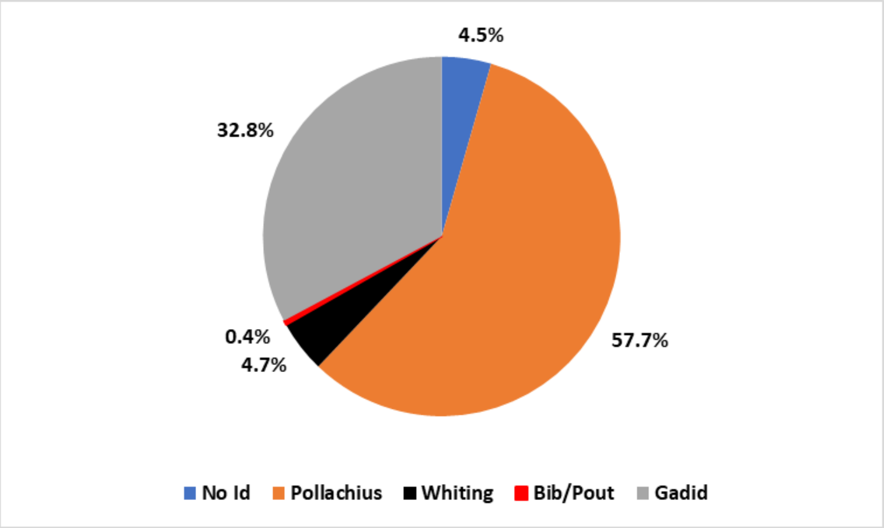


Figure C6-47: The taxonomic composition of the otolith assemblage in terms of fragments. N=470. Note that as stated in the methods this is not a statement of the composition of the fish assemblage overall.

6.5.8.6 Biometric Analysis

The diminutive size of the fish at TNB2 has already been commented on, and the fish at PMS are even smaller; much smaller, with H_0 being rejected at the 99.9% confidence level with both context 5 and context 11. The taxonomic composition is shown in figure C6-47, and the size distribution in figure C6-48. The distribution is centred around fish between 93mm and 122mm, weighing between 7g and 16g and the presence of only one modest outlier, is interesting. It is necessary to again ask; what are these fish for and how were they acquired? The preservation state is provided in figure C6-49 and there

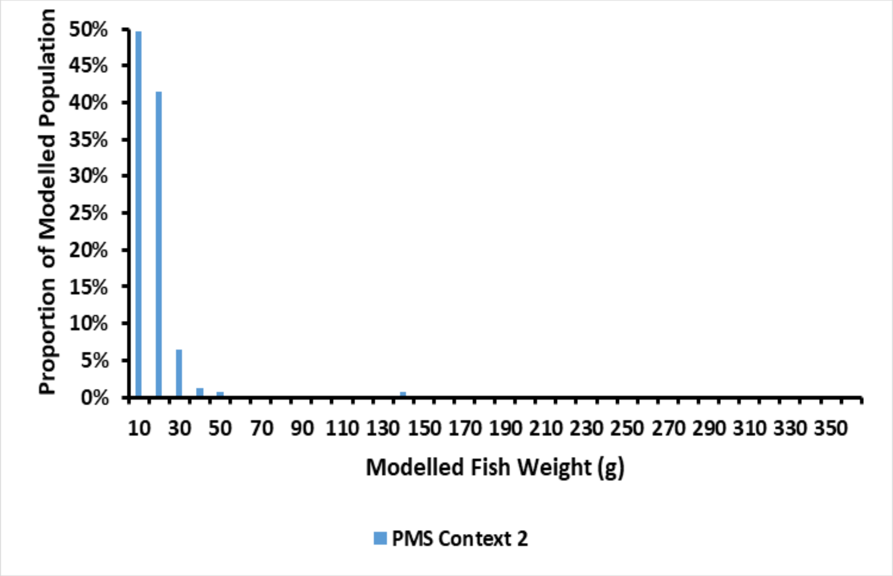


Figure C6-48: The modelled fish weight for *Pollachius* in context 2. N=157.

is no increase in the abundance of carbonised specimens compared to TNB2. The question of whether the assemblage represents subsistence resources or discard is a moot one, either the people at PMS where directly utilising smaller fish, or they are retaining smaller fish than were being discarded at TNB2. All the discussion points regarding acquisition aired for TNB2 are equally applicable here, as is the consideration of the absence of the 2nd year and older fish mode.

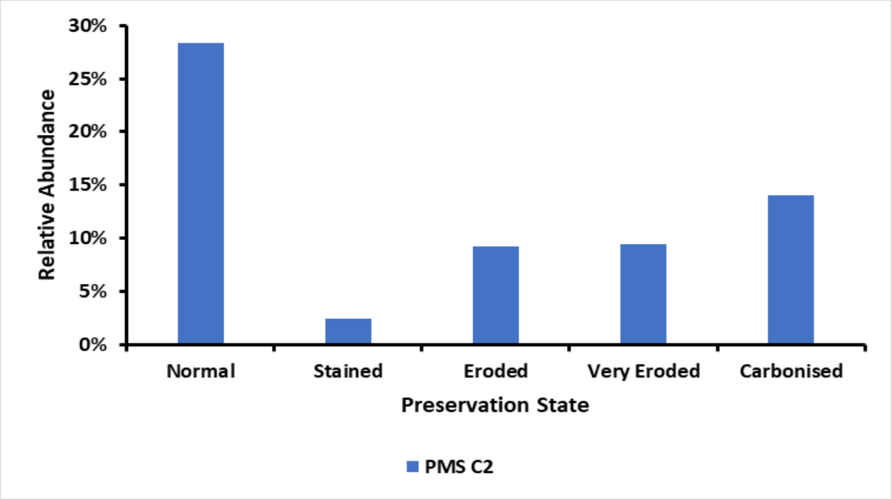


Figure C6-49: Preservation condition of all otolith fragments.

6.5.8.7 Seasonality and Age at Death.

The bone assemblage is uninformative regarding the season of occupation other than the presence of the juvenile willow ptarmigan and a puffin, but if these as suspected, represent natural deaths then they have no analytical value. The otolith assemblage requires further consideration for the reasons discussed for TNB2. Sections were prepared from 19 randomly selected limpets ≥40mm in length (67% of this size class) and season of death was established (figure C6-50). Over one third of the specimens, were disturbed (figure C6-51) and as with TNB2 had to be eliminated from seasonality determination. The number of samples that could be utilised was only 11, as three further specimens lacked growth line resolution. The resulting seasonality profile must therefore be treated with caution, especially as in contrast to TNB2, there is no corroboration available from the avian assemblage.

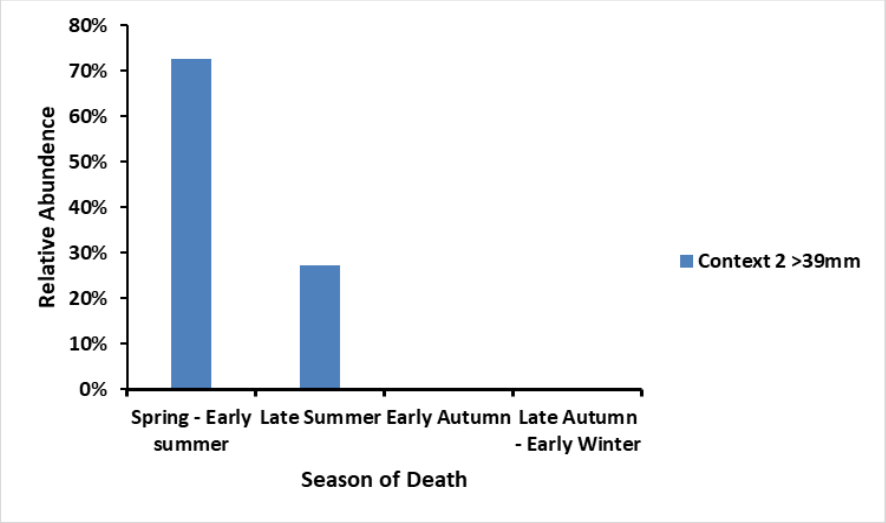


Figure C6-50: Season of death of limpets in context 2. N=11.

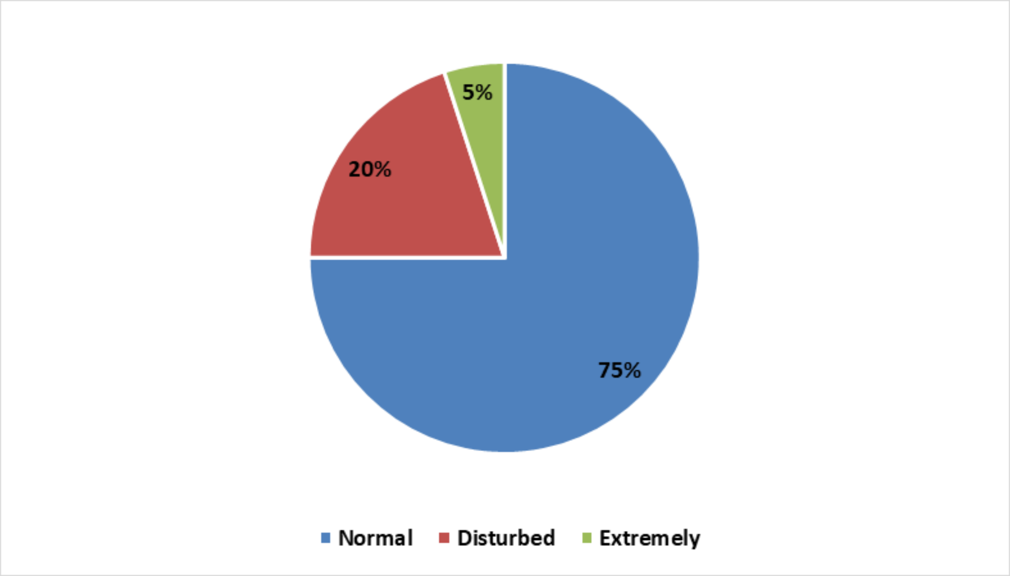


Figure C6-51: Disturbance profile for limpets greater than >40mm in length. N=19.

6.5.9 Summary.

PMS is a very small exploratory sample and the need to treat it with caution must be reiterated; yet some conclusions can be drawn. Limpets dominate the assemblage, but their contribution and yield are probably overstated due to a large number of isolated apices. The abundance levels are probably continuing the trend observed in context 15 at TNB2. A proportion of these highly fragmented specimens may even result from an earlier period of occupation associated with the earlier radiocarbon PD. Razor clam is no longer the second most abundant taxon, but the yields are comparable with context 15 of TNB2 and therefore continuity in the atypical exploitation of this taxon can be asserted.

The fish are very small continuing (accelerating?) the size reduction observed between contexts 5 and 11 at TNB2. The limited bone assemblage also continues a trend of decreasing evidence for the exploitation of vertebrates other than fish. The site can be cautiously considered as one of spring and summer occupation. Around 4,400 cal BC the Mesolithic people appear to have abandoned, to any meaningful degree, the exploitation of mammalian and avian resources, or at least they no longer pursue such resources where they procure their molluscs, crabs, and fish. This continues a trend first seen at the northern extremity of TNB2. Season of occupation still appears to be still focused on the spring and summer and certain 'signature characteristics' are maintained such as the exploitation of razor clam albeit at reduced levels, there is however and increased interest in dog whelk relative to periwinkle as also observed at the extremities of TNB2, especially context 15.

The above mixture of change and continuity appears to take place against a background of dramatically reduced fish size and high levels of disturbance to limpet growth. Which implies some level of environmental change may be occurring, and the reduced focus on periwinkle and razor clam may also be further indicators of such change. The evidence for environmental change is the subject of chapters 7 and 8 and will be considered there.

6.5.10 Traigh na Beirigh 9.

Initially it was thought that the inhumation would have turbated and potentially fragmented the faunal remains to a point where trends in metrics would be of little value. Compositional data was only collected with a view presenting it at a site level (excluding the interface layer) for a degree of completeness. As the project was drawing to a close it became apparent that metric capture from TNB9 and also TNB1 contexts 15 and 9 may have more value than originally thought. As the number of shells in all the above were relatively low the small exercise of gathering metrics from all the above was scheduled as a 'break from writing' exercise on Saturday mornings during the spring of 2020; then the covid-19 pandemic arose, and consequently only compositional data is presented (figure C6-52).

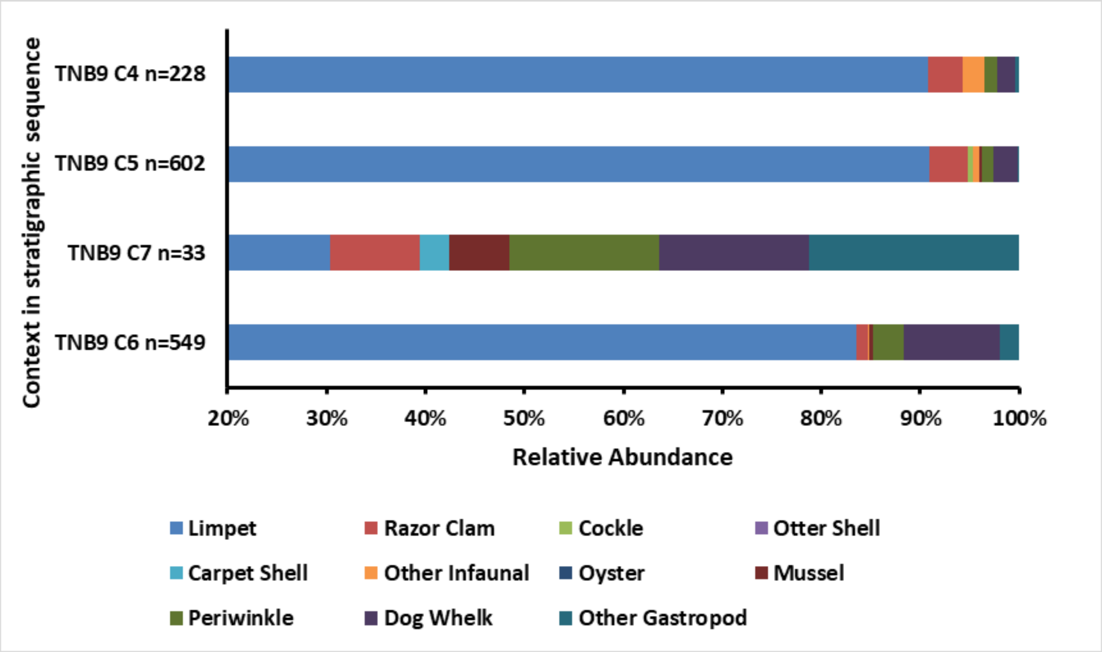


Figure C6-52: The composition of the molluscan taxa from the scoop adjacent to the human burial and the context underlying the human burial. Material in and around the remains of the individual have not been considered.

Although the context sheet records the presence of shell fragments, context 9 is not depicted in figure C6-52 as it contained no quantifiable shells in the 4R fraction. Context 6 sees dog whelks more abundant than periwinkle and razor clam continuing the situation observed at the extremity of TNB2 and PMS. Context 7 is the fill of a cut (not the grave cut) and the sample size is small, but the composition is consistent with others that might be deemed to represent direct human consumption (see TNB1 below). Context 5 sees razor clam restored as the second most abundant taxon, but dog whelks remain more abundant than periwinkles continuing the characteristic first observed at the northern extremity of TNB2.

The bone assemblage is very poor at the 4R level, and only one specimen could be positively identified as avian and this was a vertebra in context 9, although a couple of diaphysis fragments were noted in context 6 as possibly of avian origin. Context 6 also has what is probably a fragment of distal ulna from a carnivore, which is burnt. All other identifiable remains were from mountain hare and are from the appendicular skeleton. In stark contrast to contexts at the other Cnip sites, no dentition is present as also observed at the Toe Head sites. The human burial no doubt disturbed the deposits and possibly explains why there is a left and right astragalus, which size suggests may be from the same mountain hare, distributed between contexts 5 and 6.

6.5.11 Traigh na Beirigh 1

The results presented in this section will focus on the section C-D. Compositional data is available for section A-B, but the basic biometric analysis was not conducted by Evans (2015). This is not because the data from section A-B is without interest, but no radiocarbon PD exist for section A-B and certain characteristics are shared with the extremities of TNB2. As the project progressed the author experienced some regret that basic biometric analysis had not been undertaken for section A-B by Evans (2015).

6.5.11.1 Marine Molluscs

6.5.11.1.1 Composition

Quantification was carried out for all samples from all contexts and the results are provided in figures C6-53 and C6-54. It is likely that the midden contains two categories of deposit the first being the more extensive time aggregated (contexts 8, 9, 14 and 15) and the second more discrete and temporally concentrated (context 11), also interpreted by the excavation team as discrete small scale deposition event. Putting context 11 to one side for now, there are trends in composition common to both section A-B and C-D. The abundance of dog whelk decreases, and razor clam again becomes the second most abundant taxon, as observed at TNB2 and context 5 of TNB9. There is also a small but consistent

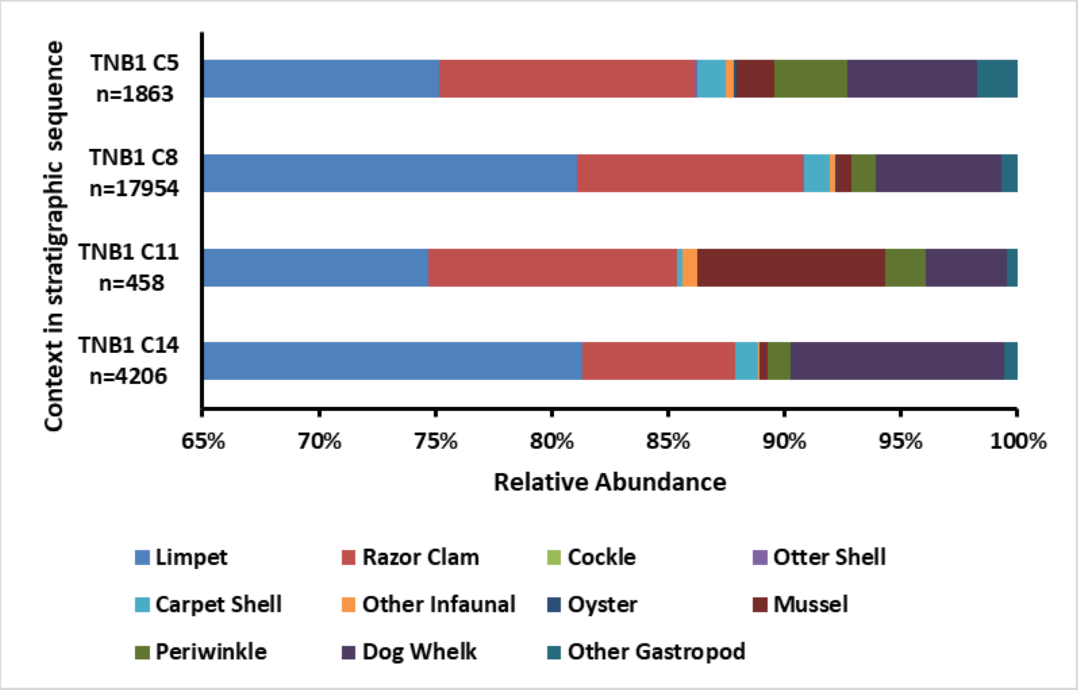


Figure C6-53: Molluscan composition in section C-D. TNB1 C5 is only provided for completeness as it is an interface layer and also contains post-Mesolithic material.

increase in mussel and periwinkle, which the author considers is more important than its magnitude might suggest, and this will be explored further below. The abundance of limpet is almost identical and remains basically constant. In both sections there is a move away from the PMS like composition of the pre-midden layer to something new which is associated with midden formation. As is typical of the region the contexts are numerically dominated by limpets, with an increasing contribution from infaunal bivalves overtime, primarily due to razor clam, the second most abundant taxon in contexts 8, 9 and 11. The unique character of the assemblages observed at TNB2, PMS and TNB9 is sustained, although at the reduced abundance levels of context 15 of TNB2. In contexts 14 and 15, which are interpreted as reflecting occupation(s) prior to midden formation commencing, razor clam is relegated to third place by dog whelk as is observed at PMS and contexts 6 and 7 of TNB9. The increased abundance of dog whelk relative to periwinkle first observed at the extremity of TNB2, PMS context 2 and TNB9 contexts 6 and 7 is sustained.

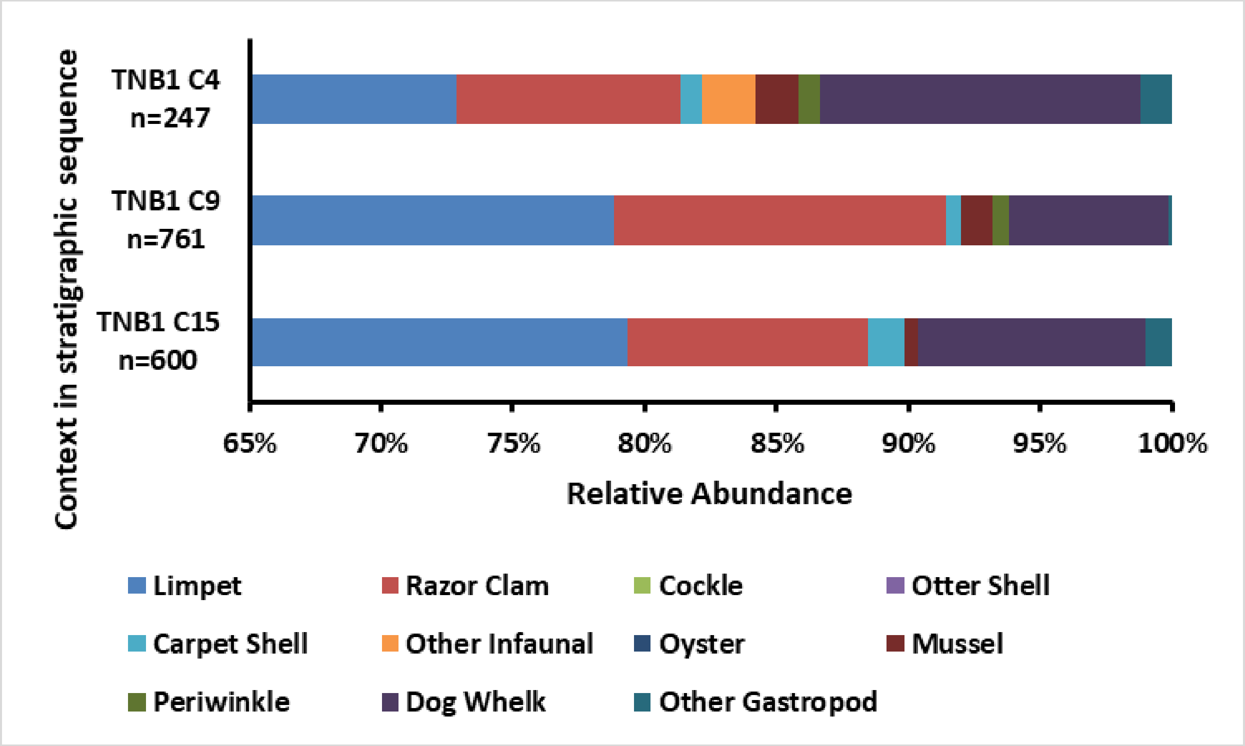


Figure C6-54: Molluscan composition section A-B. TNB1 C4 is only provided for completeness as it is an interface layer and also contains post-Mesolithic material.

Returning to context 11 which is considered to be a specific deposition event, it must be noted that its composition is different to either the pre-midden deposits or the midden deposits. Mussel plays a significant role and razor clam is once again the second most abundant taxon. Periwinkle also increases whilst dog whelk decreases significantly, as does limpet. The species exhibiting the positive vectors are those that many may associate with (preferred?) human consumption and that hypothesis will be tested further in due course but is consistent with the small increase in mussel in the middens highlighted earlier. If the hypothesis is assumed to be true, then it suggests that only part of the main midden is a result of direct (or preparation for) consumption and that some components are probably associated with non-consumption related activities. The intensity of deposition increases between context 14 and context 8. Contexts 11 is small in terms of litres as might be expected of discrete small scale deposition event, but its yields per litre are the highest. Evans (2015) utilised biodiversity using the methods of Whittaker, (1960) and the sampling principles of Hawkins and Hartnoll, (1980) in relation to seashores to support the small scale and discrete nature of this context. Dupont *et al* (2016) attempted the approach at a site level for the Brittany's middens and concluded the method did not work. Dupont *et al* (2016)'s attempt was never likely to succeed. When considering deposition of time aggregated sites that are occupied intermittently, the principles and results of Hawkins and Hartnoll (1980) indicate that maximum biodiversity will have been attained in a much shorter period than a site is typically occupied for. Yield levels in section A-B are noticeably lower than in C-D (figures C6-55 and C6-56), the latter appears to continue the trends first apparent in PMS, although at a less extreme level. Whilst yields vary the compositions in A-B and C-D (excluding context 11) are very similar at each phase. Yields in contexts 14 and 15 are closer to those at the northern end of TNB2.

The observations made for TNB2 in regard to the other gastropod grouping, in terms of composition, spatial patterning and preservation are applicable here also. Over 95% of *L. fablis* and *L. obtusata* are whole, in excellent condition, and retain colour. It is possible to tentatively suggest that some time elapsed between the deposition of context 14 and context 11 and again prior to context 8. Context 14 may reflect an element of natural background, in terms of these small species being already present when human occupation began. Further quantitative analysis will be confined to section C-D and mainly focused on contexts 8 and 14.

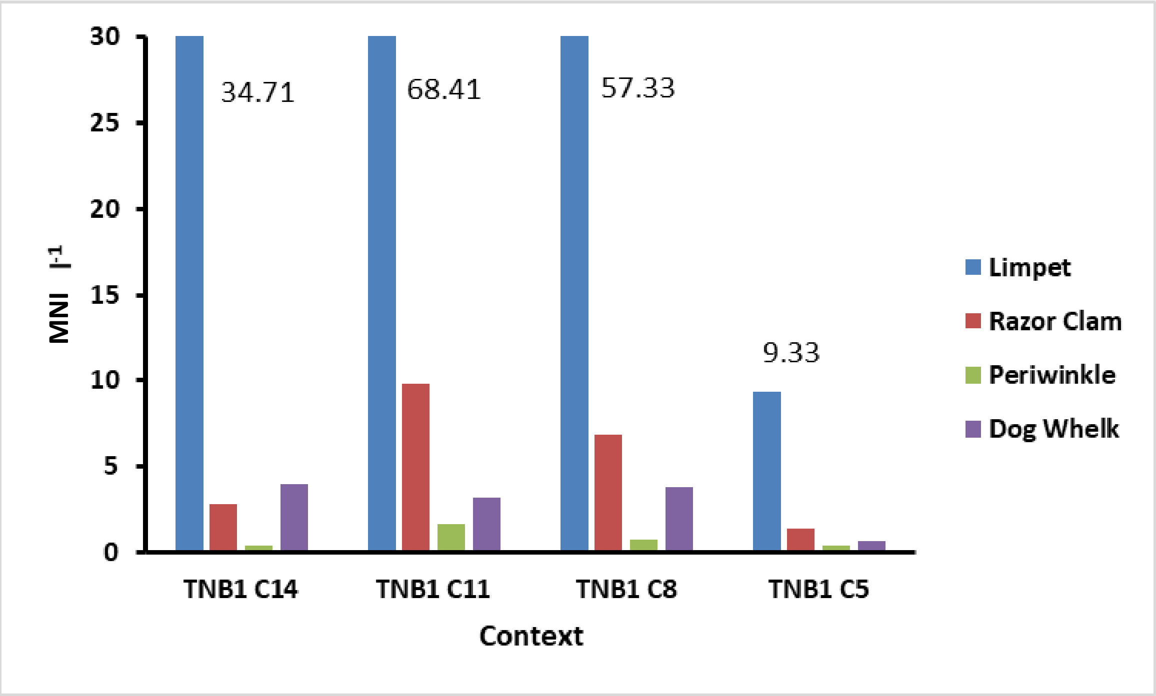


Figure C6-55: Yields of selected molluscan taxa in section C-D. Note the Y-axis is truncated and the values adjacent to the limpet columns give the actual values for limpets.

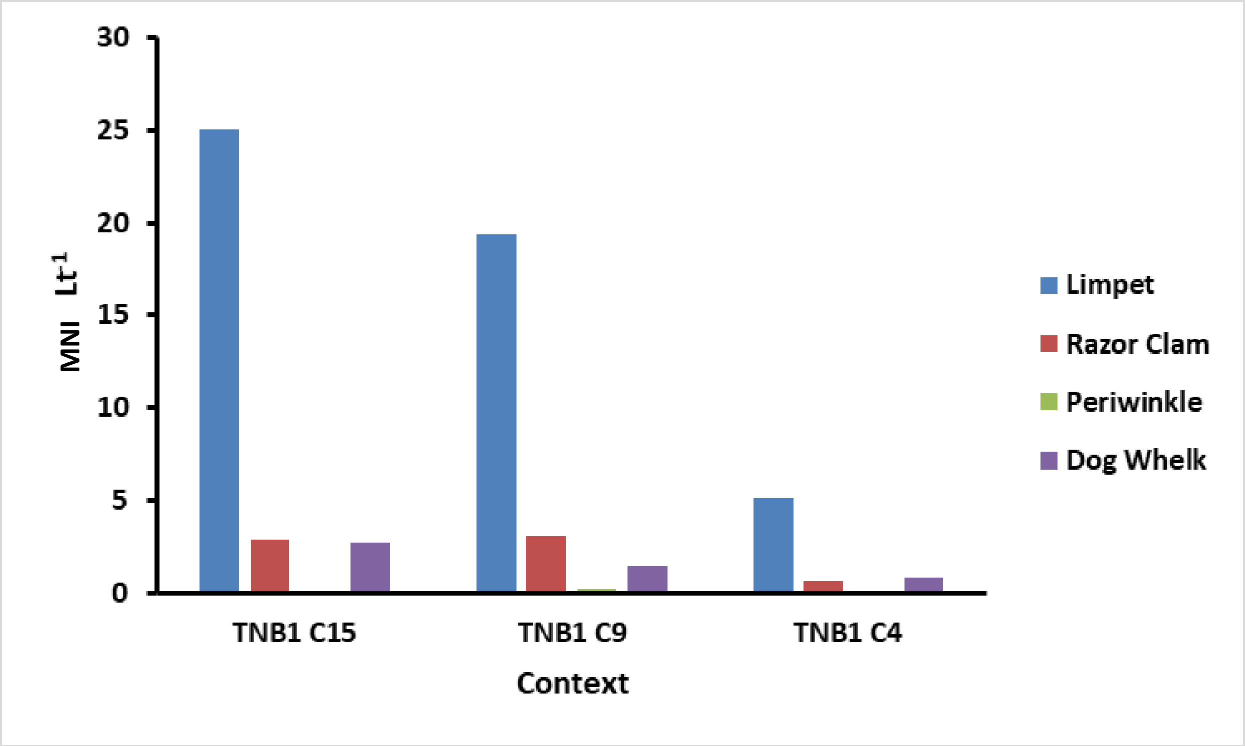


Figure C6-56: Yields of selected mollusc taxa in section A-B.

6.5.11.2 Biometrics

The size of limpets in terms of length is presented in figure C6-57. The limpets at TNB1 are small by most standards and context 11 is just about devoid of larger specimens exceeding 40mm in length, thus the majority yield very little flesh. When examining such specimens, it is difficult to envisage how the effort of procurement is rewarded by nutritional return. Most of these limpets are yielding less than 2g of wet flesh and many less than 1g (Evans, 2015, based upon Santini, 1995). If context 11 is a specific small scale deposition event, the opportunity for the people to be selective, either did not present itself, or for whatever reason was not exploited. As observed at TNB2 these distributions do not reflect natural populations, even if we discount the very smallest limpets (SL_P<20mm) that numerically dominate natural populations. Again the 30-39mm class is overrepresented, and with the unique exception of context 14, the second mode of limpets >40mm in length (cf. Baxter, 1982; Blackmore, 1969, Lewis and Bowman, 1975, Thompson, 1980, Ballantine, 1961a) is missing. Baxter (1982)'s population occupied an area of 8.25m^2 and therefore these assemblages could only arise through the exploitation of a very extensive area of the shore and that exploitation cannot have been that intensive, either that or the population was rested regularly for a year or two at least. Comparison of limpet length between contexts 8 and 14 fails to reject H_0 at a 95% confidence level. The external volumes are significantly different for all contexts. H_0 can be rejected at the 99.9% confidence level between context 8 and the other two. For context 11 and 14 H_0 can be rejected at the 99% confidence level.

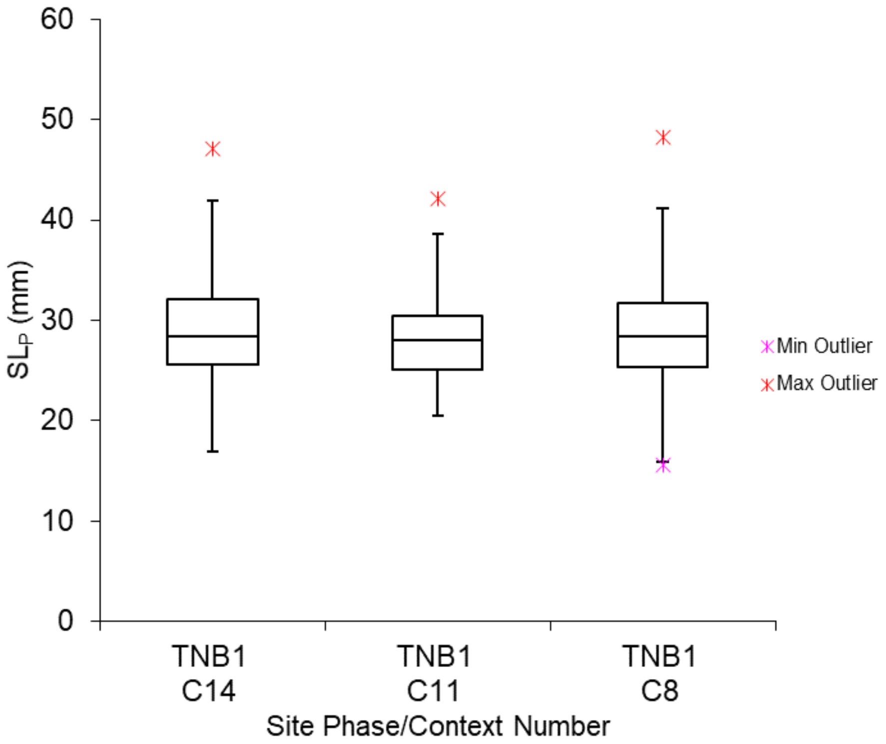


Figure C6-57: The size of limpets in (selected excavation samples from context 8) at TNB1, section C-D. Samples 6 and 25 Context 8 n=1448. context 11 n=176, and context 14 n=671.

The conicity of the limpets can be assessed to establish the nature of the desiccation regimes present and the degree to which the lowest shore and highest shore were exploited (figure C6-58). The conicity of the limpets in contexts 8 and 11 are similar but the conicity in context 14 is significantly different to both context 11 (H_0 rejected at CL=99%) and context 8 (H_0 rejected at 99.9%). Context 14 exhibits a fairly normal distribution centred around the fairly non-diagnostic middle values which neither designate high-shore or low shore origins but rather local differences with the environment in terms of rock pool residence, shade, and weed cover in the mid-tidal zones. Contexts 11 exhibits restricted range as might be expected of a short term single deposition event, which probably occurred either at one state of the tide or another; or at least a constrained period within the lunar cycle. Consistency with TNB2 is observed as the range of the values for volume and conicity varies with the excavated volume of a context. In summary, whilst the limpets in contexts 8 and 14 have similar lengths (H_0 cannot be rejected at CL=95%) the former has the larger limpets that give the greatest yield irrespective of length (H_0 rejected at CL=99.9%); selection appears to be based upon the manner in which the three dimensions combine for a better outcome.

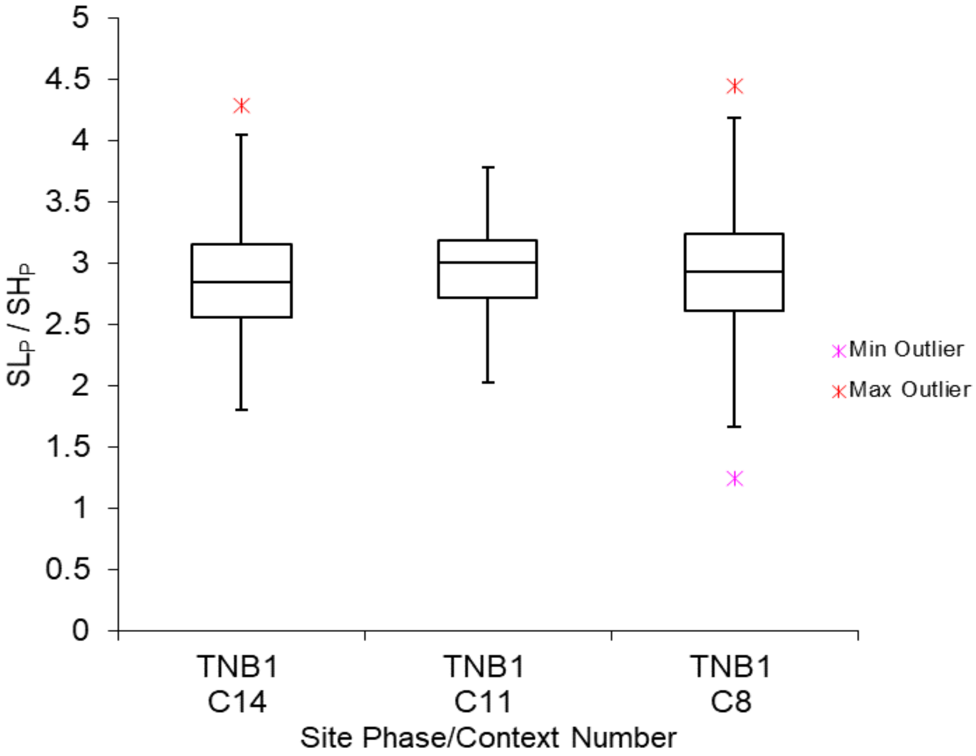


Figure C6-58: The population structures in terms of conicity from section C-D. Samples sizes as per figure C6-56.

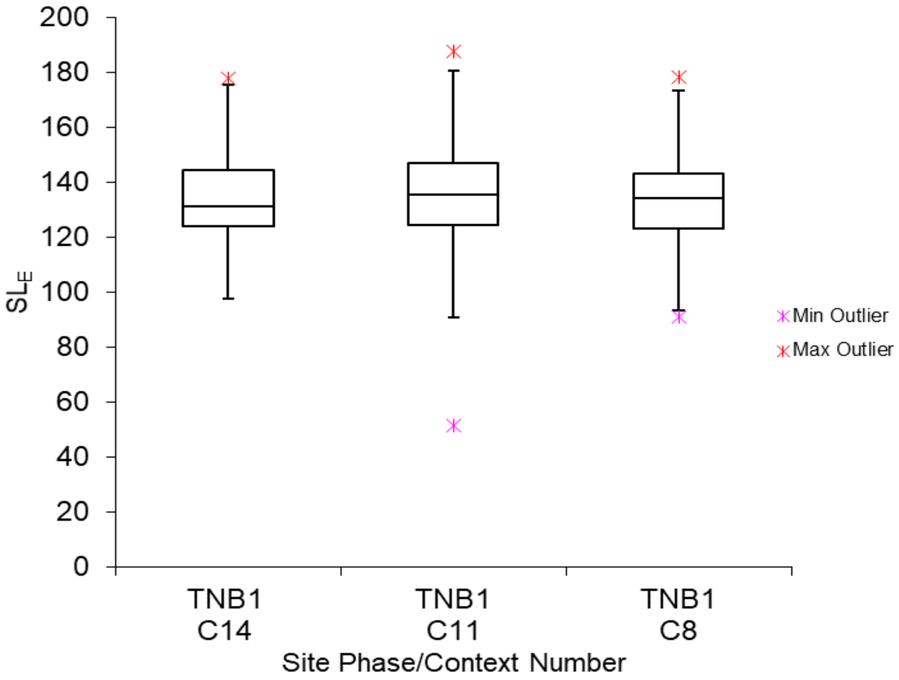
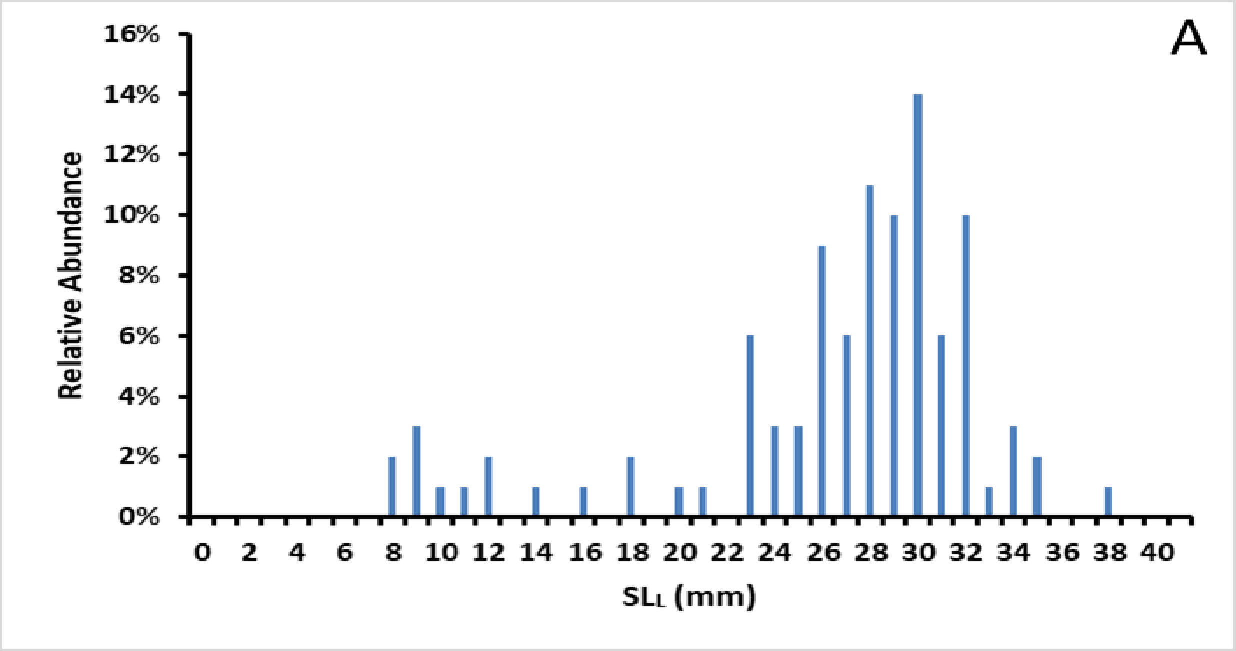


Figure C6-59: The population structures of razor clam in terms of modelled length. Context 14 n= 64, context 11 n=19, and context 8 (excavation samples 6 and 33) n=270.

The size distributions of razor clam are provided in figure C6-59. The size of razor clams is consistent between all contexts (Failure to reject H_0 for all combinations). All three contexts have a larger number of specimens that fall into the *Ensis siliqua* range (>150mm) beyond that of *Ensis magnus* compared to TNB2. Context 11 has a small assemblage of surprising range in terms of size. It is not



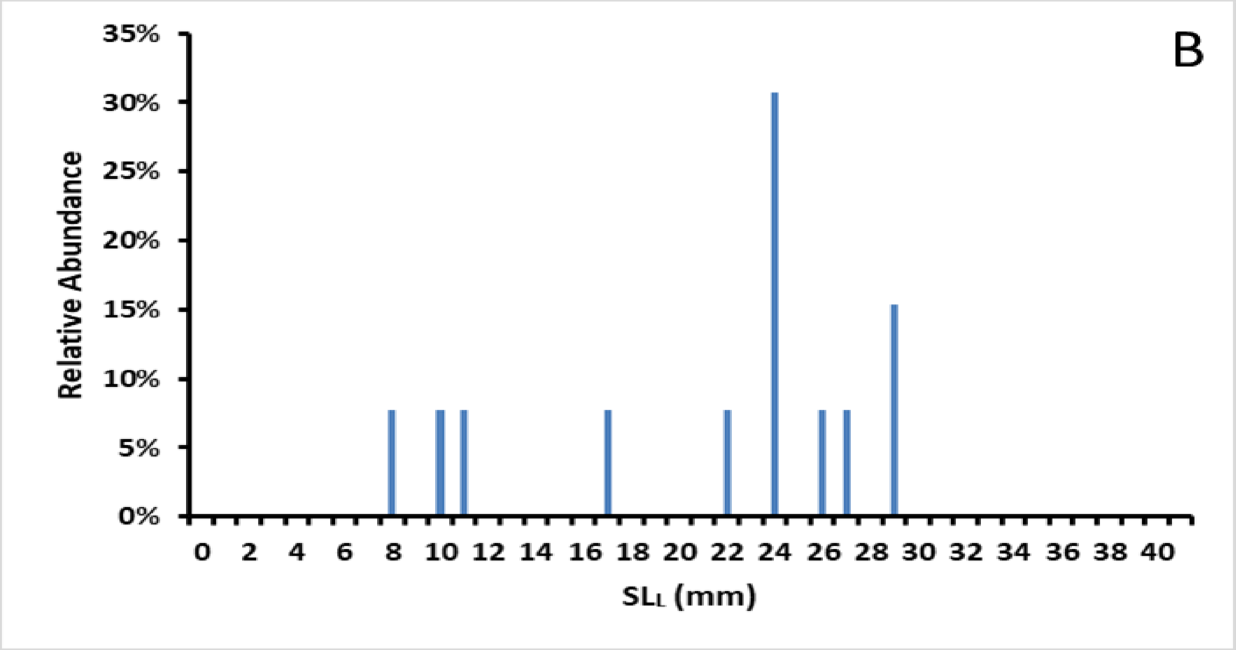


Figure C6-60: Periwinkle lengths in context 8 (A) and context 14 (B). The data includes both measured lengths and modelled lengths. Context 14 n=13 and context 8 n=100. The strength of the mode of non-economic specimens results in the acceptance of H_0 if they are included. If these specimens (SL_L<20mm) are eliminated H_0 is rejected at the CI given.

difficult to envisage some frantic digging at the turn of a spring tide and taking whatever turns up irrespective of size. But it is consistent with a focus on human consumption where a thorough acquisition effort was made, whilst the limpets were just taken based upon accessibility.

The size distributions for periwinkle are provided in figure C6-60. Only the data from contexts 8 and 14 is presented as the sample size from context 11 is too small to draw any inferences from.

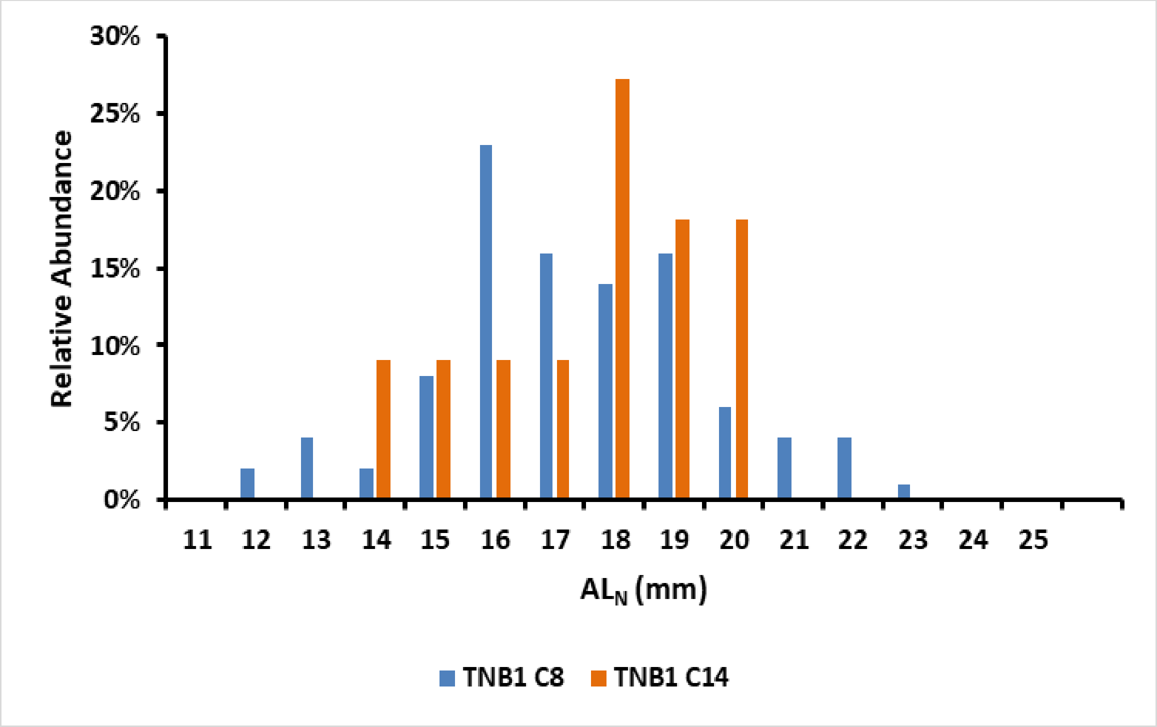


Figure C6-61: The size of dog whelks in terms of aperture height. Context 8 n=100 and context 14 n=11.

The periwinkle distributions are both bimodal with the first comprised of larger specimens greater than 24 to 25mm in height and the second of very small specimens around 10mm in height. These smaller specimens are unlikely to have been of economic importance (cf. Milner, 2009a) and are probably specimens that entered the assemblage whilst adhering to other larger molluscs or seaweed. The number of measurable periwinkles, even to the extent that the length could be modelled is very low in context 14. Ignoring the non-economic size class, the periwinkles in context 8 are large, with some exceeding the view of maximum size held today (Hayward and Ryland, 2012), whilst the periwinkles in context 14 are significantly smaller (H_0 rejected at CL = 95%). The people who deposited context 14 appeared to have a very limited choice of periwinkles despite the conicity of the limpets suggesting they foraged over quite a wide region of the shore and razor clam requiring attention to be paid to the lowest levels of the inter-tidal zone. The dog whelk populations are presented in figure C6-61 and clearly a greater size range is present in context 8, whilst context 14 is skewed towards a larger size class. H_0 is accepted at a CL of 95%.

Table C6-22: Fragmentation levels of limpets and razor clams against MNI.

Context 8	**Complete**	**EHL**	**LTL**	**Delta**
Limpet	27.8%	N/A	N/A	
Razor Clam	0.0%	24.6%	85.0%	60.4%
Context 11	**Complete**	**EHL**	**LTL**	**Delta**
Limpet	51.5%	N/A	N/A	
Razor Clam	0.0%	38.8%	85.7%	46.9%
Context 14	**Complete**	**EHL**	**LTL**	**Delta**
Limpet	19.6%	N/A	N/A	
Razor Clam		23.1%	88.1%	65.0%

The fragmentation levels are generally typical for these middens although the number of measurable limpets is relatively low in context 14 (table C6-22). Table C6-23 shows the proportions of periwinkles dog whelks that are complete in their length compared to those that were not. For context 8 figure C6-62 breaks this down further for specimens that could yield at least one biometric measurement. The difference in fragmentation is significant with H_0 being rejected with a Chi^2 test at a confidence level of 99.9%. The relative absence of extreme fragmentation in dog whelks is due to the robustness of the apertures which permits them to survive in isolation which is rarer for periwinkle (SI-Chapter6-3). The differential treatment of these two marine snails observed at TNB2 is sustained. The implications of this differential have already been presented in the section on TNB2.

Table C6-23: Number of periwinkles and dog whelks with complete lengths against MNI.

	Periwinkle	Dog Whelk
TNB1 C8	42.7%	1.9%
TNB1 C11	12.5%	12.5%
TNB1 C14	33.3%	2.8%
TNB1 C9	20.0%	2.2%
TNB1 C15	n.d	n.d

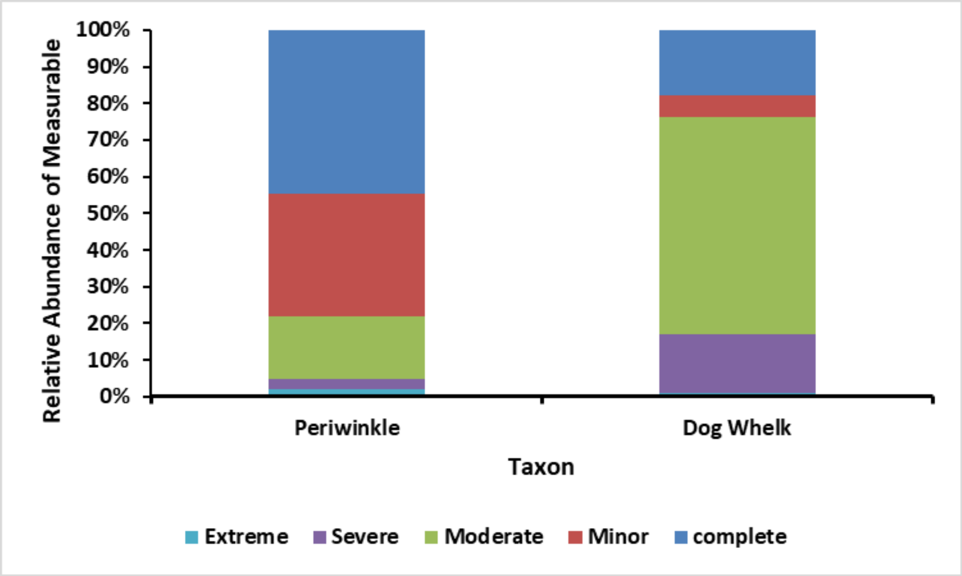


Figure C6-62: The relative fragmentation level of dog whelk and periwinkle as a proportion of those that yielded at least one measurement, that is were not just an isolated apex. The proportion complete therefore does not match table C6-23 as complete here means all measurements could be taken whereas a complete specimen in table C6-23 may appear here as extreme if shell height was the only measurement that could be taken.

6.5.11.3 Interim Summary

The assemblage at TNB1 is typical of those of Atlantic Europe and north western Scotland in that it is dominated by limpets. Generally, the second most abundant taxon is razor clam, and this is atypical of both north-west Scotland (excluding TNB2) and Atlantic Europe as a whole. However, the earliest phases of occupation (contexts 14 and 15) continue the pattern that emerges in the extremities of TNB2 and continues at PMS with dog whelk exceeding razor clam abundance. Infaunal bivalves in general are exploited to a much greater degree than at the other sites in north-west Scotland where they are represented by the odd specimen. The assemblage is in other ways also typical of north-western Scotland in that oyster is all but absent and so is cockle. The fact that context 11 probably represents an individual deposition event, possibly from short term occupation combined with the data from NT and TB, potentially hints at differential use of molluscs as the contribution from razor clam, infaunal bivalves and epifaunal mussels is greater and that of limpets lower. The increase in limpets in context 8 may hint that some of the procured population was not for human consumption. The switch from exploiting periwinkle to exploiting dog whelk which commenced at the extremities of TNB2 and continued at PMS is also sustained throughout. The increase in yields per excavated litre, first observed at PMS, are also continued, even if at moderated levels, in section C-D. At TNB1 the unique characteristics (and trends within) of the mollusc assemblages on the Isle of Lewis are repeated.

6.5.11.4 The Bone Assemblage.

6.5.11.4.1 Composition

The bone assemblage was evaluated from the 4R fraction and the number of bone fragments by context is provided in table C6-24. It is highly likely that greater than 95% of the bone fragments belong to hare, the remainder being otter.

Table C6-24: Summary of the sparse bone assemblage.

TNB1					
Context	**Mammal**	**Bird**	**Unknown**	**Total**	**Yield l^{-1}**
5	9	6	25	40	0.27
8	128	19	113	260	1.02
11	9	0	1	14	1.40
14	17	1	28	46	0.47
4	0	0	0	0	0
9	4	2	2	8	0.26
15	1	0	4	5	0.26

Within section C-D only three bird bones could be identified to species and that is a diaphysis fragment from the radius of a grey heron. Herons, beyond the provision of meat and leather, are potentially useful to hunter-gatherers as a source of feathers, long straight bones, and beaks for tools or ornamentation (chapter 3, Tuck, 1971). Two specimens were identified from cormorant (*Phalacrocorax carbo*) in the upper interface layer (context 5), but these cannot be securely attributed to the Mesolithic. There is nothing to indicate that these three specimens were deposited by humans and they could have been natural deaths on the midden. In section A-B two bird bones were identified as belonging to the auk family (alcidae). The mammalian remains are a little more extensive and the number of identified specimens and minimum number of individuals (MNI) by context are provided in table C6-25. A number of the specimens identified as mountain hare (*Lepus timidus*) were charred evidencing their exploitation

Table C6-25: The assemblage in terms of NISP and MNI.

Context	**Hare (NISP)**	**Otter (NISP)**	**Med Ungulate (NISP)**	**Heron (NISP)**	**Auk (NISP)**	**Cormorant (NISP)**	**Hare (MNI)**	**Otter (MNI)**	**Med Ungulate (MNI)**	**Heron (MNI)**	**Auk (MNI)**	**Cormorant (MNI**
5	8	0	1	0	0	2	1	0	1	0	0	1
8	103	2	0	1	0	0	1	1	0	1	0	0
11	5	0	0	0	0	0	1	0	0	0	0	0
14	11	2	0	0	0	0	1	1	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
9	4	0	0	0	2	0	1	0	0	0	1	0
15	1	0	0	0	0	0	1	0	0	0	0	0

by humans. Two specimens of hare appeared to be juvenile based upon epiphyseal fusion, as is the case with the unfused proximal epiphysis of an otter's ulna. Otters are known to have been eaten, and they are a good source of fur, but there is nothing to suggest other than a natural death on the midden, presumably during a period when humans were not in attendance.

At first glance the assemblage is spectacular in its paucity of remains in general, and especially those from birds. Yet there are some interesting features. Firstly, the ungulate is from what is a post-Mesolithic context, and its condition, especially the lack of root acid etching suggests that ungulates were not part of the archipelago's ecosystem by 4,000 BC. The chunks of terrestrial mammal bone that are possibly waste from tool production are absent. NT and TB confirm that mountain hares were present in the archipelago from early in the 7th millennium BC and therefore their presence at TNB1 demonstrates a viable population existed for over two millennia, despite human exploitation and the 8.2K cal bp event. It is worth mentioning that the 103 NISP of mountain hare in context 8 results in a MNI of only one. This is because most of the remains are either single examples of dentition, metapodial fragments or fragments of phalanges. What is also significant is what is missing, namely birds, which is unusual for the region, excepting TNB2 context 15 and PMS. No specimens of marine mammal bone were identified. Most parts of the hare are represented except for the femur (proximal hind limb) the major meat baring bone with similar physical characteristics to a non-auk's humerus (SI-Chapter6-8). It appears to be a simple fact that mammals and especially birds were not exploited to any great extent at TNB1. This continues the trend first observed at the extremities of TNB2 and PMS.

6.5.11.5 The Crab Assemblage.

6.5.11.5.1 Composition

The analysis of crabs was conducted against the 4R fraction and the results are provided both in terms of NISP and MNI. Compared to the other sites crab remains are very abundant (figure C6-64). The first result of note is that whilst all the fragments were examined individually no carapace margins were identified, even for species where the margins are very distinctive such as the edible crab. The fragments appeared to originate from the chela (claws) or the other limbs. The compositional make up is provided in figure C6-65 and table C6-26. The two most abundant species are the edible crab and the shore crab, the third most abundant group is the swimming crabs. A couple of claws had a very distinct morphology in terms of curvature and taper of the dactylus and these have been assigned as either stone crabs (Norwegian king crab) *Lithodes maja*; or burrowing crab (*Atelecyclus spp.*). The quantitative analysis was conducted against the claws (propodus and dactylus). It should be noted that presence of one additional taxonomic group the nut crabs (*Ebalia spp.*) could be determined from the fragments but could not be quantitatively analysed from claw components. Members of the strawberry crab (*Eurynome spp.)* are also probably present within the fragments. These two taxonomic designations are not reflected in compositional data. Crab remains are very abundant and whilst a small proportion are carbonised, the overwhelming majority are white or grey suggesting some form of heat treatment: possibly baking in ashes. Further biometric analysis is restricted the edible and shore crabs within contexts 8 and 14 to ascertain if any intra-site temporal variation exists. Prior to proceeding it can be stated that the yields of fragments are generally similar in the lowest levels, but context 8 appears to represent a more intensive exploitation. As observed in relation to molluscs, section A-B reflects a far less intensive exploitation (data not shown).

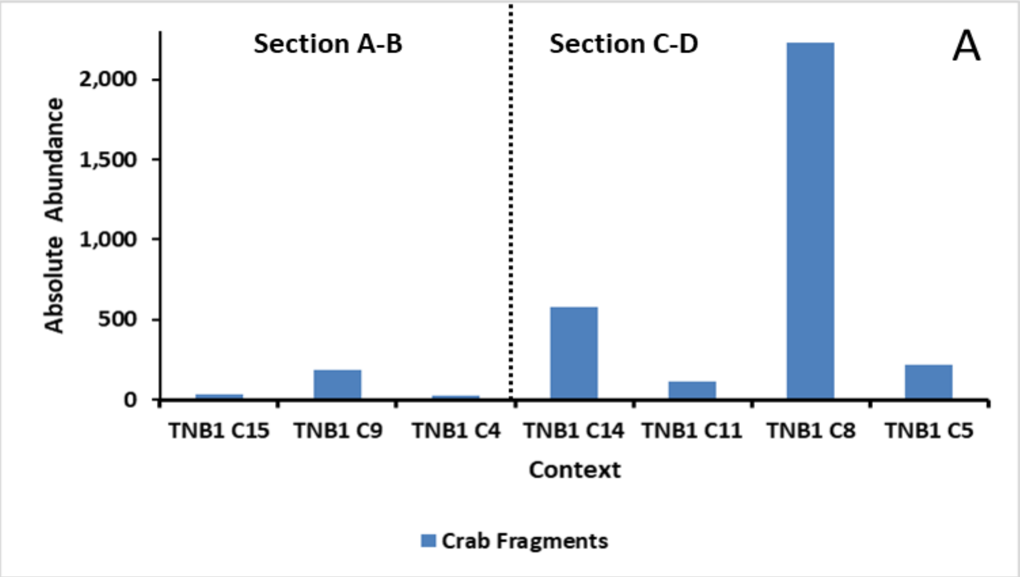


Figure C6-63: Fragments of crab remains in in sections A-B and C-D.

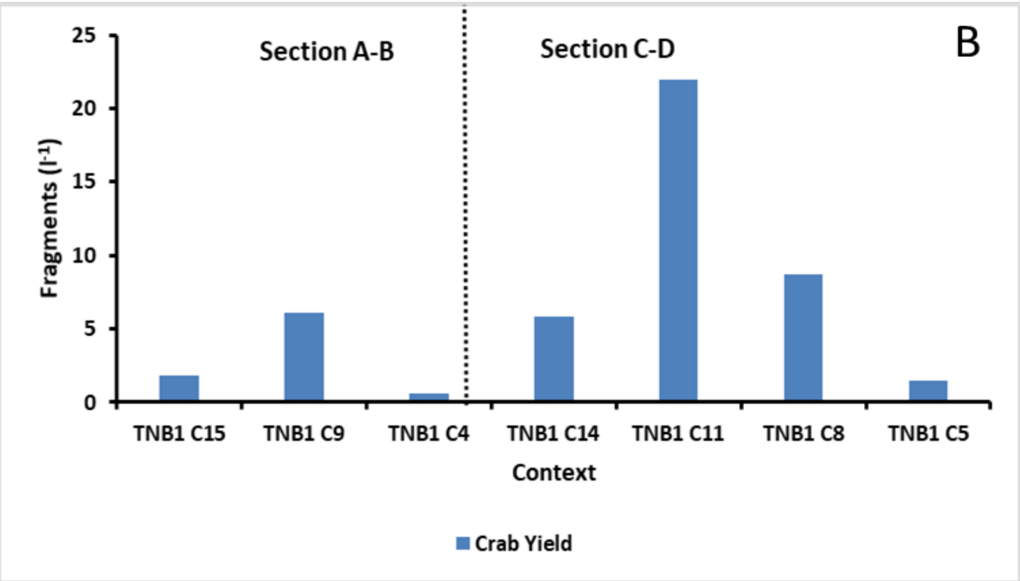


Figure C6-64: Yield of crab remains in sections A-B and C-D.

Table C6-26: The key components of the crab assemblage.

MAU	TNB1 C8	TNB1 C14
Edible	21	7
Shore	10	2
Swimming	3	1

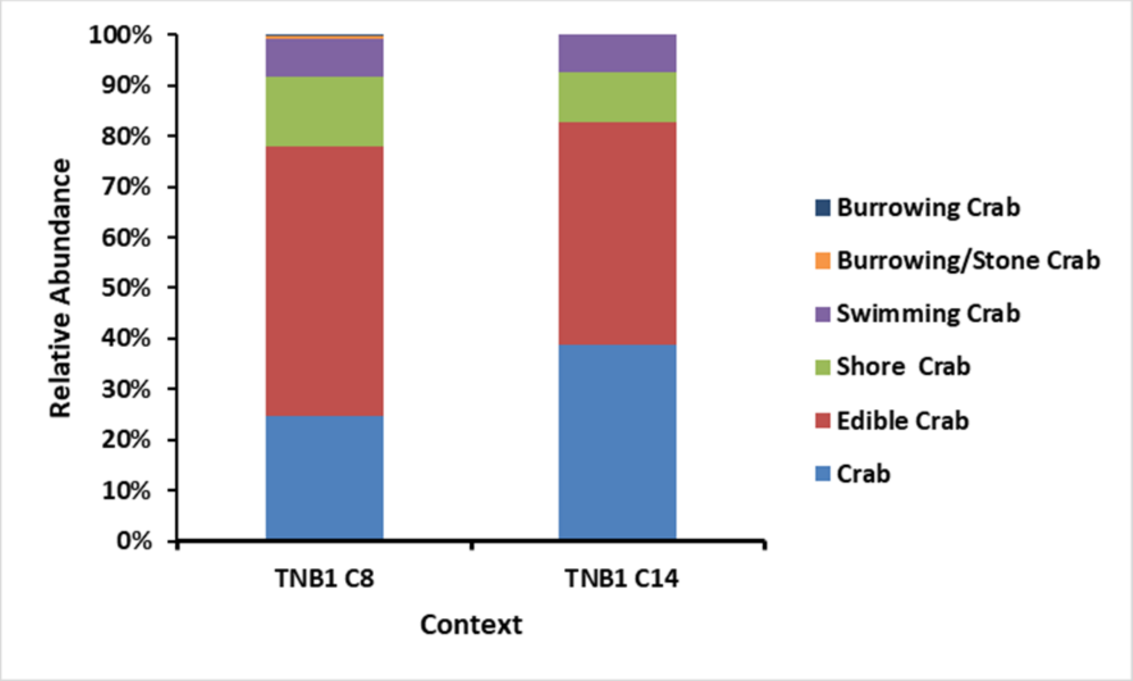


Figure C6-65: Compositional analysis of the crabs conducted against dactyli and propodi NISP. Context 11 has the remains of what is probably a single large edible crab. Context 9 has a small assemblage with a greater contribution from the swimming crabs.

6.5.11.5.2 Biometric Analysis

The size, in terms of carapace width, has been estimated for edible crab and shore crab utilising models constructed against the dactylus and propodus, the results are presented in figure C6-66. The result is quite intriguing as the edible crab distribution is clearly bimodal, whilst the shore crab population can be viewed as potentially bimodal. The mode in edible crab population in context 8 around 70mm aligns with the size beyond which the edible crab leaves the intertidal zone. The mode around 125 – 150mm can therefore be considered as indicative of procurement from the infralittoral or shallow sublittoral. The shore crab population is also interesting as it appears to reflect selective procurement of shore crab which is centred around the larger sizes encountered in rock pools and when lifting boulders and large stones (pers. obs.). The 75mml mode in the edible crab population appears to be consistent with the shore crab population and jointly these two components of the overall population probably reflect selective foraging within the intertidal zone. The larger edible crabs (>70mm) and possibly some of the larger shore crabs (>60mm) are likely to have been obtained from beyond the intertidal zone. The sample size from context 14 is very small but in general it is consistent with context 8 for both species. Context 11 contains the remains of what is possibly a single specimen of edible crab of at least (the full width of the large dactyli was not available) 140mm carapace width. The assemblage from context 9 is also small but contains a very large specimen of swimming crab which based upon size (Crothers and Crothers, 2014; Hayward and Ryland, 2012) must be a velvet swimming crab and at the limit of the size range for that species. There are two examples of edible crab one modelled at 65mm carapace width and the other at 141mm.

One component of the population of both species can be attributed to selective foraging within the intertidal zone and therefore the question arises as to how crabs are acquired from beyond the intertidal zone. One possibility is that the large edible crabs were ejected onto the shore during storms and the occupants, being aware of this phenomenon, rushed down to acquire them. This explanation is difficult to accept, although impossible to refute, given the relative abundance of such windfall specimens is much greater than either the shore crabs or edible crabs procured from the constantly available intertidal zone. Procurement by visual acquisition (the waters around northern Scotland are exceptionally clear) using spears is not consistent with the lack of material culture within the assemblages, although the use of tools constructed entirely of wood as discussed in chapter 3 is a possibility. The main challenge with this latter explanation is that edible crabs and larger shore crabs are nocturnal, making visual acquisition problematic, unless they were encouraged to modify their habits by regular and frequent baiting of specific areas.

An alternative is the use of traps, either of the ‘lobster creel’ variety placed into deeper water by boat, or from intertidal traps utilised to catch fish from which crabs are a very welcome by-product. The size profile makes the latter option unlikely without a strategy to modify crab behaviour by encouraging them into the intertidal zone during the hours of darkness. Due to isostatic readjustment the latter will now be submerged and the former archaeologically invisible due to being constructed entirely from perishable materials. In chapter 3 it is noted that constructs of this type were utilised in British Columbia to procure a variety of marine resources simultaneously. During the pursuit of otoliths, the 1R and 2R fractions of samples from both these contexts were examined and whilst crab shell was observed from time to time, no claws or fragments thereof were noted. The population structures are unlikely to be due to the loss of smaller specimens from the 4R fraction. No claws from hermit crabs were observed in either the 1, 2, or 4R fraction, these are very distinctive as hermit crabs are not technically crabs but more closely related to lobsters and crayfish.

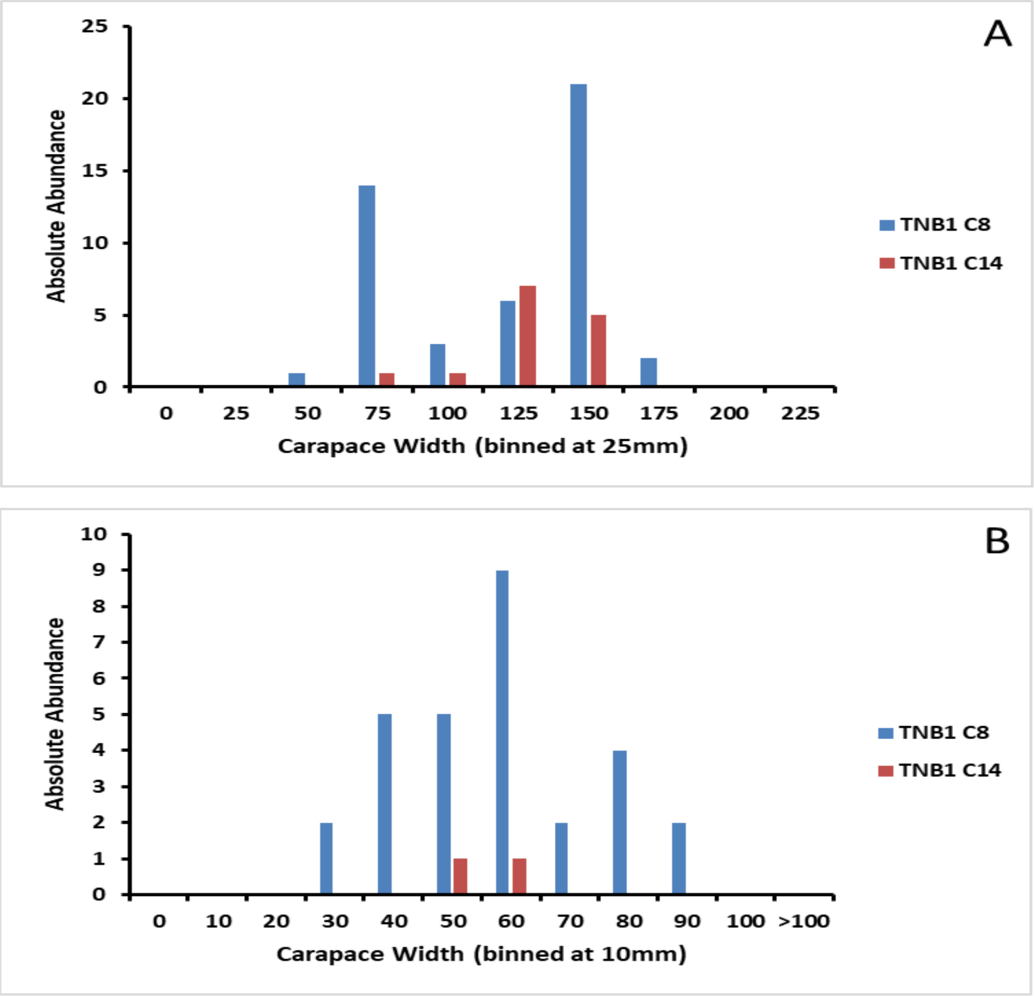


Figure C6-66: Modelled carapace width for edible crab (A) and shore crab (B).

6.5.11.6 Interim Summary

Crabs are a major resource at TNB1, the major species exploited are the same as TNB2, but the level of exploitation is far greater. In contrast to TNB2 a targeted and selective acquisition of crabs from the intertidal zone is evidenced. The consideration of how these were acquired as discussed for TNB2 is equally applicable here.

Prior to moving on to consider the fish remains it is worth noting that the shell of sea urchins is present in the 1R, 2R fractions and one fragment was also located in the 4R. These are encountered fairly frequently in the smaller fractions, along with the carapace of barnacles. The urchin fragments are in two states, the first being angular at the edges and these presumably are a result of human activity; the second is rounded and, borrowing terminology from lithic analysis, extremely well rolled. These are probably components of the shell sands that from time to time will have been deposited by strong winds.

6.5.11.7 The Otolith Assemblages.

The otoliths were assessed from both the 1R, 2R and 4R fractions but at TNB1 no otoliths were present in the 4R fraction. The assemblage had been previously analysed by Morley (2015) but this analysis considered only otolith length. The entire assemblage from TNB1 sample 6 context 8 were revaluated and completeness categorised as stated in the methods.

6.5.11.7.1 Composition

The work here confirms the observations of other researchers in that speciation between many members of gadidae is problematic (Mellars and Wilkinson, 1980; Jones, 1991, Wilkinson n.d., pers. com cited in Jones 1991, Parks, 2009), and especially so when the otoliths are fragmented and relatively few are complete. Whilst certain species can be reliably stated to be present (figure C6-67), the issue of speciation within the *Pollachius* genus and to a lesser extent between cod (*Gadus morhua*)., whiting (*Merlangius merlangius*.), blue whiting (*Micromesistius* spp) and haddock (*Merluccius merluccius*) amongst themselves and in relation to *Pollachius* spp. cannot be understated. Over and above the species where a definite presence can be asserted, tentative identifications (data not presented) of fragments suggest that hake, cod, haddock, polar cod and sand goby are probably present at very low frequencies or as exotics. Taxonomic composition is very similar for both contexts and the difference between gadidae and *Pollachius* being down to greater levels of fragmentation and therefore more challenging task of identification to genus level.

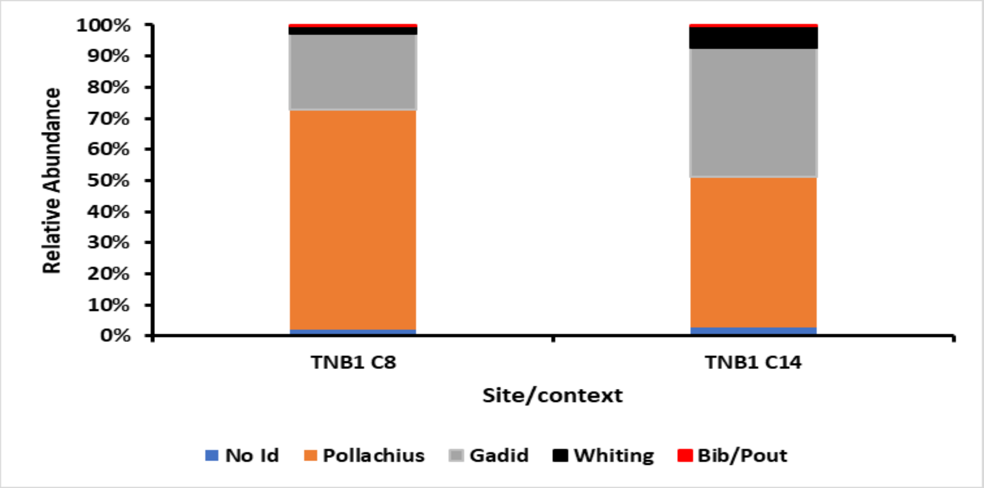


Figure C6-67: Relative taxonomic composition of the identified NISP.

The minimum number of otoliths (MNO), and MNI from each context is provided in table C6-27 along with the MNO per excavated litre. As with other taxonomic classes context 8 represents a more intensive period of deposition.

Table C6-27: The abundance and yields of otoliths belonging the *Pollachius* genus.

TNB1	**S6 C8**	**S36 C14**
MNO	329	113
MNI	165	57
Yield l^{-1}	7.3	0.7

6.5.11.7.2 Biometric Analysis

The population size structures were determined for the *Pollachius* genus from complete otoliths lengths and otolith lengths modelled from otolith width using the assemblages from the western isles and also the assemblage from Sand Rock Shelter (Parks, 2009), and these are presented in figure C6-68. As already observed in relation to TNB2 and PMS these fish are exceedingly small and a second mode in the distribution reflecting 2nd or 3rd year fish in the 0.5kg to 1.5kg class is absent. There is a pretty even contribution from fish of length 93mm and weight 7g to fish of 176mm in length weighing 46g.

The preservation state of the otolith fragments is presented in figure C6-69 Fragmentation levels are provided in SI-Chpater6-6. What is clear is that some of these tiny fish were burnt although the proportion of carbonised specimens is very low in context 8 (figure C6-69). The greater proportion of

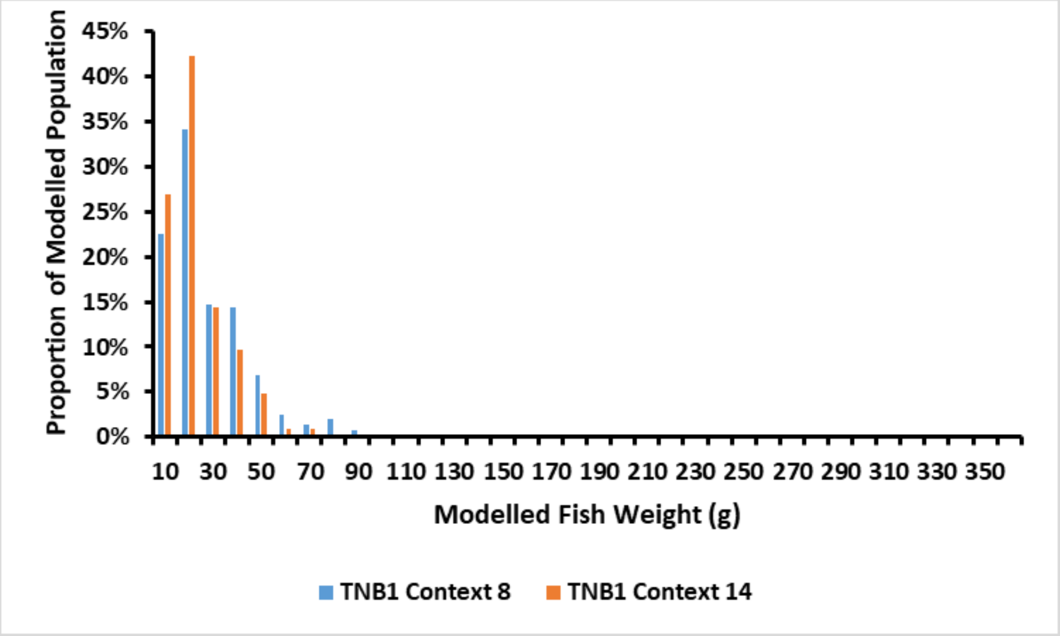


Figure C6-68: Modelled fish weights for Pollachius spp. A size increase is observed in relation to PMS (H_0 rejected at a CL=99.9%). H_0 can be rejected between context 8 and 14 at a confidence level of 95%. For all combinations of TNB2 context 5 and 11 and TNB1 contexts 8 and 14 H_0 can be rejected at a confidence level of 99.9%.

carbonised remains in context 14 is probably a consequence of greater fragmentation levels and is also consistent with the sites already discussed. The eroded, and in particular the very eroded specimens, may have been through the digestive tract of a human or carnivore (see Jones, 1991, p.85-91), but unlike TNB2 there is no other evidence for the presence of dogs. In context 8 all the carbonised specimens were less than 50% complete, whilst in context 14 only 10.5% of the carbonised specimens were greater than 50% complete, and none were fully complete. In general, these very small fish were processed in a manner that minimised the chances of burning, at that includes the possibility that they are discard. However, compared to PMS there has been something of a recovery in the size of the fish, and as stated earlier whether the assemblage reflects a prime resource or discard is a moot point in this regard.

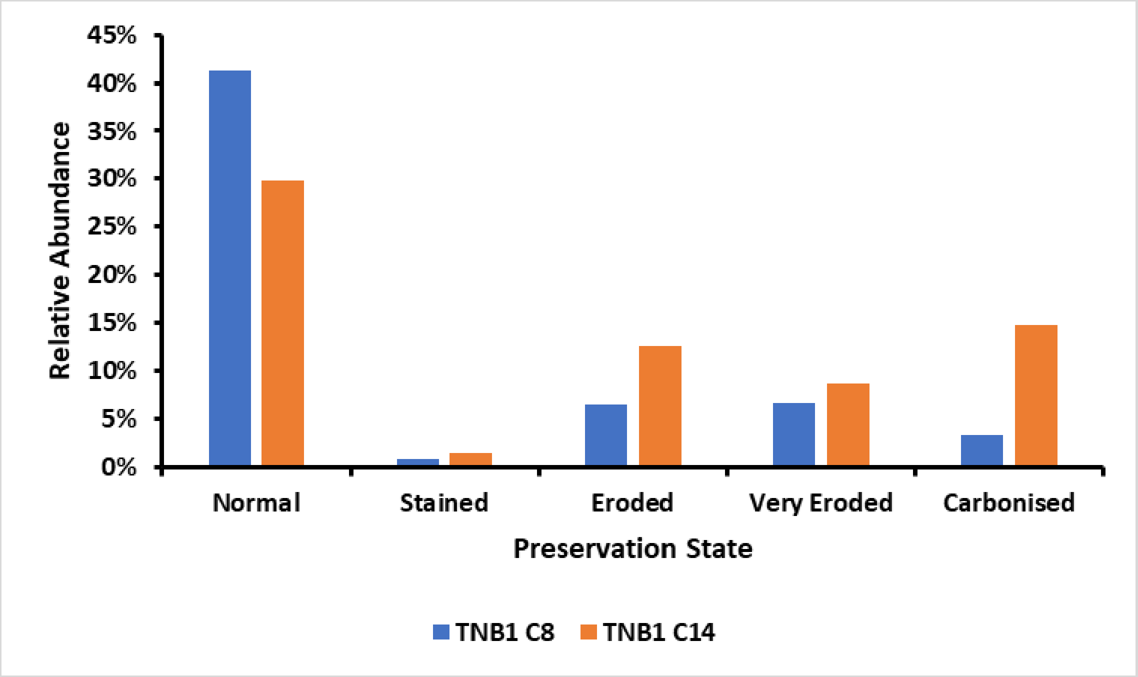


Figure C6-69: The preservation of otolith fragments all fragments.

6.5.11.8 Seasonality and Age at Death

The season of occupation at a hunter-gatherer site is fundamental attribute that informs us about how these early inhabitants of the islands organised their lives. TNB1 presents a problem as the seasonal indicators are just about absent, as they are in the northern end of TNB2 and PMS. The bird assemblage contains no information regarding seasonality, other than in context 9 of section A-B, which contains two possible fragments of auk which suggests spring through to mid-summer.

For the reasons given in chapter 4, and discussed above in relation to TNB2, the application of the otolith lengths as a seasonal indicator is potentially problematic unless the size-season profile can be independently verified via another source. As discussed earlier the exercise in sectioning limpets for seasonality assessment turned up some unusual results in the form of growth disturbances. The prevalence of growth disturbance of limpets from context 8 is provided in figure C6-70. The pattern observed at TNB2 is repeated in that disturbance is more prevalent in the larger size class, although much lower than TNB2 in both classes and PMS in the larger size class. The same data for the >= 40mm size classes from context 14 is provided in figure C6-71 and the prevalence of disturbance is as high as observed at PMS.

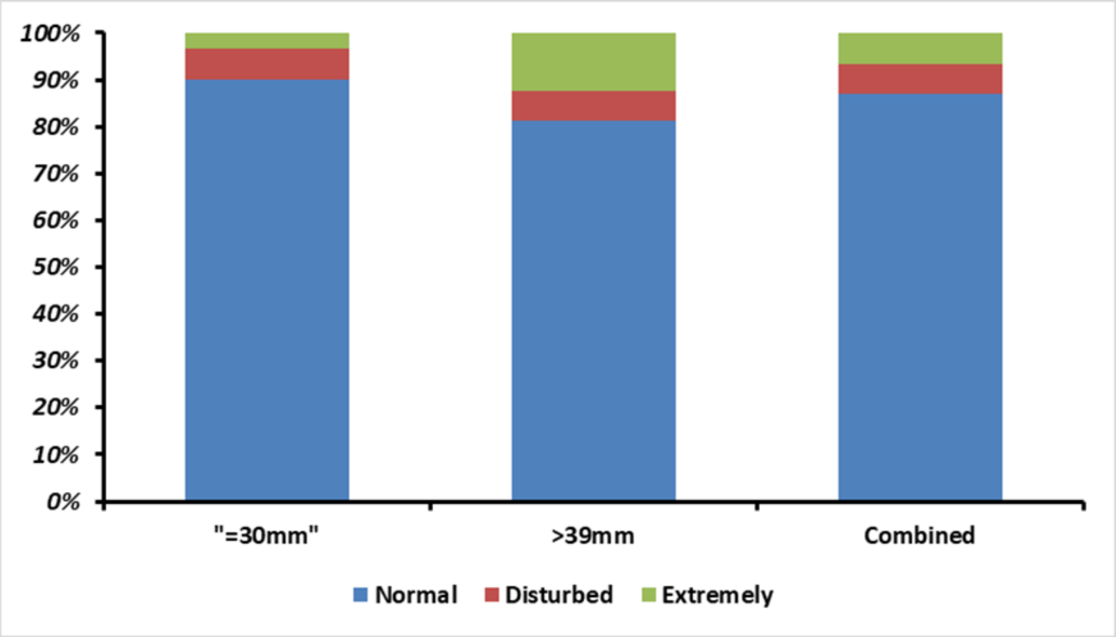


Figure C6-70: The levels of disturbance in the sectioned limpets within context 8.

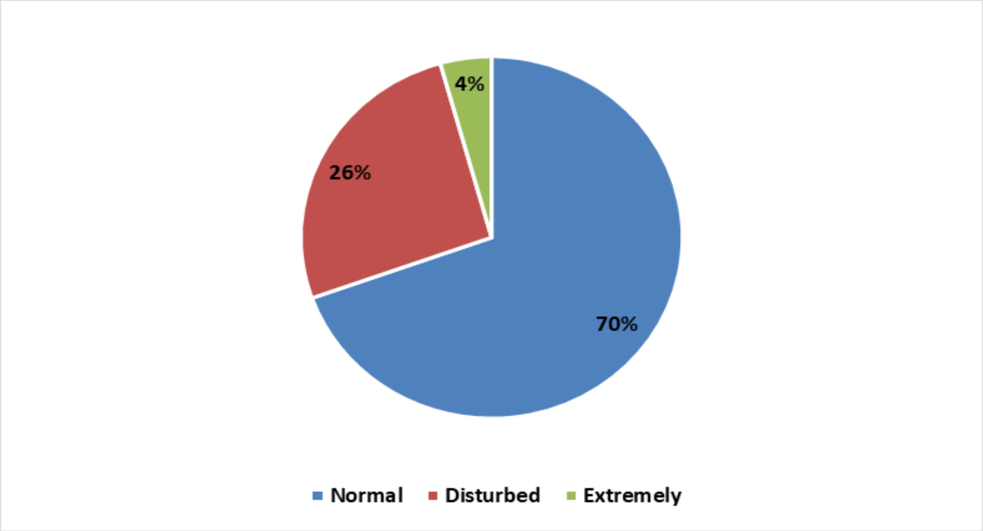


Figure C6-71: Levels of disturbance of sectioned limpets in context 14.

The seasonality and age at death estimation is therefore confined to limpets with no or minor disturbance and in which growth increments can be resolved, which for TNB1 leaves 34 out of the 46 samples processed. The data in figure C8-72 indicates that the site was visited throughout most of the year. Most of the shellfish procurement occurring in the spring early summer with a second focus of activity in the early autumn. This pattern is consistent in the two size classes utilised. A final observation

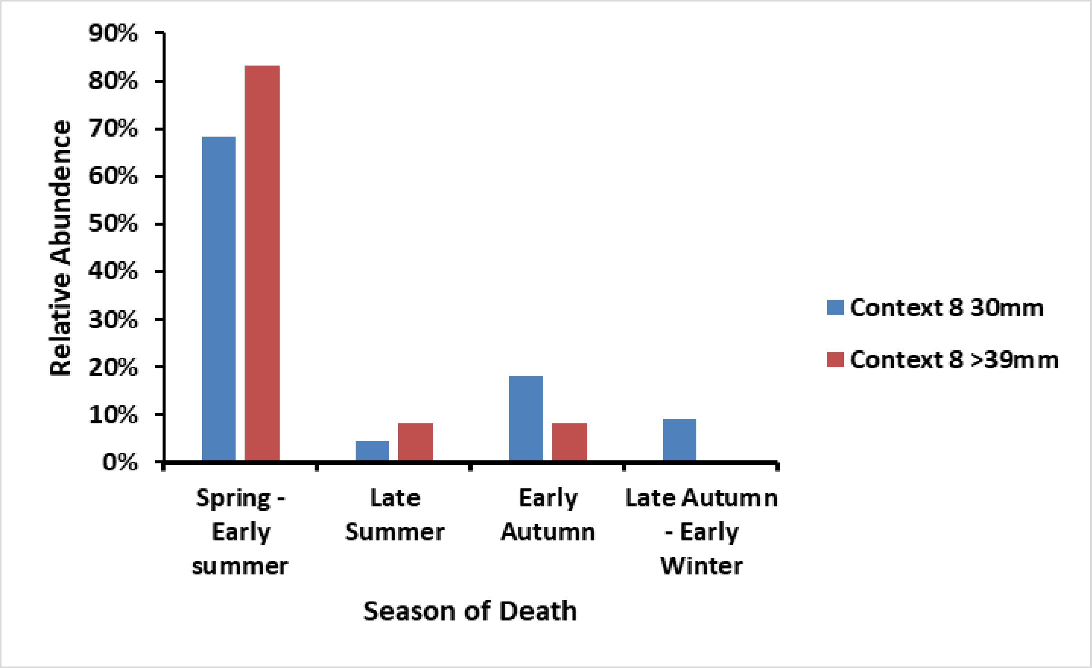


Figure C6-72: Seasonality from sectioned limpets in context 8.

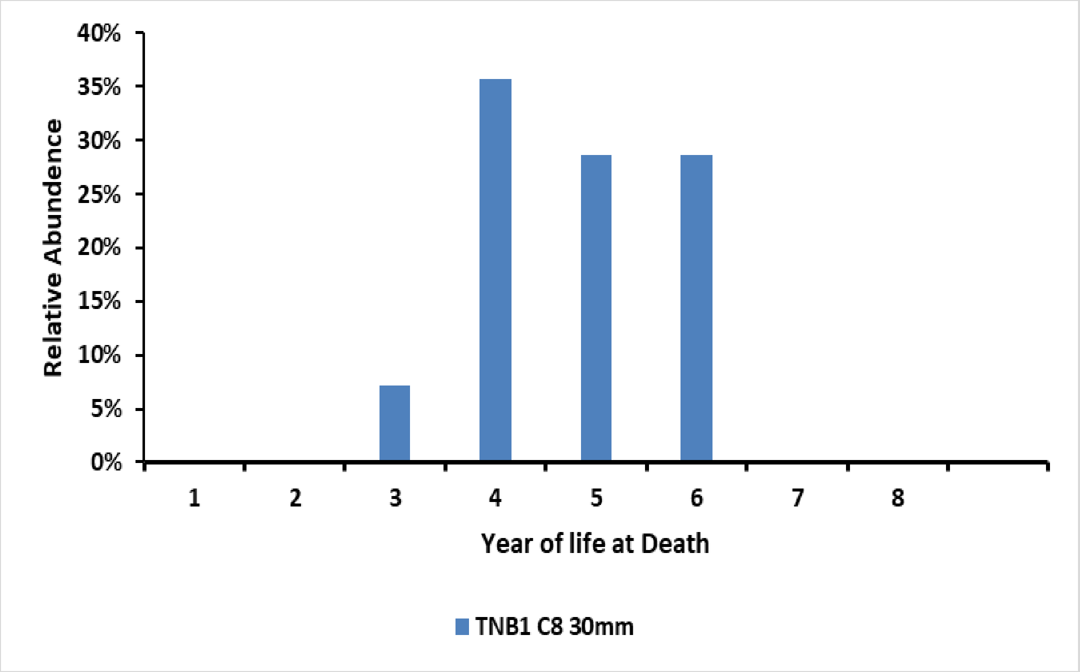


Figure C6-73: Year of life during which death occurred for limpets of 30mm in length.

is that compared to TNB2 a greater proportion of the limpets in this length class reached it during their 4th year of life (figure C6-73). Possible explanations for this are considered in chapter 8.

6.5.12 Summary

The initial deposition at TNB1 in context 14 maintains characteristics observed at PMS and the lower layers of TNB9, and in some respects, the northern extremity of TNB2. Dog whelks continue to outnumber razor clams and the limpets exhibit high prevalence of growth disturbance. The popularity or availability of periwinkles also remains supressed, and crab exploitation continues with a focus on larger specimens with less attention to the intertidal zone. Whilst there is some recovery in fish size compared to PMS the demographics observed in TNB2 are not reached. The periwinkles are particularly small and are similar to those observed at TB. It appears as if the occupation represented by context 14 took place within a similar environmental regime as that of PMS, which itself continued trends first observed at the extremities of TNB2.

Context 8 sees the restoration of razor clam to second most abundant taxa (as observed in the upper layer of TNB9) and there is a marked reduction in limpet growth disturbance. There is also a further recovery in fish size but still not to the levels seen at TNB2. The fish assemblage now also includes rare examples of the much larger fish as observed at TNB2. The differential treatment of dog whelks and periwinkles is again visible (there are insufficient samples in context 14 to support an analysis) and is consistent with TNB2. However, whilst there are many aspects of TNB1 that could be considered as a moving towards a restoration of the 'normality of TNB2', there are many aspects in which this is not the case. The restoration of periwinkle abundance above that of dog whelk does not occur and crabs assume a much greater role and selective procurement is occurring not only from beyond the intertidal zone, but within it also. The exploitation of mammals and birds remains just about non-existent. There is now a greater proportion of the razor clams (larger sizes) that fall into the *Ensis siliqua* range beyond the upper limit for *Ensis magnus*. The site appears to be visited more often outside of spring summer than any of the others.

Context 11 requires a specific discussion as this discrete deposition event constitutes an interruption to the trends discussed above. Firstly, it contains relatively large amounts of mussel at the expense of dog whelk, and razor clam abundance is back at TNB2 levels, whilst periwinkle abundances remain more or less constant. It is possible that these contexts provide an insight as the relative roles of different molluscs, or size classes of particular species, in human subsistence. Prior to moving on to consider the site of West Voe it is necessary to conduct some direct comparisons between TNB1 and TNB2 as well as developing an overall and integrated view on what was going on the Cnip headland during the second half of the 5th millennium BC.

6.5.13 The Mesolithic Occupation of the Cnip Headland.

The approach thus far has been to in effect layer the sites in their approximate chronological sequence by providing a commentary for a site against the sites already presented. It is possible to construct a phasing regime for the Cnip Headland and the associated inshore island. Based upon all the data available the occupation of the Cnip headland on the Isle of Lewis can be defined in four phases (figure C6-74).

6.5.13.1 Phase 1 (circa 4,650 – 4,400 cal BC).

Phase 1 exhibits trends in resource exploitation throughout its entirety but has been split into two sub-phases a and b. This is primarily based upon the level of exploitation of terrestrial mammals, birds, mussels, and the relative abundance of periwinkles to dog whelks. Had razor clam abundance also reduced below that of dog whelk then phase 1b would have been designated as phase 2a.

Phase 1a is represented by contexts 5, 11 of TNB2. During this phase periwinkles are exploited in preference to dog whelks and a substantial component of the molluscan assemblage is the razor clams. Given its general tendency not to preserve the presence of mussel is at reasonable levels. Fish of a reasonable size are being exploited, and this holds true whether the assemblage is interpreted as discard or exploitation. The rarer larger specimens are therefore either, regrettably rare, but nevertheless pleasant surprises, or fortunately rare disappointments. A notable feature, relative to other published sites is the absence of a population of fish from the 2 years old and greater classes. Occupation is focused on the spring and summer and the economy includes the exploitation of terrestrial mammals and marine birds, particularly pursuit divers. Surprisingly, the data revealed that from time to time limpets experienced growth disturbances, and this is far more prevalent in context 5. Large crabs were also acquired, albeit in relatively small numbers, most likely from the infralittoral, with little evidence of acquisition from the inter-tidal zone. The people of phase 1a had their dogs with them and the dogs enjoyed a diet of almost entirely marine resources. Compared to context 5, context 11 shows what might be considered deterioration in certain characteristics. Limpet abundance increases but size decreases as the limpets get flatter. Razor clam abundance decreases but size increases, which is possibly due to a change in species (see chapter 8). The size of periwinkle increases and the difference in abundance between periwinkle and dog whelk reduces. The dog whelks decrease in size but a greater range of sizes is exploited. The difference in fragmentation levels compared to periwinkle also reduces; larger specimens are probably being consumed directly. A period of cockle exploitation is observed which is unknown in north-west Scotland other than at the more recent Northton phase 3. Finally, the size of fish decreases slightly in context 11. It is currently unclear whether context 5 predates contexts 11 and 18, or whether midden formation commences with context 11 and context 5 and 18 follow, the latter reflecting a short term occupation. An argument can be made for both scenarios and a resolution to this will be sought in chapter 8.

The deposits contain small amounts of material culture (worked shell, lithics, bone artifacts and the waste from bone tool production) suggesting possibly a close association with a residential camp, but the zooarchaeology suggests that dressed birds, the main bodies of the crabs, and possibly the missing population of fish, were being taken elsewhere, and wherever that was, is where the debris from human consumption will be found. In this sense the midden does not reflect the type of residential camp utilised by a Yamana-like society discussed in chapter 3. That said phase 1 is not a period of total stability and hence it is split into two sub phases.

Phase 1b is represented by contexts 18 and 15 at TNB2. Limpet abundance continues to increase, and size continues to decrease. Razor clam abundance also continues to reduce with an increase in size, especially the maximum size. Dog whelks are now more abundant than periwinkles, but they are still less abundant than razor clam and mussels are now all but absent. The exploitation of terrestrial mammals is greatly reduced, and the exploitation of birds has all but ceased.

6.5.14 Phase 2 (circa 4,400 cal BC – 4,300 cal BC)

Phase 2 is represented by context 2 of PMS, contexts 6 and 9 of TNB9 plus contexts 14 and 15 of TNB1. The focus on dog whelk over periwinkle which first appears in phase 1b continues. Razor clams reach their maximum average size after which it reduces, but the size ranges increase as does the maximum sizes obtained. The interpretation of these vectors will be discussed in chapter 8. Dog whelks now relegate razor clam to the 3rd most abundant taxon. The role of limpets increases before finally subsiding in contexts 14 and 15 of TNB1, but never to the levels of phase 1a. The evidence for mussel and bird exploitation is all but eliminated and exploitation of terrestrial mammals is now minimal. The size of the fish plummets at PMS prior to recovering partially in context 14 of TNB1. Limpets also experience elevated growth disturbance levels compared to TNB2 context 11 (compared to TNB2 C5 disturbance levels are reduced) levels of growth disturbance at PMS, which then increases slightly in context 14 of TNB1. Crab exploitation also continues at a slightly elevated level compared to Phase 1. Occupation remains focused on spring and summer. Material culture during this phase is limited to lithics but the presence of dog is probable. Phase 2 can be interpreted as a period when acquiring the type and size of resources favoured during phase 1 was possibly challenging.

6.5.15 Phase 3 (circa 4,300 cal BC – 4000 cal BC)

Phase 3 has been broken down into two sub-phases. Phase 3a is represented by contexts 11 at TNB1 and context 7 of TNB9 where for small scale and probably short term occupations are likely and the taxonomic composition suggests refuse from human consumption. It is possible that these contexts represent the discontinuity in radiocarbon PDs between TNB2 and TNB1 commented on by Asclough *et al*, 2017. During this phase it is possible that occupation is limited to short stays by small groups, possibly whilst in transit. Whether context 15 of TNB2, currently assigned to Phase 1b, should be assigned instead to phase 3a is open to debate.

Phase 3b is represented by contexts 9 and 8 of TNB1 plus context 5 of TNB9 and is the period when midden accumulation commences. Razor clams are now once again the second most abundant molluscan taxon, and the role of limpets further reduces but not to Phase 1a levels. Dog whelks are still favoured over periwinkles and the differential in handling these two marine snails returns to the levels observed in context 5 of TNB2 in phase 1a. The exploitation of crabs is elevated significantly, with evidence of purposeful pursuit within the intertidal zone as well as in deeper water. The size of the fish also recovers but again not to phase 1a levels. The exploitation of terrestrial mammals remains minimal, as does the, all but non-existent, exploitation of birds and therefore some continuity with phase 2 is evident. The disturbance levels of limpet growth are at their lowest levels of any phase. Material culture is limited to lithic artefacts at much lower levels per excavated litre than in phase 1. For the first time there is no evidence for the presence of dogs. Phase 3 appears to be a period when marine resources of the required type and size were again more plentiful and easier to obtain. It is also the first time regular attendance at the site outside of the spring and summer seasons can be reasonably asserted.

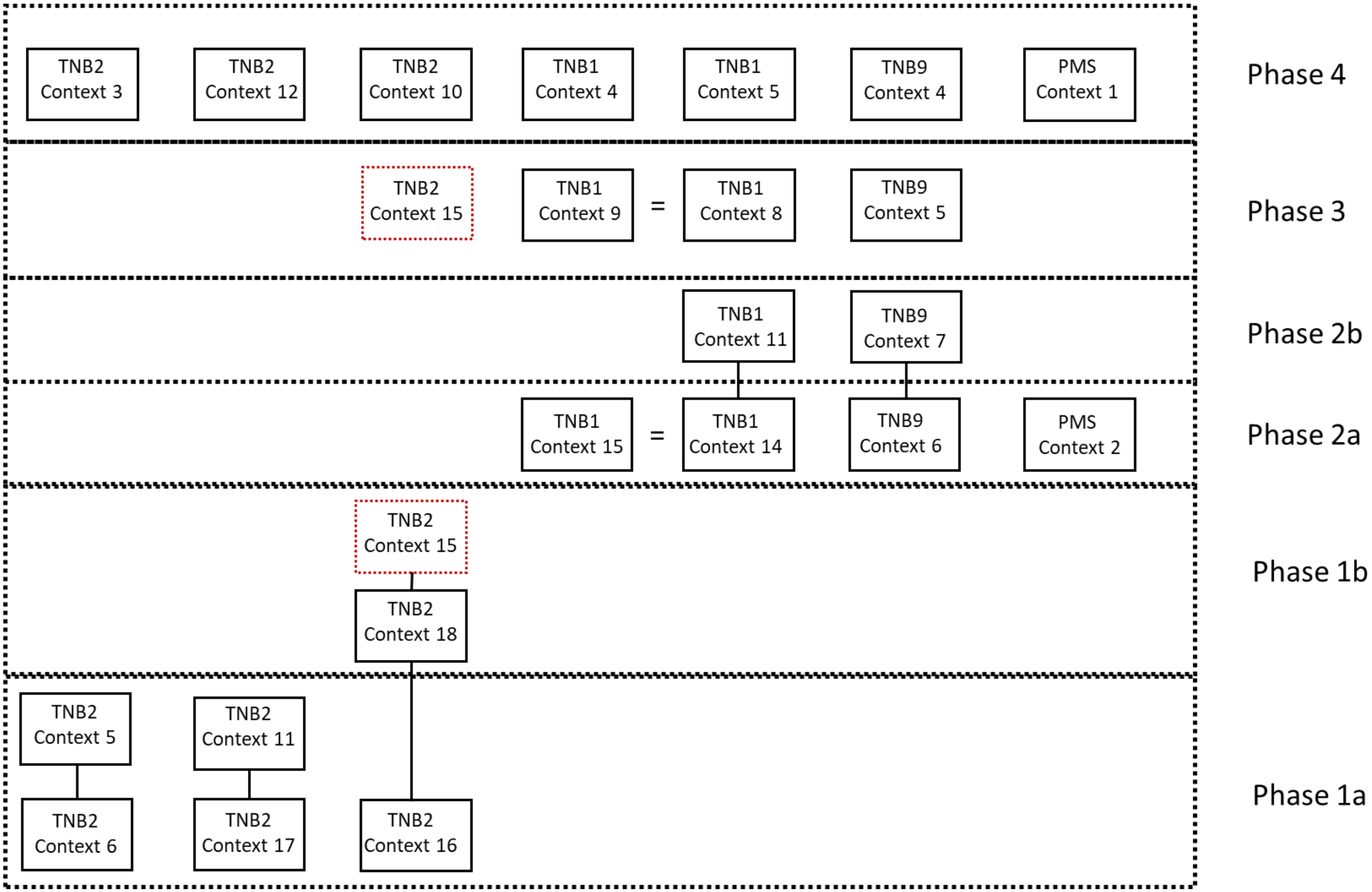
6.5.15.1 Phase 4 (after circa 4,000 cal BC).

Phase 4 is represented by contexts 3, 9, 12, 10 of TNB2, 1 of PMS, 4 of TNB9, and 4 and 5 of TNB1. These have not been subjected to any detailed analysis beyond taxonomic composition. There is therefore little to say as their composition is highly variable, although limpets dominate, and razor clam are also a significant component. The key observation that can be made is that all recognisable skeletal elements from ungulates belong to this phase.

6.5.16 Final Observations

This project provides a rare opportunity to observe a people so clearly undergoing transition, making choices, and the choice was to adapt rather than relocate. The evidence considered in this chapter suggests that environmental vectors were almost certainly operating and therefore influencing the choices the people made, and the nature and wider regional extent of these vectors is what is considered in chapter 8. What is clear is that TNB1 context 8 is not a return to the ‘normal’ of TNB2 contexts 5 and 11, but instead a ‘new normal’ exists, albeit that certain unique attributes that can be traced back to TNB2, and in some cases Toe Head, are maintained. This latter point includes some indication of structured refuse management on the Cnip headland which contrasts with the less structured approach on Toe Head.

Figure C6-74: Phasing of occupation of the Cnip headland. The main text places TNB2 context 15 in phase 1b, but in reality it is unclear whether it should be in phase 3.



6.5.17 West Voe.

West Voe is in process of being published and the report by the author dealing with the molluscs and crabs is attached to this thesis as SI-Gen-1 and is referred to as Evans (forthcoming) in the main text). Comparative analysis was constrained to published assemblages and the PhD Thesis of Derek Sloan (1993). In this section the content of the report will be summarised to permit the assemblage to be positioned against the others already presented and the additional analysis since conducted by this project will be presented. The focus is on the lower midden that is the midden lying below the sterile sand layer (context 408), although brief references will be made to the upper midden when appropriate.

6.5.17.1 The Marine Molluscs

6.5.17.1.1 Composition

The midden exhibits an unusual composition as unlike the other middens of northern and Western Scotland there is a major contribution from oysters (figure C6-75). A glance at a map confirms that Shetland, whilst certainly in the north, is not actually in the west. As stated in Evans (forthcoming) it is in the open Atlantic but at a ‘crossroads’ between the open Atlantic where typically limpets dominate assemblages and oysters and cockles are all but absent, and the North Sea where cockle and oyster middens are abundant. Another feature which distinguishes the assemblage from those already

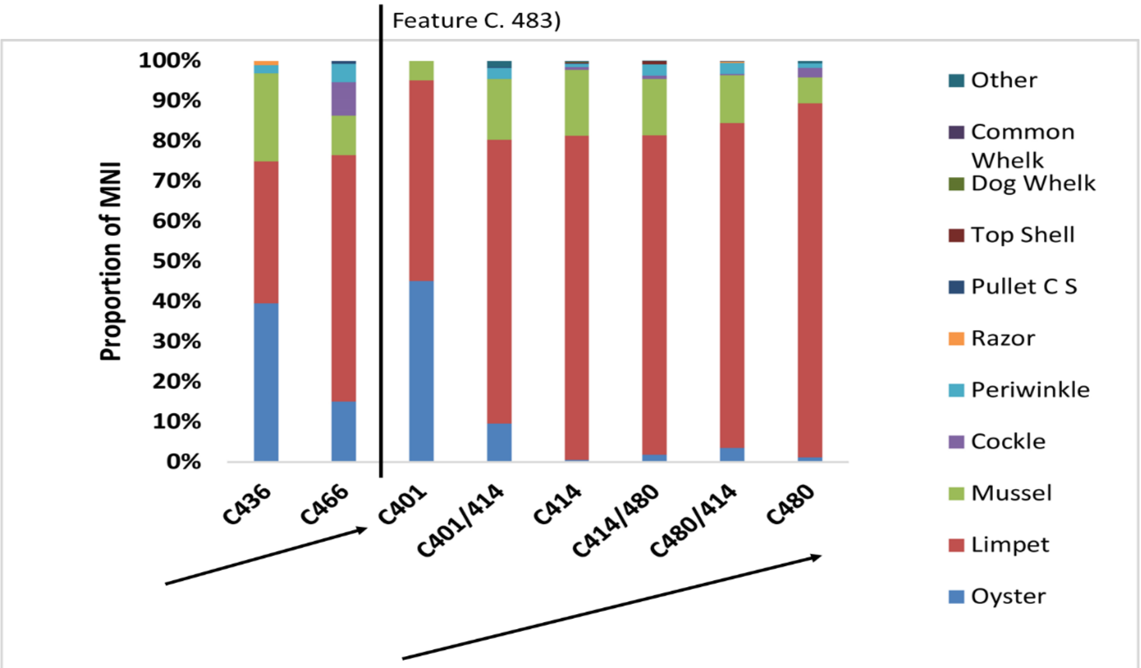


Figure C6-75: Composition of the molluscan assemblage in terms of MNI. Reproduced from Evan s(forthcoming). The arrows indicate the increasing stratigraphic levels each side of the feature. Sample sizes are provided in Evans (forthcoming), attached.

presented is the absence of dog whelk with only a single specimen present in sample 51 of context 414. Whilst Melton and Nicholson (2004) and Melton (2009) refer to an oyster midden followed by a limpet midden, oysters do not actually dominate (>50%) any context and they are not even the most abundant taxon in any context, but close to it in context 401. Melton (2009), as do other authorities for other assemblages (cf. Anderson, 1898; Lacaille, 1954), makes explicit reference to razor clam. Yet razor clam is a very minor component of the assemblage, with nothing more than a few fragments originating from one or two valves in each sample, if anything at all. The oysters are very large and extremely robust (Evans forthcoming) and therefore occupy a disproportionate amount of space when the midden is viewed *in situ*, and this is further factored due to each organism potentially contributing two valves. Razor clams having a very distinctive morphology and brittle shells which fragment extensively, may also have their abundance over estimated when viewed *in situ*. At Toledo the grooved razor is 13.52% of the assemblage by NISP but only 3.06% by MNI (Araújo, 2016). The key point is that care is required when interpreting abundances implied in older literature that are a result of or based upon *in situ* visual inspection. Clearly the data presented in figure C6-75 suggests that composition changes spatially and therefore temporally.

6.5.17.1.2 Biometric Analysis

When it comes to molluscs Shetland, based upon the data from West Voe, can be legitimately termed the ‘land of the giants’. The limpets are truly huge compared to published assemblages and so are the oysters (Evans, forthcoming). Figure C6-76 provides a comparative analysis of limpet length between contexts, with volume presented in SI-Chapter6-1. A comparison with context 5 of TNB2, the longest limpets in the Western Isles, is provided in figure C6-77. What is perhaps not self-evident is that the West Voe, unlike the sites of the Western Isles, represents a natural population, or to be more precise, a naturally occurring sub-population. It reflects the second mode of >40mm limpets recorded by

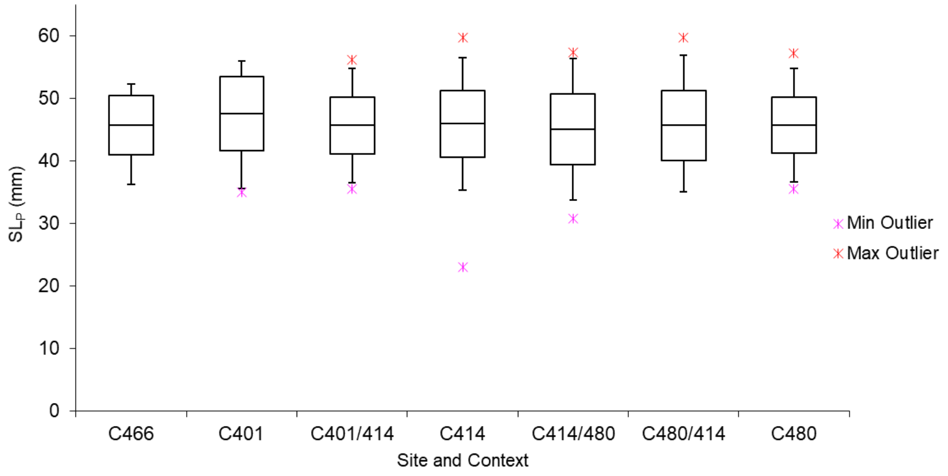


Figure C6-76: Limpet lengths from West Voe.

ecologists (cf. Baxter, 1982) and weakly represented in context 14 of TNB1. The oyster metrics were provided with the project archive. A decision was taken not to remeasure as it was clear that the specimens had been fragmenting whilst in storage or transit and any new measurements taken would be reduced compared to those initially captured in 2005-2006. The drawback to this decision is that the oyster metrics were captured at midden block level which aggregates the values from various stratigraphic contexts at a column level (figure C6-78). Given that a meaningful level of oyster exploitation is confined to the lowest stratigraphic levels the available data provides a, whilst not ideal, reasonable basis for comparison between contexts 401 and 436 plus 466. The oysters are significantly larger than those from the Forth Estuary and far more robust (Evans, forthcoming).

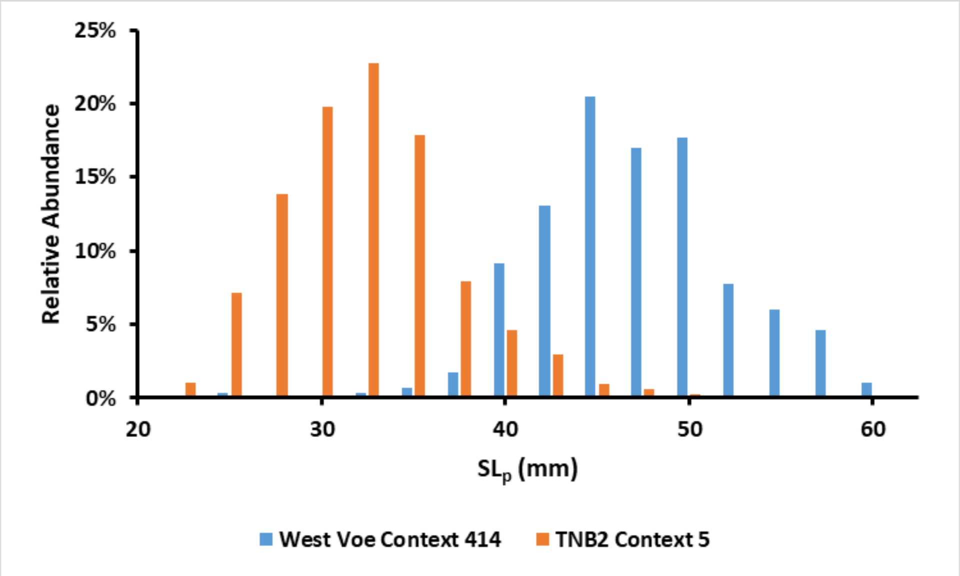


Figure C6-77: Limpets length comparison. West Voe context 414 n=283. TNB2 context 5 n=1037. Binned at 2.5mm.

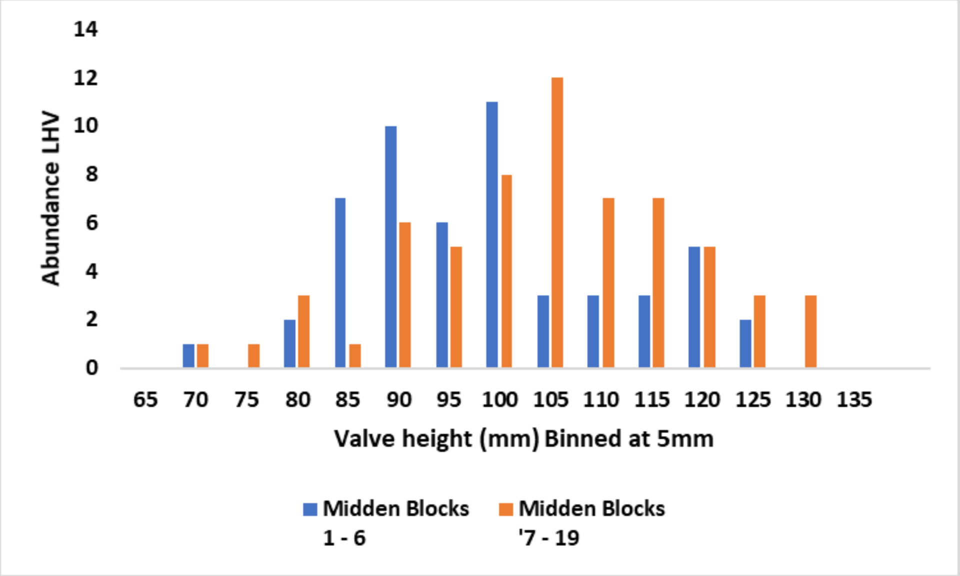


Figure C6-78: Shell height for oysters. Reproduced from Evans, forthcoming.

Periwinkles, although ubiquitous, are present in very low absolute quantities that make inter-context comparisons problematic. Therefore, the shell heights have been pooled to provide a site (Shetland) level view (figure C6-79). The periwinkles are small and of a similar size to those at TB and the second mode around 10mm observed at other sites is present. Metrics were also gathered for cockles and these will be considered along with those from the Western Isles in chapters 7 and 8.

Fragmentation levels for limpets are very variable as shown in table C6-28. Of note is the difference between those contexts to the south of feature C483 compared to those to the north. The abundance of the large oyster shells does not appear to offer protection from, or be an agent of, limpet fragmentation. Of the 48 specimens of periwinkle present 32 (75%) were complete in terms of shell height, which is good given the shells are so small and therefore gracile, even for their species. Yield levels of limpets are variable, and unsurprisingly very low in the contexts dominated spatially by the huge and extremely thick oyster shells. It is also of interest that the midden is extended to the north midden block 20 (contexts 570-575) and above in the form of a layer of crushed mussel under which there is no archaeology and only natural substrate. It is possible that this layer is of a non-anthropogenic origin as it might be evidence of eider duck roosting. Eider ducks preferred food is mussel which are swallowed whole (crabs have the limbs removed and the body treated as described for mussel), the shell is then crushed within the digestive tract, and then excreted. In some places the context 412/413 might represent a mixture of this natural phenomena and underlying anthropogenic discard. This situation is unclear, and more research is required into crushed (and often concreted) mussel surfaces as they are observed elsewhere and might be a proxy for a hiatus in human occupation. Guano is an excellent soil modification material, useful to farmers and guano rich in calcium carbonate presumably even more so when faced with acidic soils.

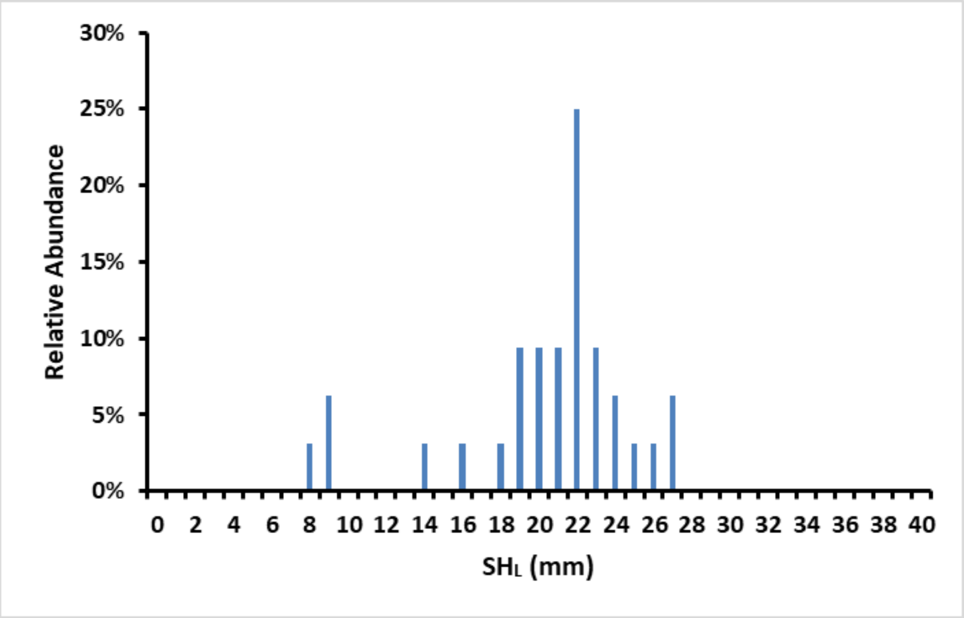


Figure C6-79: Periwinkle lengths pooled from all contexts.

Table C6-28: Limpet sample sizes, fragmentation and yield.

Unit	MNI	Complete	Measured	Volume	Yield Lt-1
C436	34	2	5.88%	14.0	2.43
C466	81	7	8.64%	18.0	4.50
C401	31	14	45.16%	19.0	1.63
C401/414	280	135	48.21%	20.0	14.00
C414	545	250	45.87%	22.0	24.77
C414/480	223	62	27.80%	20.0	11.15
C480/414	314	165	52.55%	24.0	13.08
C480	151	27	17.88%	28.0	5.39

6.5.17.2 The Bone Assemblage

6.5.17.2.1 Composition

The bone assemblages can only be presented in summary pending the publication of Nicholson (forthcoming) and Worley (Forthcoming). Dr. Nigel Melton kindly supplied the unpublished data structure reports (Nicholson, 2005) for the bird bone to support the author’s MSc dissertation and therefore some detail on that component is available. The opportunity to inspect the bird and mammal assemblages presented itself and the following can be added to the information provided in the published material and the data structure reports. The assemblage is far less fragmented that those from the Western Isles and refits were quite frequent at the sample level.

Mammalian and bird bone are present throughout but is concentrated in context 414. The mammal bones are predominantly seal (Melton, 2009), with some cetacean (Melton and Nicholson, 2004), otter is notably absent. Ungulates are present and mainly confined to the final phase prior to the inundation by sand, the other examples in lower levels are considered to be intrusive. Both common seal and grey seal are present, and the assemblage includes both adults and juveniles. The bird bone assemblage is dominated by the cormorant family, but also includes eider duck, mallard (*Anas platyrhynchos*), whooper swan, goose, and gull. There is an atypical paucity of auks with just a few fragments of puffin and a fragment or two razorbill/guillemot. Whilst Melton and Nicholson (2004) report great auk, Nicholson (2005) explicitly states that great auk is not present. This must be a matter of stratigraphy (or non-stratification) as the great auk fragment was located within the archive by the author.

There is a paucity of fishbone that is uncharacteristic of the middens of the Western Isles and the Scottish mainland. The majority of the few fishbones that were recovered were from the crushed mussel layers. The species present include small examples of gadidae, mackerel, and herring. These are represented by between one and ten vertebra per taxon. Eider duck eat predominantly molluscs, but occasionally fish, so this is not inconsistent with the earlier hypothesis for a non-anthropogenic origin.

6.5.17.3 The crab assemblage

The crab remains are not very spectacular. Fragments of shore crab and edible crab are present and a fragment of edible crab is specifically referred to by Melton and Nicholson (2004), this was located within the archive and is a right hand dactylus that came from a large specimen with a carapace width of between 150mm and 170mm; there is also a sizable specimen of shore crab (right hand dactylus) with a carapace width of between 75mm and 85mm. The majority of the remains however come from specimens of small shore crabs of the size normally encountered in the intertidal zone.

6.5.17.4 Seasonality and Age at Death

A small number of limpets were retained when the archive was returned to the museum so that seasonality and age at death could be assessed. Of the eight shells sectioned five exhibited at least one episode of disturbance or extreme growth disturbance. This made assessing seasonality, already quite challenging for organisms of this size due to asymptotic growth profiles, difficult. Even for the three shells that did not exhibit disturbance seasonality modelling must be considered indicative at best, and collection during spring through early summer tentative and potentially unreliable. The seasonality of the oysters differs between the areas of the midden. Those to the south of feature 483 were collected in winter-spring, those to the north were collected in spring-summer (Melton, 2009). The seasonality obtained from limpets (such as it is) is consistent with the results from the oysters. Age at death assessment was also problematic due to the one or more periods of growth disturbance and any attempt at precise values recklessly optimistic. One very large and very conical shell had 23 lines in its apex. The apices are very thick, exceeding 11mm, not only in the sectioned specimens, but also broken apices measured directly (Evans, forthcoming). What can be stated is that all eight shells are at least 10 years old and the majority probably are between 12 and 15 years old, but some may be over 20 years old. The presence of mackerel suggests summer occupation, if these are anthropogenic in origin, which is not inconsistent with breeding seasons of most birds, when they are generally more accessible.

6.5.17.5 The Mesolithic Occupation of Shetland.

West Voe is an intriguing site in which a key question is in which direction did the midden grow and therefore what chronological sequence do the deposits record. This is particularly key due to the inter-species inconsistencies and intra-species consistency in the ^{14}C assays, irrespective of stratigraphic position. As with the Western Isles faunal seriation can be attempted. Evans (forthcoming) trialled the approach and the conclusion remains a valid one. The clear pattern is that abundance, size and age of oysters diminishes, and initially oysters are replaced by mussels, but eventually the contexts are overwhelmingly dominated by limpets, as apparently the supply of mussels also runs out.

The first aspect on which the author and Milner (forthcoming) reach a clear conclusion on is that the earliest phases of occupation exploited a pristine ecosystem. This does not mean (but it might) the site represents the first time people visited the archipelago, but it seems likely that the immediate area had not been exploited for a couple of decades at least. The site is also unusual because when the juvenile seals (common and grey) are considered along with the bird assemblage, the molluscs and the fish, evidence is available for all seasons of the year. Signatures relating to winter occupation are rare at the published coastal sites of north-west Scotland, but winter indicators are noted as present at two sites in Lacaille (1954)'s table V.

Whilst it seems likely that the initial depositions reflect Mesolithic occupation, the later phases prior to inundation by sand may reflect Neolithic occupation and as with phase 3 at Northton, this requires further consideration. In chapter 3 it was demonstrated that a group of hunter-gatherers finding themselves, even if unintentionally, on a remote island could 'get up and running' provided they have access to subsistence resources, and shells and wood to construct the tools required to acquire such resources. Once the first captures have been made then skins and bones can be added to their resource inventory. A Neolithic colonisation requires something more akin to a campaign. How many, presumably young, bound, and hooded, domestic animals need to be taken? How long will it be until the domestic economy of crops, dairy products and meat become self-sustaining? Even if multiple trips are made, young animals need to mature and breed and this needs to occur until there is sufficient surplus to allow slaughter for meat, raw material for tools and to stimulate milk production. This leads to the question of what difference will be observed between a group of hunter-gatherers going about their normal business and a group of farmers 'getting by' in what might be thought of as a beachhead? The data from Neolithic Northton (Murphy and Simpson, 2006) suggests that in the absence of domestic and wild ungulates, tool production and hence many other activities, including boat maintenance, will be challenging. This latter point is material as small scale farming communities surely have the need to maintain contact through travel for all the same reasons as hunter-gatherers highlighted in chapter 3. Furthermore, in an environment where wild terrestrial mammals are absent the colonising farmers still have a need for bone tools, plus wood, bark and skins. Which explains why the bevelled ended bone tools of north-west Scotland have been directly dated from early in the Mesolithic through to the bronze age (Saville and Hardy, 2009). In conclusion the author suspects very little difference will be observed beyond perhaps (but only perhaps, cf. chapter 7) a few sherds of ceramic and maybe the lithic technology.

6.6 Discussion: The Mesolithic Occupation of the Remote Scottish Islands.

This review of the assemblages from the remote Scottish Islands has considered the evidence from the Western Isles (excluding St Kilda for which the author is aware of no evidence for a Mesolithic occupation) and the Shetland Isles. It is noted that Mesolithic type artefacts are also known from the Orkney Isles and also Fair Isle, but unfortunately faunal remains are currently lacking from these two locations.

The occupations can be characterised as, in many ways, being typical of the north-west of Scotland and sharing many features with sites such as Sand Rock Shelter, An Corran Rock Shelter, Ulva Cave and Oronsay. Similarities can also be asserted in relation to the cave sites in and around Oban and also Risga, but noting the caution needed given the way they have been reported. There is also notable divergence from the mainland sites that provides very strong evidence for specific adaptions to the ecosystems of the islands and the results strongly support the view that during the Mesolithic the islands had either no resident terrestrial mammals or that this class was restricted to mountain hare. Certain similarities and differences between the occupations of the archipelagos, the mainland, Oronsay and Colonsay will be explored in chapters 7 and 8.

The methods (compositional, biometrical and taphonomic) devised have yielded strong evidence for temporal changes in subsistence activities or preferences during the occupations at each site. That is changes in eco-behaviour are observed. These changes are not simply intra-site fluctuations, but sustained vectors that can be traced across multiple phases and sites within an area. A further point is that, as discussed in chapter 4, there are sound theoretical reasons why biodiversity and the range of a metrics are linked to excavated sample size, yet the vectors identified are present irrespective of the excavated size of a context. Whether these changes in behaviour are a case of people finding different and presumably better ways of doing things or are to some degree 'enforced' by changes in the environment will be considered in futured chapters. In addition to the above, certain other key observations can be made at this stage.

The sites on the Toe Head peninsula record both occupations prior to the 8.2K cal bp climatic event (and Storegga Slide) and after these events, separated by a hiatus. The start and end for the hiatus are in close agreement with the mainland sites and the implications of this are explored in chapter 7. The occupations on Toe Head are simply interpreted as short term or a series of short term occupation events by mobile groups, where the remains reflect what was consumed, which is consistent with a highly mobile society as defined in chapter 3.

The occupations on the Cnip headland reflect a different situation to Toe Head. Here we observe the remains of resource processing and those elements to be consumed are probably removed elsewhere. The people doing the processing of course also required sustenance and therefore a few burnt hare bones, otoliths and the claws of crabs are present. This implies a different approach to task scheduling and spatial use on the headland and therefore a different kind of organisation to that of a highly mobile society as defined in chapter 3. This difference may be due to differences in the size of the mobile group, but further research and comparative analysis is required. The occupation at TNB1 might be indicative a reduction in the frequency of residential moves, but an assertion (even tentative) of sedentism constitutes writing a cheque the data is simply unable to cash. There is also evidence for at least two specific short term occupations where the assemblage appears to reflect more closely what is likely to have been eaten, as observed on Toe Head.

The occupation on Shetland is in many ways similar to that on Oronsay with evidence for occupation during all seasons of the year, but as with the Western Isles, sedentism cannot be asserted. The evidence for multiple seasons of occupation is what sets it apart from the Western Isles, along with a lack of fish remains. This is accompanied with the absence of the molluscan taxa, and size classes of specific taxa, that might be associated with fishing bait. What is of great interest is that the site provides a snapshot of a people engaging with an unexploited ecosystem and this will aid the future interpretation of shell-middens. It is possible that due to SST oysters were a marginal resource that is exhausted quite rapidly (chapters 7 and 8). If taken at face value the assemblage suggests that the full gamut of marine resources is not being exploited; either because the occupants were unable to, or because they did not need to (Evans forthcoming). Of course, it is possible that periwinkles, crabs, and fish were exploited but removed elsewhere, but why extremely large limpets would not be is difficult to reconcile with such a scenario. Change is evident, particularly in terms the relative abundance of the taxa exploited, and in the case of oysters their size. It seems likely that at least the earliest phases of WV were contemporary with the final occupation at TNB1.

Are the Mesolithic people of the Western Isles and Shetland logistical collectors or foragers (*sensu* Binford 1980a)? For the reasons discussed in chapter 2 the answer is of course an ambiguous 'yes'. Encounter based acquisitions (Plate C6-19) were welcome supplements to logistical approaches. Binford (1980a) also associates collectors with storage which also means Woodburn (1982)'s immediate versus delayed return models must be considered. This, at first glance, is a more difficult topic to reach a conclusion on, for as observed in chapter 3, the enabling artefacts and processes associated with delayed return and storage are (in an aceramic society) archaeologically invisible. For this reason, if no other, there is simply no evidence for delayed return approaches in the Western Isles or Shetland. As discussed in chapter 2, given Binford (1980a)'s and Woodburn (1982)'s definitions there must be significant doubt as to whether any society exploiting marine resources extensively can avoid a delayed return and logistical approach. Which therefore forces a conclusion that the Mesolithic people of the Western Isles and Shetland had a delayed return economy carried out in a logistical manner. The evidence for, and need for, seasonal surpluses being carried forward to seasons of resource paucity, however, is somewhere between minimal and zero.

The best evidence the archaeological record of north-west Atlantic Europe can offer for delayed return, is the possible evidence for fish fermentation offered by Boethius (2016), and the substantial cache of hazelnuts on the Island of Colonsay in the Inner Hebrides (Mithen *et al*, 2001); noting that this predates the 8.2K cal bp event (ibid) and the arboreal pollen decline. The assemblages and isotope values from Oronsay (chapter 8) and the evidence from Tierra del Fuego suggests that such an approach is simply not necessary in these types of biotope. In fact, without the excesses of potlatch, it is possible that delayed return was not required from a purely subsistence perspective in British Columbia (chapter 3).

In chapter 1 it was stated that a key objective of this project was to face up to methodological and interpretive challenges and a number of these have already been identified and considered in chapter 4 and the conclusions reached have been applied during this chapter. These are as follows:

Archaeologists dealing with later prehistoric periods and certainly the historic periods encounter deep stratigraphy which has accumulated over centuries of continuous year round occupation by larger populations, with obvious consequences for taphonomic and diagenetic loss of faunal material. Assumptions can be made that barely anything survives. Consequently, each NISP can be considered, in all probability, to originate from a different specimen. The experience of the author and the data presented thus far suggests a different interpretative framework is required when dealing with seasonally mobile hunter-gatherers organised into relatively small social groups. The assemblages we encounter at a context level are small, and whilst taphonomic and diagenetic loss will have occurred it is necessary to take them more at face value and base interpretation more on what is present. In the author's view whilst this might result in some discomfort on the part of the archaeologist, this discomfort comes with the territory and must be faced up to.

The above issue is compounded by what can only be described as the imprecision of radiocarbon dating as discussed in chapter 4. Greater chronological granularity is required and possibly the unpacking approaches trialled by Koppel (2017) should become a more standard component of the chronology strategy for shell-middens. It was not practicable to include such an approach here as this project was well underway by the time the research came to the author's attention. The unpacking approach adopted here is one of faunal stratigraphy or seriation (stratigraphy or seriation of human eco-behaviour is a more accurate description) and it is conducted using multiple proxies and in what might be termed multiple dimensions. Vertebrate remains and molluscan (specific taxa) remains are considered in terms of relative abundance, and in the case of selected molluscan taxa, also in terms of biometrics and taphonomy. The view here is that this approach and the that of the previous paragraph has resulted in an enhanced understanding of the lives of the Mesolithic people of the archipelagos.

The basic zooarchaeology and methodological development is now complete and armed with the enhanced view of the occupation of islands claimed above, plus greater confidence in the methodological approaches developed and deployed to achieve it, the next two chapters will seek to understand the degree to which the changes observed are environmentally driven and to what degree any environmental vectors, if identified, apply at a wider regional level.

6.7 Plates

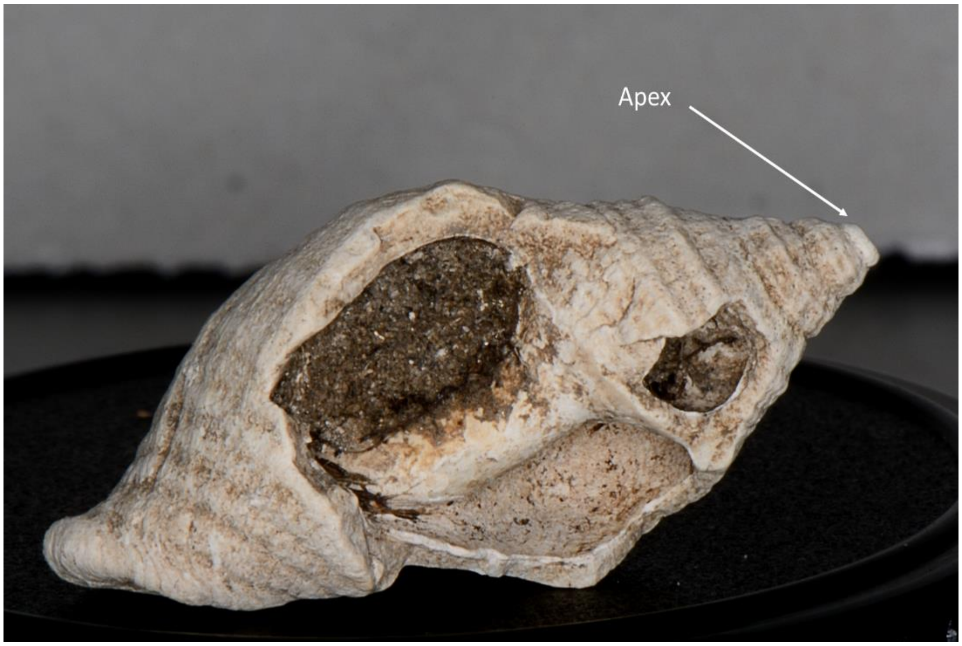


Plate C6-1: An example of the elongated ectomorph of dog whelk with the apex used as the NRE marked. Note also how robust the shell is in terms of thickness. The sediment within the shell also highlights the issue of using weight as the unit of quantification unless each shell is inspected and cleansed, and in such a scenario it may as well be counted. ©M.J.Evans.

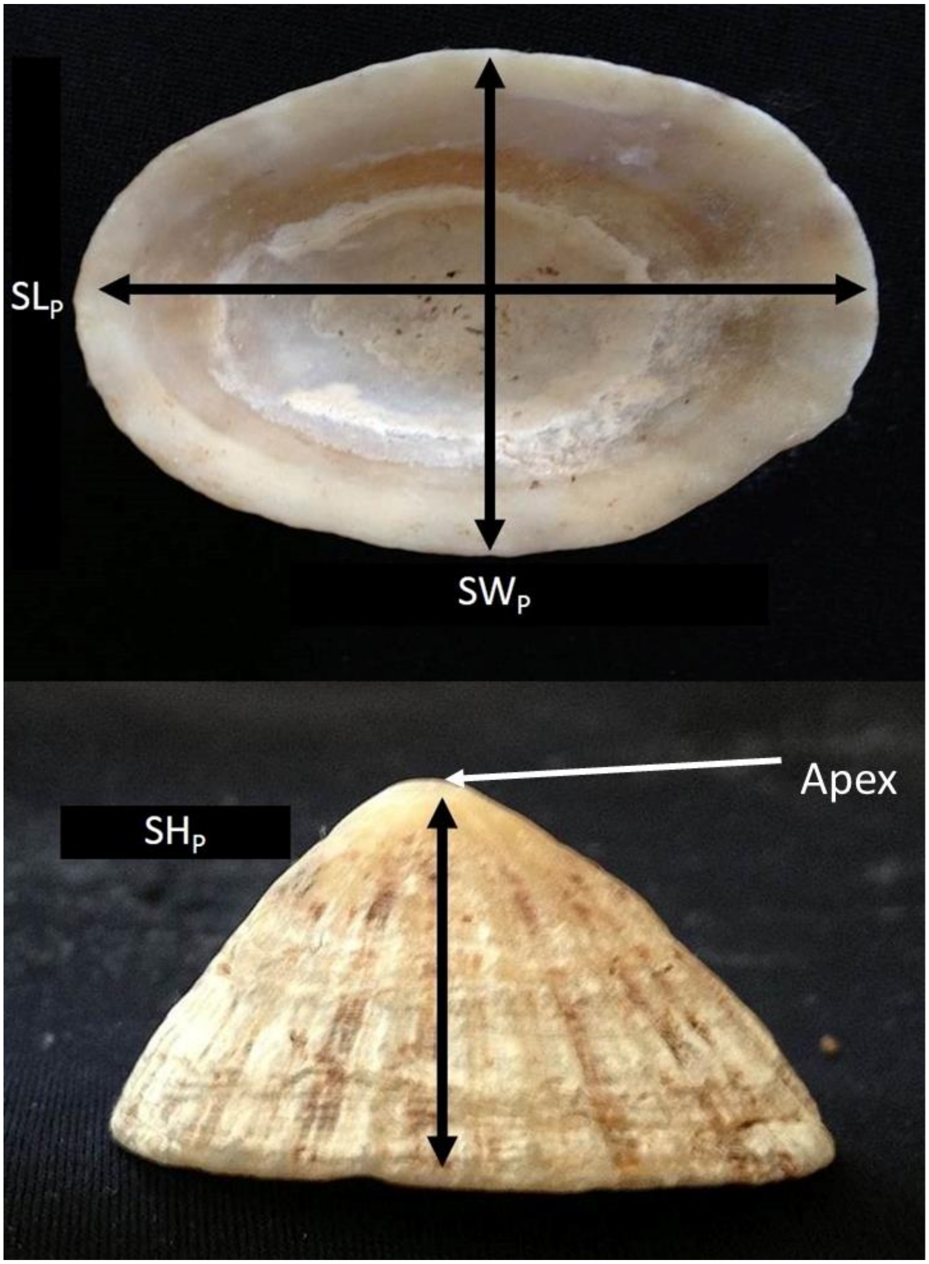


Plate C6-2: Measurements recorded for limpets.

Plate C6-3: Umbo of a marine bivalve. ©M.J.Evans.

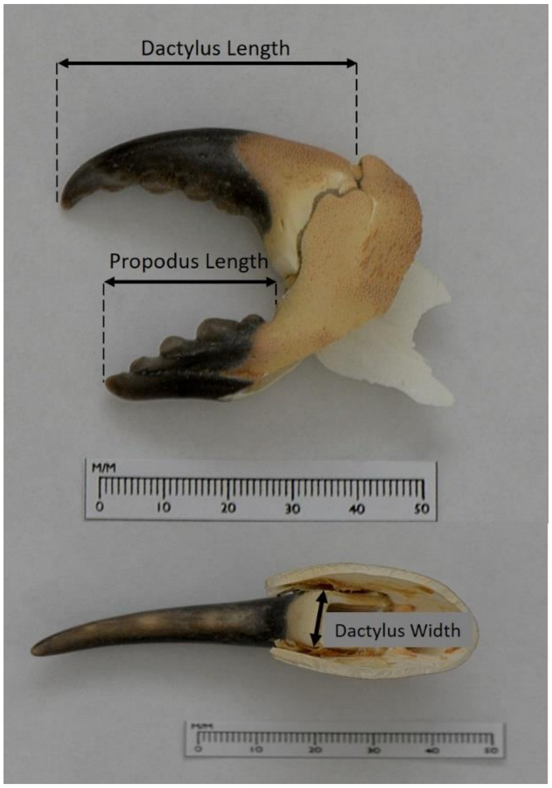


Plate C6-4: Left hand chela from a modern edible crab (Cancer paguras) with the dactylus and propodus highlighted. ©M.J.Evans

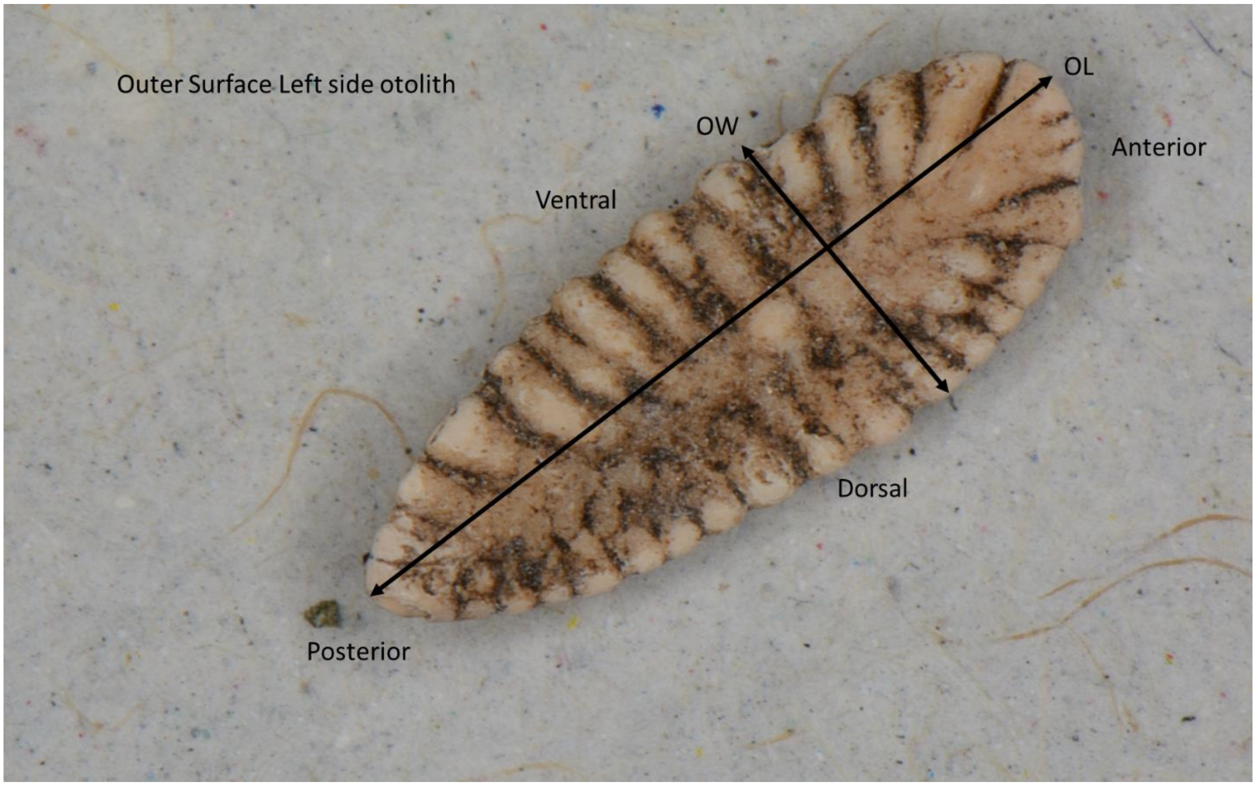


Plate C6-5: Outer surface of a left side otolith from an archaeological saithe (*Pollachius virens*). ©M.J.Evans

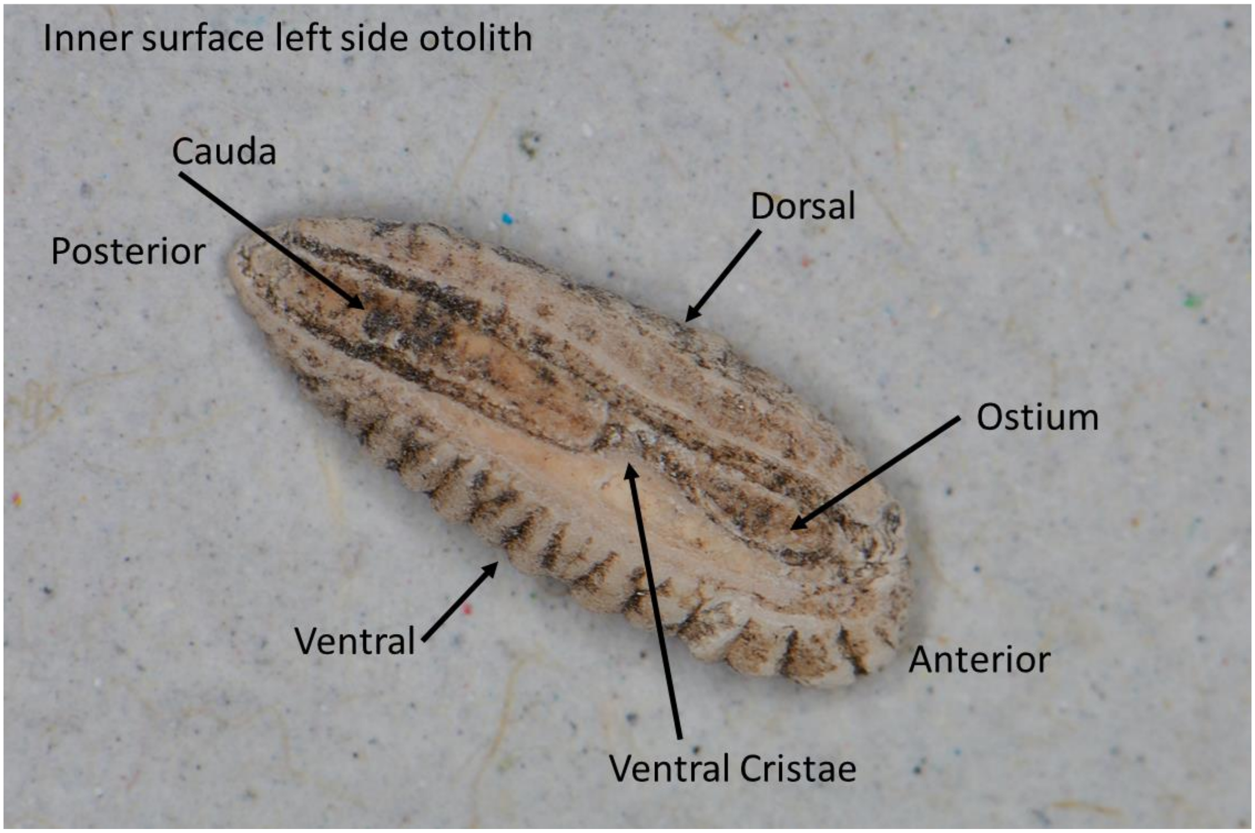


Plate C6-6: Inner surface of a left hand otolith from an archaeological saithe. Features named following Harkonen (1986) ©M.J.Evans

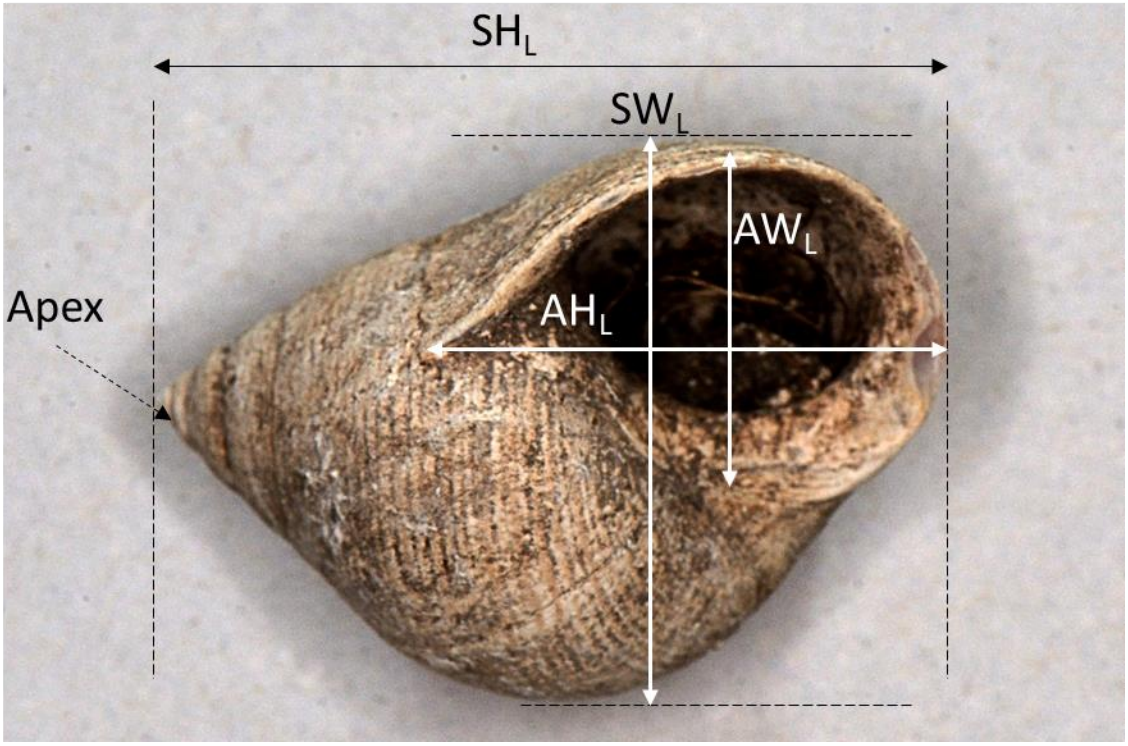


Plate C6-7: Archaeological periwinkle (*Littorina littorea*) with the captured metrics highlighted. ©M.J.Evans.

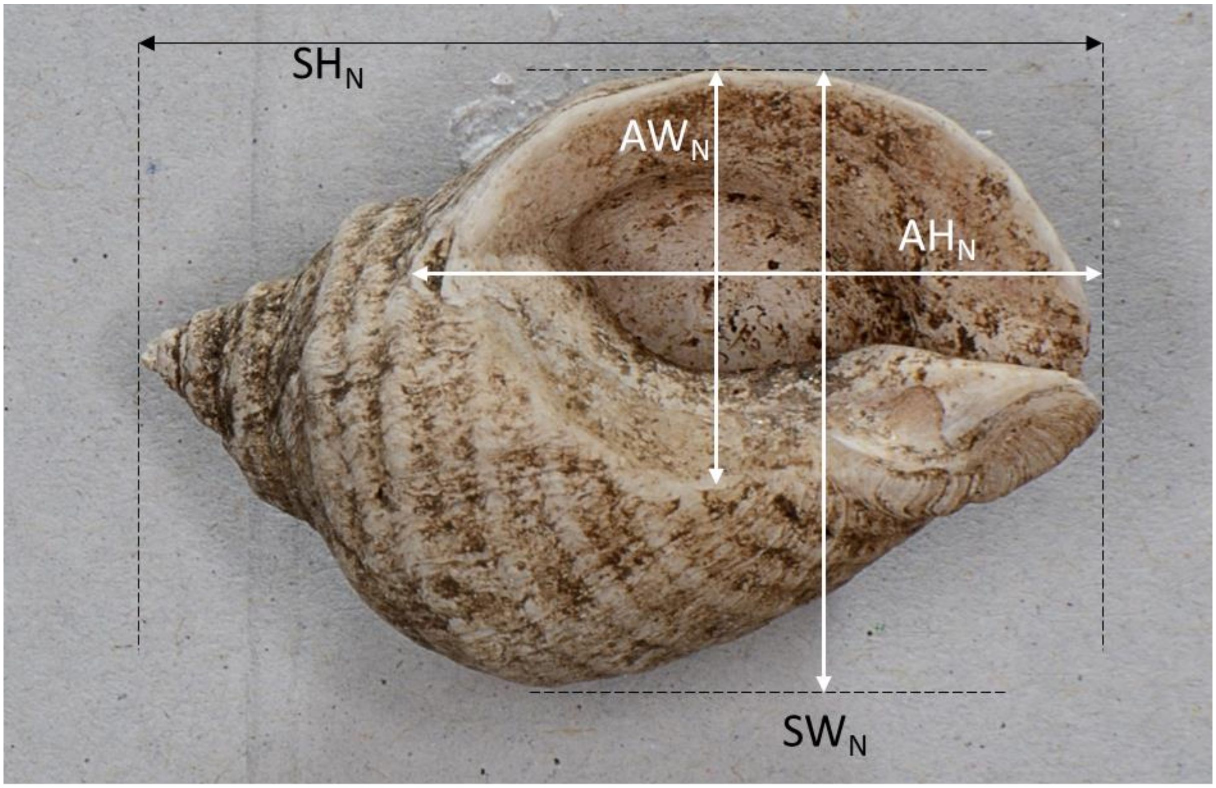


Plate 6-8: Metrics collected from dog whelk. Further metrics are defined in Plate 6-9. ©M.J.Evans

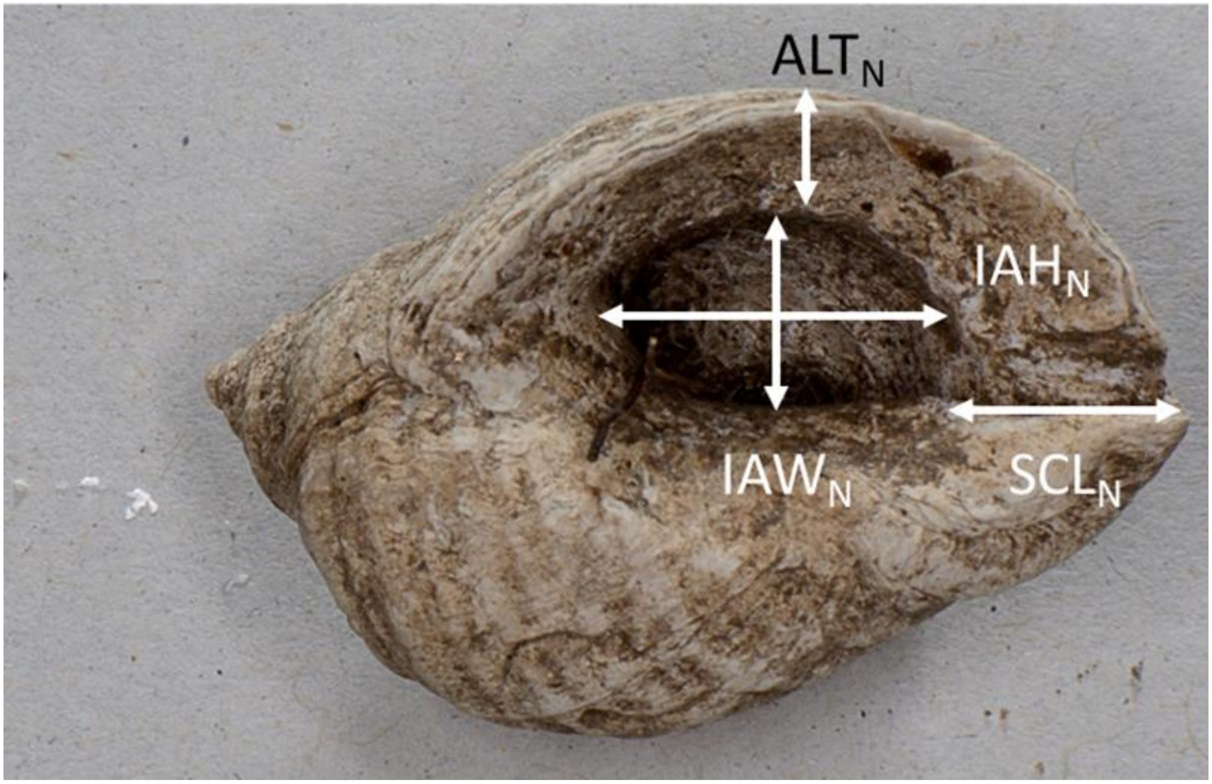


Plate 6-9: Metrics collected from dog whelk. Further metrics are defined in Plate 6-7. ©M.J.Evans

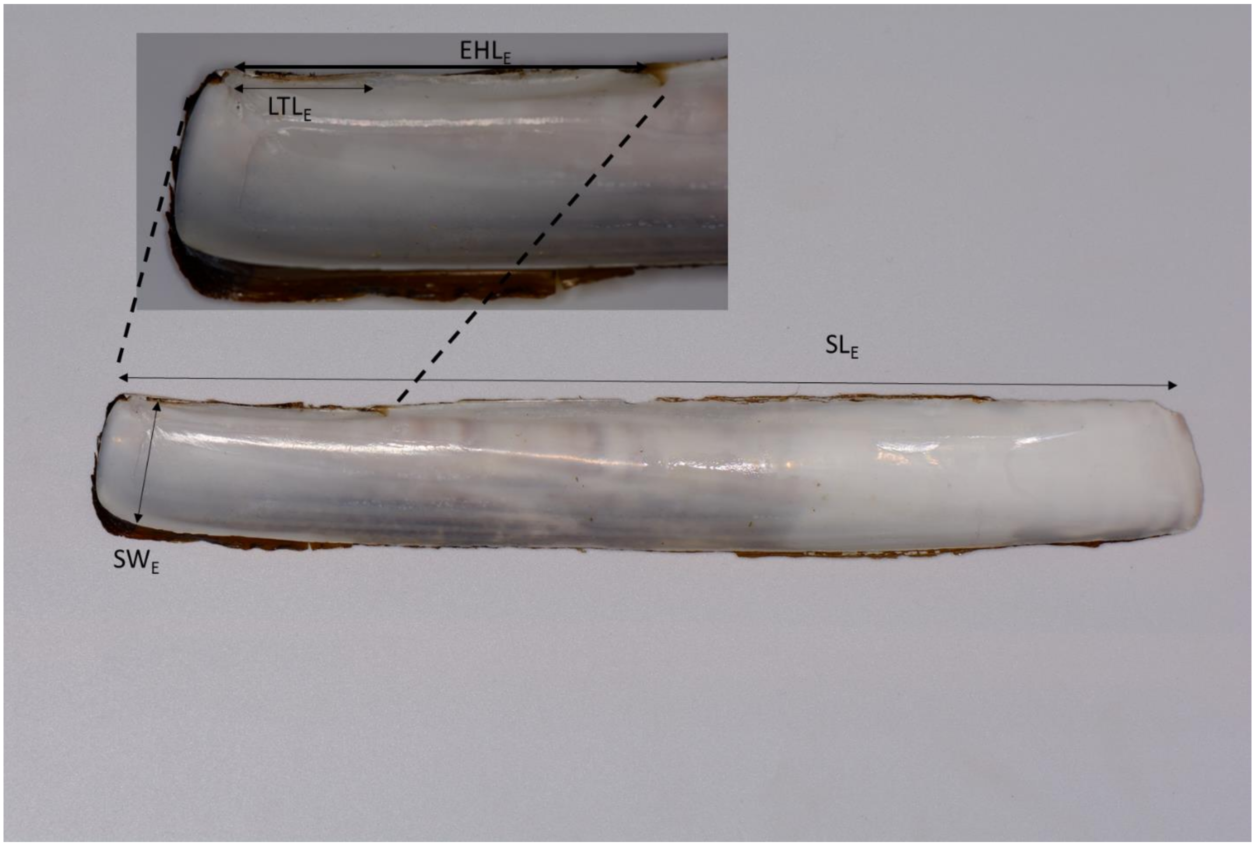


Plate C6-10: A modern specimen of Ensis siliqua with the gathered metrics defined. Note shell length as defined is the length of the ventral margin. ©M.J.Evans

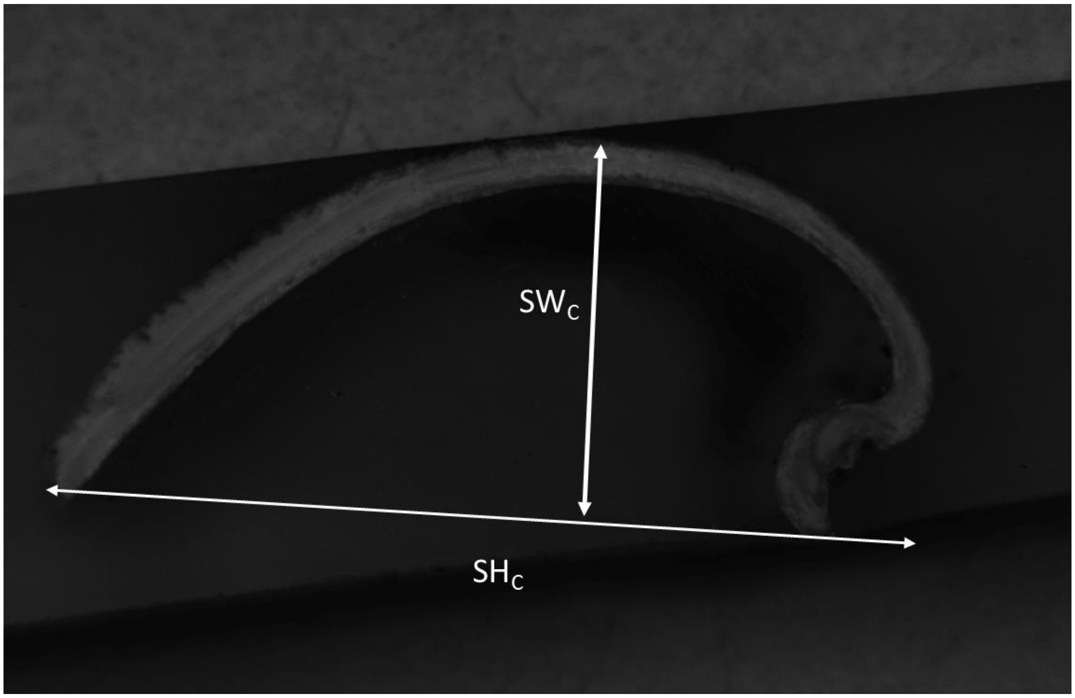


Plate C6-11: Metrics collected from cockles. ©M.J.Evans.

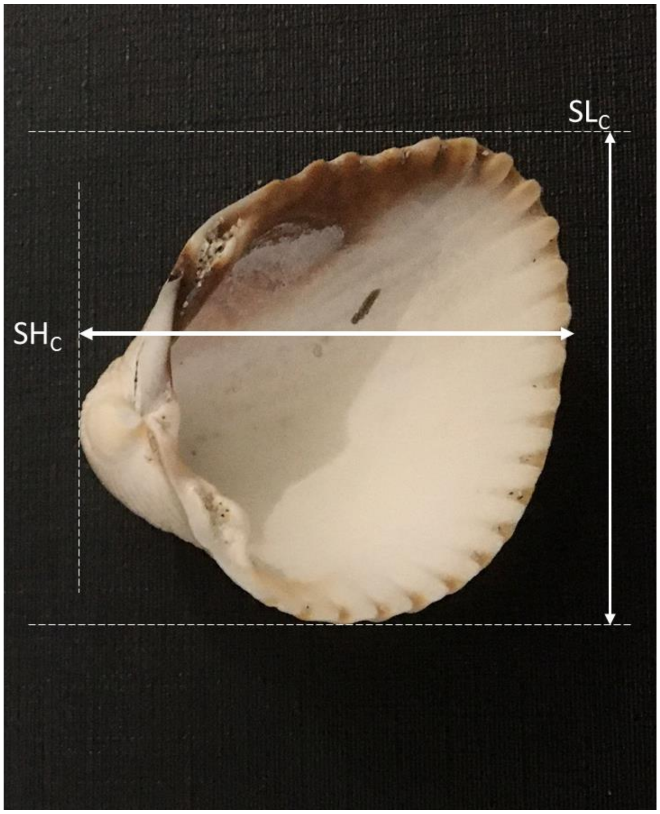


Plate C6-12: Metrics captured from cockles. ©M.J.Evans.

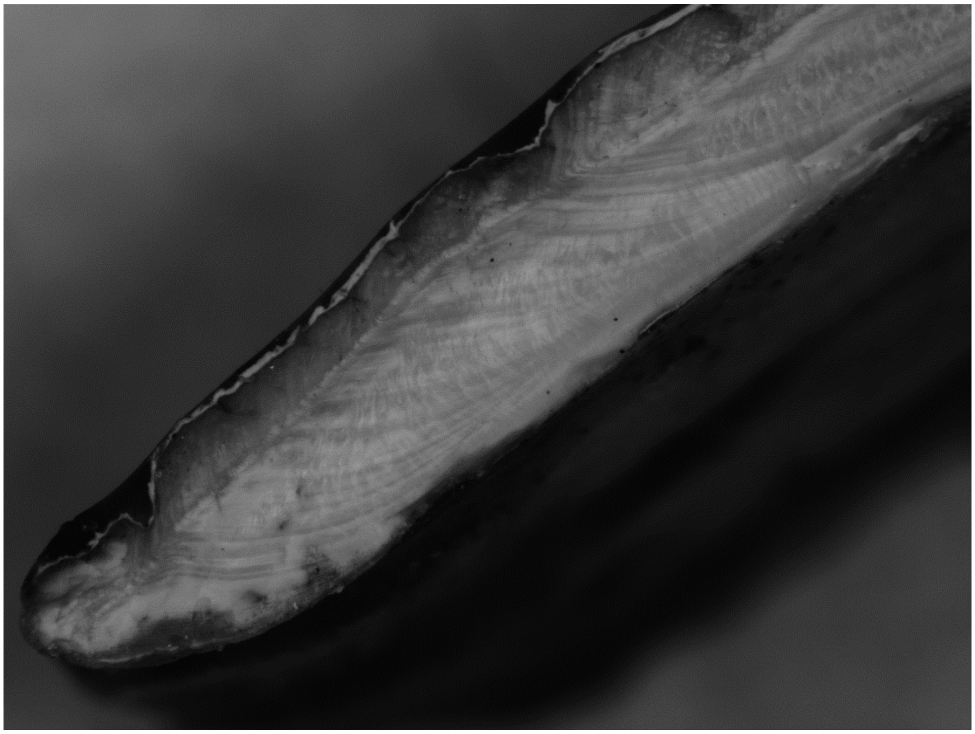


Plate C6-13: A cockle from TNB2 collected during the spring. ©M.J.Evans.

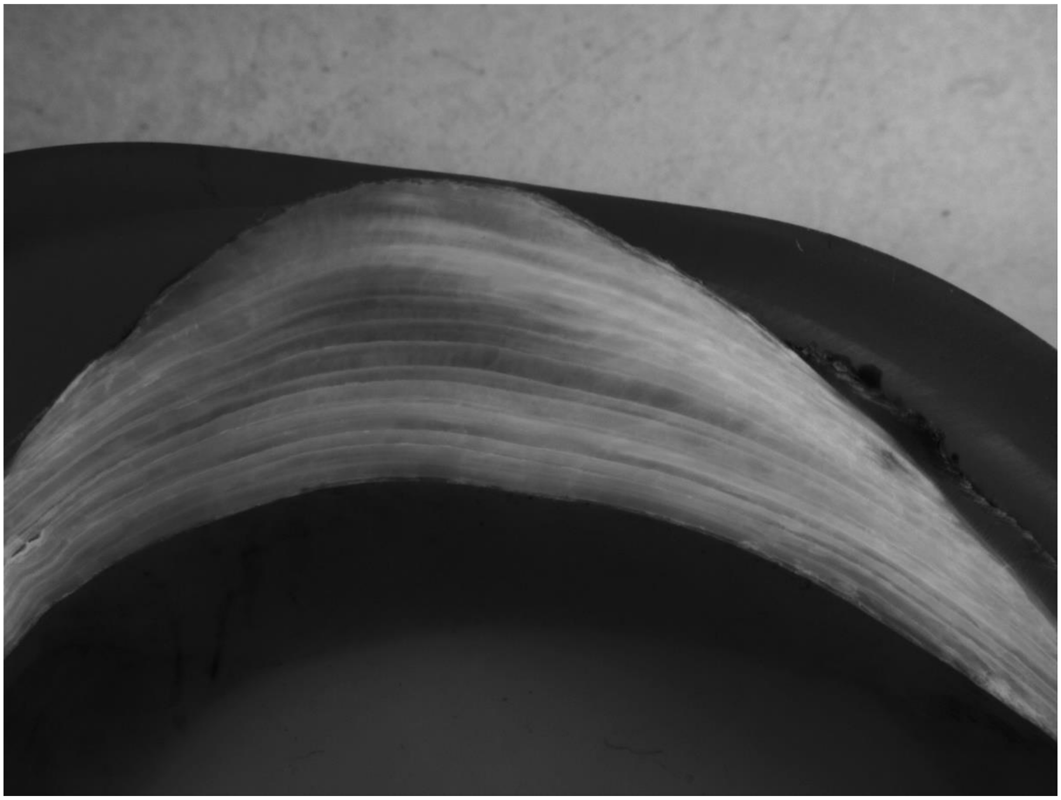


Plate C6-14: One of the younger limpets from West Voe context 414. ©M.J.Evans.

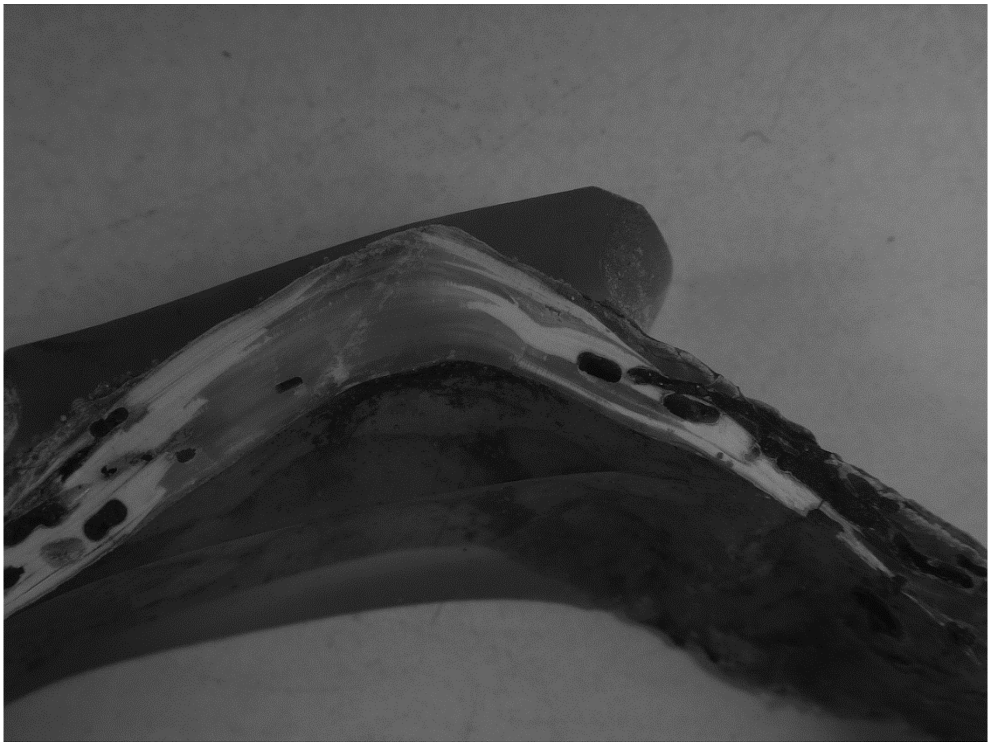


Plate C6-15: An extremely disturbed 30mm limpet from context 5 of TNB2. ©M.J.Evans

Plate C6-16: A disturbed limpet from context 8 of TNB1. ©M.J.Evans.

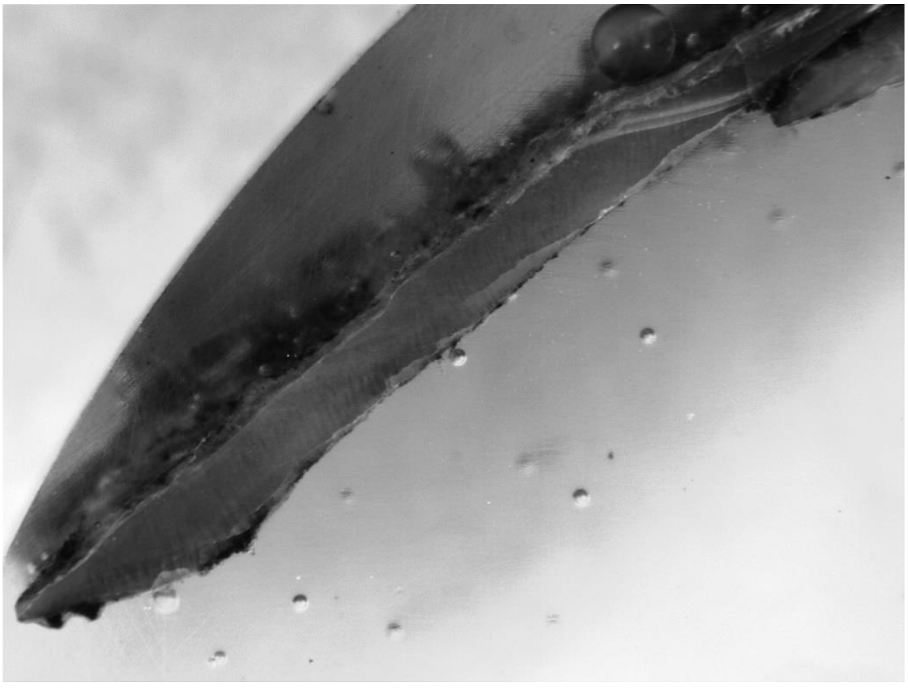


Plate C6-17: A limpet from context 5 of TNB2 exhibiting minor disturbance. ©M.J.Evans.

Plate C6-18: A limpet exhibiting no or ephemeral growth lines from context 2 of PMS. ©M.J.Evans

Plate C6-19: A dead juvenile grey seal on the shore of South Uist following the severe storm of the first week of January 2019. ©M.J.Evans.

Plate C6-20: A bone point from TNB2 C5. ©M.J.Evans.

7 The 8.2K cal bp Event

7.1 Introduction.

This chapter considers the relationship between human and their environment during the period known as the 8.2K cal bp event, the duration of which also includes the Storegga Slide tsunami. The nature of the events is summarised and consideration of what phenomena and vectors the Mesolithic people would have experienced is developed based upon the detailed, but generic consideration developed in chapter 3. The published archaeological record is then examined to identify elements of the defined scenario. As the climatic event is conventionally presented as cal bp all references to millenniums and dates in this chapter are implicitly cal bp.

The 8.2K event is often referred to within the literature, usually with reference to a climatic cooling event. The use of the term event is slightly misleading as the environmental research suggests that the environmental forcing occurred on a centennial scale (Matero *et al*, 2017, Lawrence *et al*, 2016); it is unclear what the lag effect is between cooling starting and the disturbance reaching a magnitude that is visible in the Greenland ice cores. This protracted period of climatic perturbance was punctuated by the Storegga Slide tsunami (tsunami henceforth) around 8.15±0.1K (cf. Weninger *et al*, 2008). For the coastal dwelling populations of the Atlantic façade of Europe this can only be considered as something of a 'multiple whammy' as defined in chapter 3. Naturally, understanding the impact these phenomena had upon the populations of the time has attracted the attention of researchers from far and wide. Generally, such research has focused on understanding the environmental conclusions and hypothesising on their generic implications for human groups (cf. Wicks and Mithen, 2014; Waddington and Wicks, 2017). The specifics of the cold 'event' and the tsunami can now be considered and related to the archaeology of the region. The two events are characterised below.

7.2 Characterising the 8.2K bp climatic event.

The climatic event around 8.2K is one of the major climatic episodes identified by Bond *et al*, (1997; 2001), that are now collectively known as Bond Events. Unlike most Bond events it is one of the few, along with the end of the Pleistocene, that is visible in all the Greenland ice cores (Vinther *et al*, 2009; Wanner *et al*, 2011; 2015). The initial forcing agent of this climatic change was proposed as the collapse of the Laurentide Ice sheet and the draining of the glacial lakes Agassiz and Ojibway into the north-west Atlantic. Such an influx of cold fresh water is then believed to have disrupted the Atlantic meridional overturn current (AMOC) and therefore the circulatory dynamics of the North Atlantic Gyre (NAG), with the consequence that its moderating influence on the climate of the north east Atlantic was diluted. Not all authorities are content that changes in the observed climatic proxies can be satisfactorily explained by the model above (Matero *et al*, 2017; Lawrence *et al*, 2016; Ullman *et al*, 2016). More recent models are based upon the collapse and melting of the Labrador Saddle, which coupled with the draining of the glacial lakes results in multiple pulses of freshwater, at varying rates against a background of slowly increasing eustatic sea-level (ibid). The duration of the cold event is estimated at around 160 calendar years (Lawrence *et al*, 2016; Matero *et al*, 2017). There seems little doubt that much more research effort will be expended before a true consensus on both the nature of the forcing mechanism, and the duration and magnitude of the 'event' is arrived at.

The models are consistent regarding two key outcomes of the event. Firstly, that cooling did occur and that this was accompanied by a significant increase in the rate of increase in eustatic sea level with variation superimposed. The estimates for environmental impacts are provided in table C7-1. The event has been implicated in changes throughout the world, including the opening of the Beagle and Magellan Channels in South America (McCulloch *et al*, 1997, p. 27; Borrero, 1997, p.62) and a transgression into the lower valley of the Tagus river (van der Schriek *et al*, 2007;2008; Bicho *et al*, 2010). The severance of Great Britain from continental Europe and the inundation of Doggerland (Weninger *et al*, 2008; Sturt *et al*, 2013; but see Walker *et al*, 2020) have also been associated with the eustatic sea level rise in combination with the tsunami. If these associations are correct, then the level

Table C7-1: Modelled estimates of environmental anomalies as a result of the 8.2K event as stated by Matero *et al* (2017) and Ullman *et al* (2016). Sea Surface Temperature (SST), Surface Air Temperature (SAT) and Sea Surface Salinity (SSS).

Sub-region	**Eustatic Sea-level**	**SST (°C)**	**SAT (°C)**	**Precipitation (%)**	**SSS (PSU)**
Atlantic Façade					
Northern Atlantic Norway	≈ 4m±0.5	-5.0±1.0	-3.5±0.5	-30±10	-2.5±0.5
Mid Atlantic Norway	≈ 4m±0.5	-3.5±0.5	-2.5±0.5	-15±5	-2.5±0.5
Southern Atlantic Norway	≈ 4m±0.5	-2.5±0.5	-2.5±0.5	-0±2.5	-1.75±0.25
Northern Atlantic Scotland	≈ 4m±0.5	-3.5±0.5	-2.5±0.5	-15±5	-2.5±0.5
Southern Atlantic Scotland	≈ 4m±0.5	-2.5±0.5	-2.5±0.5	-7.5±2.5	-2.5±0.5
Atlantic Ireland	≈ 4m±0.5	-2.5±0.5	-2.5±0.5	-7.5±2.5	-2.5±0.5
Atlantic England	≈ 4m±0.5	-1.5±0.5	-1.5±0.5	-0±2.5	-1.25±0.25
Atlantic France	≈ 4m±0.5	-1.5±0.5	-1.5±0.5	-0±2.5	-1.25±0.25
Atlantic Spain	≈ 4m±0.5	-1.5±0.5	-1.5±0.5	-0±2.5	-1.25±0.25
Atlantic Portugal	≈ 4m±0.5	-2.5±0.5	-2.5±0.5	-7.5±2.5	-2.5±0.5
Irish Sea					
North	≈ 4m±0.5	-1.5±0.5	-1.5±0.5		
South	≈ 4m±0.5	-1.5±0.5	-1.5±0.5		
North Sea Basin					
Southern Norway	≈ 4m±0.5	-0.25±0.25	-1.5±0.5	-0±2.5	-1.25±0.25
Western Sweden	≈ 4m±0.5	-0.25±0.25	-1.5±0.5	-0±2.5	-1.25±0.25
Northern Denmark	≈ 4m±0.5	-0.25±0.25	-1.5±0.5	-0±2.5	-1.25±0.25
Eastern Scotland	≈ 4m±0.5	-2.5±0.5	-2.5±0.5	-7.5±2.5	-2.5±0.5
Eastern England	≈ 4m±0.5	-1.5±0.5	-1.5±0.5	-0±2.5	-1.25±0.25

of eustatic sea-level rise of *circa* 4m seems a reasonable working value, although by no means constituting an upper or lower bound. The exact manifestation of the event at different localities is not well understood, but certain environmental parameters have been modelled as shown in table C7-1. There is a sharp drop in the temperature proxies in all the Greenland Ice cores and ice bergs were drifting south in the eastern Atlantic as far as Ireland (Bond *et al*, 1997). Icebergs can drift as far as 40^{O}south today but on the western coast and can be particularly numerous around the Grand Banks of Newfoundland. This pattern is observed because the currents that make up the NAG are not conducive to southerly drifting in the eastern Atlantic. Clearly the circulation of the northern Atlantic, in and around the event, was somewhat different to what is considered 'normal'. These observations are consistent with a weakening of the north easterly AMOC current and therefore cooler sea temperatures, which in turn, is consistent with ice bergs penetrating further south.

The data patterning in table C7-1, at least in terms of temperature, can be sense checked against the modern SST data presented throughout chapter 5. As expected, the deltas are greatest on the Atlantic façade where moderation is highest and lower or minimal in the eastern North Sea Basin. The reduction in precipitation was initially a surprise to the author. This was because the laws of thermodynamics are relentless in their pursuit of the objective of equalising temperature between the equator and poles. If the contribution to heat transport by the oceans is reduced as described above then the atmosphere must pick up the slack, so to speak. Therefore, an increase in storm energy and frequency is a reasonable, albeit neither can it be a certain, expectation. An increase in cyclonic weather systems is usually associated with increased precipitation. Presumably, the lower temperatures reduce evaporation over the ocean and therefore moisture within the atmosphere and consequently a reduction in precipitation is the outcome. The trajectory of such cyclonic weather systems may well be different to that generally observed today. Such winds will also be cooler as the ocean they traverse is cooler in this scenario, and therefore their moisture holding capacity is reduced. The high pressure anticyclonic systems that are associated with severe winters such as those of 1947 and 1963, which today tend to exert greater influence over southern and eastern Britain, may have had more influence in northern and western Britain in the above scenario. Whether such events were more frequent is currently an unknown. The second aspect is that the various figures provided in chapter 5 attest just how moderated the SSTs on the Atlantic Façade of Europe are at all latitudes, and that the moderation is most evident in terms of winter temperatures. Any temperature reduction is likely to disproportionately affect the cooler seasons of the year.

Table C7-1 illustrates another feature in terms of the lack of latitudinal variation in the SAT delta. Bishop *et al* (2018, fig. 11, p.166) in their consideration of the timing of woodland decline in the Western Isles comment that there are no latitudinal trends within the Western Isles. This is exactly what should be expected as the air temperature deltas in table C7-1 are within the tolerance the tree species concerned. The observation of Bishop *et al* (2018) is totally consistent with a loss of low lying coastal woodland in response to sea-level rise (and associated changes in tidal range) and a tsunami during the 9th millennium. The absence of a latitudinal trend, in terms of timing, is because the overriding considerations are local coastal geography, configuration, and bathymetry (chapter 3). This scenario is also totally consistent with the sea-level modelling of Sturt *et al* (2013). Some decline in birch and hazel could be expected due to reduced precipitation, although this will be localised depending upon topography and therefore run off routing and storage. Whilst probably intending to distance the palynological results from the temperature reductions associated with the 8.2K event, Bishop *et al*

(2018) also provide a valuable observation that can be incorporated into the efforts to decipher environmental change during the 9th millennium, at least in Atlantic Scotland.

In summary, the situation facing the Mesolithic people is one of reduced temperature especially in the cooler half of the year. This is combined with increased storm energy and frequency, albeit with a reduction in precipitation and an accelerated inundation of low lying coastal plains. The vectors all combine to alter the wave energy levels in the littoral zone. This combination is familiar as it is one of the scenarios evaluated in chapter 3 against the two model populations. The final observation is that humans studying the past (including some archaeologists) tend to lose, what might be termed, temporal perspective. Climatologists regularly refer to the event as ‘only lasting 150 years or thereabouts’. That is six human generations or more, potentially six generations where the way of life is seriously compromised, and by the end of such a period the way things used to be are just part of cultural memory (cf. Griffiths and Robinson, 2018).

7.3 The Storegga Slide.

This substantial submarine rockslide occurred north west of Norway and has been dated to 8.15K, and there is no doubt that it was an event (*sensu stricto*) that happened at a point (one day) in time. The evidence in terms of sea floor deposits appears to be irrefutable (Bryn *et al*, 2005), and likewise the majority of the putative tsunami deposits which have been identified throughout the North Sea basin (Weninger *et al,* 2008*;* Bondevik *et al,* 2005; Smith *et al*, 2004). The extent of the tsunami has generally been established by identifying tsunami sedimentary deposits left after the water had once again retreated. The occurrence of such deposits is limited to areas where either isostatic readjustment has been positive and exceeded eustatic sea-level rise, or locations where the tsunami run up height exceeds the amount of relative sea-level rise (eustatic sea-level rise plus negative isostatic readjustment) that has occurred since the event. In other areas the tsunami deposits or anomalies are now below sea-level (Selby and Smith, 2016) and the influence of the wave has, for these areas, been mathematically modelled (cf. Long *et al*, 2016; Sturt *et al*, 2013). The run up heights based upon field observations and the modelled wave amplitudes are presented in figure C7-1, and an image of a 22.6m wave is provided for context in Plate C7-1. An important point is that the modelled amplitudes cannot be directly compared with the run up heights as the run up height will be greater than the wave amplitude (Didenkulova and Pelinovsky, 2018, p.1389-1390; Harbitz, 1992, p.13-15). Sediment may also be removed and gaps in stratigraphic sequences maybe observed, with younger layers of deposition residing on much older sequences, and something appears to be missing in between. One reason for the lack of attention on this aspect is understandable. Can the removal of sediment by the tsunami be differentiated from removal by extreme storm events, such as that which removed 30m of dune system on the west coast of the Isle of North Uist in 2005? As discussed in chapter 3 the actual run up height at any given location is very dependent upon the local bathymetry. Low lying coastal plains and estuarine systems are obvious examples of habitats that could be destroyed due to tsunami inundation, as discussed in chapter 3 (cf. also Waddington and Wicks, 2017). The majority of research into the tsunami has focused on the North Sea basin, yet since waves diffract basic physics suggests that west coasts would also have experienced the event, a line of reasoning supported by the models cited above.

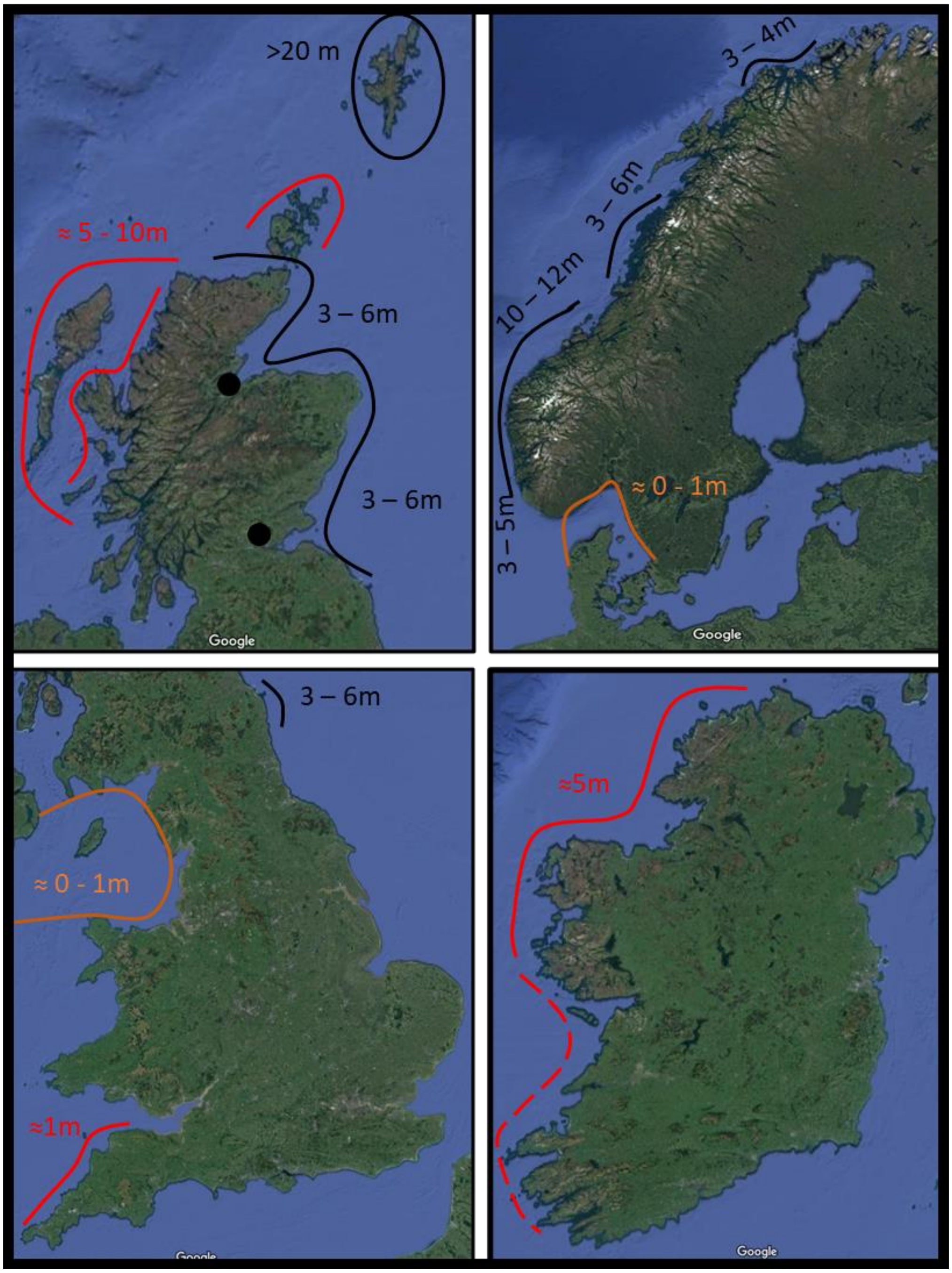


Figure C7-1: A consensus statement of the observational (run up) and modelling data (amplitude) of the tsunami. Solid black lines and circles reflect field observations. Solid red lines reflect modelled wave amplitudes. Dashed red lines indicate the situation is unclear. Solid orange lines depict specific areas where the modelled wave amplitude is negligible or zero. Actual run up heights are very dependent upon the local bathymetry as discussed in the main text. Data from Sturt *et al*, 2013; Long *et al*, 2016; Weninger *et al*, 2008; Bondevik *et al*, 2005; Hill *et al*, 2014; Blankholm, 2018).

Plate C7-1: A 22.6m (officially measured electronically) wave being successfully surfed by Maya Gabeira in Portugal. This wave is a typical oceanic wave with a wavelength of 250 to 300m which means the amount of water that runs onto the shore is relatively low. A tsunami has a wavelength in the 100s of Km range if deep water is close to the shore, or if there is a wide shelf of shallower water 5 to some 10s of Km. The amount of water inundating the coastal zone is therefore orders of magnitude higher and inundation can continue for hours. The run up height of the tsunami in Shetland is estimated at >20m.

7.4 The Methodology

The methodology consists of a number of stages as defined below.

Step 1: Apply the deltas to SST in table C7-1 to modern SST in a weighted manner. 75% of the total annual reduction applied to the six cooler months (December to May) and 25% to the warmer months (June to November).

Step 2: Review and select species to serve as bioindicators in relation to SST and establish their approximate temperature tolerance based upon their current distribution from the national biodiversity network atlas (NBNA) and the modern SST data.

Step 3: The response of species to the winter of 1963 (Crisp *et al*, 1964) is also considered as a factor in terms of resilience, as is a species' dispersal capability. The resilience of species to changes in shore exposure was considered against Ballantine (1961b)'s biological exposure scale.

Step 4: Compare the bioindicator species profiles with the reconstructed temperature profiles.

Step 5: Assess whether each sub-region exhibits changes in eco-behaviour and how these relate to the events utilising the assessments carried out in chapter 3.

Step 6: The causes of changes in eco-behaviour are then considered in terms of the wider implications for human groups defined in chapter 3.

Some detailed considerations and nuanced approaches are required during steps 2 and 3 and these are defined in SI-Chapter7-1. Once each region has been characterised the sites identified for detailed review in chapter 5 were considered in terms of faunal composition and biometric trends. In the case of Spain with its numerous sites a further step was executed by reviewing sites grouped by proximity to each other based upon the data available in Gutierrez-Zugasti, 2011a; 2011b; Clarke (1971; 1983); Alvarez-Fernandez, 2011; 2015; García-Escárzaga *et al*, 2017). The spatial groups are defined in SI-Chapter5-1.2.

As discussed in chapters 4 and 5 establishing chronologies is a major challenge. It is worth reviewing past approaches to handling this issue and clarifying the approach adopted. The approach is also based upon a fundamental view of what a calibrated date is and what information it contains. Firstly, a calibrated radiocarbon date (PD) is not actually a date it is a quantitative statement of the uncertainty in when an event (in the case of some charcoal samples or adult vertebrates, a decade) in time actually occurred. A radiocarbon date, or even set of dates, do not define a period of occupation, although they are often misinterpreted in this manner within the literature. One strategy is to construct a view of when a site was or was not occupied, and by considering several sites, this has been extended to regional levels as discussed below.

The use of summed probability distributions (SPD) to identify trends in human population levels or the presence of human populations in given regions is prevalent within the literature. The technique is heavily dependent upon the taphonomy of the materials utilised to obtain the PDs that are incorporated into the models as Bishop (2015) highlights in relation to the spread of cereal agriculture. A particular challenge in relation to the period under examination here are cave sites. Palaeolithic archaeology often deals with this issue as caves are frequented or occupied by carnivores and these often bring their kills to the caves. Therefore, the use of PDs derived from bones that do not display any evidence of human modification or butchery is not without risk. The technique has been deployed in relation to occupation in and around the 8.2k event (Wicks and Mithen, 2014; Solheim and Persson, 2018; Shennan *et al*, 2013) with diverse conclusions reached. Griffiths and Robinson (2018) prefer a revised approach, and they correctly point out that temporal bins of two or more centuries are not appropriate to answer the question in hand (ibid, p252). Their approach supplements PDs with *a priori* assumptions within a Bayesian statistical model. The resulting posterior density estimates (ibid, fig 2, p.254) are very difficult to relate to the actual archaeology and it seems likely that the approach is over engineered, at least in the way it treats north-western Scotland. There are periods of zero probability that last over half a millennium in the western isles and at mainland sites, these periods coincide on both the mainland and Western Isles. That is the potential hiatus in occupation is 'contemporary' and the same before and after delta in mollusc exploitation is observed. Loch A Sguirr's PDs do extend past 8.1K, but if priors are to be applied then based upon the 'PD gap' at other sites Loch A Sguirr must be considered as a pre-event occupation for the reasons relating to trade, social relations and mating networks highlighted in chapter 3. A possible cessation of occupation is also observed at Druimvargie, Rachoille and Ulva Cave, further to the south. The previous studies cited above consider population in relation to the 8.2K cold event, the fact that a major tsunami occurs *circa* 8.15k is generally ignored.

There appears to be little point in persisting with a strategy that consists of finding new ways to manipulate PDs to arrive at broad generalisations that lose sight of the actual archaeology. Alternatively, this can be positioned as; the temptation to torture PDs until they confess to anything must be resisted. The approach is to consider evidence for occupation during the 9th and 8th millenniums and to analyse the composition of the faunal assemblages in conjunction with other published environmental data such as palynology. Here PDs are taken for what they are, nothing more and nothing less; the position already stated is key so it will be repeated. PDs are quantitative statements of temporal uncertainty in when a point in time (a decade in time in some instances) event occurred. Of interest however are periods when the probability on either an inter or intra site basis is zero, and especially so when the elapsed period of zero probability is extensive. Of course, such ‘gaps’ may simply be artefacts of sampling, other lines of evidence must be consulted as mitigation. The concept and practice of chronological hygiene has been a positive introduction to archaeology during past decades. The approach generally deals with the quality and provenance of the materials used to generate the ^{14}C assays, but the view here is that it must be complemented by a critique of the resulting PDs. This can be summarised as; does the resulting PD make archaeological sense. That is, does a particular PD reflect a realistic profile for a site or is it (more likely) a mathematical artefact, which is an artefact of the calibration curve? (Chapter 4 and the example provided in SI-Chapter7-2). This may appear to introduce an element of subjectivity, but in the author’s view no more so than *a priori* assumptions in Bayesian models.

7.4.1 Notes on the presentation of Results

1. The sample sizes for the sites in the Western Isles have been provided in chapter 6. The sample sizes for the biometric data from other sites are presented as part of the summary statistics available in SI-Chapter7-3, along with the outputs from statistical tests. The sample sizes for other sites relating to taxonomic composition are provided in a separate table in SI-Chapter7-3.
2. At some sites data cleansing identified records that must be dropped. The dropped records (with justification) are detailed in chapter SI-Chapter7-4. The number of data observations utilised here may therefore differ slightly from those previously published.

7.5 Results

7.5.1 Selection of Bioindicator Species.

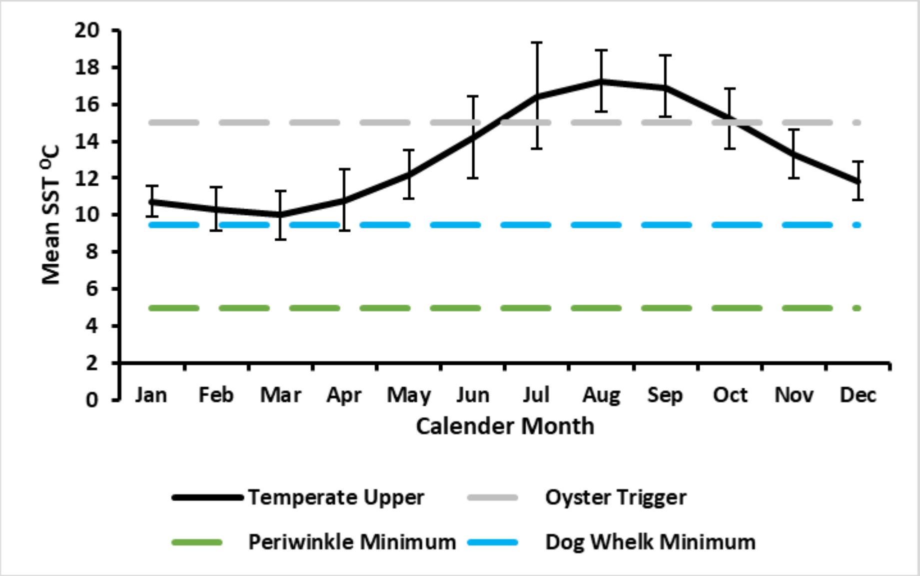


Figure C7-2: Maximum temperature profile based upon current distribution for the cod and auk families and grey seal. Blue line reflects oyster spawning trigger temperature, whilst green and light blue lines are the temperature at which spawning commences (SI-Chapter7-9).

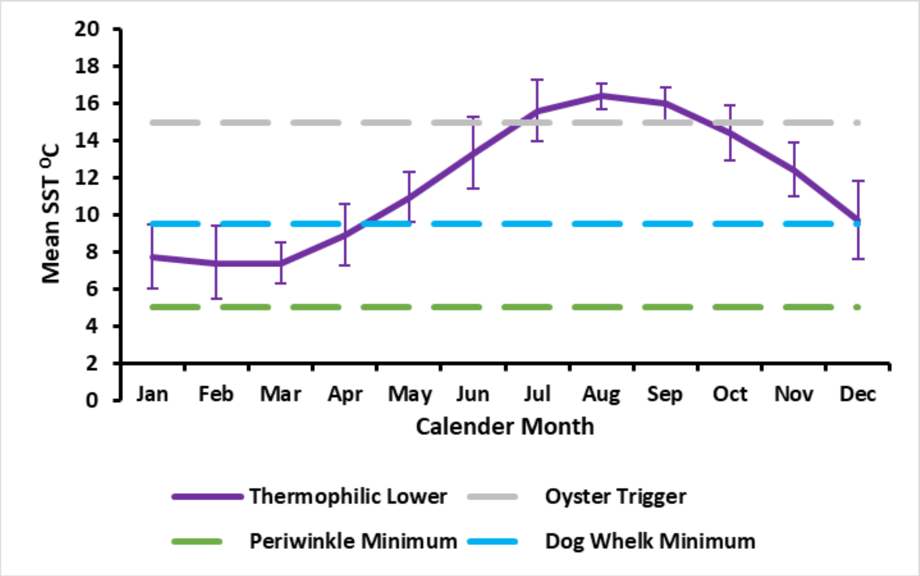


Figure C7-3: Minimum temperature profile for thick top shell, peppery furrow shell, chequered carpet shell, sea bream, furrowed crab, and spider crab, based upon current distribution. The temperature profile of distribution today is roughly that of Irish Sea coast of Northern Ireland and North Wales around Llandudno. The spider crab's range extends slightly further north. Blue line reflects oyster spawning trigger temperature, whilst green and light blue lines are the temperature at which spawning commences (SI-Chapter7-9).

The selected bioindicators and their utilisation are given in table C7-2. Figures C7-2 and 3 show the temperature profiles constructed utilising the methodology outlined. The families represented in figure C7-2 are seasonal migrants and will avoid the warmest months during the warmest summers. Figure C7-3 depicts the winter temperatures below which the species will be either absent from and the summer temperatures that must be met if spawning and juvenile development are to be successful.

Table C7-2: Table of bioindicator species utilised in this chapter and chapter 8. The grey seal is also a potential indicator of cooler conditions in Brittany and Spain. Detailed information regarding the species selected is provided in SI-Chapter7-9 with the references consulted. Winter temperature refers to resilience to low temperatures. Summer temperature relates to both physiological resilience to high temperatures and spawning trigger temperatures. Recovery relates to dispersal capability and therefore recovery from local extirpation,whether due to natural or anthropogenic causes.

Species	Winter Temp.	Summer Temp	Shore Exp.	Substrate	Recovery	Land Cover	Littoral Cover
Mammal							
Wild Boar						Y	
Roe Deer						Y	
Elk						Y	
Birds							
Auk Family		Y					
Eider Duck							Y
Fish							
Bream (sparidae)	Y	Y					
Gadidae		Y					
Sea Bass	Y						
Wrasse	P	P					Y
Crustaceans							
Harbour/Sandy swimming crab				Y			
Velvet swimming crab				Y			
Edible crab			Y	Y			
Shore crab			Y				Y
European Spider Crab	Y	Y					
Furrowed Crab	Y	Y		Y			
Molluscs							
Red Lipped Rock Shell	Y	Y		Y			
Dog Whelk			Y	Y	Y		Y
Periwinkle			Y	Y	Y		Y
Thick Top Shell	Y	Y	Y	Y	Y		Y
Peppery Furrow Shell	Y	Y		Y			
Chequered Carpet Shell	Y	Y		Y			
Razor Clam (E. siliqua)	Y		Y	Y			
Razor Clam (E. magnus)	Y		Y	Y			
Razor Clam (E. ensis)	Y		Y	Y			
Common Cockle			Y	Y			
Lagoon Cockle			Y	Y			

7.5.2 Sub-region Temperature Profiles

The modelled SST profiles for each of the sub-regions of Atlantic Europe are provided below, along with comparative profiles for the eastern North Sea and the Irish Sea provided in (SI-Chapter7-5). Two modelled scenarios were generated. That presented is the weighted distribution as described above. The modelled temperatures for the Irish Sea and North Sea are provided in SI-Chapter7-5.

7.5.2.1 Portugal

The revised temperature profile for Atlantic Portugal is provided in figure C7-4. Little change in faunal composition should be anticipated due to temperature. It is possible that certain species of fish and birds preferring a temperate environment could frequent the coasts of Portugal during cooler years, whilst the thermophilic species would also continue to succeed in the sub-region. The spawning of thermophilic invertebrates should also be sustained possibly at a lowered efficiency level, or even with interruption during the cooler years represented by the error bars. The key implications are that there is no reason to expect any substantive change in the composition of the archaeological assemblages. It is possible that some biometric variation may be recorded in terms of reduced size of poikilothermic organisms due to lower temperatures. An unknown is the thermal tolerance of the red lipped rock shell which reaches its northern limit in Portugal and Spain. Most changes in the faunal record are therefore most likely to originate from changes in eustatic sea-level and the resulting increases or decreases in shore exposure level, depending upon local factors.

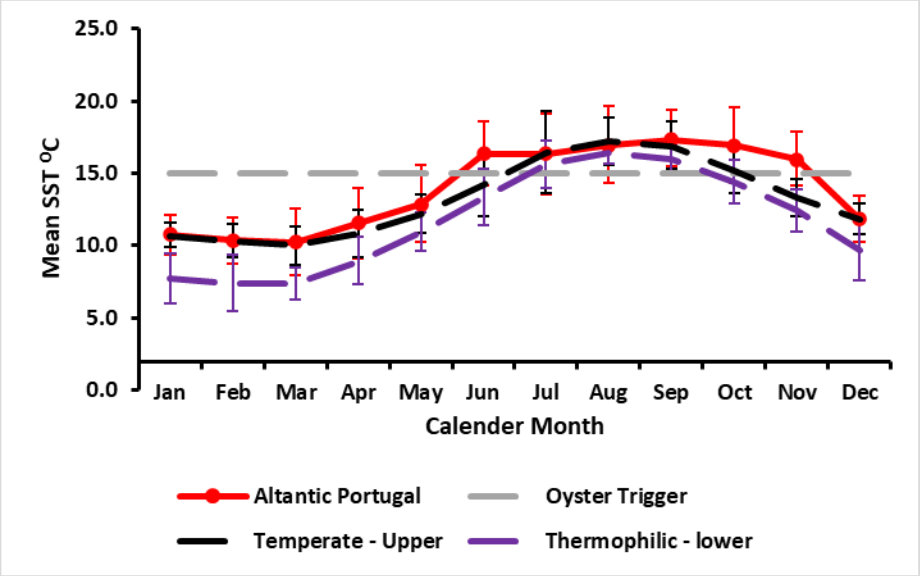


Figure C7-4: The modelled temperature for Portugal based upon the modern data for Figueira da Foz.

The scenario for human groups is not severe in absolute terms as the SST profile exceeds that in the north of Scotland and southern Atlantic Norway today. However, perception of how severe the reduction is lies in the eye of the beholder, and this very much depends upon what individuals are accustomed to and how easy it is to make any required adjustments to behaviour and technical buffering, such as clothing or shelter design, if any are required at all.

7.5.2.2 Cantabrian Spain.

The revised temperature profile for Cantabrian Spain is provided in figure C7-5. There should be no expectation of substantive changes in the composition of faunal assemblages. The requirements of thermophilic species are comfortably satisfied, and the tolerance of the temperate species is clearly exceeded, except during mid-winter. Most changes in the faunal record are therefore most likely to originate from changes in eustatic sea-level and the resulting increases or decreases in shore exposure level, depending upon local factors. Some biometric trends maybe observed in thermophilic taxa due to lowered temperatures. The climatic scenario will have remained more than comfortable for humans and little or no adjustment to technological buffering appears to be required.

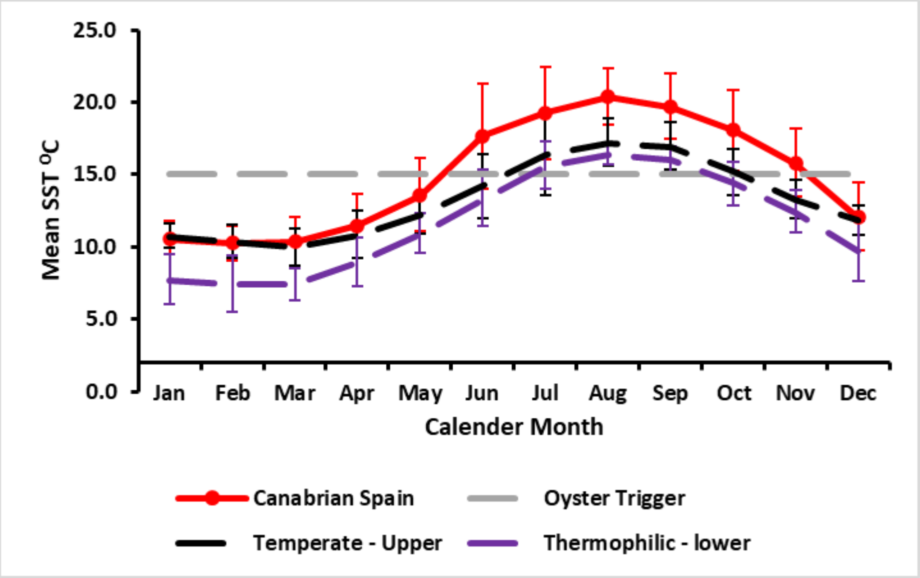


Figure C7-5: The modelled temperature for Spain based upon the modern data for Santander.

7.5.2.3 Brittany France.

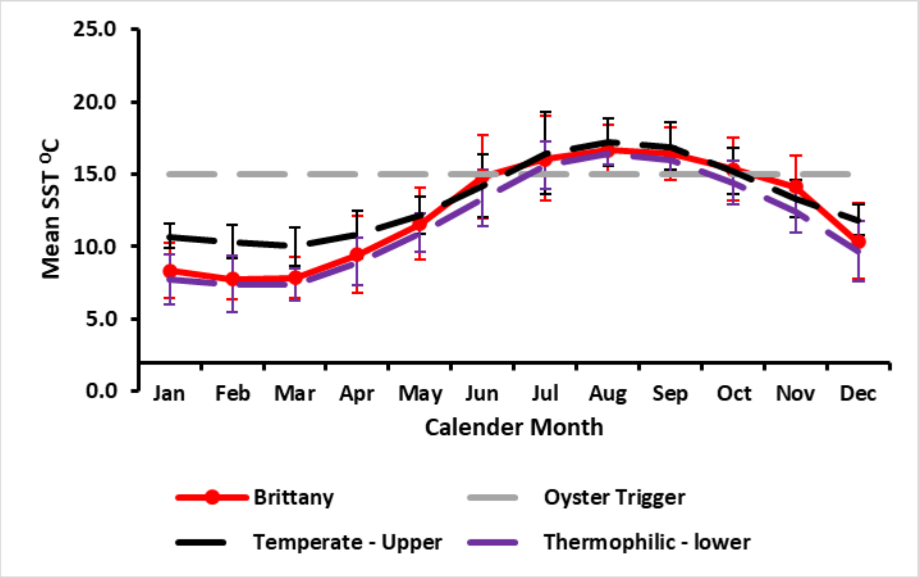


Figure C7-6: The modelled temperature for Brittany based upon the modern data for Lanester.

The revised temperature profile for Brittany is provided in figure C7-6. This is the first sub-region in which there are potential implications for the faunal record. Generally, the thermophilic species should still be present although possibly abundance will be reduced as the situation is marginal. In the cooler years spawning may be inhibited and sustainable exploitation may have been problematic for a period. Growth in the thermophilic species may also be retarded and this may manifest itself in terms of biometric trends. It is also possible that temperate species such as the auk and cod families as well as grey seal will be available in the area more frequently. It seems likely based upon modern temperatures that the people of Brittany utilised some form of winter clothing, but figure C7-6 suggests only incremental adjustments would have been required.

7.5.2.4 Atlantic England.

The revised temperature profile for Atlantic England is provided in figure C7-7. The situation is now more favourable for the temperate species and they are likely to be more abundant than they were previously. The thermophilic species are likely to be present only during warmer episodes. Changes in the faunal record can be anticipated with some certainty. Oysters will also be a marginal resource as in some years spawning will be reduced or inhibited. As with Brittany, it seems likely that any adjustments to technical buffering such dwelling design or winter clothing would be incremental. Biometric vectors due to reduced growth or shore energy levels as a consequence of sea-level change can also be expected in some locations.

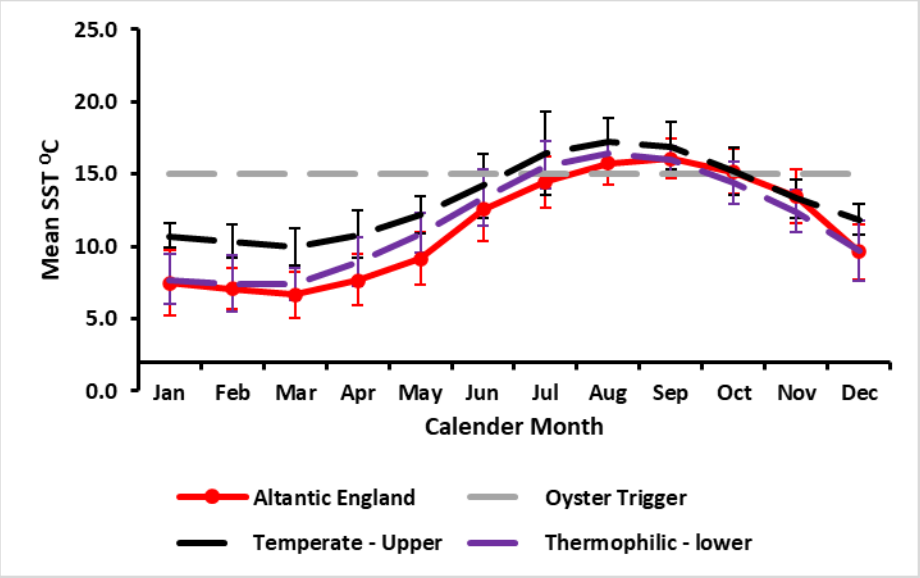


Figure C7-7: The modelled temperature for Atlantic England based upon the modern data for Weymouth on the south coast. The difference between Weymouth and sites in Cornwall and the Bristol Channel is minimal and do not merit a specific treatment.

7.5.2.5 Ireland.

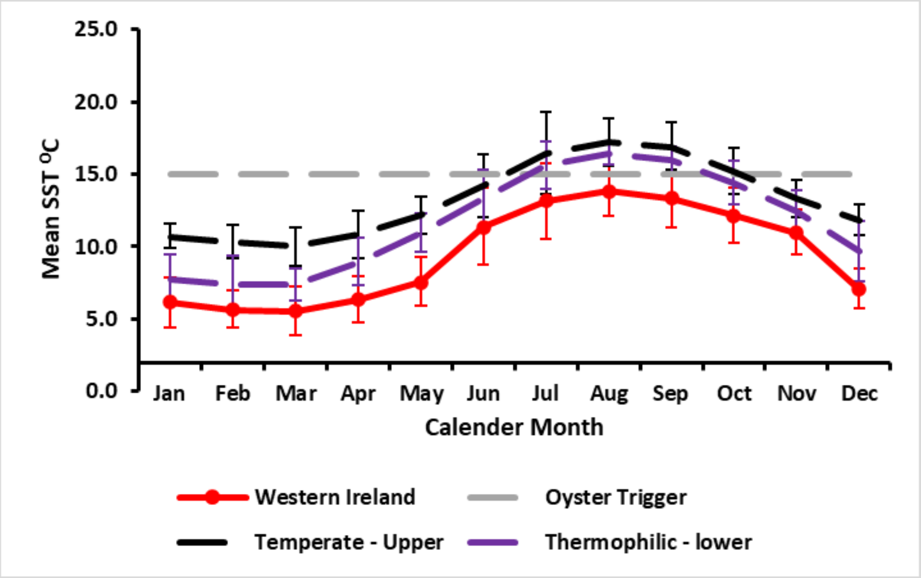


Figure C7-8: The modelled temperature for western Ireland based upon the modern data for Clifden on the Atlantic Coast.

The revised temperature profile for western Ireland is provided in figure C7-8. Thermophilic taxa are likely to be absent whilst the temperate species will be abundant. For the first time the exploitation of oysters is not a sustainable option. Whilst adult populations may persist, spawning will be very ineffective and probably rare. Any existing beds would be exhausted rapidly. The situation in the Irish Sea reflects slightly higher SST but the magnitude does not alter the above prognosis (SI-Chapter7-5). Local factors could be important, for example elongated loughs such as Lough Swilly (also being on the Irish Sea) may well have continued to provide summer temperatures conducive to oyster spawning, at least periodically. Such locations are however more prone to mortality during extreme winters (Crisp *et al*, 1964).

7.5.2.6 Atlantic Scotland.

At this latitude on the Atlantic façade the situation becomes very clear cut. Modern SST are sub-optimal for oysters although as with Ireland, elongated lochs such as Lochs Etive, Sunnart or Leven, may support spawning colonies. The modelled palaeotemperatures in figure C7-9 suggest that thermophilic species would be extirpated. Growth rates of invertebrates will be suppressed, with a definite winter abatement, although these will be aggregated with changes due to shore exposure levels. Changes in the composition of faunal assemblages however are not expected due to the ecosystem being populated by species adjusted to temperate conditions. Biometric trends in growth are an expectation if exploitation levels remain constant. The winter temperatures may also increase natural mortality, especially of younger age classes (Crisp *et al*, 1964). At this latitude it is probable that the birthing seasons of terrestrial mammals shift towards the summer and the period of birthing contracts. Contraction can also be expected in the period species such as red deer spend at altitude (chapter 3). The distribution of molluscan species on the shore can be expected to favour the lower reaches of the

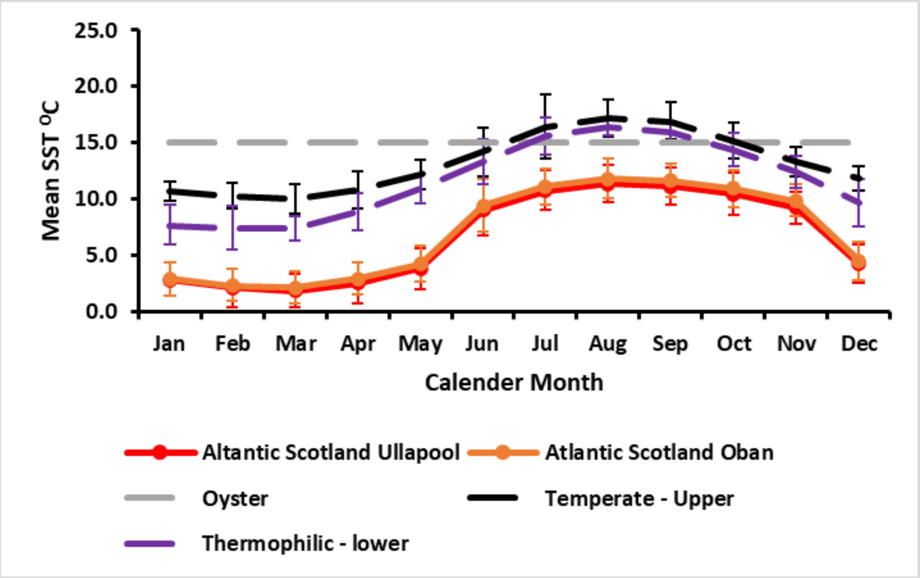


Figure C7-9: The modelled temperature for Atlantic Scotland based upon the modern data for Ullapool and Oban.

intertidal zone and possibly, in severe periods, be predominantly infralittoral. Continued human occupation must have required a significant change in the technological buffering employed as the temperature profile is now well below that of Tierra del Fuego. An increase in the presence of fur bearing mammals might be expected within the assemblages, although if these are skinned at point of capture the remains will be limited to phalanges, possibly metapodials and for some species cranial components; certain methodologies will not report this. The situation for eastern Scotland is presented for comparative purposes in SI-Chapter7-5.

7.5.2.7 Atlantic Norway.

Atlantic Norway is interesting in terms of SST today. Southern locations such as Sandnes and Bergen have lower winter temperatures and higher summer temperatures than locations such as Kristiansund further north; this, despite these sites being at a similar latitude to Shetland and apparently open to the Atlantic. Their temperature profiles throughout the year are the same as southern Norway around Oslo Fjord, although less extreme. This profile of annual SST variation is apparently more influenced by whether the location is on the continental shelf that is the northern North Sea basin or not. Clearly the Atlantic is moderating as attested by the less extreme profile observed above. The modelled SST profile for Atlantic Norway are provided in figure C7-10. The first observation to make is that in northern Norway every winter appears to be an extreme 1963 winter, at least for invertebrates occupying the intertidal zone. Most molluscs will only survive in the infralittoral. In mid-Norway the situation is very similar to that described above for Scotland. In southern Norway it is possible that oyster could spawn intermittently (as it has in Norway in recent times (Nelson, 1928)), although colonies would not withstand much, if any, procurement pressure. Most of the observations made in relation to Scotland can be repeated here although the situation is more extreme in terms of magnitude. The

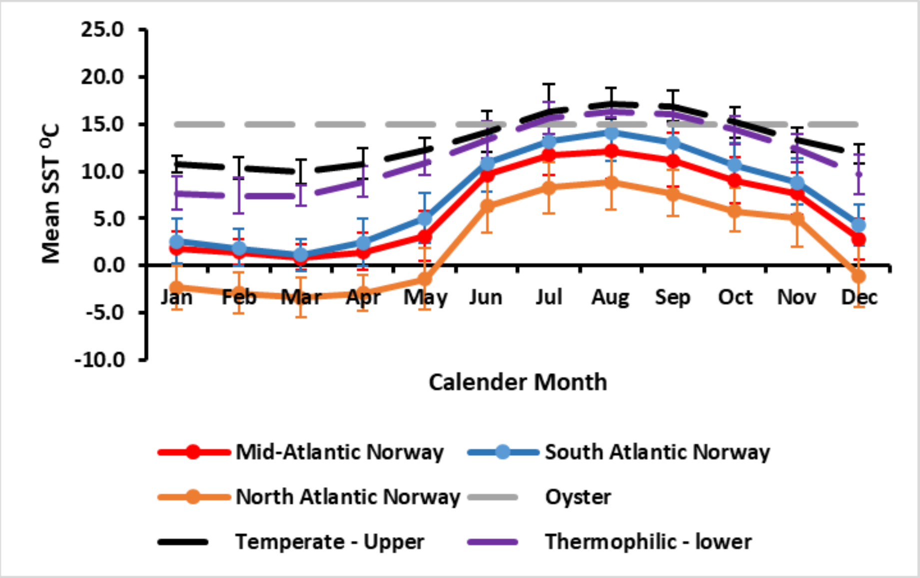


Figure C7-10: Modelled SST for Atlantic Norway utilising Bergen, Kristiansund and Tromso.

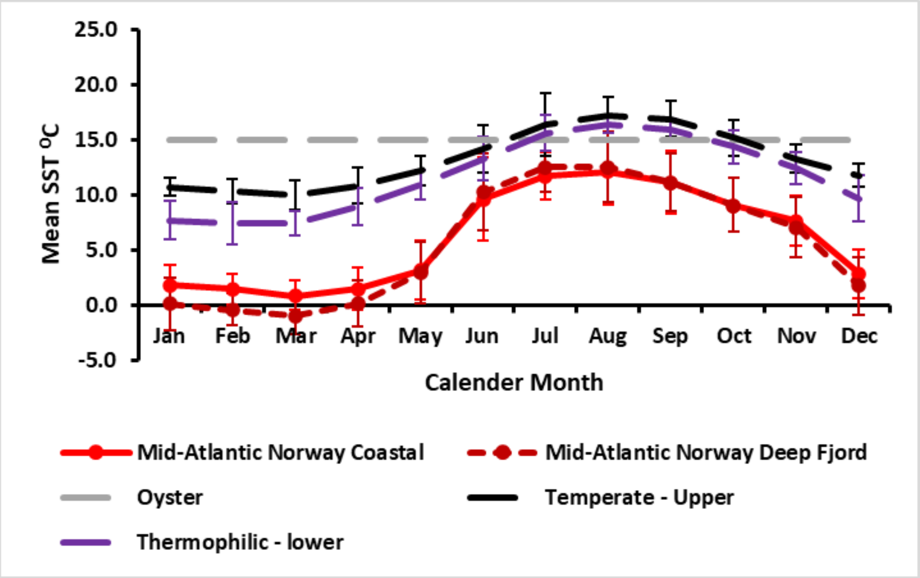


Figure C7-11: Modern SST profiles from Kristiansund on the coast and Steinkjer at the head of a very long fjord. These locations offer warmer conditions in the summer but are colder in the winter. The people must make a trade-off between colder temperature versus projection from storms and especially wind as the Moachat of British Columbia did. The situation depicted is maintained in the modelled 8.2K event data (not shown).

Mesolithic people of Norway must adopt greater levels of technological buffering if occupation is to continue and in northern Norway an Inuit like solution was probably required.

A final point is that as observed in relation to Ireland and Scotland, the situation on the open coast can vary relative to the situation deep within elongated loughs, lochs and fjords, as also observed in Tierra del Fuego and British Columbia (chapter 3). This can be illustrated in mid-Atlantic Norway using two sites as shown in figure C7-11. The situation for southern Norway in the North Sea is presented for comparative purposes in SI-Chapter7-5.

7.5.2.8 Summary.

The discussion and characterisation of the sub-regions is complete. Unsurprisingly given the nature of the 8.2K event strong latitudinal vectors are observed. In Spain and Portugal there is little expectation of change in the faunal assemblages or the technical buffering employed by the people. Brittany and southern England start to offer some potential for observing change in fauna, although the need for other than nuanced changes in technical buffering appears minimal. In Ireland, Scotland and Norway the need for significant changes in technical buffering strengthens and, in the case of the latter two sub-regions continued occupation during the event is not without significant challenges. Most changes in faunal composition will be manifest biometrically rather than compositionally. Although not presented graphically, the data in table C7-1 suggests very little adjustment will be required by the people of southern Norway (or western Sweden or northern Denmark) as the effect of the event is minimal and these people are already adapted to very cold winters. The question now is whether the archaeological record supports the above hypotheses.

7.5.3 Evidence for Occupation

All sub-regions provide evidence for occupation during the 9th millennium prior to 8.2K and all sub-regions also provide evidence for occupation after 8.2k during the 8th millennium. Some sites have PDs that include the late 9th millennium, but these are rare if disassociated minor probability maxima (SI-Chapter7-2) are excluded. The situation is highly variable between sub-regions as might be expected, but a component of this variability is down to how many 'old' radiocarbon bulk samples were assayed using traditional beta decay counting technique (and not supplemented by subsequent assays on short lived materials combined with the AMS technology). A further source inter sub-region variability is the spatial and temporal resolution, or lack thereof, in the ΔR values used to generate PDs from materials containing carbon of marine origin.

Relatively few sites offer quantitative taxonomic compositional data and even less can provide this with at appropriate temporal or stratigraphic resolution. The number of sites offering biometric data is even lower and the number of sites that can provide this with temporal resolution is very low. In some sub-regions the spatial clustering of numerous sites does permit some temporal resolution to be achieved. A total of 507 ^{14}C assays were reviewed and of these 28% generated PDs with a temporal resolution < ¼ of a millennium with a further 47% permitting positioning within ½ a millennium. If the event is considered to have occurred between 8.25K and 8.1K, which includes the tsunami around 8.15K, relatively few PDs encroach into the period of the event (table C7-3).

Table C7-3: A breakdown of the reviewed ^{14}C assays in relation to the defined period of the 8.2k event rounded to the nearest integer value. n=507.

Definition.	**Proportion of ^{14}C essays**
^{14}C assays generating PDs that terminate prior to the event	23%
^{14}C assays generating PDs that commence after the event during the 8th millennium.	16%
^{14}C assays generating PDs commencing in the 7th millennium or later.	26%
^{14}C assays generating PDCs that span the period of the event.	9%
^{14}C assays generating PDCs that commence during the event.	4%
^{14}C assays generating PDCs that end during the event.	2%
^{14}C assays relate to occupation commencing in the 8th millennium and ending in a later millennium.	19%

7.5.3.1 Atlantic Portugal

Evidence for environmental change in Portugal, is primarily based upon two thermophilic species, the thick top shell and red lipped rock shell. These feature strongly in the 10th millennium, but they become marginalised in the late 10th millennium and then disappear from the record. This trend is matched by variation in size of the thick top shell (figure C7-12). They reappear late in 8th millennium and also again in the late in the 7th millennium. Oyster features in the 9th millennium but disappears from the record just prior to 8.2k; it does not feature strongly again.

The formation of the Muge and Sado middens have been associated with the 8.2K event (cf. Bicho *et al*, 2010) and the PDs appear to support this, at least at first glance. Various reasons for a hypothesised withdrawal from the coast, including eustatic sea level rise, climate, and marine productivity have been proposed (ibid). Yet very few coastal sites with evidence for marine resource exploitation offer evidence for occupation leading up to the event. A number of these only offer such evidence because of the larger value of ΔR from St. Juliao A of +940 ± 50 and the sense that this value may reflect incorrectly paired samples is difficult to put to one side. The use of the lower value from St. Juliao A at these sites clearly disassociates them from the 8.2K event. The majority of sites are abandoned much earlier, in the early 9th or 10th millenniums (Bicho *et al*, 2010, table 1, pp89-90).

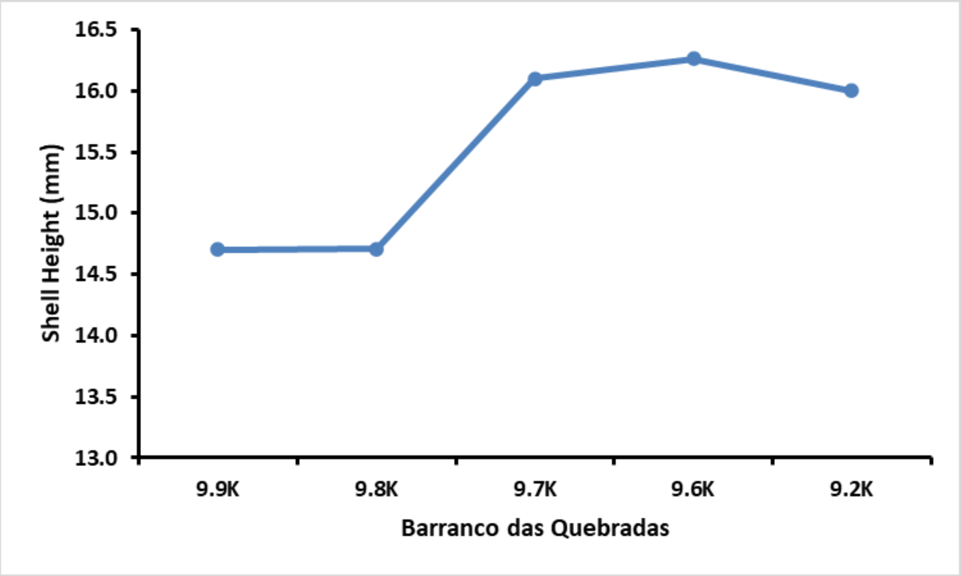


Figure C7-12: Shell height for the thick lipped top shell. Each phase has multiple spits (not shown). The final decrease in shell size is more pronounced in the final two spits and size is again < 15mm as this sequence comes to an end. Data from Dean *et al* (2012, table 2, p.106).

The situation in Portugal is very unclear because of the various factors described above. It seems that little faunal change occurs as a consequence of the 8.2K event, as predicted in the models presented, but for a different reason than the author envisaged. The thermophilic species had disappeared late in the 10th millennium. There is continuity is the exploitation of fish, suggesting any change late in the 9th millennium was limited in magnitude. There appears to be little motivation for people to abandon the coast. It is possible that the Muge and Sado middens developed simply because the eustatic sea-level rise (van der Schriek *et al*, 2007) presented the people with an additional and attractive option and they made a choice. Perhaps the people were not pushed from the coast but were enticed away by a new environment.

7.5.3.2 Atlantic Spain

The literature pertaining to Spain is more extensive than that available in other sub-regions because more sites exist, and significant effort has been expended considering the Pleistocene to Holocene transition, as well as the Mesolithic to Neolithic transition. Such analyses have inevitably generated data sets that are useful in considering the 8.2K event. In common with other sub-regions detailed compositional data is rare and biometric data rarer. Spain does have one advantage over the other sub-regions and that is the spatial clustering of the sites. When supported by PDs these sites can collectively provide a temporal sequence, where otherwise there would be none. Many sites are abandoned well before the 8.2k event and many exhibit hiatuses for varying periods of time and often these cannot be associated with the event. At first glance there appears to be temporal variation in the ordinal abundance of limpet, mussel, and thick top shell. The vast majority of this variation is eliminated when the sites are considered in their spatial groupings. Where temporal variation remains on an intra-group basis it is usually (El Mazo being the exception in the late 10th or early 9th millennium) a function of assemblage size. The ordinal abundance of thick top shell and oyster exhibits an inverse relationship with assemblage size. Within the period of interest only Mazaculos II offers stratigraphic resolution accompanied by biometrics.

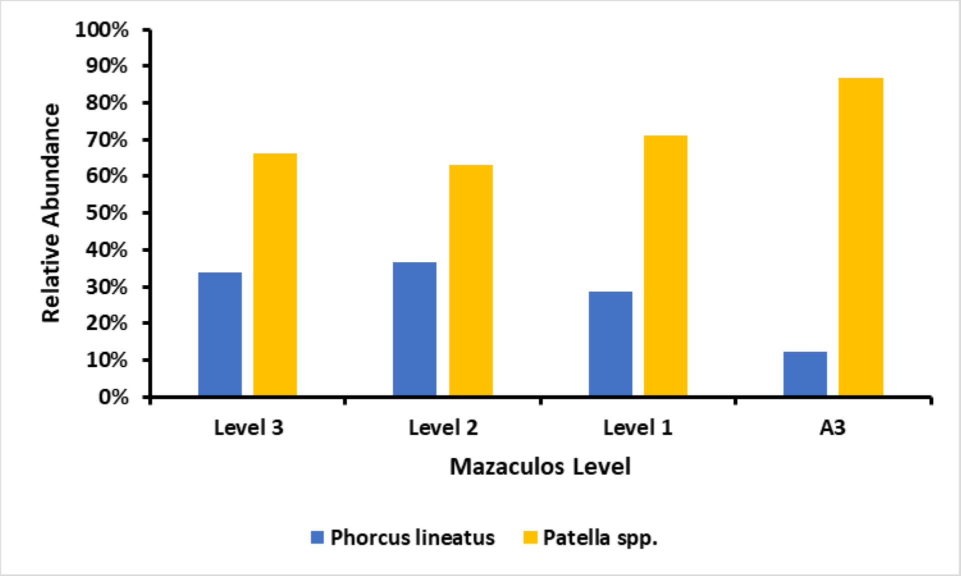


Figure C7-13: Relative taxonomic composition at Mazaculos II. No data is available for sub-levels 1.1 1.2 and 1.3. Data from Gutierrez-Zugasti (2009).

After a small increase there is steady fall in the abundance of the thick top shell during the 9th millennium (figure C7-13). There is an initial decline in the height of thick top shells until the middle of the 9th millennium and then after a sharp reduction (figure C7-14). The decline in the size of limpets is very gradual, if the very low value for level 1.1, which also has no data for *Patella depressa*, is considered an artefact of preservation (figure C7-15). During this period there is also a steady increase in the squatness of the thick top shells which is indicative of increasing shore energy level (figure C7-16).

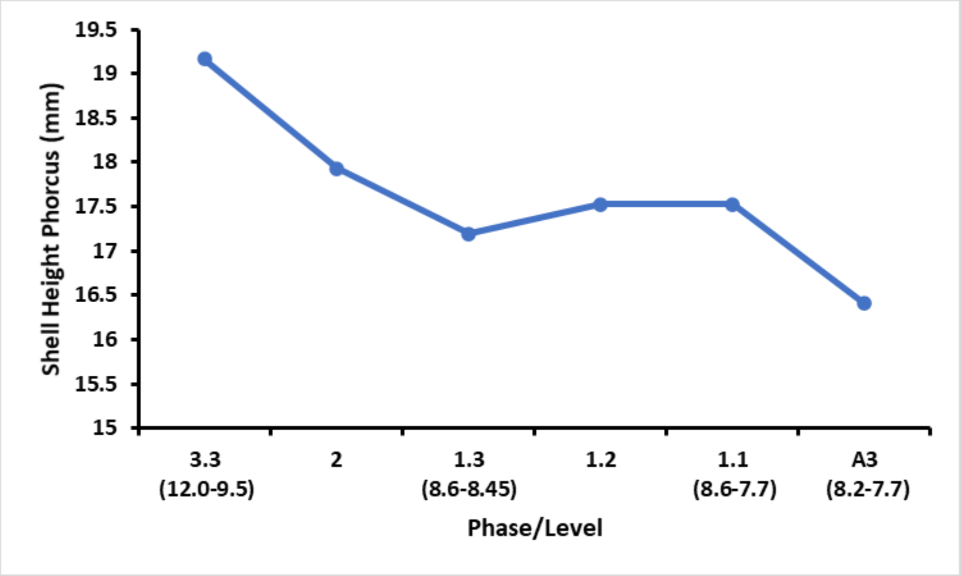


Figure C7-14: Shell height of the thick top shell from Mazaculos II. Numbers in brackets reflect the calibrated date range bp. The raw ^{14}C dates were obtained some decades ago and have very large standard errors. Data extracted electronically from Gutierrez-Zugasti (2009, fig. 6.41, p.196)

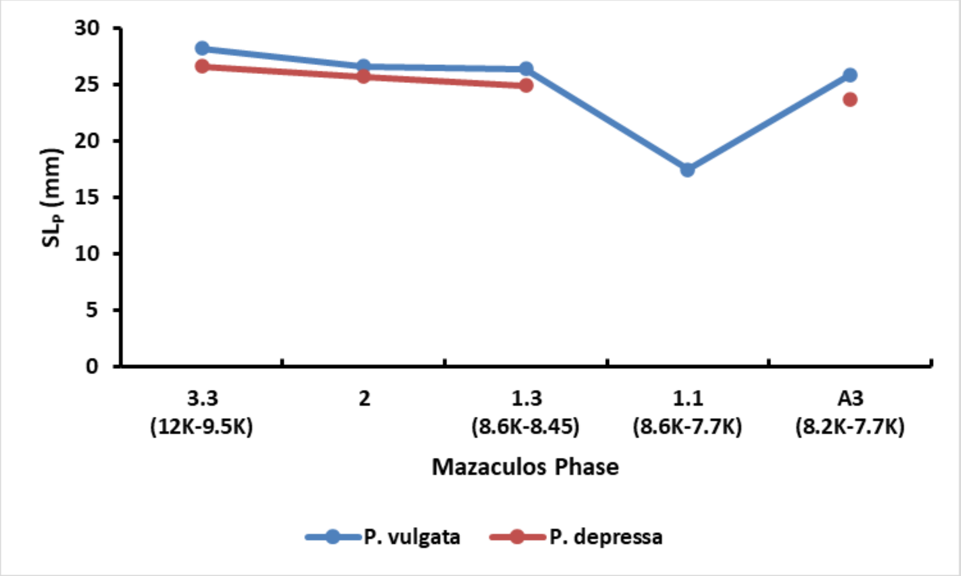


Figure C7-15: SL$_P$ of two species of limpet from Mazaculos II. Numbers in brackets reflect the range of the PDs.There is no data available for sub-level 1.2. The raw ^{14}C assays were obtained some decades ago and have very large standard errors. Data from Gutierrez-Zugasti (2009; 2011a).

There is, based upon the SST models, no reason to expect a reduction in oysters during the event. Yet oysters only ever have a minor role and these appear to be temporarily grouped. Oysters, when they feature at all do so either in early occupations (10th or early 9th millennium) and much later occupations

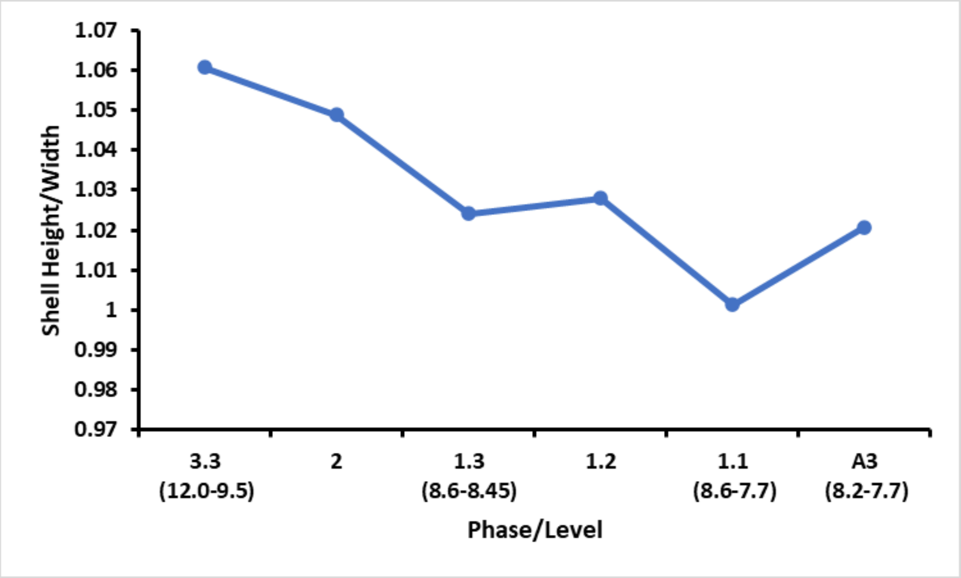


Figure C7-16: Shell morphology at Mazaculos II showing an increase in squatness over time, which is normally a response to increasing shore exposure. The magnitude of the reduction is consistent with the ecological literature comparing exposed versus sheltered shores at proximal locations in Portugal (Antunes da Costa, 2015, table V, p.25). The only issue is that whilst morphology does appear to be limited at a lower/upper value of 1.0 in both datasets, the modern Portuguese specimens are always wider than they are tall, the reverse of the data presented above from Gutierrez-Zugasti (2009, fig. 6.41, p.196).

in the 7th millennium. The remains of crabs are also scarce rarely exceeding an MNI of 1 or 2 until the 7th millennium. As stated in chapter 5, how these cave sites fitted within the overall settlement system remains an unknown. Probably the major exploitation and processing of, not only molluscs, but also fish, and crabs, occurred elsewhere, as in many cases the MNI counts for units hardly constitute a shell-midden and reflect more occupation sites such as Northton or Teampuill an Bagh in Scotland. A small number of sites exhibit gaps in the coverage of the PDs, potentially indicating hiatuses in occupation. Two such sites are La Garma (level Q), which was potentially unoccupied between 8.25K and 7.95K, and La Fragua (Phase 1) was potentially unoccupied between 8.2K and 7.85K. Another site Santimamine appears to be abandoned just prior to 8.2K with a resumption more than a millennium later. Notwithstanding uncertainty in site function, in general, the situation in Spain is exactly as the modelled scenario predicts. The model suggests little impact should be observed for the thermophilic species and there is continuity for the thick top shell and *Patella depressa* throughout the period. There is no evidence for temperate species of bird or fish, although there is very little evidence beyond molluscs (often in very small quantities) for the exploitation of marine resources at all. Why top shells and limpets are getting smaller is an interesting question. It is either an increase in human demand and therefore procurement pressure, or shore energy levels are starting to exceed the threshold of the thick top shell and the smaller communities that remain in favoured microhabitats are under more procurement pressure, even though demand remained constant. The latter explanation is consistent with the morphology vector.

7.5.3.3 France

Except for St. Gildas 1B, occupation in France appears in all likelihood to post-date the 8.2K event if old ^{14}C assays with very large standard errors are ignored. There is a human burial dated to the period of the 8.2k event, but this date is not consistent with those obtained from the fauna and appears to be a burial that predates midden formation at Beg-er-Vil by around 1,500 years. At both St Gildas 1B and 1C the thermophilic peppery furrow shell, is the most abundant taxon, both before and after the event, little else can be said based upon these small assemblages. At Beg-an-Dorchenn the mollusc assemblage is dominated by limpet and the thermophilic peppery furrow shell, along with cockle. This site yields a very wide range of PDs covering (8.2K to 6.6K) and there is age depth consistency within squares and the majority of the PDs support occupation during the 8th millennium or later. Two PD span the event covering the late 9th millennium to early 8th millennium. The faunal assemblage has only been published at site level so further comment is difficult. The situation at Hoedic is very similar, whilst occupation at Teviec is confined to the 8th millennium or later. The grey seal appears to have expanded its range southwards and its remains are present Teviec and Beg-er-vil, the two later sites. In the absence of further stratigraphic or temporal resolution it is difficult to draw any further conclusions, beyond conditions during the 8th millennium were suitable for the thick top shell, which is not a surprise as it is present in southern England at the same time (see below). The thick top shell is never more than 3rd most abundant taxon at any of the sites, where present. The fish species are a mixture of warm water sparidae and colder water gadidae, but in the case of the latter only those species whose range reaches the Channel Islands today, which in conjunction with the observations on molluscs make the presence of grey seal somewhat anomalous.

7.5.3.4 England and Wales

Only Culver Island was possibly occupied prior to or even through the 8.2k event and is the only site that has been published with any stratigraphic resolution in terms of the faunal assemblage. The lowest layer 13 contains little evidence for marine resource exploitation but does contain knapping debris and other lithic materials. The more recent samples from Culver Island record occupation through the 8th millennium through to the early 7th millennium (Mannino and Thomas, 2001). The site is useful because it contains the thermophilic thick top shell in reasonable quantities, far greater than the few specimens at Ulva Cave. The assemblage has been analysed in terms of taxonomic composition, age versus size at death and incremental oxygen isotopes (Mannino and Thomas, 2001; Mannino *et al*, 2003).

The isotope data presented by Mannino *et al*, (2003, fig. 7, p.676) demonstrates that summer temperatures were increasing during the 8th millennium (levels 12 to 8) and likewise winter temperatures which authors specifically comment on (ibid, p.676). The shell from layer 8 in the second half of the 8th millennium experiences warmer summers than the modern shells from nearby Golden Cap (ibid, fig. 5, p.673). It is within this context that the composition and biometric variation in the shell-midden must be evaluated.

The relative abundance and mean shell size by layer is provided in figure C7-17. Layer 12 contains very few molluscs and the assemblage is dominated by limpets. As might be anticipated based upon the isotope data the abundance of the thick top shell increases from level 12 to 8. Relative abundance cannot be compared directly with European sites due to variation in the screening that produces the MNI counts. The data presented by Mannino and Thomas (2001) reflects both the 4R and 2R fractions. Based upon comments in the paper (ibid, p.1107) it seems certain that if only the 4R faction was considered then the thick top shell would be less abundant than limpet and periwinkle in all layers.

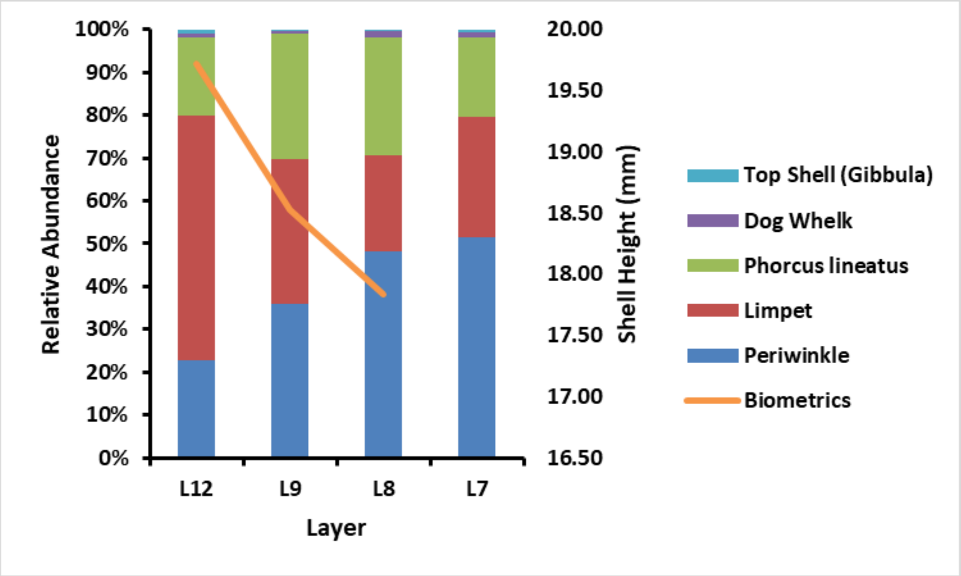


Figure C7-17: Compositional make up of Culver Island combined with biometric data on shell diameter for Thick Top Shell. Data from Mannino and Thomas (2001).

The vector in shell size against relative abundance is consistent with increased procurement pressure as suggested by Mannino and Thomas (2001), although other factors may be either responsible or contributing. Age at death was also considered but only mean values are available (ibid) and as discussed in chapter 4 mean values for age and size are unsatisfactory, it is the distribution of age versus size that is informative. It is also unclear whether the top shells are simply getting smaller rather than squatter in response to changes in shore energy level. The ameliorating temperatures should favour the growth of thick top shell and in the absence of biometrics for periwinkle and limpet it is difficult to reach a firmer conclusion.

7.5.3.5 Ireland

Ireland has only one coastal site (Sutton) that suggests possible occupation before and after the 8.2K event and there is no stratigraphic resolution or meaningful documentation of the faunal assemblage.

7.5.3.6 Atlantic Scotland

Only the earliest phase of the site Druimvargie demonstrates occupation during the 10th millennium in conjunction with the exploitation of marine resources (SI-Chapter7-8). A number of other cave sites exist that either lack PDs and or appear to have been disturbed and turbated in later periods. In many cases these sites were not formally excavated prior to destruction. There are not many sites, open or cave, that demonstrate occupation during the 9th millennium and fewer unequivocally. Cnoc Coig has produced early PDs but the stratigraphic position they came from is unclear and the majority are much later in the terminal Mesolithic. Raschoille Cave and Loch A Sguirr are similar in that a wide array of PDs have been produced and relating these to what are probably turbated faunal remains is probably impossible. The site of An Corran is an unfortunate situation as the excavation team made a herculean effort to excavate the site with stratigraphic resolution whilst under serious time pressure, and the post-excavation analysis was conducted at the same stratigraphic resolution. Unfortunately, it is now clear that the site is extremely turbated (Saville and Hardy, 2012, tables 35-36, pp.74-75), this plus other issues mean that the site cannot be utilised by this project (SI-Chapter7-8). The site has produced PDs from context 36 that suggest a hiatus in occupation from just before 8.2k to the middle of the 8th millennium. The sites that can be progressed numbers just five, although one has no usable faunal data.

The first sites requiring consideration are Northton and Teampuill an Bagh. The initial phase of occupation at Northton early in the 9th millennium bp (table C6-1) lacks evidence for molluscs but attests the exploitation of aquatic birds and a mixture of mammalian taxa (figures C6-13, 14 and 15). A few centuries on and phase 4 now includes the exploitation of sea birds, ducks and geese as well as seal and otter, plus hares, and some fish, although molluscs are all but absent (two limpets and a mussel). Marine resources are being exploited but it seems likely that the site was not immediately on the contemporary shoreline. Occupation ends shortly before the 8.2k event. Occupation recommences sometime after 7.7k some tens of meters away at Teampuill an Bagh (table C6-2). The people are now exploiting seabirds and hares, although the exploitation of molluscs is barely attested (two limpets) in phase 2. This quickly changes in phase 3 as limpets and periwinkles are exploited along with small quantities of dog whelk and cockle (figures C6-16, 19 and 20). This suggests the site is now closer to its contemporary coastline as suggested by Sturt *et al* (2013)'s data.

The next site of interest is that of MacArthur Cave where the initial occupation took place on the gravel floor of a former sea cave. Occupation ceased and a further 0.15m to 0.46m of archaeologically sterile marine gravel was deposited prior to occupation commencing once again (Anderson, 1895). A single PD is available although its stratigraphic origin is unknown, and this is in the 8th millennium (SI-Chapter5-6). Unless an argument can be made for such a rise in sea-level during the 8th millennium or later, the sensible conclusion is that this location provides evidence for site abandonment due to rapid eustatic sea-level rise, probably during the late 9th millennium bp.

7.5.3.6.1 Sand Rock Shelter (Sand henceforth)

This site was subject to an extensive excavation. There are two phases of occupation in terms of PDs which are basically aligned with the occupations of Northton and Teampuill an Bagh and therefore potentially reflect pre and post 8.2K event occupation. The mollusc assemblage and bird assemblages are notable for their lack of biodiversity. Stratigraphy was generally discernible from the section drawings a major inhibitor to progress is where contexts 28 and 12 fit into the overall scheme. This was

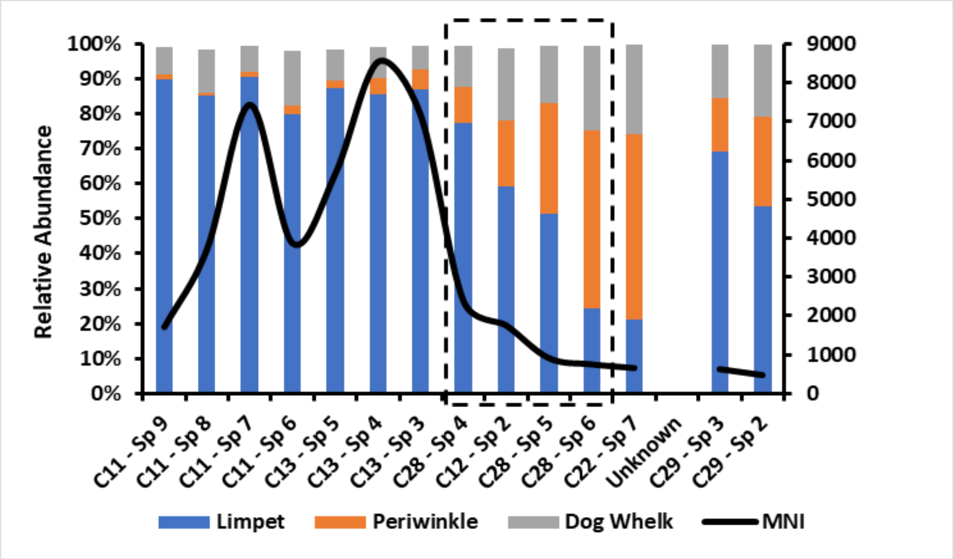


Figure C7-18: Relative composition of the main 9th millennium shell-midden (contexts 11 and 13 spits 9 to 3), showing a minor but progressively increasing role for periwinkle. The stratigraphic positions of contexts 12 and 28 are unclear and the depiction is tentative. Data from Milner (2009, downloadable archive). The rectangle bounds the region of stratigraphic and therefore temporal uncertainty and within which a hiatus may have occurred.

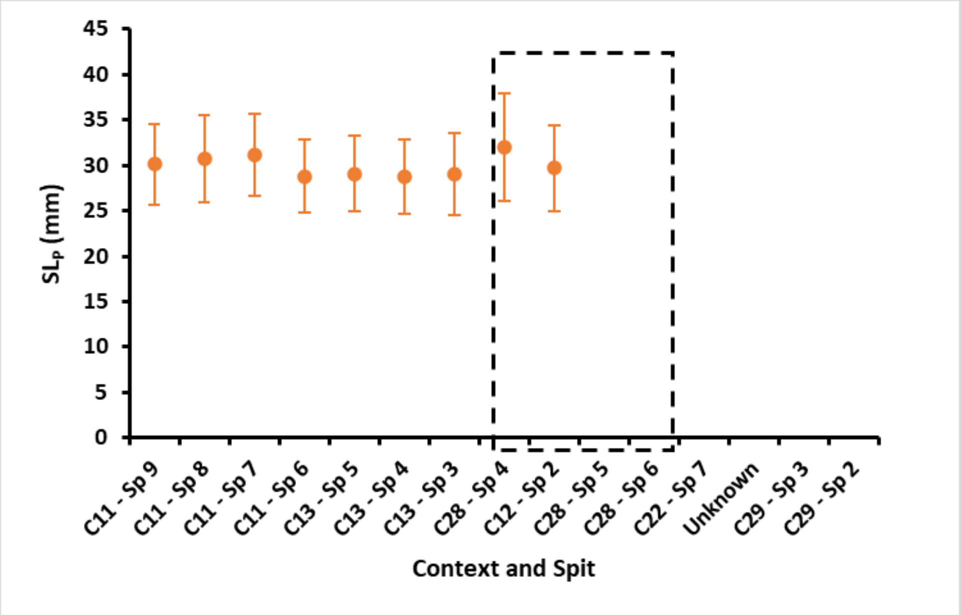


Figure C7-19: Limpet size within the main 9th millennium shell-midden (contexts 11 and 13 spits 9 to 3), showing a progressive increase in limpet length until spit 6 after which stability is observed. Regrettably no (beyond 2 or 3 specimens) measurable limpets exist in context 22 or 29. The stratigraphic positions of contexts 12 and 28 are unclear and the depiction is tentative. Data from Milner (2009, downloadable archive). The rectangle bounds the region of stratigraphic and therefore temporal uncertainty and within which a hiatus may have occurred.

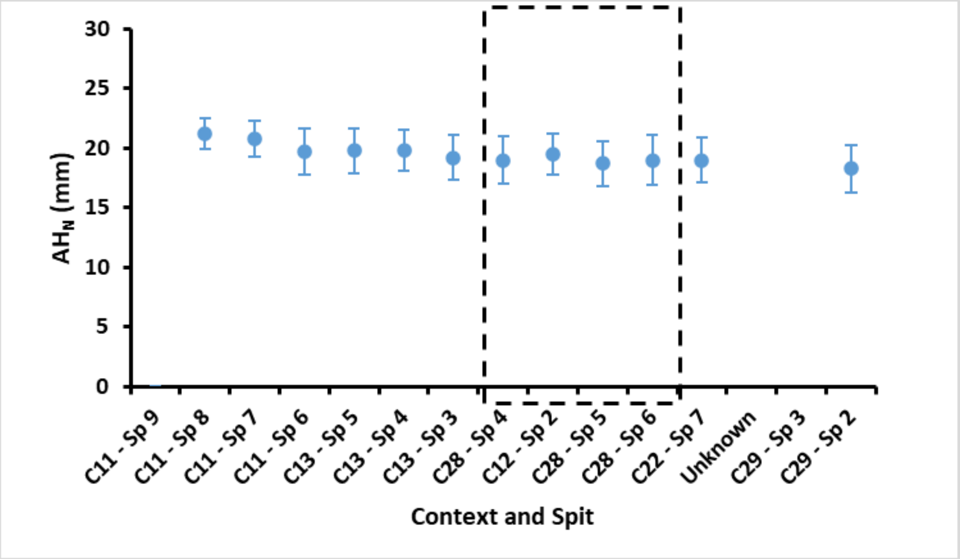


Figure C7-20: Dog whelk size within the main 9th millennium shell-midden (contexts 11 and 13 spits 9 to 3), showing a marked reduction in spit 6 and a further reduction in spit 3. Regrettably, no biometrics for dog whelks exist for context 11 spit 9. The stratigraphic positions of contexts 12 and 28 are unclear and the depiction is tentative. Data from Milner (2009, downloadable archive). The rectangle bounds the region of stratigraphic and therefore temporal uncertainty and within which a hiatus may have occurred.

evaluated extensively utilising the commentary of Hardy (2009) and the section drawings (SI-Chapter7-6), and eco-behavioural stratigraphy. The lack of PDs from these two contexts makes the task rather problematic, especially as to where in the sequence a hiatus in occupation, if any, occurred. The

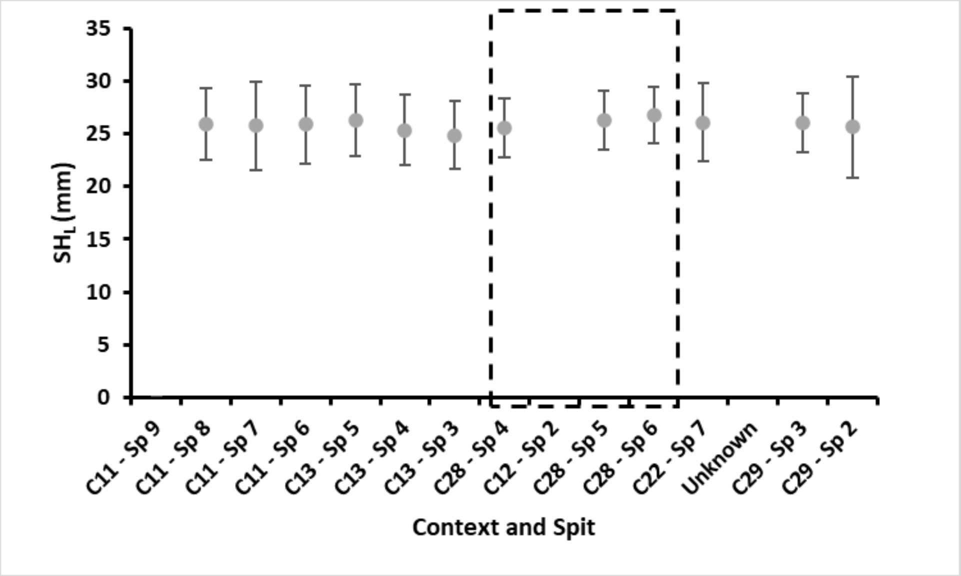


Figure C7-21: Periwinkle size within the main 9th millennium shell-midden (contexts 11 and 13 spits 9 to 3), showing relatively stable periwinkle size until spit 5 after which a decline is observed. Regrettably, no biometrics for periwinkles exist for context 12. The stratigraphic positions of contexts 12 and 28 are unclear and the depiction is tentative. Data from Milner (2009, downloadable archive). The rectangle bounds the region of stratigraphic and therefore temporal uncertainty and within which a hiatus may have occurred.

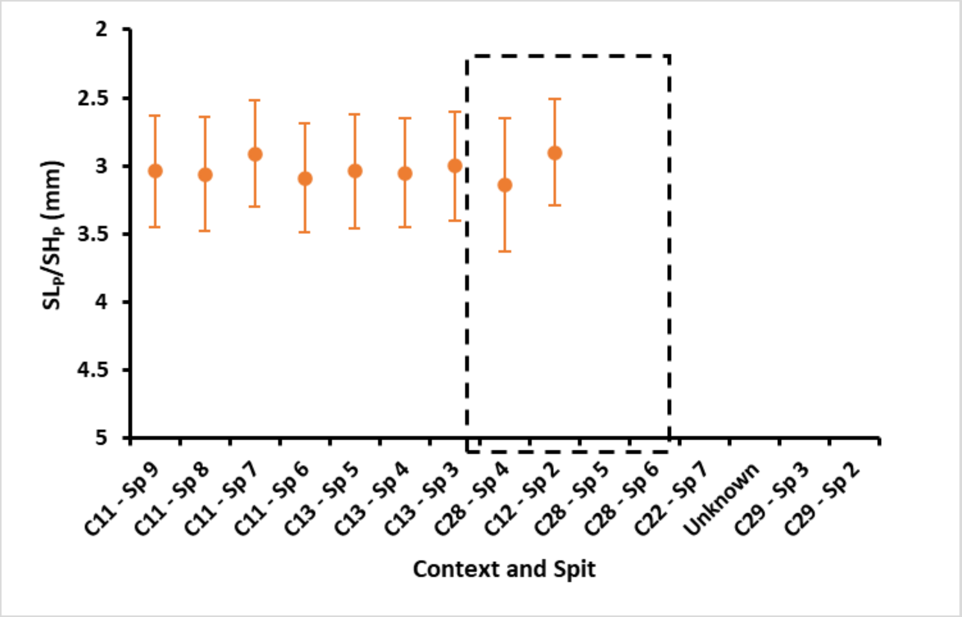


Figure C7-22: Limpet conicity within the main 9th millennium shell-midden (contexts 11 and 13 spits 9 to 3), showing a progressive increase in limpet conicity until spit 6 after which stability is observed. Regrettably no (beyond 2 or 3 specimens) measurable limpets exist in context 22 or 29. The stratigraphic positions of contexts 12 and 28 are unclear and the depiction is tentative. Data from Milner (2009, downloadable archive). The rectangle bounds the region of stratigraphic and therefore temporal uncertainty and within where a hiatus may have occurred.

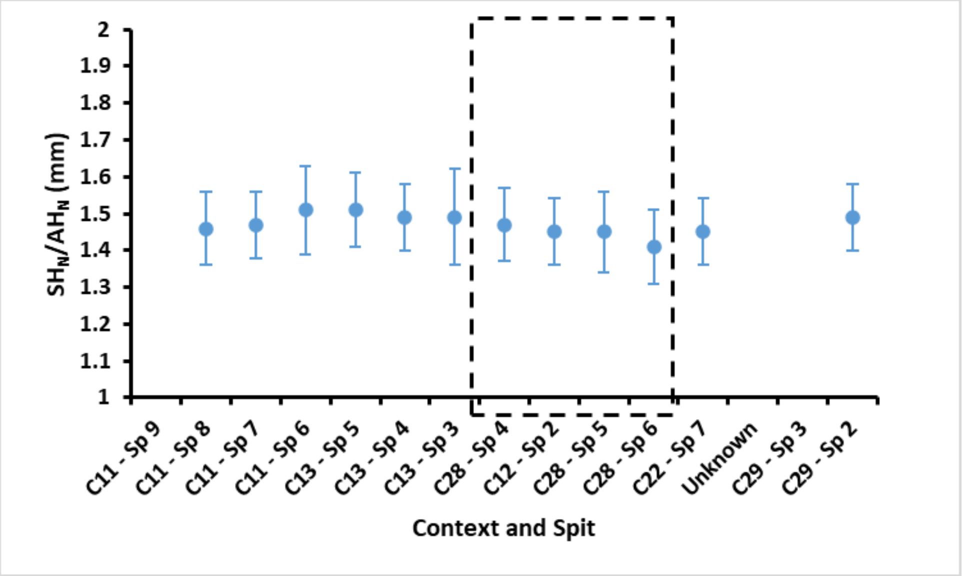


Figure C7-23: Dog whelk morphology within the main 9th millennium shell-midden (contexts 11 and 13 spits 9 to 3), showing a showing a general increase in elongation until spit 6. Regrettably no (beyond 2 or 3 specimens) of measurable dog whelks exist in context 11 spit 9. The stratigraphic positions of contexts 12 and 28 are unclear and the depiction is tentative. Data from Milner (2009, downloadable archive). The rectangle bounds the region of stratigraphic and therefore temporal uncertainty and within where a hiatus may have occurred.

stratigraphic positions of these contexts as presented are based upon context 28 toppling, and inverting its stratigraphy, over context 22 rather than sliding over it (figures C7-18 to C7-23). In some locations, context 13 (presumably also slumped) lies directly over context 22. Context 12 only overlies context 13 in some areas, otherwise it is absent. Two alternative models are available in SI-Chapter7-7.

The scenario presented (and the alternatives) support the key observations that can be made. The possibility that the maxima in MNI observed in spits 7 and 4 are the same phenomena must be considered, however, the biometrics do not support such an interpretation. The increasing limpet length until spit 7 and positive excursion in limpet conicity in spit 7 suggests that exploitation levels are within the ecosystem's capacity. The limpet conicity may indicate the shore was rested for a short period permitting a selective use of larger more conical limpets yielding more flesh as observed at West Voe. Periwinkle sizes are stable and the reduction in dog whelk size is not significant. Spit 6 records a disturbance to the eco-behavioural profile, and it is present not only in the composition and deposition intensity, but all the biometrics except periwinkle length. The reductions in dog whelk size and limpet size are not consistent with an almost 50% reduction in exploitation intensity. If excessive procurement is to be proposed it must be against a now less productive environment. The dog whelk morphology suggests shore energy is decreasing but becomes more variable in spit 6. Such a development may be due to more energetic weather but could also reflect a pulse of eustatic sea-level rise, especially given that Applecross is sheltered from the open Atlantic by the Isles of Skye and Raasay to the west and south west, and to a lesser degree the Western Isles to the north west. Yet reduced shore energy levels due to weather systems is consistent with viable travel to and from the Western Isles at an acceptable risk level, which the archaeological record supports. It is possible that mollusc growth and dog whelk breeding was constrained towards the end of this period due to temperature.

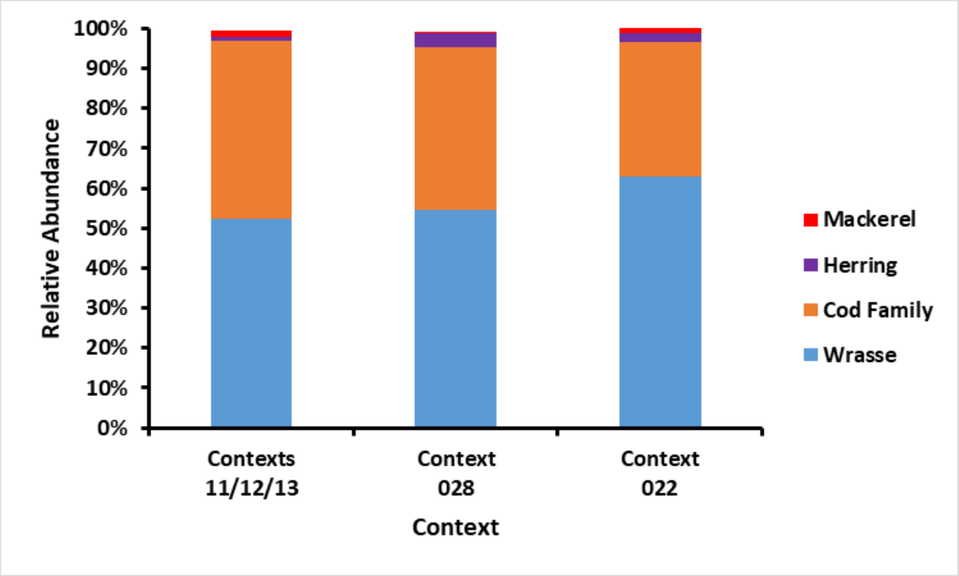


Figure C7-24: Composition of the fish assemblage identified to at least family level. Unfortunately, context 12 has been aggregated with 11 and 13. Data from Parks and Barratt (2009).

The next phase of occupation exhibits steadily increasing levels of exploitation and incremental increases in periwinkle exploitation and a corresponding incrementally reducing role for dog whelk. Limpet length is basically stable and conicity reduces slightly. The periwinkles are now getting smaller probably due to, at least in part, the increasing exploitation. Dog whelk morphology is suggesting shore energy levels are increasing and in spit 3 again become less stable, which may also be contributing to the reduction in the size of the periwinkles. Spit three also sees a reduction in dog whelk size, despite decreasing relative and absolute exploitation levels. During both the above phases red deer, wild boar, are the main species exploited, along with some roe deer. In terms of birds, it is limited to the extensive exploitation of the auk family. The fish assemblage is a fairly even mix of the wrasse and cod families (figure C7-24). The *Pollachius spp*. otoliths exhibit a bimodal distribution that includes the very small that are also present on the Cnip headland. The size estimates based upon the skeletal elements includes the tiny class (Parks and Barrett, 2009). This suggests either trapping or netting, in the case of latter the larger fish blocking the net so smaller specimens are also acquired. Wrasse are either solitary or in pairs and trapping and netting would not be effective, and line fishing, either hand or set, would be the method of choice. Dual approaches to fishing appear to have been deployed and the netting probably explains the composition of the bird assemblage. In the early phase some thermophilic taxa are present such as the Spanish horse mackerel (*Trachurus trachurus*) and even one specimen of sea bream (sparidae).

The period of stratigraphic uncertainty is now reached. No matter how the stratigraphy is sequenced (for example spit 3 of context 13 could be included in this period; scenario not shown) this period represents a very significant reduction in deposition of all taxonomic classes. Periwinkle abundance rapidly approaches parity with, and then exceeds that of dog whelk. The role of gastropods, excluding limpet, is greatly enhanced. This characteristic in relation to assemblage size has already been noted in Spain, and context 11 of TNB1 (chapter 6). There is a significant increase in the size of limpet (CL=0.0001) and periwinkle (CL=0.05). Morphologies are also significantly different for both limpet (CL=0.05) and dog whelk (CL=0.001). The energy level of shore is increasing, and a far greater area of the shore is being utilised to obtain the reduced levels of limpet. It is possible that travel between the mainland and the Western Isles may have been inhibited; this is consistent with the archaeological record. Periwinkles should be disadvantaged by increasing shore energy, but human demand is very supressed and the small populations occupying suitable niches were apparently sufficient. Another consideration is temperature, as periwinkle could successfully spawn every year, whereas dog whelk will be marginal most years. During this period, the evidence for the exploitation of mammals is sparse and consists of just a few fragments of red deer (Parks and Barrett, 2009). The fish assemblage shows a slight increase in wrasse relative to the cod family and the thermophilic taxa are now absent (ibid). The exploitation of birds is still focused on the auk family but vastly reduced. Very few otoliths exist for context 28 but they are large, and the ordinal size composition derived from skeletal elements lacks the tiny class (Parks and Barrett, 2009). This, the increase in wrasse and minimal bird assemblage, suggests a greater focus on line fishing. Whether this is because such an approach requires far less raw material, such as bark, which may be in short supply (chapter 3) in convenient locations, or increased risk for net fishing from canoes due to rough sea conditions is unresolved.

Temporal 'certainty' is re-established with context 22 in the 8th millennium, regrettably at the expense of eco-behavioural resolution as morphology and size data for limpets is unavailable during the later phases of context 28 or context 22. Certain characteristics such as low levels of deposition, with an ever increasing focus on non-limpet gastropods; slowly increasing exploitation of wrasse; focus on red deer (only one wild boar bone and no roe deer); lack of thermophilic fish; as well as low levels of bird exploitation entirely focused on auks, are sustained in context 22. The major differences are a decrease in periwinkle size and reduced shore energy level. The latter point may have made travel to and from the Western Isles, or locations such as An Corran and Loch A Sguirr, possible at an acceptable risk level, which the archaeological record supports. The presence of the tiny class of fish also suggests that possibly net fishing has recommenced.

Was there a hiatus at Sand? This is an interesting question for an archaeologist as it seeks to assess a lack of archaeology, a task not without its theoretical challenges. If the premise that SST is very depressed during the 8.2k event is accepted, then biomass production by poikilothermic organisms will also be supressed. The most likely signature of a period of abandonment is a significant increase in the size of such organisms due to a lack of predation over time. If abandonment of Sand occurred, it did so most likely between context 13 spit 3 and contexts 28/12. This argument works equally well whether the view presented, or one of alternatives in the SI-Chapter7-7 of context 28's, stratigraphy is utilised.

7.5.3.6.2 Ulva Cave

The next site to be considered is Ulva Cave which is further south off the coast of the Isle of Mull and therefore relatively close to the Oban cave sites. The focus of the published analysis is a column sample excavated in four layers with L4 being the oldest. Layer 4 has PDs in the 9th millennium and the upper most layer L1 early in the 7th millennium. There are no PDs available for the intervening layers. The taxonomic composition of the molluscan assemblage is presented in figure C7-25 and it appears as if L1 belongs to a very different eco-behavioural regime to that L4 to L2. A notable difference to sand is that periwinkles are substantially more abundant than dog whelks in all layers. The site is, despite its

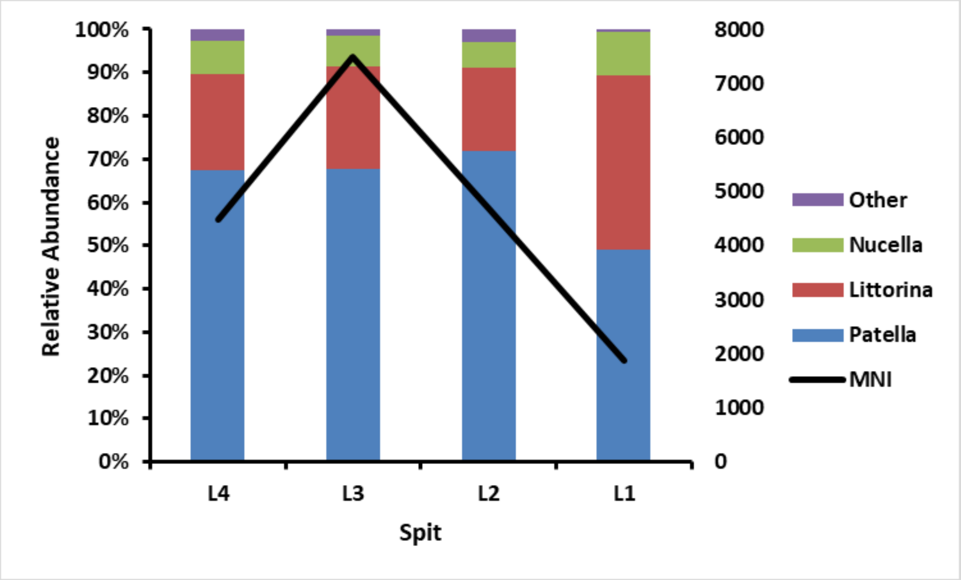


Figure C7-25: Taxonomic composition of Ulva Cave. It should be noted that different NRE were utilised for dog whelk and periwinkle, the former based upon the more robust siphonal canal as discussed in chapter 4. It should also be noted that the MNI figure for limpet in L1 is modelled from weight data and does not represent a physical count, as it does for other taxa in that level and all taxa in the other levels. It is possible that the reduction in limpet abundance is overstated (cf. Thomas and Mannino (2017). Data and notes from Russell *et al*, (1995).

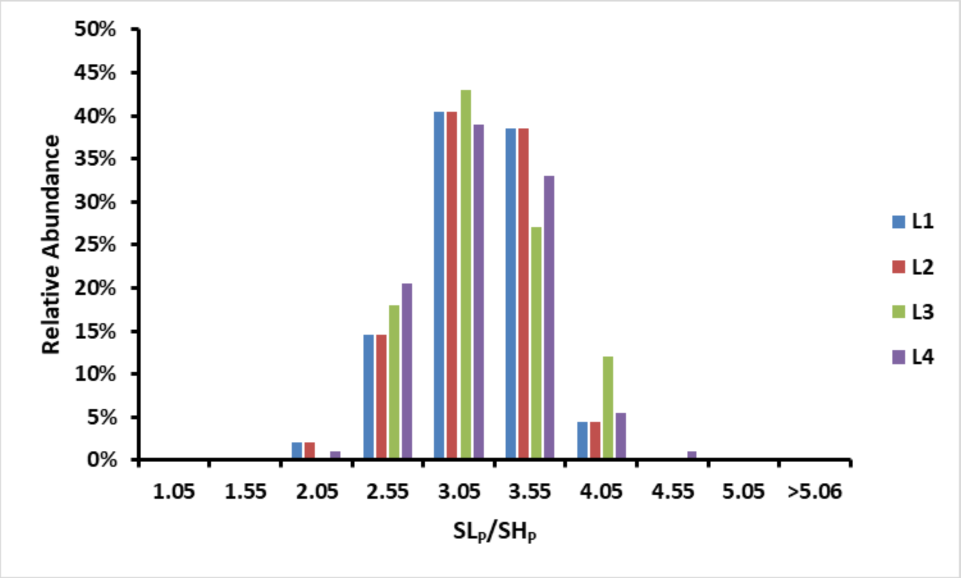


Figure C7-26: Limpet conicity at Ulva Cave. There are no significant differences between adjacent layers or between layers 1 and 4. Kolmogorov-Smirnov test. Data from Russell *et al*, (1995).

generally more exposed situation compared to Sand, sheltered by a peninsula in a similar manner to West Voe.

The biometric data for limpets, periwinkles and dog whelks is presented in figures C7-26, 27, 28 and 29, respectively. The values for dog whelk size are not directly compatible with those from Sand as only SH_N and not AH_N have been published. The data in figure C7-29 therefore potentially represents a combination of changes in organism size and morphology.

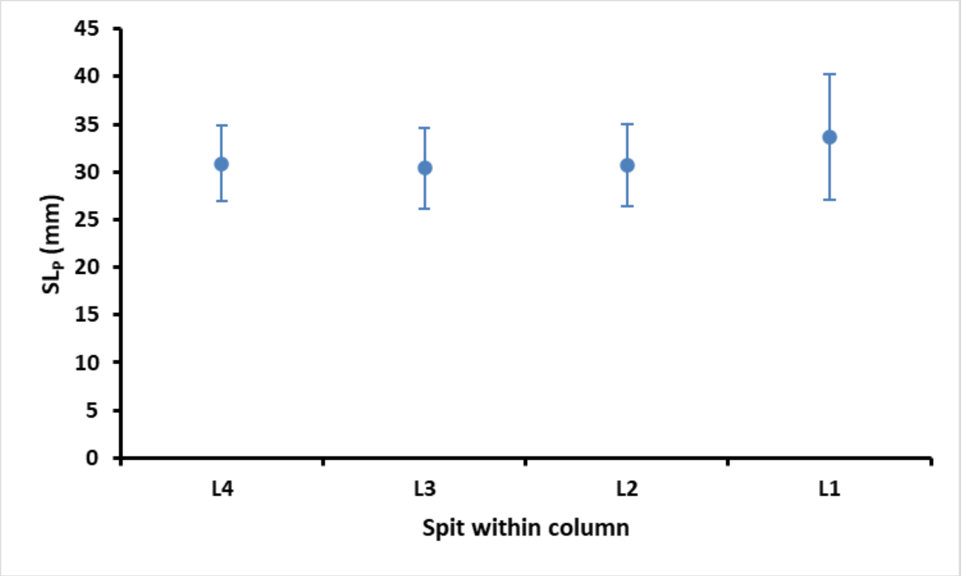


Figure C7-27: SL_P data for Ulva Cave. In general, the limpets are of a reasonable size. The only significant difference is between L2 and L1 and L4 and L1 (CL=0.05). Only summary statistics are available for Ulva Cave and statistical testing was conducted using these rather than actual measurements (SI-Chapter7-3).

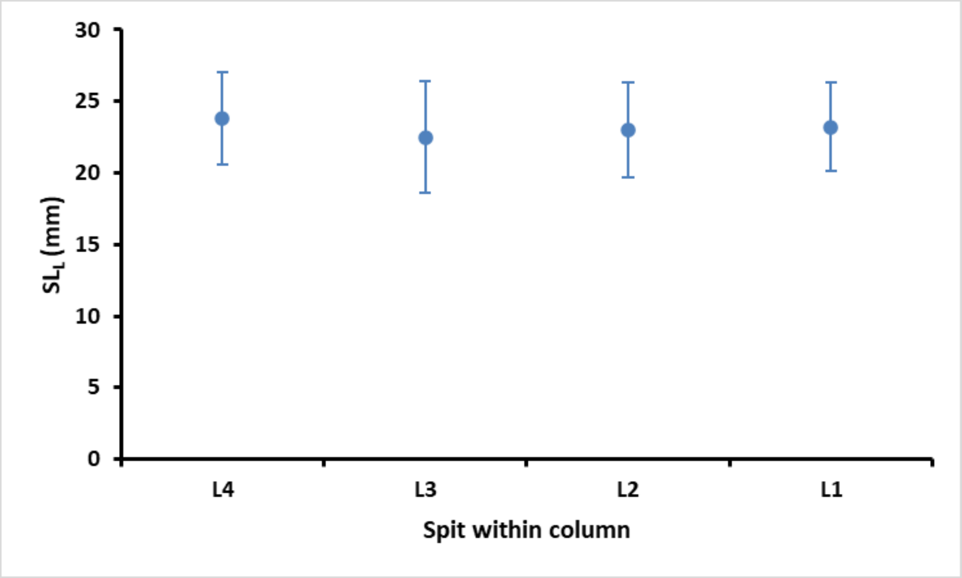


Figure C7-28: Periwinkle size at Ulva Cave. There is a temporary reduction in periwinkle size in L3 and this reduction and the subsequent recovery in L2 are significant (CL=0.05). Only summary statistics are available for Ulva Cave and statistical testing was conducted using these rather than actual measurements (SI-Chapter7-3).

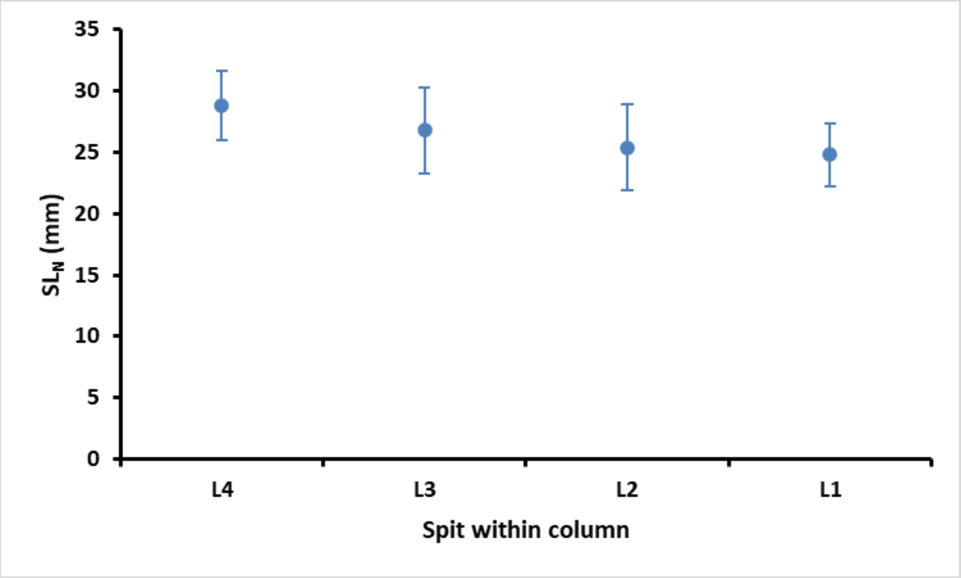


Figure C7-29: Dog Whelk size at Ulva Cave. The only instance of when there is no significant reduction in dog whelk size is between L2 and L1. The differences are significant between L4 and L3, L3 and L2, and L1 and L4 (CL=0.05). Only summary statistics are available for Ulva Cave and statistical testing was conducted using these rather than actual measurements (SI-Chapter7-3).

Periwinkle sizes reduce significantly in L3 prior to recovering. The trends in dog whelk size are clear and significant. The difficulty is that it is unclear whether the dog whelks are actually getting smaller or just squatter. Overall it appears that based upon the biometrics L3 should be grouped with L4 and they reflect occupation during the 9th millennium where limpet size and conicity are stable, whilst both periwinkles and dog whelks are reducing in size probably due to a combination of reducing temperature and increasing wave exposure levels. It seems likely that L3 reflects a scenario late in the 9th millennium.

Russel *et al* (1995) report that a small and decreasing number of the thermophilic thick top shell are present in levels 4 through 2 but are absent in L1, presumably extirpated. The presence of this species at this latitude reflects a northerly extension to its range compared to today. Pickard and Bonsall (2009) report the presence of the European spider crab (*Maja squinado*) in the lower levels of the midden. This is also a thermophilic species, and in recent decades has been expanding its range northwards into Scotland. Its presence at Ulva Cave suggests warmer conditions than in the recent past which is consistent with the presence of the thick top shell. Based upon the taxonomic composition and biometrics it seems very likely that L2 is the final period of an initial period of occupation during the 9th millennium. L2 is possibly contemporary with context 13 spit 3 at Sand. Pickard and Bonsall (2009) interpret the site as reflecting the development of a sheltered shoreline due to sea-level rise. The interpretation of L1 is that it represents later human activity after a protracted hiatus in occupation.

Ulva is a cave site and Sand is an open site next to an overhang. The spit depths are different, and no doubt deposition rates were also. The environmental setting is also very different, not least in terms of latitude. The temptation to wiggle match fluctuations in the biometrics between the two sites has therefore been resisted. What can be stated is that certain biometric fluctuations and trends are consistent with the record at Sand.

7.5.3.7 Norway

The Norwegian sites of Sævarhelleren and Olsteinhelleren are two cave sites in very close proximity (< 50m) to each other deep within Hardanger fjord. Both sites have generated several PDs (SI-chapter 5-7). Olsteinhelleren is the later site and all dates fall in the 8th millennium and provide a terminus post quem of 7.6K. Of the seven PDs available from Sævarhelleren five predate the 8.2k event, the sixth, if actively critiqued (SI-Chapter7-2) also supports occupation prior to the event. The final PD

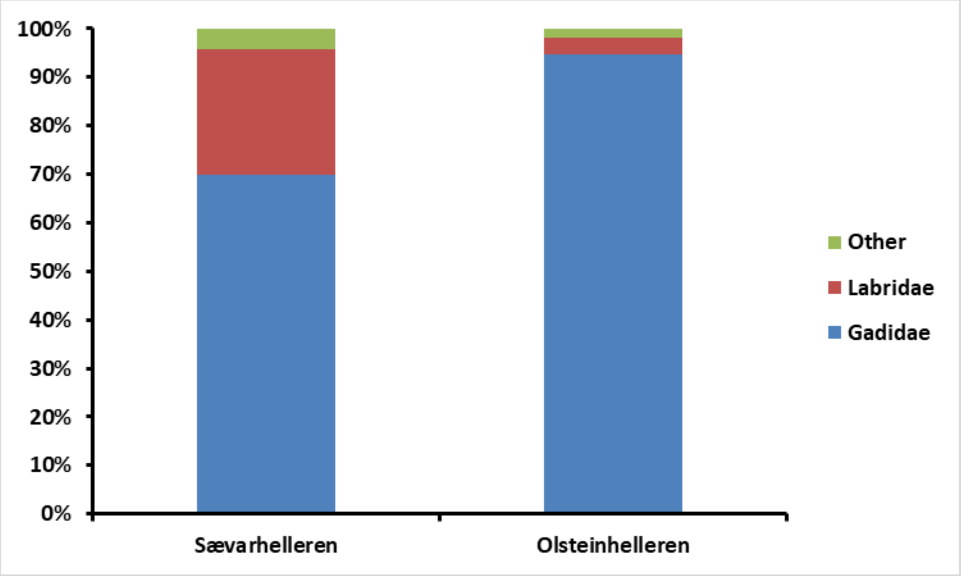


Figure C7-30: Inter-site comparison of the fish assemblages as relative abundance. Data from Richie *et al* (2016, table 1, p.311).

suggests occupation following the event but significantly earlier than the occupation at Olsteinhelleren. These sites exhibit some significant differences in the fauna exploited. There is a change in focus from exploiting wild boar and elk to one on red deer and otter (Bergsvik and Hufthammer, 2009, table 22.2, p.442). These sites were considered along with others by Rosvold *et al* (2013)'s consideration of elk and red deer and the observed switch is consistent with the larger scale patterns they identified. Wild boar in Norway appear to have occupied coastal forests (Rosvold *et al*, 2010) and combined with the reduction in elk a decline in the availability of this habitat is suggested. The fish assemblage also exhibits changes as the role of wrasse is greatly reduced in favour of the cod family at Olsteinhelleren (figure C7-30) and the abundance of warmer water summer visitors such as skate and mackerel also diminish (Richie *et al*, 2016, table 1, p.311). There is a period where the relative abundance of the cod family temporarily reduces at Sævarhelleren (ibid, figure 3, p.312) but it is unclear how the stratigraphic units map to the PDs based upon the unit references provided by Bergsvik and Hufthammer (2009). Another feature is that the composition of the gadidae remains also changes between the sites. Sævarhelleren is dominated by cod whereas Olsteinhelleren is dominated by saithe (figure C7-31). The changes in mammalian fauna suggests a change in the terrestrial environments exploited or available within hunting range of the site. The changes in the fish assemblages are probably more related to changes in technology and fishing methods as suggested by Richie *et al* (2016), but the question of why methods and technology may have changed remains open. It is possible that the tsunami devastated invertebrate populations and therefore a reduction in wrasse and the benthic Atlantic cod is observed. It is not possible to assess the mollusc assemblage as the vernacular and binomial names of the most abundant species are misaligned in Bergsvik and Hufthammer, (2009, p.441) and which should take precedence is unclear. The assemblage is either dominated by periwinkle with some mussel or vice versa, the two species are noted for their tolerance of freezing (Aarset, 1982). These sites suggest a period of occupation with a hiatus followed by a small scale ephemeral visit and then occupation re-established in

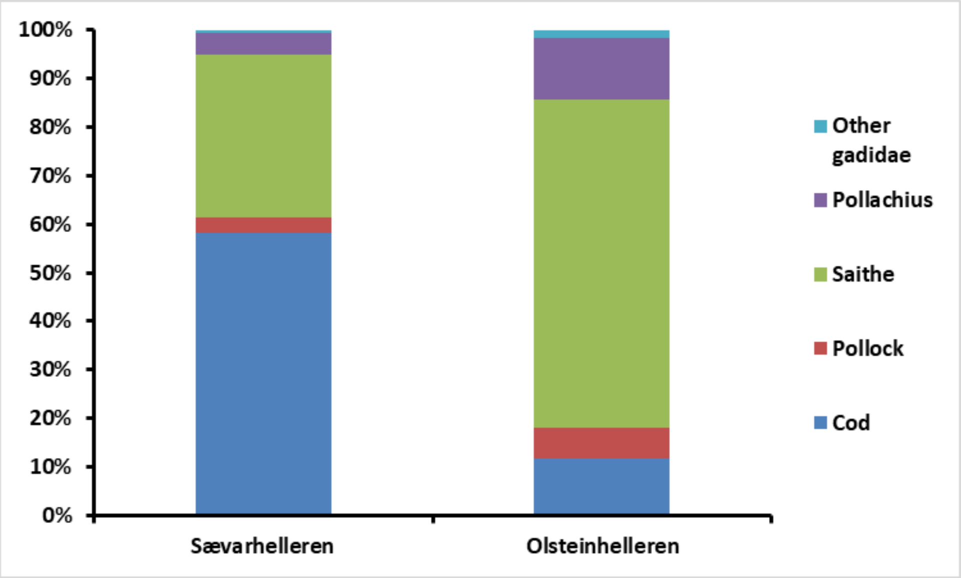


Figure C7-31: Inter-site comparison of the cod family assemblages as relative abundance of specimens identified to at least genus. Data from Richie *et al* (2016, table 1, p.311). The author could not generate the same abundances from the cited table and presented by Richie *et al* (2016, figures 5, 6, pp.313-314).

the other cave. One common feature to both sites in terms of eco-behaviour, is the absence of the small saithe (Richie *et al*, 2016, figures 8 and 9, p.314) observed at Sand, the Oronsay Middens and the Cnip Headland. Either small fish were selected out by the acquisition method or they were discarded elsewhere at the point of capture.

Only two other coastal sites fall into this time period. The first is Vistehulen where layer I has evidence for occupation until the second half of the 9th millennium, a hiatus appears to follow, and reoccupation occurs from the middle of the 8th millennium when the exploitation of molluscs is evidenced (Indrelid, 1978; Bjerck, 2007). The mammalian assemblages do not indicate any real change either side of the hiatus. The other site is Kotadalen where the primary interest is phases H, D, C and B (Warren, 1993). Significant volumes of deposit were analysed and the assemblages in some instances are quite large, but identification was hindered by preservation levels (ibid, tables 12, 13, 14, pp.184-188). The sizes of the assemblages are generally a function of excavated and analysed volume and the yield of mammal bones per litre, for example, is not unusual. Layers C and B contain very little faunal material and little if anything can be stated. Layer H's PDs reflect pre 8.2K event occupation and layer D's after it (ibid; SI-Chapter 5-7), but it also seems likely that occupation persisted and abandonment, if any, was very short term. Seals dominate both layers whilst in layer H otter are more abundant than wild boar, level D sees parity between these two species (ibid). As the abundance of otter diminishes the abundance of other fur bearing carnivores increases and diversifies (ibid). This could be an act of compensation due to a lack of otters or is evidence for carnivores being in residence during a hiatus in human occupation. Whilst any mammal can be consumed, the assemblage at Kotedalen suggests the people had a requirement for fur.

Whilst cod are never dominant, their abundance reduced over time as observed elsewhere (ibid). What is slightly surprising is that whilst saithe initially dominate the assemblage the generally more southerly distributed pollack achieves parity in layer D. It seems likely that, as stated by Richie *et al* (2016) for Sævarhelleren and Olsteinhelleren, a change in fishing methods is a possible cause, of course the question of why is equally applicable here. The bird assemblage is small, and the main trend is a reduction of pursuit diving species (ibid), which may be a collateral outcome of the fishing effort, and hence reflect a change in methods or approach.

7.5.3.8 The Tsunami.

The general effects and implications of a tsunami for human groups have been fleshed out in chapter 3, although not aggregated with the other vectors. At this stage it is possible to consider certain aspects in more detail and address the lack of previous aggregation. This consideration is primarily based upon invertebrates, especially molluscs and crabs. The more direct evidence for the effect on human groups would be mass cemeteries of the 'correct date' like those that have been associated with tsunamis in the prehistory of Polynesia (Cain *et al*, 2019). These have not been identified in Western Europe in relation to the tsunami. The other obvious signature is an absence of people due to mass mortality in coastal regions. Such an absence does not need to be total, but a significant reduction has implications for social aspects as outlined in chapter 3. If populations need to spatially contract to maintain adequate trade, especially if the mode is one of goods diffusion through encounter, then the availability of ‘real-estate’ will exceed demand in some areas. Certain regions or areas may therefore be abandoned, or the frequency of visits becomes so low that the debate becomes one of semantics.

A less direct consideration is the destruction of key elements of the ecosystem. If the intertidal, infralittoral and shallow sub-littoral mollusc communities experience mass mortalities along with the crabs occupying these zones there are implications. Recovery will be factored by recolonisation from populations in less affected areas. Based upon the profile in SI-Chapter7-9 the following can be stated. Periwinkles can recolonise effectively from some distance and they can breed effectively at low temperatures. Dog whelk recolonisation will be very protracted and breeding marginal many years, but local survival due to populations living at depth is likely. Limpets exist entirely in the ‘high risk’ intertidal and infralittoral zones and surviving local populations may be absent unlike periwinkles and dog whelks. Limpets can recolonise although not as quickly as periwinkle for a given distance. Oyster can recolonise from populations that have sufficient population density, but spawning will be limited or even non-existent until critical population density is achieved. A significant reduction in latitude is required to find viable oyster breeding temperatures. Recolonisation north through planktonic larval dispersal will be slower in a scenario where north easterly drift is inhibited due to the suppression of AMOC. Mollusc populations will be restructured for a period following widespread mortality, a criterion also put forward by Goff *et al*, 2012. The best candidates for such a restructuring are context 12 or context 28 spit 6 at Sand. The latter requires the similarity between its composition and context 22 to be a consequence of different phenomena.

Crabs will have suffered mortality and although immediate survivors will be presented with a veritable feast of recently deceased molluscs and fish, the situation will become limiting over time. Crabs however have a planktonic larval stage, and the adults migrate (often one way only) over considerable distances so recolonisation should be rapid into environments with established mollusc and other invertebrate communities. As with the tsunami itself the recovery prognosis is based upon local bathymetry as this dictates the degree to which some species can be replenished from off-shore beds in the littoral zone. The reduced crab and mollusc populations will have implications for benthic feeders such as Atlantic cod, dog fish, and mollusc specialists such as wrasse and eider duck, to name but a few. If the tsunami has occurred during a cold spell, then the rate of biomass production will be supressed exacerbating the situation. A longer duration to achieve sexual maturity also compounds the problem.

The data reviewed for Scotland and Norway does not totally fit with the scenario described above. For example, at Sand wrasse become more abundant albeit it at very low exploitation levels. The increasing exploitation of periwinkle, despite increasing shore energy levels, is consistent with the scenario, as is the reduction in cod, but again low levels of exploitation blur the picture. The reduction in cod is also observed in Norway again lending support to the scenario. Overall however, the hiatuses in occupation at all the sites considered, which may be in the form of relatively infrequent visits by a smaller group at Sand, are probably the firmest (but by no means concrete) proxy for the tsunami. The dramatic reduction in limpet abundance between spits 5 and 6 of context 28 to well below that observed in context 11 of TNB1 or at Northton or Teampuill an Bagh may reflect the passing of the tsunami as the two most abundant species are those that inhabit depths beyond the intertidal zone. In this scenario occupation is evidenced either at the time of tsunami or soon afterwards, as even during a period of supressed temperature the limpet population structure should have recovered within five to ten years. If a hiatus in occupation due to the tsunami is assumed at a site it does not necessarily follow that the human mortality occurred at the site or that the site was directly impacted. If the people were elsewhere because of their seasonal movements or even due to attending a multigroup communal event such as a ceremony or whale stranding, as occurred in Tierra del Fuego, that is where mortality may have occurred. Such seasonal and socially motivated mobility could either spare a population from the attentions of a tsunami or increase the risk and impact as discussed by Blankholm (2018). Wherever the mortality occurred the consequence is the same, a surplus of 'real-estate' as appears to be the case in north-west Atlantic Europe.

7.6 The 9th and 8th Millenniums.

In Portugal it appears that the period offered additional opportunities in the form of estuarine environment that the people chose to exploit. In Spain, the period can probably be summed up as presenting some level of irritating inconvenience from time to time, this can probably be stated for southern England also. The situation in France is less clear and probably the 8th millennium saw the withdrawal of certain marine mammals and temperate fish species, with some adjustments required to human behaviour as a result. The people of Scotland and Norway appear to have had a less benign experience, with constant fluctuation in the ecosystem during this period. In the case of Norway and Scotland fishing methods appear to change, and at Sand there is a switch from dog whelk to periwinkle. Remaining unknowns are the deltas that may have been experienced in terms of berry and nut yields and availability and shifts in the timing of seasons for collection.

The manifestation of the 8.2k event's eustatic sea-level rise and the tsunami is localised, but one aspect arises in more than one sub-region, although local variability means never at all sites. This aspect is a loss of woodland on low lying coastal plains with a concomitant reduction in terrestrial mammals that prefer such a biotope. This hypothesis is supported by the palynology data presented by Bishop *et al*, 2018; Edwards (1996, 2004, 2009) and Andrews *et al*, (1987) for the remote Scottish islands, and the summarised data presented by Wicks and Mithen (2014). One implication is that raw materials must be sourced further inland and in Scotland and Norway, and probably the Asturias of Spain, this inevitably means increased elevation. Increasing elevation during a period of supressed temperatures, whether on a foraging trip, and especially for residency, is a counter intuitive initiative. Such an initiative could be considered, at least in terms of residency, an exacerbation rather than a mitigation strategy; unless of course it spares the group from the tsunami, albeit unintentionally. A final consideration at Sand is that the change in deposition may be a result of changes in group organisation. Whether the site changed from a seasonal group camp to a task force location is unclear. There is no suggestion that the larger fish were being removed at Sand as is probably the case on the Cnip headland (chapter 6). The mammal assemblage of context 28 is too small to be interpreted, whilst that of context 22 does lack the femurs from large ungulates that are present in contexts 11 and 13 (Parks and Barrett, 2009, table 143), which may suggest that the major meat baring bones were removed. The birds are uninformative as the protocol employed at Sand only quantifies limb bones and the coracoid.

The approach adopted has considered what usable faunal evidence there is on an integrated multi-proxy basis and in doing so has identified eco-behavioural change during the period in Portugal, Spain, Scotland, and Atlantic Norway. A supporting role is played by Culver Island as it provides evidence for ameliorating temperatures during the 8th millennium. The approach has sought to relate the actual archaeology to the environmental vectors that were likely to be operating during the period. The view here is that the result is an improvement on the standalone analysis of individual species and in particular taxonomic classes, prevalent within the literature. Milner (2009a, p.390; p.397) questions the utility of the biometrics in terms of equifinality in outcomes. The author is forced to concur, if the analysis seeks to make interpretations on a single taxonomic group within a taxonomic class. The situation is different if multiple proxies are considered both on an intra and inter class basis. Certainly, eco-behavioural observations, by definition, often do not resolve the contributions of behaviour and environment, and the charge of equifinality can be made (in places) against the above account. Yet, eco-behavioural change identifies where further investigation is warranted. When that investigation is based upon a multiproxy approach on an intra and inter class basis, the confidence with which investment in further analytical techniques can be advocated is increased. The author believes a journey to obtaining greater insight into what was going on and what this meant for people has, in some small way, begun. A future extension of the work in this chapter to embrace other techniques deployed in chapters 6 and 8, is an enticing prospect. Chapters 6 and 8 demonstrate the approach of targeting more expensive analyses based upon an eco-behavioural review.

8 Change in the 5th Millennium cal BC.

8.1 Introduction.

The 5th millennium cal BC, especially the latter half, is an important period in north-western Europe as it constitutes the run up to the expansion of the Neolithic into more northerly latitudes after a hiatus in expansion of over 1000 years (Rowley-Conwy, 1984; 2011). The 5th millennium is also interesting as it commences with the presence of cod and auks in the assemblages of northern Spain at Herriko Barra and Pico Ramos, which constitutes a southerly extension of their range compared to today, as does the presence of grey seal at Beg-er-vil in Brittany (chapter 5). The end of the period is also of interest, for whilst small shell-middens had started to accumulate in Denmark from the middle of the 6th millennium (Andersen, 1995, pp.49-51), the accumulation of the huge *Kokkenmoddinger* commences in the 2nd half of the 5th millennium (ibid), and from late in the millennium large oyster middens start to appear in eastern Scotland (Sloan, 1993; Myers and Gourlay, 1991; Ashmore and Hall, 1997) and also within sea loughs of Ireland (Milner and Woodman, 2007). The fragility of oyster to a combination of environmental conditions and procurement pressure has been discussed in chapter 7 and the emergence of intensive and long term exploitation of this resource suggests two things. Firstly, harvesting must have been carried out in a manner that maintained localised population density at the level required to support effective broadcasting of male gametes and internal fertilisation within the females. The second factor is that summer temperatures must have been at a level that supported regular and efficient spawning. Given this latter point it is no surprise that these large middens generally form within the North Sea basin, Irish Sea, or elongated sea lochs or sea loughs. It is against this background that the middens of the Atlantic façade can be considered further.

A key question is why the sudden and comprehensive expansion of the Neolithic occurred when it did. A possible root cause is environmental change disrupting the way of life for the incumbent hunter-gatherers, or assisting the farmers in their expansion, although this is by no means accepted universally (cf. Shennan *et al*, 2013). In chapter 6 the biostratigraphy presented suggested a period of environmental change or fluctuation occurred between *circa*, 4.4K cal BC and 4.1K cal BC in the Western Isles. This chapter seeks to explore the above aspects in more detail and examine whether these are evident within the wider region or reflect a localised phenomenon. The focus is upon the Atlantic façade of Scotland and Ireland. This restricted spatial treatment is to avoid the issue of the Neolithic arriving earlier in other sub-regions such as France, Spain and Portugal and the lack of clarity on which culture some of the marine resource assemblages should be associated with (chapter 7). Whilst focused on Scotland and Ireland other sub-regions will be consulted on an ad hoc basis when appropriate. Pending the publication of Fanore More, the availability of suitable assemblages is limited to the Western Isles, Shetland, and Oronsay in Scotland, plus Ferriter's Cove in southern Island. The latter however can only contribute to the compositional data, for whilst SH_N, AH_N, SH_L and AH_L were recorded (McCarthy *et al*, 1999, p.92), neither the data nor ratios of SH_N to AH_N are presented, the same observation being applicable to periwinkle. Length and height of limpets are only presented as summary statistics for three features and two of the three have a sample size less than five, the third has a sample size of 42.

The objective of this chapter is to establish the following:

Can the case for environmental change on the Cnip headland be strengthened using the remains of dog whelk and razor clam?

Is the temporary reduction in the size of saithe in the Western Isles due to changes in seasonality of human occupation?

Are the changes in biostratigraphy and saithe growth observed in the Western Isles replicated elsewhere in the sub-region?

Is there any evidence for regional environmental vectors within the eco-behavioural profiles during this important period?

8.2 Methodology.

The analysis of published data for Oronsay and Ferriter's Cove utilises absolute and relative abundance as described in chapter 6. The key challenge of associating PDs with faunal remains at each of these sites will be discussed as the results are presented.

8.2.1 Dog Whelk Morphology.

The assessment of dog whelk morphology as a proxy for shore energy level was not presented in chapter 6 due to the lack of complete dog whelks, which is constraining at a site level, and even more so at context level. An alternative approach was sought and developed. Palmer (2010) provides a number of models linking various aspects of dog whelk morphology to SH_N. The models are presented for two communities in Wales, one from an exposed shore and another from a sheltered shore (ibid). The equations were manipulated and combined algebraically such that SH_N was eliminated and a model reflecting biometrics that could be captured from the archaeological specimens was available. These were evaluated for usefulness.

8.2.2 Razor Clam Seasonality.

The method for determining the species composition of razor clam, and therefore shoreline conditions, was evaluated. Whilst the additional modern specimens assisted with creating more robust models for SL_E, the modern collection was insufficiently large, especially for *Ensis siliqua*, to support speciation based upon biometrics. H_0 could not be rejected between *E. magnus* and *E. siliqua* and this meant there was no sound basis for interpreting the obtained rejection of H_0 between some stratigraphic units and also the rejection of H_0 between certain stratigraphic units and either the modern *E. magnus* or *E. siliqua* populations. Whilst encouraging, the author must follow the lead of Mellars and

Wilkinson (1980) and state that the modern dataset is insufficient to support the presentation of any results here.

8.2.3 Saithe Seasonality and Relative SST.

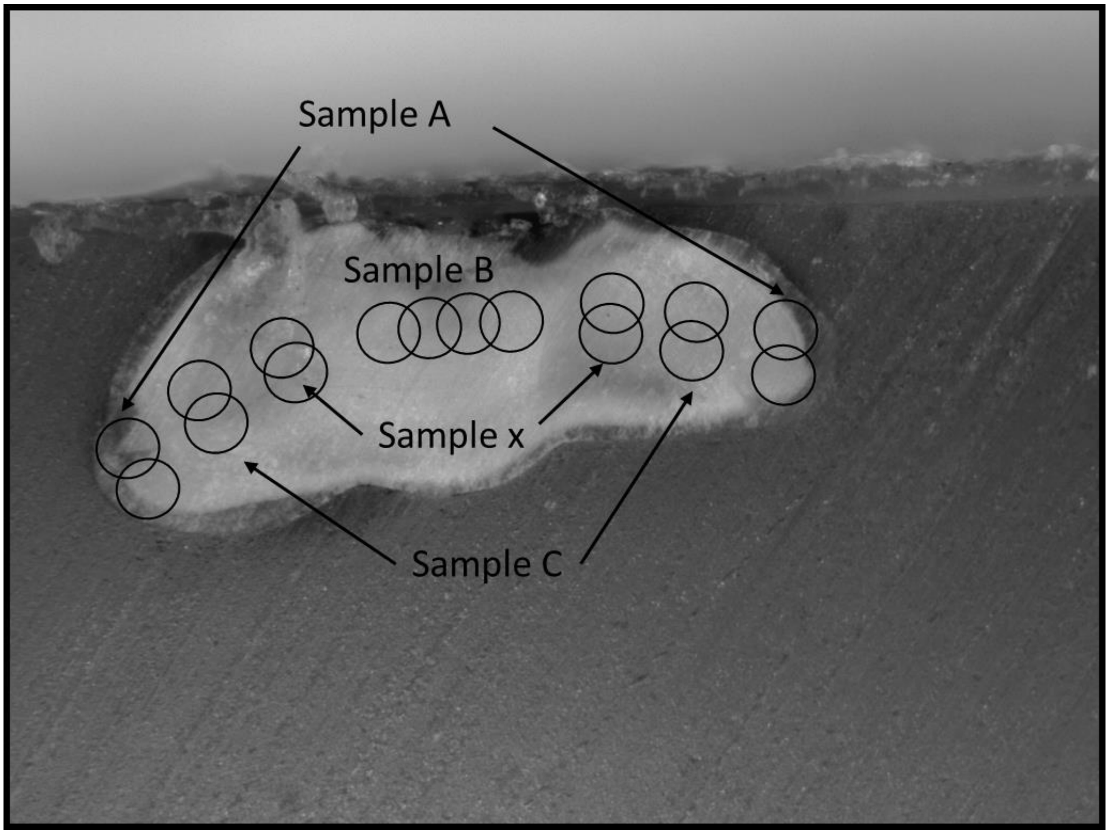
The author has reservations regarding the use of otolith size as a proxy for season of capture as stated in chapter 4. The primary concern is the portability of such a model both spatially and temporally. The approach adopted was to use oxygen isotope ratios to determine the season of death. As stated in chapter 4 and elucidated in SI-Chapter7-9 the interpretation of thin translucent bands in the otoliths of gadidae is problematic if the prevailing environmental conditions are unknown.

The background to and principles of using oxygen isotopes from biogenic carbonates have been presented in chapter 4. Many of the implementations utilise very large specimens of otolith as this permits many incremental samples to be taken, this does generally cause the results from very few otoliths to be presented due to a lack of suitably large and well preserved specimens (cf. West *et al*, 2012; Hufthammer *et al*, 2010; Dias *et al*, 2019). With very large specimens the cost associated with each incremental sample soon brings budgetary pressures to the fore, which is almost certainly another factor that results in the low numbers of otoliths generally presented. An obvious concern given the objectives of this project is the characterising a single stratigraphic unit, or even an entire site from a few or even a single specimen, will not record either environmental changes or flexibility in hunter-gatherer behaviour.

The challenge with the assemblages from the Western Isles is that very few large fish are present, and by the standards within the published literature, this can be revised to none. An alternative approach was designed to serve as a proof of concept for the use of small and very small otoliths, that when aggregated will provide a result in terms of season of death. This approach permits more otoliths to be analysed and therefore more coverage, per unit of available budget, per stratigraphic unit. The use of very small otoliths required the incremental samples to be positioned across the width of the otolith rather than its length. This is because a suitable drilling depth cannot be achieved as the milling location approaches the anterior and posterior ends, especially of small otoliths. There is also less asymmetry in deposition rates of the aragonite per unit time between dorsal and ventral margins compared to that between the anterior and posterior. Drilling in parallel to dorsal and ventral margin at the otoliths

Table C8-1: Temperature variation and isotope ratio variation. Gothenburg is only presented to illustrate that the variation in August can be greater than the annual variation in the Western Isles.

Isle of Lewis	**SST (^{O}C)**	**$\partial^{18}O/^{16}O$ ($^{0}/_{00}$)**
Maximum August Range	1.5	0.31
Maximum Annual Range	6.5	1.34
Minimum Annual Range	3.5	0.72
Gothenburg		
Maximum August Range	4.4	0.91



PlateC8-1: The approach to milling saithe otoliths. The circles that depicting milling sites are not to scale with the otolith shown but for small specimens where only the A and usually a B sample can be taken the scale is approximately correct although taking C to x samples is not possible. For the largest specimen, the sample sequence was A, C, D, E, F, G and B.

widest point, therefore constitutes an isochron, or as close as is practicable. Sampling across the width of the otolith is not without precedent as this approach was utilised by Hufthammer *et al*, (2010). The detailed methods and laboratory protocols are defined in SI-Chapter8-1. The milling profile is shown in plate C8-1. The actual number of incremental samples depended upon the size of the otolith. The results were sense checked against the values in table C8-1. The conversion between SST and isotope ratio was calculated using the equation provided by Campana, (1999, p.276) assuming the salinity of the coastal waters is constant (ibid, p.278). The ranges are theoretical in that they assume the minimum March mean SST can occur in the same year as the maximum mean August SST. This assumption primarily relates to the consideration of individual otoliths as time aggregated assemblages may well reflect the entire range. Figure C8-1 provides an interpretative framework for the results obtained.

The presence of translucent bands was also assessed against otolith size and isotope values and compared to the data from Finlay *et al*, 2019. This permitted an assessment of whether the formation of such bands can be taken as a seasonality indicator as proposed.

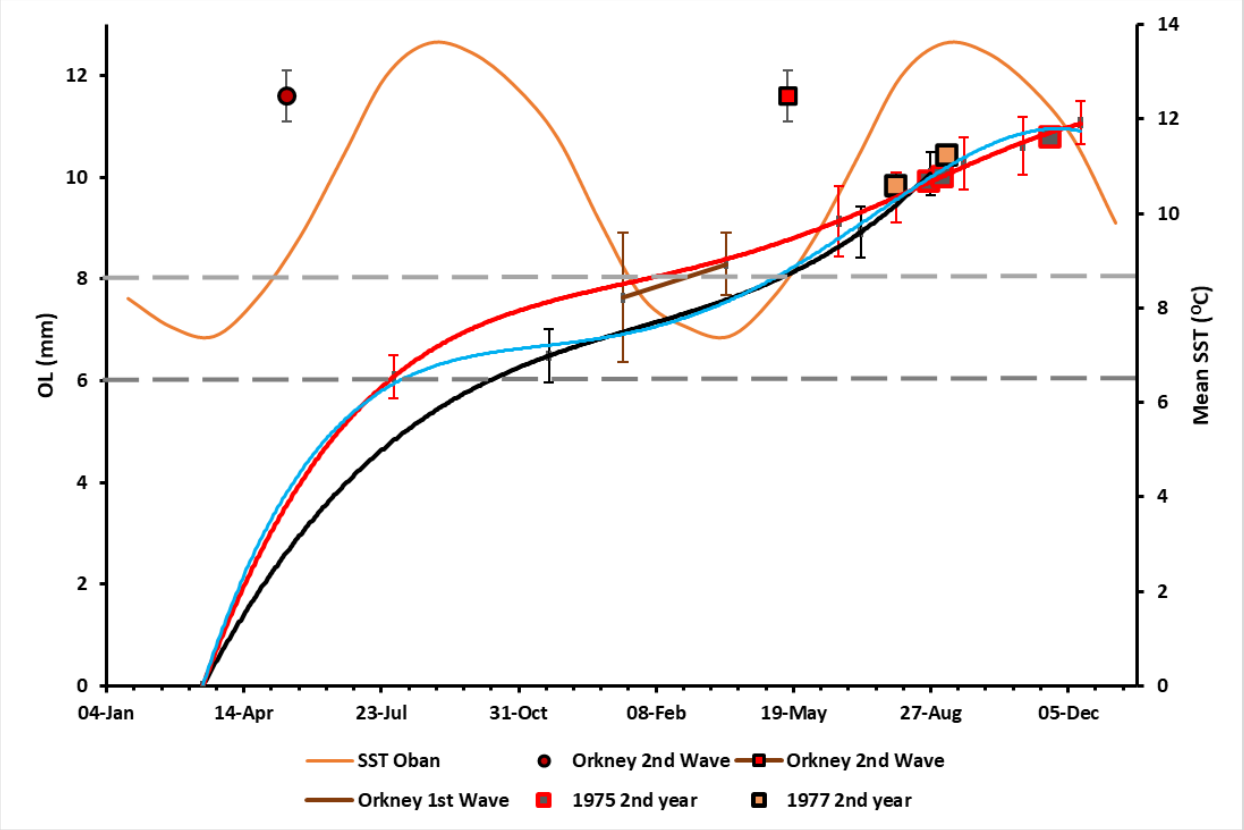


Figure C8-1: Modern Oronsay data and Historical Orkney data in relation to annual temperature variation. The red curve links the 1st year fish from 1975 with the 2nd year fish of 1976, the black line similarly 1977 with 1978. The blue curve is a composite fit of the 1st year fish of 1975 and 1977 with the second year fish of 1976, 1977 and 1978. The 2nd wave at Orkney is represented in duplicate to aid comparison with 1st and 2nd year fish. There are no 1st year fish datasets for 1974, 1976 or 1977. There is only a remote possibility that otoliths less than 6mm originate from fish caught in the early autumn; spring and late summer are far more likely. Modern SST is for Oban, data from Seatemperature.org. Oronsay data from Mellars and Wilkinson (1980). Historical data for Orkney from Low (1813).

8.3 Results

8.3.1 The Western Isles' Dog Whelks and Limpets.

8.3.1.1 Dog Whelks

The morphology of dog whelks from these sites is problematic as so few specimens are intact and therefore yield a value for SH_N. The absence of this metric inhibits the fundamental analysis of dog whelk morphology as a proxy for shore energy level (SH_N/AH_N).

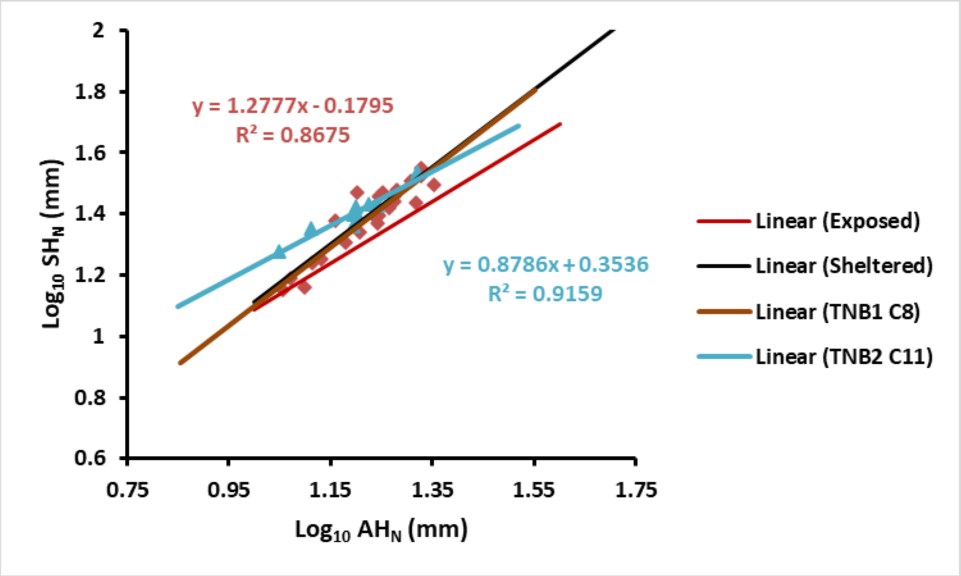


Figure C8-2: The relationship between SH_N and AH_N. The exposed and sheltered shore curves are generated from the equations provided by Palmer (1990). TNB2 context 11 (n=9) exhibits the same profile as the exposed shore but with a consistent off-set. TNB1 context 8 (n=23) is closer to the sheltered shore.

The relationship between of SH_N and AH_N are provided in (figure C8-2). The sample sizes for which SH_N is available are very small (n=3 for TNB2 context 5) due to the very high fragmentation rates of dog whelk (chapter 6). The exact matching of TNB1 context 8's linear regression and Palmer (1990)'s sheltered shore is uncanny. The sheltered shore standard and TNB1 context 8 clearly show that the aperture is growing more slowly relative to the shell overall; the shells are more elongated. The reverse is true for TNB2 context 11 and the exposed shore, as the shells are squatter. There are one or two observations from TNB1 context 8 that may be a better fit to the exposed standard. There is an off-set between Palmer (1990)'s sites and TNB2 which is converging slowly. The off-set is presumably of environmental origin; for example, how sheltered is a sheltered shore, given Palmer's sites are in North Wales and the archaeological samples are from the west coast of the Isle of Lewis. The final observation is that the exposed and sheltered shore standards converge at smaller shell sizes. The implication is that any delineation between exposed and sheltered shores will be constrained to shells above a certain size threshold.

Various combinations of the other metrics gathered (defined in chapter 6) were evaluated to assess whether relationships between them could serve as a proxy for shore energy, thus increasing the sample sizes beyond the limited number of specimens for which SH_N was available. The regression equations provided by Palmer (1990, table 2, p.161), that link various biometrics to SH_N, were algebraically combined to eliminate SH_N in favour of AH_N (EQC8-1 and EQC8-2). This was carried out for various combinations, for example eliminating SH_N in favour of SW_N. Mostly this endeavour was ineffective as in general the biometric features are simply a function of size (AH_N) at both exposed shore and sheltered shores. Evaluating the residual distributions of the Western Isles' assemblages against the exposed and sheltered models provided by Palmer (1990) was ineffective due to sample sizes. One variable did offer potential and that is the lip thickness around the aperture of the shell (figure C8-3).

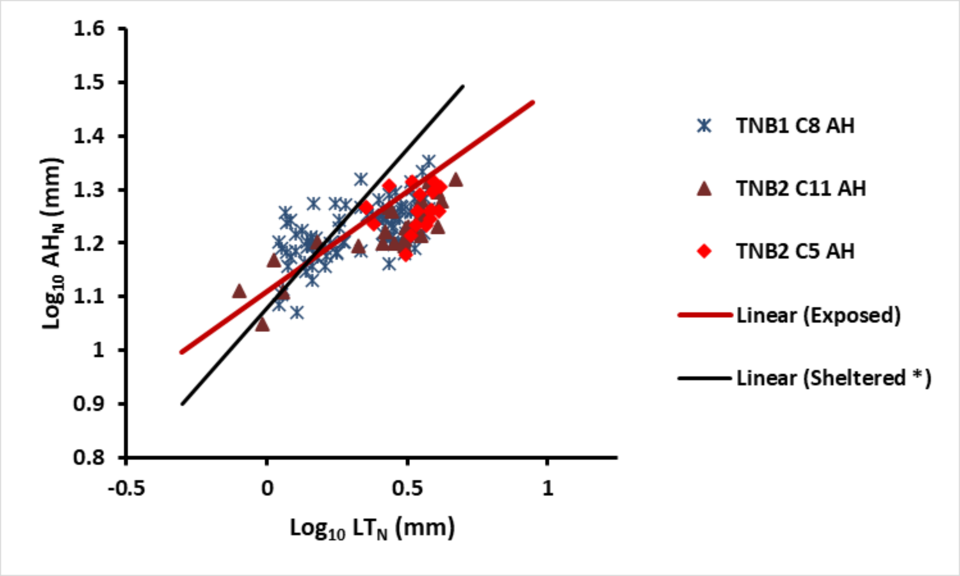


Figure C8-3: The relationship between aperture lip thickness and aperture height. The exposed and sheltered standards were generated from the equation relating SH_N and SH_N and the equation relating ALT_N and SH_N to eliminate SH_N. TNB1 context 8 n=93, TNB2 context 5 n=18, TNB2 context 11 n=28.

Exposed shore: EQC8-1 $\text{Log}_{10}(AH_N) = 0.372\ \text{Log}_{10}(LT_N) + 1.109$
Where $LT_N \geq 0.8\text{mm}$ and $\leq 4.1\text{mm}$

Sheltered shore: EQC8-2 $\text{Log}_{10}(AH_N) = 0.592\ \text{Log}_{10}(LT_N) + 1.078$
Where $LT_N \geq 0.8\text{mm}$ and $\leq 4.1\text{mm}$

The interpretation of the results is generally straight forward and consistent with the data presented SI-chapter6-3 and repeated here for convenience (figure C8-4). The conclusion is that TNB2 contexts 5 and 11 were deposited when shore energy levels were higher than when TNB1 context 8 was deposited, although this requires qualification. There is a clear relationship between ALT_N and AH_N in context 11 (R^2=0.74) consistent with a high energy environment. One material consideration is that TNB2 context 11 has the lowest levels of dog whelk fragmentation and this has resulted in the survival of smaller specimens which clearly reside in the non-diagnostic convergence zone already described. The situation in TNB2 context 5 is somewhat different as the shells are uniformly robust with thick shells and almost no relationship between ALT_N and AH_N (R^2=0.026). The same trend in AH_N and ALT_N observed in context 11 probably exists but smaller specimens are unavailable. The interpretation of TNB1 context 8 is not straight forward. If treated as a single population the above biometric relationship is evident but not particularly strong (R^2=0.37). If treated as two distinct populations, the relationship within each group is much weaker (R^2=0.11) and consistent with figure C8-4. The situation appears to be that two populations were exploited. There is of course a weak relationship between AH_N and ALT_N but with a significant overlap in shell size between a gracile and robust population (figures C8-3 and 4).

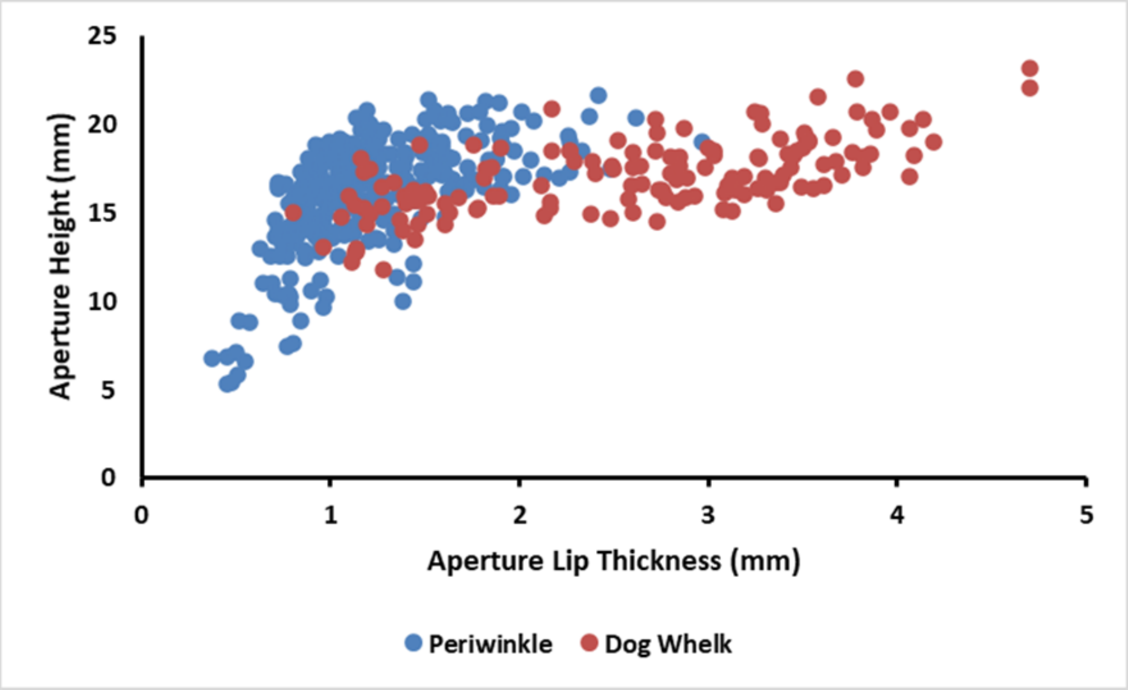


Figure C8-4: Relative robustness of periwinkle and dogwhelk shells from the pooled archaeological assemblages and a small number of modern shells in the author's collection. Note: this figure is not a Log_{10} transform. Some communities of dog whelk will increase in size with modest increases in shell robusticity and therefore coincide with the values for periwinkle, other communities will exhibit rapid increases in shell robusticity in response to modest increases in shell size.

8.3.1.2 Limpets

It was observed in chapter 6 that the limpets from TNB1 context 8 were achieving a length of 30mm at a younger age than those from TNB2 context 5 and this has been explored further. This observation cannot be explained by the collective conicity of the sub-samples chosen for sectioning (CL=95%). Figures C8-5 and 6 do show that the four year old limpets from context 8 are more conical than those from context 9. SL_P is increasing faster in the more conical limpets, which is the reverse of the situation in the >40mm classes both from the western Isles and Shetland. Why should this be the case? Ballantine (1961a, pp.150-158) offers a possible explanation. TNB1 context 8 has the highest yield of limpets and this implies more intensive exploitation. The removal of limpets by thinning the population, rather than clearing an area, results in increased growth rates of the remaining limpets. Clearing an area risks colonisation by barnacles and this inhibits both spat settlement and growth rates.

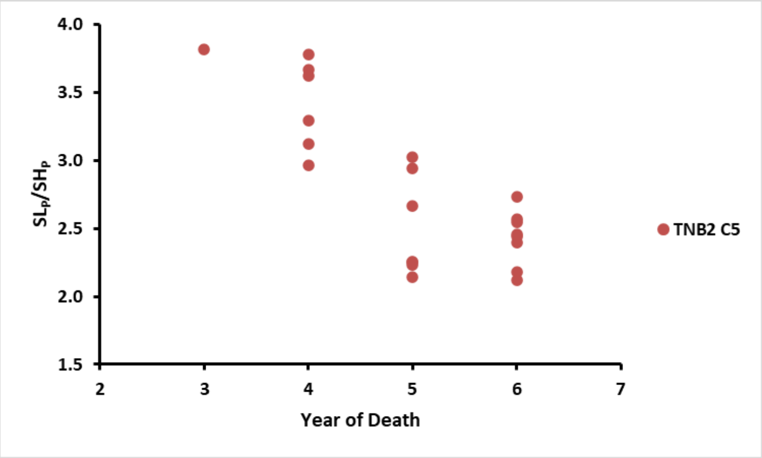


Figure C8-5: The age at death for 30mm limpets appears to cluster based upon conicity. Year of death is the year of life during which death occurred.

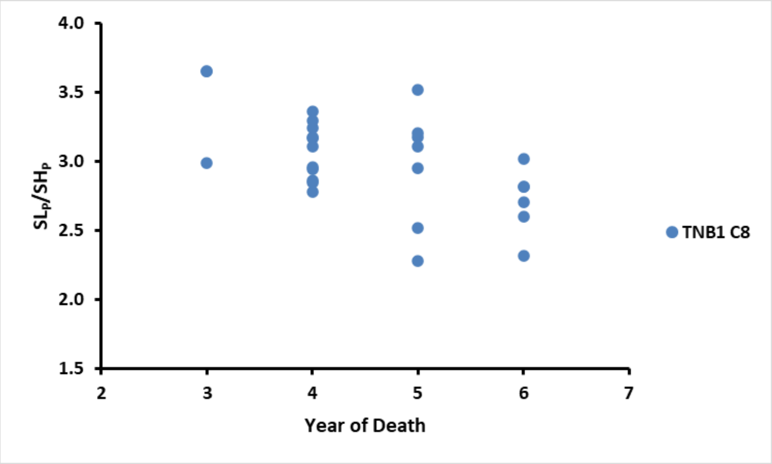


Figure C8-6: The same clustering is evident in 30mm Year of death is the year of life during which death occurred.

8.3.1.3 Discussion.

These results suggest that contexts 5 and 11 of TNB2 reflect the exploitation of exposed shores, whilst TNB1 context 8 reflects the exploitation of both a sheltered and exposed shore. Whether this latter observation relates to spatial variability in exposure between contemporary shores or a temporal sequence is not resolved by the data. Spatial variability where it did not exist before could be because the breaching of natural barriers, coupled with RSL, may have generated a shallow and protected lagoon like environment and possibly this is what attracted the people to spend more time in the area in more seasons of the year. The exposed nature of shores exploited at TNB2 is consistent with the limpet growth disturbances identified which generally result from either impact by wave mobilised objects, or dislodgement and then reattachment in a different desiccation risk regime (cf. Moore, 1934, plate 24; Taylor, 2016). Limpet shell thickness also responds to scouring by water or wind mobilised sediments (Jefford, 2015). One or more of these phenomena appear to have been more frequent in certain phases, which includes TNB2 context 5. One aspect that the data, and that presented in chapter 7, makes clear is that the Mesolithic hunter-gatherers were partial to periwinkles and appear to put in the effort, and possess the knowhow required to acquire them, even from environments where their abundance and ubiquity should be relatively low.

The assemblage of limpets in TNB1 context 8 is consistent with a thinning out approach to harvesting which promotes more rapid growth and reduces the risk of barnacle invasion. Whether this was a conscious decision as part of an established technique practiced by the occupants is open to debate. But it is consistent with the site being visited more frequently and during more seasons of the year. Of course, the data might just be a snapshot of an over exploited population on a glide path to collapse.

The need to consider cultural filtering when considering the ecological profiles of taxa is underlined. Some consistency is observed and there has been little change in certain aspects of human behaviour since the 7th millennium, as the observations regarding periwinkles was made in chapter 7 with reference to Sand Rock Shelter.

8.3.2 The Saithe.

In chapter 6 the data presented suggests a reduction in the size of saithe during phase 2 of occupation on the Cnip headland prior to a recovery in phase 3. One possible interpretation is that the reduction in fish size is due to a change in the season of occupation. Mellars and Wilkinson (1980) provide a seasonality statement for the Oronsay middens based upon fish two years and older. The data they obtained from smaller and putatively younger fish from the assemblages is not leveraged due to a lack of modern data (ibid). The modern data for the younger age class does however provide a couple of useful comparative data points.

Table C8-2: Headline analytical success. The reasons for rejecting samples are provided in SI-Chapter8-1

	Milled	Accepted Assays
Otoliths	90	74
Samples	200	144

In total 200 incremental samples were successfully milled from otoliths originating from TNB2 contexts 5 and 11; TNB 1 contexts 8 and 14, and PMS C2. The outcome of each assay is provided in SI-Chapter8-5. The headline sample numbers are provided in table C8-2, which excludes samples lost during the milling process. Samples were rejected due to physical quality control, analytical quality control and equipment failures during both milling and mass spectrometer assay. One weight grouped set of samples in tranche 1 batch 2 had a high analytical error for the LS VEC international standard. The results from this group resulted in very anomalous otolith profiles and consequently these otoliths were rejected in all but three cases. This was because if just the affected incremental sample was dropped interpretation of the otolith was problematic and potentially misleading, hence caution was exercised. In three instances the interpretation of the otolith was not compromised, and the analytical error has been provided for the three incremental samples as error bars in the relevant figures.

Table C8-3: This key of symbols should be utilised in conjunction with the figure specific keys provided with each figure.

Symbol	Outline Colour	Fill colour	Meaning
Line solid	Sample specific		
Line broken	Sample specific		In complete sequence as one of the none end point samples was lost or failed.
Circle	Sample specific	Sample specific	Incremental sample values that are neither the inner most or outer most sample.
Triangle	Sample specific	Red	Inner most sample.
Diamond	Sample specific	Back	Outer most sample.
Square	Sample specific	Purple	Not an end point as a sample was lost or failed. If the highest value the data values do not reflect the point of capture.

From this perspective the author chose otoliths from just about the worst location possible. The level of analytical error that demanded rejection would not be an issue for otoliths from Oslo Fjord, Gothenburg, northern Denmark, New York, Portugal etc, as the annual range in temperature is so much greater. The highly moderated environment of western Scotland (probably also western Ireland and southern Atlantic Norway) is a material consideration when choosing the specification of the equipment to be utilised.

As archaeologists the focus is on human ‘stories’, but the first observation that can be made is how diverse the life stories of these young fish are, and these are discussed below during the interpretation of the data. Similar variation in the life histories of individual Atlantic cod is observed in Atlantic Norway during the late 6th millennium BC (Hufthammer *et al*, 2010, fig 3, p.82).

8.3.2.1 TNB2 Context 5.

The results obtained from TNB2 context 5 are presented in figure C8-7. Fishing appears focused on the spring and summer prior to or as peak summer temperatures are reached. OT0011 does appear,

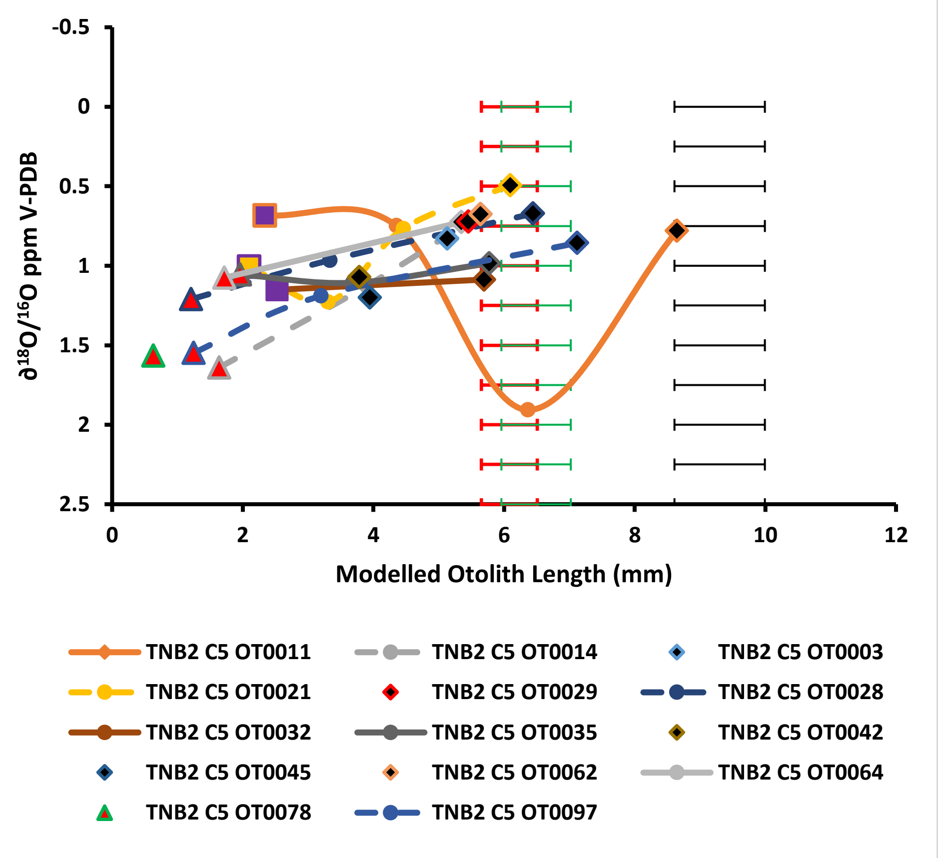


Figure C8-7: The isotope results for otoliths from TNB2 context 5. The error bars (1 standard deviation) depict the range of fish sizes acquired around Oronsay on the 22nd November 1975 (green) and the 1st of August 1977 (red), 2nd year fish 21st of June (black). Oronsay data from Mellars and Wilkinson (1980). See table C8-3 for detailed key.

to have grown very slowly during its first year. It also seems likely that OT0097 is an autumn capture, unfortunately the additional data point that would have confirmed a summer peak around 6mm length failed quality control. The scenario appears to reflect fishing during the spring and summer. Possibly the site was occupied infrequently during the autumn, possibly short term by a group in transit. The results are consistent with the avian assemblage and the limpet seasonality (chapter 6). Other than OT0011 the growth profile of the saithe seems comparable with that of 1977-1978 in figure C8-1.

8.3.2.2 TNB2 Context 11.

TNB2 context 11 also evidences primarily spring and summer fishing (figure C8-8). OT0004 appears to reflect a late winter capture possibly by a group in transit or the group arriving early for the spring season. Again, as with TNB2 context 5, the fish that have entered their second year appear to have grown slowly. OT0054, OT0087 are ambiguous as they are a good fit with a slow growing or fast growing profile (figure C8-1). There is more evidence for a reduction or variability in growth rate than in

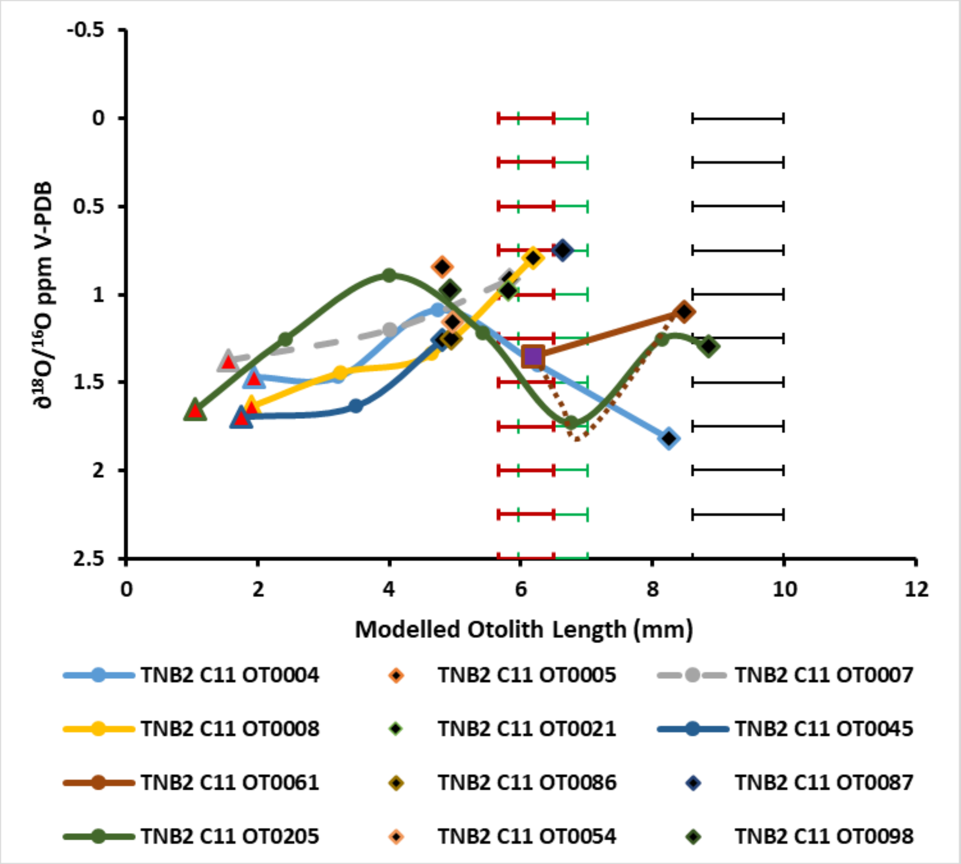


Figure C8-8: The isotope results for otoliths from TNB2 context 11. The error bars (1 standard deviation) depict the range of fish sizes acquired around Oronsay on the 22nd November 1975 (green) and the 1st of August 1977 (red), 2nd year fish 21st of June (black). Oronsay data from Mellars and Wilkinson (1980). The brown dotted line is the author's qualitative estimate of the likely profile. See table C8-3 for detailed key.

context 5. The seasonality profile is totally consistent with the avian assemblage and the limpet seasonality assessment (chapter 6).

8.3.2.3 PMS Context 2

PMS context 2 (and TNB1 context 14) must be considered ‘unlucky’ as the aging and seasonality analysis of limpet was unsuccessful and in the general sense so was the isotope analysis of the otoliths. The results from PMS are presented in figure C8-9. The fish appear to be growing more slowly and experiencing warmer temperatures at a smaller size. The seasonality is clearly spring or summer if OT0080 is accepted as a year 2 capture of a very slow growing fish (figure C8-1). The primary difference between TNB2 and PMS is that all sizes classes appear to be growing slowly.

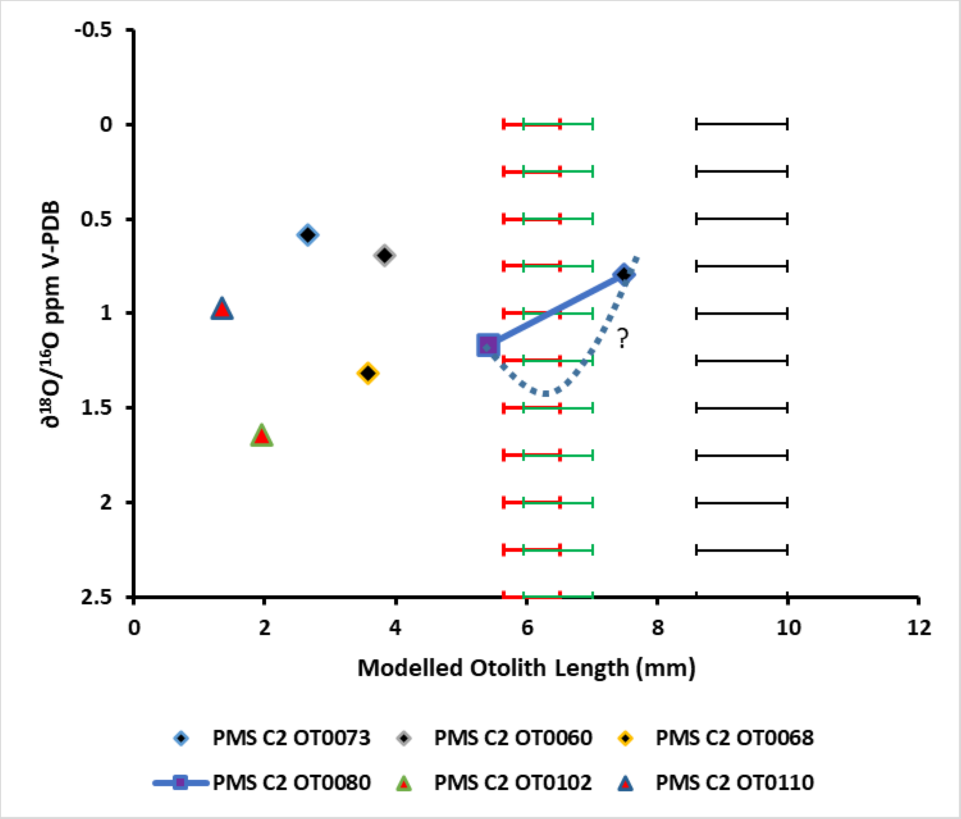


Figure C8-9: The isotope results for otoliths from PMS context 2. The error bars (1 standard deviation) depict the range of fish sizes acquired around Oronsay on the 22nd November 1975 (green) and the 1st of August 1977 (red), 2nd year fish 21st of June (black). Oronsay data from Mellars and Wilkinson (1980). The blue dotted line is the author’s qualitative estimate of the likely profile. See table C8-3 for detailed key.

8.3.2.4 TNB1 Context 14

As stated above, context 14 was the other 'unlucky' context. The data supports spring summer fishing, and the higher temperatures are now experienced at larger sizes (figure C8-10). This possibly suggests, noting the analytical error in OT0256, some recovery in saithe growth rates. This is also the first context that has no evidence for the capture of 2nd year fish during the spring. OT0259 possibly reflects an autumn capture of a slower growing fish but may reflect a fish only recently arrived in near shore waters.

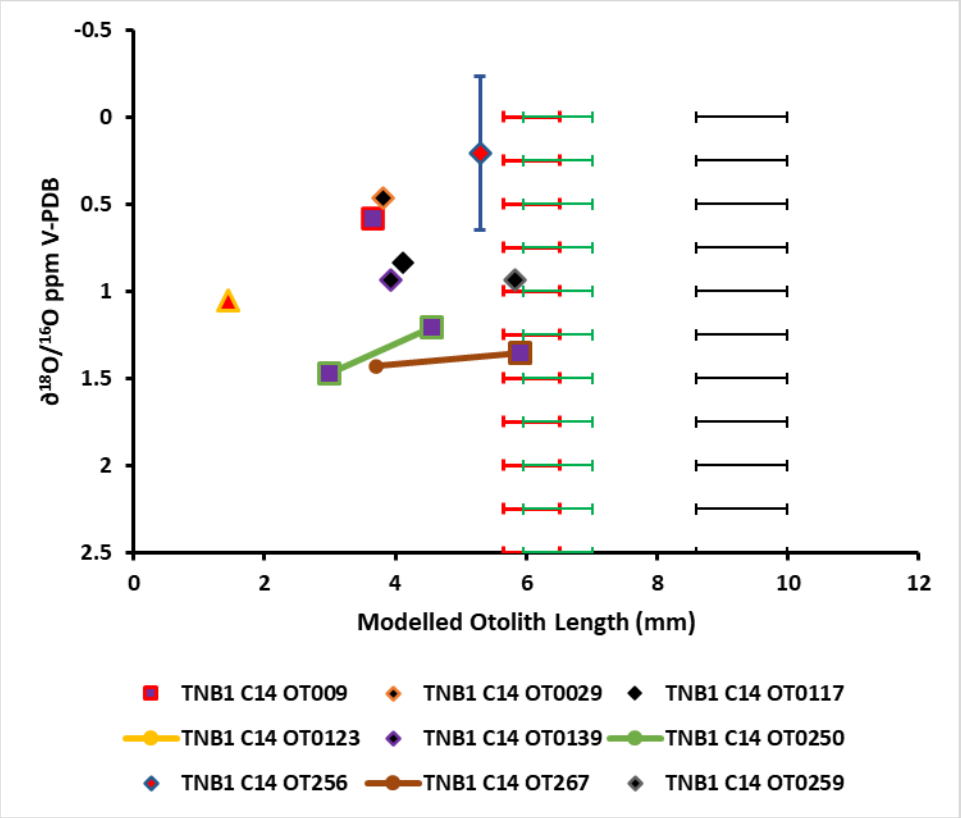


Figure C8-10: The isotope results for otoliths from TNB1 context 14. The error bars (1 standard deviation) depict the range of fish sizes acquired around Oronsay on the 22nd November 1975 (green) and the 1st of August 1977 (red), 2nd year fish 21st of June (black). Oronsay data from Mellars and Wilkinson (1980). See table C8-3 for detailed key.

8.3.2.5 TNB1 Context 8

TNB1 context 8 has a very diverse assemblage (figure C8-11). There is clear evidence for spring-summer fishing and despite the large analytical error OT0008 almost certainly reflects an autumn capture. OT0187 and OT0174 also demonstrate that not all fish move into the warmer inshore waters at the earliest opportunity. The latter specimen probably reflects an autumn capture. The warmer temperatures are experienced at slightly larger sizes than in context 14 suggesting a further slight improvement in growth rate. OT0043 and OT0007 also suggests that some fish are now growing at a rate comparable with TNB2. There is ambiguity as OT0177 may have an unresolved peak aligned with OT0387 which suggests an early autumn capture of a slightly slower growing fish. The situation can probably be described as fishing in multiple seasons in conditions that vary in a manner similar to that in the mid-1970s (figure C8-1) and this is consistent with the limpet seasonality (chapter 6). As with context 14 there is no direct evidence for the capture of 2nd year fish in the spring.

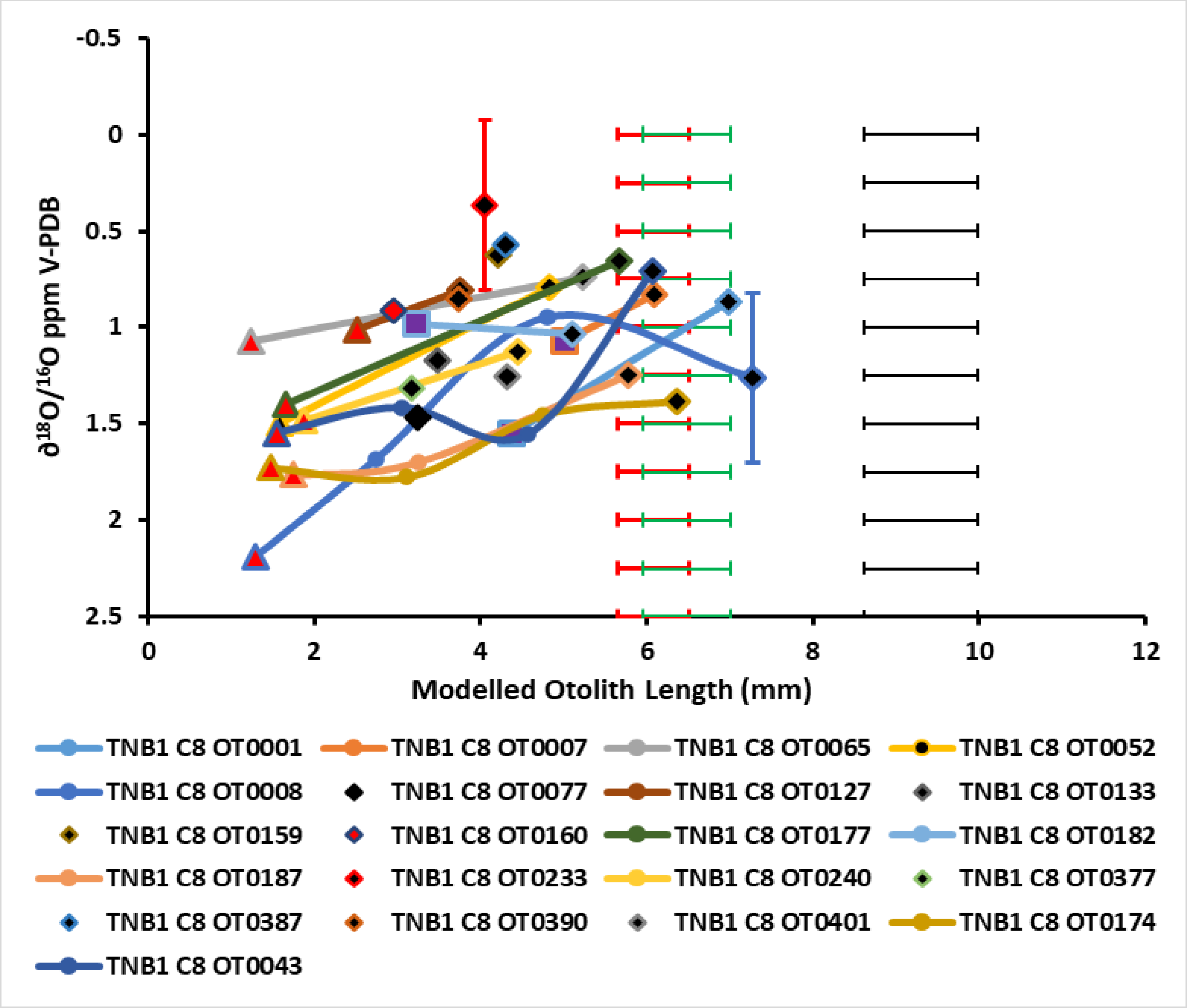


Figure C8-11: The isotope results for otoliths from TNB1 context 8. The error bars (1 standard deviation) depict the range of fish sizes acquired around Oronsay on the 22nd November 1975 (green) and the 1st of August 1977 (red), 2nd year fish 21st of June (black). Oronsay data from Mellars and Wilkinson (1980). See table C8-3 for detailed key.

8.3.2.6 Otolith Growth.

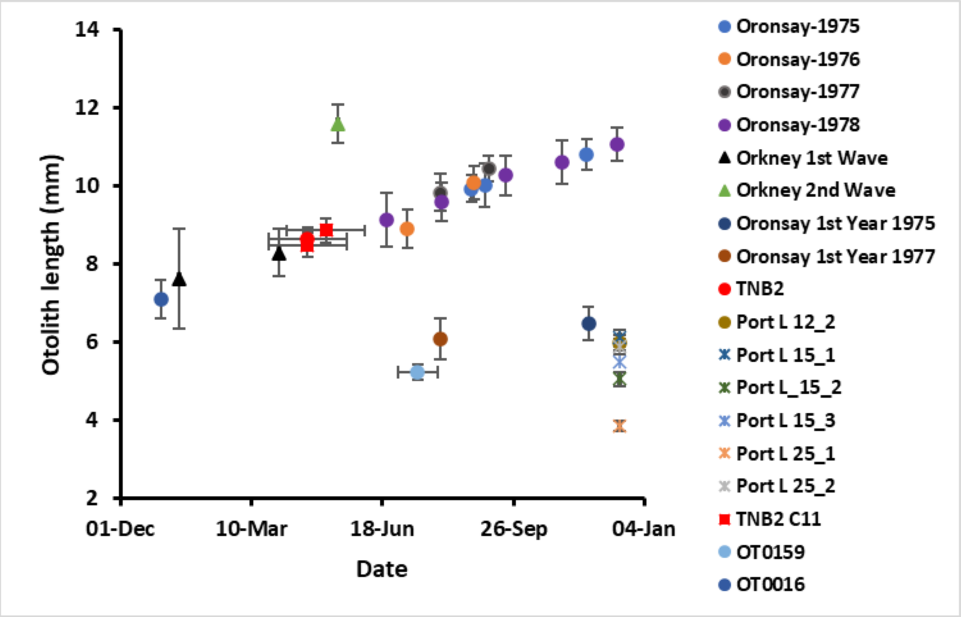


Figure C8-12: Figure showing the modern Oronsay data (Mellars and Wilkinson, 1980); selected archaeological otoliths from the Western Isles and the purported archaeological autumn captures from Port Lobh (Finlay *et al,* 2019). The otolith widths for Port Lobh were extracted electronically from the images and the length generated using equation EQC6-10.

Winter growth bands are often referred to both in relation to marine mollusc shells and fish otoliths. The reasons for the formation of such bands are however variable and include high temperature stress, nutritional stress, and in sexually mature organisms, spawning stress. The formation of winter growth bands in the highly moderated waters of the north-western Scotland is probably intermittent and most likely to occur in March but could also be in February or April. Figure C8-12 highlights the anomaly the interpretation of Finlay *et al*, (2019) presents.

From a size perspective the Port Lobh otoliths are evidently spring to late summer captures, and therefore the translucent band formation requires explanation. OT0159 (figure C8-11; plate C8-2) illustrates a possible explanation. The Port Lobh otoliths are probably recording the start of the formation of the translucent layer present in OT0159 which based upon its isotope values and size is a spring-summer capture. This observation is consistent with the research of Neat *et al*, 2008 (and references therein). OT0016 (plate C8-3) illustrates the problem further as its translucent layers were laid down some time prior to death. In figure C8-12 this otolith has been allocated an arbitrary date of death of 1st of January. In such a scenario the translucent layers were probably laid down in late summer. If the translucent layers are associated with the lowest water temperatures, possibly in February, but more usually March, then the date of death must have been late April or more likely May, which is anomalous in terms of growth (figure C8-1). OT0011 (figure C8-7) might be described as somewhat ‘boring’ as it is opaque throughout. The highly moderated marine environment almost certainly means that the formation of translucent winter growth lines will be intermittent and probably rare. With larger sexually mature fish care is required as spawning stress can also generate a translucent growth band (ibid). Translucent banding as an indicator of winter fishing is probably valid during the 8.2K cal bp event, but under the normal moderated conditions it is probably on most occasions, an indicator higher summer temperature. Translucent growth bands were not utilised by this project to determine or verify seasonality assessments as they are simply unreliable.

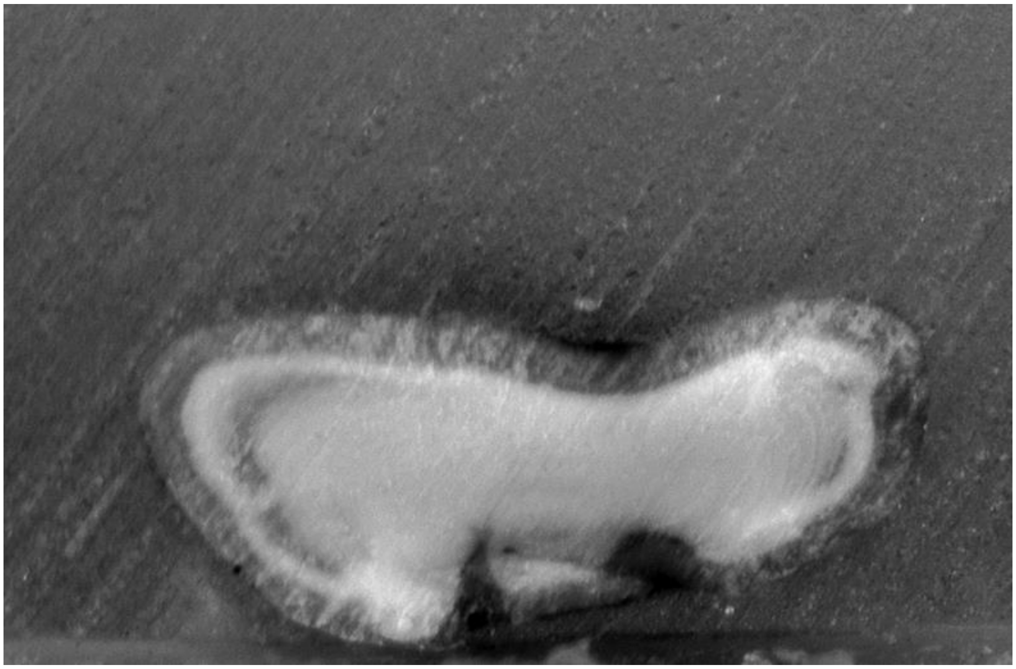


Plate C8-2: OT0159 in section. This otolith has laid down translucent layers.

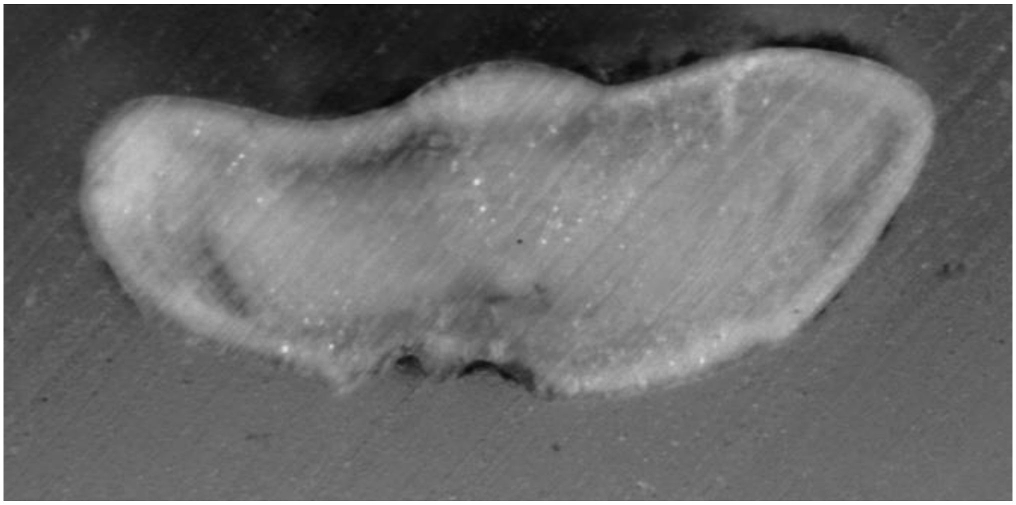


Plate C8-3: OT0016 in section. This otolith has laid down translucent layers. There is no isotope result for this specimen as the sample was destroyed by a faulty septum.

8.3.3 Discussion.

The use of small otoliths has been evaluated and the results have proven useful but not totally in the manner the author envisaged. Primarily the concept of building one, (or two if environmental conditions changed), large 'composite otoliths' for each stratigraphic unit proved to be invalid due to the diversity in fish life histories. The exercise was also plagued by a number of unfortunate technical equipment failures. Following this proof of concept and confirmation that useful information yields are available, the author in any future exercise, would revise the manner in which the otoliths are milled. These aspects are discussed in more detail in SI-chapter8-2.

The key findings are of significance for future work.

- The modern first year size data obtained by Mellars and Wilkinson (1980) for 1975 and 1977 provide a useful guide range for variation in 1st year saithe growth.
- The few larger fish that are discarded in TNB2 contexts 5 and 11 and PMS context 2 have grown very slowly; was this because of injury, disease or infestation as hypothesised in chapter 6?
- Mean sizes of otoliths and size distributions cannot be utilised to assess the seasonality of archaeological assemblages without corroborating evidence, either in the form of isotopes, or other proxies such as that available from molluscs or vertebrates, and all vertebrate classes must be considered.
- The historical accounts from Orkney of saithe frequenting inshore waters during winter and spring is confirmed by the data obtained by this project. This species therefore constitutes a viable resource for human groups during these seasons. This is almost certainly due to the highly moderated winter SSTs observed in north-west and northern Scotland (cf. the isotope values in Weidman and Millner, 2000, fig. 3, p.331).
- The $\eth^{18}O/^{16}O$ data obtained and that provided by (Hufthammer *et al*, 2010) indicate the delta in SST moderation experienced in Scotland and Norway today was similar during 5th millennium BC. This is a relative statement and not an assertion of comparable absolute SST today and in the 5th millennium.
- Unless there is reason to suspect that the month in which maximum and minimum SST occurs differed significantly from today then the data suggests there is a reduction in saithe growth or a delay in spawning late in the 5th millennium, prior to a recovery. The reduction in fish size cannot be reliably attributed to changes in human seasonality.
- Small otoliths can contribute to achieving a research outcome and the information yield (ignoring losses due to technical failures) could be increased by revising the milling approach.
- Peak temperatures recorded within otoliths must be sense checked as the variation in life histories can suggest quite dramatic reductions in summer SSTs when in fact there are none.
- Determining the season of occupation of a context or site from one or a couple of otoliths is high risk.

8.3.4 Oronsay.

To the author’s knowledge very few aspects of the Oronsay middens have been published in any detail (cf. Mellars, 1978; 1987 (ed.); 2004). Given the number of pages that have been dedicated to these iconic shell-midden mounds, the absence of any published detail on the marine mollusc assemblages is perplexing; especially as coverage is given to the terrestrial molluscs. Andrews *et al* (1985; 1987) reviewed dog whelk morphology as a proxy for shore energy level at an uninformative inter-midden level, but not an intra-midden basis. A more detailed treatment on both an inter and intra midden basis is available for saithe otoliths as a proxy for season of capture (Mellars and Wilkinson, 1980). To make further progress two PhD theses were consulted as these provided at least summarised, but nevertheless quantitative, data in relation to the bone assemblages from Cnoc Coig and the marine molluscs from each of the middens (Nolan, 1986, Jones, 1984). One observation that can be made is that all the Oronsay middens contain a very high percentage of limpet (usually just under 95% but in one case more than 98%) and excepting pit 6 of Cnoc Coig, fairly large specimens (Jones, 1984, table 52, p.225). The availability and granularity of the available data is variable and in some cases typical datasets had to be inferred or reconstituted from the data available. The basis upon which this was carried out is provided in SI-Chapter-8-3.

The original aim was to consider inter and intra midden variability. There is a lack of clarity in terms of the stratigraphic relationships between samples, especially at Cnoc Coig, where Mellars and Wilkinson (1980) do not define which samples the pre-midden and within-midden aggregates contain. It is known that sample 3 is pre-midden and sample 19 is within the midden (ibid, p.23), but nothing further. It was also established that samples 17-21 are a stratigraphic sequence from pit 6 and samples 9-12 are a stratigraphic sequence from pit 10 (Jones, 1984, tables 31-33, pp.184-185). The stratigraphic relationship between these two pits is however uncertain (ibid, p.178). This means that Mellars and Wilkinson, (1980, fig.12, p.38) is problematic as the sequencing by size ignores the stratigraphic relationships above. Furthermore, the reasoning behind such sequencing by size eludes this author completely.

Mellars and Wilkinson (1980) based their analysis on the 2nd year fish, which they state exhibit no significant differences in size, rather than the smaller 1st year fish. In 2016 the author noticed that there are significant changes in the size of 1st year saithe in three of the Oronsay middens and a difference in the overall assemblage in the fourth. As only summary statistics are available t.tests were utilised on three middens. For the fourth midden only histograms are available, and the values were extracted electronically and a Kolmogorov-Smirnov test utilised. The observations of the author and Mellars and Wilkinson (1980) are consistent with the observations of Sande *et al* (2019, p.100), where the effect of environmental factors such as temperature or food supply is less on 2nd year fish; whilst for first year fish growth is more sensitive to such factors, for example growth rate is higher at warmer temperatures. For third year and older fish, the dynamic is reversed, and optimal growth occurs at cooler temperatures (ibid). The biometrics for the Oronsay remains are presented in figures C8-13 through 18.

Prior to considering the biometric and compositional data further some analytical and interpretative orientation is warranted. Given the available PDs (chapters 4 and 5) it seems highly probable that the individual middens overlap in terms of the elapsed period during which occupation occurred. This does not necessarily imply that different middens were occupied concurrently, yet it is certainly possible that certain stratigraphic units may reflect true concurrency of occupation. These observations can be extended to the possible temporal relationships of Oronsay to the middens of the Western Isles and Ferriter's Cove, and the latter two to each other. As in chapter 7 the temptation to 'wiggle match' the data must be resisted. The primary theoretical constraint is that each midden is almost certainly recording the passage of time on a different chronological scale and between different termini. This is best illustrated through figures C8-13a and C8-17a. Is the former recording the same period of increased deposition as layers 3 and 2 in the latter?

The Oronsay middens can be broadly categorised in two ways. Firstly, there is the deposition profile of the molluscs which in all but one instance, records an increase followed by a decrease, the. exception is Cnoc Silgeach. The second categorisation relates Cnoc Silgeach, Caisteal nan Gillean I, both columns of Cnoc Coig, plus Priory midden which record a 'reset', where the role of the marine snails reduces. Caisteal nan Gillean II is slightly different as it records a continuous increase in the abundance of these snails, and it is possible that this midden reflects a chronological subset of the other middens where increases are observed either side of the 'reset', or there is simply no temporal no intersection at all. In the case of the Cnoc coig columns and Caisteal nan Gillean II, the reset also restores dog whelk abundance above that of periwinkle. The exceptions are Priory, where periwinkles always out number dog whelks, but the 'reset' reduces the ratio from *circa* 0.36 to 0.6, and Caisteal nan Gillean II where the situation is unclear as the MNI counts for both snails are so low.

At this point it must be clarified that the data does not exist to support checking for size bias due to differential fragmentation in otoliths and the two marine snails as conducted for the Western Isles. Other biometric data is now considered in relation to the 'reset' points. At Cnoc Silgeach (CL=0.05), Cnoc Coig (column 6, CL=0.005) and Priory (CL=0.005), the 'reset' is associated with a temporary or on going reduction in the otolith length of 1st year fish. The situation at Caisteal nan Gillean II is unclear given the need to crudely estimate the means. But the major drop in snail abundance is associated with a statistically significant shift in the sub-populations of larger otoliths when the assemblage is considered overall (CL=0.001, SI-Chapter8-4). Mellars and Wilkinson (1980) make frequent reference to anomalous 1st year fish, although the reason for this qualification appears to be that they are larger than the fish they caught up until December 14th and smaller than the fish they caught from the 21st of June. Clearly these fish are of a size that would be expected in the '6 month gap' in the modern data (figure C8-1). The isotope data obtained from the Western Isles confirms this. Such fish are either right at the very end of their 1st year or the very start of their 2nd year and are spring captures. As such the seasonality of Cnoc Coig must be revised to include spring and summer fishing. This is consistent with the extensive assemblage of auks, which includes one of the largest collections of great auk bones (Nolan, 1986). Whilst Mellars and Wilkinson (1980) leverage juvenile grey seals to support their assertion of autumn fishing, the bird assemblage is not considered. The histograms presented by Mellars and Wilkinson (1980) for each site by layer show shifts towards a greater contribution from smaller size classes in each 'year class'. These changes do not reflect gross switches from autumn to spring or winter to summer fishing. They are more consistent with modest reductions, and possibly reflect reductions in growth rate, Priory in particular exhibits a reduction in the size of otoliths that can be described as incremental. A further issue is that prior to the industrial scale fishing of the 20th and 21st centuries (Lowe, 1813) it is known that very large saithe, (November or December captures in Mellars and Wilkinson (1980)'s construct), move inshore during the spring (figures C8-12; C6-15) and this probably occurred during the

Mesolithic. Modest reductions in growth rates will result in ambiguity between spring fish and late autumn fish. Without isotope data it is not possible to draw firmer conclusions.

Variation in other biometrics can, in some instances, be explained by deposition, and therefore exploitation, rates. In others, this is not the case, but sample sizes are generally so small statistical testing is problematic. Specific cases where the biometric trends are discordant with the deposition trends are as follows. Cnoc Silgeach has increasing limpet and dog whelk size in response to increasing deposition suggesting the site is rested between visits. Cnoc Coig pit 6 layers 21 and 20 exhibits similar profile. It is unfortunate that the increasing abundance of dog whelk cannot be correlated with morphology changes. The final phases of Caisteal non Gillean II have periwinkle and dog whelk all reducing in sizes in response to reduced relative and absolute exploitation; the same observation can be made for limpet length in relation to absolute exploitation. Layer G is interesting as the dramatic increase in the spread of limpet conicity suggests the people were working harder to find their limpets. Layer 5 of Priory sees a reduction in limpet size despite a dramatic reduction in deposition.

At this point it the author would have liked to consider possible changes in site functionality and type as discussed for the Western Isles. In the absence of crab assemblages this must be considered entirely in terms of the balance between 2nd year fish and 1st year fish and therefore possible discard patterns. Whilst data is available, it only addresses complete otoliths and therefore does not constitute an MNI for the two year classes, which raises the risk of incorrect conclusions being drawn due to inter-midden variation in fragmentation. As illustrated for the Western Isles, the biometrics of otoliths need the support of isotope data, and or unambiguous assemblages from other classes, if the risk misinterpretation is to be minimised.

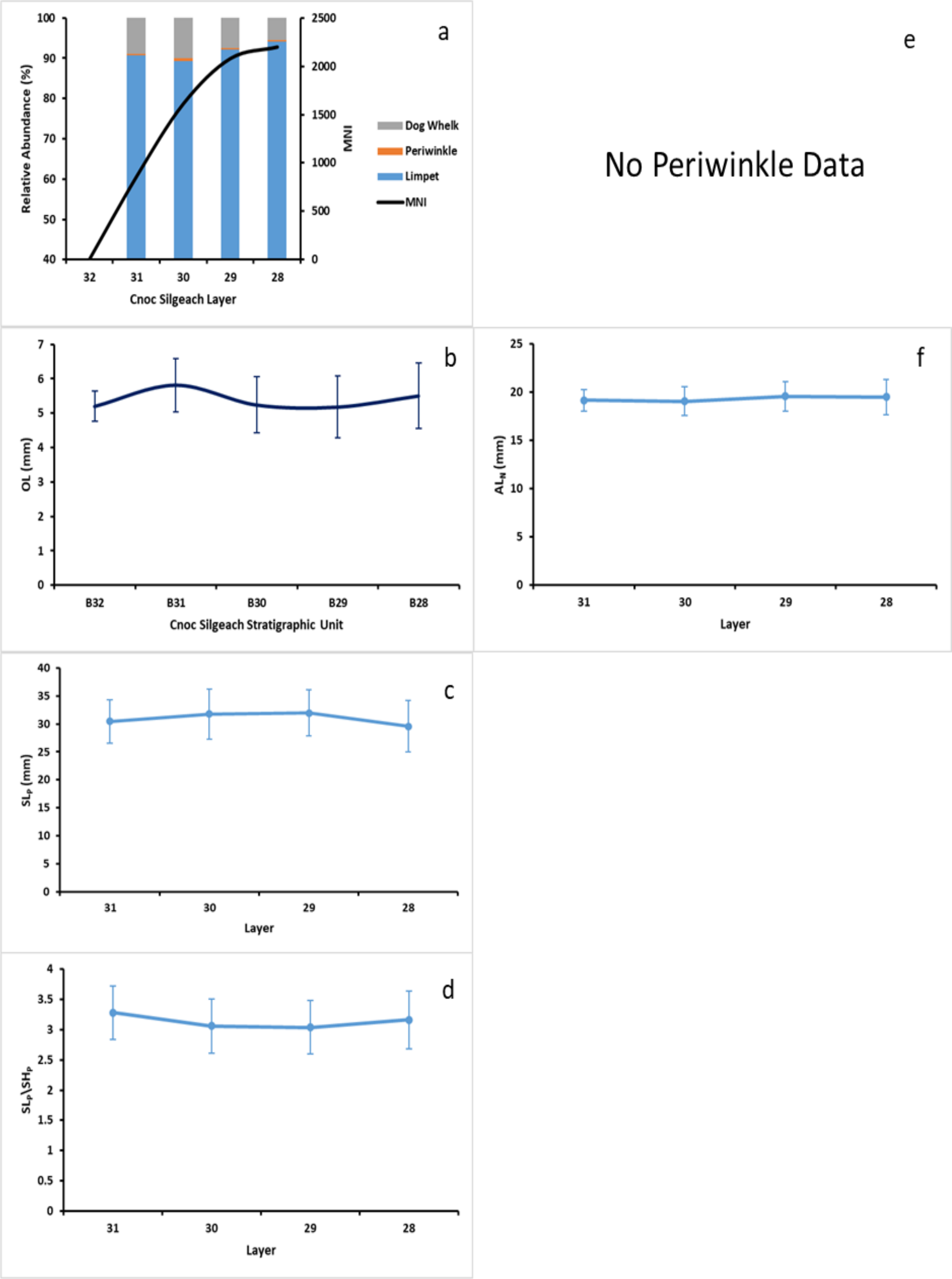


Figure C8-13: Biometric data from the Cnoc Silgeach midden. Data from Mellars and Wilkinson (1980) and Jones (1984).

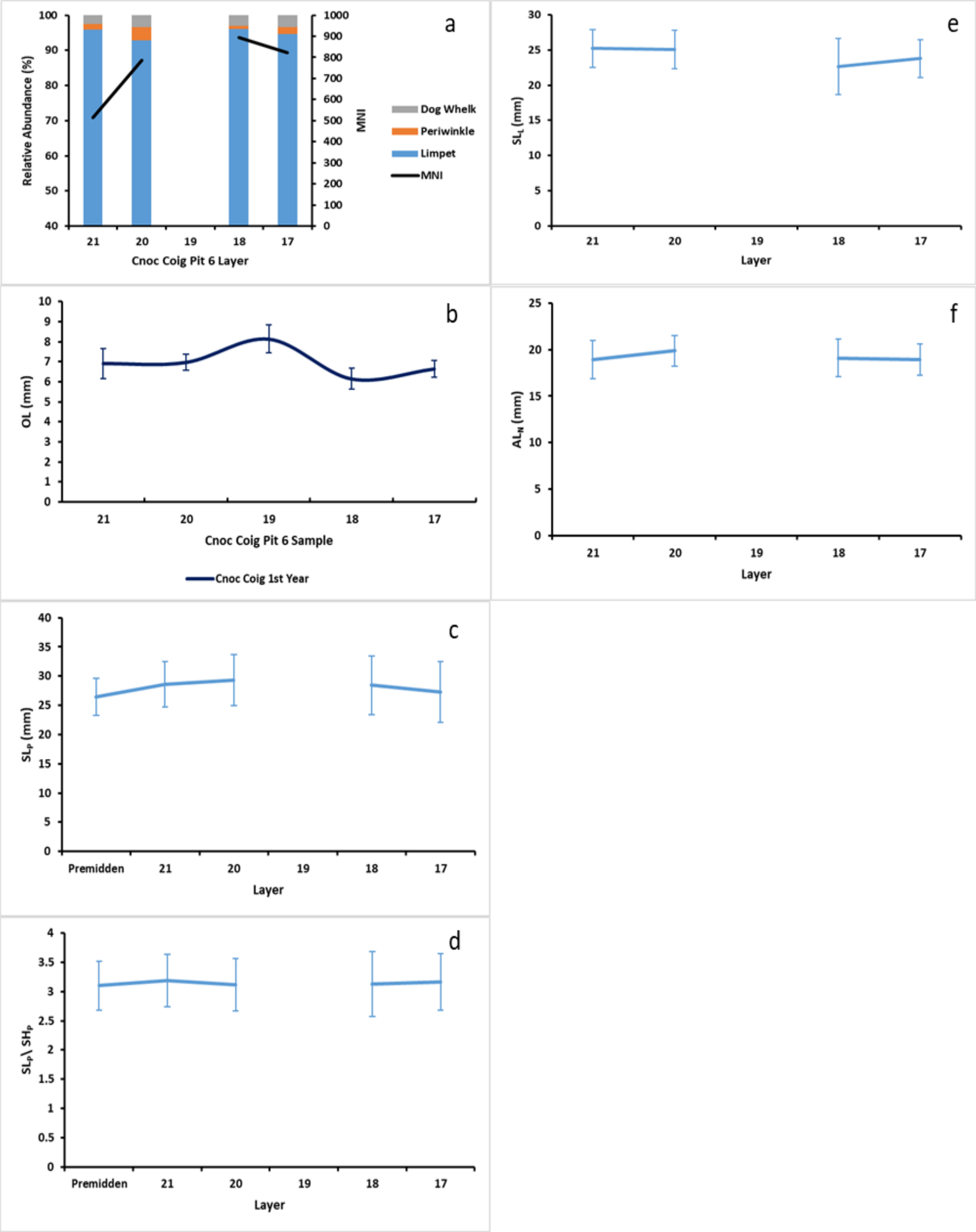


Figure C8-14: Biometric data from the Cnoc Coig midden Pit 6. Data from Mellars and Wilkinson (1980) and Jones (1984).

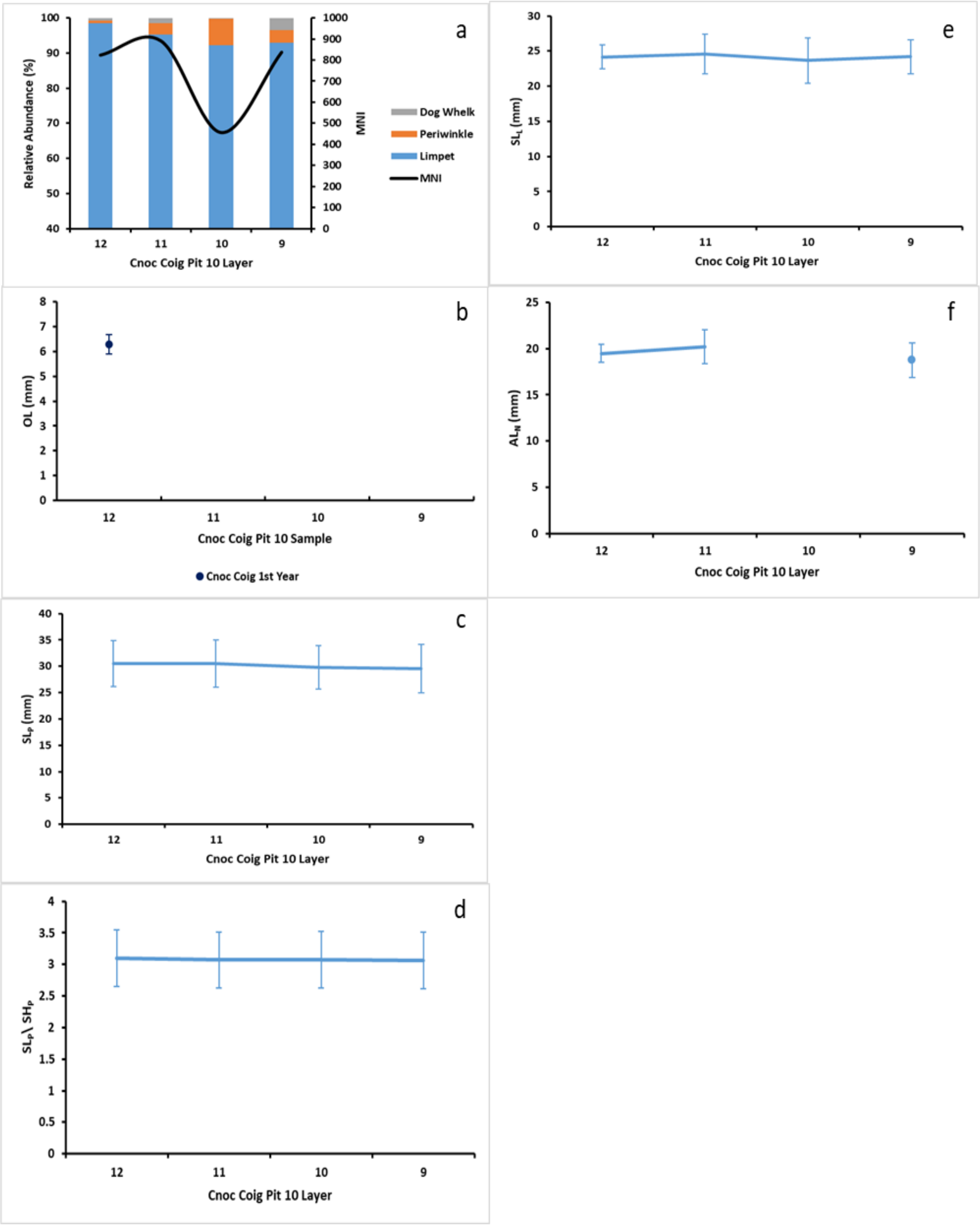


Figure C8-15: Biometric data from the Cnoc Coig midden pit 10. Data from Mellars and Wilkinson (1980) and Jones (1984).

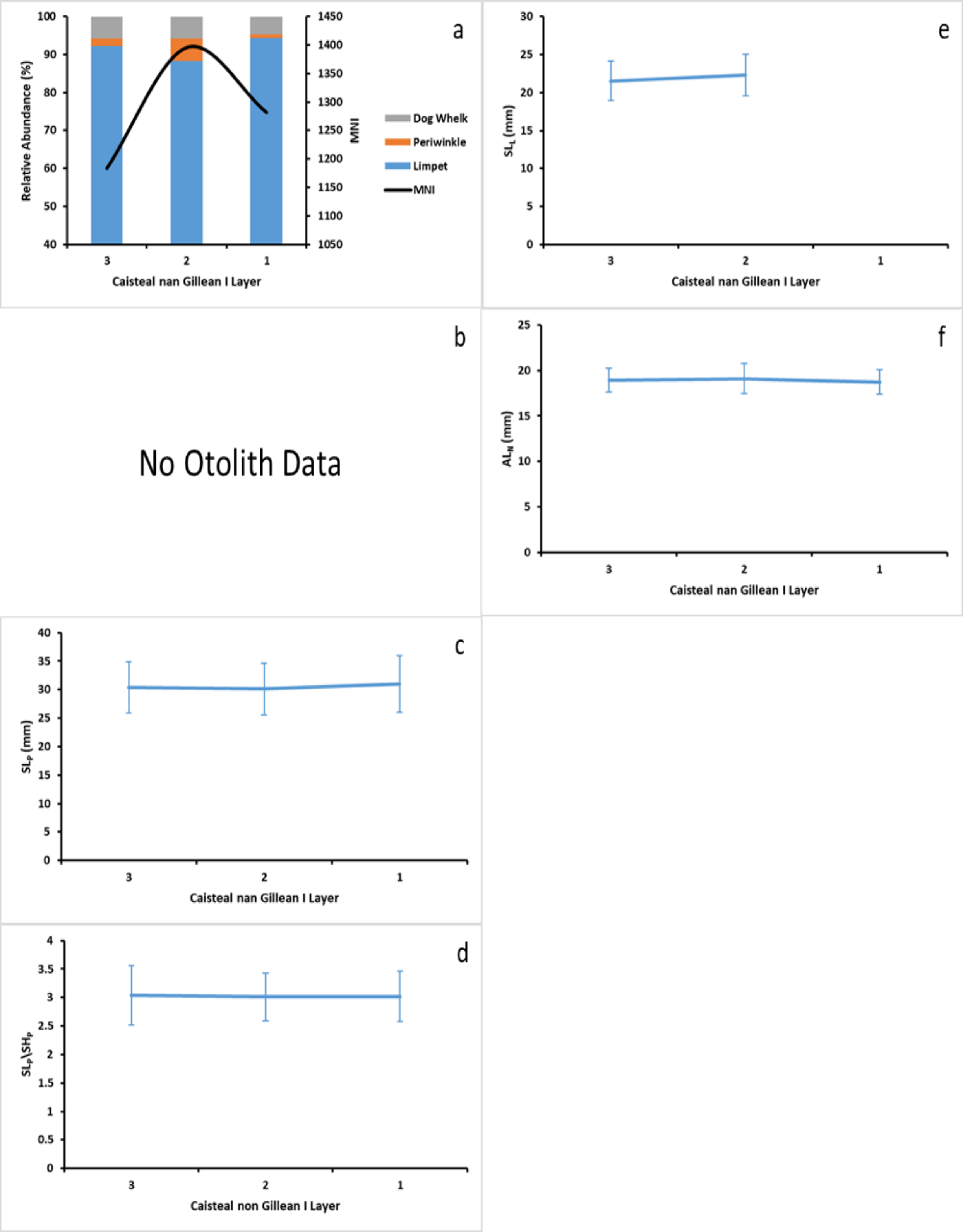
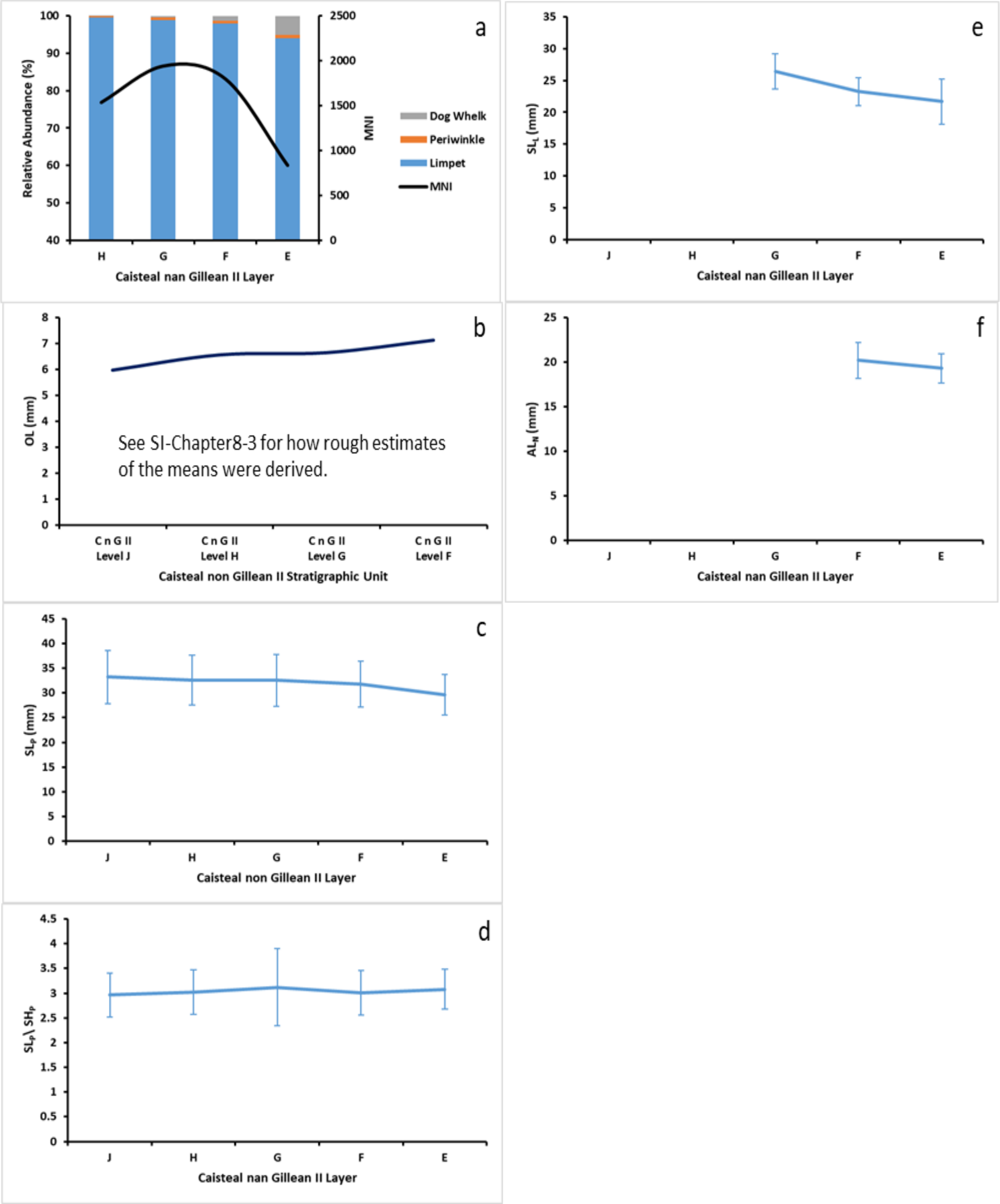


Figure C8-16: Biometric data from the Caisteal nan Gillean I midden. Data from Jones (1984).



See SI-Chapter8-3 for how rough estimates of the means were derived.

Figure C8-17: Biometric data from the Caisteal nan Gillean II midden. Data from Mellars and Wilkinson (1980) and Jones (1984). The histograms for the otoliths have been recreated in SI-Chapter8-3.

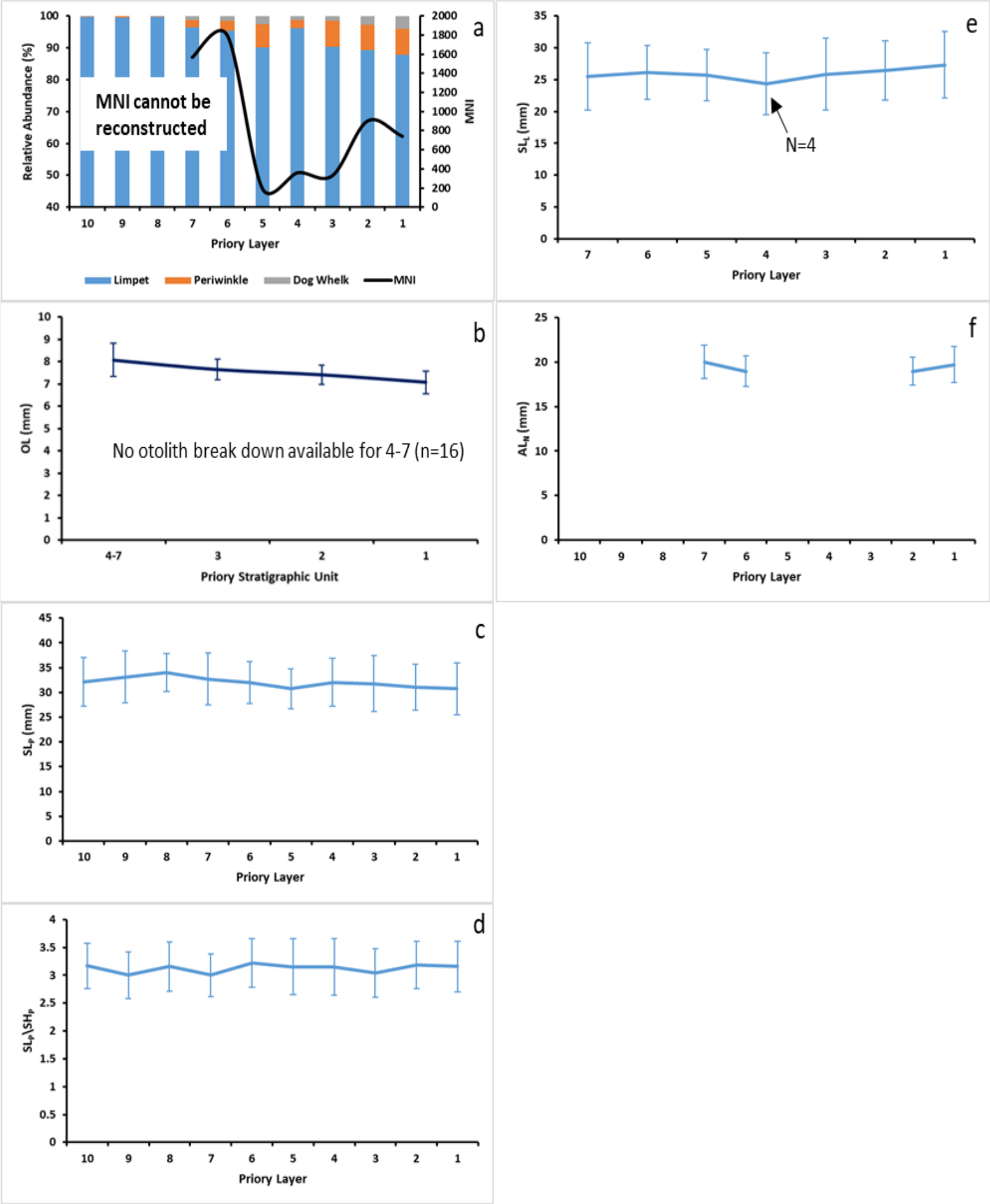


Figure C8-18: Biometric data from the Priory midden. Data from Mellars and Wilkinson (1980) and Jones (1984).

8.3.5 Ferriter's Cove

The chronological status of the faunal remains at this site is even more challenging as the excavation is of an open type and the datasets and PDs are associated with features rather than stratigraphic sequences. In the central and southern areas, the PDs are not from those samples or features that yield the greatest number of faunal remains, often the opposite is true. The relative abundance of dog whelk does exhibit spatial patterning (table C8-4). The chronology is too uncertain to assert any temporal patterning, but it is possible that a switch between periwinkle and dog whelk occurred during the 2nd half of the 5th millennium BC.

Table C8-4: The number features within each area where periwinkles out number dog whelks or vice versa. The spatial patterning extends to the contribution to the overall assemblage, and also the size of the assemblage at feature level in which one species or the other is more abundant. Units with an MNI of less than 10 have been excluded. Data from McCarthy *et al* (1999).

Area	**Periwinkle Features**	**Dog Whelk Features**	**Balanced Features**	**Mean MNI Periwinkle**	**Mean MNI Dog Whelk**	**Mean MNI Balanced**	**Proportion of total (%) Periwinkle**	**Proportion of Total (%) Dog Whelk**
North	3	3		273	51		46.39	29.09
Central	1	7	1	154	3708	131	36.93	60.43
South	1	2		210	846		16.98	28.23

8.4 Discussion.

The review and analysis presented above has yielded some interesting results and in the author's mind the archaeology is being 'wilfully provocative', and it seems only appropriate to engage with it. But first a few words on Oronsay. Mellars and Wilkinson (1980) utilised 2nd year fish and seals to assert the seasonality of each midden. All the middens contain fish that must have been spring-summer captures both in terms of the small specimens OL<6mm and also OL>8mm specimens. This signal is weakest at Priory Midden. There is change through the stratigraphy, but this is incremental and appears more likely to be due to changes in growth rate than gross changes in seasonality.

Now it is possible to respond to the provocation. The Oronsay, Cnip Headland and Ferriter's Cove middens are roughly contemporary (chapter 4, 5 and 6), although Ferriter's Cove contribution to the discussion is limited. The trends in fish size, mollusc composition and biometrics highlight common eco-behavioural changes. These are most clearly observed on the two isolated islands, hundreds of miles apart. This being down to pure chance seems unlikely, or to put it another way, the possibility that the phenomena are synchronous responses to some regional environmental vector must at least be considered.

If the changes in the otolith assemblages are to be attributed to arbitrary changes in the seasonality of human behaviour, the detailed data appears to require these two spatially distinct communities to change their fishing season 'synchronously', at least on a temporary basis. What is difficult to justify is such a switch by highly skilled and knowledgeable groups for no reason. Why would such groups arbitrarily decide to change their schedule and visit a site at less optimum time? This appears to be very unlikely in the absence of external forcing, and in any case a change in fishing season does not best fit the data from the Western Isles.

The author is forced to conclude that at a sub-regional scale an environmental vector is operating which causes people to favour, or turn to, dog whelks whilst also reducing the growth rate of saithe. The first part is probably best explained by increasing shore exposure, which probably relates to weather patterns, although localised factors may amplify or moderate the situation at a given site. To the best of the author's knowledge there is no case for some previously unidentified major climatic event during this period. It therefore seems likely that the saithe growth can be associated with food supply, which in turn is likely to be influenced by localised currents and their relationship to weather dynamics. It is well established that changes in weather patterns or upwelling may well influence the distribution of nutrients within the marine environment (chapter 7). The final position and conclusion must however be that, as in the case of the 8.2K cal bp event, further targeted research is required.

9 Review and Conclusions.

This chapter reviews the project against its aims and objectives. It reflects on the approaches adopted and how they fit into the discipline as it exists today, along with consideration of recent developments.

9.1 Aims and Objectives.

9.1.1 The Zooarchaeology of the Remote Scottish Islands.

This project sought to improve the understanding of the Mesolithic hunter-gatherers of Atlantic Europe. The approach was to firstly extend the Mesolithic record by revealing the characteristics of faunal exploitation in the Western Isles and Shetland Isles. This has been achieved and it is clear that the occupants of the archipelagos adopted specific solutions in response to the ecology of the islands and the adaptability of hunter-gatherers is clearly demonstrated. It has also been possible to observe aspects beyond simply what the people and their dogs ate. In the Western Isles a change in site function, and therefore most probably the spatial organisation of settlement in the area, is evident. The results obtained also contributed to the consideration of the 8.2K cal bp event and consideration of environmental change during the 5th millennium BC as discussed below. The assemblages also highlighted a specific theoretical challenge of a taphonomic nature. If the fish remains constitute unwanted discard, then any calculation of the contribution to the subsistence economy of these very small specimens will erroneously understate that contribution. In Shetland, human engagement with a pristine ecosystem is observed, along with an apparently rapid exhaustion of what was an ecologically marginal resource. A clear cut case of hunter-gatherers having a detrimental environmental impact and altering their environment.

9.1.2 The Relationship of Hunter-gatherers to their Environment.

This project's journey through the Mesolithic of Atlantic Europe has been a rewarding one and as highlighted several instances of, or what are likely to be, changes in the environment which were negotiated by the Mesolithic hunter-gatherers and these are summarised in figure C9-1. A primary objective of the project was to better understand the relationship between hunter-gatherers and their environment. This required something of a 'drains up' review to consider the real requirements of hunter-gathering groups for different subsistence resources and raw materials, and this revealed just how critical wood and the other products obtained from trees are. It also highlighted a significant role for mollusc shell, and a relatively minor role for lithics, in the technocomplexes. Considering the botanical environment purely in terms the supply of firewood and fruit is inadequate. Whilst the author's engagement with the specialised literature was no doubt inadequate, within the general archaeological literature the author encountered little consideration of the sensitivity of trees, berry bushes and their yields to climate, for example variations in precipitation; neither was a consideration of the timing and length of the harvesting window in response to temperature changes encountered. There is a need to catalyse greater integration and collaboration between the specialists in faunal remains and those in botanical remains, and in the case of the latter, greater engagement with those employing an ecological perspective.

In terms of furthering understanding of the relationship between hunter-gatherers and their environment a multi-proxy approach was adopted. The concept of eco-behaviour was employed, and it was changes in eco-behaviour that were initially identified. Within the body of literature consulted the integrated analysis of species within the same taxonomic class was very rare; integration across multiple taxonomic classes was even rarer, as also observed by Parks (2012, p.12). In chapter 3 the matters of association without causation or causations lacking associations were discussed. This is a major challenge as it is very improbable that climatic reports or weather reports will ever be available to prehistorians for a specific, century, decade, never mind shorter periods. The approach adopted was one of identifying changes in eco-behaviour in relation to a single taxonomic group and then cross-referencing these to the eco-behaviour profiles of other taxa. This was carried out in conjunction with published climatic proxies (or models), to generate a parsimonious consensus on probable causal relationships. At the time of writing the author does not believe such a process can be parameterised, but must at least for now, remain predominantly a human endeavour. This highlights one important aspect and that is human cultural influences on the archaeological record, as exemplified by the humble periwinkle at more northerly latitudes. The consideration of molluscs as proxies for environmental

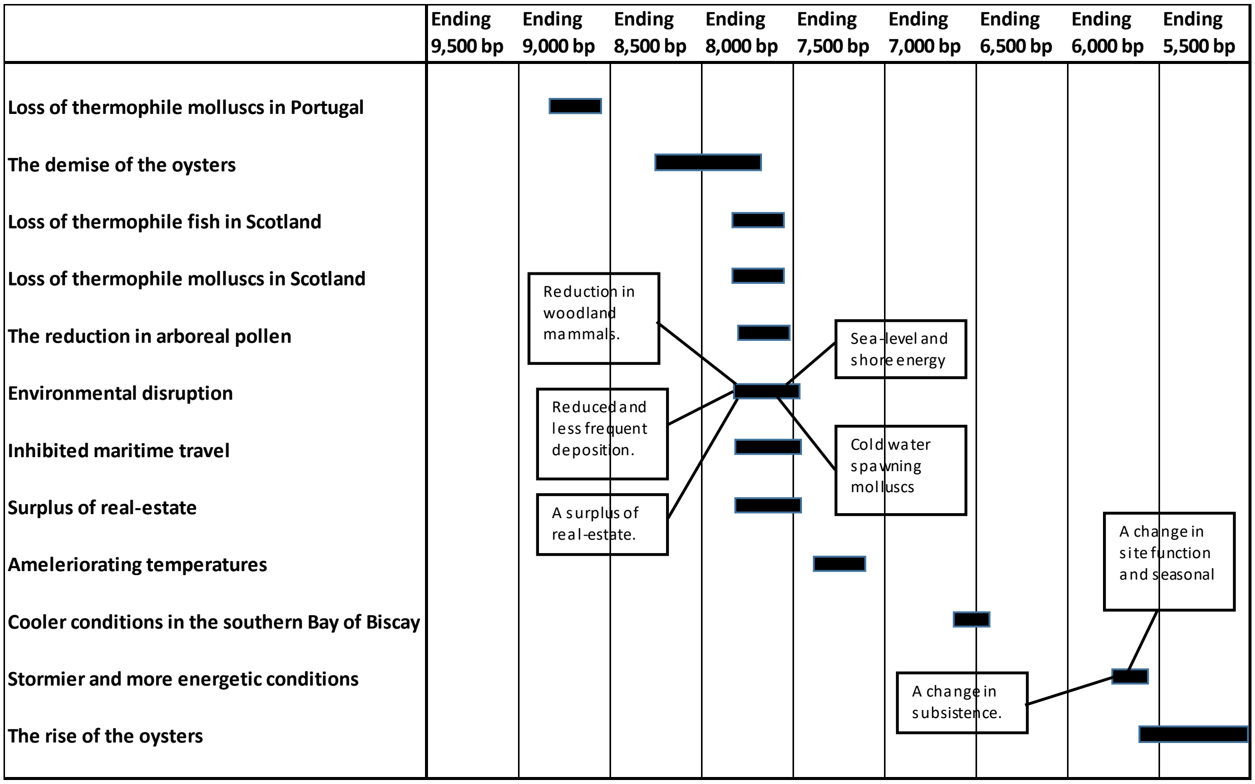


Figure C9-1: Approximate chronology of the environmental and eco-behavioural changes identified by this project. Many are associated with known environmental events such as the 8.2K climatic event and Storegga Slide, the cause of others is less clear. Dates are cal. bp.

conditions and vectors highlighted how favoured by hunter-gatherers this marine snail is. In principle it should be a proxy for lower shore energy levels and weed cover. Yet even when all other proxies suggest its abundance should be minimal, or its size should be reduced, it still features strongly or is present when it should not be at all. The people desired them, knew where to obtain them, and made every effort to secure them, even if their abundance and spatial distribution were constrained. This is a clear example of where a change in eco-behaviour, after consideration of multiple proxies, turned out to be primarily behavioural in nature. Given this clear preference, any switch towards dog whelks must either be related to a disruptive environmental change or a new and alternative use for dog whelk.

Identifying eco-behavioural change rather than behavioural change or ecological change at the taxon level was the approach adopted. This permits change to be identified but postpones interpretation until multiple proxies have been consulted. Consulting multiple proxies can permit the eco-behavioural change to be decomposed into behavioural and biological-ecological components. Where such decomposition cannot be immediately achieved the eco-behavioural change will point to future research agendas, and potential methodological approaches.

9.1.3 The 8.2K cal bp Event.

The review of the 8.2K cal bp event highlighted that human groups experienced challenges that are consistent with the theoretical considerations of a cold period compounded with tsunami. The archaeological record is consistent with the climatic modelling of the event. On the Atlantic façade of continental Europe, it seems likely that the event was probably inconvenient rather than disruptive, the situation further north was almost certainly more challenging. Whether north-western Scotland and Atlantic Norway were abandoned is for the author a moot point. The author unsurprisingly failed to analyse an absence of archaeology. The evidence suggests smaller group sizes, less frequent visits to some sites, constrained maritime travel, and based upon the available PDs, hiatuses in occupation at other sites, and therefore a surplus of real-estate.

Identifying an absence of archaeology is challenging and identifying a tsunami is equally so. But it was possible to identify a profile where the structure of deposition in terms of taxonomic abundance was unlike anything elsewhere in Scotland and suggested a possible restructuring of the mollusc community, but this remains very open to debate. Similar profiles are known from southern England, and some of the features at Ferriter's Cove in Ireland exhibit similar abundances and possibly similar magnitudes of change, but neither site can be associated with a tsunami. It would have been advantageous in terms of methodological development if the tsunami and the cold event had not been contemporary. No doubt the hunter-gatherers held this view but from a rather different, and certainly more justifiable, perspective.

9.1.4 Environmental Change during the 5th Millennium cal BC.

Consideration of the 5th millennium cal BC has highlighted changes in eco-behaviour which can be related to changes in the environment, particularly shore energy levels, possibly culminating in a reconfiguration, or extension, of the shoreline available for exploitation. The initial increase in shore energy level may be a local phenomenon, but there is evidence that it was more geographically extensive. This latter point cannot be argued with such certainty as it can for the Western Isles alone. The primary reason for this is simply that it has not been possible to supplement the data available from Oronsay and Ferriter's Cove with that which can be obtained through the application of the methods and techniques deployed on the Western Isle's assemblages. The application of these methods and techniques could have resolved the seasonality of saithe fishing further and untangled the overlap between 1st and 2nd year classes of fish which makes the interpretation of demographic histograms such an exercise in mental contortionism. The morphology of the dog whelks and therefore shore exposure levels could have been established on an intra-midden basis despite the lack specimens of complete length. Similarly, the gaps in the periwinkle data could have been addressed. For otoliths, and both marine snails, more robust sample sizes would have been achievable, and preservation biases related to size established. This can also be said in relation to Sand and Ulva cave during the 9th millennium cal bp[7]. It may also be possible to use the results from such techniques to explore the stratigraphic integrity of An Corran and possibly generate sufficient confidence to bring it 'back into the fold' and further elucidate the 8.2k cal bp event.

9.1.5 Facing up to the Challenges.

As anticipated when defining the project's aims and objectives the challenges of the archaeology, including those hiding in plain sight within the literature, had to be engaged with. This required the development of new approaches, or revisions to existing methodologies, in support of the application of established, and verified, techniques. The strategy permitted the population dynamics of procured razor clams to be tracked. Likewise shore exposure levels and differential processing of marine snail species could be identified from assemblages that were highly fragmented and generally would have been side-lined due to an insufficient sample size of complete specimens. This latter point raises a key point the author would like to restate. The biometrics of all fragmented specimens must be reconstructed (where technically possible) even when the sample sizes of complete specimens are 'sufficient to support analysis'. It is essential that any size or morphology related taphonomic bias is understood. This 'philosophy' extends to fish, marine molluscs, and crustaceans. The situation with other vertebrates requires further consideration as this project did not encounter such remains in sufficient quantities or diversity to support the development of a hypothesis.

Ignoring matters such a micro-mill 'going rogue' and a broken (for an extended period) mass spectrometer, the approach to isotope analysis can be improved and this was reviewed in SI-Chapter8-2.

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[7] To be clear, compared to most assemblages considered by this project Sand Rock Shelter borders on the utopian in terms of availability and resolution of data.

The project also experienced some abject failures. The biometrical speciation of the razor clam populations, to support the evidence for changes in shore energy level, could not be achieved due to the inadequacy of the author's modern collection. The intention to compare the growth rates of cockle around the 8.2K cal bp event with other periods was abandoned (after sectioning and analysis), as it was clear from a review of further ecological literature that the reasons for differential growth were too numerous and varied. The former the author hopes to address soon through further visits to the beaches of north-west mainland of Scotland and the Western Isles. The latter requires more consideration to develop a solution if one is even possible. The collection of biometrics from the NHM's hare collection was a failure and limited the time the author could spend with the crab collection, which whilst very successful, was limited due to the author's failure to appreciate the significance of the swimming crabs and therefore collect biometrics from them.

The project has been an enjoyable and rewarding endeavour but not without its frustrations and it may surprise some that the equipment failures described above are only a very minor component of such frustration. The observations that follow relate specifically to coastal shell-middens, although they may be applicable, at least in part or conceptually, in other spheres of the wider discipline. The first source of frustration is the total lack of standards for the publication of faunal assemblages. This observation is equally applicable to both the information available and the granularity with which it is available. For limpets, all three dimensions were recorded for Spanish assemblages, yet width is not for Scottish assemblages. If the height and length are being recorded, then it takes just a couple of seconds extra to record the width. Some publications only record (or present) the height of dog whelk shells even though this is environmentally variable. The Culverwell paper cites the site's monograph in support of a statement that the dog whelk morphology reflects a sheltered shore. The monograph contains a written statement to this effect but no supporting data. Rather than a citation, this reference is a quotation of an unsubstantiated claim. In Europe, some papers describe the thick top shell in terms of height, others in terms of width, making comparative analysis impossible. The requirements for a DNA sequence are defined by standards and the same principle should exist for faunal remains. For example, each limpet should have width, length and height recorded, those for which width is unavailable due to fragmentation can be flagged. A limpet that has height or length unavailable is of little use and hence should not be uploaded at all. The standard for periwinkle should include SH_L and AH_L and fragmented specimens should have AH_L if it can be captured. Such a regime does not prevent the upload of additional metrics but defines the minimum requirements, which from time to time can be subjected to a review, and if warranted, amendment.

There is no doubt that the inadequacy of the published data, often not even extending to a useable set of summary statistics, is a consequence of the publication process. The restrictions on figures and tables are arbitrary and combined with arbitrary word limits simply reduce the effectiveness of publication and therefore the investment in research. The publication of the raw data must occur in a location and form other than a journal or printed volume, as even the use of on-line supplementary information or appendices would not permit the publication of raw data at maximum stratigraphic resolution.

Further issues exist in relation to aggregated values. The data should be available at the greatest level of stratigraphic resolution. How and what to aggregate should be left as a decision, with justification, for the researcher generating the raw data and the future researchers that utilise it. In this regard the Scotland's First Settler's team demonstrated considerable vision and made the raw data available for download at the greatest stratigraphic resolution; and in doing so also addressed many of the aspects discussed in the preceding paragraph. This model must be adopted, not just more widely, but as a prerequisite to publication as is the case with DNA, where publication is predicated on the new sequences having been loaded and verified on Genbank. DNA and aDNA simply could not function in the absence of a standardised regime. Whilst it is expected that excavations conducted prior to the middle of the 20th century will not have recorded faunal remains adequately and will therefore always be a source of 'legacy drag', it is concerning that in the 2nd half of 20th century and on into the 21st century tomorrow's 'legacy drag' is still being created.

It is beyond the scope of this project to propose a set of standards, but the above gives a flavour of the way in which the discipline can more forward, not only in terms of the primary objective of generating improved archaeological understanding, but also, even if only *en passent*, making robust contributions to paleoenvironmental research and therefore research into the consequences of future environmental change on human societies, and especially the most vulnerable ones. It is not an accident that the issue of sampling has been avoided thus far. It should be relatively 'easy' to agree a standard for what proportion of a taxon's remains within a stratigraphic unit should be subject to biometric analysis. Excavation sampling is a different matter; should analysis be conducted against a single 1m square column or several smaller columns? If the biometric standards include those that permit reconstruction from fragmented specimens then smaller excavation samples (but maybe more of them) should be a viable option. Based upon the author's engagement with the West Voe archive and the published descriptions of other excavations, it is obvious that publishing excavations is extremely difficult, especially if they are to be easily understood by individuals not involved in the excavations. The author expended significant amounts of time trying to understand the stratigraphy at various sites. Dating is perennially an issue, even ignoring the lack of accuracy, dates are rarely available from the stratigraphic units the faunal remains are taken from. This is not an easy problem to solve in the absence of an infinite budget. Probably a significant portion of a project's dating budget should be held back to date those aspects that are of significance once the post excavation analysis is well underway or complete.

Another aspect to be considered here is that of interpretation. There is often little evidence of engagement with or understanding of the ecology, behaviour, or physiology of the taxa whose remains are analysed. A specialist report on bird bones highlighting 'the notable absence of diving birds in the assemblage' when it is dominated by members of the cormorant family, and a peer reviewed paper asserting the presence of penguins in the northern Atlantic must be a cause for concern within the discipline. The whole seasonality debate on Oronsay is built upon the false premise that larger saithe do not frequent inshore waters during six months of the year. One cited authority commented on the surprising absence of oysters in an assemblage. This author is not surprised given the heavily supressed summer temperatures of the Atlantic facade; oysters would not be a viable or sustainable resource due to spawning trigger temperatures being reached for very short periods, or not at all. A more complete knowledge of the physiology and ecology of exploited taxon greatly enhances the prospects for an outcome. One aspect that has received little attention is the resilience of different taxa to exploitation and their ability to recover from excessive exploitation or mass mortality of a natural origin. Too many instances were encountered where only a rudimentary knowledge of a taxon is all too evident in published work.

The introduction of the 2020 calibration curves with no impact assessment is something the author simply cannot relate to. What now is the acceptable separation of terrestrial and marine samples for pairing to support ΔR calculation? Whilst calibration has, through the monumental efforts of specialists, facilitated great strides in archaeology, the occurrence of the disassociated maxima suggests to the author that the stage has been reached where the calibration process is no longer improving the outcome, but may be instead compromising it by generating noise. It is not difficult to envisage a situation, sooner rather than later, where researchers will need to switch to one sigma rather than two sigma PDs; surely a retrograde step?

9.2 The End of the End.

The opportunity offered by this project to observe just how adaptable hunter-gatherers were in both in their way of life, and to environmental changes at varied scales, has been a welcome one. One aspect that became clear to the author is that if change can be seen in the archaeological record then the level of change actually going on must have been much greater and that has permanently revised the way the author will consider the archaeological record. Prior to ending this work, it seems appropriate to address one more matter and that is the ‘elephant in the lab’. Can inferences of the nature of those made by this project be based upon a couple, or even one column sample (1m by 1m for example), from each site? It is an important question as it is unlikely that either excavation or post-excavation budgets will grow in real terms. The author’s view is yes; the data analysed in the manner it has been does not show random backward and forward variation, but rather specific vectors that can be identified in multiple sites, and probably across extended regions. Whether the ‘reset’ identified in the Western Isles, Oronsay and possibly Ireland, can be considered an isochron does however require more research. Overall, it seems that during the Holocene the hunter-gatherers of the Atlantic façade rarely, if ever, experienced environmental stability and adapting to change was just a way of life. Some of the conclusions reached and methodologies employed by this project will no doubt be challenged at some future date and rightly so. Reaching conclusions and developing methodologies is akin to setting records, their primary value is in provoking others to improve upon them. If this work achieves nothing more than provoking further research and method development from others, then the author is more than content.

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Hunter-gatherer and Environmental Relations during the Mesolithic of Atlantic Europe.

Volume II

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Introduction.

This is the second volume of the PhD thesis ‘Hunter-gatherer and Environmental Relations during the Mesolithic of Atlantic Europe’. It contains information that supports the main body of the thesis presented in volume I. It includes:

- Detailed data observations in both textual and summary statistic form.
- Detailed outputs from statistical inference testing.
- Detailed technical methodological descriptions and definitions.
- Justifications for decisions stated in the volume I.
- Other supporting information considered to be of value.

The sources cited in this volume are included in the bibliography supplied with volume I.

SI-Chapter3.

SI-Chapter3-1: Raw Data Regarding the Moachat

The ethnographic Source – Background.

It should be noted that Jewitt (1824)'s account post-dates initial European contact and the subsequent rise of the fur trade, particularly in the pelts of the sea otter. European ships who trade for the skins from the indigenous people and then transport them to China for onward trade (p.90; p.230-231). John Jewitt was one of two Europeans taken as slaves on 22nd of March 1803 following the sacking of their ship The Boston. These individuals remained as slaves of the Moachat for nearly three years, during which time John Jewitt maintained a journal that provides a valuable view of the Moachat's way of life.

The edition available to this project is that published in 1824 and the preface acknowledges that several editions had already been available in the United States of America. Some caution appears to be necessary, for example, McMillan (1966) cites the 1915 edition extensively, whilst acknowledging the valuable insights it provides and notes that like Drucker (1951, cited in McMillan, 1966), Jewitt (1915, cited in McMillan, 1966) does not report the extensive carving of the building frame posts. Yet in the 1824 edition Jewitt states the structural posts were carved in the form of huge heads which were also painted. However, in general the description of economic practices appears to be consistent between the editions. Jewitt (1824) very helpfully highlights the influences of European contact, which permits a correction to be made such that the risk evaluation can be based upon the indigenous technologies; examples include muskets over bow and arrow and the use of iron over lithics for knives, and also fishhooks and harpoon heads.

Raw Data in support of the tables provided in volume I:

General

1. The Moachat and the indigenous peoples of the British Columbia in general practised a logistically based economy that harvested resources during periods of seasonal abundance and employed storage to address seasonal shortfalls in abundance. Within Binford's (1980) classification the Moachat will be considered as collectors and in Woodburn (1982) scheme delayed return.
2. The fits however are not perfect. Binford (1980)'s collectors usually exhibit sedentary habits with task groups going to locations for what are short residential occupations in order to procure resources which are then returned to the residential base. The Moachat do not rigidly conform to this definition as the Moachat move the entire population (*circa* 1,500 - 2000 individuals) to the seasonally available resources through residential moves between three locations.

3. The one exception to this behaviour is the mixed sex task force which takes up temporary residence to collect yama berries. The above highlights that the probably this deviation is due to the fact that longer distances can be traversed in canoe and likewise larger amounts of resource transported back to the residential camp.
4. When the Moachat definitely do generate Binford's location site type it is when they obtain a terrestrial resource from the interior (Yama berries).
5. Suttle's (1967; 1987)'s discussion of other groups within the wider region implies that the Moachat of Friendly Cove may be an exception and where the marine adaption is less extreme a different situation manifests itself. The extended group identity is fixed against the winter camp location and this is a location of group fusion and the summer camps are on a smaller scale and more distributed and these become populated through seasonal fission of the group.
6. In terms of Woodburn (1982)'s delayed return model the Moachat certainly meet this definition, but they do not amass resources during the seasons of abundance and then scrape through the winter as the Paiuti do, at each residential location substantial additional resources enter the system as described below.
7. There is evidence that the antiquity of extensive and intensive exploitation of salmon is only around 500 years prior to which the primary resource was herring (Moss *et al*, 2016).

Social Structures and Architecture

1. There is almost universal agreement that indigenous people of the north-west Pacific were hunter-gatherers exhibiting complex and hierarchical social structures at the time of European contact.
2. There are a large number of groups who identify themselves as distinctively different from their neighbours. Based upon Suttles' (1987) there are 22 language groups who had direct access to the coastal margin either directly onto the Pacific or the various inlets and estuaries in the area.
3. A further ten groups had territories that provided direct access to the many rivers in the area, especially the Frazer River and its tributaries. The Moachat occupy western (Pacific) coast of Vancouver Island.
4. Jewitt (1824, p.102-105) notes that many of the visiting groups spoke the same language. Suttles (1987, p.31-40) highlights that whilst the economic systems of the extended area can be generally grouped as based upon seasonally abundant marine resources, there is actually significant variety in the biotopes exploited by particular groups and therefore also in the detail of their economic systems. Suttles (1987, pp.42-43) also notes that this in turn results in nuances in social behaviour, such as in the way potlatch demonstrations of wealth distribution were conducted.
5. Jewitt (1824, p.102-103)'s account supports this view given that specific mention is given to a group who had trading ties with the Moachat group, that whilst speaking the same language, had a far greater focus on terrestrial hunting. McMillan (1966) notes that the Moachat were probably the group with the greatest degree of adaption to a marine resource exploitation and that this is consistent with the high-levels of

precipitation, which when combined with physical relief and dense forest cover made movement overland difficult.

6. Jewitt (1824, p.132) also observes that whilst a great variety of resources are exploited by the Moachat all are, but incidental, compared to the roles of fish (including whale) and yama berries; of course, Jewitt's comments relate only to consumption and not raw materials.
7. The Moachat are generally classified as complex hunter-gatherers whose social structures contained at least three tiers below the overall chief. Sahlins (1963, p.287) suggests the social hierarchy and political organisation is analogous to those observed in Polynesian chiefdoms. The tiers were populated by chiefs, commoners and slaves (Jewitt, 1824, pp.; Suttles, 1987, p.6; pp.16-17). A nuance in terms of the overall social structure was the existence of what Jewitt (1824, pp.100-101) refers to as vassal tribes who lived in separate 'satellite' villages and who were not permitted a chief class or the ownership of slaves.
8. Jewitt (1824) describes events that can only be considered instances of potlatch. He quotes Maquina as stating that his right to be chief was based upon success at generating and redistributing wealth (Jewit, 1824, p.nn).
9. Potlatch was an integral component of their economic and cultural system and some form of bear cult was practiced (Jewitt, 1824, pp.132-135) which is not uncommon in the northern Pacific or temperate environments in general.
10. The Moachat cannot be considered sedentary as they exhibit low frequency residential mobility, which involves moving between three locations as part of a seasonal round (Jewett, 1824; Suttles, 1987).
11. The summer village at Yukwat contained around twenty large houses which were very substantial and were made by putting a planking skin over a substantial load bearing frame (Jewitt, pp.68-70).
12. The width of the plank houses was fairly consistent at between 11 and 12 m, length was more variable between 15m and 46m and appears to have been linked to social rank (ibid, p.67-68).
13. The relocations are undertaken by canoe and involve the entire community. As well as relocating all their belongings, the planking that covers the longhouses is also relocated leaving the substantial framework in place ready for their return (Jewitt, 1824, p.117).
14. Such frameworks are present at each of the three locations they utilise on a seasonal basis. These cannot be considered anything other than very substantial with timber members of up to 31m long and 2.5m in circumference and therefore about 0.8m in diameter (ibid, p.68).
15. Ames (1991) suggests that the evidence for substantial architecture either in the initial form of thatched long houses, and later the plank house, exhibits significant time depth and precedes European contact by a millennium at least.
16. Funeral descriptions are generally available for the elite and the bodies were placed in wooden boxes (sometimes a canoe; McMillan, 1966) in a sitting position with the knees against the chest. Grave goods were incorporated both in terms of the deceased's personal wealth and that of relatives.

17. Goods included sea otter skins, cloth and blankets, and strung dentalium shell (Jewitt, 1824, pp.155-156; pp.147-148). This latter item is probably a good proxy for the state of the prestige economy as it can only be obtained through trade with a particular group, or in payment for a valuable item such as a slave (ibid p.104).
18. Prestige goods were also burnt in what can be described as a wake, the goods were those that belonged to the deceased but also those of relatives wishing to attest the deceased status (Jewitt, 1824, pp.155-156; pp.147-148).
19. Deceased slaves were simply thrown into the sea.
20. The Moachat are heavily dependent upon their canoes, for whaling, hunting and fishing activities. These range from small single man vessels to larger examples that are specifically for war and whaling. Canoes also enable the residential moves to be executed in the manner described above, which would almost certainly be impossible overland given the observations made earlier.
21. Jewitt (1824, p.93) measured the largest canoe at 14 meters in length and states that it carried a crew of 40. The method of manufacture is basically that of a dugout canoe with the largest examples being made from large pine trees.
22. Jewitt (1824) noted that despite he and his colleague being able to fell a large tree in hours using iron axes, the Moachat preferred their traditional approach of using chisels, even though it took three of four men several days to fell a large tree.
23. Trees were not only utilised for canoes and of course firewood, but also to produce substantial ‘vats’ for storing and cooking food, these were produced in a manner similar to making a dugout canoe (Jewitt, 1824, p.72).
24. The bark of trees was used to make the Moachat’s cloth, nets, rope and cord. Huge amounts must have been required.
25. The component parts of baskets and weirs were secured with flexible twigs and not bark twine (Jewitt, 1824, p.n)
26. the narrative provided by Jewitt (1824) highlights a number of aspects of interest.
27. Firstly, that terrestrial animal resources are consumed immediately with Jewitt (1824, p.135) noting that terrestrial meat is only consumed when absolutely fresh and the limb bones of deer were used to make whistles for use in ceremonies.
28. Marine resources, particularly whale meat and fish spawn, are often consumed in a putrefied state (ibid, p.121, p.135).
29. Whether consumption in such a state by a European would lead to food poisoning, in a potentially fatal form, is unclear. What Jewitt describes as the unbearable stench to, which he could not acclimatise, appears to have discouraged him from conducting the experiment on our behalf. Suttles’ (1987, p.55) description of fish spawn in this preserved state is as being something akin to cheese.
30. It is possible that the economic system of people such as the Moachat is underpinned by physiological adaption, relative to Europeans.
31. It also highlights that delayed return economies may be heavily dependent upon resources that are archaeologically invisible, and unlike plants, in any circumstance.
32. It also highlights that resources that might be considered unsuitable for storage without modern refrigeration were in fact utilised in just such a manner.

33. Yukwat is occupied from the end of February until the end of August after which the group move to Tashees (50Km) until the end of December. The group then relocate to Cooptee 25Km until the end of February, after which they return to Yukwat (25Km).

The Village of Yukwat (March – August).

1. This the location where the group spend the most time and undertake a number of important economic activities. Jewitt (1824) identifies this location as Yukwat (actually Nootka) village.
2. The correct designation is Yukwat according to McMillan (1966) and this identifier is utilised going forward.
3. This location provides access to open oceanic waters. Hunting focuses on seal (*Phoca vitulina*). sea lion (*Eumetopias jubatus*), sea cow (the now extinct *Hydrodamalis gigas*), toothed and baleen whales (odontoceti and mysticeti) and sea otter (*Enhydra lutris*), although ducks and geese (anseriformes) are also procured (Jewitt, 1824, p.89), albeit in relatively small quantities.
4. Given the sea otter was being acquired using muskets (Jewitt, 1824, p.n) they were, presumably, traditionally acquired with a bow and arrow.
5. The otter was consumed and it's pelt was utilised in clothing (Jewitt, 1824, p.73), and the teeth were often used as status decoration during burials (McMillan, 1966); but as already stated it seems likely the focus on this animal observed by Jewitt is an artefact of its value to European traders.
6. Fishing activity is focused on halibut, cod and salmon using hook and line (ibidem, p.91).
7. It seems likely that the salmon caught were chinook and coho as these species are still actively feeding when they arrive back in nearshore waters, whereas sockeye, pink and chum are not (Suttles, 1987, p.33-34).
8. The modern local fishing reports (of which there are very many due to the active focus on conservation) suggest that capture during the spring and summer is also consistent with these two species being targeted in this manner.
9. Ignoring the effects of the recent hatchery initiatives, only chum and coho frequent the smaller rivers such as the Conuma and Gold in any numbers (Suttles, 1987, p.34).
10. ignoring the effects of recent hatchery initiatives in this part of the region, the procurement effort appears to be an interception of fish making their way back to the Fraser and other rivers.
11. It is also significant to the archaeologist that the hooks utilised are not what we would recognise as a hook or even hook shaped (Jewitt, 1824, p.91; McMillan, 1966). Form (straight with both ends pointed) is similar to that used as gorge hook for snaring birds both by other groups in the region and also the people of Tierra del Fuego.
12. The bait utilised is a sprat (although this is clearly something different to the European sprat) but Jewitt (1824) provides no indication of how these were, acquired fresh. Sprat were taken in large numbers at Cooptee during the winter and maybe this is, after preservation, the source of the bait. Such an approach however contradicts modern experience as fresh bait always outperforms preserved bait, whether it is frozen, or some other technique used (pers. obs). At some venues, for some species, fresh bait is

basically the only approach that works, and the use of preserved bait can be considered nothing more than giving it a punt whilst enjoying the view and sea air. (Pers. obs).

13. The method described by Jewitt (1824, p.91) for taking salmon would today be described as trolling. 15 fish could be taken in a morning.
14. The approaches adopted to catching halibut and cod are not described by Jewitt (1824), but generally bait or lure would need to be presented at much greater depths, which can be a significant technical challenge in the presence of any non-trivial current, including the tidal race (pers. obs). Today one would resort to very thin wire line in such circumstances combined with 0.7kg to 1kg of lead.
15. A variety of smelt (*Thaleichthys pacificus*) known as the candle fish can also be taken from the lower reaches of rivers in the region but was not a key or abundant resource in the area occupied by the Moachat (Suttles, 1987, p.47-48) and Jewitt (1824)'s account makes little or no reference to it.
16. One of the last economic activities to be undertaken at Yukwat is the procurement of herring spawn. This is undertaken by using (weighted down) pine branches and similar, to simulate the eel grass (*Zostera spp.*) that herring target for spawning (Jewitt, 1824, p.119-120; xxxxxx et al, yyyy). The spawn is washed, dried and stored in baskets and is transported during the residential move to Tashees.
17. The relocations to the autumn and winter residencies appears to have two motivations, the first is to exploit specific seasonal resource abundances and the second to move up the inlet to be more sheltered from frequent and often protracted winter storms.
18. Whaling is also carried out at Yukwat and appears to have certain social customs related to social rank associated with it (Jewitt, 1824, p.93).
19. The procurement of whales was actively undertaken in large canoes utilising harpoons, these had a leader of whale sinew (7 or 8m in length) which was attached to rope made from bark, which Jewitt (1824 p.92) describes as being up to 110m long. To this were attached between 20 and 30 inflated seal skins to inhibit diving by the whale (ibid, p.n).
20. The head of the harpoon was composite being made from a combination of whale bone and sharpened mussel (*Mytilus californianus*) shells (ibid, p.92, p.151).
21. The whale flesh was consumed, as was the blubber, one particular aspect highlighted throughout Jewitt (1824)'s account is that whale oil (train oil) was used as a condiment to almost everything the group ate; be it poultry, meat, fish, fish spawn, or fruit. Suttles (1987, p.55) highlights that several researchers have suggested that this was probably a nutritional necessity due to the lack of carbohydrates in the diet.
22. Oil was acquired by boiling the blubber of sea mammals and skimmed of the surface (Jewitt, 1824, p.n). Oil was stored in seal skin bags (often made up of several skins).
23. The largest bags of oil took six men to lift them (Jewitt, p.nn).
24. The only root crop that receives and attention is the quawnoose (*Camassia* spp.) which was obtained solely through trade with another group.
25. It is highly probable that oil from the blubber of other sea mammals was also utilised in this manner in the southern part (the Moachat and further south) of the region. Further north, from the Kwakiutl up to the Skeena system the primary source of oil was from the candle fish (ibid).

26. The Moachat and Kwakiutl have adjoining territories and the fact that the risks applicable to sourcing this nutritionally critical resource were different will be given attention in due course. Whale bone was also utilised for tool manufacture and constant reference to this raw material are made throughout Jewitt (1824)'s account, including in the construction of harpoons and herring rakes.
27. Bone tools were utilised extensively as wedges, awls and hammers. The spines of the dogfish (*Squalus suckleyi*) were also utilised as awls and needles although the flesh was ignored (McMillan, 1966); an attitude the author can empathise with. The use of dogfish skin as an abrasive is also a possibility.
28. Other coastal resources were also exploited to varying degrees and these include sea urchins (echinoidea), a type of crab (brachyura) and clams. The latter were preserved by drying (Jewitt, 1824, p.n).
29. It seems likely the major species exploited were the butter clam (*Saxidomus gigantea*), horse clam (*Tresus spp.*) and possibly the geoduck[8] (*Panopea generosa*). It is also possible that scallops (*Pectan spp.*) were exploited.
30. Jewitt (1824) only refers to the collections of clams and is no more specific, highlighting only that this resource was preferred during the summer, and therefore the implication is that it was exploited at Yukwat.
31. Suttles (1987, p.34) when discussing the Coast Salish people also states that clam digging was a summer activity but with the objective of preservation as winter stores. Jewitt (1824, p.158) does refer to the consumption of dried clams in December.
32. He does however highlight the importance of mussels (*Mytilus spp.*) to the people. These molluscs were not only consumed but the shells utilised as vessels for liquids and also tools when the edge was sharpened; uses include components within harpoon heads and pelt scraping (ibid).
33. Jewitt (1824, p.98), explicitly mentions cockle (*Cerastoderma edule*) although not in relation to general consumption as this species and mussels were also strung to make rattles for use during musical rituals.
34. Two species of mussel are available within the area, the blue (common) mussel (*Mytilus edulis*) and the giant pacific mussel (*Mytilus californianus*).
35. When the physiology and ecology of these species are explored in more detail the results are quite a revelation for anyone whose experience is limited to the shell middens of Atlantic Europe.
36. Of note, are the butter clam whose shell can be 150 mm in length and can weigh 0.5 kg. This species also burrows to quite a reasonable depth of 0.35 meters when compared to the common cockle which only burrows to a depth of around 0.05m.
37. The horse clam burrows to a depth of around 0.4 m and has a shell length of up to 200mm and can weigh 1.8Kg.
38. Even more startling is the geoduck with a shell length of 200mm which burrows to a depth of around 1.3m, and the syphon through which it feeds extends to the surface and an individual animal can weigh up to 6kg, although 0.7kg is more typical.

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[8] Jewitt (1824) makes a concerted effort to highlight aspects that fellow Europeans may have found interesting or unusual. Given the extraordinary size of this bivalve and the absence of any reference by Jewitt to such a resource, acquired or traded, suggests that it was not exploited to any degree.

39. Whilst the blue mussel is the same species as that observed in the north Atlantic and grows to a length of 100 mm, but within the intertidal zone 20 to 30mm is typical.
40. The giant pacific mussel grows to a length of 200 mm. All the above suggest that even the molluscan resources were available on a much greater scale than is normally assumed. It is notable that whilst "clams" are sought and also stored; the consumption of cockles, the smaller blue mussel, and limpets were a famine response (Jewitt, 1824, p.162) and this is consistent with the assemblages presented by McMillan (2008).

Tashees Village (September - December).

1. At Tashees the economic focus was on salmon and given this occurred during the autumn it is likely that the species exploited were either chum and or coho salmon.
2. The Moachat's territory does not include the Frazer River but numerous smaller (by the standards of the region) rivers yet yields were potentially very high. Jewitt (1824, pp.120-122) reports that the fish are captured in weirs and basket traps and asserts that he observed over 700 salmon being caught in 15 minutes, and a delivery of around 2,500 processed salmon being delivered to the chief's long house.
3. The traps are not deployed in a totally passive manner, but the fish are actively driven towards them (ibidem). As Tashees was occupied during the autumn it is likely that this seasonal harvest was primarily of running coho, and possibly chum, salmon.
4. A variety of wild berries, including strawberry and blackberry were harvested and consumed when in season and on a small scale for immediate consumption (Jewitt, 1824, p.132); suggesting that such exploitation occurred primarily at Tashees during the autumn. Whilst at Tashees, Jewitt observes that the only logistical exploitation of plant resources occurred.
5. Whilst in residence at Tashees task groups were despatched into the mountains of the interior for the explicit purpose of harvesting of what appears to have been from the description, the berries *Amelanchier alnifolia*, a common shrub with numerous vernacular names and which Jewitt (1824, p.131-132) refers to as yama berries.
6. The collection was carried out by the women who stayed in camps for several days. These groups also included men tasked with protecting the group from wild animals. Based on the author's experience of the remoter fishing streams of Vancouver Island this appears to be a prudent measure.
7. The guides operating today do not consider bears as such a serious threat as they are noisy, and one knows if one is relatively nearby. The greater threat is that of the cougar (*Puma concolor*) which stalks silently and when it attacks allows no time to react with a chemical mace. The number of attacks recorded remains very low, but incidents of being stalked appear to be more common.
8. These berries are the only type of fruit that were preserved and stored, this was achieved by pressing and drying (ibid). Jewitt (1824, p.131) makes the interesting observation that these berries if eaten fresh, and without oil, cause cholics; attesting further the key enabling role sea mammal oil had within the Moachat's subsistence economy.

Cooptee Village (January and February).

1. Cooptee also offered relative shelter from winter storms. The period of occupation was short lived and focused on the acquisition of herring and sprats (Jewitt, 1824, p.143) using a rake of wood with sea mammal bone teeth, to scoop multiple fish per stroke into the canoe.
2. The amount of bark rope required to make a net with a small enough mesh to efficiently acquire herring is probably impracticable and hence the raking approach above.
3. Jewitt (1824) describes little other procurement activity, but he does describe great feasting of the whole group augmented by over 100 members of other groups (ibid, p144). The behaviour is described as an excessive consumption and waste of resources; where the objective can be interpreted as a desire to consume any accumulated stocks[9] (ibid).
4.

Other observations

1. Jewitt (1824) states that the Moachat had little interest in terrestrial hunting. Bears, carnivores and large ungulates were trapped, using a wooden structure the animal would enter and then it would be killed by triggering a load of larger boulders to fall on it (ibid).
2. Ducks and geese were targeted with bow and arrow (Jewitt, 1824, p.n), presumably deer would have been hunted with bow and arrow on occasion.
3. Another group who traded birds to the Moachat acquired them by startling them at night with a lit torch, the same way the Yamana do.
4. Another example of hunter-gatherers adopting innovative approaches to enhance the productivity and yield of desired resources are to be found on the North-west pacific coast of North America. One encourages the growth of saltmarsh root crops and the other marine molluscs. The principles are however very similar, particularly in terms of the human investment in construction and therefore they are considered together in this section.
5. Whilst there is no evidence that such an approach was adopted by the Moachat, the presence of clam and salt marsh plant[10] gardens is advocated within the literature. McMillan, 1966 summary of the Atlantic coast of Vancouver islands suggests very limited locations within the Moachat's terratory where such an approach could be adopted.
6. Groesbeck *et al* (2014) explored these features which they describe as the construction of walled terraces to extend the region within the intertidal zone to increase the yield of biomass from infaunal bivalves. The examples they consider are on the sheltered inner

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[9] This is something of a contradiction of the 'concern for the future' hypothesis suggested by Suttles and others in (Lee and DeVore, 1968, pp.89-92).

[10] An attempt to investigate this matter more fully was thwarted when the inter-library lone of a key source eventually arrived just as Covid-19 restrictions closed the university's library and prevented travel to collect it. Consideration is therefore limited to the summary provided in the sources cited.

(eastern) coastline of Vancouver Island in the territory of the Kwakiutl. In experiments these researchers observed a fourfold increase in biomass production from the targeted molluscs including the butter and horse clams referred to above.

7. Caldwell *et al* (2012) conducted a survey of such features in Coast Salish area encompassing the mainland, the inner coast of the south of Vancouver Island and numerous small off-shore islands.
8. These features are observed frequently and have a variety of defined shapes and occur at different tidal heights (ibid). One of the features noted was the clearance of boulders and stones from natural depressions in the bed rock to improve efficiency in trapping fish and other taxa, and notably this requires no actual construction effort.
9. Their interviews with local elders do not highlight the use of these features as specifically targeting mollusc production; the evidence suggesting that the mollusc harvest was improved by simply clearing rocks and boulders from the beach and piling them up either at the sides of a clam producing area or below the low water mark (ibid, p.223).
10. McMillan (1966) describes features very similar to this and that are formed through clearing of rocks to each side of an area as canoe skids for beaching canoes.
11. Clearly piling rocks at or below the low water mark is likely to trap sediment and possibly encourage bivalve colonisation, albeit unintentionally. The features were usually referred to by the interviewees as fish traps, from which several taxa were obtained including some invertebrate resources such as crabs and molluscs (ibid). A key unknown is, whilst there appears to be little doubt of the antiquity of these features, the depth of that antiquity remains uncertain (Groesbeck, 2014).

SI-Chapter3-2: Raw Data Regarding the Yamana

The Ethnographic Source - Background.

The source utilised is that of Martin Gusinde who visited the region for reasons of observation and study during the 1920s. The account combines his own observations with those of various accounts dating back 16th Century; the latter which he treats in an appropriately critical manner.

The version utilised is that translated from German into English by Frieda Schutze and published in 1961. Very detailed information is made available and evaluated by Gusinde. Clearly all the accounts, by definition, post-date European contact. Gusinde highlights were changes were occurring, particularly during the 19th and early 20th century due to such contact. For example, whale strandings and hunts were becoming very rare due to the efforts of the European Whaling Fleet.

The same is observed in relation to the availability of fur seals can be made as fur sealing fleets all but exterminated the sea lion population leaving the Yamana with the much smaller true seal to rely on. See also Yesner (2004).

The impact of the iron axe and iron in general is also commented upon. One aspect which is unclear from the accounts is whether, prior to the effects of European contact, the Yamana did really move around as an isolated family unit, often being concerned if a location they arrived at had recently been exploited by another family (p.376)?

The initial impression is that socialising was vital but not the norm. Was this a consequence of reduced resource availability and territorial constraint and was aggregation more common prior to contact? See Yesner (2004) for a discussion.

Citations from Gusinde (1961) are provided as page numbers only. Other sources are provided in conventionally.

Raw Data in support of the tables provided in Volume I.

Social Structure and Interaction.

1. The basic social unit is that of the nuclear family (p.384, p.583; Chapman, 1997, p.82, 85) and this unit in the most part operates as self-contained economic unit, which includes very integrated and complementary roles for the husband and wife (pp.217-281, pp.450-462; Chapman, p.82).
2. There is no formal hierarchy (p.634-636) but the opinions of male and female elders (who were also of past good character) were sought and respected (p.940).

3. In general monogamy is practiced, although there are certain circumstances where a widow may become a second wife, specifically a sister-in-law, if the brother of the man has died (pp.412-413).
4. Social order and behaviour are regulated through custom and the value applied to an individual's reputation, in other words public opinion (pp.938-940).
5. Throughout his account Gusinde emphasises the independence of the family unit not only economically but also in terms of mobility. Generally, when the account is viewed holistically it seems likely that family groups encountered each other, and shared campsites more often than the initial statements of independence imply (p.927-928; See below the activities requiring teams). (Note: compare the pinniped zooarchaeological record Munoz (2011) with seal butchery below).
6. The wider structure of the Yamana is made up of 5 dialect groups each of which have a defined territory (p.384). These territories are not (usually) defended and social visits between them by the Yamana occur without any constraint (pp.629-630, p.931), border violation by non-Yamana groups are considered illegal, but violent defence is not carried out (p.854).
7. The boundaries do appear to be enforced by certain social rules when it comes to economic activities, which can be summarised as groups undertake such activities within their dialect territory (p.855) and usually within the local territory. The dialect territory concept does not apply to activities to procure critical resources whose distribution is uneven; for example, bark, flint, iron pyrites (p.856). The principle is also extended to stranded whales (ibid).
8. Smoke signals in specific patterns are utilised to communicate; assistance required (illness or injury), immediate assistance required due to a crisis (including canoe loss, tool loss and

loss of hut fire (really?!, author), a death, a whale stranding (including. live stranding) (pp.932-933)

9. Each dialect territory is sub-divided into local groups (p.630, p.931) based upon closeness of kinship (p.633). There is no formal social hierarchy although a certain respect for the opinions of aged individuals is evident and this is often augmented by the 'exemplary' past conduct of the individual, their past deeds, and wisdom (p.671).
10. The Yamana appear to acknowledge a certain level of craft specialisation as certain individuals appear to be acknowledged as canoe making experts, whale butchery experts, as well as spear and harpoon shaft experts (p.109; p.310; p.168).
11. As might be expected large social gatherings are not the norm, exceptions being the initiation into adulthood which each individual does twice (p.639-640, p.658). Note: Archaeologically the large hut might imply sedentism or even a large tent.
12. In these ceremonies an individual is elevated, temporarily, to a status of being in charge (p.671) based upon a consensus that the individual is the most qualified and experienced available (ibid).
13. It is notable that such ceremonies do not have specific locations or schedules for where and where they occur. The events are catalysed by an event which results in a large number of families converging on a given location; such events include the acquisition of a whale or a mass stranding of herring (p.271, p.664-669).
14. Detailed high resolution studies of archaeological shell-middens which have evidence for a large number of huts indicate that these resulted from many single or double occupations over time and not large aggregations of people (Orquera *et al*, 2011; Godino *et al*, 2011).
15. Marriages and funerals are small scale affairs, unless the latter is for a very well respected and aged individual, and particularly if they are acknowledged as a medicine man (pp.665-

669). It is not possible to say more regarding funerals, other than burials are known to have occurred in midden deposits and within a family's hut (p.349). This latter point may actually be a simple consequence of the huts being constructed on midden deposits (pp.343-344; Orquera *et al*, 2011; Godino *et al*, 2011, p.127), which of course may already contain a burial. The Yamana are universally considered to be semi-nomadic and therefore their settlement locations are diverse and their architecture necessarily expedient.

16. The Yamana trade and acquire materials through gifts (pp.852-879). There are however no formal trade routes were a group sources particular items and trades them to groups who cannot source them (cf. the Nootka). The movement of raw materials, resources and artefacts appears to have been extensive, but the dynamic can be described as "the movement and distribution via diffusion".
17. Exchange (via diffusion) of materials and resources takes place within a dispersed network where the individual nodes (families) are mobile. Whale strandings generate a short term convergence of the nodes and reduce distribution distance and therefore increase speed.

Residential Mobility

1. The Yamana make camp wherever they need to, especially in response to rapid changes in the weather (p.21-23). Families reuse sites but only after being "left fallow" so that the targeted species of marine mammal and birds reoccupy the location and lose any fear they have developed (p.376).
2. As a consequence, a Yamana family runs the risk that their chosen (or enforced) campsite may have only recently been occupied by another family and the hunting and gathering may be compromised (ibid).

3. When the weather permits a more decerning selection of campsite, locations are sought that offer access to invertebrate resources, permit camping within a few meters of the shore and offer some shelter from the winds (pp.262-263).
4. Eventually elderly relatives are unable to relocate or hunt and forage for raw materials or subsistence. Widows or widowers accompany their children or close relatives (p.941).
5. An elderly couple remain together and become more sedentary and are provisioned by their children, grandchildren and close relatives (ibid).
6. Sheltered shallow inlets are favoured as the fish species targeted prefer them (p.262-263). Water depth is also a factor as the procurement of crabs, sea urchins, and large shellfish including mussels are acquired from the canoe using tools that have a maximum manageable length; as already stated immersion is avoided by the Yamana unless it is unavoidable or a particularly rich reward is on offer (p.260).
7. Where the family goes next is determined by three factors: does the weather permit movement at all (p.5), the direction and strength of wind and currents/tides, and the resource they would like to acquire next (pp.21-24).
8. In general, journeys are confined to the north of False Cape Horn and portage is carried out so avoid navigation south of False Cape Horn (p.379; Borerro, 1997, p.67-68); which is consistent with the limited visits to Isla Ildefonso being at least partly unintentional. (Note: how does a Mesolithic group end up in Shetland?)
9. A few families have been proven to have visited the Isla Ildefonso south west of Cape Horn (p.132), although the implication is that this may have been accidental when concentration on pursuing a whale resulted in a loss of bearings (or good sense) (ibid). The Yamana visiting the Diego Ramirez Archipelago is only supposed and no evidence exists (p.132; *Contra*, Mackie *et al*, 2011, p.91).

10. A point of note is that the Yamana are not very focused on housekeeping within their hut and if conditions become intolerable, they simply build a new one some meters away (p.31). This occurs when the period of residency exceeds around two weeks, as might be the case during an extended period of stormy weather or whilst exploiting a large whale carcass and participating in the social gatherings such events catalyse (p.31-32).
11. The Yamana's architecture reflects their high levels of residential mobility. There is evidence that the two hut types identified exhibit a geographic affinity (pp.9-12). The domed hut is observed in the wetter but less windy west of the region and the conical form in the drier windier east (p.9-12). Residential mobility is of course dependent upon the method of travel.
12. Residential mobility is enabled by the canoe. The solution developed by the Yamana contrasts strongly with the north-west Pacific (see main text), or for that matter the plank canoes of the Californian Chumash marine hunter-gatherers (Rick *et al*, 2011).
13. The difference appears to be rooted in population structure, density, and technology. What is less clear is why the Yamana do not make their craft from marine mammal skin like the Aleutian Islanders (Anichtchenko, 2012). Limited uses are made of such skins for other purposes and demand to satisfy a requirement for clothing is not one of those.
14. The Yamana utilise the extremely thick bark of the Magellan's Beech (*Nothofagus betuloids*). Three strips of bark are required each circa 5m in length and these are obtained from the very large examples that grow in isolation in the centre of islands (p.110).
15. The bark is removed using mussel shell cutting tools and a striping device of whale bone (pp.111-112). It is notable given that the social unit is that of the nuclear family that at least three adult men are required to harvest the required bark (p.110).

16. The bark requires special handling and treatment but not with any special substances (pp.115-118) and details of the treatment are therefore not material to this discussion.
17. A wooden frame is constructed, and the bark pieces are sewn to it using ideally sea mammal sinew, but fibres obtained from under the bark of the Antarctic beech (*Nothofagus antarctica*) can be utilised (p.118).
18. Seams are caulked soaked stalks of wild celery and also moss, grass and fine red seaweed. The canoe's gunwhale is further buffered against damage by pieces of bark from Magellan's mayten (*Maytenus magellanica*) (pp.119-120).
19. The canoe is usually between 4 and 5m in length and its width in and around 1m (p.110, p.122). A canoe usually lasts around 1 year but is known to last for 2 years. Its lifetime however can be as short as 2 to 3 months (p.133).
20. A final point regarding canoe construction is that the bark Magellan's Beech is in the required condition during the spring (p.115). Bark is therefore extracted and stored in swamp close to one of the more frequently visited locations in case out of season repairs are required (p.116).
21. A lit hearth is maintained in the canoe (p.44).
22. A special mooring rope is made from three strand braid of rushes (p.127).
23. The Yamana expect their canoe to leak and each one is equipped with a baling bucket made from stitched bark; the children (female) have a specific responsibility for baling during journeys (p.126-127). The canoes are known for riding high in the water and being unstable and yet very functional in the hands of their owners (p.129). Note: Such observations require an additional perspective of which there are many modern examples. High performance equipment only delivers its benefit if the operator is highly skilled and in the hands of an average operator perform more poorly than equipment deemed to be in the

lower performance category; an example is the ultra-fast action fly rod. Such equipment will cast much further and far more accurately than slower action models, but only if the angler's technique and, especially, timing and rhythm, are of a correspondingly very high standard. For those not possessing such skill levels greater accuracy and distance will be obtained from a slower action, lower performance model. Other modern examples of this dynamic include the Pitts Special aerobatic aeroplane, and Olympic level competition white water canoes.

Architecture

1. The domed hut is usually less than 1.9m in height at around 1.75m for a single family version. The diameter of the circular base is between 3.3 and 3.6m, but during the winter the hut is sometimes extended into an extended oval and a second (related) family may cohabit (p.33).
2. The framework is a loose 'basket weave' like construction of young thin supple beech trunks that remain under tension (not unlike a modern geodesic tent's thin fibreglass poles, author) and secured together with ties made from rushes. The framework is covered with seal skins, turf, lumps of soil and grass bundles (pp.20-21).
3. The conical hut is made from thicker straighter trunks stacked against each other at the apex. The apex being was usually around 1.8m and the diameter of the base around 3.6m (p.16). It is covered in a manner similar to the domed hut but tends to be less wind proof, which in turn improves its resilience to strong winds.
4. A hearth is also always present in both hut types, it is often protected from the wind by being placed in a depression around 50cm deep (p.24). Both types of hut are often constructed on shell middens and their presence has been recorded in the archaeological record (Orquera *et al*, 2011; Godino *et al*, 2011).

5. There is some debate as to whether the conical hut is a result of the Selk'nam (and Yamana?) obtaining access to iron (axes, author) to cut larger trunks from Europeans (Borerro, 1997, p.73).
6. In the case of the Yamana they appear to have been perfectly capable of cutting sufficiently large trunks using shell cutting tools and rope (p.156).
7. The hut frameworks were left after the coverings had been removed (which with the exception of the skins, were also left behind) and could be reused (p.18; Orquera *et al*, 2011).
8. Even if the site was not visited for some time, whether by the original architect or another family and the structure had collapsed, the required timbers would be present, ready to be erected. Within the archaeological record the post-holes associated with such structures are observed, especially within midden deposits (Orquera *et al*, 2011; Godino *et al*, 2011).

Acquisition of Raw Materials

1. The acquisition of raw materials for canoe and dwelling construction have been presented above but there are other resources, which are also key or critical within the overall system, that must be given consideration.
2. The Yamana generally use what is available in the vicinity. Their cutting and scraping tools are larger mussel shells (*Mytilus chilenensis*), either held in the hand or hafted to a stone with sinew or leather (p.187). Note: In the drawings the stone haft looks similar to the stone bevel-ended stone tools from the UK Mesolithic.
3. Precision cutting is performed with a razor clam shell and it is noted that the flesh of this species is not consumed (p.189-190).

4. The ethnographic accounts make little, if any, reference to the use of lithics for scrapers and cutting edges, but the archaeological record attests their utilisation ((Orquera *et al*, 2011; Godino *et al*, 2011).
5. The use of pumice as an abrasive finishing tool is also noted (p.194).
6. How prevalent the usage of lithics was relative to shell and bone is unclear as lithics persist well in the archaeological record compared to bone, and a worn and broken shell cutters and scrapers may not even be recognised as such during excavation. The relative importance of these lithic implements must be considered in the context of the sites being aggregated over time by multiple families. It is possible that only a small percentage of the families that visited a site needed to possess a (and discard) single implement to generate the archaeological record.
7. Awls are usually made from the long bones of birds, with the humerus being preferred; it should be noted that the figure that accompanies this statement is of a tibio-tarsus (fig 46, p.191).
8. The heads of their spears, javelins and harpoons are made from whale ribs (and sometimes wood) and again this is acquired as a result of the subsistence effort. Whales also yielded very strong sinews utilised in the construction of weapons.
9. The shafts for the harpoons, spears and javelins, which vary between 2.5 and 3.5m in length are constructed from appropriately long and straight (note: important) trunks, usually from young beech trees (*Nothofagus betuloides*). Shafts when completed are precisely octagonal (p.156-157).
10. Small Harpoon has detachable head tethered to the shaft by circa 1m of leather (p.160). The small harpoon’s head detaches, and the shaft was dragged behind the seal on the cord of leather. The shaft becomes snagged in seaweed and prevents the seals escape (ibid).

11. The large harpoon is basically the same as the small harpoon but attached to a 20m seal leather rope which the hunter retains hold of (p.163). Armatures of around 150mm in length are used for seals. A larger one 400mm in length might be used for elephant seals or male sealions and always for whale (ibid).
12. Javelins have the same octagonal shaft but are about 3m in length (p.165). Armatures do not detach. Used to hunt seals on land (ibid). Shorter double toothed armature used for smaller prey (ibid).
13. Spears used for birds and has a serrated armature (p.166) and the fish spear is basically a leister with two serrated points (p.167). Wood serrated points are also used for the fish spear (ibid).
14. Note: potentially the size and form of the armatures found in the archaeological record serve as a proxy for the type and size of prey being exploited.
15. (close to the shore with very shallow root systems, which negates the need for felling (p.n) as they can be uprooted
16. This same observation can be made in relation to the specialised wooden tools utilised to gather submerged mussels (and other molluscs), crabs and sea urchins from depths of 3 m or slightly more (p.181-182).
17. Arrow heads are made from lithic materials (slate, flint, quartz) although examples made from bone are known (p.152; Orquera *et al*, 2011; Godino *et al*, 2011); bone was also utilised (p.153). Slate is ground to form the artefact; quartz is pressure flaked (pp.151-152). Use of bow and arrow is probably more prevalent where guanacos are available such as Navarino Island (p.146). Arrow heads will probably exhibit regional abundance levels in the archaeology.

18. The Yamana also utilise a dagger or lance the primary difference being that the latter has a much longer shaft and a bone armature that is basically has a distinctive shape (p.172). The dagger has a lithic armature (slate) and is attached to a much shorter 0.2-0.4m shaft (p.170). Used to despatch sea lions by stabbing it in the throat (ibid). The daggers armature is basically exactly the same as an arrowhead but twice the length (ibid). These were probably mistaken for arrows in early ethnographic accounts (p.169).
19. The archaeological record archaeological record provides confirmation for some aspects of the Yamana's material culture. Excavations have provided examples of the armatures from arrows, harpoon heads and spearheads. The vast majority of the material culture however is perishable and rarely survives. Other aspects are not readily recognised such as mussel scrapers, which are fractured during manufacture to facilitate hafting to a stone. The images and drawings of the stone scraper hafts portray them as something similar to the bevel ended tools (aka limpet hammer, especially the stone variety) found at British Mesolithic sites
20. The Yamana utilise little in the way of clothing, a piece of seal skin is used as a cape which reaches midway down the back or just above the waste (p.50-52) and small pieces of leather are hung over the genitals for reasons of modesty (p.55).
21. Women appear to prefer the leather of sea birds, otters or foxes (p.58). A few families may also possess a guanaco (rarely) or seal skin bed cover (p.24-25).
22. The Yamana employ two major mitigations against the cold. The first is proximity to the fire in their hearth, whether this be in the hut or in the canoe (p.43; p.44). The second is to mix blubber with certain burnt clays and liberally coat their entire bodies with the mixture (pp.51-54; pp.67-68). Note: fundamentally the approach is not dissimilar to that adopted by a swimmer attempting to cross the English Channel.

23. Nevertheless, observers note that at times the Yamana stand shivering quite violently and with their teeth chattering (p.n), both of which are designed to maintain the body's core temperature and avoid the onset of hypothermia. Given the climate, and particularly the precipitation levels, the Yamana's rejection of clothing does make sense. The Yamana's dislike of clothing is discussed at some length in the ethnographic accounts and can be summarised as the limitations they place on the way everyday activities are carried out (p.51).
24. Related to clothing is the Yamana's taste for personal adornment and grooming. Mussel shells are used to trim hair, either in a razor like fashion or as tweezers for plucking; the Yamana do not like any form of bodily hair and pluck it out using mussel tweezers (p.82).
25. Hair combs are either porpoise maxilla with dentition present or are carved from flat whale bones (p.84).
26. The Yamana do like to adorn themselves and probably the most important aspect is face and body painting, using black (charcoal), red (iron oxides scraped from pebbles and cobbles) and white (calcium carbonates) pigments (pp.92-93). Note: An interesting point in relation to the white pigment is the fact that chalk is preferred, but this is only available in a certain area (ibid). If they have no chalk, they grind up burnt marine mollusc shells (ibid), Note: which it is common knowledge are chalk in the making, so to speak. Pigments pastes are stored; avian oesophagus preferred (p.93).
27. Painting is not just carried out for events such as initiations, funerals or weddings, but also when paying a social visit to another family (pp.96-98). If visitors are expected, then the hosts also paint themselves ready for the visitor's arrival. If the visitor's are unexpected then host makes a point of returning the visit suitably painted (ibid).

28. The Yamana also like to wear bracelets, anklets and necklaces. The materials utilised are mainly those that are acquired as part of the normal procurement processes. The cords for bracelets and anklets are made from leather, with women preferring guanaco to seal; in most areas the former will be acquired through trade (p.99).
29. The dried umbilical cords of otters are also utilised (p.100) and this suggests a specific effort to acquire them. This observation may also be applicable to the red beaks of oystercatchers which are also favoured (p.102). A particularly valued necklace is made from the dried windpipe of a swan (*Cygnus spp.*) which rarely frequents the Yamana's territory (p.105). Traded from the Haush.
30. Most necklaces however incorporate "everyday" objects for decoration such as perforated marine gastropod shells, or the long bones of birds (p.100-103). These objects maybe subjected to atypical treatments such as the colouring of bone black using sea mammal oil and fire, or burnishing the mollusc shells with pumice and sandstone (pp.102-103).
31. Reeds and rushes were acquired from where they were naturally available and utilised to weave baskets and net bags (p.200-201), and as ties for securing one element to another. Other storage items were leather bags and pouches (p.198) and the use of intestines and other similar tissues (p.200).
32. Seaweed stalks were harvested and utilised to create fishing lines (pp-184-185).and fine strands of seaweed were used to caulk canoes (p.119).
33. The puffball fungus was an extremely critical resource as it was utilised as tinder for starting fires using iron pyrites and flint. These resources are critical to the Yamana and they are stored are stored in a waterproof pouch (p.40).

Subsistence.

1. Storage is not logistical in the sense that it seeks to address seasonal shortfalls in resources. Neither is the storage of whale blubber in swamps; again, this is not logistical provision for lean seasons, but simply the fact that the Yamana appreciate the taste of whale blubber and they do not know when their next treat will come along (p.338).
2. The ethnographic accounts do not suggest any kind of seasonal round with a fixed number of locations, as might be anticipated of a people who are semi-nomadic (pp.284-285). As already described above the destination of the next residential move is dictated by the resource to be targeted but heavily factored by the weather.
3. The resources they exploit however will exhibit seasonal variation, not only in terms of abundance, but also spatially. Pinnipeds have their favourite hauling out spots throughout the year, but certain locations will be preferred for mating and pupping. The accessible fish stocks also move away from the outer islands in winter to more sheltered waters (ibid) and presumably some species head for the relative calm of the deeps during the same period (ibid).
4. Active hunting revolves around pinnipeds and marine birds (particularly cormorants and penguins) as these are major sources of protein and in the case of the former, skins and blubber.
5. Bird bones are utilised for tools and ornamentation; the quills are utilised for painting and also as the tippet on the fishing line (see below).
6. Birds are often pursued on land using a spear, or if a large dense flock is present then multiple stones are fired simultaneously from a sling (seal or otter skin) in the hope of stunning or disabling one or more (p.231-233). This takes place after the wife has paddled the husband out to a suitable rock outcrop, where she leaves him whilst she pursues other activities (p.236). She returns to collect him at an agreed time, but this can be significantly delayed (at times by days) due to rapid changes in the weather (ibid).

7. Usually, cormorants and penguins were taken with spear or sling whilst the hunter was in the canoe (p.231). When birds aggregate in flocks multiple projectiles are fired from the sling simultaneously in a hit and hope manner (p.175).
8. Cormorants were also trapped and snared on land using bait on double pointed piece of bone attached to an anchored line (p.237). Note: This double ended unbent "hook" is similar to the Nookta's salmon and halibut fishing hooks.
9. Cormorants were also actively stalked using a sliding noose attached to a wooden rod (p.234). Of note is the approach of startling sleeping birds at night using a lit torch (p.233) Note: in a manner that sounds very similar to that used by the group who used to trade birds to the Nootka.
10. Flocks of grazing geese are also snared in a multiple loop variation of the anchored snare loop referred to above (p.179); although such a device was not commonly owned by a Yamana family.
11. In all the above scenarios the sliding loop snares were constructed from line made from either whale sinew or cord made from whale bone fibres (ibid).
12. Tivoli (2011) suggests that the relative exploitation of bird taxa exhibits temporal and spatial trends.
13. Birds also provide a seasonal resource in the form of eggs. These were gathered from colonies during the spring and early summer (p.274).
14. Pinnipeds were hunted both on land where they are slow and clumsy, often using a stealthy approach and a club, after the initial attack others would be chased and clubbed (pp.218-221). Remarkably, this approach appears to be utilised even when pursuing the huge southern elephant seal or male sea lions (ibid).

15. Harpoons were also used both on land but also from the canoe, the approach, as with penguins, is to cause massive damage and wait for the animal to bleed out.
16. Usually the seal was butchered at the point of capture (p.69). The head was removed and discarded; the skin was removed but with the flippers still attached (ibid). Meat and blubber is then removed from the carcass and these, along with the skin transported by canoe to the hut for processing (stretching and hair plucking) or consumption (p.69).
17. In a situation where one or more other families were camped at the same location the pinniped, if it were a large specimen such as the southern sea lion or a southern elephant seal, would be returned whole to the camp and the meat and blubber distributed (p.314-315.).
18. Note: How an elephant seal or adult male sea lion was put into or removed from the bark canoe is not described, but it must have been quite difficult, and not without risk to this critical piece of equipment.
19. Whales were a highly valued resource, clearly whales provide huge amounts of meat and blubber (and as a consequence oil), but they also provide the large flat and hard bone required to make key tools including harpoon and spear heads, but also those involved in harvesting bark for canoe construction (p.224).
20. The extremely strong sinews are used as rope, fishing line and harpoon tethers.
21. Whale carcasses also catalysed large social gatherings which in term facilitate the holding of certain key and important ceremonies as well as initial introductions of future spouses. Despite this contribution it questionable as to whether the Yamana can be considered as active whalers.
22. Exploitation mainly focused on stranded dead whales which could be detected due to the huge and noisy flocks of seabirds they attracted. Live whales (live stranding in modern terminology) were killed but these were usually wounded by predators such as Orca spp. or exhausted by

escaping the pursuit of such predators; in some cases, the whale would simply be sick or old (p.224, p.227).

23. Such whales were attacked relentlessly by harpoon and spear by many (30 or more) families (p.226); the strategy once again is to cause the animal to bleed out.
24. Whales are large and the attacks had to be sustained over prolonged periods; one recorded instance commenced at 16:00 on a Friday and the whale finally succumbed at around 22:00 on Saturday (p.225).
25. Live whales sometimes attempted to flee and they would tow the (many) canoes as the occupants were holding onto the harpoons 20m tether (p.226). Prior to the introduction of alcohol by European's this was the major source of fatal capsizes as either canoes were flung into the air, smashed or overturned (p.225).
26. The carcass was towed to shore at a location where the local currents aided the effort (p.224); the access to the carcass during butchery was coordinated by the man who had first seen or touched the whale (p.309). Exploitation of the carcasses of the largest species could persist for up to a month (p.313).
27. Originally whale strandings were more common in the region than most would expect. By the early 1900's standings were extremely rare, decadal, bordering on generational events (p.225). This is because of the past activity of the European whaling fleets during the 17th and 19th centuries.
28. Clearly, as unlikely is it might at first be perceived, whale strandings, prior to European contact, could have been a major, and importantly, reliable source of resource to the Yamana. It may even have been the case that the risks associated with attacking live (if debilitated) whales could have been avoided prior to stocks being reduced by the Europeans.

29. Fishing was important to the Yamana, but not so much as birds and marine mammals. Line fishing was carried out by the female from the canoe using fishing lines of two types. The first line type is constructed from seaweed stalks and is cheap in terms of raw material availability and effort to construct. It; is used when targeting shoals of smaller fish (pp.184-185). Fishing only possible in calm weather.
30. The second type is constructed platting 3 filaments of whale or seal sinew and is far stronger and utilised when larger more powerful fish are likely (ibid).
31. Fishing lines were in excess of 8m in length and a stone sinker was used (ibid). No hook is utilised, the fish is permitted fully engorge the tied on bait and this secures the fish sufficiently for it to be landed. The bait was tied to a tippet made from bird feather quill (ibid). Note: In modern terms this is a stiff link leader and is employed when targeting bottom dwelling species that suck and blow as they feed. The stiff leader makes ejection of the bait by blowing very difficult (pers. obs).
32. Most fish are acquired through line fishing, but large fish were also speared in shallow water using a specific twin pointed spear, which is basically a leister.
33. Fish also provided another windfall bounty to complement that provided by whale strandings. Shoals containing millions of individual fish arrive unpredictably and are made up of mainly herring and sprats, large numbers of larger predatory fish are also present (pp.269-271).
34. The predators drive the fish into shallow water and huge numbers of fish become stranded on the beach (ibid). Note: The author has observed similar events, but on a reduced scale in Scotland when mackerel drive sand eels right up to the beach. The windfall does not just relate to the thousands of stranded fish that the Yamana collect of the beach but also to the large numbers of pinniped and birds these events attracts, which the Yamana take to opportunity to procure using the methods already outlined p.270).

35. The scale of these events means that the overall exploitation can last for a week or more and provides another opportunity for social gatherings to occur (ibid).
36. In the case where the shoal does not beach a loose weave basket is attached to a pole and the fish are scooped out of the water and into the canoe (pp.271-272).
37. Large specimens of the predatory Patagonian blenny (*Eleginops maclovinus*) are speared around the edge of the bait shoal (ibid).
38. In general the Yamana do not adopt trapping strategies within their procurement methods; but when several families are experiencing inhibited travel and food supplies are dwindling, a woven tidal weir trap may be constructed to trap fish at high tide (p.273).
39. Three types of invertebrate contributed a significant amount to the Yamana's economy, and these are marine molluscs, sea urchins (echinoidea) and large crabs (brachyura). Whilst there are nuances in the form of equipment utilised to collect these resources, the procurement methods are fundamentally the same, but with some differences in the structure of the functional end of the tool. They are gathered from the canoe below the low-water mark using a long handled implement (3 to 4) m in length (pp-181-184). Note: This is exploitation of the infralittoral.
40. Procurement takes place when the sea is calm and clear, which is not that often, and individual specimens are observed through the water column and retrieved individually using the tool (p.255; p.259; p.262).
41. In terms of molluscs, large mussels (*Mytilus edulis* and *Mytilus chilensis*) are predominantly targeted (p.254), although other species such as *Voluta spp*. *Pecten spp*., *Patella spp*. and *Chiton spp* are exploited (p.257).

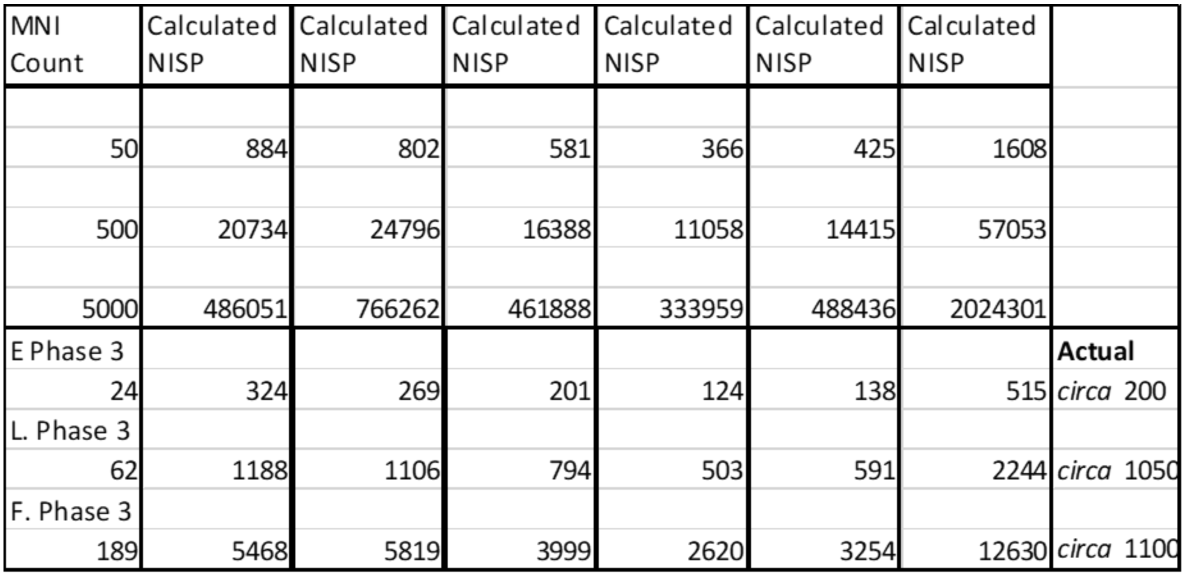
42. The mussels acquired in this manner are much larger than those available within the inter-tidal zone and as well as contributing to the diet provide the Yamana with a critical tool making material.
43. Smaller mussels and other molluscs are also obtained during low tide by hand gathering into baskets (p.255).
44. The crab species exploited are the false king crab (*Paralomis granulosa*) and southern king crab (*Lithodes santolla*); the latter having a leg span of up to 0.65m and carapace width of 190mm (p.261).
45. Whilst some species of small marine gastropods are used in necklace manufacture only the large Voluta is exploited for food to any degree; it is also used as a vessel to collect oil (pp.318-319).
46. In terms of the archaeological record provides confirmation for some aspects of the Yamana's subsistence activities. Although many of their tools are perishable and do not survive.
47. The Yamana, like the Nookta, are known for their predominantly carnivorous diet with a limited contribution from other resources. The main contributors are fungi, but only those found on trees and not those that grow on the ground (p.278). Each species (around 10 species) appears to have a specific month when it is considered harvestable (ibid)
48. Berries are also consumed during the short season in which they are available (p.279-281).
49. There is clearly a lack of carbohydrate in the Yamana's diet and it is possible that their very frequent drinking, in small amounts, of marine mammal oil is a necessary measure (p.300, p.332). It may also contribute to maintaining a higher base metabolic rate (RMR), whether this was a feature of Yamana physiology is unclear.
50. Food preparation is either grilling on the fire or between heated stones. Food is also baked in hot ashes. Mussels are 'self-steamed' by heating in ashes.

51. The Yamana generally practice an immediate return economy and therefore can be considered as foragers, albeit that a large seal will last a family several days.
52. Some limited storage is practiced primarily of oil and fat in sausages within animal intestines (pp.320-321). This permits the continued consumption of oil and the availability of fat for body insulation.
53. This is not logistical in the sense that it seeks to address seasonal shortfalls in resources. Neither is the storage of whale blubber in swamps; again, this is not logistical provision for lean seasons, but simply the fact that the Yamana appreciate the taste of whale blubber and they do not know when their next treat will come along (p.338).

SI-Chapter4.

Si-Chapter4-1: MNI NISP Relationship

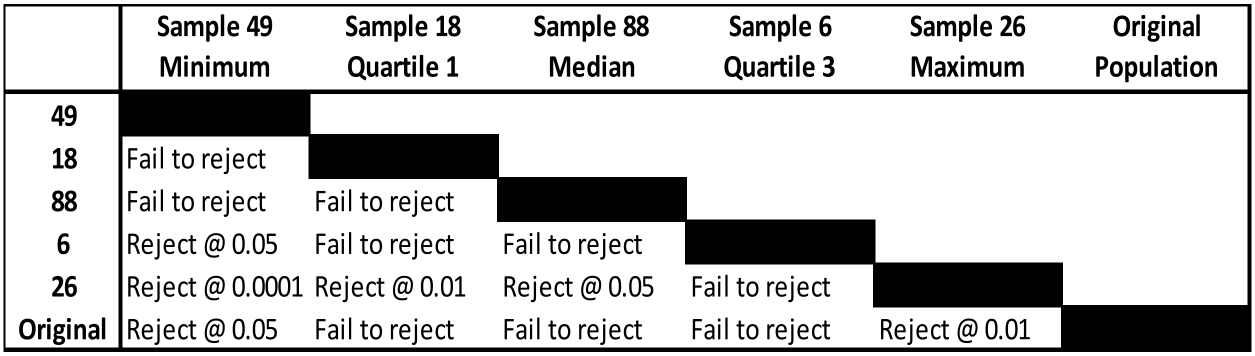
Table SI-Chapter4-2.1. NISP values calculated using the regression equations provided in Grayson (1985, figure 2.18). The MNI values 50, 500, 5000 are for illustrative purposes. The lower half of the table shows the calculations from the MNI values provided for Scalloway by Ceron-Carrasco, (1998, tables 52-54). The actual values on the right are those from Ceron-Carrasco (1998, fig. 75).



MNI Count	Calculated NISP	Calculated NISP	Calculated NISP	Calculated NISP	Calculated NISP	Calculated NISP	
50	884	802	581	366	425	1608	
500	20734	24796	16388	11058	14415	57053	
5000	486051	766262	461888	333959	488436	2024301	
E Phase 3							**Actual**
24	324	269	201	124	138	515	*circa* 200
L. Phase 3							
62	1188	1106	794	503	591	2244	*circa* 1050
F. Phase 3							
189	5468	5819	3999	2620	3254	12630	*circa* 1100

SI-Chapter4-2: Statistical Testing of Simulated Sampling.

Table SI-Chapter4-2.1: Statistical tests derived from 100 samples of 390 observations from a population of 3,393 observations. Testing with a Z-test with known variance. The samples represent the minimum, quartile 1 median quartile 3 and maximum values of the means within the 100 samples.



	Sample 49 Minimum	**Sample 18 Quartile 1**	**Sample 88 Median**	**Sample 6 Quartile 3**	**Sample 26 Maximum**	**Original Population**
49						
18	Fail to reject					
88	Fail to reject	Fail to reject				
6	Reject @ 0.05	Fail to reject	Fail to reject			
26	Reject @ 0.0001	Reject @ 0.01	Reject @ 0.05	Fail to reject		
Original	Reject @ 0.05	Fail to reject	Fail to reject	Fail to reject	Reject @ 0.01	

Table SI-Chapter4-3.2: Statistical tests derived from 100 samples of 100 observations from a population of 3,393 observations. Testing with a Z-test with known variance. The samples represent the minimum, quartile ,1 median, quartile 3, and maximum values of the means within the 100 samples.

	Sample 57 Minimum	Sample 51 Quartile 1	Sample 49 Median	Sample 33 Quartile 3	Sample 20 Maximum	Original Population
57						
51	Reject @ 0.05					
49	Reject @ 0.05	Fail to reject				
33	Reject @ 0.01	Fail to reject	Fail to reject			
20	Reject @ 0.0001	Reject @ 0.05	Fail to reject	Fail to reject		
Original	Reject @ 0.001	Fail to reject	Fail to reject	Fail to reject	Reject @ 0.05	

SI-Chapter4-3: Shell weight versus MNI.

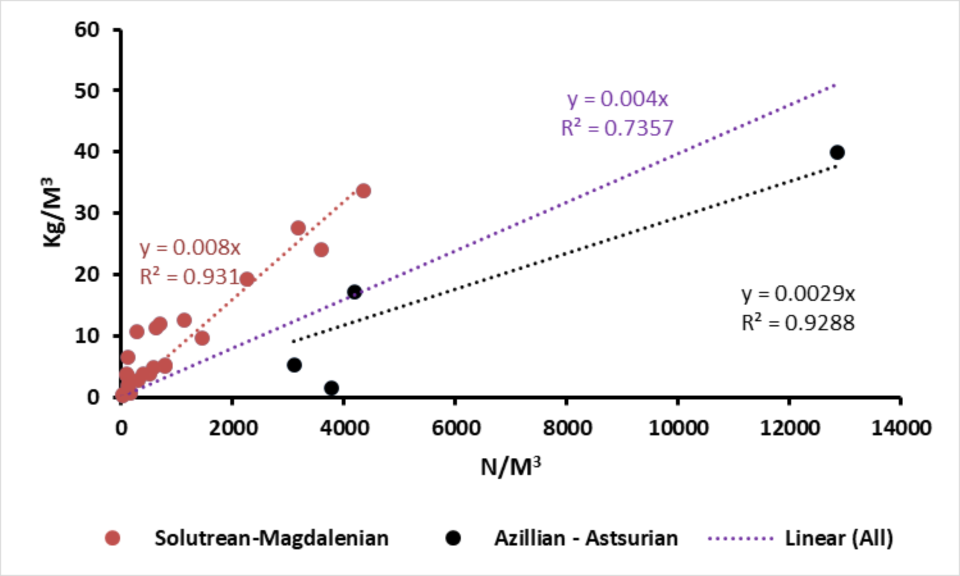


Figure SI-Chapter4-3.1: The relationship between shell weight and MNI, data from Bailey and Craighead (2003, table 1, p.180).

SI-Chapter4-4: Reconstructing Limpet Length.

The regressions provided in the Ambrose *et al* (2016) relate to two locations, one in Shetland and the other in Norway (ibid, p.83). The two equations (EQC4-1 and EQC4-2) are stated in the main text. The length range of the Norwegian limpets was 33.1 to 48.3mm and those from Shetland 38.2 to 46.7mm (ibid).

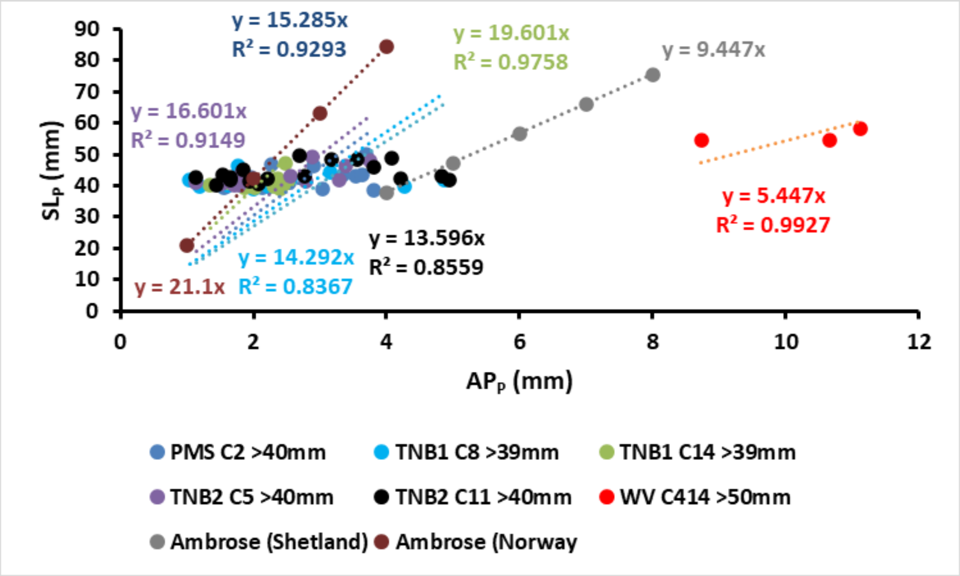


Figure SI-Chapter4-4.1: The author's regressions in comparison with Ambrose *et al* (2016)'s pooled regressions. Disturbed limpets (Chapter 6) were excluded from the author's dataset.

Unfortunately, and as expected based upon Moore (1933), the author was unable to replicate the results even with the regressions forced through the origin as Ambrose *et al* (2016) did. The relationship between shell length and apex thickness either did not exist or was extremely weak (figures SI-Chapter4-4.1, 4.2). The author's data suggests that the apex thickness is a combined function of shell conicity, age with a minimal influence from length. Regrettably, this project was unable to use apex thickness regressions, either those generated, or those of Ambrose *et al* (2016), to evaluate preservation bias by size class. As Ambrose *et al* (2016) do not present their regressions graphically it is unclear whether their results are an artefact of sampling strategy, or whether the regressions were determined algebraically without graphical confirmation, and therefore whether relationship between the observations and the regression curve take the same form as those observed by the author. The author's data suggests that major contributors to apex thickness are conicity, age and that size has a minimal influence unless the former two variables are held constant. The issue of sampling strategy will be considered more widely in a subsequent section. A critical point must be made at this juncture to avoid misunderstanding. The author is not asserting that Ambrose *et al*, (2016)'s regressions are incorrect, only that they have a very limited interval of applicability, and it is probable that the interval of applicability needs to be stated in terms of conicity rather than SL_P. It must also be made clear that despite the high values of R^2 (coefficient of determination) stated for the author's regressions in figure SI-Chapter4-4.1, they are not being proposed and neither is the pooled regression in figure SI-Chapter4-4.2. These high-values are an artefact of converting either a linear regression with a very shallow slope and large intercept value, or a non-linear relationship, to a linear relationship forced through the origin. The numerous models generated in chapter 6 all exhibit this behaviour, which is why model evaluation is based only in part on R^2, but more strongly influenced by the skew, standard deviation, and absolute range of the residuals. Another critical assessment is how consistent the above attributes are throughout a useful size range of the independent variable. A consequence of this approach is that the models selected in chapter 6 are not necessarily those with the highest values for R^2.

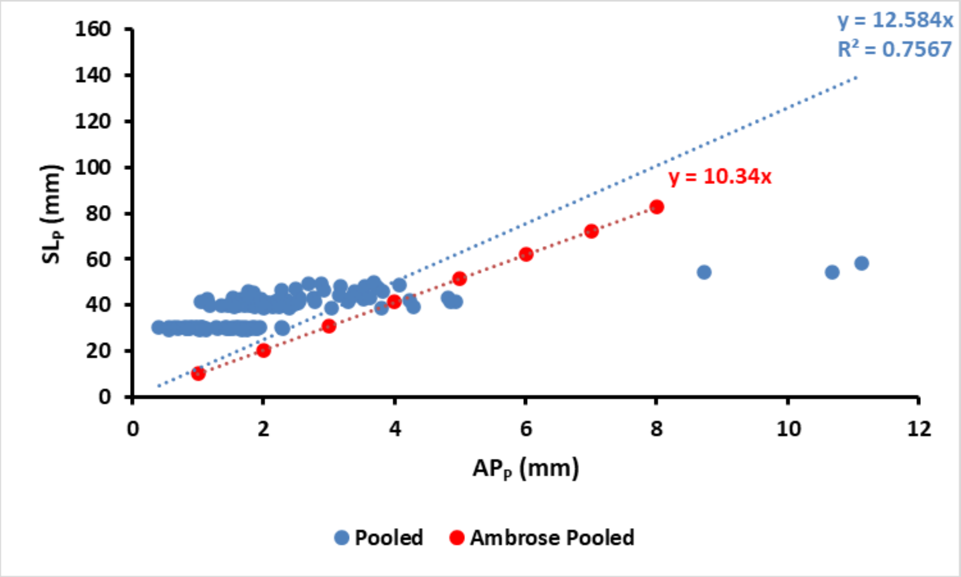


Figure SI-Chapter4-4.2: The author's pooled regressions in comparison with Ambrose *et al* (2016)'s pooled regressions. Disturbed limpets were excluded from the author's dataset.

SI-Chapter4-5: Asking the Correct Question in the Correct Way.

A case in point is Harris *et al*, (2018)'s analysis of limpets from Viking Age Shetland. A standard set of metrics are gathered and derived from assemblages pertaining to different phases of occupation. The resulting datasets for (SL_P, SH_P, Conicity) are evaluated for normality in the usual way and non-parametric inference tests were selected and executed. What is difficult to understand, using the example of limpet length, is why the having executed the non-parametric inference test, the metrics are binned with a (unusual) bin width of 8mm and then a Chi-squared test is executed to determine if H_0 can be rejected or not. Chi-squared is a test for independence or homogeneity and the way it is conducted by Harris *et al*, (2018) it is for independence. The rejection of H_0 in this case implies there is an association between phase and binned size and not whether the distributions overall are different to each other as asserted by Harris *et al* (2018), which in any case had already been established by the Kruskal-Wallis test and appropriate post-hoc tests (ibid). Another issue is that Chi-squared independence testing must be conducted against absolute values and not relative ones. Binning the ratio data into bin definitions that are of ecological or archaeological interest, for example uneconomic, medium, and very large and checking of independence of these bins makes sense to the author (if the requirement for using absolute abundance is met), but the chosen bin size of 8mm is not articulated or justified in such a manner. The Chi-squared process was also carried out for conicity. Presumably, Harris *et al*, 2016) were dissatisfied with the results for conicity, despite the results from the Kruskal-Wallis and Chi-squared test, as they analysed the covariance (ANCOVA) of SL_P and SH_P (aka conicity) for equality of slopes, which again is difficult to understand. The conclusion must be, firstly, to ensure the test utilised is asking the question that requires an answer and secondly, other than in very exceptional circumstances, ask the question once even if it does curtail the variety of statistical techniques on display.

SI-Chapter4-6: Future Research Agendas

The visual targeting highlighted by Groom *et al* (2019) is of interest as the people of Tierra del Fuego did the same (chapter 3). It would be useful to explore how the state of sea therefore influences success, noting that the Fuegians where constrained to calm conditions. North-west Scotland is at a much higher latitude than Tierra del Fuego and therefore success rates during late Autumn through to early Spring, when the hours of darkness are greater, is something worth exploring. Any modern angler, the author included, will observe that, unless targeting a predator with a moving lure, success at sea fishing (and freshwater fishing) comes in the hours of darkness. Even lure fishing is more successful at night if there is moon light. It should be noted that modern sea anglers are not targeting fish visually, hence night fishing is viable. Groom *et al*, (2019) also provide very useful breaking strain data for the traditionally manufactured lines. It would be useful to know the breaking strain when knotted[11] as this would permit a view of at what combination of net size and mesh size a net constructed from such lines would structurally fail under its own weight when saturated.

The depth of fishing with natural material lines could be explored further given the large diameters of the lines produced by Groom *et al*, (2019). Fishing beyond a few tens of meters down in a reasonable current or tidal flow usually requires a switch to ultra-thin wire line rather than nylon. If this is not done the water flow pressure on the nylon will lift even 0.7 or 0.9kg off the bottom. In shallow water with higher tidal flow (over sand banks or similar) the weights are modified to what are basically grappling hooks, the weight is not what holds the bait in position. These are other aspects that the author hopes Groom *et al* (2019) will have the opportunity to explore in the future.

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[11] Knotted strength is around 40-50% of the stated breaking strain for modern nylon (using a half tucked blood knot) and slightly better for fluorocarbon line, although this requires a different knot (5 turn grinner) to change the way the mechanical stresses are distributed to exploit the mechanical properties of the material (prior to exposure to water). The raw breaking strain and knot strength is maintained to a greater degree by fluorocarbon compared to nylon once emersed in water.

SI-Chapter5.

SI-Chapter5-1 – Detailed Site Information.

SI-Chapter5-1.1 - Atlantic Portugal

Table SI-Chapter5-1.1-1: Detailed dating for the sites in Portugal. Data from the sources in table SI-Chapter5-1.1-6.

Sub-region	Site	Level/Phase/Unit	Laboratory Code	^{14}C Assay	Marine (%)	PD Start BC (2σ)	PD End BC (2σ)	PD Mean BC	Error ±	Δ R ^{14}Cyrs
Portugal	Barranco das Quebradas	1 Early		9200	0	8400	8400	8400	0	
Portugal	Barranco das Quebradas	1 Late		8600	0	7600	7600	7600	0	
Portugal	Barranco das Quebradas	3 (Bottom)		8400	0	7500	7500	7500	0	
Portugal	Barranco das Quebradas	3 (Top)		8000	0	6900	6900	6900	0	
Portugal	Barranco das Quebradas	4		8500	0	7560	7560	7560	0	
Portugal	Barranco das Quebradas	5		8000	0	6900	6900	6900	0	
Portugal	Rocha das Gaivotas	3		8600-8000		7600	6900	7250	350	
Portugal	Rocha das Gaivotas	2 (Lower)		6900-6700		5800	5630	5715	85	
Portugal	Rocha das Gaivotas	2 (Upper)		6400		5400	5400	5400	0	
Portugal	Toledo	Pandeiro 1	TO-707	7800 ± 110	0	7030	6457	6744	287	
Portugal	Toledo	Main Level 2	Sac-1587	9000 ± 60	100	6796	6407	6602	195	940 ± 50
Portugal	Toledo	D21 (T45–56)	Sac-1533	9120 ± 80	100	7016	6502	6759	257	940 ± 50
Portugal	Toledo	B12 (T45–13)	Sac-1529	9200 ± 70	100	7061	6601	6831	230	380 ± 30
Portugal	Vale Frade	Levels 5–6	Sac-1586	9810 ± 65	100	7825	7416	7621	205	940 ± 50
Portugal	Vale Frade	Levels 5–6	Sac-1577	9090 ± 75	100	6982	6473	6728	255	940 ± 50
Portugal	Vale Frade	Level 2b (base)	Gif-1438	8500 ± 110	0	7817	7194	7506	312	
Portugal	Casal Papagaio	Base	ICEN-369	9710 ± 70	0	9298	9298	8838	460	
Portugal	Casal Papagaio	Middle	ICEN-372	9650 ± 90	0	9272	8790	9031	241	
Portugal	Casal Papagaio	Upper	Hv-1351	8870 ± 100	100	7457	6856	7157	301	380 ± 30
Portugal	S. Juliao A	F1	ICEN-78	7810 ± 90	0	7028	6467	6748	281	
Portugal	S. Juliao A	Q2 F1b C	ICEN-151	7940 ± 140	100	7283	6479	6881	402	170±50
Portugal	S. Juliao A	F1 C1	ICEN-83	9090 ± 60	100	6961	6486	6724	238	940±50
Portugal	S. Juliao A	F1 C2	ICEN-84	9060 ± 50	100	6892	6460	6676	216	940±50
Portugal	S. Juliao A	E1,1	ICEN-73	7610 ± 80	0	6636	6264	6450	186	
Portugal	S. Juliao A	E1,2	ICEN-77	7580 ± 70	0	6592	6259	6426	167	
Portugal	S. Juliao A	E1 C1	ICEN-106	8060 ± 50	100	6555	6240	6398	158	170±50
Portugal	S. Juliao A	E1 C2	ICEN-107	8130 ± 50	100	6630	6339	6485	146	170±50
Portugal	S. Juliao B	Q5 A1	ICEN-179	8120 ± 100	0	7452	6714	7083	369	
Portugal	S. Juliao B	Q5 A1 C1	ICEN-108	8400 ± 50	100	7334	6991	7163	172	-70±40
Portugal	S. Juliao B	Q5 A1 C2	ICEN-109	8550 ± 70	100	7507	7109	7308	199	-70±40
Portugal	S. Juliao B	Q2 A2 C1	ICEN-152	8430 ± 60	100	7393	7012	7203	191	-70±40
Portugal	S. Juliao B	Q2 A2 C2	ICEN-153	8340 ± 45	100	7263	6845	7054	209	-70±40
Portugal	S. Juliao B	Q2 A2 O	ICEN-154	7390 ± 90	100	5957	5560	5759	199	170±50

Sub-region	Site	Level/Phase/Unit	Laboratory Code	^{14}C Assay	Marine (%)	PD Start BC (2σ)	PD End BC (2σ)	PD Mean BC	Error ±	Δ R ^{14}Cyrs
Portugal	S. Juliao C	QC6 2A M	Sac-1720	5700 ± 60	100	3914	3618	3766	148	380±30
Portugal	S. Juliao C	QB6 2A C1	Sac-1795	6820 ± 60	100	5182	4812	4997	185	380±30
Portugal	S. Juliao C	QB6 2A C2	Sac-1796	7520 ± 70	100	6027	5687	5857	170	170±50
Portugal	S. Juliao C	QC7/C8 2B C	Sac-1721	7650 ± 80	100	6202	5794	5998	204	170±50
Portugal	S. Juliao C	Q E6/D61 2C C1	Sac-1723	8470 ± 70	100	6844	6426	6635	209	-70±40
Portugal	S. Juliao C	QE6/D61 2C C2	Sac-1724	7630 ± 60	100	6156	5796	5976	180	170±50
Portugal	S. Juliao C	QE6/D62 2C C1	Sac-1800	7170 ± 90	100	5725	5352	5539	187	170±50
Portugal	S. Juliao C	QE6/D62 2C C2	Sac-1801	7460 ± 60	100	5968	5655	5812	157	170±50
Portugal	S. Juliao C	QC3 2G V1	Sac-1802	6390 ± 90	100	4706	4301	4504	203	380±30
Portugal	S. Juliao C	QC3 2G V2	Sac-1803	7200 ± 90	100	5756	5375	5566	191	170±50
Portugal	S. Juliao D	UE2 C1	Sac-2965	7620 ± 40	100	6096	5808	5952	144	170±50
Portugal	S. Juliao D	UE2 C2	Sac-2966	7580 ± 45	100	6051	5766	5909	143	170±50
Portugal	S. Juliao D	UE4 M1	Sac-2963	4460 ± 40	100	3067	2733	2900	167	-160±40
Portugal	S. Juliao D	UE4 M2	Sac-2964	4490 ± 40	100	3092	2771	2932	161	-160±40
Portugal	S. Juliao D	UE4 P1	Sac-2961	4360 ± 40	100	2891	2594	2743	149	-160±40
Portugal	S. Juliao D	UE4 P2	Sac-2962	4410 ± 50	100	2995	2626	2811	185	-160±40
Portugal	Magoito	1A	GrN-11229	9580 ± 100	0	9251	8657	8954	297	
Portugal	Magoito	1B	ICEN-52	9490 ± 60	0	9134	6831	7983	1152	
Portugal	Magoito	1B M	ICEN-80	9970 ± 70	100	9079	8565	8822	257	160±60
Portugal	Magoito	1B P	ICEN-81	9790 ± 120	100	8921	8245	8583	338	160±60
Portugal	Magoito	1B C	ICEN-82	9910 ± 100	100	9078	8414	8746	332	160±60
Portugal	Magoito	1C M	ICEN-577	9880 ± 80	100	8997	8400	8699	299	160±60
Portugal	Magoito	Magoito 2A P1	ICEN-424	6080 ± 80	100	4316	3945	4131	186	410±40
Portugal	Magoito	Magoito 2A P2	ICEN-425	6030 ± 80	100	4303	3889	4096	207	
Portugal	Magoito	Magoito 2A T	ICEN-471	5970 ± 120	100	4292	3719	4006	287	
Portugal	Pena d'Agua	Level F	Wk-9213	7310 ± 110	0	6407	6001	6204	203	
Portugal	Formo del Telha	Level 2	Wk-18356	6764 ± 35	0	5721	5626	5674	47.5	
Portugal	Formo del Telha	Midden	ICEN-416	7320 ± 60	100	5616	5366	5491	125	380 ± 30
Portugal	Formo del Telha	Midden	ICEN-417	7360 ± 90	100	5697	5356	5527	171	380 ± 30
Portugal	Curral Velho	Midden	ICEN-270	8400 ± 60	100	6678	6395	6537	142	380 ± 30
Portugal	Curral Velho	Midden	ICEN-269	8410 ± 90	100	6818	6352	6585	233	380 ± 30
Portugal	Bocas	I	ICEN-899	7490 ± 110	100	5876	5453	5665	212	380 ± 30
Portugal	Pena de Mira		ICEN-966	7810 ± 120	0	7035	6461	6748	287	
Portugal	Lapa do Picareio	Level D	Wk-6676	8310 ± 130	0	7580	7064	7322	258	
Portugal	Pinhal de Fonte		Sac-1671	8740 ± 70	100	7196	6701	6949	248	380 ± 30

Table SI-Chapter5-1.1-2: Portuguese sites with at least ordinal data for mammal abundance not based upon weight. Data from the sources in table SI-Chapter5-1.1-6.

				Mammal	
Region	**Site**	**Phase Level**	**1st**	**2nd**	**3rd**
Central	Toledo		Rabbit	Wild Boar	Hare
Central	Vale Frade		Rabbit	Red Squirrel	Wild Boar

Table SI-Chapter-1.1-3: Portuguese sites with at least ordinal data for bird abundance not based upon weight. Data from the sources in table SI-Chapter5-1.1-6.

				Bird	
		Phase	**1st**	**2nd**	**3rd**
Central	Toledo		Wood Pigeon	Partridge	Ducks/Geese
Central	Vale Frade		Wood Pigeon	Grouse/Geese/Ducks	Grouse/Geese/Ducks

Table SI-Chapter5-1.1-4: Portuguese sites with at least ordinal data for fish abundance not based upon weight. Data from the sources in table SI-Chapter5-1.1-6.

				Fish	
Region	**Site**	**Phase Level**	**1st**	**2nd**	**3rd**
Central	Toledo		*Sea Bream*	*Tope*	*Mullet/Sea Bass*
Central	Vale Frade		*Sea Bream*	Mullet	Carangidae

Table SI-Chapter5-1.1-5: Portuguese sites with at least ordinal data for mollusc abundance not based upon weight. Data from the sources in table SI-Chapter5-1.1-6.

					Mollusc	
Region	**Site**	**Phase Level**	**MNI**	**1st**	**2nd**	**3rd**
Algarve	Barranco das Quebradas	1a	3842	Thick Top	Limpet	Mussel
Algarve	Barranco das Quebradas	1b	601	Thick Top	Limpet	Mussel/Red Lipped Rock
Algarve	Barranco das Quebradas	3 (lower)	5454	Thick Top	Limpet/Mussel	Limpet/Mussel
Algarve	Barranco das Quebradas	3 (upper)	2981	Limpet/Mussel	Limpet/Mussel	Thick Top
Algarve	Barranco das Quebradas	4	4207	Thick Top	Limpet	Red Lipped Rock
Algarve	Barranco das Quebradas	5	5329	Limpet	Mussel	Thick Top/Red Lipped Rock
Algarve	Rocha das Gaivotas	L3	1914	Mussel	Limpet	Thick Top/Red Lipped Rock
Algarve	Rocha das Gaivotas	L2 (lower)	5967	Limpet	Mussel	Red Lipped Rock
Algarve	Rocha das Gaivotas	L2 spit 5	1191	Limpet	Mussel	
Algarve	Rocha das Gaivotas	L2 spit 4	435	Limpet	Mussel	
Algarve	Rocha das Gaivotas	L2 spit 3	437	Limpet	Mussel	
Algarve	Rocha das Gaivotas	L2 (upper)	2615	Limpet	Mussel	Red Lipped Rock
Central	Toledo		4217	Cockle	Peppery Furrow	Mussel
Central	Vale Frade			Carpet		
Central	Casal Papagaio	Upper		Cockle	Peppery Furrow	Mussel
Central	S. Juliao A	A		Cockle	Oyster	Carpet?
Central	S. Juliao B	B		Cockle	Oyster	
Central	S. Juliao C	C		Cockle	Mussel	Limpet/Oyster.
Central	S. Juliao D	Da		Cockle		
Central	S. Juliao D	Db		Mussel		
Central	Magoito	Main II		Cockle	Limpet/Mussel	Limpet/Mussel
Central	Magoito	2A - Late		Mussel		
Central	Magoito	2A - Early		Limpet	Red Lipped Rock	

Table SI-Chapter5-1.1-6: Sources of faunal and dating information for the Portuguese sites, plus other notes.

Region	**Site**	**Sources**	**Notes**
Algarve	Barranco das Quebradas	Dean *et al*, 2012 Dean and Carvalho (2011)	Mollusc MNI 3,842
Algarve	Barranco das Quebradas	Dean *et al*, 2012 Dean and Carvalho (2011)	Mollusc MNI 601
Algarve	Barranco das Quebradas	Dean *et al*, 2012 Dean and Carvalho (2011)	Mollusc MNI 5,454
Algarve	Barranco das Quebradas	Dean *et al*, 2012 Dean and Carvalho (2011)	Mollusc MNI 2,981
Algarve	Barranco das Quebradas	Dean *et al*, 2012 Dean and Carvalho (2011)	Mollusc MNI 4,207
Algarve	Barranco das Quebradas	Dean *et al*, 2012 Dean and Carvalho (2011)	Mollusc MNI 5,329
Algarve	Rocha das Gaivotas	Dean *et al*, 2012 Dean and Carvalho (2011)	Mollusc MNI 1,914
Algarve	Rocha das Gaivotas	Dean *et al*, 2012 Dean and Carvalho (2011)	Mollusc MNI 5,967
Algarve	Rocha das Gaivotas	Dean *et al*, 2012 Dean and Carvalho (2011)	
Algarve	Rocha das Gaivotas	Dean *et al*, 2012 Dean and Carvalho (2011)	
Algarve	Rocha das Gaivotas	Dean *et al*, 2012 Dean and Carvalho (2011)	
Algarve	Rocha das Gaivotas	Dean *et al*, 2012 Dean and Carvalho (2011)	Mollusc MNI 2,615
Central	Toledo	Araújo, 2009; 2016 Bicho *et al*, 2010 Soares and Diaz, 2006	Mollusc MNI 4,217 *Solen* a close 4th Fish NISP 100 Mammal NISP 996 Bird NISP 44 Indeterminate medium large mammal significant
Central	Vale Frade	Araújo, 2009; 2016 Bicho *et al*, 2010 Soares and Diaz, 2006	Molluscs weight only Fish NISP 37 Mammal NISP 141 Bird NISP 5
Central	Casal Papagaio	Bicho *et al*, 2010	
Central	S. Juliao A	Sousa and Soares, 2016 Bicho *et al*, 2010	
Central	S. Juliao B	Sousa and Soares, 2016 Bicho *et al*, 2010	
Central	S. Juliao C	Sousa and Soares, 2016 Bicho *et al*, 2010	*Stramonita/Phorcus/ L. littorea* also present
Central	S. Juliao D	Sousa and Soares, 2016	
Central	S. Juliao D	Sousa and Soares, 2016	
Central	Magoito	Bicho *et al*, 2010	
Central	Magoito	Sousa and Soares, 2016	
Central	Magoito	Sousa and Soares, 2016	
Muge	Moita de Sebatiao	Clarke, 1983 Bicho *et al*, 2010	C. elaphus, C. capreolus, S. scofa, B. primigenius, O. cuniculus, Lepus. spp..
Muge	Cabeco da Arruda	Clarke, 1983 Bicho *et al*, 2010	C. elaphus, C. capreolus, S. scofa, B. primigenius, Equus spp., O. cuniculus, Lepus. spp.. Also R. decussatus, Mytilus spp., O. edulis, Solen spp.
Muge	Vale Fonte Moca I	Clarke, 1983 Bicho *et al*, 2010	mammal bones dated but no faunal composition given.
Muge	Cabeco da Amoreira	Clarke, 1983 Bicho *et al*, 2010	C. elaphus, C. capreolus, S. scofa, B. primigenius, Equus spp., O. cuniculus, Lepus. spp.. Also R. decussatus, O. edulis, Solen spp.

SI-Chapter5-1.2 – Atlantic Spain.

Table SI-Chapter5-1.2-1: Detailed dating for the sites in Spain. ΔR values from Soares *et al* (2016). Data from sources provided in table SI-Chapter5-1.2-6.

Sub-region	**Site**	**Level/Phase/Unit**	**Laboratory Code**	**^{14}C Assay**	**Marine (%)**	**PD Start BC (2σ)**	**PD End BC (2σ)**	**PD Mean BC**	**Error ±**	**Δ R ^{14}Cyrs**
Spain	Cuetu la Hoz	Midden		Mesolithic						
Spain	Cuevas del Mar 3	Midden		Mesolithic						
Spain	Columba	Midden		Mesolithic						
Spain	Poza ÍEgua	Midden (L1)		8550±80	0	7785	7457	7621	164	
Spain	La Riera	(29/30)	GaK-3046	6500±200	0	5833	4998	5416	418	
Spain	La Riera	(29/30)	RIE-1	7516±588	100	7729	5035	6382	1347	-141±70
Spain	La Riera	B	GaK 2909	8909±309	0	9119	7345	8232	887	
Spain	Les Pedroses		GaK 2547	5933±185	0	5300	4408	4854	446	
Spain	Alloru	Midden	UBAR-781	8360±70	100	7456	6918	7187	269	-141±70
Spain	Alloru	Midden (SU104)	OxA-29115	7979±38	0	7049	6721	6885	164	
Spain	Covajorno	Midden		Mesolithic						
Spain	El Aguila	Midden		Mesolithic						
Spain	Las Arenillas	Midden	UBAR-775	6455 ± 60	100	5339	4979	5159	180	−105 ± 21
Spain	Los Canes	7		6598±333	0	6211	4831	5521	690	
Spain	Los Canes	Burial Pits	TO11219	5980 ± 70	0	5047	4711	4879	168	
Spain	Los Canes	Burial Pits	AA-5788	5865 ± 70	0	4907	4546	4727	181	
Spain	Pendueles	Midden		Mesolithic						
Spain	El Toralete	Midden		Mesolithic						
Spain	Mazaculos II	A2 Fondo			0			0	0	
Spain	Mazaculos II	A3	GaK-15222	Mesolithic	0	6202	5670	5936	266	
Spain	Mazaculos II	B		Mesolithic						
Spain	Mazaculos II	A2	GaK-15221	5050±120	0	4226	3635	3931	296	
Spain	Mazaculos II	1.1	GaK-8162	7280±220	0	6588	5731	6160	429	
Spain	Mazaculos II	1.3 (H11)	UGAM-9081	7700 ± 30	0	6596	6469	6533	63.5	
Spain	Mazaculos II	1.3 (H11)	OxA-26953	7755 ± 38	100	6326	6017	6172	155	103 ± 54
Spain	Mazaculos II	2.1		Mesolithic						
Spain	Mazaculos II	3.3	GaK 6684	9290±440	0	10031	7535	8783	1248	
Spain	El Pindel	2								

Sub-region	Site	Level/Phase/Unit	Laboratory Code	^{14}C Assay	Marine (%)	PD Start BC (2σ)	PD End BC (2σ)	PD Mean BC	Error ±	Δ R ^{14}Cyrs
Spain	La Garma A	Q	OxA–7150	6870±50	0	5877	5661	5769	108	
Spain	La Garma A	Q	OxA–6889	6920±50	0	5969	5715	5842	127	
Spain	La Garma A	Q	OxA–7495	7710±90	0	6767	6400	6584	184	
Spain	La Garma A	Q	OxA–7284	7685±65	0	6641	6438	6540	102	
Spain	La Garma A	Q	UBAR–656	8165±165	100	7365	6466	6916	450	-141±70
Spain	La Garma A	Q	UBAR–655	8295±165	100	7503	6621	7062	441	-141±70
Spain	La Garma A	Q	UBAR–658	7985±177	100	7180	6247	6714	467	-141±70
Spain	La Garma A	Q	UBAR–657	8175±165	100	7378	6475	6927	452	-141±70
Spain	El Truchiro	II								
Spain	La Garma B	A		Mesolithic						
Spain	El Mar	Midden								
Spain	Cuesta de la Encina B	A								
Spain	La Chora	Midden	GrN-20961	6360±80	0	5486	5080	5283	203	
Spain	La Fragua	1U	GrN-20965	6650±120	0	5782	5365	5574	209	
Spain	La Fragua	1M	GrN-20964	6860±60	0	5877	5641	5759	118	
Spain	La Fragua	1L	GrN-20965	7530±70	0	6491	6236	6364	128	
Spain	La Fragua	3	GrN-20966	9600±140	0	9304	8606	8955	349	
Spain	El Perro	1.3	GrN-18115	9260±110	0	8771	8277	8524	247	
Spain	La trecha (Z IV)	1	URU-0038	7500±70	100	6286	5971	6129	158	–105 ± 21
Spain	La trecha (Z II)	Midden	URU-0039	6240±100	100	5149	4620	4885	265	–105 ± 21
Spain	La trecha (Z II)	Midden	URU-0051	5600±310	0	5215	3794	4505	711	
Spain	La Trecha (Z II)	Midden	URU-0050	5430±70	0	4444	4053	4249	196	
Spain	Covacho de las Arenillas	Midden	OxA-X-2488-	7143 ± 36	0	6071	5927	5999	72	
Spain	Covacho de las Arenillas	Transition	GrN-19596	5580±80	0	4607	4262	4435	173	
Spain	Covacho de las Arenillas	Midden	OxA-27154	7374 ± 38	100	6183	5903	6043	140	–147 ± 48
Spain	Abrigo de El Craneo	B								
Spain	Los Gitanos	A4	UBAR–693	5490±200	0	4794	3817	4306	489	
Spain	Los Gitanos	A3	AA–29113	5945±55	0	4964	4709	4837	128	
Spain	Los Gitanos	A3	UBAR–521	5150±100	0	4232	3712	3972	260	
Spain	Los Gitanos	A2	UBAR–469	4370±150	0	3498	2584	3041	457	
Spain	Pico Ramos	4	UA 3051	5860±85	0	4941	4521	4731	210	
Spain	Pico Ramos	4	Beta 193569	6040±65	0	5207	4783	4995	212	
Spain	Pico Ramos	4	Beta 191083	6040±90	100	4852	4412	4632	220	–105 ± 21
Spain	Pico Ramos	4	Beta 181689	5370±40	0	4331	4057	4194	137	
Spain	Santimamine	Lsm	Beta-240898	5010 ± 40	0	3944	3704	3824	120	
Spain	Santimamine	Slm	Beta-240898	5450 ± 50	0	4446	4081	4264	183	
Spain	Santimamine	H-Sln	Beta-240899	7580 ± 50	0	6568	6272	6420	148	
Spain	Kobaederra	III	UBAR-471	5820 ± 240	0	5313	4181	4747	566	
Spain	Kobaederra	IV								
Spain	Marizulo	II	GrN-5992	5285 ± 65	0	4315	3973	4144	171	
Spain	Marizulo	Burial Human	Ua-4818	5315 ± 100	0	4346	3961	4154	193	
Spain	Marizulo	Lamb in human grave	Ua-10375	5235 ± 75	0	4314	3816	4065	249	
Spain	J3	F		Mesolithic						
Spain	J3	D		Mesolithic						
Spain	Herriko Barra	Below C	?	5810±170	0	5205	4335	4770	435	
Spain	Herriko Barra	Above C	?	4920±100	0	3959	3519	3739	220	
Spain	Colombres	A		mesolithic						
Spain	Colombres	B		mesolithic						
Spain	Colombres	D		mesolithic						
Spain	Cuento de la Mina	A		mesolithic						
Spain	Coberizas (Cueva Sabina)	L1	GaK 2907	7313±175	0	6503	5839	6171	332	
Spain	Balmori	A								
Spain	Bricia	A	GaK 2908	7004±165	0	6220	5625	5923	298	
Spain	Penicial	C/D	GaK 2906	8909±185	0	8532	7591	8062	471	
Spain	Fonfria	B	Mesolithic							
Spain	La Llana	1								
Spain	El Mazo	SU114	OxA-27969	7990±38	0	7057	6713	6885	172	
Spain	El Mazo	SU115	OxA-31054	8004±39	0	7060	6775	6918	143	
Spain	El Mazo	SU115	OxA-31055	8000±40	0	7061	6767	6914	147	
Spain	La Lloseta	C								
Spain	La Lloseta	B	GaK 2551	4594±680	0	4981	1637	3309	1672	

Table SI-Chapter5-1.2-2: Spanish sites with at least ordinal data for mammal abundance not based upon weight. Data from the sources in table SI-Chapter5-1.2-6.

		Phase		Mammal	
Region	**Site**	**Level**	**1st**	**2nd**	**3rd**
Northern	Pico Ramos	4	Red Deer	Wild Boar	Aurochs
Northern	Colombres	B	Wild Boar	Red Deer	Ibex
Northern	Colombres	D	Wild Boar	Red Deer	Ibex
Northern	Coberizas (Cueva Sabina)	L1	Red Deer	Wild Boar	Roe Deer
Northern	Balmori	A	Red Deer	Aurochs	Wild Boar/Ibex

Table SI-Chapter5-1.2-3: Spanish sites with at least ordinal data for bird abundance not based upon weight. Data from the sources in table SI-Chapter5-1.2-6.

Region	Site	Phase	1st	Bird 2nd	3rd
Northern	Pico Ramos	4	Great Auk		
Northern	Herriko Barra	C	Guillemot	Razorbill/Puffin	Razorbill/Puffin

Table SI-Chapter5-1.2-4: Spanish sites with at least ordinal data for fish abundance not based upon weight. Data from the sources in table SI-Chapter5-1.2-6.

Region	Site	Phase Level	1st	Fish 2nd	3rd
Northern	Mazaculos II	3.3	Wrasse		
Northern	Pico Ramos	4	Atlantic Cod	Ray	
Northern	Coberizas (Cueva Sabina)	L1	Boney Fish		
Northern	Balmori	A	Boney Fish		
Northern	Bricia	A	Boney Fish		
Northern	Penicial	C/D	Boney Fish		
Northern	Fonfria	B	Sole		

Table SI-Chapter5-1.2-5: Spanish sites with at least ordinal data or an MNI count for mollusc abundance not based upon weight. Data from the sources in table SI-Chapter5-1.2-6. Spatial group 99 defines sites that are not coastal.

Spatial Group	Site	Phase Level	MNI	Mollusc		
				1st	2nd	3rd
0	Les Pedroses		494	Limpet	Thick Top	Mussel
0	La Lloseta	B	256	Limpet	Mussel	Thick Top
0	La Lloseta	C	388			
1	Cuetu la Hoz	Midden	155	Limpet	Thick Top	Mussel
2	Cuevas del Mar 3	Midden	111	Limpet	Thick Top	Mussel
2	Penicial	C/D	3326	Limpet	Thick Top	Mussel
2	Columba	Midden	782	Limpet	Thick Top	
3	Poza ÍEgua	Midden	3509	Limpet	Thick Top	
3	La Riera	(29/30)	353	Limpet	Thick Top	Mussel
3	La Riera	B		Limpet	Thick Top	Cockle
3	Cuento de la Mina	A		Limpet (S)	Thick Top	Mussel
3	Coberizas (Cueva Sabina)	L1	3189	Limpet	Thick Top	Mussel
3	Bricia	A	1767	Limpet	Thick Top	Cockle
4	Alloru	Midden	164	Thick Top	Limpet	
4	Covajorno	Midden	340	Thick Top	Limpet	Mussel
4	Balmori	A	3336	Limpet	Thick Top	Periwinkle
4	Fonfria	B	21	Limpet (S)	Thick Top	Cockle
4	El Aguila	Midden	862	Thick Top/Limpet	Thick Top/Limpet	Mussel
4.5	La Llana	1	6704	Limpet	Thick Top	Mussel
5	Las Arenillas	Midden 1	247	Limpet	Thick Top	
5	Pendueles	Midden	113	Thick Top	Limpet	
5	El Toralete	Midden	494	Thick Top	Limpet	
5	Mazaculos II	A3	1073	Limpet	Thick Top	Mussel
5	Mazaculos II	B		Limpet	Thick Top	Oyster
5	Mazaculos II	A2	6587	Limpet	Thick Top	Mussel
5	Mazaculos II	1.1		Limpet	Thick Top	Mussel
5	Mazaculos II	1.3		Limpet	Thick Top	Mussel
5	Mazaculos II	2.1		Limpet	Thick Top	Mussel
5	Mazaculos II	3.3		Limpet	Thick Top	Mussel
5	Colombres	B		Limpet	Thick Top	Oyster
5	Colombres	D		Limpet	Thick Top	Oyster
5	El Mazo	SU114	389	Thick Top	Limpet	Other Top
5	El Mazo	SU115	1849	Thick Top	Limpet	Mussel
5.5	El Pindel	2	462	Limpet	Thick Top	Mussel

Spatial Group	Site	Phase Level	MNI		Mollusc	
				1st	2nd	3rd
6	La Garma A	Q (late)	2571	Limpet	Thick Top	
6	La Garma B	A	3120	Limpet	Thick Top	Mussel
6	Cuesta de la Encina B	A	235	Limpet	Thick Top	Mussel
6	El Truchiro	II	1128	Limpet	Thick Top	
6	El Mar	Midden	185	Limpet	Thick Top	
7	La Fragua	1U[1]	11900	Limpet	Mussel	Thick Top
7	La Fragua	1M		Limpet	Mussel	Thick Top
7	La Fragua	1L		Limpet	Mussel	Thick Top
7	La Fragua	3	328	Periwinkle	Limpet	Mussel
7	El Perro	1	5123	Limpet	Mussel	Thick Top
8	Covacho de las Arenillas	Midden (Late)	9240	Limpet	Mussel	Oyster/Thick
8	Los Gitanos	A4	3990	Limpet	Thick Top	
8	Los Gitanos	A3	3706	Limpet	Thick Top	
8	Los Gitanos	A2	9203	Limpet	Thick Top	
8	La trecha (Z IV)	Midden	1505	Limpet	Thick Top	Mussel
8	Abrigo de El Craneo	B	933	Thick Top	Limpet	
9	Pico Ramos	4	2180	Limpet	Thick Top	Mussel/Oyster
10	Santimamine	Slm	1641	Perry Furrow	Carpet	Oyster
10	Santimamine	Lsm	805	Peppery Furrow	Carpet	Oyster
10	Santimamine	H-Sln	35	Oyster	Peppery Furrow	
10	Kobaederra	II	191	Oyster	Carpet	Limpet/Peppery Furrow
10	Kobaederra	III	803	Oyster	Carpet	Peppery Furrow
10	Kobaederra	IV	519	Carpet	Oyster/Peppery Furrow	Oyster/Peppery Furrow
12	Marizulo	II	280	Limpet	Mussel	Grooved Razor
13	J3	F	2265			
13	J3	D	5119	Thick Top		
99	Los Canes	7	280	Limpet	Mussel	Thick Top
99	La Chora	Midden	159	Peppery Furrow	Peppery Furrow/Mussel	Oyster/Mussel

Table SI-Chapter5-1.2-6: Sources of faunal and dating information for the Spanish sites, plus other notes.

Site	**Sources**	**Notes**
Les Pedroses	Clarke (1983)	Date from Clarke (1971, 1983) No ceramics and no asturian arefacts
La Lloseta	Clarke (1983)	Phorcus very minor. Mytilus and Patella parity
Cuetu la Hoz	Alvarez-Fernandez (2015)	
Cuevas del Mar 3	Alvarez-Fernandez (2015)	Cubas *et al*, 2016, Mytilus < 1%
Penicial	Clarke (1971; 1983)	Date from Clarke (1971, 1983) Mussel very minor. Gibbula spp. and urchin present
Columba	Alvarez-Fernandez (2015)	
Poza ÍEgua	Alvarez-Fernandez (2015)	Date Gutierrez-Zugasti 2011
La Riera	Clarke (1983)	Date Gutierrez-Zugasti 2011
La Riera	Clarke (1983)	Date from Clarke (1971, 1983)
Cuento de la Mina	Clarke (1983)	Mytilus spp. in small numbers. Urchins present in large numbers. Small numbers of edible crab and velvet swimming crab
Coberizas (Cueva Sabina)	Clarke (1971; 1983)	Date from Clarke (1971, 1983) Cockles reasonably abundant. MNI after removal of terrestrial Molluscs Oyster and Periwinkle present at very very low abundances
Bricia	Clarke (1971; 1983)	Date from Clarke (1971, 1983) 3 common periwinkle and 2 Gibbula spp. present
Alloru	Alvarez-Fernandez (2015)	First date on Marine shell. Dates and marine calibration from Arias *et al* (2015)
Covajorno	Alvarez-Fernandez (2015)	
Balmori	Clarke (1971; 1983)	Chamois almost the same as sus/capra. Wild cat and Hare present. Urhin (39)
Fonfria	Clarke (1971; 1983)	Mussels in small quanities
El Aguila	Alvarez-Fernandez (2015)	
La Llana	Alvarez-Fernandez (2011) Gutierrez-Zugasti (2009)	Also present: Gibbula spp.
Las Arenillas	Arias et al (2015) Middle Alvarez-Fernandez (2015)	
Pendueles	Alvarez-Fernandez (2015)	
El Toralete	Alvarez-Fernandez (2015)	
Mazaculos II	Arroyo and Morales (2009) Gutirrez-Zugasti, 2009, 2011	Also present. 3 oysters, carptet shell, Peppery Furrow Shell, 3 periwinkles, Gibbula spp.
Mazaculos II	Arroyo and Morales (2009)	Clarke (1983)
Mazaculos II	Arroyo and Morales (2009) Gutirrez-Zugasti, 2009, 2011	Also present: 1 oyster, 1 Peppery Furrow Shell, 2 Periwinkle, 2 Gibbula spp.
Mazaculos II	Arroyo and Morales (2009) Gutirrez-Zugasti, 2009, 2011	Date Gutierrez-Zugasti 2011
Mazaculos II	Arroyo and Morales (2009) Gutirrez-Zugasti, 2009, 2011	Date Soares et al (2016)
Mazaculos II	Arroyo and Morales (2009) Gutirrez-Zugasti, 2009, 2011	
Mazaculos II	Arroyo and Morales (2009) Gutirrez-Zugasti, 2009, 2011	Date Gutierrez-Zugasti 2011. See note on other sheet reference fish
Colombres	Clarke (1983)	
Colombres	Clarke (1983)	Hiatus during the formation of level C?
Colombres	Clarke (1983)	

Site	**Sources**	**Notes**
El Mazo	García-Escárzaga *et al*, 2017	
El Mazo	García-Escárzaga *et al*, 2017	
El Pindel	Alvarez-Fernandez (2015)	Almost entirely limpet
La Garma A	Alvarez-Fernandez (2011, 2015)	Álvarez-Fernandez *et al*, 2011
La Garma B	Alvarez-Fernandez (2015)	
Cuesta de la Encina B	Alvarez-Fernandez (2015)	Some oyster
El Truchiro	Alvarez-Fernandez (2015)	
El Mar	Alvarez-Fernandez (2015)	
La Fragua	Alvarez-Fernandez (2015) Gutierrez-Zugasti, 2009, 2011	Also present: 37 Carpet Shell, 47 Grooved razor clam, 58 oyster. Gibbula spp. perwinkle and dog whelk
La Fragua	Alvarez-Fernandez (2015)	Date: Straus *et al*, 2002
La Fragua	Alvarez-Fernandez (2015)	Date: Straus *et al*, 2002
La Fragua		
El Perro	Alvarez-Fernandez (2015)	Date: Straus *et al*, 2002 oyster non-trival date for level 1.3
Covacho de las Arenillas	Gutierrez-Zugasti, 2009, 2011 (Later) Soares *et al* (2016) earlier.	Also present: 2 cockle, 2 Donax, 77 carpet shell, 43 Peppery Furrow Shell, 89 Grooved Razor Clam, Gibbula spp. Cancer, Carcinus and swimming crabs abundant, Pachygrapsus extremely abundant in transition phase.
Los Gitanos	Arias et al (2015) Middle	Álvarez-Fernandez *et al*, 2011
Los Gitanos	Soares et al (2016) earlier.	Álvarez-Fernandez *et al*, 2011
Los Gitanos	Cubas *et al*, 2016 Alvarez-Fernandez, 2011	Álvarez-Fernandez *et al*, 2011
La trecha (Z IV)	Alvarez-Fernandez (2015) Gutierrez-Zugasti, 2009, 2011 Straus et al, 2002	Also present: 87 oysters, 14 carpet shells, Peppery Furrow Shell, Grooved Razor Clam, Gibbula spp.
La trecha (Z II)	Alvarez-Fernandez (2015) Gutierrez-Zugasti, 2009, 2011 Straus et al, 2002	
Abrigo de El Craneo	Alvarez-Fernandez (2015)	
Pico Ramos	Zapata *et al*, 2007	Date from Morales et al, 2004
Santimamine	Cubas *et al*, 2016 Gutierez-Zugasti, 2009; 2011b	Also present: 1 each of Mytilus, Phorcus, Patella and 6 x Solen
Santimamine	Cubas et al, 2016 Gutierez-Zugasti, 2009; 2011b	Also present: Mytilus x 2 , cockle, Patella x 3 and Solen x 23
Santimamine	Cubas *et al*, 2016 Gutierez-Zugasti, 2009; 2011b	Also present: 1 each of Mytilus, Phorcus, Patella and Solen. Equus caballus, Sus scrofa, Cervus elaphus, Capreolus capreolus, Rupicapra rupicapra, Capra ibex pyrenaica, and Vulpes vulpes For first time Bos primigenius (auroch), Mustela putorius, the polecat), Lutra lutra the otter), Meles meles, the badger), Felis silvestris , the wildcat), and Lepus spp. Also Badger and Weasle. Clarke equates brown hare with mountain hare.

Site	**Sources**	**Notes**
Kobaederra	Gutierrez-Zugasti, 2009	Also present: Phorcus, Cockle, Grooved Razor Clam and Mussel
Kobaederra	Cubas et al, 2016 Gutierrez-Zugasti, 2009	Also present: Phorcus, Patella, Grooved Razor Clam and Mussel
Kobaederra	Cubas *et al*, 2016 Gutierrez-Zugasti, 2009	Also present: Phorcus, Patella, Grooved Razor Clam and Mussel
Marizulo	Alvarez-Fernandez (2015)	Date from Morales et al, 2004
Los Canes	Cubas *et al*, 2016	Dates from Morales *et al* (2004)
La Chora	Alvarez-Fernandez (2015) Gutirrez-Zugasti, 2009 Straus *et al*, 2002	Also present: Limpet 10.5%, Grooved Razor Cam 2.8%, carpet shell,
J3	Alvarez-Fernandez (2015)	
J3	Alvarez-Fernandez (2015)	
Penicial	Clarke (1971; 1983)	Date from Clarke (1971, 1983) Mussel very minor. Gibbula spp. and urchin present
Fonfria	Clarke (1971; 1983)	Mussels in small quanities
La Llana	Alvarez-Fernandez (2011) Gutierrez-Zugasti (2009)	Also present: Gibbula spp.
El Mazo	García-Escárzaga *et al*, 2017	
El Mazo	García-Escárzaga *et al*, 2017	
La Lloseta	Clarke (1983)	Phorcus very minor. Mytilus (1:2) Patella
La Lloseta	Clarke (1983)	Phorcus very minor. Mytilus and Patella parity
Herriko Barra	Eloraz and Marco (1993)	Great Auk also abundant. Fulmar, Manx shearwater, Common Crane and Kittiwake also present. Crabs and Urchins present

SI-Chapter5-1.3 - Brittany.

Table SI-Chapter5-1.3-1: Detailed dating for the sites in France. ΔR values from Marchand *et al* (2007). Data from sources provided in table SI-Chapter5-1.3-6.

Sub-region	Site	Level/Phase/Unit	Laboratory Code	^{14}C Assay	Marine (%)	PD Start BC (2σ)	PD End BC (2σ)	PD Mean BC	Error ±	Δ R ^{14}Cyrs
Brittany	Saint-Gildas IB		Beta-194786	8000±40	100	7046	6627	6837	210	-260±65
Brittany	Saint-Gildas IB		GiF-3531	7520±140	100	6613	5981	6297	316	-260±65
Brittany	Saint-Gildas IC		GiF-4847	6790±90	100	5801	5381	5591	210	-260±65
Brittany	Beg-an-Dorchenn	Shell Cluster	GRN-2001	5970±80	0	5198	4622	4910	288	
Brittany	Beg-an-Dorchenn	Shell Cluster	GSY-65	5440±400	0	5292	3380	4336	956	
Brittany	Beg-an-Dorchenn	Shell Cluster Top	GiF-6857	6370±70	100	5413	4971	5192	221	-260±65
Brittany	Beg-an-Dorchenn	Shell Cluster Bottom	GiF-6858	7580±80	100	6572	6122	6347	225	-260±65
Brittany	Beg-an-Dorchenn	Shell Cluster Bottom	GiF-6859	6590±110	0	5713	5344	5529	185	
Brittany	Beg-an-Dorchenn	Layer 4 Square A Context	Lyon-2267	6675±55	0	5701	5491	5596	105	
Brittany	Beg-an-Dorchenn	Square C Context 4 Square A Context 3	Ly-12284	6765±45	100	5711	5436	5574	138	-260±65
Brittany	Beg-an-Dorchenn	Square C Context 4 Square A Context 3	Ly-12285	6925±45	100	5873	5557	5715	158	-260±65
Brittany	Beg-an-Dorchenn	Square C Context 4 Square A Context 3	Ly-12286	6940±45	100	5886	5570	5728	158	-260±65
Brittany	Beg-an-Dorchenn	Square A Context 7	Ly-12287	7255±65	100	6224	5833	6029	196	-260±65
Brittany	Beg-an-Dorchenn	Square A Context 3	Ly-12288	6810±45	100	5739	5465	5602	137	-260±65
Brittany	Beg-an-Dorchenn	Square A Context 3	Ly-12289	6905±40	100	5846	5541	5694	153	-260±65
Brittany	Beg-an-Dorchenn	Square C Context 4	Ly-12290	7195±70	100	6180	5760	5970	210	-260±65
Brittany	Beg-an-Dorchenn	Human Burial	OxA-5363	4140±55	16.66	2880	2505	2693	188	-260±65
Brittany	Hoedic		GiF-227	6575±350	0	6218	4771	5495	724	
Brittany	Hoedic		OxA-6708	7165±60	85.55	6116	5756	5936	180	-260±65
Brittany	Hoedic		OxA-6709	6645±60	90	5621	5326	5474	148	-260±65
Brittany	Hoedic		OxA-6706	6280±60	87.77	5308	4919	5114	195	-260±65
Brittany	Hoedic		OxA-6707	6080±60	81.1	5105	4685	4895	210	-260±65
Brittany	Hoedic		OxA-6710	5755±55	82.22	4681	4346	4514	168	-260±65
Brittany	Hoedic		OxA-6705	5080±55	75.55	3944	3646	3795	149	-260±65
Brittany	Hoedic		OxA-11776	5750±35	70	4622	4370	4496	126	-260±65
Brittany	Teviec		OxA-6665	6740±60	64.44	5704	5474	5589	115	-260±65
Brittany	Teviec		OxA-6704	6515±65	74.44	5521	5221	5371	150	-260±65
Brittany	Teviec		OxA-6664	6510±50	55.55	5513	5296	5405	109	-260±65
Brittany	Teviec		OxA-6703	6500±65	76.66	5510	5210	5360	150	-260±65
Brittany	Teviec		OxA-6663	6440±55	59.99	5470	5214	5342	128	-260±65
Brittany	Teviec		OxA-6701	6000±60	55.55	5001	4659	4830	171	-260±65
Brittany	Teviec		OxA-10936	6515±45	57.77	5503	5299	5401	102	-260±65
Brittany	Teviec		OxA-6702	6530±60	55.55	5548	5297	5423	126	-260±65
Brittany	Teviec		OxA-6662	5680±50	44.44	4595	4344	4470	126	-260±65
Brittany	Teviec		OxA-12895	6322±40	56.66	5325	5055	5190	135	-260±65
Brittany	Beg-er-Vil		GiF-7810	6020±80	100	5043	4528	4786	258	-260±65
Brittany	Beg-er-Vil		OxA-????	7450±45	47.77	6410	6120	6265	145	-260±65
Brittany	Er Yol	EY.HS.4 (human)	OxA-10843	4240±55	19	2924	2629	6265	145	-260±65
Brittany	Er Yol	EY.HS.2	OxA-10810	3130±40	26	1492	1262	6265	145	-260±65
Brittany	Ponthezieres		Neolithic							
Brittany	La Perroche		Meolithic							

Table SI-Chapter5-1.3-2: French sites with at least ordinal data for mammal abundance not based upon weight. Data from the sources in table SI-Chapter5-1.3-6.

Brittany	Beg-an-Dorchenn		Red Deer	Wild Boar	Aurochs

Table SI-Chapter5-1.3-3: French sites with at least ordinal data for bird abundance not based upon weight. Data from the sources in table SI-Chapter5-1.3-6.

				Bird	
Region	**Site**	**Phase**	**1st**	**2nd**	**3rd**
Brittany	Beg-an-Dorchenn		Auks		
Brittany	Beg-er-Vil		Ducks/Geese	Wood Cock	Auks
Brittany	Teviec		Auks	Ducks/Geese	Wood Cock
Brittany	Er Yol		Cormorant/Shag	Gulls	Auks/Geese

Table SI-Chapter5-1.3-4: French sites with at least ordinal data for fish abundance not based upon weight. Data from the sources in table SI-Chapter5-1.3-6.

				Fish	
Region	**Site**	**Phase Level**	**1st**	**2nd**	**3rd**
Brittany	Beg-an-Dorchenn		Cartilaginous	Wrasse	Sea Bream/Hake

Table SI-Chapter5-1.3-5: French sites with at least ordinal data or an MNI count for mollusc abundance not based upon weight. Data from the sources in table SI-Chapter5-1.2-6.

				Mollusc	
Site	**Phase Level**	**MNI**	**1st**	**2nd**	**3rd**
Beg-an-Dorchenn		13324	Limpet	Scrobicularia spp.	Cockle
Beg-er-Vil			Limpet	Cockle	Oyster
Hoedic			Limpet	Mussel	Thick Top
Teviec			Limpet	Cockle	Thick Top
Saint-Gildas IB	1B	829	Peppery Furrow	Limpet	Mussel
Saint-Gildas IC	1C	172	Peppery Furrow	Limpet	Periwinkle
Ponthezieres			Limpet	Thick Top	
La Perroche			Limpet	Thick Top	Haliotus spp.

Table SI-Chapter5-1.3-6: Sources of faunal and dating information for the French sites, plus other notes.

Site	**Sources**	**Notes**
Beg-an-Dorchenn	Dupont et al, 2009 Dupont et al, 2010	Dates from Schulting (2005) and Schulting and Richards (2001) Shell NISP=170958 Ostrea, Ruditapes, Phorcus/Littorina, Nucella, Solen, Gibbula, Donax, Lutraria. The detailed data in Dupont et al (2010) does not support the figure 13.3 in Dupont *et al*, 2007, either in terms of NISP or MNI. MNI from Dupont *et al*, 2010 utilised.
Beg-er-Vil	Dupont *et al*, 2007 Dupont *et al*, 2009 Tresset (2005)	Dates from Schulting (2005) and Schulting and Richards (2001) ΔR from Marchand et al, 2009. Shell NISP= 86360 Bird NISP = 43 Common Crane present. Littorina, Phorcus/Mytilus. Grey seal present.
Hoedic	Dupont et al, 2007 Dupont et al, 2009	Dates from Schulting (2005) and Schulting and Richards (2001) ΔR from Marchand et al, 2009 Shell NISP=170958
Teviec	Dupont et al, 2007 Dupont et al, 2009 Tresset (2005)	Dates from Schulting (2005) and Schulting and Richards (2001) ΔR from Marchand et al, 2009 Shell NISP=170958. Grey Seal present. Divers, also present small numbers of pigeon and a specimen of Manx shearwater. Bird NISP = 225
Saint-Gildas IB	Dupont and Marchand (2008)	Dates from Dupont and Marchand (2008) ΔR from Marchand et al, 2009 and Patella and Mytilus minimal.
Saint-Gildas IC	Dupont and Marchand (2008)	ΔR from Marchand et al, 2009 Date from Dupont and Marchand (2008)
Er Yol	Tresset (2005)	Date from Schulting (2005) ΔR from Marchand et al, 2009 Bird NISP = 334 White Tailed Eagle also very abundant. Grey Seal Present. Divers and woodcock also present along with waders. Tresset (2005).
Ponthezieres	Dupont *et al*, 2007	Shell NISP=331814 ΔR from Marchand et al, 2009
La Perroche	Dupont *et al*, 2007	Shell NISP=18330 ΔR from Marchand et al, 2009

SI-Chapter5-1.4 – Atlantic England and Wales.

Table SI-Chapter5-1.4-4: Detailed dating for the sites in England and Wales. Data from sources provided in table SI-Chapter5-1.4-5.

Sub-region	Site	Level/Phase/Unit	Laboratory Code	^{14}C Assay	Marine (%)	PD Start BC (2σ)	PD End BC (2σ)	PD Mean BC	Error ±	Δ R ^{14}Cyrs
England and Wales	Culverwell	T41 L7	AA-28213	6800±60	100	5548	5238	5393	155	-31±56
England and Wales	Culverwell	T41 L8a	AA-28214	6730±55	100	5486	5188	5337	149	-31±56
England and Wales	Culverwell	T41 L8b	AA-28215	6410±55	100	5194	4788	4991	203	-31±56
England and Wales	Culverwell	T41 L9	AA-28216	7145±70	100	5884	5531	5708	177	-31±56
England and Wales	Culverwell	T41 L12	AA-28217	7285±60	100	5988	5666	5827	161	-31±56
England and Wales	Culverwell	T41 L13	AA-28218	7525±60	100	6240	5891	6066	175	-31±56
England and Wales	Culverwell	T41 L9-12	AA-28219	6525±60	100	5304	4918	5111	193	-31±56
England and Wales	Culverwell	T41 L12	AA-28220	6855±75	100	5616	5281	5449	168	-31±56
England and Wales	Westward Ho!	Earliest charcoal	HAR-5643	8180±150	0	7533	6709	7121	412	
England and Wales	Westward Ho!	Charcoal below midden	HAR-5644	6770±120	0	5902	5482	5692	210	
England and Wales	Westward Ho!	Midden	HAR-5645	6320±90	0	5476	5061	5269	208	
England and Wales	Westward Ho!	Oak Tree	HAR-5631	6100±100	0	5296	4794	5045	251	
England and Wales	Westward Ho!	Peat Above	Q-672	6585±130	0	5735	5306	5521	215	
England and Wales	Westward Ho!	Mesolithic Layer	Q-141			4865	4245	4555	310	
England and Wales	Westward Ho!	Mesolithic Layer	Q-587			5800	5500	5650	150	
England and Wales	Goldcliff East J		CAR-1502	6480±70	0	5605	5316	5461	145	
England and Wales	Goldcliff East A		CAR-1502	6480±70	0	5605	5316	5461	145	
England and Wales	Goldcliff East B		CAR-1502	6480±70	0	5605	5316	5461	145	
England and Wales	Nant Hall Road B	B	CAR-1356	4700±70	0	3637	3363	3500	137	
England and Wales	Nant Hall Road C	C	CAR-1355	4890±80	0	3942	3386	3664	278	
England and Wales	Nant Hall Road D	Above D	CAR-1421	4910±70	0	3939	3528	3734	206	
England and Wales	Nant Hall Road D	D	CAR1423	5270±80	0	4325	3957	4141	184	
England and Wales	Nant Hall Road D	Below D	CAR-1424	5470±80	0	4464	4057	4261	204	
England and Wales	Nant Hall Road E	104	CAR-1422	5110±80	0	4220	3702	3961	259	
England and Wales	Nant Hall Road E	105	CAR-1420	5530±80	0	4546	4182	4364	182	
England and Wales	Nant Hall Road F	F								
England and Wales	Snail Cave	horizon 1, context 7	SUERC-45175	5232±29	100	3768	3507	3638	131	6±52
England and Wales	Snail Cave	horizon 1, context 7	SUERC-45179	5334±29	100	3901	3629	3765	136	6±52
England and Wales	Snail Cave	horizon 4a, context 22	SUERC-45180	4494±29	0	3345	3094	3220	126	
England and Wales	Snail Cave	horizon 4a, context 20	SUERC- 37669	4720±30	0	3633	3376	3505	129	
England and Wales	Snail Cave	horizon 4a, context 24	SUERC- 37670	8870±30	0	8220	7846	8033	187	
England and Wales	Snail Cave	horizon 4b, context 30	SUERC- 42946	8788±31	0	8165	7724	7945	221	
England and Wales	Snail Cave	horizon 4b, context 28	SUERC-45181	8836±28	0	8170	7791	7981	190	
England and Wales	Snail Cave	horizon 5, context 34	SUERC- 42947	8862±31	0	8211	7836	8024	188	

Table SI-Chapter5-1.4-2: English and Welsh sites with at least ordinal data for mammal abundance not based upon weight. Data from the sources in table SI-Chapter5-1.4-5.

		Phase		Mammal	
Region	**Site**	**Level**	**1st**	**2nd**	**3rd**
Atlantic Devon	Westward Ho!	1863-1871 AD work	Cervus spp.	Bos spp.	
North Wales	Nant Hall Road B		Dom cow	Dom pig	
North Wales	Nant Hall Road C		Dom cow	Dom pig	
North Wales	Nant Hall Road D		Red Deer	Bos spp.	Elk?
North Wales	Nant Hall Road E	C104	Red Deer	Bos spp.	Elk?
North Wales	Nant Hall Road E	C105	Red Deer	Bos spp.	Elk?
North Wales	Nant Hall Road F		Red Deer		
Severn Estuary	Goldcliff East J		Red Deer	Bos spp.	Sus spp.
Severn Estuary	Goldcliff East A		Red Deer	Sus spp.	Roe Deer/Bos p.
Severn Estuary	Goldcliff East B		Red Deer	Sus spp.	Roe Deer/Bos p.

Table SI-Chapter5-1.4-3: English and Welsh sites with at least ordinal data for fish abundance not based upon weight. Data from the sources in table SI-Chapter5-1.4-5.

		Phase		Fish	
Region	**Site**	**Level**	**1st**	**2nd**	**3rd**
Severn Estuary	Goldcliff East A		Eel	Sea Bass	Cod Family

Table SI-Chapter5-1.4-4: English and Welsh sites with at least ordinal data or an MNI count for mollusc abundance not based upon weight. Data from the sources in table SI-Chapter5-1.4-5.

				Mollusc	
Site	Phase Level	MNI	1st	2nd	3rd
Culverwell	C1 - S4L7	382	Periwinkle	Limpet	Thick Top
Culverwell	C1 - S5L8	579	Periwinkle	Thick Top	Limpet
Culverwell	C1 - S6L8	871	Thick Top/Periwinkle	Thick Top/Periwinkle	Limpet
Culverwell	C1 - S7L8	666	Phorcus	Periwinkle	Limpet
Culverwell	C1 - S8L9	715	Thick Top/Periwinkle	Thick Top/Periwinkle	Limpet
Culverwell	C1 - S9L9-12	281	Thick Top/Periwinkle	Thick Top/Periwinkle	Limpet
Culverwell	C2 - S6L7	115	Periwinkle	Limpet	Thick Top
Culverwell	C2 - S7L8	233	Periwinkle	Limpet	Thick Top
Culverwell	C2 - S8L8	314	Periwinkle	Thick Top	Limpet
Culverwell	C2 - S9L8	602	Periwinkle	Thick Top	Limpet
Culverwell	C2 - S10L8	471	Periwinkle	Thick Top	Limpet
Culverwell	C2 - S11L9	371	Periwinkle	Limpet	Thick Top
Culverwell	C2 - S12L12	67	Periwinkle	Limpet	Thick Top
Culverwell	C3 - S5L7	156	Periwinkle/Limpet	Periwinkle/Limpet	Phorcus
Culverwell	C3 - S6L8	248	Periwinkle	Limpet	Thick Top
Culverwell	C3 - S7L8	717	Periwinkle	Limpet	Thick Top
Culverwell	C3 - S8L8	760	Periwinkle	Limpet	Thick Top
Culverwell	C3 - S9L9	279	Limpet	Periwinkle	Thick Top
Culverwell	C3 - S10L12	187	Limpet	Thick Top/Periwinkle	Thick Top/Periwinkle
Culverwell	C4 - S11L8	86	Periwinkle	Thick Top/Limpet	Thick Top/Limpet
Culverwell	C4 - S12L8	204	Periwinkle	Thick Top	Limpet
Culverwell	C4 - S13L8	565	Periwinkle	Thick Top	Limpet
Culverwell	C5 - S14L8	166	Periwinkle	Limpet	Thick Top
Culverwell	C5 - S15L8	195	Periwinkle	Thick Top	Limpet
Culverwell	C5 - S16L8	363	Periwinkle	Thick Top	Limpet
Westward Ho!	1863-1871 AD work		Oyster	Limpet	Mussel
Nant Hall Road B			Cockle	Mussel	
Nant Hall Road C			Cockle		
Nant Hall Road D			Mussel	Periwinkle	Cockle
Nant Hall Road E	C104		Mussel	Periwinkle	Cockle
Nant Hall Road E	C105		Mussel	Periwinkle	Cockle
Nant Hall Road F			Mussel	Cockle	Periwinkle
Snail Cave	horizon 1		Periwinkle/Limpet	Periwinkle/Limpet	Mussel
Snail Cave	horizon 2		Periwinkle/Limpet	Periwinkle/Limpet	Mussel
Snail Cave	horizon 3		Periwinkle/Limpet	Periwinkle/Limpet	Mussel
Snail Cave	horizon 4a, context 20		Periwinkle/Limpet	Periwinkle/Limpet	Mussel
Snail Cave	horizon 5, context 34		Periwinkle/Limpet	Periwinkle/Limpet	Mussel

Table SI-Chapter5-1.4-5: Sources of faunal and dating information for the English and Welsh sites, plus other notes.

Site	Phase Level	Sources	Notes
Culverwell	C1 - S5L8	Mannino and Thomas (2001) Thomas et al (1999)	7 dog whelk plus 2 Gibbula T. decussata present.
Culverwell	C1 - S6L8	Mannino and Thomas (2001) Thomas et al (1999)	3 dog whelk 3 Gibbula Cockle and T decussata
Culverwell	C1 - S7L8	Mannino and Thomas (2001) Thomas et al (1999)	2 dog whelk 3 Gibbula T. decussata
Culverwell	C1 - S8L9	Mannino and Thomas (2001) Thomas et al (1999)	2 Gibbula T. deccussata
Culverwell	C1 - S9L9-12	Mannino and Thomas (2001) Thomas et al (1999)	1 dog whelk 1 gibbula
Culverwell	C2 - S6L7	Mannino and Thomas (2001) Thomas et al (1999)	2 dog whelk 1 Gibbula spp. T. decussata
Culverwell	C2 - S7L8	Mannino and Thomas (2001) Thomas et al (1999)	1 Gibbula
Culverwell	C2 - S8L8	Mannino and Thomas (2001) Thomas et al (1999)	1 dog whelk
Culverwell	C2 - S9L8	Mannino and Thomas (2001) Thomas et al (1999)	8 dog whelk 1 Gibbula T. decussata
Culverwell	C2 - S10L8	Mannino and Thomas (2001) Thomas et al (1999)	6 dog whelk 1 Gibbula
Culverwell	C2 - S11L9	Mannino and Thomas (2001) Thomas et al (1999)	4 dog whelk 2 Gibbula T. decussata
Culverwell	C2 - S12L12	Mannino and Thomas (2001) Thomas et al (1999)	1 Gibbula
Culverwell	C2 - S13L12	Mannino and Thomas (2001) Thomas et al (1999)	Sample too small
Culverwell	C3 - S5L7	Mannino and Thomas (2001) Thomas et al (1999)	5 dog whelk 3 Gibbula
Culverwell	C3 - S6L8	Mannino and Thomas (2001) Thomas et al (1999)	12 dog whelk 4 Gibbula
Culverwell	C3 - S7L8	Mannino and Thomas (2001) Thomas et al (1999)	11 dog whelk 4 Gibbula
Culverwell	C3 - S8L8	Mannino and Thomas (2001) Thomas et al (1999)	14 dog whelks 2 Gibbula 1 Calliostoma zizyphinum Tapes decussata
Culverwell	C3 - S9L9	Mannino and Thomas (2001) Thomas et al (1999)	2 dog whelk 2 Gibbula T. decussata Cockle
Culverwell	C3 - S10L12	Mannino and Thomas (2001) Thomas et al (1999)	1 dog whelk. Cockle
Culverwell	C4 - S11L8	Mannino and Thomas (2001) Thomas et al (1999)	2 dog whelk
Culverwell	C4 - S12L8	Mannino and Thomas (2001) Thomas et al (1999)	5 dog whelks
Culverwell	C4 - S13L8	Mannino and Thomas (2001) Thomas et al (1999)	13 dog whelks
Culverwell	C5 - S14L8	Mannino and Thomas (2001) Thomas et al (1999)	2 dog whelks 1 Gibbula
Culverwell	C5 - S15L8	Mannino and Thomas (2001) Thomas et al (1999)	7 dog whelks 1 Gibbula
Culverwell	C5 - S16L8	Mannino and Thomas (2001) Thomas et al (1999)	2 dog whelk 4 Gibbula

Site	Phase Level	Sources	Notes
Westward Ho!	1863-1871 AD work	Rogers (1946) Churchill (1965) Bell *et al* (2007)	Red deer approaching size of Cervus canadensis. Bird femur, few roe deer, boar teeth and tusks wolf (dog?) leg and a goat skull! Cattle reported as Bos longifrons - domestic.
Westward Ho!	Different Local	Rogers (1946) Churchill (1965)	Red deer boar teeth and tusks. Fallow deer??! Mytilus edulis, Scrobicularia plana, Littorina littorea and Nucella lapillus
Nant Hall Road B		Johnson and Bell (2007) Armour-Chelu (2007)	Almost entirely cockle.
Nant Hall Road C		Johnson and Bell (2007) Armour-Chelu (2007)	Almost entirely cockle.
Nant Hall Road D		Johnson and Bell (2007) Armour-Chelu (2007)	
Nant Hall Road E	C104	Johnson and Bell (2007) Armour-Chelu (2007)	
Nant Hall Road E	C105	Johnson and Bell (2007) Armour-Chelu (2007)	
Nant Hall Road F		Johnson and Bell (2007) Armour-Chelu (2007)	
Goldcliff East J		Scales *et al* (2007)	Roe Deer also present
Goldcliff East A		Scales *et al* (2007)	Mullet, Salmon, Bib, flat fish and crabs present
Goldcliff East B		Scales *et al* (2007)	
Snail Cave	horizon 1	Smith *et al* (2014)	Note: Highly turbated domesticates present. Dog whelk and Common whelk present cowrie bead
Snail Cave	horizon 2	Smith *et al* (2014)	Note: Highly turbated domesticates present. Dog whelk and Common whelk present Gibbula present
Snail Cave	horizon 3	Smith *et al* (2014)	Note: Highly turbated domesticates present. Dog whelk and Common whelk present.
Snail Cave	horizon 4a, context 20	Smith *et al* (2014)	Note: Highly turbated domesticates present. Dog whelk and Common whelk present Gibbula present
Snail Cave	horizon 4b, context 30	Smith *et al* (2014)	
Snail Cave	horizon 5, context 34	Smith *et al* (2014)	Note: Highly turbated domesticates present. Dog whelk and Common whelk present Phorcus and Gibbula present and cockle.

SI-Chapter5-1.5 – The Island of Ireland.

Table SI-Chapter5-1.5-1: Detailed dates from sites in the Island of Ireland. Data from the sources in table SI-Chapter5-1.5-5.

Sub-region	Site	Level/Phase/Unit	Laboratory Code	^{14}C Assay	Marine (%)	PD Start BC (2σ)	PD End BC (2σ)	PD Mean BC	Error ±	Δ R ^{14}Cyrs
Ireland (island of)	Dalkey Island V	Basal	D38	5300±170	0	4461	3714	4088	374	
Ireland (island of)	Dalkey Island V	Basal	OXA-4569	7250±100	100			0	0	
Ireland (island of)	Dalkey Island V	Basal	OXA-4570	5600±80	0	4653	4271	4462	191	
Ireland (island of)	Dalkey Island II	Basal	OXA-4568	6870±90	0	5977	5626	5802	176	
Ireland (island of)	Dalkey Island II	Basal	OXA-4572	6410±110	100			0	0	
Ireland (island of)	Sutton		I-5067	5250±100	0	4331	3806	4069	263	
Ireland (island of)	Sutton		OxA-3691	6660±80	0	5710	5481	5596	115	
Ireland (island of)	Sutton		OxA-4449	7140±100	0	6227	5809	6018	209	
Ireland (island of)	Rockmarshal	Midden III	OxA-4604	5705±75	20	4681	4284	4483	199	
Ireland (island of)	Rockmarshal	Midden		5470±110	0	4537	4043	4290	247	
Ireland (island of)	Rough Island	Midden								
Ireland (island of)	Baylet	Phase 1 (occupation)	GrA 21490	6450±50	0	5486	5321	5404	82.5	
Ireland (island of)	Baylet	Phase 1 (occupation)	UB 4714	6065±40	0	5199	4843	5021	178	
Ireland (island of)	Baylet	Midden	UB 4716	5655±40	0	4581	4368	4475	107	
Ireland (island of)	Ballmoney	Test Pit	Beta-161647	6190±60	100					
Ireland (island of)	Ballmoney	Cliff (40m)	Beta-161646	5970±80	100					
Ireland (island of)	Castlequarter		Beta-155379	5360±60	100					
Ireland (island of)	Drumboy		Beta-155378	5160±60	100					
Ireland (island of)	Ballmoney Cliff		Beta-151925	5510±80	100					
Ireland (island of)	Inch Road Station		Beta-161644	5000±80	100					
Ireland (island of)	Inch Road Station		Beta-161645	3450±70						
Ireland (island of)	Ferriter's Cove Central	Context 302	OxA-3869	5510±70	0	4502	4182	4342	160	
Ireland (island of)	Ferriter's Cove Central	Context 17 (Context 213)	OxA-4918	5545±65	70	4331	4004	4168	164	-109±55
Ireland (island of)	Ferriter's Cove Central	Context 22 (K-L/4-5)	OxA-5770	5590±60	70	4386	4032	4209	177	-109±55
Ireland (island of)	Ferriter's Cove North	1983 (j-K/-7,-8)	BM-2227R	5400±220	0	4717	3715	4216	501	
Ireland (island of)	Ferriter's Cove North	1983 (j-K/-7,-8)	BM-2227AR	5420±150	0	4595	3950	4273	323	
Ireland (island of)	Ferriter's Cove North	Context 488	Q-2641	5245±55	0	4232	3966	4099	133	
Ireland (island of)	Ferriter's Cove North	Context 488	Q-2634	5680±70	100	4441	4033	4237	204	-109±55
Ireland (island of)	Ferriter's Cove Central	Context 201	BM-2228R	5750±140	0	4936	4340	4638	298	
Ireland (island of)	Ferriter's Cove Central	Context 201	BM-2228AR	5850±140	0	5056	4370	4713	343	
Ireland (island of)	Ferriter's Cove Central	Context 43	GrN-18770	5620±130	0	4789	4179	4484	305	
Ireland (island of)	Ferriter's Cove Central	Context 5	GrN-18769	5900±110	0	5051	4499	4775	276	
Ireland (island of)	Ferriter's Cove Central	Context 132	GrN-18771	5620±80	0	4678	4334	4506	172	
Ireland (island of)	Ferriter's Cove South	Context 183	GrN-18772	6300±140	0	5486	4963	5225	262	
Ireland (island of)	Ferriter's Cove South	Context 303	UB-3597	5479±56	0	4453	4235	4344	109	
Ireland (island of)	Ferriter's Cove South	Context 309	UB-3598	5727±81	0	4768	4371	4570	199	
Ireland (island of)	Ferriter's Cove South	Context 341	UB-3599	5503±45	0	4453	4262	4358	95.5	
Ireland (island of)	Ferriter's Cove	Site 3	BM-2229R	5490±160	0	4686	3983	4335	352	
Ireland (island of)	Ferriter's Cove	Site 3	BM-2229AR	5500±130	0	4652	4001	4327	326	
Ireland (island of)	Ferriter's Cove	Southern test-pit	UB-3760	4820±67	0	3761	3377	3569	192	
Ireland (island of)	Ferriter's Cove	Southern test-pit	UB-3761	5402±24	100	4102	3775	3939	164	-109±55
Ireland (island of)	Fanore More Site 1					4246	3617	3932	315	
Ireland (island of)	Fanore More Site 2					4869	4425	4647	222	

Table SI-Chapter5-1.5-2: Sites from the Island of Ireland with at least ordinal data for mammal abundance not based upon weight. Data from the sources in table SI-Chapter5-1.5-5.

		Phase		Mammal	
Region	**Site**	**Level**	**1st**	**2nd**	**3rd**
Co Kerry	Ferriter's Cove	Northern Aggregated	Wild Boar		
Co Kerry	Ferriter's Cove	Central Aggregated	Wild Boar	Domestic Cow	Mountain Hare
Co Kerry	Ferriter's Cove	Southern Aggregated	Wild Boar	Domestic Cow	Mountain Hare

Table SI-Chapter5-1.5-3: Sites from the Island of Ireland with at least ordinal data for fish abundance not based upon weight. Data from the sources in table SI-Chapter5-1.5-5.

		Phase		Fish	
Region	**Site**	**Level**	**1st**	**2nd**	**3rd**
Co Kerry	Ferriter's Cove	Northern Aggregated	Wrasse	Tope	Whiting
Co Kerry	Ferriter's Cove	Central Aggregated	Wrasse	Tope	Whiting
Co Kerry	Ferriter's Cove	Southern Aggregated	Wrasse	Whiting	Cod

Table SI-Chapter5-1.5-4: English and Welsh sites with at least ordinal data or an MNI count for mollusc abundance not based upon weight. Data from the sources in table SI-Chapter5-1.5-5.

	Phase			Mollusc	
Site	**Level**	**MNI**	**1st**	**2nd**	**3rd**
Fanore More 1	Midden		Periwinkle	Limpet	Dog Whelk
Fanore More 2	Midden		Periwinkle	Limpet	Dog Whelk
Dalkey Island V	Midden	433	Limpet	Periwinkle	Dog Whelk
Rockmarshall	Midden		Oyster	Periwinkle	Carpet
Rough Island	Midden		Oyster	Periwinkle	Carpet
Baylet	Midden I (Lower)		Oyster		
Baylet	Midden I (Higher)		Mussel	Periwinkle	
Baylet	Midden II		Oyster		
Ferriter's Cove	Site 3	385	Limpet	Dog Whelk	Periwinkle
Ferriter's Cove	Northern Aggregated	983	Periwinkle	Dog Whelk	Limpet
Ferriter's Cove	Central Aggregated	26362	Dog Whelk	Periwinkle	Limpet
Ferriter's Cove	Southern Aggregated	1902	Limpet	Dog Whelk	Periwinkle

Table SI-Chapter5-1.5-5: Sources of faunal and dating information for the sites of the Island of Ireland, plus other notes.

Site	Phase Level	Sources	Notes
Fanore More 1	Midden	Lynch (2017 and on-line resources therein)	Site has still to be published. Also present: Wrasse, Sea Bream, plaice/flounder, cod. Also present 'clams'.
Fanore More 2	Midden	Lynch (2017 and on-line resources therein)	Cowrie beads present. Site has still to be published. Also present: Wrasse, Sea Bream, plaice/flounder, cod, whiting and pollock. Top shell, mussel, scallop, oyster and carpet shell. Plus edible crab.
Sutton	Midden	Mitchell (1956; 1972) Liversage *et al*, (1967/1968)	Hardly any bone. Single NISP of hare, dog, 6 NISP pig/boar 2 nisp from large gull. Shells in abundance but no quanitification provided. Polished stone axes
Dalkey Island V	Midden	Mitchell (1956; 1972) Woodman *et al* (1997) Liversage *et al*, (1967/1968)	Animals are mainly domesticates, with some wild boar and seal, these date much earlier than the domesticates. Ceramics and polished stone axes. Odd specimen of mussel, cockle, scallop and thick top shell also present
Dalkey Island II	Midden (North)	Mitchell (1956; 1972) Woodman *et al* (1997) Liversage *et al*, (1967/1968)	Domesticates present, with some possible wild boar and seal quite abundant, the seals date much earlier than the domesticates. Some brown bear and a specimen of dolphin. Ceramics and polished stone axes. Birds present include auks, white
Dalkey Island II	Midden (South)	Mitchell (1956; 1972) Woodman et al (1997) Liversage et al, (1967/1968)	Domesticates present, Bos taurus, ovicaprines pig and dog. Seal quite abundant and brown bear present, Birds present are duck/goose. Fish gadidae (cf. cod), wrasse, conger, tope.
Rockmarshall	Midden	Mitchell (1947) Liversage *et al*, (1967/1968)	Also present limpet, common whelk, dog whelk, Gibbula spp., Phorcus spp. Mussel, Golden Carpet Shell, cockle, scallop, razor clam (siliqua), scobicularia, other veneroids. Couple of bone fox/cat and small cetacean. Crab claws present.
Rough Island	Midden	Movius *et al* (1940)	Cockle also fairly abundant. Also present, dog whelk, common whelk, mussel, scallop and various veneroids. Ceramics present.
Baylet	Phase 1 (occupation)	Milner and Woodman (2007)	
Baylet	Phase 1 (occupation)	Milner and Woodman (2007)	
Baylet	Midden I (Lower)	Milner and Woodman (2007)	
Baylet	Midden I (Higher)	Milner and Woodman (2007)	
Baylet	Midden II	Milner and Woodman (2007)	Neolithic ceramics present
Ferriter's Cove	Site 3	McCarthy (1999) McCarthy *et al* (1999) Schulting (1999)	
Ferriter's Cove	Northern Aggregated	McCarthy (1999) McCarthy et al (1999) Schulting (1999)	1 NISP gull Also present: Ling, Conger, Scad, Herring, Mullet and mussel
Ferriter's Cove	Central Aggregated	McCarthy (1999) McCarthy et al (1999) Schulting (1999)	Sheep frag. I NISP gannet, 2 NISP guillemot Also present: eel, cod, Haddock, Ling, Saithe, Thornback, conger, Scad, Herring, Mullet,
Ferriter's Cove	Southern Aggregated	McCarthy (1999) McCarthy et al (1999) Schulting (1999)	Also present: Tope, Salmon, Thornback, Conger

SI-Chapter5-1.6 – Scotland.

Table SI-Chapter5-1.6-1: Detailed dates from sites in Scotland. Data from the sources in table SI-Chapter5-1.6-6.

Sub-region	Site	Level/Phase/Unit	Laboratory Code	^{14}C Assay	Marine (%)	PD Start BC (2σ)	PD End BC (2σ)	PD Mean BC	Error ±	Δ R ^{14}Cyrs
Scotland	Risga		OxA-2023	6000±90	0	5207	4705	4956	251	
Scotland	Risga		OxA-3737	5875±65	0	4906	4555	4731	176	
Scotland	Tarradale	Primary Midden	SUERC-46140			6204	6005	6105	99.5	
Scotland	Tarradale	Primary Midden	SUERC-46141			6632	6480	6556	76	
Scotland	An Corran		AA–29315	5190±55	0	4229	3807	4018	211	
Scotland	An Corran		AA-29316	6215±60	0	5312	5019	5166	147	
Scotland	An Corran		AA-27746	6420±75	0	5518	5227	5373	146	
Scotland	An Corran		OxA-4994	7590±90	0	6608	6247	6428	181	
Scotland	An Corran		OxA-14753	7525±45	0	6462	6256	6359	103	
Scotland	An Corran		OxA-13551	7485±55	0	6440	6240	6340	100	
Scotland	Sand Rock Shelter	Main Midden (13) B25A NE Spit 4	OxA-10834	7855±60	0	7029	6572	6801	229	
Scotland	Sand Rock Shelter	Main Midden (13) B25B NE Spit 7	OxA-16487	7666±45	0	6596	6441	6519	77.5	
Scotland	Sand Rock Shelter	Main Midden (13) B25A NE Spit 8	OxA-12096	7744±37	0	6643	6486	6565	78.5	
Scotland	Sand Rock Shelter	Test Pit 9 Spit 8	OxA-9343	7765±50	0	6679	6479	6579	100	
Scotland	Sand Rock Shelter	Test Pit 9 Spit 8	OxA-9281	7715±50	0	6639	6466	6553	86.5	
Scotland	Sand Rock Shelter	Test Pit 9 Spit 8	OxA-9280	7520±50	0	6461	6252	6357	105	
Scotland	Sand Rock Shelter	Test Pit 9 Spit 7	OxA-9281	7545±50	0	6477	6257	6367	110	
Scotland	Sand Rock Shelter	A1B NE Spit 9 (22)	OxA-10176	6605±50	0	5622	5482	5552	70	
Scotland	Sand Rock Shelter	A2B SW Spit 10 (22)	OxA-16489	6343±43	0	5466	5221	5344	123	
Scotland	Ulva Cave		GU-2707	4990±60	0	3944	3657	3801	144	
Scotland	Ulva Cave		OxA-3738	5750±70	0	4770	4454	4612	158	
Scotland	Ulva Cave		GU-2603	5930±70	100	4746	4348	4547	199	-143±54
Scotland	Ulva Cave		GU-2602	6090±70	100	4950	4511	4731	220	-143±54
Scotland	Ulva Cave		GU-2601	8020±70	100	6911	6421	6666	245	-77±56
Scotland	Ulva Cave		GU-2600	8060±70	100	6966	6461	6714	253	-77±56
Scotland	Ulva Cave	Soil beneath	GU-2705	7100±130	0	6229	5728	5979	251	
Scotland	Ulva Cave	Soil beneath	GU-2704	7800±160	0	7132	6373	6753	380	
Scotland	Port Lobh	Test Pit 1 (007) S15	SUERC-16341	5620±35	100	4349	4045	4197	152	-143±54
Scotland	Port Lobh	Test Pit 1 (012) S18	SUERC-21085	5720±40	100	4484	4192	4338	146	-143±54
Scotland	Port Lobh	Test Pit 2 (007) S12	SUERC-16343	5555±35	100	4306	3996	4151	155	-143±54
Scotland	Port Lobh	Test Pit 2 (007) S13	SUERC-15043	5705± 35	100	4455	4171	4313	142	-143±54
Scotland	Loch A Sguirr		OxA-9255	7245±55	0	6223	6020	6122	102	
Scotland	Loch A Sguirr		OxA-9305	7620±75	0	6640	6272	6456	184	
Scotland	Loch A Sguirr		OxA-9254	2055±39	0			0	0	
Scotland	Carding Mill Bay	bone, animal	OxA-3739	4765±65	0	3656	3372	3514	142	
Scotland	Carding Mill Bay	charcoal	GU-2797	4980±50	0	3788	3536	3662	126	
Scotland	Carding Mill Bay	charcoal	GU-2796	5060±50	0	3965	3714	3840	126	
Scotland	Carding Mill Bay	antler	OxA-3740	5190±85	0	4237	3795	4016	221	
Scotland	Carding Mill Bay	shell	GU-2898	5410±60	100	4176	3750	3963	213	-109±55
Scotland	Carding Mill Bay	shell	GU-2899	5440±50	100	4196	3796	3996	200	-109±55
Scotland	Macarthur Cave (Lower)	Antler	OxA-1949	6700±80	0	5728	5488	5608	120	
Scotland	Macarthur Cave (Upper)	Human	OxA-4485	2170±55	0			0	0	
Scotland	Macarthur Cave (Upper)	Human	OxA-4486	2365±55	0			0	0	
Scotland	Macarthur Cave (Upper)	Human	OxA-4487	2460±55	0			0	0	
Scotland	Macarthur Cave (Upper)	Human	OxA-4488	2295±60	0			0	0	
Scotland	Druimvargie		OxA-1948	7810±90	0	7028	6467	6748	281	
Scotland	Druimvargie		OxA-4609	7890±80	0	7043	6599	6821	222	
Scotland	Druimvargie		OxA-4608	8340±80	0	7570	7177	7374	197	

Sub-region	Site	Level/Phase/Unit	Laboratory Code	^{14}C Assay	Marine (%)	PD Start BC (2σ)	PD End BC (2σ)	PD Mean BC	Error ±	Δ R ^{14}Cyrs
Scotland	Raschoille		OxA-8444	4715±45	0	3635	3372	3504	132	
Scotland	Raschoille		OxA-8434	4720±50	0			0	0	
Scotland	Raschoille		OxA-8443	4825±55	0			0	0	
Scotland	Raschoille		OxA-8404	4850±70	0			0	0	
Scotland	Raschoille		OxA-8536	4880±60	0			0	0	
Scotland	Raschoille		OxA-8442	4890±45	0			0	0	
Scotland	Raschoille		OxA-8441	4900±45	0			0	0	
Scotland	Raschoille		OxA-8433	4920±50	0			0	0	
Scotland	Raschoille		OxA-8431	4930±50	0			0	0	
Scotland	Raschoille		OxA-8432	4980±50	0			0	0	
Scotland	Raschoille		OxA-8440	4995±45	0	3943	3663	3803	140	
Scotland	Raschoille		OxA-8438	5115±55	0			0	0	
Scotland	Raschoille		OxA-8538	6460±180	0	5722	5010	5366	356	
Scotland	Raschoille		OxA-8439	7250±55	0	6225	6021	6123	102	
Scotland	Raschoille		OxA-8535	7265±80	0	6352	5990	6171	181	
Scotland	Raschoille		OxA-8540	7300±50	100	6028	5723	5876	153	-77±56
Scotland	Raschoille		OxA-8501	7390±55	100	6166	5806	5986	180	-77±56
Scotland	Raschoille		OxA-8398	7480±75	0	6470	6215	6343	128	
Scotland	Raschoille		OxA-8395	7495±50	0	6442	6248	6345	97	
Scotland	Raschoille		OxA-8397	7575±75	0	6591	6254	6423	169	
Scotland	Raschoille		OxA-8539	7580±45	100	6337	6016	6177	161	-77±56
Scotland	Raschoille		OxA-8396	7640±80	0	6648	6371	6510	139	
Scotland	Morton A		GaK-2404	6300±150	0	5543	4856	5200	344	
Scotland	Morton A		NZ-1193	6400±125	0	5615	5063	5339	276	
Scotland	Morton A		Q-989	6450±80	0	5606	5231	5419	188	
Scotland	Morton A		Q-948	6735±180	0	5997	5358	5678	320	
Scotland	Morton A		NZ-1192	6790±150	0	5985	5479	5732	253	
Scotland	Morton A		NZ-1302	7330±200	0	6594	5811	6203	392	
Scotland	Morton A		NZ-1191	8050±225	0	7522	6499	7011	512	
Scotland	Morton A		NZ-1194	12200±240	0			0	0	
Scotland	Morton B		OxA-4610	5180±70	0	4320	3798	4059	261	
Scotland	Morton B		OxA-4611	5475±60	0	4457	4175	4316	141	
Scotland	Morton B		OxA-4612	5790±80	0	4827	4460	4644	184	
Scotland	Morton B		Q-928	6115±110	0	5312	4787	5050	263	
Scotland	Morton B		Q-988	6147±90	0	5306	4848	5077	229	
Scotland	Morton B		Q-981	6382±120	0	5606	5056	5331	275	
Scotland	Cnoc Sligeach	Trench B layer 7	BM-670	5416±159	0	4612	3820	4216	396	
Scotland	Cnoc Sligeach	Unkown	GX-1904	5755±180	0	5194	4245	4720	475	
Scotland	Cnoc Sligeach	Redeposited Material	Birm-465m	5900±150	100	4922	4205	4564	359	-143±54
Scotland	Cnoc Sligeach	Redeposited Material	Birm-462m	6390±160	100	5446	4711	5079	368	-143±54
Scotland	Cnoc Sligeach	Redeposited Material	Birm-464m	6840±190	100	5859	5056	5458	402	-77±56
Scotland	Cnoc Sligeach	Redeposited Material	Birm-463m	7210±130	100	6075	5537	5806	269	-77±56
Scotland	Cnoc Coig	Trench A - Unit 3	Q-1352	5430±130	0	4519	3976	4248	272	
Scotland	Cnoc Coig	Trench E - Unit 2	Q-1351	5495±75	0	4501	4076	4289	213	
Scotland	Cnoc Coig	Human	OxA-8014	5495±55	90	4270	3933	4102	169	-109±55
Scotland	Cnoc Coig	Trench E unit 6	Q-1354	5535±140	0	4690	4047	4369	322	
Scotland	Cnoc Coig	Human	OxA-8019	5615±45	90	4352	4038	4195	157	
Scotland	Cnoc Coig	Trench E unit 8	Q-1353	5645±80	0	4683	4346	4515	169	
Scotland	Cnoc Coig	Sq N4 - Pre-midden	Q-3005	5650±60	0	4653	4353	4503	150	
Scotland	Cnoc Coig	Sq O4 - Pre-midden	Q-3006	5675±60	0	4682	4369	4526	157	
Scotland	Cnoc Coig	Human	OxA-8004	5740±65	90	4533	4166	4350	184	
Scotland	Cnoc Coig	shell	Birm-326Z	7240±200	100	6256	5466	5861	395	-77±56
Scotland	Cnoc Coig	shell	Birm-326Y	7290±120	100	6155	5627	5891	264	-77±56
Scotland	Cnoc Coig	shell	Birm-326X	7610±150	100	6527	5877	6202	325	-77±56
Scotland	Caisteal nan Gillean	Redeposited Material	SRR-1458a	4750±180	100			0	0	
Scotland	Caisteal nan Gillean	Trench C Layer 3	Q-3011	5450±50	0	4446	4081	4264	183	
Scotland	Caisteal nan Gillean	Trench C Layer 3	Q-3010	5485±50	0	4449	4247	4348	101	
Scotland	Caisteal nan Gillean	Redeposited Material	SRR-1458b	5890±70	100			0	0	
Scotland	Caisteal nan Gillean	Trench C Layer 4 Upper	Q-3009	6035±70	0	5207	4771	4989	218	
Scotland	Caisteal nan Gillean	Trench C Layer 4 Base	Q-3007	6120±80	0	5291	4842	5067	225	
Scotland	Caisteal nan Gillean	Trench C Layer 4 Base	Q-3008	6190±80	0	5321	4938	5130	192	

Sub-region	Site	Level/Phase/Unit	Laboratory Code	^{14}C Assay	Marine (%)	PD Start BC (2σ)	PD End BC (2σ)	PD Mean BC	Error ±	Δ R ^{14}Cyrs
Scotland	Caisteal nan Gillean II	Trench P Layer 3 Upper	Birm-346	5150±380	0	4844	3022	3933	911	
Scotland	Caisteal nan Gillean II	Trench P layer 4 Base	Birm-347	5450±140	0	4581	3970	4276	306	
Scotland	Caisteal nan Gillean II	Trench P layer 4 Base	Q-1355	5460±65	0	4455	4072	4264	192	
Scotland	Caisteal nan Gillean II	Human	OxA-8005	5480±55	50	4331	4004	4168	164	-109±55
Scotland	Caisteal nan Gillean II	Trench P layer 4 Base	Birm-348C	5570±140	100	4446	3786	4116	330	-109±55
Scotland	Caisteal nan Gillean II	Trench P layer 4 Base	Birm-348B	5720±140	100	4665	3990	4328	338	-143±54
Scotland	Caisteal nan Gillean II	Trench P layer 4 Base	Birm-348	5850±310	100	5211	3801	4506	705	-143±54
Scotland	Priory Midden	Control layer 7	Q-3004	5470±50	0	4448	4235	4342	107	
Scotland	Priory Midden	Control layer 9/10	Q-3003	5510±50	0	4458	4261	4360	98.5	
Scotland	Priory Midden	Control layer 18	Q-3002	5717±50	0	4691	4456	4574	118	
Scotland	Priory Midden	Control layer 19	Q-3000	5825±50	0	4793	4548	4671	123	
Scotland	Priory Midden	Control layer 19	Q-3001	5870±50	0	4881	4596	4739	143	
Scotland	Inveravon	Bottom	GX-2331	6010±180	100			0	0	
Scotland	Inveravon	Middle	GX-2332	4222±120	100			0	0	
Scotland	Inveravon	Top	GX-2333	4215±140	100			0	0	
Scotland	Inveravon	Lower Middle	GX-2334	5955±180	0	5297	4461	4879	418	
Scotland	Inveravon	Post Midden	GU-1885	4820±60	100			0	0	
Scotland	Inveravon	Top	GU-1887	5110±60	100			0	0	
Scotland	Inveravon	Base	GU-1886	5435±60	100			0	0	
Scotland	Nether Kinneil	CXVI Base F582	Gu-1260	5035±65	0	3966	3695	3831	136	
Scotland	Nether Kinneil	CXVI Base F565	Gu-1882	4690±60	0			0	0	
Scotland	Nether Kinneil	CXII Pre-Midden	SRR-1608	4715±55	0			0	0	
Scotland	Nether Kinneil	CXII Base F533	Gu-1258	4220±60	0			0	0	
Scotland	Nether Kinneil	CXVII Base L4/105	Gu-1261	4695±65	0			0	0	
Scotland	Nether Kinneil	CXVII Top	Gu-1883	4390±65	0	3332	2896	3114	218	
Scotland	Nether Kinneil	Base East F34	Srr-1485	4260±40	0			0	0	
Scotland	Nether Kinneil	Top East F2	Srr-1486	5060±50	0			0	0	
Scotland	Nether Kinneil	Top East F5	Gu-1881	5240±60	0			0	0	
Scotland	Brachead	Sub-sample 1	GU-4835	5880±60	100			0	0	
Scotland	Mumrills		GU-3284	5560±70	100			0	0	
Scotland	Mumrills		GU-3285	5790±70	100			0	0	
Scotland	Polmonthill							0	0	
Scotland	Muirtown Inverness		GU-1473	5635±65	0	4337	4045	4191	146	
Scotland	Castle Street Inverness	Lower	GU-1376	7275±235	0	6606	5711	6159	448	
Scotland	Castle Street Inverness	Upper	Gu-1377	7080±85	0	6097	5744	5921	177	

Table SI-Chapter5-1.6-2: Sites from Scotland with at least ordinal data for mammal abundance not based upon weight. Data from the sources in table SI-Chapter5-1.6-6.

		Phase		Mammal	
Region	**Site**	**Level**	**1st**	**2nd**	**3rd**
Atlantic	An Corran	Context 36	Roe Deer	Red Deer	Wild Boar
Atlantic	Sand Rock Shelter	Contexts 11 and 13 (Spit>2)	Red Deer	Wild Boar	Roe Deer
Atlantic	Sand Rock Shelter	Context 22	Red Deer		
North Sea	Morton B		Red Deer	Aurochs	
Atlantic	Cnoc Sligeach		Seal	Red Deer/Otter	Red Deer/Otter
Atlantic	Cnoc Coig		Seal	Otter	Red Deer
Atlantic	Caisteal nan Gillean II		Red Deer	Otter/Seal	Otter/Seal
Atlantic	Priory Midden		Seal	Otter	Red Deer
North Sea	Nether Kinneil	CXII	Red Deer	Bos spp.	
North Sea	Nether Kinneil	CXVII	Red Deer	Bos spp.	Ovis/Capra

Table SI-Chapter5-1.6-3: Scottish sites with at least ordinal data for bird abundance. Data from the sources in table Si-Chapter5-1.6-6.

			Bird		
Region	**Site**	**Phase**	**1st**	**2nd**	**3rd**
Atlantic	An Corran	Context 36	Auks		
Atlantic	Sand Rock Shelter	Contexts 11 and 13 (Spit>2)	Auks	Cormorant/Shag	
Atlantic	Sand Rock Shelter	Context 22	Auks		
North Sea	Morton B		Auks	Gannet	Cormorant/Shag
Atlantic	Cnoc Coig		Auks	Ducks/Geese	Cormorant/Shag

Table SI-Chapter5-1.6-4: Scottish sites with at least ordinal data for bird abundance. Data from the sources in table Si-Chapter5-1.6-6.

		Phase	Fish		
Region	**Site**	**Level**	**1st**	**2nd**	**3rd**
Atlantic	An Corran	Context 36	Cod Family	Eel	Salmo spp.
Atlantic	Sand Rock Shelter	Contexts 11 and 13 (Spit>2)	Wrasse	Cod Family	Mackerel
Atlantic	Sand Rock Shelter	Context 22	Cod Family	Wrasse	Herring
Atlantic	Sand Rock Shelter	Context 28	Wrasse	Cod Family	Herring
North Sea	Morton B		Atlantic Cod	Haddock	

Table SI-Chapter5-1.6-5: Scottish sites with at least ordinal values or MNI for molluscs. Data from the sources in table Si-Chapter5-1.6-6.

Site	Phase Level	MNI	1st	Mollusc 2nd	3rd
Tarradale	Early Midden		Mussel/Periwinkle	Mussel/Periwinkle	Oyster
An Corran	Context 36	11515	Limpet.	Periwinkle	Dog Whelk.
Sand Rock Shelter	Contexts 12 (Spit2)	1740	Limpet.	Dog Whelk/Periwinkle	Dog Whelk/Periwinkle
Sand Rock Shelter	Contexts 11 and 13 (S	37989	Limpet.	Dog Whelk.	Periwinkle
Sand Rock Shelter	Context 22	662	Periwinkle	Dog Whelk.	Limpet.
Sand Rock Shelter	Context 28	4002	Limpet.	Periwinkle	Dog Whelk.
Ulva Cave	L1	4444	Limpet.	Periwinkle	Dog Whelk.
Ulva Cave	L2	7278	Limpet.	Periwinkle	Dog Whelk.
Ulva Cave	L3	4630	Limpet.	Periwinkle	Dog Whelk.
Ulva Cave	L4	1827	Limpet.	Periwinkle	Dog Whelk.
Port Lobh	Test Pit 1		Limpet.	Periwinkle	
Port Lobh	Test Pit 2		Limpet.	Periwinkle	
Port Lobh	Test Pit 3		Limpet.	Periwinkle	
Port Lobh	Test Pit 10		Limpet.	Periwinkle	
Carding Mill Bay			Limpet.		
Druimvargie			Limpet.	Periwinkle	Oyster/Scallop
Raschoille			Periwinkle	Limpet.	Oyster/Cockle
Morton B			Cockle	Gaper	
Cnoc Sligeach			Limpet.	Dog Whelk.	Periwinkle
Cnoc Coig			Limpet.	Dog Whelk/Periwinkle	Dog Whelk/Periwinkle
Caisteal nan Gillean I			Limpet.	Dog Whelk.	Periwinkle
Caisteal nan Gillean II			Limpet.	Dog Whelk/Periwinkle	Dog Whelk/Periwinkle
Priory Midden			Limpet.	Littorina	Nucella
Inveravon			Oyster	Mussel	See notes
Nether Kinneil	CXII		Oyster		
Nether Kinneil	CXVII		Oyster		
Braehead			Oyster	Scallop	Periwinkle/Mussel
Mumrills			Oyster		
Polmonthill			Oyster	Mussel	Periwinkle/Cockle
Muirtown Inverness			Oyster	Mussel	Cockle

Table SI-Chapter5-1.6-6: Data and date sources and other notes for the Scottish sites.

Site	Phase Level	Sources	Notes
Risga		Lacaille (1954)	Limpet, Gibbula, Common whelk, Mussel, Scallop, Spiney cockle, Edible crab, Velvet swimming crab otter, Pine martin, Grey seal, Harbour seal, Red deer, Wild boar, whale, Dolphin, Goose,duck, cormorant/shag, Gannet, Tern, Gull, Great auk, Guillemot, Razorbill. Rays and shark, Conger, Haddock, Black sea bream, Mullet
Tarradale	Early Midden	Grant (2020)	Also present: Cockle then dog whelk, Gibbula and small amount of veneroid.
An Corran	Context 36	Pickard and Bonsall (2012) Bartosiewicz (2012)	Lots of medium large mammal. Canid present. Cormorant, gull and skua present. Mussel, Scallop and Gibbula present.
Sand Rock Shelter	Contexts 12 (Spit2)	Milner, 2009	Mussell also present. Bird, Fish and Mammal data only available rolled up with Contexts 11 and 13.
Sand Rock Shelter	Contexts 11 and 13 (Spit>2)	Milner (2009); Parks (2009) Parks and Barratt (2009)	Mammal. NISP=29 Frags = 6717 = 0.4%. Bird. NISP= 810 Frags = 8763 = 9.2%. Fish. NISP=9671 Frags = 34027 = 28.4% Canis, also present. Intrusive Ovis 1 NISP? 1 NISP each of fox and Bos spp. Several medium large mammal at least two are cervid. Otter and whale present but not quantified. Very diverse assemblage, herring a close 4th. Cancer paguras and Carcinus maenas present.
Sand Rock Shelter	Context 22	Milner (2009); Parks (2009) Parks and Barratt (2009)	Mammal. NISP=104 Frags = 13165 = 0.8%. Bird. NISP= 88 Frags = 2463 = 3.6%. Fish. NISP=539 Frags = 3452 = 15.6% 1 astragalus of wild boar, 1 NISP Bos spp. 5 large and medium mammal. Badger present but not quantified.
Sand Rock Shelter	Context 28	Milner (2009); Parks (2009) Parks and Barratt (2009)	Mammal. Red Deer present. NISP=3 Frags = 2524 = 0.12%. Bird. NISP= 88 Frags = 2463 = 3.6%. Fish. NISP=255 Frags = 993 = 25.7%
Ulva Cave	L1	Russel *et al* (1995) Bonsall *et al* (1992) Pickard and Bonsall (2009)	Diverse assemblage. Gibbula fairly abundant, minimal oyster and mussel. Mammals and fish present. Good crab assemblage dominated by Cancer paguras and the swimming crabs. Some shore crab.
Ulva Cave	L2	Russel *et al* (1995) Bonsall *et al* (1992) Pickard and Bonsall (2009)	Diverse assemblage. Gibbula fairly abundant, minimal oyster and mussel. Phorcus present? Mammals and fish present. Good crab assemblage dominated by Cancer paguras and the swimming crabs. Some shore crab.
Ulva Cave	L3	Russel *et al* (1995) Bonsall *et al* (1992) Pickard and Bonsall (2009)	Diverse assemblage. Gibbula fairly abundant, minimal oyster and mussel. Phorcus present? Mammals and fish present. Good crab assemblage dominated by Cancer paguras and the swimming crabs. Some shore crab.
Ulva Cave	L4	Russel *et al* (1995) Bonsall *et al* (1992) Pickard and Bonsall (2009)	Diverse assemblage. Gibbula fairly abundant, minimal oyster and mussel. Phorcus present? Mammals and fish present. Good crab assemblage dominated by Cancer paguras and the swimming crabs. Some shore crab.

Site	Phase Level	Sources	Notes
Port Lobh	Test Pit 1	Finlay *et al* (2019)	Gibbula, oyster, and infaunal bivalves present in small amounts or isolated specimens. What is the difference between a NISP and an identified fragment? Birds and mammals just about absent (present in test pits (Eg. 012) for which no other data is given. Molluscs not abundant as data is in NISP. Fish bone also not abundant.
Port Lobh	Test Pit 2	Finlay *et al* (2019)	Gibbula, oyster, and infaunal bivalves present in small amounts or isolated specimens. What is the difference between a NISP and an identified fragment? Birds and mammals just about absent (present in test pits (Eg. 012) for which no other data is given. Molluscs not abundant as data is in NISP. Fish bone also not abundant.
Port Lobh	Test Pit 3	Finlay *et al* (2019)	Gibbula, oyster, and infaunal bivalves present in small amounts or isolated specimens. What is the difference between a NISP and an identified fragment? Birds and mammals just about absent (present in test pits (Eg. 012) for which no other data is given. Molluscs not abundant as data is in NISP. Fish bone also not abundant.
Port Lobh	Test Pit 10	Finlay *et al* (2019)	Gibbula, oyster, and infaunal bivalves present in small amounts or isolated specimens. What is the difference between a NISP and an identified fragment? Birds and mammals just about absent (present in test pits (Eg. 012) for which no other data is given. Molluscs not abundant as data is in NISP. Fish bone also not abundant.
Loch A Sguirr 1		Hardy and Wickham-Jones (2009)	Shell only provided as weight for limpet and a merger of periwinkle and dog whelk. Two domesticated animals only bone.
Carding Mill Bay		Connock et al, 1991-1992 McCormick and Buckland, 2003	Bone preservation so poor very few frags could be identified from 2,000 frags. Clearly the site was used during more recent prehistory or later. Broad spectrum of molluscs in remaining 15%. 5mm mesh used. C. elaphus, C. capreolus, S. scofa, Gadus spp., P. virens, A. anguilla .
Macarthur Cave (Lower)		Anderson, 1898 Turner, 1895 Lacaille (1954)	Crab present. Limpet, Periwinkle, Common whelk. Mussel, Oyster, Scallop, cockle, Carpet shell, Razor clam Badger, otter, cat, red deer, Roe deer, wild boar. Bos taurus?? Duck Saithe? Wrasse? Lacaille (1954) has this layer almost devoid of fauna??
Macarthur Cave (Upper)		Anderson, 1898 Turner, 1895 Lacaille (1954)	Limpet, Periwinkle, Common whelk. Mussel, Oyster, Scallop, cockle, Carpet shell, Razor clam. Badger, Red Deer, Roe Deer, Bos taurus? Duck. Saithe? Wrasse? Human Iron Age burials are actually above the upper midden in the black topsoil.
Druimvargie		Anderson (1898) Lacaille (1954)	Red deer, wild boar, and otter present. Mya spp. and duck according to Lacaille (1954). Crab claws present (Anderson, 1898), some fish bone.
Raschoille		Sloan (1993)	Crabs present. Mussel also fairly abundant.
Gasworks		Lacaille (1954)	
Mackay Cave		Lacaille (1954)	
Distillary Cave		Lacaille (1954)	

Site	Phase Level	Sources	Notes
Morton A		Coles (1971)	No faunal remains reported.
Morton B		Coles (1971)	Roe deer and wild boar present. Gull, fulmar, kittiwake present. Turbot, sturgeon and salmo present. An extremely diverse assemblage. Everything that could be expected to be present, plus some others, were present. Edible crab also ubiquitous.
Cnoc Sligeach		Grigson and Mellars (1987) Mellars (1978) Richards and Sheridan (2000) Richards and Mellars (1998) Jones (1984) Mellars and Wilkinson (1980)	
Cnoc Coig		Grigson and Mellars (1987) Mellars (1978) Richards and Sheridan (2000) Richards and Mellars (1998) Nolan (1986) Mellars and Wilkinson (1980) Jones (1984)	Wild boar a close 4th. Cetacean present. Bird assemblage very diverse just about everything that might be present is. Ratios of dog whelk to periwinkle vary in pit 10 but dog whelk 2nd in pit 6. Mussels, oysters, razor clam and one of two examples of cockle, veneroids,
Caisteal nan Gillean		Grigson and Mellars (1987) Mellars (1978) Richards and Sheridan (2000) Richards and Mellars (1998) Jones (1984) Lacaille (1954)	Limpet, Periwinkle, Common Whelk, Cowrie.Mussel, Scallop, Cockle, Edible crab Otter, Martin, Seal, Red Deer, Wild Boar, Dolphin. Swan, auk, Dog fish, Thornback Mullet, sea bream, conger, gadidae.
Caisteal nan Gillean II		Grigson and Mellars (1987) Mellars (1978) Richards and Sheridan (2000) Richards and Mellars (1998) Jones (1984) Mellars and Wilkinson (1980)	Dog whelk v periwinkle varies over time
Priory Midden		Grigson and Mellars (1987) Mellars (1978) Richards and Sheridan (2000) Richards and Mellars (1998) Jones (1984) Mellars and Wilkinson (1980)	
Inveravon		Sloan (1993) Grieve (1872)	Also cockle, periwnkle, razor clam, veneroids and claws from small crabs. Sloan also test excavated and adds dog whelk, common whelk and limpet.
Nether Kinneil	CXII	Sloan (1993)	
Nether Kinneil	CXVII	Sloan (1993)	
Braehead		Ashmore and Hall (1997)	
Mumrills		Sloan (1993)	
Polmonthill		Sloan (1993) Stevenson (1945-1946)	
Muirtown Inverness		Myers and Gourlay, 1991	Small amount of unidentifyable bird bone. No fish remains. Periwinkle abundant or dominate in small spatial clusters. Small amounts of periwinkle, common whelk, razor clam, veneroids, dog whelk, limpet.

SI-Chapter5-1.7 – Atlantic Norway.

Table SI-Chapter5-1.7-1: Detailed dates from sites in Norway. Data from sources in SI-Chapter5-1.6.

Sub-region	Site	Level/Phase/Unit	Laboratory Code	^{14}C Assay	Marine (%)	PD Start BC (2σ)	PD End BC (2σ)	PD Mean BC	Error ±	Δ R ^{14}Cyrs
Norway	Sævarhelleren	20	Poz-15917	7930±50	0	7035	6661	6848	187	
Norway	Sævarhelleren	21	Poz-15918	7890±50	0	7029	6639	6834	195	
Norway	Sævarhelleren	22	Poz-19334	7470±50	0	6429	6240	6335	95	
Norway	Sævarhelleren	11	Poz-15916	7560±50	0	6500	6261	6381	120	
Norway	Sævarhelleren	10	Poz-15840	7370±40	0	6372	6097	6235	138	
Norway	Sævarhelleren	9	Poz-15839	7110±60	0	6080	5846	5963	117	
Norway	Sævarhelleren	8	Poz-15838	7360±15	0	6334	6103	6219	116	
Norway	Olsteinhelleren	11	Poz-19342	6340±40	0	5465	5220	5343	123	
Norway	Olsteinhelleren	9	Poz-19340	6620±40	0	5621	5491	5556	65	
Norway	Olsteinhelleren	8	Poz-19339	6190±40	0	5291	5026	5159	133	
Norway	Olsteinhelleren	7	Poz-19338	6290±40	0	5367	5207	5287	80	
Norway	Olsteinhelleren	6	Poz-19337	5910±40	0	4897	4705	4801	96	
Norway	Olsteinhelleren	4	Poz-19336	6090±40	0	5207	4854	5031	177	
Norway	Kotadalen	2		Mesolithic	0	6500	6000	6250	250	
Norway	Kotadalen	3		Mesolithic	0	6400	5800	6100	300	
Norway	Kotadalen	4		Mesolithic	0	6100	5500	5800	300	
Norway	Kotadalen	5		Mesolithic	0	6000	5600	5800	200	
Norway	Kotadalen	12		Neolithic	0	4500	3600	4050	450	
Norway	Kotadalen	13		Neolithic	0	4000	3600	3800	200	
Norway	Kotadalen	14		Neolithic	0	3800	3200	3500	300	
Norway	Kotadalen	15		Neolithic	0	3400	2900	3150	250	
Norway	Kotadalen	H	UA-891	8530±130	0	7963	7190	7577	387	
Norway	Kotadalen	H	T-7529	7610±90	0	6641	6256	6449	193	
Norway	Kotadalen	H	T-7258	7440±110	0	6475	6068	6272	204	
Norway	Kotadalen	H	T-6232	7330±110	0	6416	6013	6215	202	
Norway	Kotadalen	H	T-7526	7230±100	0	6358	5905	6132	227	
Norway	Kotadalen	D	T-7332	7450±100	0	6467	6088	6278	190	
Norway	Kotadalen	D	T-7333	7330±90	0	6392	6032	6212	180	
Norway	Kotadalen	D	T-7049	7150±70	0	6211	5892	6052	160	
Norway	Kotadalen	D	T-7527	7080±130	0	6221	5723	5972	249	
Norway	Kotadalen	C	T-7514	7220±100	0	6353	5894	6124	230	
Norway	Kotadalen	C	T-7762	7140±90	0	6221	5841	6031	190	
Norway	Kotadalen	C	T-7153	6800±90	0	5888	5551	5720	169	
Norway	Kotadalen	B	T-7050	7020±110	0	6081	5714	5898	184	
Norway	Kotadalen	B	T-6231	6950±130	0	6062	5626	5844	218	
Norway	Kotadalen	B	T-7515	6930±90	0	5989	5664	5827	163	
Norway	Kotadalen	B	T-7334	6920±90	0	5986	5661	5824	163	
Norway	Skipshelleren	Square H9 L11	T-1958	6000±100		5210	4690	4950	260	
Norway	Skipshelleren	Square L9 L11	T-1959	6120±90		5297	4839	5068	229	
Norway	Skipshelleren	Square H9 L14	T-2127	6230±140		5474	4848	5161	313	
Norway	Skipshelleren	Square H8 L11	TUa-5858	6275±50		5362	5072	5217	145	
Norway	Skipshelleren	Square J7 L9	TUa-5859	6490±50		5543	5341	5442	101	
Norway	Skipshelleren	Square H9 L12	Poz-11990	6420±40		5473	5326	5400	74	
Norway	Skipshelleren	Square H9 L12	Poz-11991	6440±35		5479	5341	5410	69	
Norway	Skipshelleren	Square E9 L12	Poz-11994	6630±40		5626	5491	5559	68	
Norway	Skipshelleren	Square A7 L3	Poz-11992	6420±40		5473	5326	5400	74	
Norway	Gronehelleren									
Norway	Viste	I		Mesolithic		6840	6460	6650	190	
Norway	Viste	II		Mesolithic		5470	5020	5245	225	
Norway	Mortenses			Mesolithic		4900	4400	4650	250	

Table SI-Chapter5-1.7-2: Norwegian sites with at least ordinal data for mammal abundance not based upon weight. Data from the sources in table SI-Chapter5-1.7-6.

		Phase		Mammal	
Region	**Site**	**Level**	**1st**	**2nd**	**3rd**
Atlantic	Sævarhelleren		Wild Boar	Elk	Otter
Atlantic	Olsteinhelleren		Red Deer.	Otter/Wild Boar	Otter/Wild Boar
Atlantic	Kotedalen	12	Red Deer.	Wild Boar/Seal	Otter
Atlantic	Kotedalen	13	Red Deer.	Wild Boar	Otter
Atlantic	Kotedalen	14	Seal	Red Deer/Otter	Wild Boar/Canids
Atlantic	Kotedalen	15	Seal	Otter	Wild Boar/Cervus
Atlantic	Kotedalen	H	Seal	Otter	Wild Boar
Atlantic	Kotedalen	D	Seal	Wild Boar/Otter.	Wild Boar/Otter
Atlantic	Skipshelleren		Red Deer.		
Atlantic	Gronehelleren	Phase 1	Seal/Red Deer	Seal/Red Deer	Wild Boar
Atlantic	Viste	I	Wild Boar	Elk	Seal
Atlantic	Viste	II	Wild Boar	Elk	Seal
Atlantic	Mortenses		Seal	Cetacean	Beaver

Table SI-Chapter5-1.7-3: Norwegian sites with at least ordinal data for bird abundance not based upon weight. Data from the sources in table SI-Chapter5-1.7-6.

				Bird	
Region	**Site**	**Phase**	**1st**	**2nd**	**3rd**
Atlantic	Kotedalen	12	Auks		
Atlantic	Kotedalen	13	Auks		
Atlantic	Kotedalen	14	Auks		
Atlantic	Kotedalen	15	Auks		
Atlantic	Kotedalen	H	Auk/Cormorant/Shag	Auk/Cormorant/Shag	
Atlantic	Kotedalen	D	Auks	Cormorant/Shag	
Atlantic	Gronehelleren	Phase 1	Auks	Cormorant/Shag	
Atlantic	Mortenses		Gulls		

Table SI-Chapter5-1.7-4: Norwegian sites with at least ordinal data for fish abundance not based upon weight. Data from the sources in table SI-Chapter5-1.7-6.

Region	Site	Phase Level	1st	Fish 2nd	3rd
Atlantic	Sævarhelleren		Cod Family	Wrasse	Mackerel
Atlantic	Olsteinhelleren		Cod Family	Salmo spp.	
Atlantic	Kotedalen	12	Cod Family		
Atlantic	Kotedalen	13	Cod Family	Wrasse	Mackerel/Herring
Atlantic	Kotedalen	14	Cod Family	Herring	Wrasse/Salmo
Atlantic	Kotedalen	15	Cod Family	Herring	Salmo spp.
Atlantic	Kotedalen	H	Cod Family	Wrasse	
Atlantic	Kotedalen	D	Cod Family	Wrasse	
Atlantic	Kotedalen	B	Cod Family	Herring	Salmo spp.
Atlantic	Skipshelleren		Cod Family	Salmo spp.	Mackerel
Atlantic	Gronehelleren	Phase 1	Cod Family		
Atlantic	Mortenses		Cod Family		

SI-Chapter5-1.7-5: Norwegian sites with at least ordinal data for mollusc abundance not based upon weight. Data from the sources in table SI-Chapter5-1.7-6.

Site	Phase Level	MNI	1st	Mollusc 2nd	3rd
Sævarhelleren			Mussel	Periwinkle	
Olsteinhelleren			Mussel	Periwinkle	
Skipshelleren			Mussel	Periwinkle	
Viste	II		Periwinkle	Limpet	
Mortenses			Arctica islandica	Periwinkle	

Table SI-Chapter5-1.7-6: Data and date sources and other notes for the Norwegian sites.

Site	Phase Level	Sources	Notes
Sævarhelleren		Bergsvik and Richie (2018) Richie *et al* (2016) Bergsvik and Hufthammer (2007)	Salmo spp. fairly abundant. Small amount of herring. One thrush bone. 1 red deer NISP
Olsteinhelleren		Bergsvik and Richie (2018) Richie *et al* (2016) Bergsvik and Hufthammer (2007)	Few frags of herring, flat fish, eel, sturgeon and wrasse. 2 auk bones. Canids present plus one nisp of elk.
Kotedalen	12	Bergsvik (2001)	Few bones from herring, salmo spp., wrasse and 1 mackerel bone. Few duck and gull bones. 1 bone from hare 1 from pine martin.
Kotedalen	13	Bergsvik (2001)	Mackerel and herring very minor. Couple of salmo spp. Few bones from ducks and cormorant family. 4 canid bones 1 hare bone.
Kotedalen	14	Bergsvik (2001)	Few bones from flounder, Conger and common eels. Few bones from ducks and cormorant family.
Kotedalen	15	Bergsvik (2001)	Some wrasse. Few bones from flounder, Conger and common eels. Few bones from ducks and cormorant family. Some pine martin.
Kotedalen	H	Bergsvik (2001) Warren (1993)	1 NISP of elk. Some red deer, fox and pine martin. Gadidae 2.85 NISP per liter. Slight increase in fish remains couple of frags of duck, 1 of gull. Slight increase in mammals 1 martin and 1 hare. Some potentially fur bearing mammals including carnivores, including bear, fox, lynx, otter etc.
Kotedalen	D	Bergsvik (2001) Warren (1993)	2 NISP hare. Fish recovering. Herring and Salmo spp. present. Gadidae 0.44 NISP per litre. Birds at maximum. 1 hare 1 canid, 5 seal frags. Quite a lot of potentially fur bearing mammals including carnivores, including bear, fox, lynx, otter etc.
Kotedalen	C	Bergsvik (2001) Warren (1993)	Just a few NISP present of each of otter, red deer and wild boar. No seal. Just a few NISP of gadidae and alcidae.
Kotedalen	B	Bergsvik (2001) Warren (1993)	Just a few NISP present of each of otter, red deer and wild boar. Just a few NISP of gadidae and alcidae.
Skipshelleren		Faltinsen (2018) Indrelid (1978)	Very few bones present. Bos taurus reported from 6000 bp radiocarbon years?!
Gronehelleren	Phase 1	Bjerck, 2007 Indrelid, 1978 Warren (1993)	233 frags Pisces 58% P. virens, Gadus spp., pollack Aves (8%) Mammalia (34%) Phocidae 35%, C. elaphus 33% S. scofa 20% L. lutra 12%. Shells not collected or quantified but mainly Mytilus spp. and Patella spp. with some Littorina ssp. and a few O. eduliss. Odd bone from wrasse and dog fish. Soil not screened, birds and fish probably understated. Odd bones from duck and gull.
Viste	I	Bjerck (2007) Indrelid (1978)	No molluscs as also observed in the post-Mesolithic level III. Small amounts of red deer and bear.
Viste	II	Bjerck (2007) Indrelid (1978)	
Mortenses		Bjerck (2007)	

SI-Chapter5-2.

SI-Chapter5-2.1 - Marine Calibration and Dietary Inference End Point Variability.

The consideration of different end points for the calculation of dietary sourcing proportions also has quite significant implications for the analysis of regional trends such as those considered by Fontanals-Coll *et al* (2014; fig. 5, p.546). Such scatterplots of ^{15}N and ^{13}C across multiple regions are potentially misleading given a value of 19.1$^{0}/_{00}$ in Orkney is considered just about 100% terrestrial intake (Montgomery *et al*, 2013), whilst it is considered to equate to 21.1% marine intake in Brittany (Schulting, 2005). There is also temporal variability and Schulting 2009 uses end points of -12$^{0}/_{00}$ and 19.5$^{0}/_{00}$ for marine versus terrestrial diets respectively pre-8000 ^{14}Cyrs bp and -12$^{0}/_{00}$ and 20.5$^{0}/_{00}$ post-8000 ^{14}Cyrs bp at the same location. An alternative treatment is required. Where data is available this project utilises estimates of marine intake factored by the end points asserted by each analyst. The option of standardising the marine and terrestrial end points was considered but such an approach in contrary to a fundamental principle of identifying such points from faunal remains that reflect the biosphere at the time of occupation (Bocherens *et al*, 2005). Some articles do not evaluate the contemporary fauna and therefore choose an end point range from other publications, and on what basis is very often unclear.

SI-Chapter5-2.2 - The use of Delta R Values.

For example, Araújo (2016) and Sousa and Soares (2016) utilise the figure of 95±15 ^{14}C years to calibrate Mesolithic sites with results in the range of 9,100-7,000^{14}C years citing Soares and Diaz (2006). But this value according to the cited source is applicable only to dates between 3,100 ^{14}C and 600 ^{14}C years (ibid, p.58-59) and the range within this later period is -150±45 to +210±50. The values that should be utilised are in the range of 160±60 ^{14}C and 940±50 ^{14}C (Bicho *et al*, 2010; Soares and Diaz, 2006). Certainly, turbation may be a factor that influences sample pairing as Sao Juliao I (A) generates two ΔR values of 940±50 ^{14}C (terrestrial date 9060 ± 50) and 170±50 ^{14}C (terrestrial date 8130 ± 50), whilst Sao Juliao II (B) (at the same location) produces a ΔR value of -70±40 ^{14}C (terrestrial date 8400±40). The need to generate a positive ΔR >1000 years was rejected by Ascough *et al* (2017) and taken as evidence that the mollusc remains, and terrestrial remains were from different periods and therefore could not be legitimately paired. The general observation suggesting that marine dates should not be younger than terrestrial dates (ibid) is not adhered to within literature of the Atlantic façade as a whole. The question of magnitude raised by Ascough (2017) however does appear to be well grounded. See also the section on the Oronsay middens and Port Lobh in chapter 4. Many papers do not attempt to calculate ΔR values and cite values from the Calib database which includes (usually) those from Harkness (1983) and these are all ‘modern’ < 500 years old. There is a danger that without the scrutiny and critique exercised by Ascough *et al* (2017) localised (spatially and temporally) ΔR values simply become a vehicle for covering turbated deposits. The introduction of the marine20 calibration curve appears to add circa 200 ^{14}C yrs to the MRE. Does this mean the ΔRs should be simply recalculated or should they be retracted as pairing can no longer be confidently asserted?

SI-Chapter5-2.3 - The Occurrence of Winkle in the Mesolithic of Cantabrian Spain.

Winkle normally refers to the periwinkle which as already stated disappears from the record of the sub-region at the end of the Azillian (Clarke, 1983, Gutierrez-Zugasti, 2011; Álvarez-Fernández, 2011)[12]. Either this report reflects a temporary reoccurrence of the species, which is not inconsistent with the presence of cod and auks, or it is a case of mistaken identity[13]. It should be noted that the common periwinkle is present in the area today (Álvarez-Fernandez *et al*, 2011). This report could be significant but must be treated with caution. Neither Gutierrez-Zugasti, (2011a) or Álvarez-Fernández, (2011) include this site in their comprehensive reviews of the sub-region's molluscan data, although the latter does cite the paper in relation to the bird and fish remains.

SI-Chapter5-2.4 - The Site of Port Lobh on the Island of Colonsay.

A very interesting site has recently been subject to test pitting and post-excavation analysis is ongoing. Despite the status, Finlay *et al* 2019 use this limited data to question the interpretation of the Oronsay middens. Given the time that has passed since the Oronsay middens were excavated and the lack of detailed publication beyond a couple of unpublished (but available on-line) PhD theses, this re-examination is warranted. Finlay *et al* (2019)'s exercise in comparison is probably premature and notably not based upon the actual data they present for Port Lobh.

In table 7 NISP counts are presented for various molluscan taxa. For most species in three of the test pits these numbers are qualified with a '+' sign which is defined as fragments present. If fragments can be assigned to a taxon then, by definition, they are NISP, and should be included in the totals. The author has no idea what data is being presented in this table.

In table 8 data is presented regarding the abundance of juvenile limpets which are defined as <30mm in length citing Baxter (1982). Baxter does not utilise the term juvenile but on page 100 he does define an immature individual as < 20mm in length, on page 103 it is broadened to <20-25mm, which is consistent with the publications of other authorities such as Ballantine, Orton, Southward, Bowman and Lewis and Blackmore. The term immature refers to the fact that an individual is still neuter and has not developed a biological sex. Many limpets assume male sex but later when larger become female.

On page 97 biometric data is presented regarding a small subsample of limpets (n=16 in which (apparently) the eccentricity of the aperture (aka the base) is presented. The mean length is 1.12–2.26 mm (1.54±0.35 mm) and width 3.22–4.82 mm (average 3.9±0.49 mm). Two issues: are these measurements really in mm? Having measured thousands of limpets and also reviewed extensive biometric datasets, the author can state that limpets are never wider than they are long. The measurements are also inconsistent with the length data (from an MA thesis by a different author, who despite not being a co-author on the paper, appeared to know what they were doing) presented in figure 10. The analyst goes on to assert that the width versus length data presented means the limpets

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[12] One or two specimens do occur from time to time during the Mesolithic of this region.

[13] Clarke (1983, p.33) observes that the Spanish word *bigaro* is utilised to describe both top shells and periwinkles, and therefore this may be the root of this observation.

are flatter, which is difficult to understand as the height has not been presented. So, assuming the defined metrics of length and width really refer to height and length, it is clear the analyst has abandoned standard protocol without justification; more likely they simply do not know about molluscs. The interpretation of the flatter limpets being more resistant to wave exposure is attributed to Baxter (1982) and Campbell (2008); neither author make any such statement. Why this data is presented for a sample of 16 when the sample sizes in figure 10 are in the 100s is baffling. Even if the analyst has no idea on how to measure limpets the issue of the units being mm still does not go away.

Finlay *et al* (2019) also conduct dating and compare chronologies with Oronsay (Wicks and Mithen, 2014) but use a different delta R without justification. Port Lobh should be calibrated using the ΔR used for Oronsay or the Oronsay dates should be recalibrated using the ΔR 'selected' for Port Lobh.

The final point relates to otoliths. Images are presented stating that a thin translucent band around the edge mean the fish were caught in the autumn. This statement is made irrespective of otolith size see figure below. This translucent band is present on many otoliths from the Western Isles, irrespective of size or isotope results. The feature is either of diagenetic origin, or a consequence of excessive antemortem temperatures, or disruption in food supply. There appears to be a complete disregard for the established life cycle of the organism or its physiology (cf. Høie *et al*, 2009, pp.320-321; Neat *et al*, 2008; Grønkjær, 2016). This is discussed further in chapter 8.

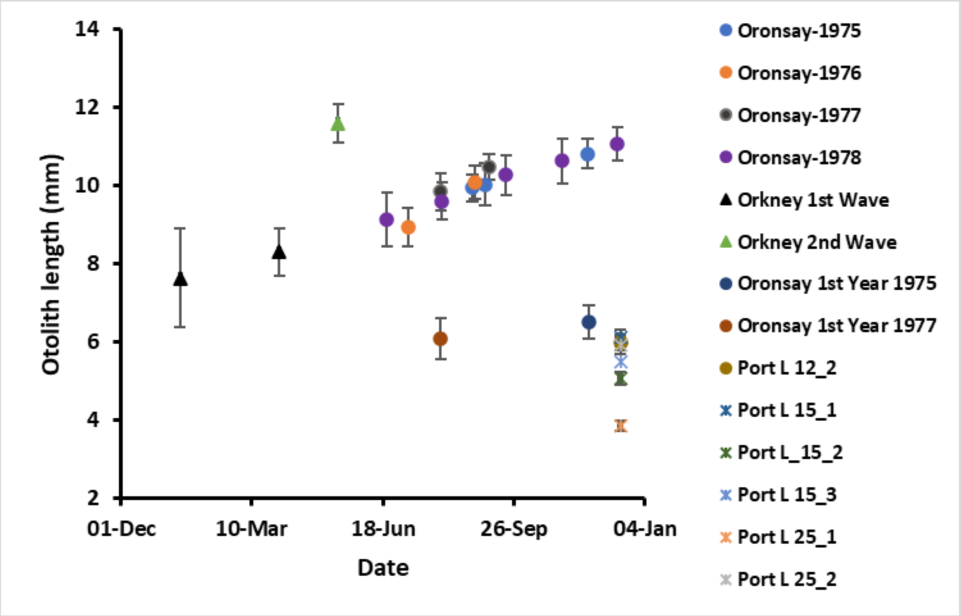


Figure SI-Chapter5-2.4-5 The Port Lobh otoliths have been positioned as mid-December because growth does not slow until the end of year and the banding occurs during the lowest temperatures of Feb and March. The winter temperatures are so moderated in Western Scotland that bands probably do not form most years. The Port Lobh otolith lengths were modelled from the widths as described in chapter 4. Vertical error bars are 1σ except for Orkney where they show range.

SI-Chapter5-3 - Details of the modern SST locations.

Table SI-Chapter5-3-1: Details of the modern SST locations.

Figure C5-4 Reference	Continent	Country	Location	Latitude Relative to the Equator	Longitude	Relative to Prime Meridion
31	Europe	Denmark	Thyborøn	56.70	8.21	East
12	Europe	France	La Rochelle	46.16	1.15	West
13	Europe	France	Lanester	47.76	3.35	West
19	Europe	Ireland	Dingle	52.14	10.26	West
20	Europe	Ireland	Rosslare	52.25	6.34	West
22	Europe	Ireland	Clifden	53.49	10.02	West
23	Europe	Ireland	Laytown	53.68	6.24	West
25	Europe	Ireland	Killybegs	54.63	8.45	West
36	Europe	Norway	Arendal	58.46	0.77	East
39	Europe	Norway	Tonsberg	59.37	10.30	East
41	Europe	Norway	Bergen	60.39	5.32	East
42	Europe	Norway	Kristiansund	63.11	7.73	East
43	Europe	Norway	Tromso	69.65	18.96	East
9	Europe	Portugal	Sagres	37.02	8.94	West
10	Europe	Portugal	Figueira da Foz	40.15	8.86	West
11	Europe	Spain	Santander	43.46	3.81	West
34	Europe	Sweden	Gothenburg	57.71	11.97	East
14	Europe	UK	Isles of Scilly	49.94	6.32	West
15	Europe	UK	Newquay	50.42	5.07	West
16	Europe	UK	Weymouth	50.61	2.45	West
17	Europe	UK	Deal	51.22	1.4	East
18	Europe	UK	Burhnam-on-Sea	51.24	2.99	West
21	Europe	UK	Aldeburgh	52.16	1.60	East
24	Europe	UK	Llandudno	53.32	3.83	West
26	Europe	UK	Monkstown	52.29	6.15	West
27	Europe	UK	Orkney	58.97	3.30	West
28	Europe	UK	Derry	55.00	7.30	West
29	Europe	UK	Berwick	55.77	2.00	West
30	Europe	UK	Ayre	55.46	4.63	West
32	Europe	UK	Oban	56.42	5.47	West
33	Europe	UK	Aberdeen	57.15	2.09	West
35	Europe	UK	Ullapool	57.90	5.16	West
37	Europe	UK	Isle of Lewis	58.52	6.27	West
38	Europe	UK	Wick	58.44	3.10	West
40	Europe	UK	Shetland	59.87	1.29	West
3	North America	Canada	Tofino	49.15	125.91	West
4	North America	Canada	Port Alberni	49.23	125.81	West
5	North America	Canada	Pangnirtung	66.15	65.70	West
6	North America	Canada	Catalina	48.52	53.08	West
7	North America	Canada	Halifax	44.65	63.57	West
8	North America	USA	New York	40.71	74.00	West
1	South America	Chile	Punta Arenas	53.16	70.92	West
2	South America	Chile	Cape Horn	55.98	67.27	West

SI-Chapter6.

SI-Chapter6-1 (Limpets)

All measurements were recorded using digital Vernier callipers, but the data is utilised at a precision one decimal place only. With encrusted specimens the areas to be measured was carefully scraped clean prior to measurement. If encrustation could not be removed the measurement was not taken and the specimen classed as unmeasurable.

The summary statistics for the archaeological contexts subject to biometrical analysis are provided below (table SI-Chapter6-1.1). Statistical analysis was conducted on an intra-midden basis but PMS context 2 was compared to both TNB1 and TNB2 (table SI-Chapter6-1.2).

The volume of the limpets from the Western Isles are provided in figures SI-Chapter6-1.1 and 2. A comparison with the limpets from a context from West Voe is provided in figure SI-Chapter6-1.3.

Summary Statistics

Table SI-Chapter6-1.1: Summary Statistics for limpets.

TNB2 Context 5	**Length (mm)**	**Volume (mm3)**	**Conicity**	**TNB1 Context 8**	**Length (mm)**	**Volume (mm3)**	**Conicity**
Mean	31.2	3866	2.852	**Mean**	28.9	3025	2.936
StDev	4.7	2127	0.443	**StDev**	4.6	1833	0.437
Median	30.8	3423	2.823	**Median**	28.4	2572	2.927
Interquartile	5.9	2309	0.604	**Interquartile**	6.3	1923	0.629
Minimum	19.9	878	1.571	**Minimum**	15.6	304	1.248
Maximum	50.1	16398	4.658	**Maximum**	48.2	16118	4.442
Skew	0.6	2	0.263	**Skew**	0.7	2	0.067
Kurtosis	0.7	5	-0.053	**Kurtosis**	0.7	8	-0.087
N=	1037	1000	1037	**N=**	1448	1440	1448
TNB2 Context 11	**Length (mm)**	**Volume (mm^3)**	**Conicity**	**TNB1 Context 11**	**Length (mm)**	**Volume (mm3)**	**Conicity**
Mean	29.7	2884	2.916	**Mean**	28.2	2270	2.956
StDev	5.2	2100	0.455	**StDev**	4.1	1328	0.402
Median	29.1	2278	2.918	**Median**	28.0	1860	2.974
Interquartile	6.5	1910	0.703	**Interquartile**	5.4	1367	0.521
Minimum	17.6	536	1.789	**Minimum**	20.5	793	1.887
Maximum	49.6	17604	4.163	**Maximum**	42.1	9666	4.213
Skew	0.9	3	0.007	**Skew**	0.6	2	0.058
Kurtosis	1.2	9	-0.681	**Kurtosis**	0.2	6	0.191
N=	549	549	549	**N=**	176	176	176
TNB2 Context 15	**Length (mm)**	**Volume (mm3)**	**Conicity**	**TNB1 Context 14**	**Length (mm)**	**Volume (mm3)**	**Conicity**
Mean	30.2	2985	2.861	**Mean**	29.3	2686	2.863
StDev	4.4	1621	0.430	**StDev**	5.0	1745	0.424
Median	30.9	2648	2.878	**Median**	28.4	2173	2.849
Interquartile	5.8	1702	0.633	**Interquartile**	6.5	1845	0.593
Minimum	22.2	795	1.937	**Minimum**	17.0	151	1.799
Maximum	39.3	7441	3.698	**Maximum**	47.1	12833	4.289
Skew	0.2	1	0.012	**Skew**	0.6	2	0.189
Kurtosis	-0.5	1	-0.435	**Kurtosis**	0.1	4	-0.247
N=	53	53	53	**N=**	671	671	671
TNB2 Context 18	**Length (mm)**	**Volume (mm3)**	**Conicity**	**PMS Context 2**	**Length (mm)**	**Volume (mm3)**	**Conicity**
Mean	28.8	2630	2.942	**Mean**	30.6	3012	2.911
StDev	4.9	2326	0.487	**StDev**	5.2	1938	0.432
Median	28.0	1989	2.885	**Median**	30.1	2433	2.908
Interquartile	4.3	1449	0.699	**Interquartile**	7.1	2176	0.630
Minimum	21.0	702	2.066	**Minimum**	20.1	287	1.757
Maximum	49.8	16810	4.094	**Maximum**	51.0	14017	4.043
Skew	1.7	4	0.344	**Skew**	0.7	2	-0.031
Kurtosis	4.6	21	-0.474	**Kurtosis**	0.7	5	-0.456
N=	65	65	65	**N=**	501	489	500

WV Context 466	Length (mm)	Volume (mm3)	Conicity
Mean	45.7	11822	2.221
StDev	3.3	5197	0.201
Median	46.4	8856	2.224
Interquartile	7.5	5955	0.169
Minimum	36.2	6924	1.856
Maximum	52.3	21278	2.744
Skew	-0.5	1	0.927
Kurtosis	-0.9	0	3.289
N=	14	7	14

WV Context 414	Length (mm)	Volume (mm3)	Conicity
Mean	45.9	13846	2.281
StDev	5.3	5752	0.280
Median	45.4	12832	2.276
Interquartile	6.7	6215	0.381
Minimum	23.0	4046	1.325
Maximum	59.8	33543	3.053
Skew	0.0	1	0.030
Kurtosis	0.8	1	0.307
N=	283	250	174

WV Context 401	Length (mm)	Volume (mm3)	Conicity
Mean	47.6	16495	2.212
StDev	6.0	7243	0.282
Median	48.0	14609	2.141
Interquartile	7.2	8371	0.355
Minimum	35.0	5073	1.806
Maximum	56.0	29910	2.826
Skew	-0.5	0	0.726
Kurtosis	-0.3	0	-0.106
N=	32	14	16

WV Context 480	Length (mm)	Volume (mm3)	Conicity
Mean	45.7	13087	2.268
StDev	4.6	3800	0.169
Median	46.0	12763	2.268
Interquartile	4.8	4574	0.255
Minimum	35.5	6349	2.028
Maximum	57.3	24064	2.669
Skew	0.2	1	0.380
Kurtosis	0.7	1	-0.504
N=	32	27	32

Statistical Testing Output - SL_P.

Table SI-Chapter6-1.2: Statistical Inference Testing Results

z-Test: Two Sample for Means			z-Test: Two Sample for Means		
SL_P			SL_P		
	TNB1 C8	TNB1 C11		TNB1 C11	TNB1 C14
Mean	28.92713	28.17313	Mean	28.17313	29.26206
Known Variance	21.57899	16.60209	Known Variance	16.60209	25.21045
Observations	1448	176	Observations	176	671
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
z	2.281372		z	-2.9983	
P(Z<=z) one-tail	0.011263		P(Z<=z) one-tail	0.001357	
z Critical one-tail	1.644854		z Critical one-tail	1.644854	
P(Z<=z) two-tail	0.022526		P(Z<=z) two-tail	0.002715	
z Critical two-tail	1.959964		z Critical two-tail	1.959964	
Reject H_0 @ 0.05			Reject H_0 @ 0.005		
z-Test: Two Sample for Means			z-Test: Two Sample for Means		
SL_P			SL_P		
	TNB1 C8	TNB1 C14		TNB1 C11	PMS C2
Mean	28.92713	29.26206	Mean	28.17313	30.62557
Known Variance	21.57899	25.21045	Known Variance	16.60209	27.30768
Observations	1448	671	Observations	176	501
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
z	-1.46211		z	-6.35689	
P(Z<=z) one-tail	0.071855		P(Z<=z) one-tail	1.03E-10	
z Critical one-tail	1.644854		z Critical one-tail	1.644854	
P(Z<=z) two-tail	0.14371		P(Z<=z) two-tail	2.06E-10	
z Critical two-tail	1.959964		z Critical two-tail	1.959964	
Fail to Reject H_0			Reject H_0 @ 0.0001		
z-Test: Two Sample for Means			z-Test: Two Sample for Means		
SL_P			SL_P		
	TNB1 C8	PMS C2		TNB1 C14	PMS C2
Mean	28.92713	30.62557	Mean	29.26206	30.62557
Known Variance	21.57899	27.30768	Known Variance	25.21045	27.30768
Observations	1448	501	Observations	671	501
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
z	-6.44678		z	-4.49347	
P(Z<=z) one-tail	5.71E-11		P(Z<=z) one-tail	3.5E-06	
z Critical one-tail	1.644854		z Critical one-tail	1.644854	
P(Z<=z) two-tail	1.14E-10		P(Z<=z) two-tail	7.01E-06	
z Critical two-tail	1.959964		z Critical two-tail	1.959964	
Reject H_0 @ 0.0001			Reject H_0 @ 0.0001		

z-Test: Two Sample for Means		
SL_P		
	TNB2 C5	TNB2 C11
Mean	31.1745805	29.7428051
Known Variance	22.102936	26.724283
Observations	1037	549
Hypothesized Mean Difference	0	
z	5.41189553	
P(Z<=z) one-tail	3.1181E-08	
z Critical one-tail	1.64485363	
P(Z<=z) two-tail	6.2361E-08	
z Critical two-tail	1.95996398	
Reject H_0 @ 0.0001		

z-Test: Two Sample for Means		
SL_P		
	TNB2 C11	TNB2 C18
Mean	29.74281	28.84431
Known Variance	26.72428	24.19337
Observations	549	65
Hypothesized Mean Difference	0	
z	1.384955	
P(Z<=z) one-tail	0.083033	
z Critical one-tail	1.644854	
P(Z<=z) two-tail	0.166066	
z Critical two-tail	1.959964	
Fail to Reject H_0		

z-Test: Two Sample for Means		
SL_P		
	TNB2 C5	TNB2 C18
Mean	31.1745805	28.8443077
Known Variance	22.102936	24.193369
Observations	1037	65
Hypothesized Mean Difference	0	
z	3.71469683	
P(Z<=z) one-tail	0.00010172	
z Critical one-tail	1.64485363	
P(Z<=z) two-tail	0.00020345	
z Critical two-tail	1.95996398	
Reject H_0 @ 0.0005		

z-Test: Two Sample for Means		
SL_P		
	TNB2 C11	TNB2 C15
Mean	29.74281	30.18208
Known Variance	26.72428	19.78731
Observations	549	53
Hypothesized Mean Difference	0	
z	-0.67618	
P(Z<=z) one-tail	0.249463	
z Critical one-tail	1.644854	
P(Z<=z) two-tail	0.498925	
z Critical two-tail	1.959964	
Fail to Reject H_0		

z-Test: Two Sample for Means		
SL_P		
	TNB2 C5	TNB2 C15
Mean	31.1745805	30.1820755
Known Variance	22.102936	19.787313
Observations	1037	53
Hypothesized Mean Difference	0	
z	1.57986966	
P(Z<=z) one-tail	0.05706836	
z Critical one-tail	1.64485363	
P(Z<=z) two-tail	0.11413672	
z Critical two-tail	1.95996398	
Fail to Reject H_0		

z-Test: Two Sample for Means		
SL_P		
	PMS C2	TNB2 C11
Mean	30.62557	29.74281
Known Variance	27.30768	26.72428
Observations	501	549
Hypothesized Mean Difference	0	
z	2.748131	
P(Z<=z) one-tail	0.002997	
z Critical one-tail	1.644854	
P(Z<=z) two-tail	0.005994	
z Critical two-tail	1.959964	
Reject H_0 @ 0.001		

z-Test: Two Sample for Means		
SL_P		
	PMS C2	TNB2 C5
Mean	30.6255689	31.1745805
Known Variance	27.3076771	22.102936
Observations	501	1037
Hypothesized Mean Difference	0	
z	-1.9938286	
P(Z<=z) one-tail	0.02308539	
z Critical one-tail	1.64485363	
P(Z<=z) two-tail	0.04617079	
z Critical two-tail	1.95996398	
Reject H_0 @ 0.05		

z-Test: Two Sample for Means		
SL_P		
	TNB2 C18	TNB2 C15
Mean	28.84431	30.18208
Known Variance	24.19337	19.78731
Observations	65	53
Hypothesized Mean Difference	0	
z	-1.54932	
P(Z<=z) one-tail	0.060652	
z Critical one-tail	1.644854	
P(Z<=z) two-tail	0.121304	
z Critical two-tail	1.959964	
Fail to Reject H_0		

z-Test: Two Sample for Means		
SL_P		
	PMS C2	TNB2 C18
Mean	30.6255689	28.8443077
Known Variance	27.3076771	24.1933687
Observations	501	65
Hypothesized Mean Difference	0	
z	2.7268432	
P(Z<=z) one-tail	0.00319717	
z Critical one-tail	1.64485363	
P(Z<=z) two-tail	0.00639434	
z Critical two-tail	1.95996398	
Reject H_0 @ 0.001		

z-Test: Two Sample for Means		
SL_P		
	PMS C2	TNB2 C15
Mean	30.62557	30.18208
Known Variance	27.30768	19.78731
Observations	501	53
Hypothesized Mean Difference	0	
z	0.678017	
P(Z<=z) one-tail	0.248881	
z Critical one-tail	1.644854	
P(Z<=z) two-tail	0.497761	
z Critical two-tail	1.959964	
Fail to Reject H_0		

Statistical Testing Output - SL_P/SH_P.

Table SI-Chapter6-1.3: Statistical testing results for limpet conicity

z-Test: Two Sample for Means		
SL_P/SH_P		
	TNB1 C8	TNB1 C11
Mean	2.935505619	2.95635692
Known Variance	0.190914088	0.161365093
Observations	1448	176
Hypothesized Mean Difference	0	
z	-0.643885713	
P(Z<=z) one-tail	0.259824774	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.519649547	
z Critical two-tail	1.959963985	
Fail to Reject H_0		

z-Test: Two Sample for Means		
SL_P/SH_P		
	TNB1 C8	TNB1 C14
Mean	2.935505619	2.862883154
Known Variance	0.190914088	0.180181828
Observations	1448	671
Hypothesized Mean Difference	0	
z	3.629426623	
P(Z<=z) one-tail	0.000142026	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.000284051	
z Critical two-tail	1.959963985	
Reject H_0 @ 0.0005		

z-Test: Two Sample for Means		
SL_P/SH_P		
	TNB1 C8	PMS C2
Mean	2.935505619	2.911320735
Known Variance	0.190914088	0.186375556
Observations	1448	500
Hypothesized Mean Difference	0	
z	1.07664196	
P(Z<=z) one-tail	0.140820125	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.281640251	
z Critical two-tail	1.959963985	
Fail to Reject H_0		

z-Test: Two Sample for Means		
SL_P/SH_P		
	TNB1 C11	PMS C2
Mean	2.95635692	2.862883154
Known Variance	0.161365093	0.180181828
Observations	176	671
Hypothesized Mean Difference	0	
z	2.714950788	
P(Z<=z) one-tail	0.003314281	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.006628562	
z Critical two-tail	1.959963985	
Reject H_0 @ 0.01		

z-Test: Two Sample for Means		
SL_P/SH_P		
	TNB1 C11	PMS C2
Mean	2.95635692	2.911320735
Known Variance	0.161365093	0.186375556
Observations	176	500
Hypothesized Mean Difference	0	
z	1.254106372	
P(Z<=z) one-tail	0.104901672	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.209803345	
z Critical two-tail	1.959963985	
Fail to Reject H_0		

z-Test: Two Sample for Means		
SL_P/SH_P		
	TNB1 C14	PMS C2
Mean	2.862883154	2.911320735
Known Variance	0.180181828	0.186375556
Observations	671	500
Hypothesized Mean Difference	0	
z	-1.912754072	
P(Z<=z) one-tail	0.027889772	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.055779543	
z Critical two-tail	1.959963985	
Fail to Reject H_0		

z-Test: Two Sample for Means		
SL_P/SH_P	C5	C11
Mean	2.85223996	2.91567433
Known Variance	0.1965311	0.20738266
Observations	1037	549
Hypothesized Mean Difference	0	
z	-2.6633708	
P(Z<=z) one-tail	0.00386811	
z Critical one-tail	1.64485363	
P(Z<=z) two-tail	0.00773621	
z Critical two-tail	1.95996398	
Reject H_0 @ 0.01		

z-Test: Two Sample for Means		
SL_P/SH_P	C5	C18
Mean	2.85223996	2.94204728
Known Variance	0.1965311	0.23670831
Observations	1037	65
Hypothesized Mean Difference	0	
z	-1.4509257	
P(Z<=z) one-tail	0.07340028	
z Critical one-tail	1.64485363	
P(Z<=z) two-tail	0.14680056	
z Critical two-tail	1.95996398	
Fail to Reject H_0		

z-Test: Two Sample for Means		
SL_P/SH_P	C5	C15
Mean	2.85223996	2.86072718
Known Variance	0.1965311	0.18483286
Observations	1037	53
Hypothesized Mean Difference	0	
z	-0.139966	
P(Z<=z) one-tail	0.44434341	
z Critical one-tail	1.64485363	
P(Z<=z) two-tail	0.88868682	
z Critical two-tail	1.95996398	
Fail to Reject H_0		

z-Test: Two Sample for Means		
SL_P/SH_P	C11	C18
Mean	2.91567433	2.94204728
Known Variance	0.20738266	0.23670831
Observations	549	65
Hypothesized Mean Difference	0	
z	-0.4159847	
P(Z<=z) one-tail	0.33871061	
z Critical one-tail	1.64485363	
P(Z<=z) two-tail	0.67742121	
z Critical two-tail	1.95996398	
Fail to Reject H_0		

z-Test: Two Sample for Means		
SL_P/SH_P	C11	C15
Mean	2.91567433	2.86072718
Known Variance	0.20738266	0.18483286
Observations	549	53
Hypothesized Mean Difference	0	
z	0.88381537	
P(Z<=z) one-tail	0.18839794	
z Critical one-tail	1.64485363	
P(Z<=z) two-tail	0.37679589	
z Critical two-tail	1.95996398	
Fail to Reject H_0		

z-Test: Two Sample for Means		
SL_P/SH_P	C18	C15
Mean	2.94204728	2.86072718
Known Variance	0.23670831	0.18483286
Observations	65	53
Hypothesized Mean Difference	0	
z	0.96312177	
P(Z<=z) one-tail	0.16774321	
z Critical one-tail	1.64485363	
P(Z<=z) two-tail	0.33548642	
z Critical two-tail	1.95996398	
Fail to Reject H_0		

z-Test: Two Sample for Means		
SL_P/SH_P	C5	PMS
Mean	2.85223996	2.91132074
Known Variance	0.1965311	0.18637556
Observations	1037	500
Hypothesized Mean Difference	0	
z	-2.4915737	
P(Z<=z) one-tail	0.00635893	
z Critical one-tail	1.64485363	
P(Z<=z) two-tail	0.01271786	
z Critical two-tail	1.95996398	
Reject H_0 @ 0.05		

z-Test: Two Sample for Means		
SL_P/SH_P	C11	PMS
Mean	2.91567433	2.91132074
Known Variance	0.20738266	0.18637556
Observations	549	500
Hypothesized Mean Difference	0	
z	0.15891828	
P(Z<=z) one-tail	0.43686663	
z Critical one-tail	1.64485363	
P(Z<=z) two-tail	0.87373326	
z Critical two-tail	1.95996398	
Fail to Reject H_0		

z-Test: Two Sample for Means		
SL_P/SH_P	C18	PMS
Mean	2.94204728	2.91132074
Known Variance	0.23670831	0.18637556
Observations	65	500
Hypothesized Mean Difference	0	
z	0.48495612	
P(Z<=z) one-tail	0.31385374	
z Critical one-tail	1.64485363	
P(Z<=z) two-tail	0.62770747	
z Critical two-tail	1.95996398	
Fail to Reject H_0		

z-Test: Two Sample for Means		
SL_P/SH_P	C15	PMS
Mean	2.86072718	2.91132074
Known Variance	0.23670831	0.18483286
Observations	53	500
Hypothesized Mean Difference	0	
z	-0.7275424	
P(Z<=z) one-tail	0.23344686	
z Critical one-tail	1.64485363	
P(Z<=z) two-tail	0.46689372	
z Critical two-tail	1.95996398	
Fail to Reject H_0		

Statistical Testing Output SV_P

Table SI-Chapter6-1.4: Output from Kolmogorov-Smirnov inference testing.

TNB2 C5 n=	1000	TNB2 C15 n=	53
TNB2 C11 n=	549	TNB2 C18 n=	18
Test statistic	0.314806922	Test statistic	0.307982583
Critical Value	0.104110758	Critical Value	0.251701207
H_0	Reject @ 0.001	H_0	Reject @ 0.05
TNB2 C5 n=	1000	PMS C2 n=	489
TNB2 C15 n=	53	TNB2 C5 n=	1000
Test statistic	0.193849057	Test statistic	0.246562372
Critical Value	0.191696931	Critical Value	0.108155595
H_0	Reject @ 0.05	H_0	Reject @ 0.001
TNB2 C5 n=	1000	PMS C2 n=	489
TNB2 C18 n=	65	TNB2 C11 n=	549
Test statistic	0.444076923	Test statistic	0.068244549
Critical Value	0.250884711	Critical Value	0.084566233
H_0	Reject @ 0.001	H_0	Fail to Reject
TNB2 C11 n=	549	PMS C2 n=	489
TNB2 C15 n=	53	TNB2 C15 n=	53
Test statistic	0.178712582	Test statistic	0.110468033
Critical Value	0.195619906	Critical Value	0.196673654
H_0	Fail to Reject	H_0	Fail to Reject
TNB2 C11 n=	549	PMS C2 n=	489
TNB2 C18 n=	65	TNB2 C18 n=	65
Test statistic	0.137144458	Test statistic	0.197514551
Critical Value	0.178394	Critical Value	0.179548873
H_0	Fail to Reject	H_0	Reject @ 0.05

TNB1 C8 n=	1440	PMS C2 n=	489
TNB1 C11 n=	176	TNB1 C8 n=	1440
Test statistic	0.235479798	Test statistic	0.052718132
Critical Value	0.156508947	Critical Value	0.071181862
H_0	Reject @ 0.001	H_0	Fail to Reject
TNB1 C8 n=	1440	PMS C2 n=	489
TNB1 C14 n=	421	TNB1 C11 n=	176
Test statistic	0.116323568	Test statistic	0.205997862
Critical Value	0.108594283	Critical Value	0.172288437
H_0	Reject @ 0.001	H_0	Reject @ 0.001
TNB1 C11 n=	176	PMS C2 n=	489
TNB1 C14 n=	421	TNB1 C14 n=	421
Test statistic	0.126929929	Test statistic	0.098349111
Critical Value	0.122075551	Critical Value	0.090419922
H_0	Reject @ 0.05	H_0	Reject @ 0.05

Limpet Volumes

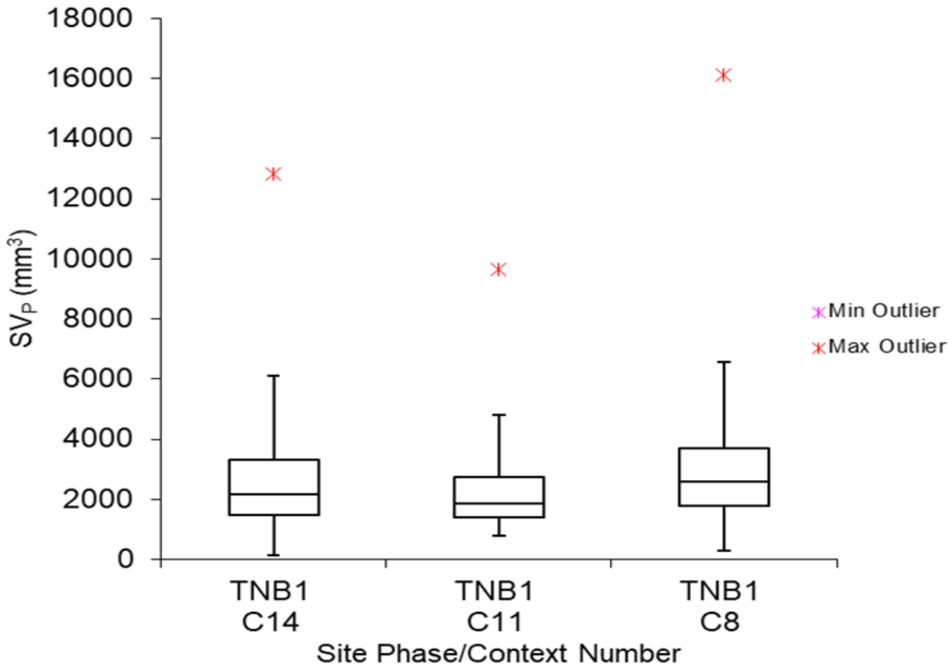


Figure SI-Chapter6-1.1: Volume of limpets at TNB1.

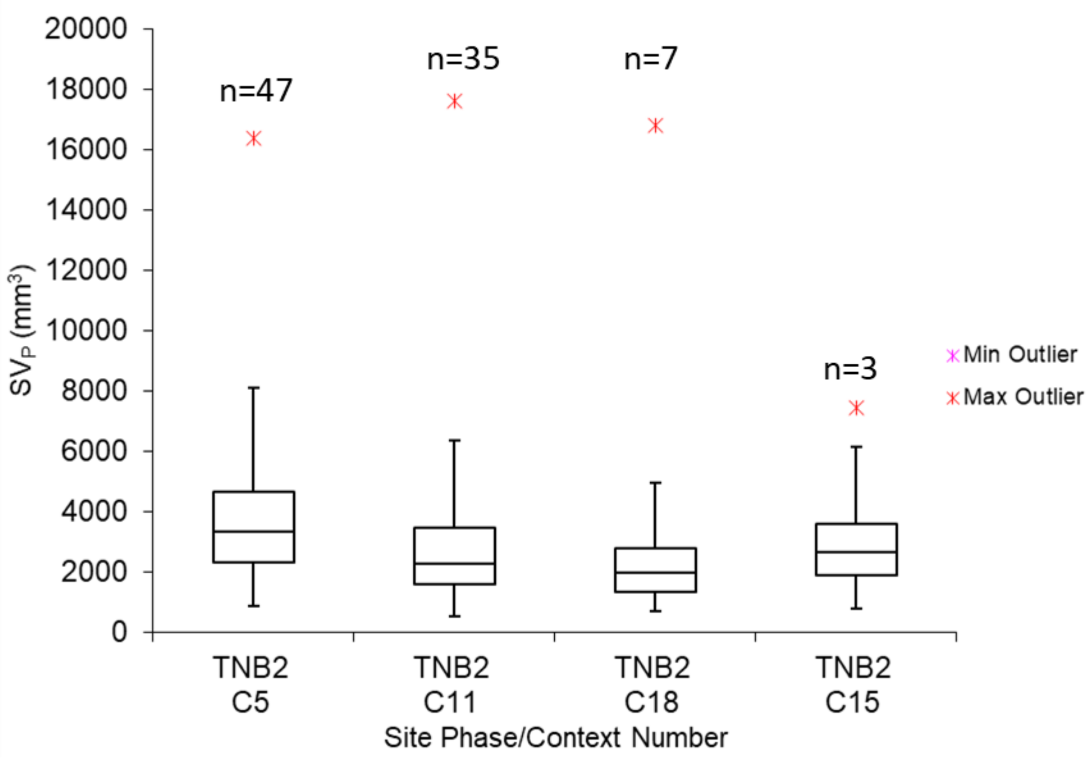


Figure SI-Chapter6-1.2: Volume of limpets at TNB2. Numbers define the number of outliers.

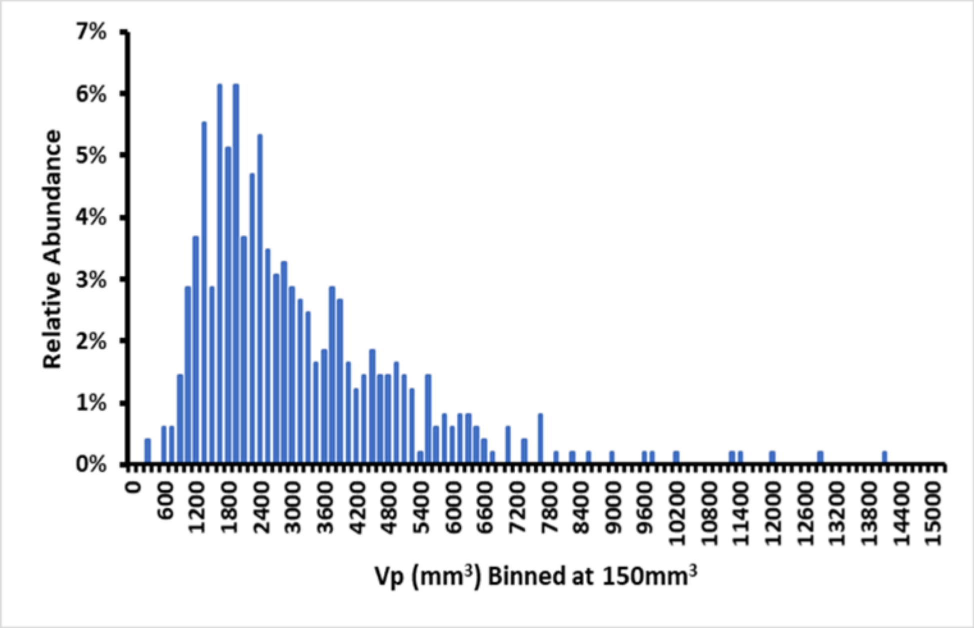


Figure SI-Chapter6-1.3: Population structure of PMS context 2 in terms of volume.

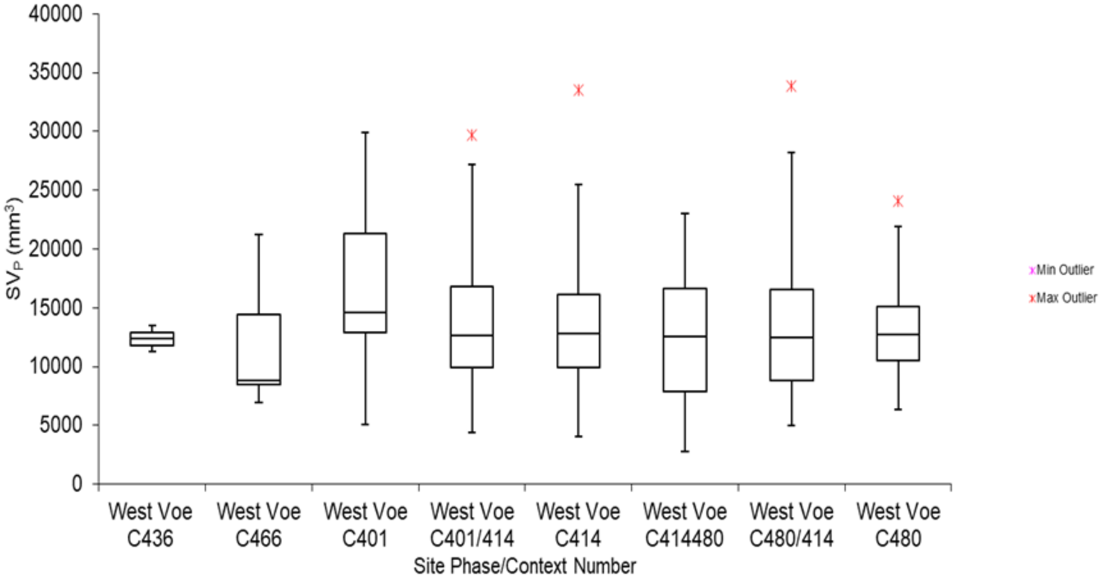


Figure SI-Chapter6-1.4: Limpet volume by context at West Voe.

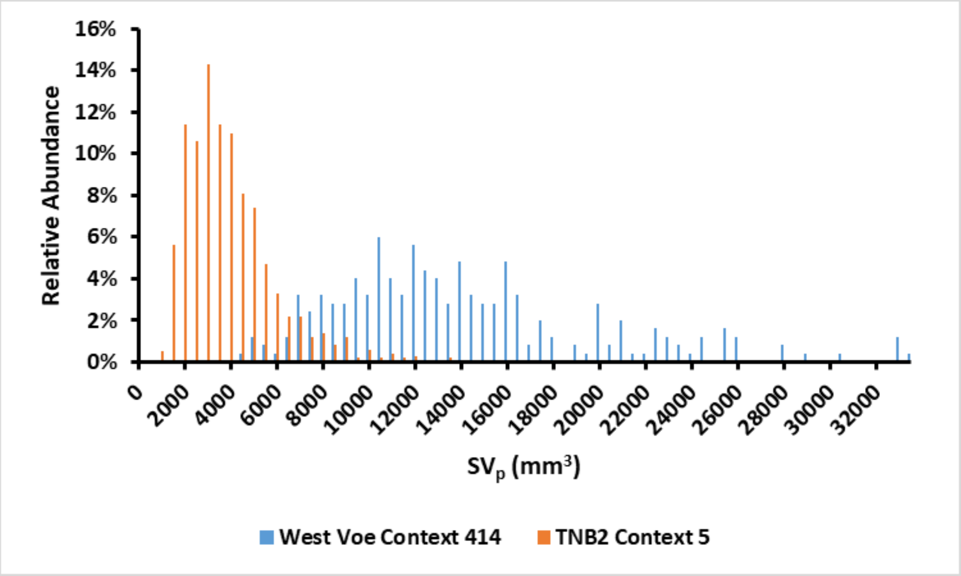


Figure SI-Chapter6-1.5: Comparison between West Voe and TNB2 Context 5. West Voe n=250 TNB2 n=1000.

SI-Chapter6-2: Razor Clams.

Quantification

Razor clams were quantified using the umbo. Metrics were recorded using Vernier callipers and documented to one decimal place. It proved impossible to speciate fragmented archaeological specimens either visually or metrically. Width versus length is an excellent method but neither length nor width preserve. The form and angle of the pallial line at the anterior end looked promising but was not good enough. Speciation was hoped for as the three species have different substrate preferences and one species has a greater tolerance to wave exposure.

Biometric Analysis

The analysis of razor clam was augmented from Evans (2015) by a second metric and associated model, which permitted the size of even more fragmentary specimens to be modelled, this was satisfactory for *Ensis siliqua,* but inadequate for *Ensis magnus* (Figures SI-Chapter6-2.1 to 2.4). The issue is that *Ensis magnus* exhibits far more variability in the curvature of its dorsal margin than the other two species. *Ensis ensis* is very curved, *Ensis siliqua* is very (totally) straight. *Ensis magnus* is never as curved as *Ensis ensis* and never as straight as *Ensis siliqua* but the variability is considerable. This results in greater variability in the relationship between EHL_E and LTL_E and the length of the dorsal margin when measured as a straight line. The reason for variability is unknown but it is probably a mixture of substrate composition and wave exposure level. As the composition of the archaeological assemblage is unknown, other than modelled lengths often far exceed the accepted maximum lengths of *Ensis magnus.* This is a material consideration as *Ensis ensis* is the much smaller of the three species (Hayward and Ryland, 2012). Therefore, a composite model based upon EHL_E was utilised (figure SI-Chapter6-2.2) to reconstruct length.

Analysis suggests that as the relationship between EHL and LTL is much tighter for *Ensis siliqua,* evaluating the archaeological assemblages in terms of the distribution of residuals when the model for *Ensis siliqua* is utilised, combined with the proportion exceeding accepted maximum length, will permit the relative shifts in the taxonomic composition to be identified. These serve as proxy for wave exposure level of the shore. The results obtained are encouraging, but a larger sample of modern Ensis siliqua is required and this approach was not deployed by this project.

Summary statistics for the razor clam assemblages are provided in table SI-Chapter6-2.1 and the statistical testing output in table SI-Chapter6-2.2.

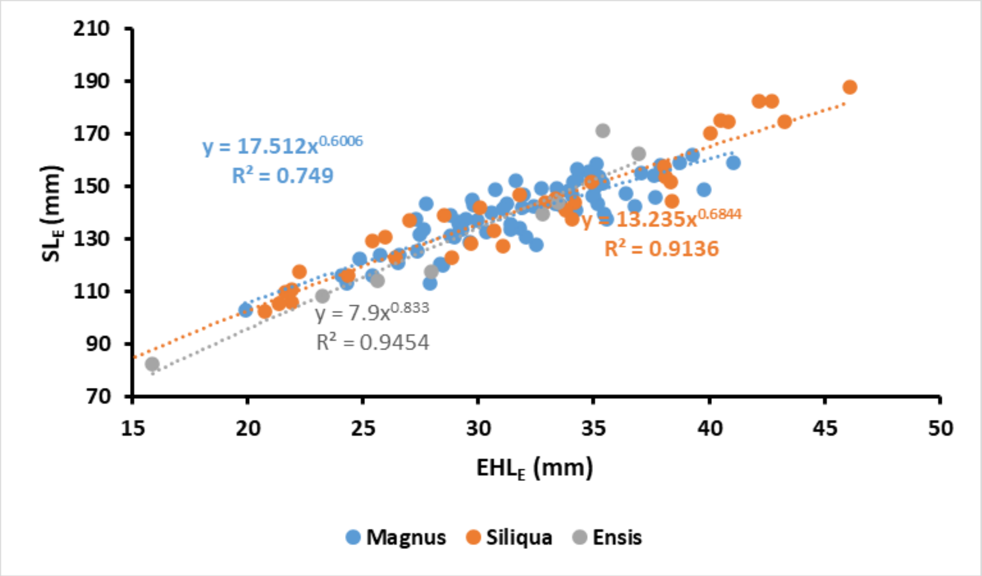


Figure SI-Chapter6-2.1: The relationship between EHL and SL of modern specimens. Specimens from Gairloch Bay and Traigh na Beirigh pooled.

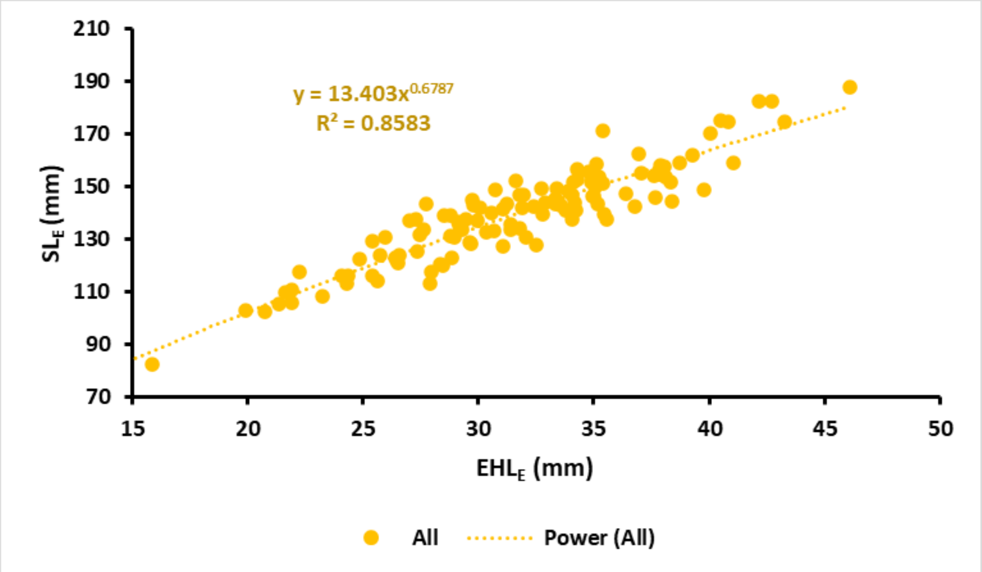


Figure SI-Chapter6-2.2: Relationship between EHL and SL for modern specimens when *Ensis spp*. pooled. Specimens from Gairloch Bay and Traigh na Beirigh pooled.

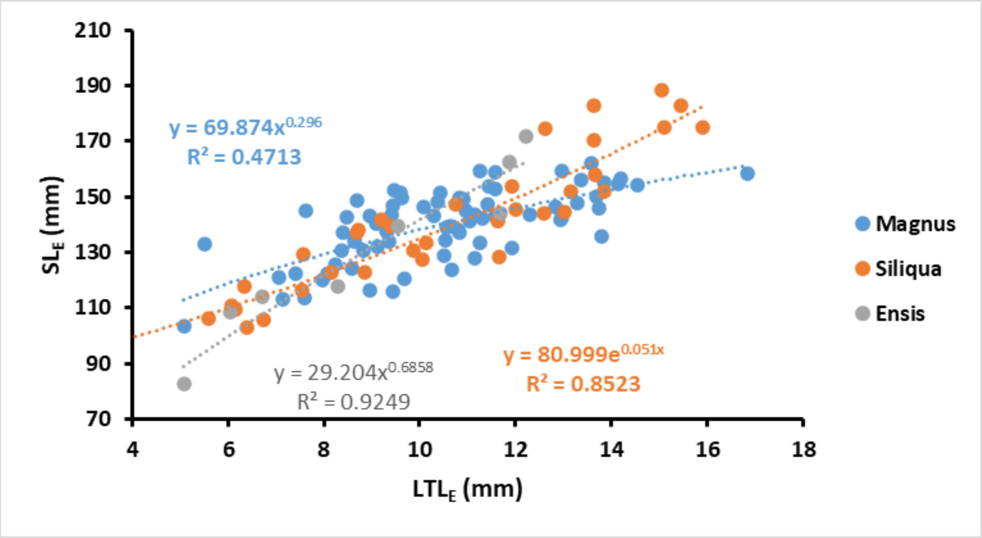


Figure SI-Chapter6-2.3: Relationship between LTL and SL of modern specimens. Specimens from Gairloch Bay and Traigh na Beirigh pooled.

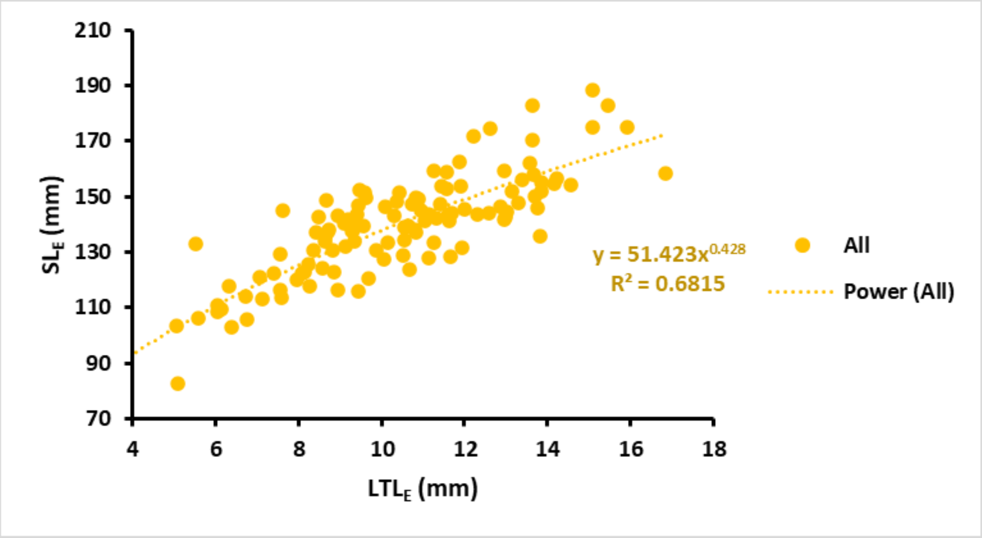
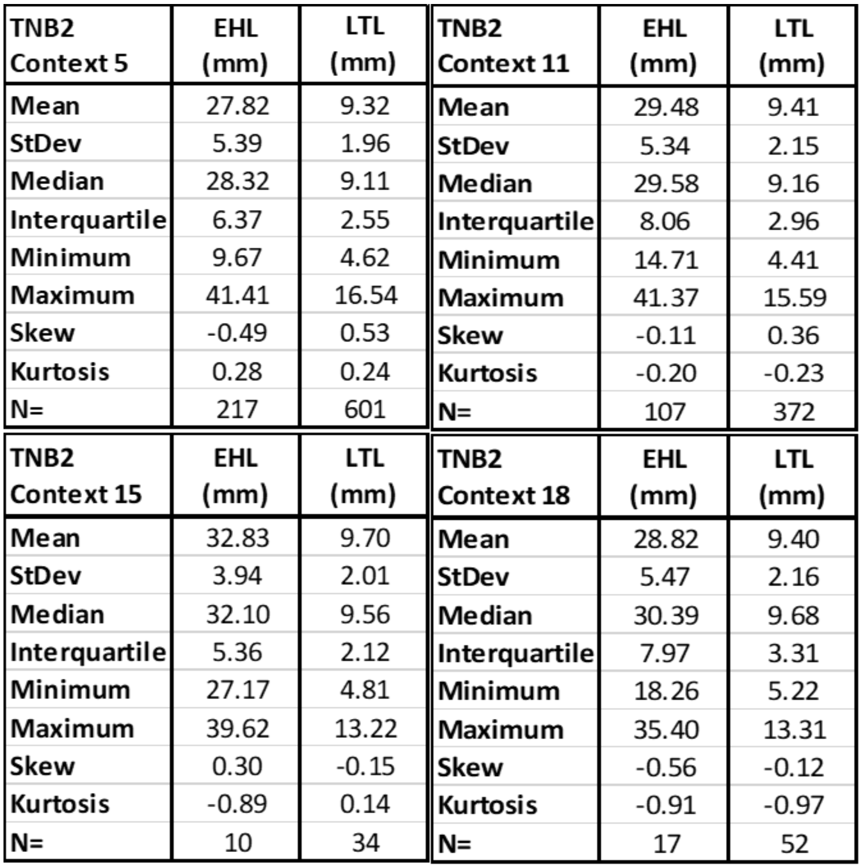


Figure SI-Chapter6-2.4: Relationship between LTL and SL for modern specimens when Ensis spp. pooled. Specimens from Gairloch Bay and Traigh na Beirigh pooled.

Summary Statistics

Table SI-Chapter6-2.1: Summary Statistics for Razor Clam.



TNB2 Context 5	EHL (mm)	LTL (mm)
Mean	27.82	9.32
StDev	5.39	1.96
Median	28.32	9.11
Interquartile	6.37	2.55
Minimum	9.67	4.62
Maximum	41.41	16.54
Skew	-0.49	0.53
Kurtosis	0.28	0.24
N=	217	601

TNB2 Context 11	EHL (mm)	LTL (mm)
Mean	29.48	9.41
StDev	5.34	2.15
Median	29.58	9.16
Interquartile	8.06	2.96
Minimum	14.71	4.41
Maximum	41.37	15.59
Skew	-0.11	0.36
Kurtosis	-0.20	-0.23
N=	107	372

TNB2 Context 15	EHL (mm)	LTL (mm)
Mean	32.83	9.70
StDev	3.94	2.01
Median	32.10	9.56
Interquartile	5.36	2.12
Minimum	27.17	4.81
Maximum	39.62	13.22
Skew	0.30	-0.15
Kurtosis	-0.89	0.14
N=	10	34

TNB2 Context 18	EHL (mm)	LTL (mm)
Mean	28.82	9.40
StDev	5.47	2.16
Median	30.39	9.68
Interquartile	7.97	3.31
Minimum	18.26	5.22
Maximum	35.40	13.31
Skew	-0.56	-0.12
Kurtosis	-0.91	-0.97
N=	17	52

Context 8	EHL (mm)	LTL (mm)
Mean	30.6	10.3
StDev	4.7	2.3
Median	30.6	10.1
Interquartile	6.4	3.2
Minimum	18.2	3.4
Maximum	45.3	17.8
Skew	0.1	0.2
Kurtosis	0.0	-0.4
Specimens	250	474

TNB1 Context 11	EHL (mm)	LTL (mm)
Mean	30.62	10.03
StDev	9.27	2.48
Median	30.28	10.06
Interquartile	7.35	3.37
Minimum	7.26	4.93
Maximum	48.86	14.25
Skew	-0.25	-0.20
Kurtosis	1.68	-0.56
N=	19	42

TNB1 Context 14	EHL (mm)	LTL (mm)
Mean	29.85	10.05
StDev	5.50	2.34
Median	28.80	9.96
Interquartile	6.72	3.23
Minimum	18.64	5.45
Maximum	45.14	16.73
Skew	0.34	0.40
Kurtosis	-0.04	-0.23
N=	64	244

PMS Context 2	EHL (mm)	LTL (mm)
Mean	29.29	9.73
StDev	7.39	2.59
Median	29.46	9.71
Interquartile	11.92	3.58
Minimum	17.68	4.59
Maximum	38.80	15.27
Skew	-0.28	0.23
Kurtosis	-1.38	-0.67
N=	18	60

Statistical Testing Output

Table SI-Chapter6-2.2: Statistical Inference Testing output.

z-Test: Two Sample for Means		
EHL_E		
	TNB2 Context 5	TNB2 Context 11
Mean	27.81769585	29.48093458
Known Variance	29.06586226	28.49933
Observations	217	107
Hypothesized Mean Difference	0	
z	-2.628848878	
P(Z<=z) one-tail	0.004283721	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.008567442	
z Critical two-tail	1.959963985	
Reject H_0 @ 0.01		

z-Test: Two Sample for Means		
EHL_E		
	TNB2 Context 5	TNB2 Context 18
Mean	27.81769585	28.81588235
Known Variance	29.06586226	29.95599
Observations	217	17
Hypothesized Mean Difference	0	
z	-0.724912394	
P(Z<=z) one-tail	0.234252888	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.468505777	
z Critical two-tail	1.959963985	
Fail to Reject H_0		

z-Test: Two Sample for Means		
EHL_E		
	TNB2 Context 5	TNB2 Context 15
Mean	27.81769585	32.832
Known Variance	29.06586226	15.5611067
Observations	217	10
Hypothesized Mean Difference	0	
z	-3.857094575	
P(Z<=z) one-tail	5.73714E-05	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.000114743	
z Critical two-tail	1.959963985	
Reject H_0 @ 0.0005		

z-Test: Two Sample for Means		
EHL_E	C11	C18
	TNB2 Context 11	TNB2 Context 18
Mean	29.48093458	28.81588235
Known Variance	28.49933	15.5611067
Observations	107	17
Hypothesized Mean Difference	0	
z	0.611787566	
P(Z<=z) one-tail	0.270339159	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.540678317	
z Critical two-tail	1.959963985	
Fail to Reject H_0		

z-Test: Two Sample for Means		
EHL_E	C11	C15
	TNB2 Context 11	TNB2 Context 15
Mean	29.48093458	32.832
Known Variance	28.49933	15.5611067
Observations	107	10
Hypothesized Mean Difference	0	
z	-2.48229823	
P(Z<=z) one-tail	0.006526899	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.013053797	
z Critical two-tail	1.959963985	
Reject H_0 @ 0.05		

z-Test: Two Sample for Means		
EHL_E		
	TNB2 Context 5	PMS Context 2
Mean	27.81769585	29.28888889
Known Variance	29.06586226	54.60106928
Observations	217	18
Hypothesized Mean Difference	0	
z	-0.82665165	
P(Z<=z) one-tail	0.204217267	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.408434533	
z Critical two-tail	1.959963985	
Fail to Reject H_0		

z-Test: Two Sample for Means		
EHL_E		
	TNB2 Context 11	PMS Context 2
Mean	29.48093458	29.28888889
Known Variance	28.49933	54.60106928
Observations	107	18
Hypothesized Mean Difference	0	
z	0.105721812	
P(Z<=z) one-tail	0.457901537	
z Critical one-tail	1.644853627	
P(Z<=z) two-tail	0.915803074	
z Critical two-tail	1.959963985	
Fail to Reject H_0		

t-Test: Two-Sample Assuming Unequal Variances		
EHL_E		
	TNB2 Context 15	TNB2 Context 18
Mean	32.832	28.81588235
Variance	15.56110667	29.95598824
Observations	10	17
Hypothesized Mean Difference	0	
df	24	
t Stat	2.20471948	
P(T<=t) one-tail	0.018651758	
t Critical one-tail	1.71088208	
P(T<=t) two-tail	0.037303517	
t Critical two-tail	2.063898562	
Reject H_0 @ 0.05		

t-Test: Two-Sample Assuming Unequal Variances		
EHL_E		
	TNB2 Context 15	PMS Context 2
Mean	32.832	29.28888889
Variance	15.56110667	54.60106928
Observations	10	18
Hypothesized Mean Difference	0	
df	26	
t Stat	1.653872111	
P(T<=t) one-tail	0.055089222	
t Critical one-tail	1.70561792	
P(T<=t) two-tail	0.110178444	
t Critical two-tail	2.055529439	
Fail to Reject H_0		

t-Test: Two-Sample Assuming Unequal Variances		
EHL_E		
	TNB2 Context 18	PMS Context 2
Mean	28.81588235	29.28888889
Variance	29.95598824	54.60106928
Observations	17	18
Hypothesized Mean Difference	0	
df	31	
t Stat	-0.215998013	
P(T<=t) one-tail	0.41520215	
t Critical one-tail	1.695518783	
P(T<=t) two-tail	0.830404301	
t Critical two-tail	2.039513446	
Fail to Reject H_0		

SI-Chapter6-3: Dog Whelks and Periwinkles.

Introduction

Dog whelks and periwinkles where quantified using the apex as the NRE. Metrics were gathered using Vernier callipers and recorded to one decimal place, except for the internal aperture measurements for dog whelk which were recorded to two decimal places. It is not possible to generate a satisfactory model for reconstructing the shell height of fragmented dog whelks from their aperture height as there are two ecomorphs where the key variation is the ratio of these two biometrics. Such a model was created for periwinkle and a composite model created from the pooled archaeological specimens, supplemented by modern species to ensure coverage of the smaller size classes. There is little variation, and this is consistent with the prevailing view that periwinkles do not have ecomorphs. There is however one technicality that had to be dealt with.

Hayward and Ryland (2012) list two large species of periwinkle, namely, *Littorina nigrolineata* and *Littorina littorea*. The word register of marine species (WORMS) does not recognise the former and states it is a form of *Littorina littorea*. The reality is that these two forms have very different ratios of aperture height to shell height. Just about all the periwinkles in the archaeological assemblages and the photographs of the species provided within published archaeological literature show that the periwinkles of the region are *Littorina nigolineata* (*sensu* Hayward and Ryland, 2012). The models present here and in the main text only work for *Littorina nigolineata* and not *Littorina littorea* (*sensu* Hayward and Ryland, 2012). Specimens of the latter, of which there were only three in the entirety of the assemblages of the Western Isles and Shetland, are extreme outliers and were excluded from the modelling.

The relative robusticity of dog whelk shell compared to periwinkle is shown in figure SI-Chapter6-3.1. The overall fragmentation levels within the pooled archaeological assemblages are shown in figures SI-Chapter6-3.2 to 3.4. The shell height reconstruction models are shown in figures SI-Chapter6-3.5 and 3.6. As so few dog whelks have their shell height preserved determining the relative abundance of the two ecomorphs is problematic. This is unfortunate as the two ecomorphs serve as a proxy for shore wave exposure level. Analysis (chapter 8) suggests the ecomorphs can be identified using an alternative approach.

Biometrics

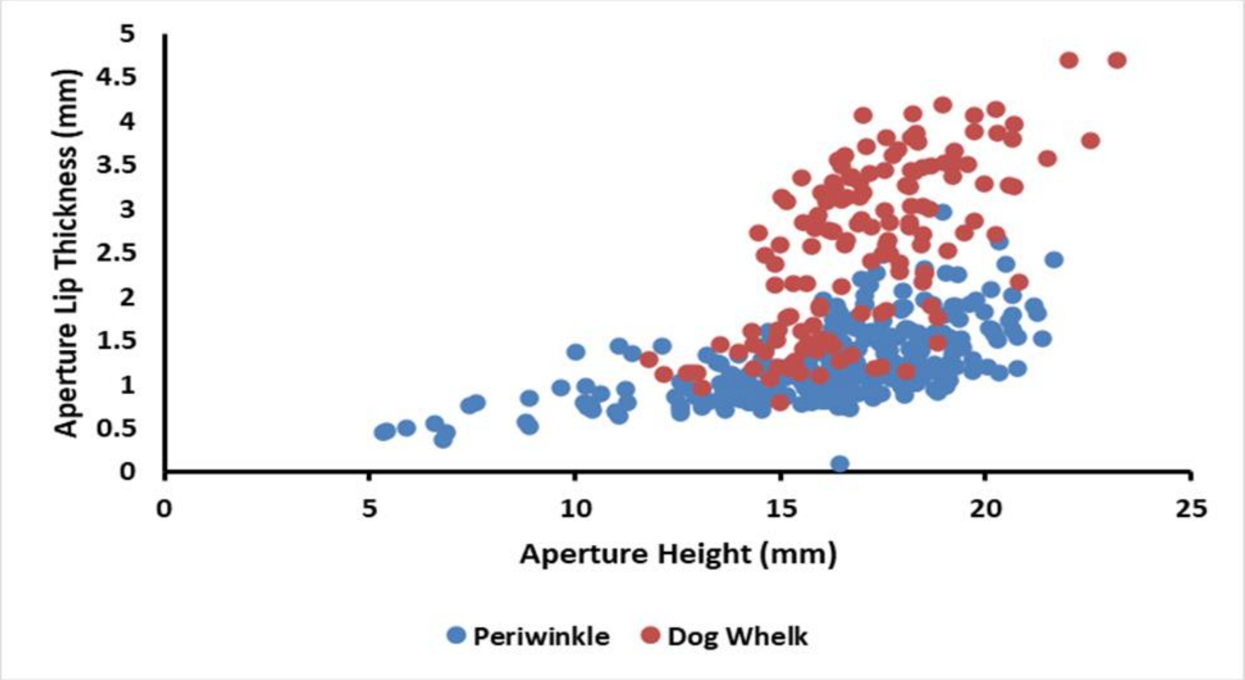


Figure SI-Chapter6-3.1: The robusticity of dog whelk shells compared to those of periwinkles. Archaeological assemblages pooled.

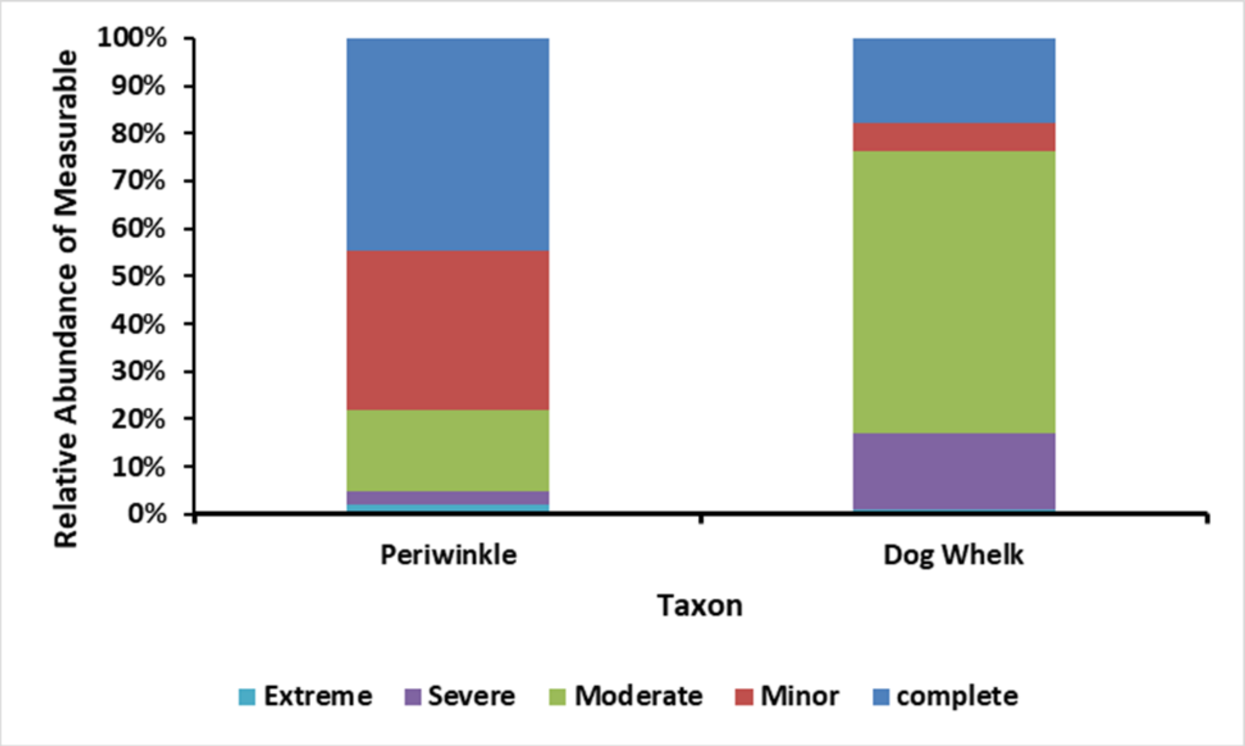


Figure SI-Chapter6-3.2: Fragmentation within the pooled archaeological assemblages from which at least one metric could be gathered. The difference between the two snails is significant H_0 rejected at 0.05 as shown in table SI-Chapter6-3.5.

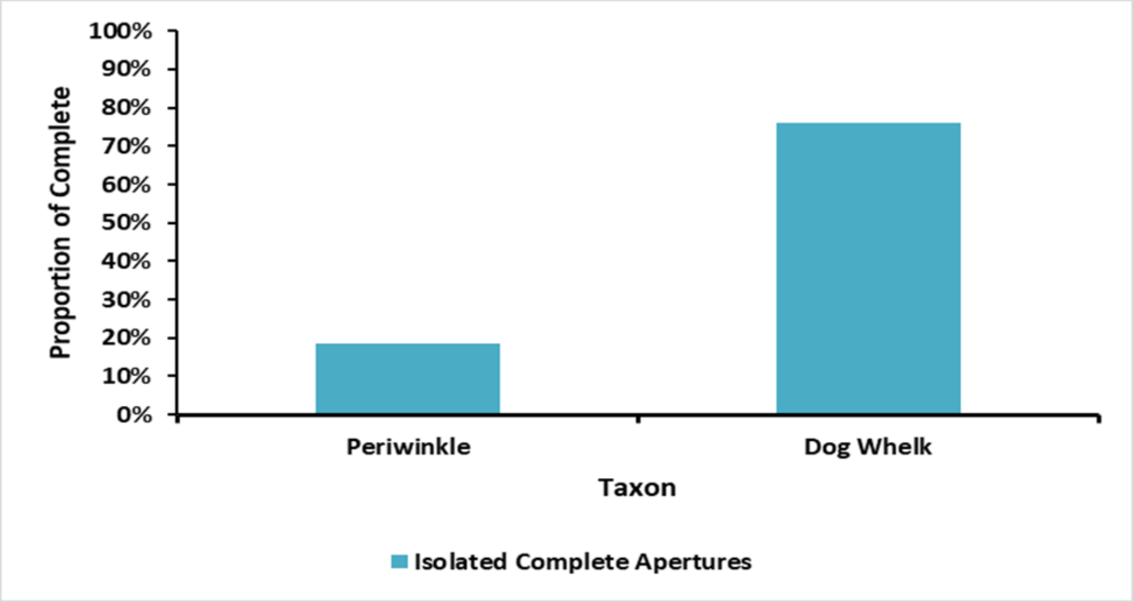


Figure SI-Chapter6-3.3: Whilst dog whelks overall are more fragmented than periwinkles their apertures survive intact more frequently in accordance with the differential robustness shown in figure SI-Chapter6-3.1.

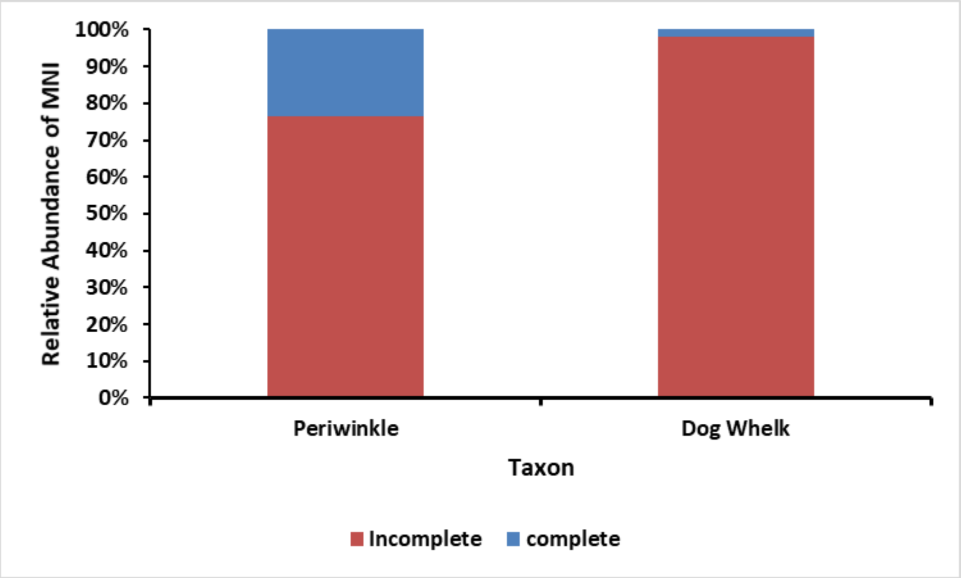


Figure SI-Chapter6-3.4: In terms of the total MNI dog whelks are rarely intact.

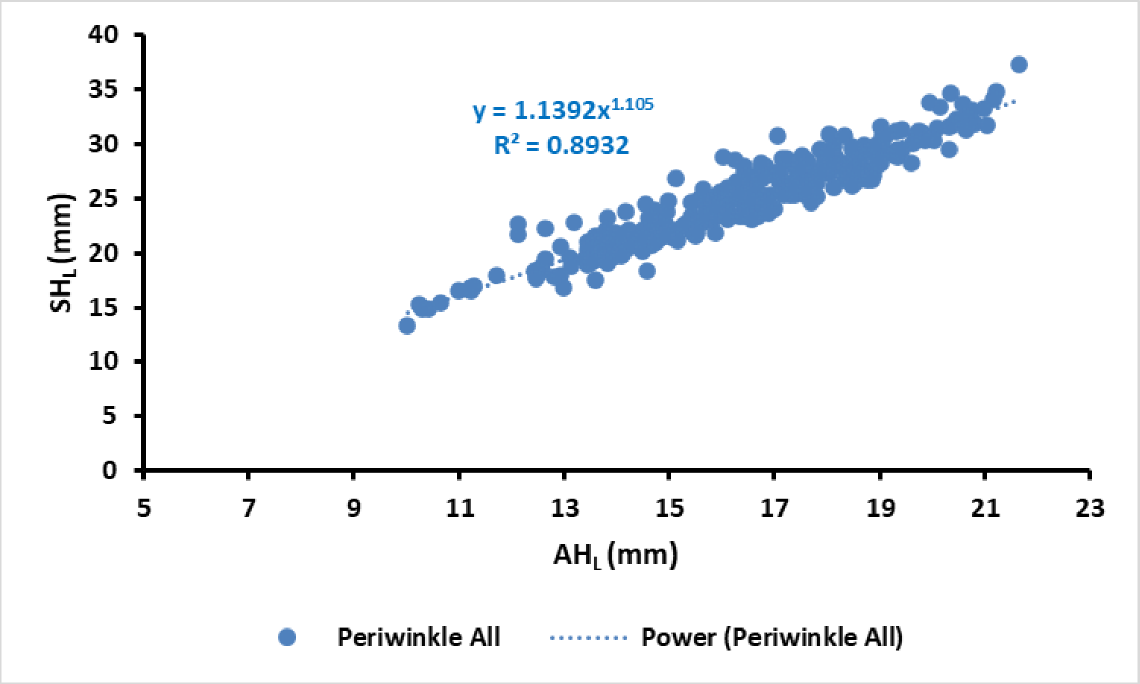


Figure SI-Chapter6-3.5: Length reconstruction model for periwinkle as presented in EQC6-2. Three specimens of *Littorina littorea* (*sensu* Hayward and Ryland, 2012) removed.

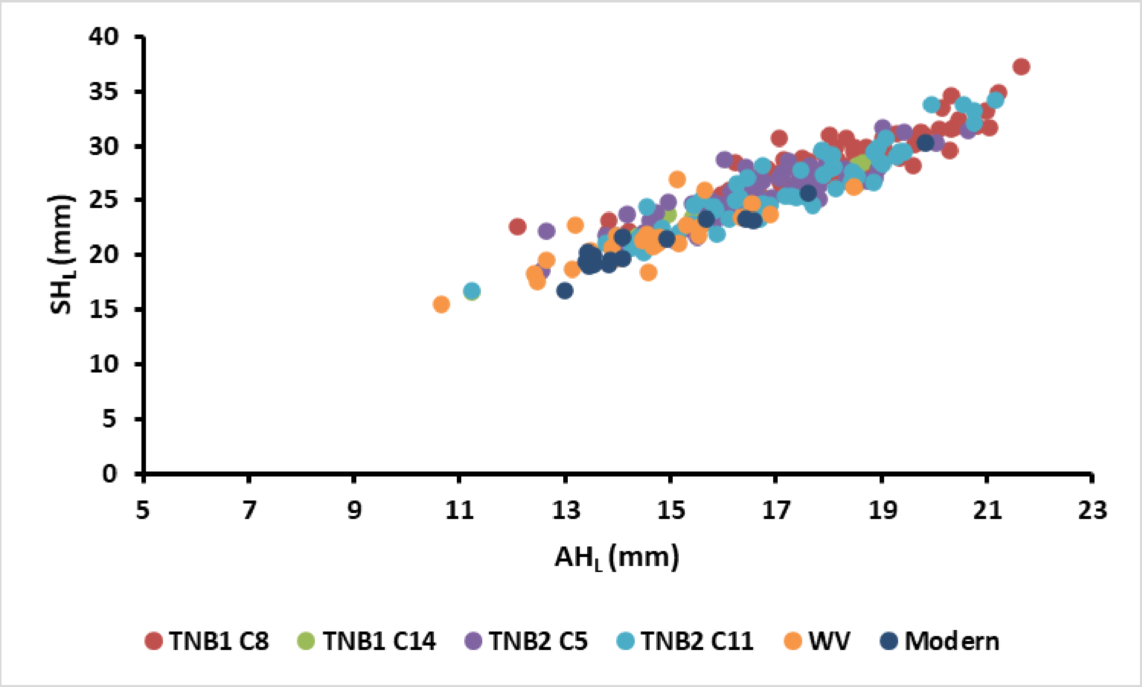


Figure SI-Chapter6-3.6: Individual components of the pooled model shown in figure SI-Chapter6-3.5.

Summary Statistics - Periwinkle

Table SI-Chapter6-3.1: Summary statistics for periwinkles.

TNB2 Context 5	**Height (mm)**	**Aperture Height (mm)**	**TNB1 Context 8**	**Height (mm)**	**Aperture Height (mm)**
Mean	25.01	16.46	**Mean**	26.91	16.84
StDev	3.78	2.28	**StDev**	6.36	3.63
Median	25.22	16.62	**Median**	28.39	17.44
Interquartile	3.58	2.03	**Interquartile**	4.86	2.81
Minimum	6.43	4.44	**Minimum**	7.46	5.35
Maximum	31.64	20.64	**Maximum**	37.26	21.65
Skew	-2.07	-2.16	**Skew**	-1.90	-1.78
Kurtosis	8.49	9.60	**Kurtosis**	3.51	3.16
N=	72	83	**N=**	81	96
TNB2 Context 11	**Height (mm)**	**Aperture Height (mm)**	**TNB1 Context 14**	**Height (mm)**	**Aperture Height (mm)**
Mean	25.43	17.00	**Mean**	20.61	13.94
StDev	5.12	2.69	**StDev**		
Median	25.33	17.29	**Median**		
Interquartile	5.16	2.52	**Interquartile**		
Minimum	8.74	6.60	**Minimum**	7.33	5.76
Maximum	31.12	21.38	**Maximum**	28.52	18.66
Skew	-1.26	-1.67	**Skew**		
Kurtosis	2.65	4.66	**Kurtosis**		
N=	68	104	**N=**	13	13
PMS Context 2	**Height (mm)**	**Aperture Height (mm)**	**TB Phase 3b**	**Height (mm)**	**Aperture Height (mm)**
Mean		16.47	**Mean**	19.02	12.51
StDev			**StDev**	3.13	2.03
Median			**Median**	19.74	12.92
Interquartile			**Interquartile**	3.51	3.10
Minimum		15.13	**Minimum**	10.52	7.60
Maximum		18.02	**Maximum**	25.44	16.66
Skew			**Skew**	-0.70	-0.49
Kurtosis			**Kurtosis**	0.84	-0.45
N=		4	**N=**	30	55
WV Site	**Height (mm)**	**Aperture Height (mm)**	**TB Phase 3a**	**Height (mm)**	**Aperture Height (mm)**
Mean	19.94	13.54	**Mean**	17.16	14.43
StDev	4.80	3.10	**StDev**		
Median	21.05	14.51	**Median**		
Interquartile	4.05	2.18	**Interquartile**		
Minimum	7.48	5.54	**Minimum**	14.84	11.11
Maximum	26.91	18.47	**Maximum**	20.95	17.00
Skew	-1.35	-1.52	**Skew**		
Kurtosis	1.79	2.18	**Kurtosis**		
N=	32	32	**N=**	8	9

Summary Statistics – Dog Whelk

Table SI-Chapter6-3.2: Summary Statistics Dog Whelk

Context 5	**Height (mm)**	**Aperture Height (mm)**	**Context 8**	**Height (mm)**	**Aperture Height (mm)**
Mean	30.04	18.33	**Mean**	25.14	16.89
StDev		1.48	**StDev**	6.19	2.21
Median		18.21	**Median**	26.30	16.59
Interquartile		2.11	**Interquartile**	8.49	2.76
Minimum	28.49	15.05	**Minimum**	14.22	11.36
Maximum	31.20	20.69	**Maximum**	35.53	22.57
Skew		-0.11	**Skew**	-0.37	0.07
Kurtosis		-0.15	**Kurtosis**	-0.81	0.14
N=	3	20	**N=**	23	100
Context 11	**Height (mm)**	**Aperture Height (mm)**	**Context 14**	**Height (mm)**	**Aperture Height (mm)**
Mean	24.60	17.09	**Mean**	25.24	17.15
StDev	4.22	2.09	**StDev**	3.85	2.09
Median	25.52	16.95	**Median**	25.70	17.61
Interquartile	3.88	2.54	**Interquartile**	5.76	2.25
Minimum	16.26	12.84	**Minimum**	18.12	13.34
Maximum	34.42	20.04	**Maximum**	30.87	19.84
Skew	0.83	0.16	**Skew**	-0.36	-0.56
Kurtosis	2.36	0.36	**Kurtosis**	-0.51	-0.33
N=	10	28	**N=**	11	11

Statistical Testing Output: Periwinkles

Table SI-Chapter6-3.3: Statistical test outputs for periwinkles.

z-Test: Two Sample for Means		
AH_L		
	TNB1 C8	TNB2 C5
Mean	17.68091	16.69813
Known Variance	4.660192	2.755314
Observations	88	80
Hypothesized Mean Difference	0	
z	3.324352	
P(Z<=z) one-tail	0.000443	
z Critical one-tail	1.644854	
P(Z<=z) two-tail	0.000886	
z Critical two-tail	1.959964	
Reject H_0 @ 0.001		

z-Test: Two Sample for Means		
AH_L		
	TNB2 C11	TNB2 C5
Mean	17.386	16.69813
Known Variance	3.6484	2.755314
Observations	100	80
Hypothesized Mean Difference	0	
z	2.582906	
P(Z<=z) one-tail	0.004899	
z Critical one-tail	1.644854	
P(Z<=z) two-tail	0.009797	
z Critical two-tail	1.959964	
Reject H_0 @ 0.01		

z-Test: Two Sample for Means		
AH_L		
	TNB2 C11	TNB1 C8
Mean	17.386	17.68091
Known Variance	3.6484	4.660192
Observations	100	88
Hypothesized Mean Difference	0	
z	-0.9861	
P(Z<=z) one-tail	0.162042	
z Critical one-tail	1.644854	
P(Z<=z) two-tail	0.324085	
z Critical two-tail	1.959964	
Fail to Reject H_0		

t-Test: Two-Sample Assuming Unequal Variances		
AH_L		
	TNB1 C14	TNB2 C11
Mean	16.047	17.386
Variance	5.283712	3.6484
Observations	10	100
Hypothesized Mean Difference	0	
df	10	
t Stat	-1.78161	
P(T<=t) one-tail	0.052576	
t Critical one-tail	1.812461	
P(T<=t) two-tail	0.105152	
t Critical two-tail	2.228139	
Fail to Reject H_0		

t-Test: Two-Sample Assuming Unequal Variances		
AH_L		
	TNB1 C14	TNB2 C5
Mean	16.047	16.69813
Variance	5.283712	2.755314
Observations	10	80
Hypothesized Mean Difference	0	
df	10	
t Stat	-0.86793	
P(T<=t) one-tail	0.202891	
t Critical one-tail	1.812461	
P(T<=t) two-tail	0.405782	
t Critical two-tail	2.228139	
Fail to Reject H_0		

t-Test: Two-Sample Assuming Unequal Variances		
AH_L		
	TNB1 C8	TNB1 C14
Mean	17.68091	16.047
Variance	4.660192	5.283712
Observations	88	10
Hypothesized Mean Difference	0	
df	11	
t Stat	2.142976	
P(T<=t) one-tail	0.027659	
t Critical one-tail	1.795885	
P(T<=t) two-tail	0.055318	
t Critical two-tail	2.200985	
Fail to Reject H_0		

Statistical Testing Output: Dog Whelk

Table SI-Chapter6-3.4: Statistical testing output for dog whelk.

t-Test: Two-Sample Assuming Unequal Variances		
AH_N		
	TNB1 C8	TNB1 C14
Mean	16.8923	17.15
Variance	4.892	4.36412
Observations	100	11
Hypothesized Mean Difference	0	
df	13	
t Stat	-0.38602	
P(T<=t) one-tail	0.352861	
t Critical one-tail	1.770933	
P(T<=t) two-tail	0.705723	
t Critical two-tail	2.160369	
Fail to Reject H_0		

t-Test: Two-Sample Assuming Unequal Variances		
AH_N		
	TNB2 C5	TNB2 C11
Mean	18.3305	17.09
Variance	2.202163	4.361259
Observations	20	28
Hypothesized Mean Difference	0	
df	46	
t Stat	2.405826	
P(T<=t) one-tail	0.010106	
t Critical one-tail	1.67866	
P(T<=t) two-tail	0.020213	
t Critical two-tail	2.012896	
Reject H_0 @ 0.05		

t-Test: Two-Sample Assuming Unequal Variances		
AH_N		
	TNB1 C8	TNB2 C5
Mean	16.8923	18.3305
Variance	4.892	2.202163
Observations	100	20
Hypothesized Mean Difference	0	
df	38	
t Stat	-3.60647	
P(T<=t) one-tail	0.000445	
t Critical one-tail	1.685954	
P(T<=t) two-tail	0.00089	
t Critical two-tail	2.024394	
Reject H_0 @ 0.001		

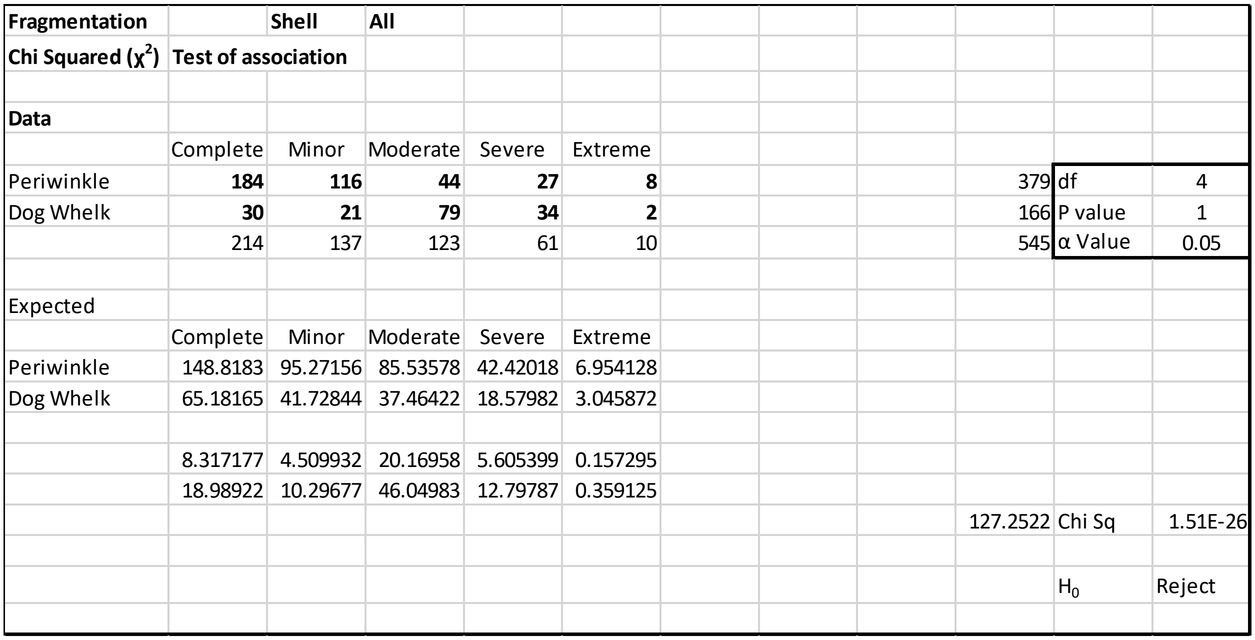
t-Test: Two-Sample Assuming Unequal Variances		
AH_N		
	TNB2 C5	TNB1 C14
Mean	18.3305	17.15
Variance	2.202163	4.36412
Observations	20	11
Hypothesized Mean Difference	0	
df	16	
t Stat	1.658165	
P(T<=t) one-tail	0.058378	
t Critical one-tail	1.745884	
P(T<=t) two-tail	0.116757	
t Critical two-tail	2.119905	
Fail to Reject H_0		

t-Test: Two-Sample Assuming Unequal Variances		
AH_N		
	TNB1 C8	TNB2 C11
Mean	16.8923	17.09
Variance	4.892	4.361259
Observations	100	28
Hypothesized Mean Difference	0	
df	45	
t Stat	-0.43699	
P(T<=t) one-tail	0.332105	
t Critical one-tail	1.679427	
P(T<=t) two-tail	0.66421	
t Critical two-tail	2.014103	
Fail to Reject H_0		

t-Test: Two-Sample Assuming Unequal Variances		
AH_N		
	TNB2 C11	TNB1 C14
Mean	17.09	17.15
Variance	4.361259	4.36412
Observations	28	11
Hypothesized Mean Difference	0	
df	18	
t Stat	-0.08072	
P(T<=t) one-tail	0.468277	
t Critical one-tail	1.734064	
P(T<=t) two-tail	0.936555	
t Critical two-tail	2.100922	
Fail to Reject H_0		

Differential Fragmentation between Marine Snails

Table SI-Chapter6-3.5: Chi2 assessment of dog whelk fragmentation. The criterion for ≥ the expected values being greater than 5 was met so Fisher's exact test was not required.



Fragmentation		**Shell**	**All**								
Chi Squared (χ^2)	**Test of association**										
Data											
	Complete	Minor	Moderate	Severe	Extreme						
Periwinkle	**184**	**116**	**44**	**27**	**8**				379	df	4
Dog Whelk	**30**	**21**	**79**	**34**	**2**				166	P value	1
	214	137	123	61	10				545	α Value	0.05
Expected											
	Complete	Minor	Moderate	Severe	Extreme						
Periwinkle	148.8183	95.27156	85.53578	42.42018	6.954128						
Dog Whelk	65.18165	41.72844	37.46422	18.57982	3.045872						
	8.317177	4.509932	20.16958	5.605399	0.157295						
	18.98922	10.29677	46.04983	12.79787	0.359125						
									127.2522	Chi Sq	1.51E-26
										H_0	Reject

SI-Chapter6-4: Cockles.

Introduction

Cockles are not abundant in the assemblages of the Western Scotland or the lower midden at West Voe in Shetland. The method for size reconstruction was developed so that sizes at death could be established from fragmented specimens. Complete specimens were also sectioned to obtain a corroborating view on season of occupation compared to other species of molluscs and other taxonomic classes. The shape of cockles in the assemblages does not conform particularly well with the figures provided in the references such as Hayward and Ryland (2012). In particular the cockles exhibit the obliquely truncated margin that is a characteristic of the lagoon cockle (*Cerastoderma glaucum*) but the ribs are not present on the inner surface of the valve beyond the pallial line, which rules out this species along with others. The other genus that has the ribs spatially constrained by the pallial line and has an obliquely truncated margin is *Parvicardium* but rib counts and size rule this out. Due to the variability in truncation of one margin the size of cockles is stated as valve height rather than valve length. Biometrics were taken with Vernier callipers and recorded at two decimal places. Valve width was utilised to reconstruct valve height as it exhibited a good level of correlation across shells from different locations and time periods (figures SI-Chapter6-4.1 and 2). A pooled assemblage was utilised to create the model utilised as this permitted smaller size classes to be included, as complete small cockles were rare in the archaeological assemblages.

Cockles were sectioned following the same protocol described for limpets and otoliths. The seasonality modelling used the same principle in terms of relative growth increment but the modelling parameters for growth distribution during the calendar year and the start and end of the growing seasons were different. Summary statistics are provided in table SI-Chapter6-4.1. The number of samples that could be assessed for seasonality was very very low as cockle growth rapidly assumes asymptotic behaviour

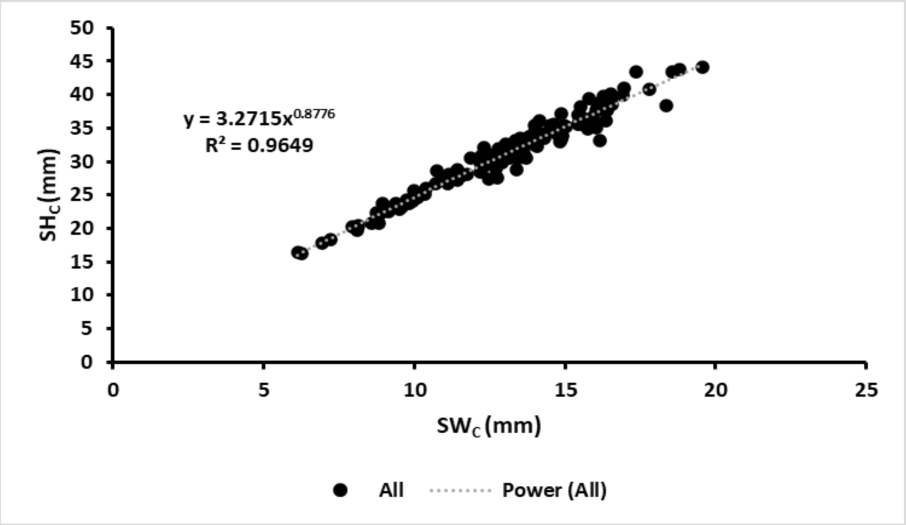


Figure SI-Chapter6-4.1: The regression model for reconstructing the shell height of the common cockle.

and therefore even minor edge damage inhibited the calculation. The relative growth rates during the first two years of life is presented in chapters 7 and 8.

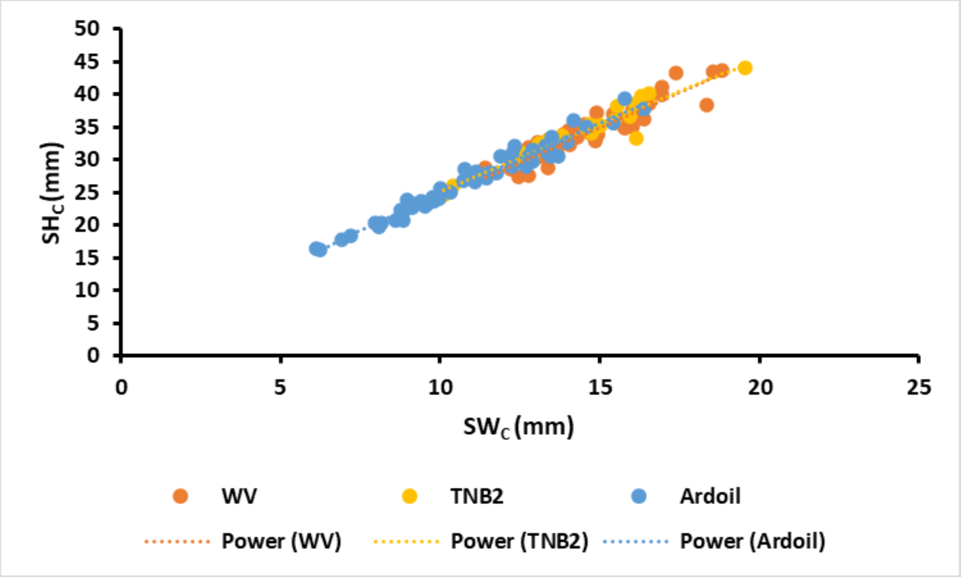


Figure SI-Chapter6-4.2: The regressions generated for common cockle from the upper midden of West Voe, context 11 of TNB2 and specimens collected from Ardoil on the west coast of the Isle of Lewis.

Table SI-Chapter6-4.1: Summary Statistics for Archaeological Cockles

TNB2 Context 11	**Height (mm)**	**Width (mm)**	**TNB1 Context 8**	**Height (mm)**	**Width (mm)**
Mean	33.90	14.26	**Mean**	34.15	10.45
StDev	4.49	2.16	**StDev**		3.96
Median	34.13	14.62	**Median**		
Interquartile	4.96	2.75	**Interquartile**		
Minimum	24.61	10.11	**Minimum**	32.81	4.47
Maximum	44.16	19.56	**Maximum**	35.42	13.98
Skew	0.14	0.29	**Skew**		
Kurtosis	0.29	0.64	**Kurtosis**		
Specimens	25	24	**Specimens**	2	5

NT Phase 3	**Height (mm)**	**Width (mm)**	**WV Upper**	**Height (mm)**	**Width (mm)**
Mean	37.20	11.84	**Mean**	34.04	14.27
StDev		4.25	**StDev**	3.91	1.68
Median			**Median**	33.43	14.00
Interquartile			**Interquartile**	5.07	2.43
Minimum	35.72	5.53	**Minimum**	27.40	10.99
Maximum	38.67	16.12	**Maximum**	43.70	18.81
Skew			**Skew**	0.66	0.66
Kurtosis			**Kurtosis**	0.14	0.16
Specimens	2	6	**Specimens**	57	75

SI-Chapter6-5: Crabs.

Methods

Crab fragments were quantified from all contexts and the fragments inspected to understand which elements preserve and whether a metric that might be related to the size of the crab in terms of its carapace width was available. A set of designated reference metrics were designed, and these were collected from crabs in the Natural History Museums reference collection in London. To these were added measurements from two specimens in the departments reference collection. Identification was carried out as described in the main text. The NHM's reference specimens are kept in cold storage in large jars[14] containing as many specimens as can be fitted in, which can be one large specimen to more than 100. Therefore, the reference specimens utilised do not have unique specimen numbers and neither is the sex known. Metrics were gathered for the shore crab and the edible crab, with hindsight more time should have been scheduled to permit the collection of metrics from the velvet swimming crab.

Fragmentation for the edible crab was assessed using the number of teeth present on either the dactylus or the propodus (figures SI-Chapter6-5.1 and 5.2).

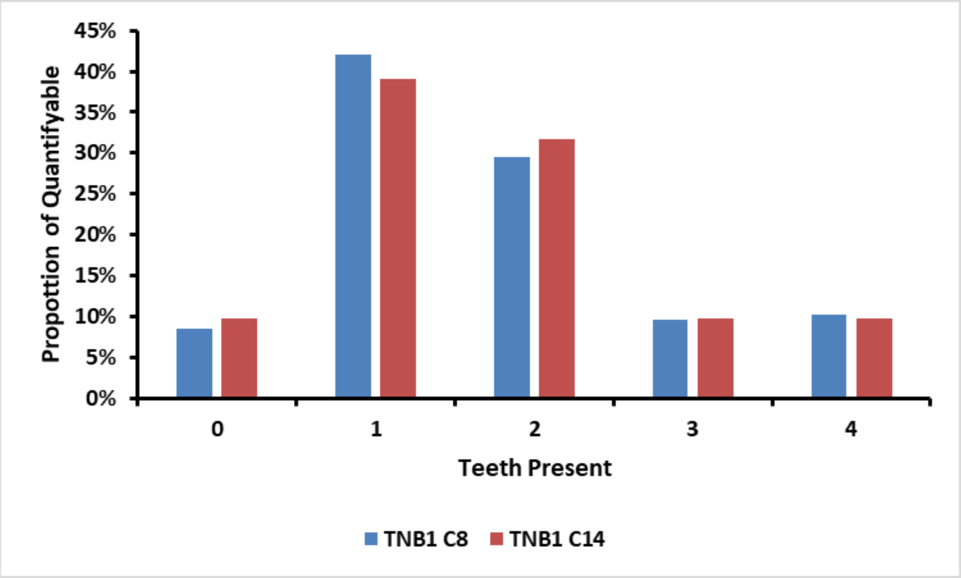


Figure SI-Chapter6-5.1: Fragmentation levels of edible crab claws from TNB1.

The measurements taken from the reference specimens were utilised to construct models that would estimate the carapace width of the crab. The relationships are stronger for edible crab than for shore crab. The archaeological specimens were measured using Vernier callipers and recorded to two decimal places. The mean value of the values obtained from the left and right hand claw was utilised

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[14] Getting the jars open can take considerable time and effort due to cold storage and infrequent access and this needs to be factored in by anyone considering a similar exercise.

and it is probably this that has made the models weaker for shore crab. Two extremely large specimens of edible crab were pathological with a congenital condition which results in, firstly, over sized claws and secondly the growth of an extra claw from the propodus, although the dactylus of the extra claw does not articulate but is fixed. These 'growths' are variable in where they appear and in one specimen actually prevented the normal claw from closing. These specimens were excluded from model creation so that the distribution of residuals remained acceptable. The models for both species are provided in figures Si-Chapter6-5.3 to 5.8.

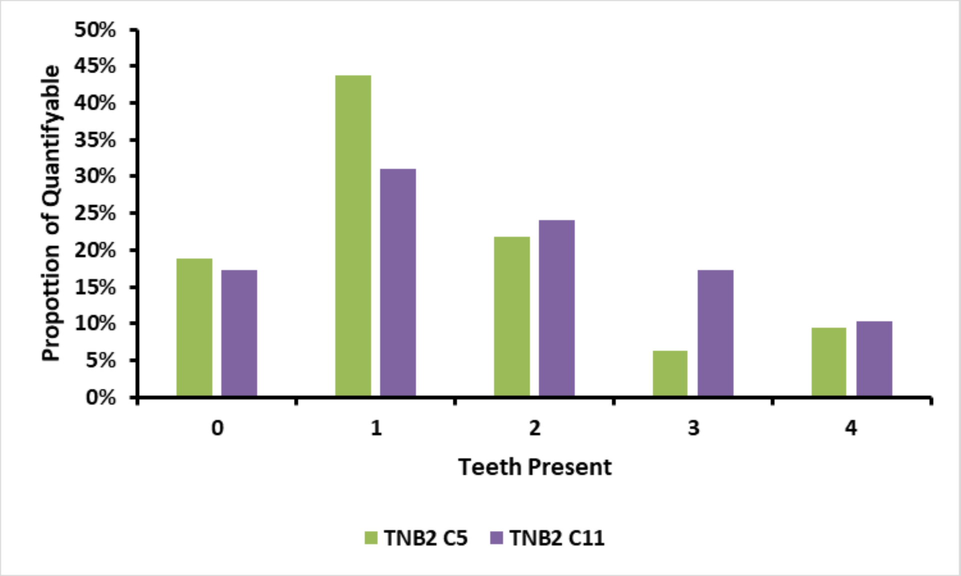


Figure SI-Chapter-5.2: Fragmentation levels of edible crab claws at TNB2.

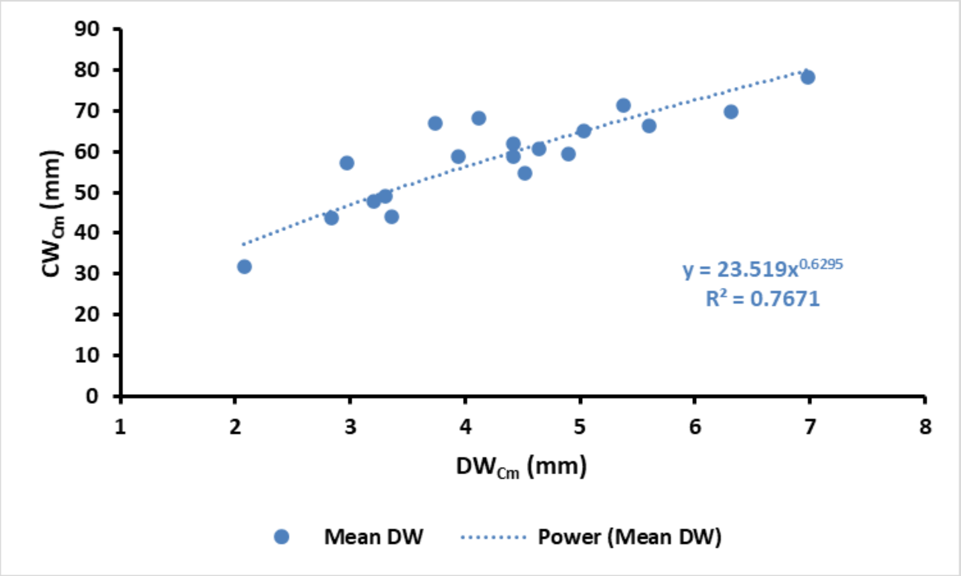
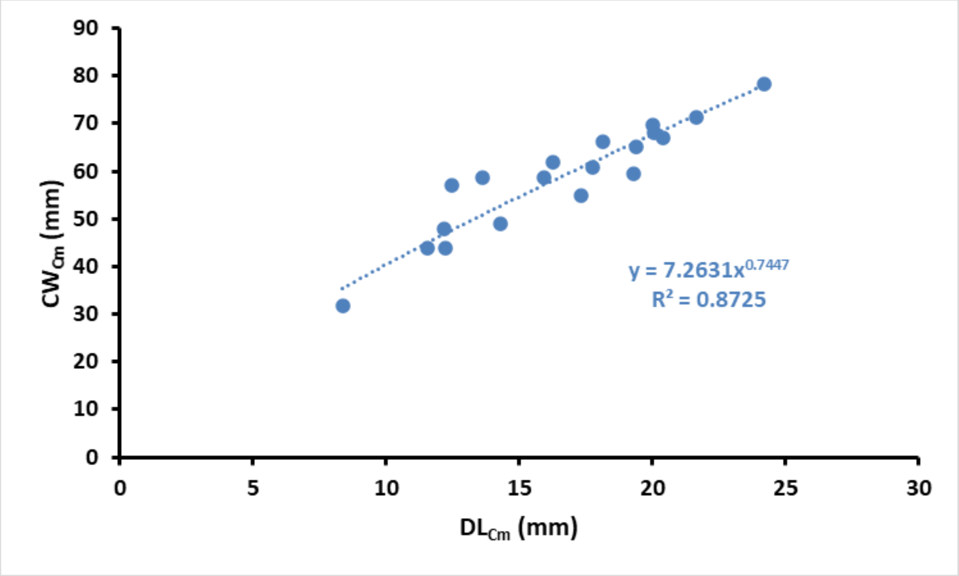
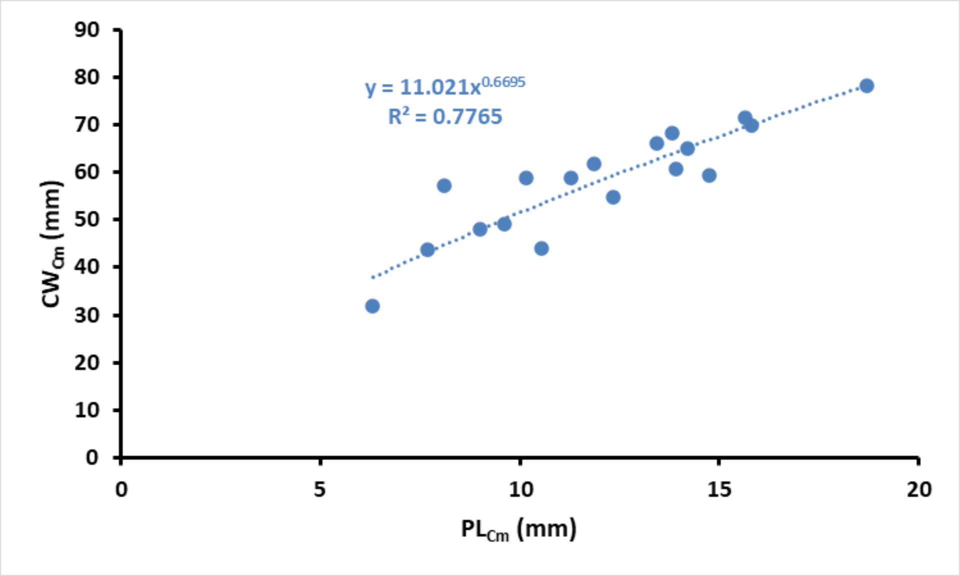


Figure SI-Chapter6-5.6: The model linking carapace width and dactylus width for shore crab.



SI-Chapter6-5.4: The model linking dactylus length with carapace width for shore crab.



SI-Chapter6-5.5: The model linking propodus length and carapace width for shore crab.

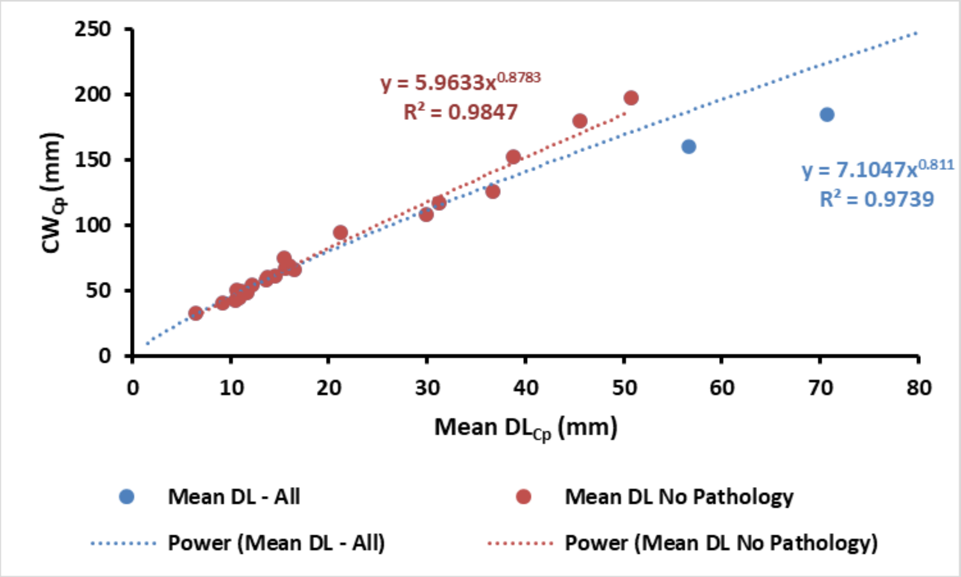
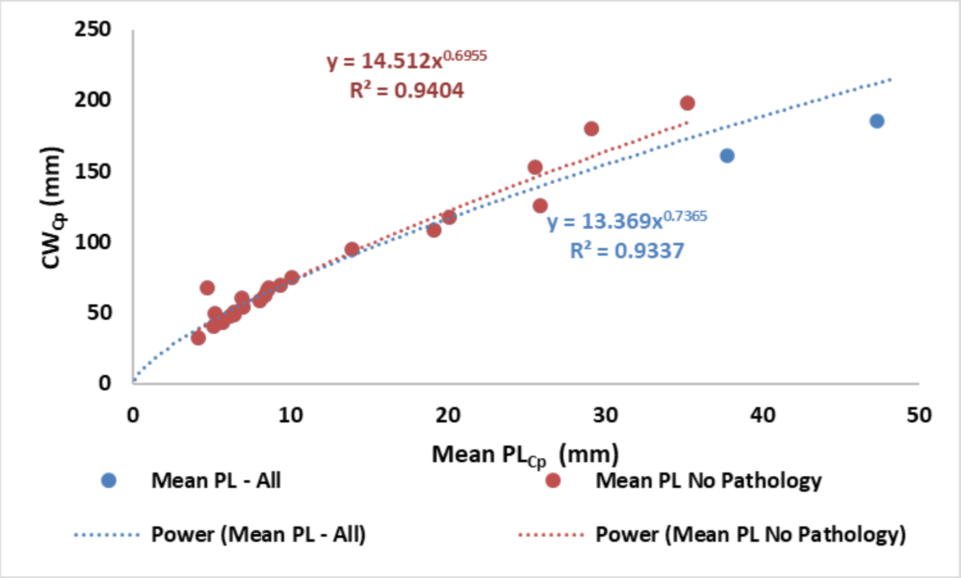


Figure SI-Chapter7-5.6: The model linking dactylus length with carapace width for edible crab.



FigureSI-Chapter6-5.7: The model linking propodus length and carapace width for edible crab.

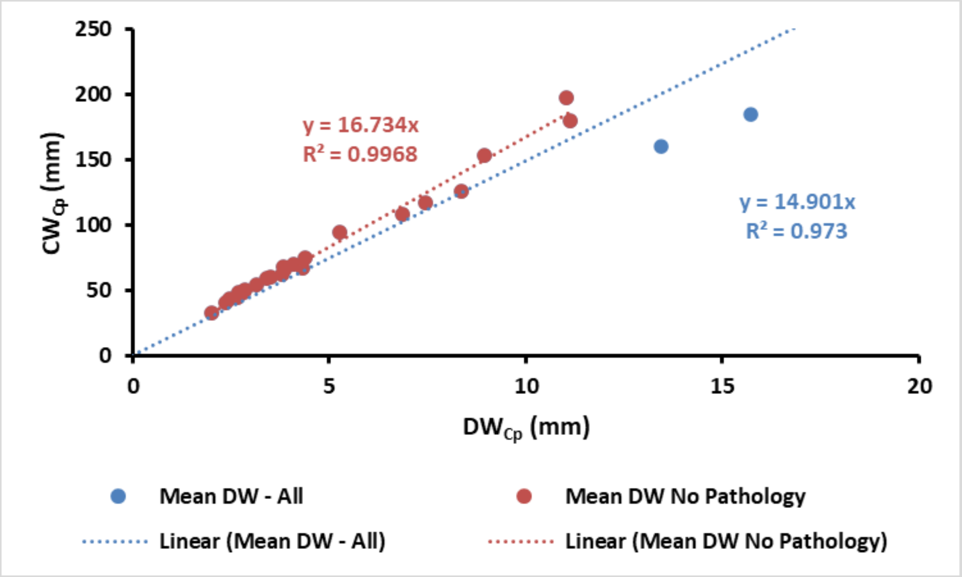


Figure SI-Chapter6-8: The model linking carapace width and dactylus width for edible crab.

Dactylus proximal height also works in principle and was collected but a systematic correction is required due to the difference in the height of the aperture the dactylus protrudes from and the height that is measurable on a complete reference specimen. This is because the claw needs to move. The correction has not yet been developed.

SI-Chapter6-6-Fish Otoliths

General

Otoliths were retrieved from the 1R, 2R and 4R fractions of contexts 8 and 14 of TNB1 and contexts 5 and 11 of TNB2 plus context 2 of PMS. The fragmentation level was determined based upon the proportion of the otolith present which is a qualitative assessment based upon physical features and the curvature of the dorsal and ventral margins as also carried out by Jones (1991). The length and width were measured for complete specimens. Specimens were also categorised as being anterior, posterior or medial providing both the dorsal and ventral margin were present. If one or more of these margins were absent, then the specimen was recorded as a fragment (figures SI-Chapter-6.1 to 6.3). The length and width were measured for complete specimens and the width for those specimens that were greater than 50% complete as this ensured the greatest width was present. All measurements were taken with Vernier callipers and recorded to two decimal places as the otoliths are quite variable in their curvature along the length axis which makes accurate measurement with a microscope time consuming.

Identification was conducted using Harkonen (1986) and the departments reference collection (larger specimens only). Speciation within the *Pollachius* genus was attempted but all data is presented at genus level. The identification to species level was conducted simply to ensure as much morphological consistency as possible when selecting specimens for stable isotope analysis. Two aspects became clear during the analysis. Otoliths exhibit morphological development as they get larger and Harkonen (1986) provides images of the interior and exterior surfaces at three different sizes. These must be considered as type specimens as the author encountered otoliths of 6.5 mm in length with the morphology of the 12.8mm type specimen.

There were very few otoliths complete in length and reaching meaningful conclusions would be challenging. Jones (1991) provides direct regression models between fish length, fish weight and otolith width, but the large fish Jones was dealing with meant that the demonstrated interval of applicability barely overlapped the size range (largest outliers) present in the Mesolithic assemblages. A new model was created by pooling the archaeological samples with the measurements from Sand Rock Shelter (Parks and Barratt, 2009), after they had been evaluated individually (figure SI-Chapter6-6.4). The very largest otoliths from Sand exhibited strong asymptotic behaviour and were outliers even when a non-linear model was applied. The resulting model utilised by this project has an interval of applicability that does not extend to the full size range of the otoliths at Sand Rock Shelter (figure SI-Chapter6-6.5). Summary statistics for the Western Isles are provided in table SI-Chapter6-6.1 and statistical outcomes in table SI-Chapter6-6.2.

The growth of 1st year saithe is variable. There are two critical size levels where the risk of ambiguity and incorrect seasonality interpretations is significant. The two sizes are $OL \approx 6.0$mm and $OL \approx 8.0$mm.

Otolith Fragmentation

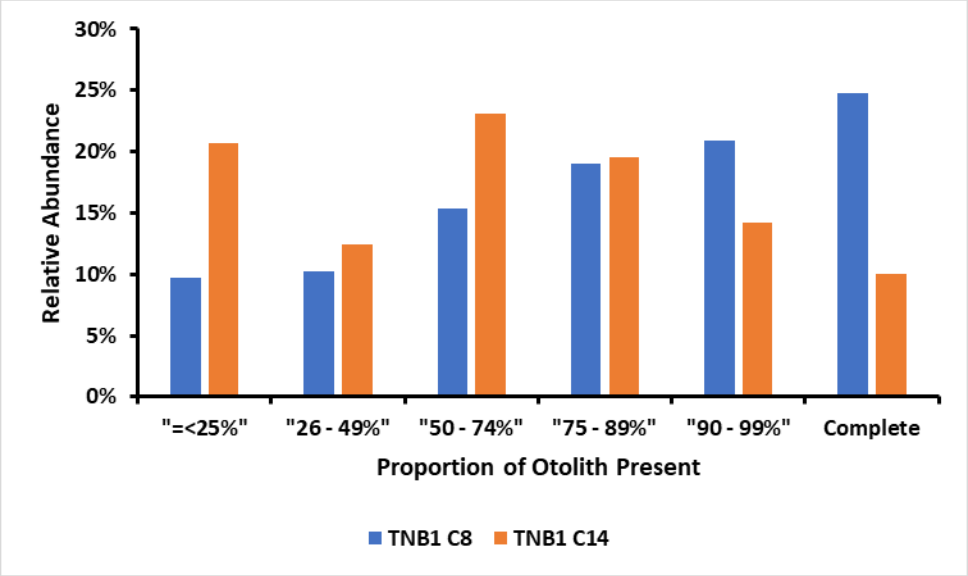


Figure SI-Chapter6-6.1: Otolith fragmentation at TNB1.

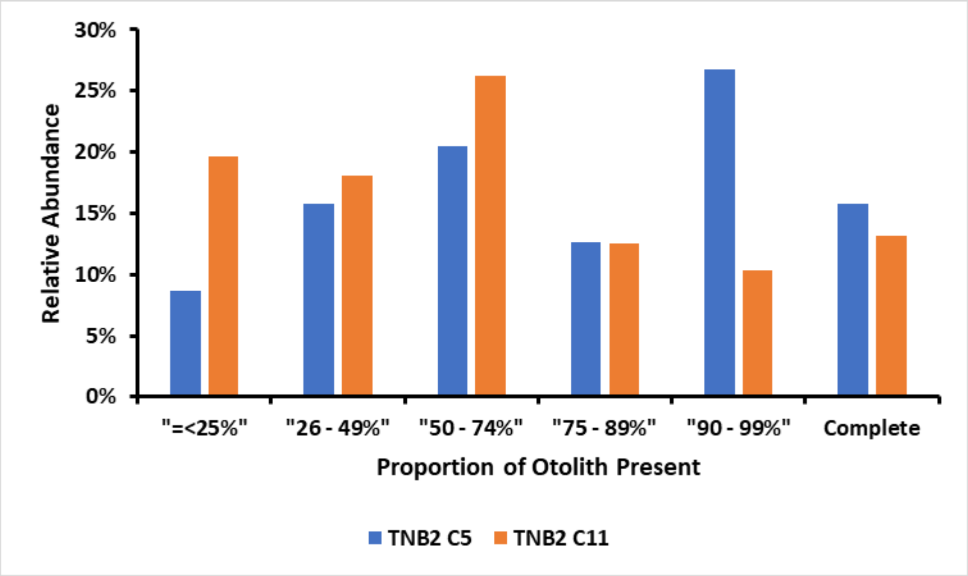


Figure SI-Chapter6-6.2: Otolith fragmentation at TNB2.

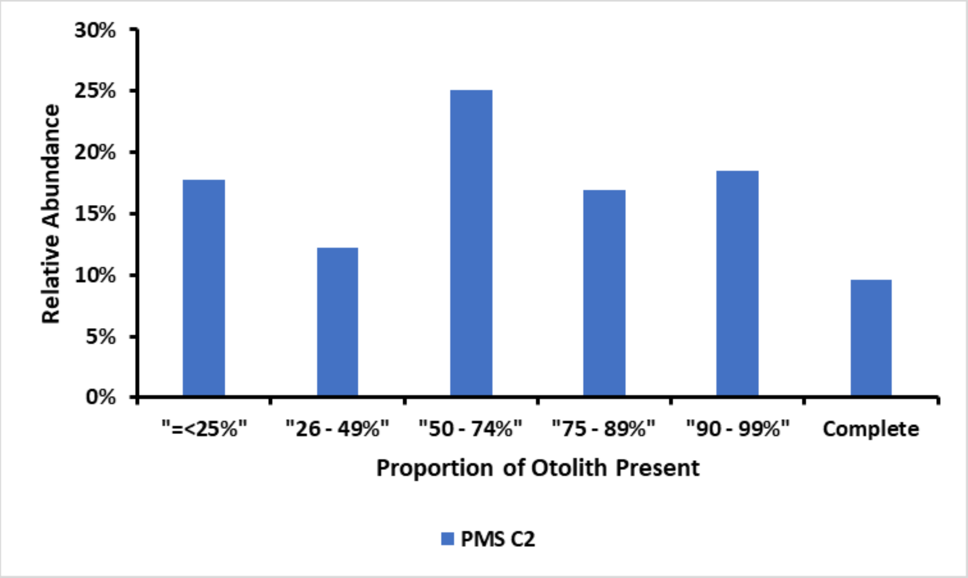


Figure SI-Chapter6-6.3: Otolith fragmentation levels at PMS.

Biometrics

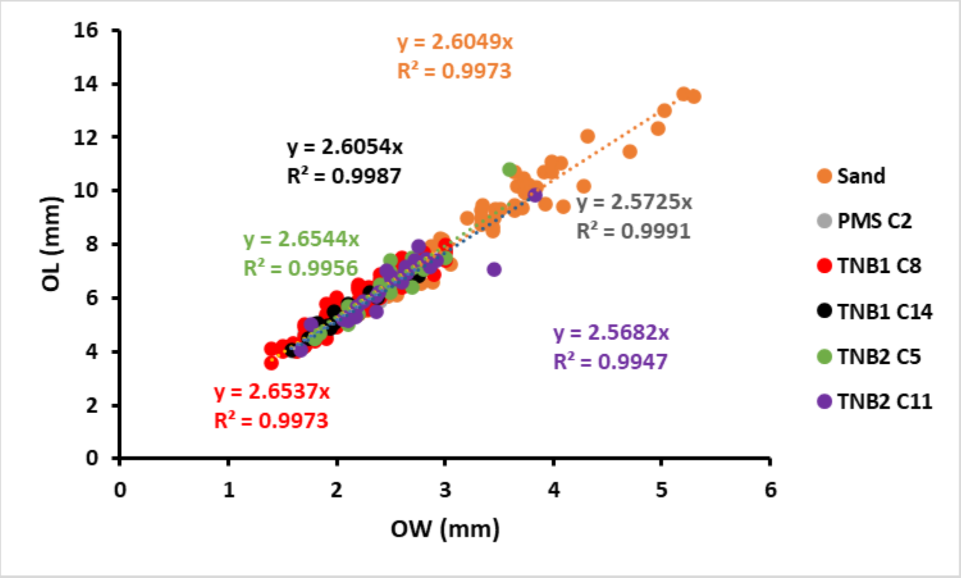


Figure SI-Chapter6-6.4: The relationship between otolith length and otolith width for otoliths assigned to *Pollachius spp.* Otoliths beyond the interval of applicability are excluded.

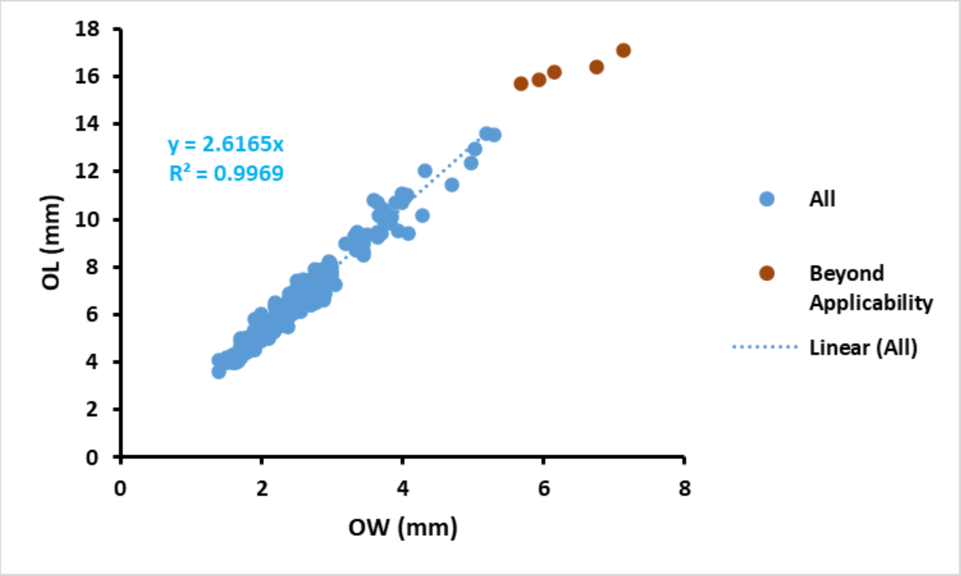
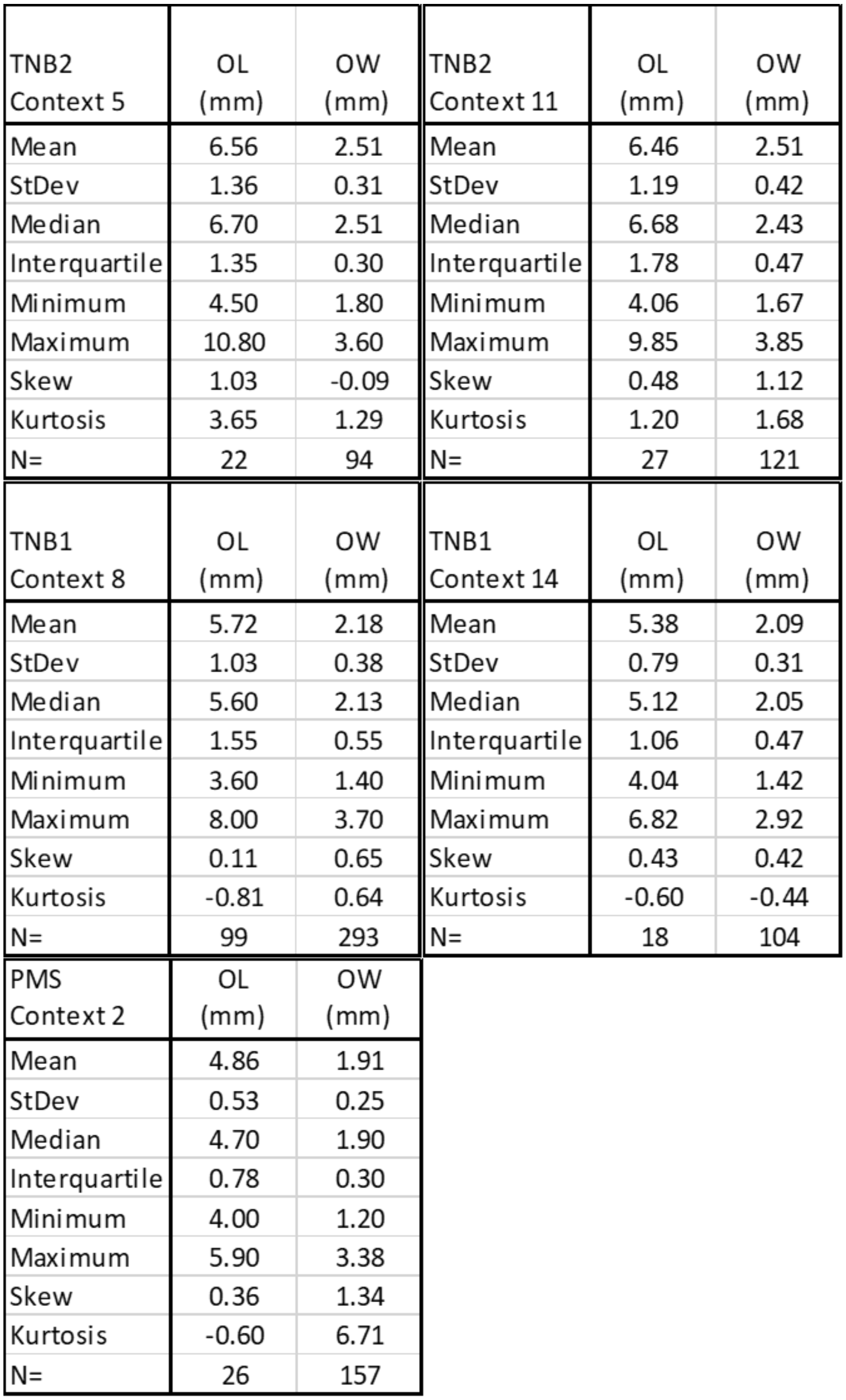


Figure SI-Chapter6-6.5: Pooled model for reconstructing otolith length from otolith width. The otoliths beyond applicability were excluded from the model generation to manage the distribution of residuals.

Summary Statistics and Statistical Outputs

Table SI-Chapter6-6.1: Summary Statistics for Otoliths.



TNB2 Context 5	OL (mm)	OW (mm)
Mean	6.56	2.51
StDev	1.36	0.31
Median	6.70	2.51
Interquartile	1.35	0.30
Minimum	4.50	1.80
Maximum	10.80	3.60
Skew	1.03	-0.09
Kurtosis	3.65	1.29
N=	22	94

TNB2 Context 11	OL (mm)	OW (mm)
Mean	6.46	2.51
StDev	1.19	0.42
Median	6.68	2.43
Interquartile	1.78	0.47
Minimum	4.06	1.67
Maximum	9.85	3.85
Skew	0.48	1.12
Kurtosis	1.20	1.68
N=	27	121

TNB1 Context 8	OL (mm)	OW (mm)
Mean	5.72	2.18
StDev	1.03	0.38
Median	5.60	2.13
Interquartile	1.55	0.55
Minimum	3.60	1.40
Maximum	8.00	3.70
Skew	0.11	0.65
Kurtosis	-0.81	0.64
N=	99	293

TNB1 Context 14	OL (mm)	OW (mm)
Mean	5.38	2.09
StDev	0.79	0.31
Median	5.12	2.05
Interquartile	1.06	0.47
Minimum	4.04	1.42
Maximum	6.82	2.92
Skew	0.43	0.42
Kurtosis	-0.60	-0.44
N=	18	104

PMS Context 2	OL (mm)	OW (mm)
Mean	4.86	1.91
StDev	0.53	0.25
Median	4.70	1.90
Interquartile	0.78	0.30
Minimum	4.00	1.20
Maximum	5.90	3.38
Skew	0.36	1.34
Kurtosis	-0.60	6.71
N=	26	157

Table SI-Chapter6-6.2: Statistic testing output for otoliths.

z-Test: Two Sample for Means		
OW		
	PMS	C8
Mean	1.912803	2.175392
Known Variance	0.065011	0.144535
Observations	157	293
Hypothesized Mean Difference	0	
z	-8.71735	
P(Z<=z) one-tail	0	
z Critical one-tail	1.644854	
P(Z<=z) two-tail	0	
z Critical two-tail	1.959964	
Reject H_0 @ 0.0001		

z-Test: Two Sample for Means		
OW		
	PMS	C14
Mean	1.912803	2.094615
Known Variance	0.065011	0.095938
Observations	157	104
Hypothesized Mean Difference	0	
z	-4.97313	
P(Z<=z) one-tail	3.29E-07	
z Critical one-tail	1.644854	
P(Z<=z) two-tail	6.59E-07	
z Critical two-tail	1.959964	
Reject H_0 @ 0.0001		

z-Test: Two Sample for Means		
OW		
	C8	C14
Mean	2.175392	2.094615
Known Variance	0.144535	0.095938
Observations	293	104
Hypothesized Mean Difference	0	
z	2.146799	
P(Z<=z) one-tail	0.015905	
z Critical one-tail	1.644854	
P(Z<=z) two-tail	0.031809	
z Critical two-tail	1.959964	
Reject H_0 @ 0.05		

z-Test: Two Sample for Means		
OW		
	C8	C5
Mean	2.175392	2.511809
Known Variance	0.144535	0.096084
Observations	293	94
Hypothesized Mean Difference	0	
z	-8.64179	
P(Z<=z) one-tail	0	
z Critical one-tail	1.644854	
P(Z<=z) two-tail	0	
z Critical two-tail	1.959964	
Reject H_0 @ 0.0001		

z-Test: Two Sample for Means		
OW		
	C8	C11
Mean	2.175392	2.511809
Known Variance	0.144535	0.176678
Observations	293	94
Hypothesized Mean Difference	0	
z	-6.90624	
P(Z<=z) one-tail	2.49E-12	
z Critical one-tail	1.644854	
P(Z<=z) two-tail	4.98E-12	
z Critical two-tail	1.959964	
Reject H_0 @ 0.0001		

z-Test: Two Sample for Means		
OW		
	C5	C14
Mean	2.094615	2.511809
Known Variance	0.095938	0.096084
Observations	104	94
Hypothesized Mean Difference	0	
z	-9.46055	
P(Z<=z) one-tail	0	
z Critical one-tail	1.644854	
P(Z<=z) two-tail	0	
z Critical two-tail	1.959964	
Reject H_0 @ 0.0001		

z-Test: Two Sample for Means		
OW		
	C11	C14
Mean	2.094615	2.512787
Known Variance	0.095938	0.176678
Observations	104	122
Hypothesized Mean Difference	0	
z	-8.58855	
P(Z<=z) one-tail	0	
z Critical one-tail	1.644854	
P(Z<=z) two-tail	0	
z Critical two-tail	1.959964	
Reject H_0 @ 0.0001		

z-Test: Two Sample for Means		
OW		
	C5	C11
Mean	2.511809	2.512787
Known Variance	0.096084	0.176678
Observations	94	122
Hypothesized Mean Difference	0	
z	-0.01968	
P(Z<=z) one-tail	0.492148	
z Critical one-tail	1.644854	
P(Z<=z) two-tail	0.984295	
z Critical two-tail	1.959964	
Fail to Reject H_0		

z-Test: Two Sample for Means		
OW		
	PMS	C5
Mean	1.912803	2.511809
Known Variance	0.065011	0.096084
Observations	157	94
Hypothesized Mean Difference	0	
z	-15.8058	
P(Z<=z) one-tail	0	
z Critical one-tail	1.644854	
P(Z<=z) two-tail	0	
z Critical two-tail	1.959964	
Reject H_0 @ 0.0001		

z-Test: Two Sample for Means		
OW		
	PMS	C11
Mean	1.912803	2.512787
Known Variance	0.065011	0.176678
Observations	157	122
Hypothesized Mean Difference	0	
z	-13.9033	
P(Z<=z) one-tail	0	
z Critical one-tail	1.644854	
P(Z<=z) two-tail	0	
z Critical two-tail	1.959964	
Reject H_0 @ 0.0001		

SI-Chapter6-7- Growth and Age of Molluscs

Methods

Limpets were randomly selected for sectioning. Two approaches were evaluated as larger specimens require a large amount of resin to totally encapsulate them. The resin was created by mixing the resin EPO-SET Resin combined with EPO-FLOW Hardener as the curing agent to the manufacturer’s instructions the treated specimens were left to cure for 72 hours under extraction in a fume cupboard. The resin and curing agent are expensive so two approaches were evaluated.

A) The first approach as suggested by the thin section team in the Earth Sciences department was to ‘paint’ the limpets to provide a layer of support during sectioning. This approach met with mixed results and was dropped. The specimens that produced usable sections were retained for analysis. Note: the painting approach worked well when evaluated on modern specimens.
B) The limpets were totally encapsulated in the conventional manner using silicon moulds that remove the need for a releasing agent.

The encapsulated or ‘painted’ limpets were sectioned by the author using the sectioning saw in the thin section laboratory. One half of the sectioned mollusc was polished by the author successively using 600 and then 1200 grit grinding paper on a water lubricated lapping wheel. The polished sections were then photographed using a Leica camera mounted on a Leica microscope using the Leica photographic suite in the archaeological science laboratory within the Department of Archaeology. Measurements were taken electronically using the Image-J software based upon a physically measured feature of each specimen for image calibration.

The age of limpets was determined by counting the growth lines within the apex. Older and larger limpets often produce secondary growth lines during spawning. The annual lines tend to be more distinct but reading the lines is difficult and an age range was derived. It was also noticeable that some growth abatement lines were very diffuse, presumably due to mild winters, both within the apex but also within the shell itself. Living limpets often lack the outer most layers at the apex which is likely to be due to abrasion based upon the work on thick top shell by Cabral (2020). This means the 1st and sometimes second growth is often absent and not included in the age count. The loss of these thin layers does not materially affect biometrics but does introduce additional uncertainty into age determination.

Season of death was estimated by comparing the size of the final growth increment compared to the preceding increment. The period of growth in neuter (not yet having assumed male or female sex) limpets generally occurs between March and November. Sexually mature specimens are initially nearly all male prior to a proportion becoming female, (as limpets exhibit sequential hermaphroditism, Orton, 1928a; Dodds, 1956). The asserted lengths at which limpets become sexually mature is highly variable within the literature cited within the main text but is consistently less than 30mm, and therefore when growth starts to become asymmetrically distributed either side of July is open to question. Limpets were selected randomly from two size classes SL_P = 30mm (>29.5mm and <30.5mm) and the second size class was >40mm. This kept sample sizes manageable in terms of expenditure on resin and processing time but offered excellent coverage (>60% sampled) of the size class in a given context at a given site.

The random selection from within a context's size class also ensured a mix of conicities was included. The model utilises the percentage of previous years growth to generate a calendar date which is assigned into a designated season and the model parameters utilised are 66% of growth between mid-March and the end of July and the remaining 34% between August and mid-November.

- Spring-early summer is death prior to the end of June.
- Late summer is death prior to the end of August.
- Early autumn is death prior to mid-November.
- Late Autumn-early winter is death after mid-November.

The model was evaluated by altering the percentage of growth prior to the end of July and the percentage post-July to maintain a total of 100% and checking if the season of death changed. The seasonality determination is insensitive to changes in this parameter between 55%-45% and 80%-20%. At 55%-45% specimens with a nominal date of death in mid-June start to move from Spring-Early summer to Late summer. The seasonal bins utilised are similar to Bailey and Craighead (2003, table IV, p.198) but revised to reflect the ecological studies at more northerly latitudes cited above.

Age at Death versus Conicity

An interesting pattern is evident in terms of age at death.

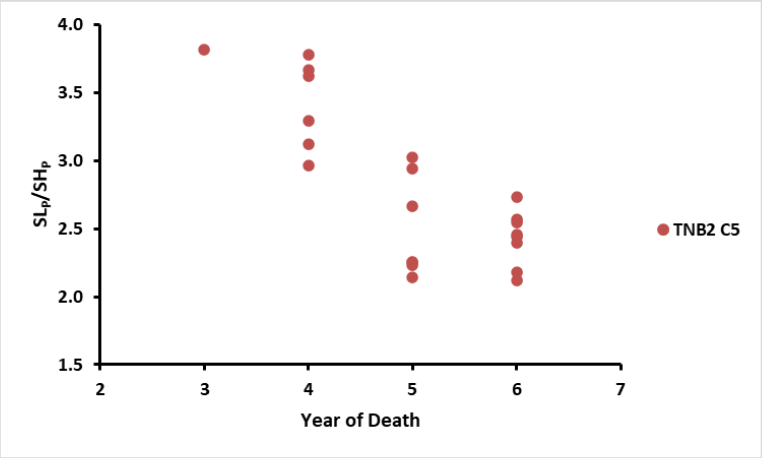


Figure SI-Chapter6-7.1: The age at death for 30mm limpets appears to cluster based upon conicity. Year of death is the year of life during which death occurred.

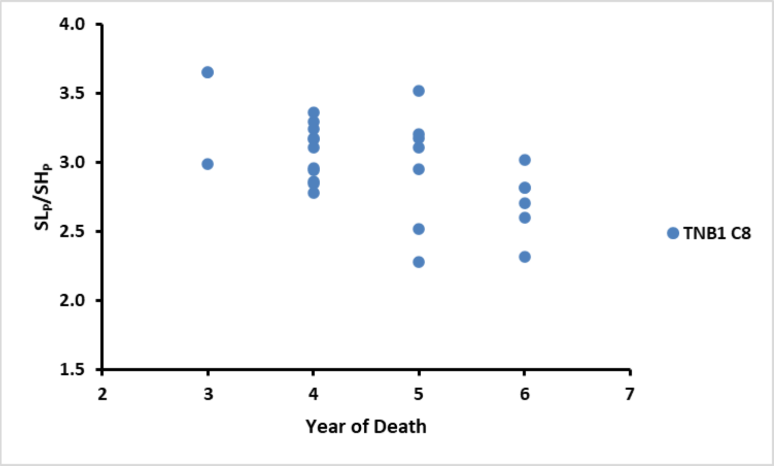


Figure SI-Chapter6-7.2: The same clustering is evident in 30mm limpets as that shown in figure SI-Chapter6-6.2 Year of death is the year of life during which death occurred.

This demonstrates that conicity is a major influence on age at death and therefore age at death versus length at death is problematic in the absence of conicity data.

SI-Chapter6-8-Vertebrates

Hares versus Birds

The figure below illustrates the challenge associated by an assemblage dominated by hares and birds.

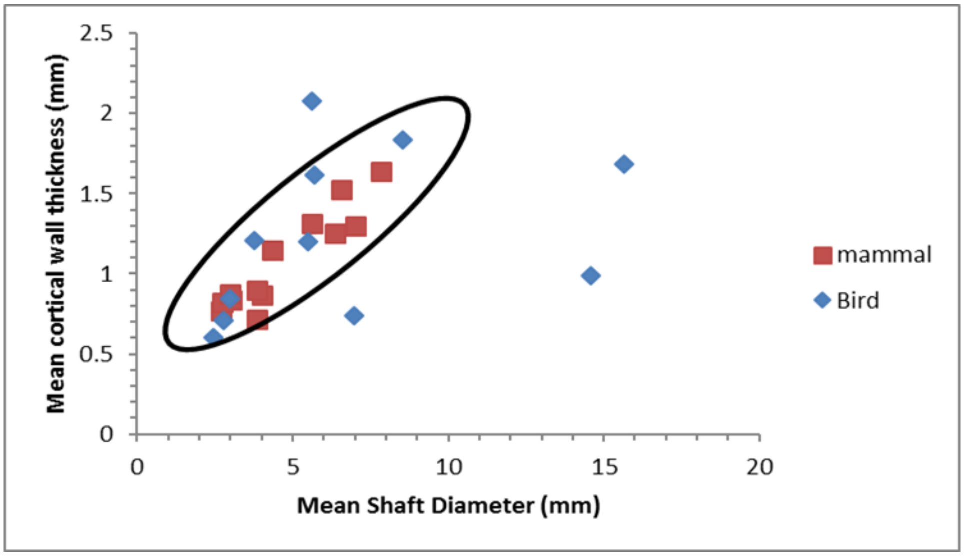


Figure SI-Chapter6-8.1: Cortical wall thickness versus bone diameter for hares and birds. For bones less than 10mm in diameter the use of wall thickness is unsafe without other corroboration. Reproduced from Evans (2016).

The Mammalian Remains.

Identification

Mammalian remains were identified using the reference collection of Durham University and some metrics were gathered from the reference collection of the Natural History Museum in London. As discussed in Evans (2016) the assemblages presented a specific challenge that it is worth repeating here. The assemblages are highly fragmented ranging from pulverised to extremely pulverised and they are dominated by birds and hares. Fragments or diaphyses that under normal circumstances would be designated as avian based upon the relatively thin cortical wall thickness (cf. McCarthy, 1999) could not be due to this characteristic being shared by hares as demonstrated in figure SI-Chapter6-8.1). Often relative cortical wall thinness combined with cross-sectional profile were insufficient to delineate between mammalian and avian origin. This is illustrated by comparing the humerus of a gannet with the femur of a hare. The consequence is that whilst in many published analyses, the counts of bones identified as avian or mammalian will amount to almost the total number of bone fragments, this is not the case with the assemblages discussed here. In many cases a designation between avian and mammalian could not be made with any confidence.

Quantification

Quantification is presented as both NISP and MNI; the latter being based upon the most numerous NRE. The assemblage is highly fragmented by any standard one would care to apply. The application of bone zonation approaches (*sensu* Dobney and Rielly, 1988) were not adopted, as based upon the results obtained from a trial on the avian assemblage, the nature of the assemblage promised little additional information yield, if any. The initial quantifications for TNB1 and TNB2 are provided in Evans (2016), however the assemblages where revisited during this project and the final results are slightly, but not materially, different. The predominance of dentition, phalanges and the variation in the number of vertebra and phalanges between taxa can be addressed utilising the York Protocol (Parks and Barratt, 2009; Parks, 2012) which also contributes some degree of normalisation of analyst ability and quality of reference collection, between analyses. This approach was not adopted as it causes taxa to disappear from the published record as is the case with otter at Sand Rock Shelter. It will eliminate the record of carcasses that have been skinned at the point of capture and returned to the site (Chapter 2). The Protocol for birds only quantifies the coracoid and limb bones. The elimination of taxa from the record and an inability to understand possible exploitation strategies or even natural deaths, was considered too higher price to pay.

Biometric Capture.

As it was known that the mammalian assemblages was made up almost of entirely hare, data capture was attempted the Natural History Museum's collection. This was unsuccessful as most of the hard tissue specimens turned out to be crania only. The small number that included the post-cranial skeleton were still articulated through the use of wire and glue. The highly fragmented nature of the archaeological assemblages provided very limited opportunity for biometric capture.

Age at Death.

Hares lose the deciduous teeth they have not already lost in utero, within a couple of days of birth. The teeth are open rooted and grow throughout life and hence neither dental eruption stage nor wear state can be utilised (Hillson, 1986). The literature on aging hares almost exclusively relates to game estate and forestry management and utilises the dry weight of the lens from the eye an option not available to archaeologists. Juvenile status was assessed by comparing epiphyseal fusion states with the known developmental schedule for rabbits Rowley-Conwy (1992).

Season of Death.

Due to the species present season of death is constrained to the documented duration of a species' breeding season. Neither mountain hare or otter have strongly defined breeding or birthing seasons; the birthing season for both species extends throughout most of the year. This means that just about any stage of epiphyseal fusion can be found at almost any time of year.

Preservation

The strength of colour was recorded or whether the specimen was calcined or carbonised.

The Avian Remains

Identification

Avian remains were primarily identified using the reference collection of Durham University. Some identifications, including those of great auk, were confirmed during a visit to the Natural History Museum's reference collections at Tring.

Quantification

Quantification is presented as both NISP and MNI; the latter being based upon the most numerous NRE. The assemblage is highly fragmented by any standard one would care to apply, although at least a small portion of the avian remains were more complete than those of the mammals. The application of bone zonation approaches Cohen and Serjeantson (1996) were attempted but resulted little additional information yield, if any. The initial quantifications for TNB1 and TNB2 are provided in Evans (2016), however these where revisited during this project and the final results are slightly, but not materially, different to those previously documented.

Biometric Capture.

The highly fragmented nature of the assemblages provided very limited opportunity for biometric capture. The measurements when taken, followed Cohen and Serjeantson (1996), were targeted at determining possible juvenile status or speciation based upon published datasets (Livezey, 1988) and the biometrics captured from the Natural History Museum's collections and the universities reference collection. Speciation is key if the objective is to determine juvenile status by size as figure 2 shows identification to genus, in this case *Larus*, is insufficient. The bone zonation approach of Cohen and Serjeantson (1996) was evaluated but offered little additional information yield.

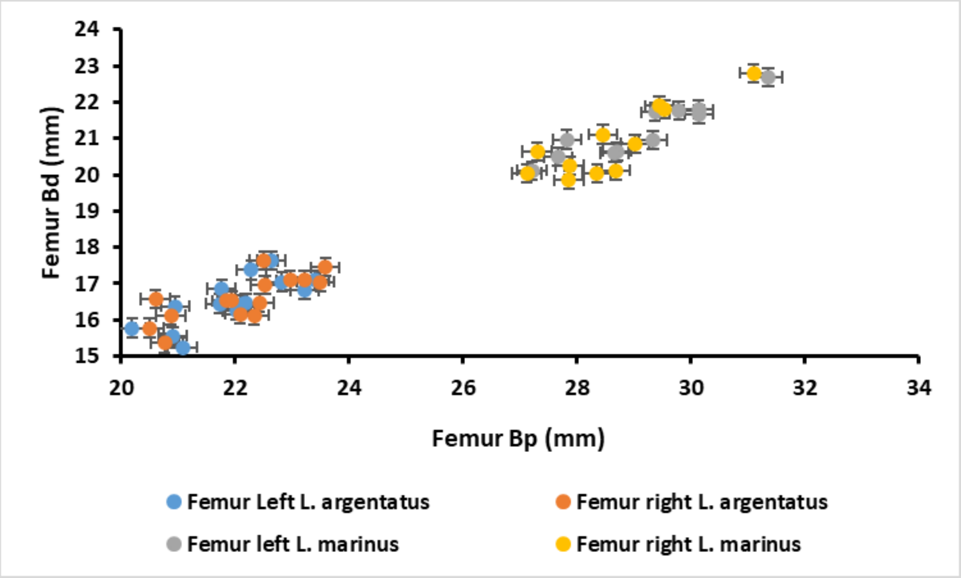


Figure SI-Chapter6-8.2: Metric differentiation between adult Herring Gulls and Greater Black Backed Gull. Data from the NHM's adult reference specimens.

When possible, metrics were gathered from specimens belonging to the auk family and compared to the adult ranges provided by Livezey (1988, table 3 and table 4) and no specimens were identified as juvenile based upon size.

Season of Death.

Season of death was inferred primarily on behavioural characteristics such as when a given pelagic species frequented the coastal zone, or other migratory patterns. One other approach applicable to birds is worth mentioning at this point. In some species medullary bone forms during the breeding season as a physiological adaption to support the metabolic demands for calcium during the production of eggshell, with any surplus being reabsorbed within a couple of weeks of laying being complete (Lentacker and Van Neer, 1996; Serjeantson, 2009). This is only present in female birds and the duration of its presence, if present at all, will be factored by the typical clutch size of the species in question, as more eggs requires more calcium over a concentrated period of time. Attempts to identify the presence of medullary bone were not particularly successful and only two possible candidates were identified. Very little research has been conducted on medullary bone beyond domestic fowl. It seems unlikely that the auk family, which lays only a single egg, would need to develop medullary bone. Birds laying larger clutches of four to six eggs are more likely to have evolved to utilise medullary bone; examples of potential interest to research in the British Mesolithic being the ducks and geese, the grouse family and the cormorant family.

The strength of colour was recorded or whether the specimen was calcined, carbonised.

Skeletal Zone Representation

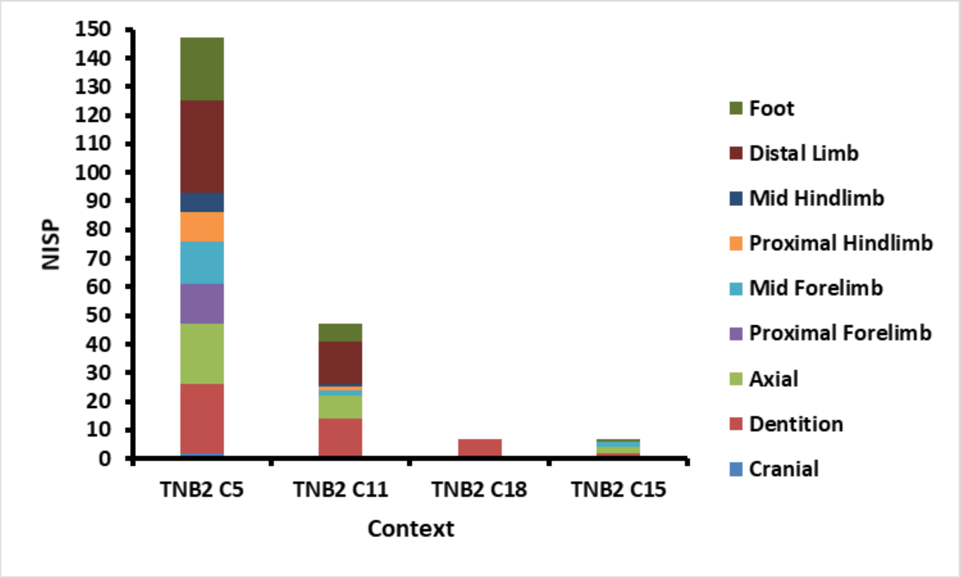


Figure SI-Chapter6-8.3: Skeletal zone representation for mountain hare. After Evans (2016).

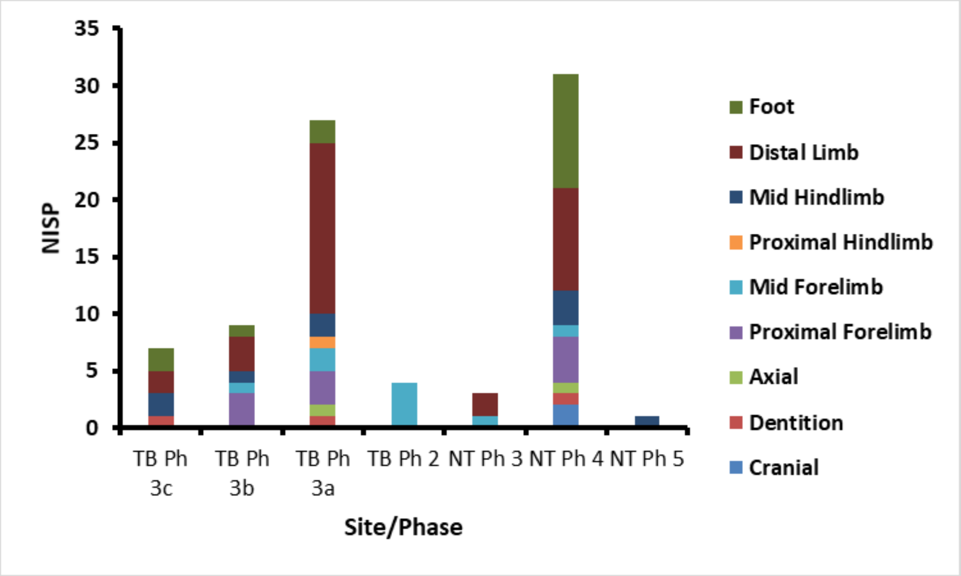


Figure SI-Chapter6-8.4: Skeletal zone representation for mountain hare.

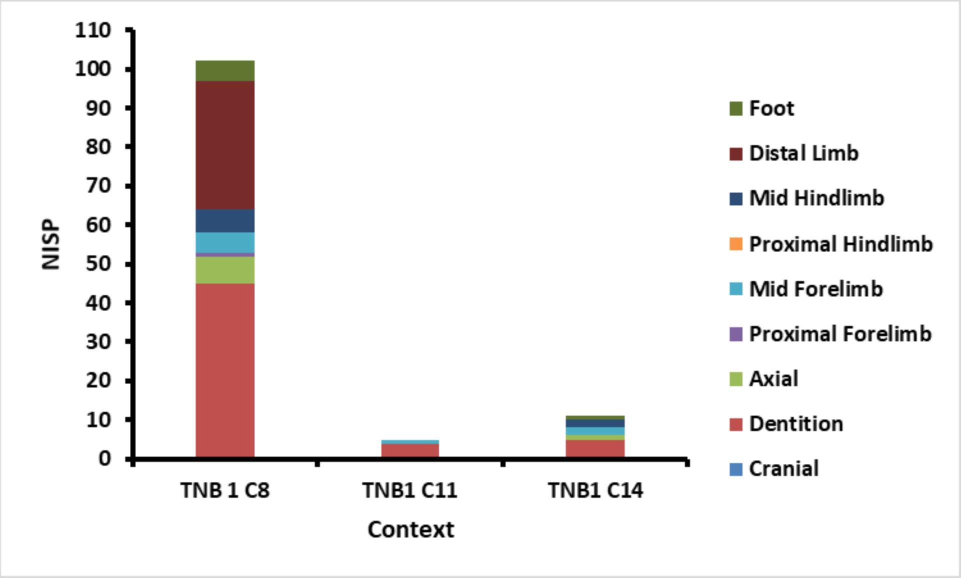


Figure SI-Chapter6-8.5: Skeletal zone representation for mountain hare. After Evans (2016).

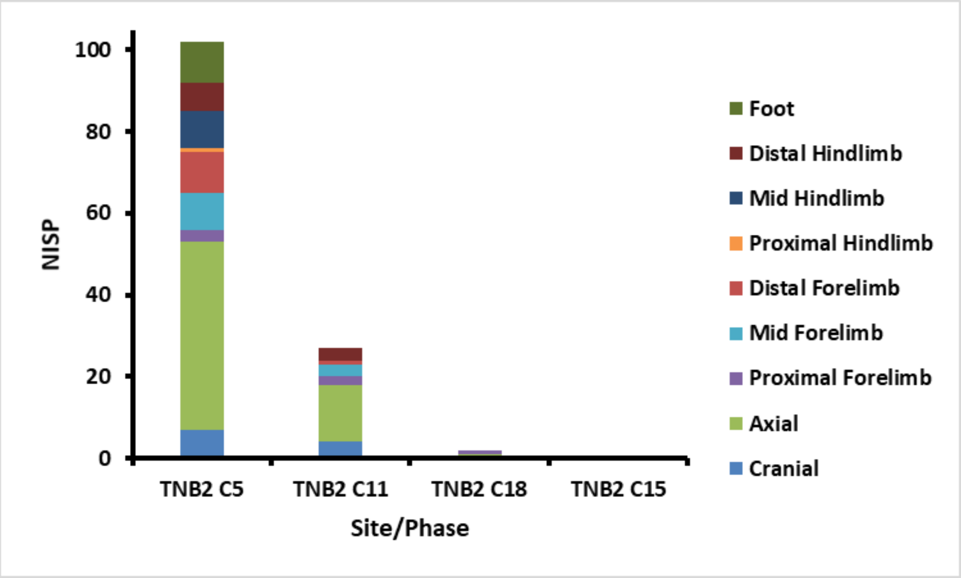


Figure SI-Chapter6-8.6: Skeletal zone representation for birds. After Evans (2016).

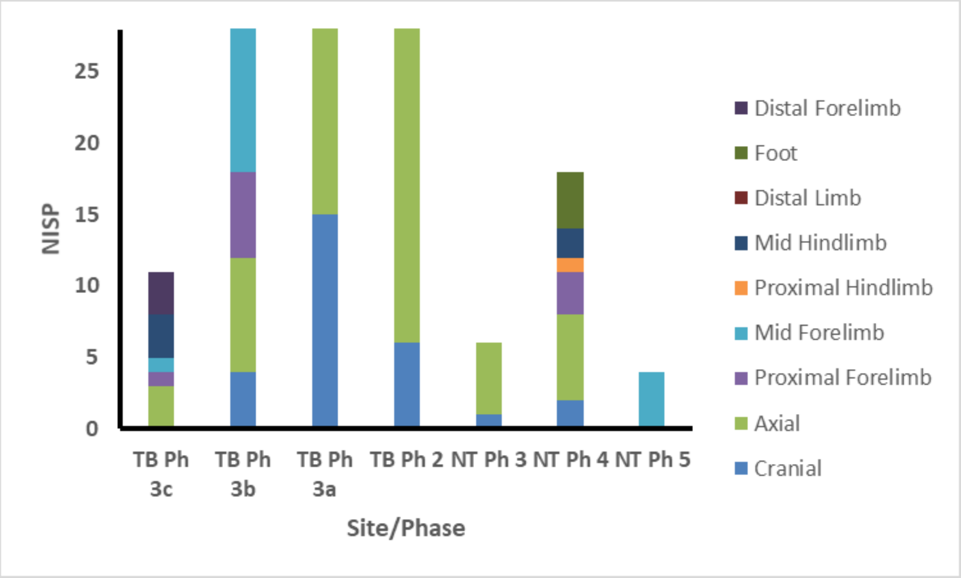


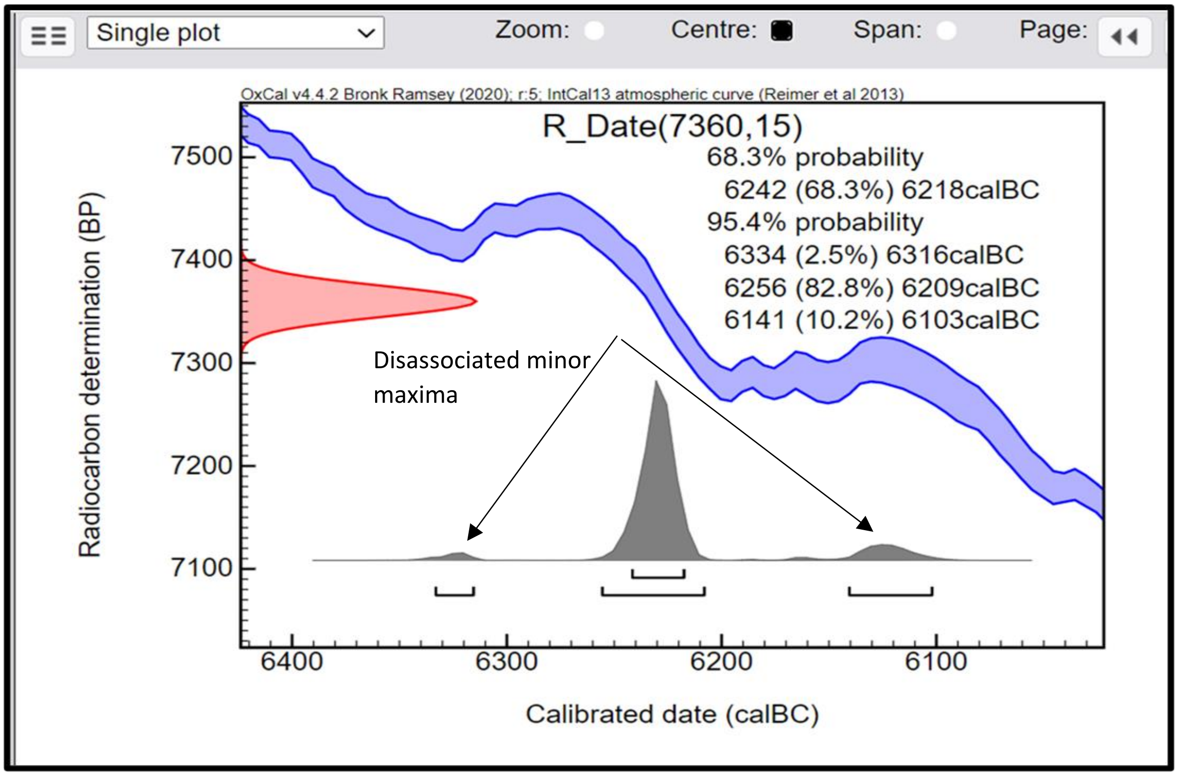
Figure SI-Chapter6-8.7: Skeletal zone representation for birds.

SI-Chapter7.

SI-Chapter7-1: Establishing Geographic Range for Fauna.

SST and upper oceanic temperatures have been rising rapidly in recent decades and receive frequent references in the news in relation to the current climate change debate. The distribution of thermophilic species is therefore dynamic. Candidate taxa were reviewed against NBN Atlas utilising the interactive map function to filter by date and very recent (since 1980) expansions in range were excluded. For example, *Patella depressa* has now been reported as far north as Shetland, yet in 1961 the shoreline of Cornwall was the species' northerly limit (Orton and Southward, 1961). A second consideration was that of probably isolated populations that are likely not self-sustaining and can appear to extend a taxon's range (cf. Crothers, 2001). Isolated observations that were not supported by later and increasing observations were excluded.

SI-Chapter7-2: Probability Distribution Curves.



R_Date(7360,15)
68.3% probability
6242 (68.3%) 6218calBC
95.4% probability
6334 (2.5%) 6316calBC
6256 (82.8%) 6209calBC
6141 (10.2%) 6103calBC

Figure SI-Chapter 7-2.1: Radiocarbon PD (Poz-15838) from the Norwegian Mesolithic site of Sævarhelleren. The elapsed period is extended by just under 400% to obtain 12.7% increase in confidence level. Based upon the other dates from this unit this ^{14}C assay is considered to reflect activity that occurred pre-6,200 cal BC.

As stated in chapter 4 the handling of disassociated minor maxima must be actively critiqued in terms of the increase in uncertainty in the elapsed period (figure SI-Chapter7-1).

SI-Chapter7-3: Summary Statistics and Statistical Inference Output.

For Sand Rock Shelter the statistical outputs are provided for intra-context level and also between the terminal and initial spits of stratigraphically adjacent contexts. For Ulva Cave the results are presented between spits and between the first and last spit in the column. The results are presented for Dog Whelk, Periwinkle and Limpet.

Sand Rock Shelter - Limpet

Table SI-Chapter7-3.1: Statistical inference tests for SL_P from Context 11 of Sand Rock Shelter. Data from Milner (2009, downloadable archive) as modified by SI-Chapter7-4.

z-Test: Two Sample for Means			z-Test: Two Sample for Means		
SL_P			Conicity		
	Spit 6	Spit 7		Spit 6	Spit 7
Mean	28.75933	31.24908	Mean	3.085385	2.909614
Known Variance	16.02	20.24	Known Variance	0.16	0.15
Observations	2465	1416	Observations	2465	1416
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
z	-17.2663		z	13.44777	
P(Z<=z) one-tail	0		P(Z<=z) one-tail	0	
z Critical one-tail	1.644854		z Critical one-tail	1.644854	
P(Z<=z) two-tail	0		P(Z<=z) two-tail	0	
z Critical two-tail	1.959964		z Critical two-tail	1.959964	
Reject H_0 @ 0.0001			Reject H_0 @ 0.0001		
z-Test: Two Sample for Means			z-Test: Two Sample for Means		
SL_P			Conicity		
	Spit 7	Spit 8		Spit 7	Spit 8
Mean	31.24908	30.69492	Mean	2.909614	3.057917
Known Variance	20.24	22.59	Known Variance	0.15	0.18
Observations	1416	197	Observations	1416	197
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
z	1.54312		z	-4.64437	
P(Z<=z) one-tail	0.061401		P(Z<=z) one-tail	1.71E-06	
z Critical one-tail	1.644854		z Critical one-tail	1.644854	
P(Z<=z) two-tail	0.122802		P(Z<=z) two-tail	3.41E-06	
z Critical two-tail	1.959964		z Critical two-tail	1.959964	
Fail to reject H_0			Reject H_0 @ 0.0001		
z-Test: Two Sample for Means			z-Test: Two Sample for Means		
SL_P			Conicity		
	Spit 8	Spit 9		Spit 8	Spit 9
Mean	30.69492	30.0518	Mean	3.057917	3.041648
Known Variance	22.59	19.5	Known Variance	0.18	0.17
Observations	197	305	Observations	197	305
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
z	1.52176		z	0.424171	
P(Z<=z) one-tail	0.064035		P(Z<=z) one-tail	0.335721	
z Critical one-tail	1.644854		z Critical one-tail	1.644854	
P(Z<=z) two-tail	0.128069		P(Z<=z) two-tail	0.671441	
z Critical two-tail	1.959964		z Critical two-tail	1.959964	
Fail to reject H_0			Fail to reject H_0		
z-Test: Two Sample for Means			z-Test: Two Sample for Means		
SL_P			Conicity		
	Spit 6	Spit 9		Spit 6	Spit 9
Mean	28.75933	30.0518	Mean	3.085385	3.041648
Known Variance	16.02	19.5	Known Variance	0.16	0.17
Observations	2465	305	Observations	2465	305
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
z	-4.87002		z	1.753278	
P(Z<=z) one-tail	5.58E-07		P(Z<=z) one-tail	0.039777	
z Critical one-tail	1.644854		z Critical one-tail	1.644854	
P(Z<=z) two-tail	1.12E-06		P(Z<=z) two-tail	0.079554	
z Critical two-tail	1.959964		z Critical two-tail	1.959964	
Reject H_0 @ 0.0001			Fail to reject H_0		
z-Test: Two Sample for Means			z-Test: Two Sample for Means		
SL_P			Conicity		
	Spit 7	Spit 9		Spit 7	Spit 9
Mean	31.24908	30.0518	Mean	2.909614	3.041648
Known Variance	20.24	19.5	Known Variance	0.15	0.17
Observations	1416	305	Observations	1416	305
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
z	4.280688		z	-5.12658	
P(Z<=z) one-tail	9.32E-06		P(Z<=z) one-tail	1.48E-07	
z Critical one-tail	1.644854		z Critical one-tail	1.644854	
P(Z<=z) two-tail	1.86E-05		P(Z<=z) two-tail	2.95E-07	
z Critical two-tail	1.959964		z Critical two-tail	1.959964	
Reject H_0 @ 0.0001			Reject H_0 @ 0.0001		

Table SI-Chapter7-3.2: Statistical inference tests for SL_P from Context 13 of Sand Rock Shelter. Data from Milner (2009, downloadable archive) as modified by SI-Chapter7-4.

z-Test: Two Sample for Means			z-Test: Two Sample for Means		
SL_P	Context 13		Conicity	Context 13	
	Spit 3	Spit 4		Spit 3	Spit 4
Mean	29.00703	28.82301	Mean	3.003642	3.054482
Known Variance	19.94	17.14	Known Variance	0.16	0.16
Observations	2428	3303	Observations	2428	3303
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
z	1.589623		z	-4.75447	
P(Z<=z) one-tail	0.05596		P(Z<=z) one-tail	9.95E-07	
z Critical one-tail	1.644854		z Critical one-tail	1.644854	
P(Z<=z) two-tail	0.11192		P(Z<=z) two-tail	1.99E-06	
z Critical two-tail	1.959964		z Critical two-tail	1.959964	
Fail to Reject H_0			Reject H_0 @ 0.05		
z-Test: Two Sample for Means			z-Test: Two Sample for Means		
SL_P	Context 13		Conicity	Context 13	
	Spit 5	Spit 4		Spit 5	Spit 4
Mean	29.10306	28.82301	Mean	3.041635	3.054482
Known Variance	18.04	17.14	Known Variance	0.18	0.16
Observations	1612	3303	Observations	1612	3303
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
z	2.188154		z	-1.01529	
P(Z<=z) one-tail	0.014329		P(Z<=z) one-tail	0.154985	
z Critical one-tail	1.644854		z Critical one-tail	1.644854	
P(Z<=z) two-tail	0.028658		P(Z<=z) two-tail	0.30997	
z Critical two-tail	1.959964		z Critical two-tail	1.959964	
Reject H_0 @ 0.05			Fail to Reject H_0		
z-Test: Two Sample for Means			z-Test: Two Sample for Means		
SL_P	Context 13		Conicity	Context 13	
	Spit 5	Spit 3		Spit 5	Spit 3
Mean	29.10306	29.00703	Mean	3.041635	3.003642
Known Variance	18.04	19.94	Known Variance	0.18	0.16
Observations	1612	2428	Observations	1612	2428
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
z	0.689376		z	2.851186	
P(Z<=z) one-tail	0.245293		P(Z<=z) one-tail	0.002178	
z Critical one-tail	1.644854		z Critical one-tail	1.644854	
P(Z<=z) two-tail	0.490587		P(Z<=z) two-tail	0.004356	
z Critical two-tail	1.959964		z Critical two-tail	1.959964	
Fail to Reject H_0			Reject H_0 @ 0.005		

Table SI-Chapter7-3.3 Statistical inference tests for SL_P between the interface layers between contexts of Sand Rock Shelter. Data from Milner (2009, downloadable archive) as modified by SI-Chapter7-4.

z-Test: Two Sample for Means			z-Test: Two Sample for Means		
SL_P			SL_P		
	C13 Spit 3	C28 Spit 4		C 13 Spit 5	C 11 Spit 6
Mean	29.0070305	31.9609231	Mean	29.1030583	28.7593347
Known Variance	19.14	35.33	Known Variance	18.04	16.02
Observations	2428	65	Observations	1612	2465
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
z	-3.9778908		z	2.58431127	
P(Z<=z) one-tail	3.4765E-05		P(Z<=z) one-tail	0.00487868	
z Critical one-tail	1.64485363		z Critical one-tail	1.64485363	
P(Z<=z) two-tail	6.9529E-05		P(Z<=z) two-tail	0.00975737	
z Critical two-tail	1.95996398		z Critical two-tail	1.95996398	
Reject H_0@0.0001			Reject H_0@0.01		
z-Test: Two Sample for Means			z-Test: Two Sample for Means		
Conicity			Conicity		
	C13 Spit 3	C28 Spit 4		C 13 Spit 5	C 11 Spit 6
Mean	3.00364236	3.13580869	Mean	3.04163493	3.08538502
Known Variance	0.16	0.24	Known Variance	0.18	0.16
Observations	2428	65	Observations	1612	2465
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
z	-2.1559097		z	-3.2924485	
P(Z<=z) one-tail	0.01554536		P(Z<=z) one-tail	0.0004966	
z Critical one-tail	1.64485363		z Critical one-tail	1.64485363	
P(Z<=z) two-tail	0.03109072		P(Z<=z) two-tail	0.00099319	
z Critical two-tail	1.95996398		z Critical two-tail	1.95996398	
Reject H_0@0.0001			Reject H_0@0.001		

Sand Rock Shelter - Periwinkle

Table SI-Chapter7-3.4 Statistical inference tests for SL_L from contexts 11 and 13 of Sand Rock Shelter. Data from Milner (2009, downloadable archive) as modified by SI-Chapter7-4.

z-Test: Two Sample for Means		
SL_L	Context 13	
	Spit 3	Spit 4
Mean	24.88679	25.38016
Known Variance	10.32	10.57
Observations	371	308
Hypothesized Mean Difference	0	
z	-1.97927	
P(Z<=z) one-tail	0.023893	
z Critical one-tail	1.644854	
P(Z<=z) two-tail	0.047786	
z Critical two-tail	1.959964	
Reject H_0 @ 0.05		

z-Test: Two Sample for Means		
SL_L	Context 13	
	Spit 5	Spit 4
Mean	26.28122	25.38016
Known Variance	11.55	10.57
Observations	98	308
Hypothesized Mean Difference	0	
z	2.309844	
P(Z<=z) one-tail	0.010448	
z Critical one-tail	1.644854	
P(Z<=z) two-tail	0.020897	
z Critical two-tail	1.959964	
Reject H_0 @ 0.05		

z-Test: Two Sample for Means		
SL_L	Context 13	
	Spit 5	Spit 3
Mean	26.28122	24.88679
Known Variance	11.55	10.32
Observations	98	371
Hypothesized Mean Difference	0	
z	3.653478	
P(Z<=z) one-tail	0.000129	
z Critical one-tail	1.644854	
P(Z<=z) two-tail	0.000259	
z Critical two-tail	1.959964	
Reject H_0 @ 0.0005		

z-Test: Two Sample for Means		
	Context 11	
SL_L	Spit 6	Spit 7
Mean	25.86619	25.79
Known Variance	13.77	17.35
Observations	97	50
Hypothesized Mean Difference	0	
z	0.108952	
P(Z<=z) one-tail	0.45662	
z Critical one-tail	1.644854	
P(Z<=z) two-tail	0.91324	
z Critical two-tail	1.959964	
Fail to reject H_0		

t-Test: Two-Sample Assuming Unequal Variances		
SL_L	Context 11	
	Spit 7	Spit 8
Mean	25.79	25.94167
Variance	17.3499	11.58428
Observations	50	24
Hypothesized Mean Difference	0	
df	55	
t Stat	-0.16651	
P(T<=t) one-tail	0.434184	
t Critical one-tail	1.673034	
P(T<=t) two-tail	0.868368	
t Critical two-tail	2.004045	
Fail to reject H_0		

t-Test: Two-Sample Assuming Unequal Variances		
	Context 11	
	Spit 6	Spit 8
Mean	25.86619	25.94167
Variance	13.77446	11.58428
Observations	97	24
Hypothesized Mean Difference	0	
df	38	
t Stat	-0.0955	
P(T<=t) one-tail	0.462209	
t Critical one-tail	1.685954	
P(T<=t) two-tail	0.924419	
t Critical two-tail	2.024394	
Fail to reject H_0		

Table SI-Chapter7-3.5: Statistical inference tests for SL_L from Context 28 of Sand Rock Shelter. Data from Milner (2009, downloadable archive) as modified by SI-Chapter7-4.

z-Test: Two Sample for Means	Context 28	
SL_L		
	Spit 4	Spit 5
Mean	25.60225	26.2739
Known Variance	7.79	7.64
Observations	80	82
Hypothesized Mean Difference	0	
z	-1.53867	
P(Z<=z) one-tail	0.061943	
z Critical one-tail	1.644854	
P(Z<=z) two-tail	0.123885	
z Critical two-tail	1.959964	
H_0 Fail to Reject		

z-Test: Two Sample for Means	Context 28	
SL_L		
	Spit 6	Spit 5
Mean	26.80467	26.2739
Known Variance	7.45	7.64
Observations	92	82
Hypothesized Mean Difference	0	
z	1.271883	
P(Z<=z) one-tail	0.101707	
z Critical one-tail	1.644854	
P(Z<=z) two-tail	0.203415	
z Critical two-tail	1.959964	
H_0 Fail to Reject		

z-Test: Two Sample for Means	Context 28	
SL_L		
	Spit 6	Spit 4
Mean	26.80467	25.60225
Known Variance	7.45	7.79
Observations	92	80
Hypothesized Mean Difference	0	
z	2.847194	
P(Z<=z) one-tail	0.002205	
z Critical one-tail	1.644854	
P(Z<=z) two-tail	0.004411	
z Critical two-tail	1.959964	
Reject H_0 @ 0.005		

Table SI-Chapter7-3.6: Statistical inference tests for SL_L between the interface layers between contexts of Sand Rock Shelter. Data from Milner (2009, downloadable archive) as modified by SI-Chapter7-4.

z-Test: Two Sample for Means		
SL_L		
	C 13 Spit 3	C 28 Spit 4
Mean	24.886792	25.60225
Known Variance	10.32	7.79
Observations	371	80
Hypothesized Mean Difference	0	
z	-2.0220695	
P(Z<=z) one-tail	0.0215846	
z Critical one-tail	1.6448536	
P(Z<=z) two-tail	0.0431692	
z Critical two-tail	1.959964	
Reject H_0 @ 0.05		

z-Test: Two Sample for Means		
SL_L		
	C 13 Spit 5	C 11 Spit 6
Mean	26.281224	25.866186
Known Variance	11.55	13.77
Observations	98	97
Hypothesized Mean Difference	0	
z	0.8142466	
P(Z<=z) one-tail	0.2077518	
z Critical one-tail	1.6448536	
P(Z<=z) two-tail	0.4155037	
z Critical two-tail	1.959964	
Fail to reject H_0		

Sand Rock Shelter - Dog Whelk

Table SI-Chapter7-3.7: Statistical inference tests for SL_N from Context 11 of Sand Rock Shelter. Data from Milner (2009, downloadable archive) as modified by SI-Chapter7-4.

z-Test: Two Sample for Means	Context 11		z-Test: Two Sample for Means	Context 11	
AL_N			Morphology		
	Spit 6	Spit 7		Spit 6	Spit 7
Mean	19.67638	20.82344	Mean	1.514863	1.470073
Known Variance	3.41	2.27	Known Variance	0.01	0.01
Observations	224	64	Observations	224	64
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
z	-5.09465		z	3.16009	
P(Z<=z) one-tail	1.75E-07		P(Z<=z) one-tail	0.000789	
z Critical one-tail	1.644854		z Critical one-tail	1.644854	
P(Z<=z) two-tail	3.49E-07		P(Z<=z) two-tail	0.001577	
z Critical two-tail	1.959964		z Critical two-tail	1.959964	
Reject H_0 @ 0.0001			Reject H_0 @ 0.001		
z-Test: Two Sample for Means	Context 11		z-Test: Two Sample for Means	Context 11	
AL_N			Morphology		
	Spit 8	Spit 7		Spit 8	Spit 7
Mean	21.2125	20.82344	Mean	1.45901	1.470073
Known Variance	1.68	2.27	Known Variance	0.01	0.01
Observations	16	64	Observations	16	64
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
z	1.038077		z	-0.39579	
P(Z<=z) one-tail	0.149617		P(Z<=z) one-tail	0.346131	
z Critical one-tail	1.644854		z Critical one-tail	1.644854	
P(Z<=z) two-tail	0.299234		P(Z<=z) two-tail	0.692262	
z Critical two-tail	1.959964		z Critical two-tail	1.959964	
Fail to reject H_0			Fail to reject H_0		
Student's t.test unequal variance	0.308509	Fail	Student's t.test equal variance	0.659981	Fail
z-Test: Two Sample for Means	Context 11		z-Test: Two Sample for Means	Context 11	
AL_N			Morphology		
	Spit 8	Spit 6		Spit 8	Spit 6
Mean	19.67638	21.2125	Mean	1.514863	1.45901
Known Variance	3.41	1.68	Known Variance	0.01	0.01
Observations	224	16	Observations	224	16
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
z	-4.43027		z	2.158351	
P(Z<=z) one-tail	4.71E-06		P(Z<=z) one-tail	0.01545	
z Critical one-tail	1.644854		z Critical one-tail	1.644854	
P(Z<=z) two-tail	9.41E-06		P(Z<=z) two-tail	0.030901	
z Critical two-tail	1.959964		z Critical two-tail	1.959964	
Reject H_0 @ 0.0001			Reject H_0 @ 0.05		
			Student's t.test equal variance	0.050783	Fail

Table Si-Chapter7-3.8: Statistical inference tests for SL_N from Context 13 of Sand Rock Shelter. Data from Milner (2009, downloadable archive) as modified by SI-Chapter7-4.

z-Test: Two Sample for Means			z-Test: Two Sample for Means		
Morphology	Context 13		AL_N	Context 13	
	Spit 3	Spit 4		Spit 3	Spit 4
Mean	1.505965	1.487011	Mean	19.18724	19.83347
Known Variance	0.01	0.01	Known Variance	3.02	2.74
Observations	170	438	Observations	170	438
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
z	2.097571		z	-4.16966	
P(Z<=z) one-tail	0.017972		P(Z<=z) one-tail	1.53E-05	
z Critical one-tail	1.644854		z Critical one-tail	1.644854	
P(Z<=z) two-tail	0.035943		P(Z<=z) two-tail	3.05E-05	
z Critical two-tail	1.959964		z Critical two-tail	1.959964	
Reject H_0 @ 0.05			Reject H_0 @ 0.0005		
z-Test: Two Sample for Means			z-Test: Two Sample for Means		
Morphology	Context 13		AL_N	Context 13	
	Spit 3	Spit 5		Spit 3	Spit 5
Mean	1.505965	1.506963	Mean	19.18724	19.82941
Known Variance	0.01	0.01	Known Variance	3.02	3.51
Observations	170	305	Observations	170	305
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
z	-0.10424		z	-3.75336	
P(Z<=z) one-tail	0.458488		P(Z<=z) one-tail	8.72E-05	
z Critical one-tail	1.644854		z Critical one-tail	1.644854	
P(Z<=z) two-tail	0.916977		P(Z<=z) two-tail	0.000174	
z Critical two-tail	1.959964		z Critical two-tail	1.959964	
Fail to Reject H_0			Reject H_0 @ 0.0005		
z-Test: Two Sample for Means			z-Test: Two Sample for Means		
Morphology	Context 13		AL_N	Context 13	
	Spit 4	Spit 5		Spit 4	Spit 5
Mean	1.487011	1.506963	Mean	19.83347	19.82941
Known Variance	0.01	0.01	Known Variance	2.74	3.51
Observations	438	305	Observations	438	305
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
z	-2.67534		z	0.030466	
P(Z<=z) one-tail	0.003733		P(Z<=z) one-tail	0.487848	
z Critical one-tail	1.644854		z Critical one-tail	1.644854	
P(Z<=z) two-tail	0.007465		P(Z<=z) two-tail	0.975696	
z Critical two-tail	1.959964		z Critical two-tail	1.959964	
Reject H_0 @ 0.01			Fail to Reject H_0		

Table SI-Chapter7-3.9: Statistical inference tests for SL_N from Context 28 of Sand Rock Shelter. Data from Milner (2009, downloadable archive) as modified by SI-Chapter7-4.

z-Test: Two Sample for Means			z-Test: Two Sample for Means		
Morphology	Context 28		AL_N	Context 28	
	Spit 4	Spit 5		Spit 4	Spit 5
Mean	1.468467	1.449198	Mean	18.96804	18.67111
Known Variance	0.01	0.01	Known Variance	4.05	3.48
Observations	168	72	Observations	168	72
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
z	1.367924		z	1.103203	
P(Z<=z) one-tail	0.085668		P(Z<=z) one-tail	0.134969	
z Critical one-tail	1.644854		z Critical one-tail	1.644854	
P(Z<=z) two-tail	0.171336		P(Z<=z) two-tail	0.269939	
z Critical two-tail	1.959964		z Critical two-tail	1.959964	
Fail to Reject H_0			Fail to Reject H_0		
z-Test: Two Sample for Means			z-Test: Two Sample for Means		
Morphology	Context 28		AL_N	Context 28	
	Spit 6	Spit 5		Spit 6	Spit 5
Mean	1.42019	1.449198	Mean	19.03612	18.67111
Known Variance	0.01	0.01	Known Variance	4.4	3.48
Observations	85	72	Observations	85	72
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
z	-1.81115		z	1.153687	
P(Z<=z) one-tail	0.035059		P(Z<=z) one-tail	0.124314	
z Critical one-tail	1.644854		z Critical one-tail	1.644854	
P(Z<=z) two-tail	0.070118		P(Z<=z) two-tail	0.248629	
z Critical two-tail	1.959964		z Critical two-tail	1.959964	
Fail to Reject H_0			Fail to Reject H_0		
z-Test: Two Sample for Means			z-Test: Two Sample for Means		
Morphology	Context 28		AL_N	Context 28	
	Spit 6	Spit 4		Spit 6	Spit 4
Mean	1.42019	1.468467	Mean	19.03612	18.96804
Known Variance	0.01	0.01	Known Variance	4.4	4.05
Observations	85	168	Observations	85	168
Hypothesized Mean Difference	0		Hypothesized Mean Difference	0	
z	-3.62698		z	0.247168	
P(Z<=z) one-tail	0.000143		P(Z<=z) one-tail	0.402389	
z Critical one-tail	1.644854		z Critical one-tail	1.644854	
P(Z<=z) two-tail	0.000287		P(Z<=z) two-tail	0.804779	
z Critical two-tail	1.959964		z Critical two-tail	1.959964	
Reject H_0 @ 0.0005			Fail to Reject H_0		

Table SI-Chapter7-3.10: Statistical inference tests for SL_N between the interface layers between contexts of Sand Rock Shelter. Data from Milner (2009, downloadable archive) as modified by SI-Chapter7-4.

z-Test: Two Sample for Means		
AH_N		
	C13 Spit 3	C28 Spit 4
Mean	19.1872353	18.9680357
Known Variance	3.02	4.05
Observations	170	168
Hypothesized Mean Difference	0	
z	1.07121994	
P(Z<=z) one-tail	0.14203527	
z Critical one-tail	1.64485363	
P(Z<=z) two-tail	0.28407055	
z Critical two-tail	1.95996398	
Fail to reject H_0		

z-Test: Two Sample for Means		
AH_N		
	C 13 Spit 5	C 11 Spit 6
Mean	19.8294098	19.6763839
Known Variance	3.51	1.68
Observations	305	224
Hypothesized Mean Difference	0	
z	1.10992723	
P(Z<=z) one-tail	0.13351519	
z Critical one-tail	1.64485363	
P(Z<=z) two-tail	0.26703039	
z Critical two-tail	1.95996398	
Fail to reject H_0		

z-Test: Two Sample for Means		
Morphology		
	C13 Spit 3	C28 Spit 4
Mean	1.50596543	1.46846685
Known Variance	0.01	0.01
Observations	170	168
Hypothesized Mean Difference	0	
z	3.44695497	
P(Z<=z) one-tail	0.00028347	
z Critical one-tail	1.64485363	
P(Z<=z) two-tail	0.00056694	
z Critical two-tail	1.95996398	
Reject H_0 @ 0.001		

z-Test: Two Sample for Means		
Morphology		
	C 13 Spit 5	C 11 Spit 6
Mean	1.50696318	1.51486278
Known Variance	0.01	0.01
Observations	305	224
Hypothesized Mean Difference	0	
z	-0.8977419	
P(Z<=z) one-tail	0.18466158	
z Critical one-tail	1.64485363	
P(Z<=z) two-tail	0.36932317	
z Critical two-tail	1.95996398	
Fail to reject H_0		

Ulva Cave – Limpet, Periwinkle and Dog Whelk.

Table SI-Chapter7-3.11: Statistical inference tests for SL_P SH_N and SH_L from Ulva Cave. Data from Andrews *et al* (1995) as modified by SI-Chapter7-4.

Dataset	Mean	SD	Dataset	Mean	SD	n	Dataset	Mean	SD	n
Limpet			Periwinkle				Dog Whelk			
P5/1	33.7	6.6	P5/1	23.2	3.1	877	P5/1	24.8	2.6	164
P5/2	30.7	4.3	P5/2	23	3.3	907	P5/2	25.4	3.5	200
Confidence	0.05		Confidence	0.05			Confidence	0.05		
DF	1007		DF	1782			DF	362		
Critical	2.17E-07		Critical	0.18754			Critical	0.069367		
t.test			t.test				t.test			
	s^2	20.08333		s^2	10.26077			s^2	9.777983	
t statistic	5.220361		t statistic	1.318396			t statistic	1.821431		
H_0	Reject		H_0	Fail to Reject			H_0	Fail to Reject		
Dataset	Mean	SD	Dataset	Mean	SD	n	Dataset	Mean	SD	n
Limpet			Periwinkle				Dog Whelk			
P5/2	30.7	4.3	P5/2	23	3.3	907	P5/2	25.4	3.5	200
P5/3	30.4	4.2	P5/3	22.5	3.9	671	P5/3	26.8	3.5	128
Confidence	0.05		Confidence	0.05			Confidence	0.05		
DF	1475		DF	1576			DF	326		
Critical	0.194318		Critical	0.005982			Critical	0.000469		
t.test			t.test				t.test			
	s^2	18.18342		s^2	12.72655			s^2	12.25	
t statistic	1.298502		t statistic	2.752492			t statistic	3.533809		
H_0	Fail to Reject		H_0	Reject			H_0	Reject		
Dataset	Mean	SD	Dataset	Mean	SD	n	Dataset	Mean	SD	n
Limpet			Periwinkle				Dog Whelk			
P5/3	30.4	4.2	P5/3	22.5	3.9	671	P5/3	26.8	3.5	128
P5/4	30.9	4	P5/4	23.8	3.2	238	P5/4	28.8	2.8	48
Confidence	0.05		Confidence	0.05			Confidence	0.05		
DF	690		DF	907			DF	174		
Critical	0.183402		Critical	4.4E-06			Critical	0.00049		
t.test			t.test				t.test			
	s^2	17.26446		s^2	13.91133			s^2	11.05879	
t statistic	1.331688		t statistic	4.619838			t statistic	3.553411		
H_0	Fail to Reject		H_0	Reject			H_0	Reject		
Dataset	Mean	SD	Dataset	Mean	SD	n	Dataset	Mean	SD	n
Limpet			Periwinkle				Dog Whelk			
P5/1	33.7	6.6	P5/1	23.2	3.1	877	P5/1	24.8	2.6	164
P5/4	30.9	4	P5/4	23.8	3.2	238	P5/4	28.8	2.8	48
Confidence	0.05		Confidence	0.05			Confidence	0.05		
DF	222		DF	1113			DF	210		
Critical	0.000134		Critical	0.00866			Critical	3.39E-17		
t.test			t.test				t.test			
	s^2	23.94523		s^2	9.744151			s^2	7.001714	
t statistic	3.886689		t statistic	2.629845			t statistic	9.211544		
H_0	Reject		H_0	Reject			H_0	Reject		

Summary Statistics – Sand Rock Shelter.

Limpet

Table SI-Chapter7-3.12: Summary statistics for limpets from context 11.

Context 11 Spit 6	SL_P (mm)	SH_P (mm)	Conicity	Context 11 Spit 7	SL_P (mm)	SH_P (mm)	Conicity	Context 11 Spit 8	SL_P (mm)	SH_P (mm)	Conicity	Context 11 Spit 9	SL_P (mm)	SH_P (mm)	Conicity
Mean	28.8	9.5	3.09	Mean	31.2	11.0	2.91	Mean	30.7	10.3	3.06	Mean	30.1	10.1	3.04
StDev	4.0	2.0	0.40	StDev	4.5	2.4	0.39	StDev	4.8	2.5	0.42	StDev	4.4	2.2	0.41
Median	28.2	9.2	3.09	Median	30.8	10.6	2.90	Median	30.3	9.9	3.07	Median	29.6	9.8	3.01
Interquartile	5.2	2.4	0.55	Interquartile	6.1	2.9	0.52	Interquartile	6.4	3.0	0.55	Interquartile	6.5	3.2	0.53
Minimum	19.0	5.0	1.81	Minimum	21.1	5.8	1.73	Minimum	18.8	4.6	1.95	Minimum	19.1	5.2	2.05
Maximum	48.6	18.3	4.39	Maximum	51.4	22.0	4.78	Maximum	48.1	18.9	4.63	Maximum	47.9	17.8	4.98
Skew	0.7	1.0	0.03	Skew	0.6	1.0	0.16	Skew	0.4	0.7	0.18	Skew	0.5	0.6	0.53
Kurtosis	0.8	1.6	-0.13	Kurtosis	0.6	1.6	0.03	Kurtosis	0.7	0.9	0.32	Kurtosis	0.3	0.3	1.41
n =	2465	2465	2465	n =	1416	1416	1416	n =	197	197	197	n =	305	305	305
Variance	16.02	3.83	0.16	Variance	20.24	5.68	0.15	Variance	22.59	6.07	0.18	Variance	19.50	4.81	0.17

Table SI-Chapter7-3.13: Summary statistics for limpets from context 13.

Context 13 Spit 3	SL_P (mm)	SH_P (mm)	Conicity	Contex t13 Spit 4	SL_P (mm)	SH_P (mm)	Conicity	Context 13 Spit 5	SL_P (mm)	SH_P (mm)	Conicity
Mean	29.0	9.8	3.00	Mean	28.8	9.6	3.05	Mean	29.1	9.8	3.04
StDev	4.5	2.1	0.40	StDev	4.1	2.0	0.40	StDev	4.2	2.1	0.42
Median	28.5	9.5	3.00	Median	28.4	9.3	3.05	Median	28.6	9.4	3.05
Interquartile	5.7	2.6	0.55	Interquartile	5.1	2.5	0.55	Interquartile	5.2	2.6	0.59
Minimum	14.5	4.6	1.83	Minimum	11.2	3.7	1.77	Minimum	10.2	3.3	1.58
Maximum	50.3	20.5	4.42	Maximum	55.4	21.1	4.49	Maximum	53.7	20.3	4.93
Skew	0.6	0.9	0.11	Skew	0.7	0.9	0.10	Skew	0.8	1.0	0.06
Kurtosis	0.9	1.3	-0.19	Kurtosis	1.4	1.6	-0.11	Kurtosis	1.8	1.7	0.00
n =	2428	2428	2428	n =	3303	3303	3303	n =	1612	1612	1612
Variance	19.94	4.59	0.16	Variance	17.14	3.87	0.16	Variance	18.04	4.50	0.18

Table SI-Chapter7-3.14: Summary statistics for limpets from contexts 12 and 28.

Context 28 Spit 4	SL_P (mm)	SH_P (mm)	Conicity	Context 28 Aggregated	SL_P (mm)	SH_P (mm)	Conicity	Context 12 Spit 2	SL_P (mm)	SH_P (mm)	Conicity
Mean	32.0	10.5	3.14	Mean	32.4	10.9	3.09	Mean	29.7	10.4	2.90
StDev	5.9	2.8	0.49	StDev	5.9	3.0	0.52	StDev	4.7	2.2	0.39
Median	32.5	10.2	3.08	Median	33.1	10.4	3.06	Median	28.9	9.9	2.88
Interquartile	8.5	3.4	0.42	Interquartile	8.1	3.5	0.44	Interquartile	6.6	3.0	0.55
Minimum	19.7	5.2	2.14	Minimum	19.7	5.2	1.92	Minimum	20.5	6.0	1.99
Maximum	46.4	19.3	5.55	Maximum	46.4	19.3	5.55	Maximum	48.8	17.0	4.11
Skew	-0.1	0.5	1.79	Skew	-0.3	0.6	1.29	Skew	0.8	0.8	0.17
Kurtosis	-0.3	0.8	8.40	Kurtosis	-0.3	0.4	6.55	Kurtosis	0.7	0.0	-0.22
n =	65	65	65	n =	72	72	72	n =	391	391	391
Variance	35.33	7.85	0.24	Variance	34.33	9.25	0.27	Variance	22.37	4.97	0.15

Periwinkle

Table SI-Chapter7-3.15: Summary statistics for periwinkle from contexts 11.

Context 11 Spit 6	SH_L (mm)	Context 11 Spit 7	SH_L (mm)	Context 11 Spit 8	SH_L (mm)
Mean	25.9	**Mean**	25.8	**Mean**	25.9
StDev	3.7	**StDev**	4.2	**StDev**	3.4
Median	25.2	**Median**	25.2	**Median**	25.7
Interquartile	5.6	**Interquartile**	4.3	**Interquartile**	3.6
Minimum	19.2	**Minimum**	12.3	**Minimum**	19.8
Maximum	34.4	**Maximum**	37.7	**Maximum**	33.0
Skew	0.4	**Skew**	0.3	**Skew**	0.3
Kurtosis	-0.8	**Kurtosis**	2.5	**Kurtosis**	-0.3
n =	97	**n =**	50	**n =**	24
Variance	13.77	**Variance**	17.35	**Variance**	11.58

Table SI-Chapter7-3.16: Summary statistics for periwinkle from contexts 13.

Context 13 Spit 3	SH_L (mm)	Context 13 Spit 4	SH_L (mm)	Context 13 Spit 5	SH_L (mm)
Mean	24.9	**Mean**	25.4	**Mean**	26.3
StDev	3.2	**StDev**	3.3	**StDev**	3.4
Median	24.8	**Median**	25.1	**Median**	25.6
Interquartile	4.0	**Interquartile**	3.3	**Interquartile**	4.3
Minimum	11.3	**Minimum**	5.9	**Minimum**	18.2
Maximum	35.0	**Maximum**	35.6	**Maximum**	37.5
Skew	-0.5	**Skew**	-0.3	**Skew**	0.8
Kurtosis	1.9	**Kurtosis**	4.5	**Kurtosis**	0.8
n =	371	**n =**	308	**n =**	98
Variance	10.32	**Variance**	10.57	**Variance**	11.55

Table Si-Chapter7-3.17: Summary statistics for periwinkle from contexts 28.

Context 28 Spit 4	SH_L (mm)	Context 28 Spit 5	SH_L (mm)	Context 28 Spit 6	SH_L (mm)	Context 28 Aggegated	SH_L (mm)
Mean	25.6	**Mean**	26.3	**Mean**	26.8	**Mean**	26.3
StDev	2.8	**StDev**	2.8	**StDev**	2.7	**StDev**	2.8
Median	25.3	**Median**	26.4	**Median**	26.8	**Median**	26.2
Interquartile	3.5	**Interquartile**	4.1	**Interquartile**	3.6	**Interquartile**	3.9
Minimum	18.4	**Minimum**	20.0	**Minimum**	19.1	**Minimum**	18.4
Maximum	33.2	**Maximum**	35.4	**Maximum**	33.6	**Maximum**	35.4
Skew	0.4	**Skew**	0.3	**Skew**	0.0	**Skew**	0.2
Kurtosis	0.7	**Kurtosis**	0.3	**Kurtosis**	0.2	**Kurtosis**	0.2
n =	80	**n =**	82	**n =**	92	**n =**	254
Variance	7.79	**Variance**	7.64	**Variance**	7.45	**Variance**	7.80

Table SI-Chapter7-3.18: Summary statistics for periwinkle from contexts 22.

Context 22 Spit 7	SH_L (mm)
Mean	26.1
StDev	3.7
Median	26.0
Interquartile	3.8
Minimum	17.2
Maximum	37.4
Skew	0.3
Kurtosis	0.4
n =	104
Variance	13.94

Dog Whelk

Table SI-Chapter7-3.19: Summary statistics for dog whelk from contexts 11.

Context 11 Spit 6	**SH_N (mm)**	**AH_N (mm)**	**Morphology**	**Context 11 Spit 7**	**SH_N (mm)**	**AH_N (mm)**	**Morphology**	**Context 11 Spit 8**	**SH_N (mm)**	**AH_N (mm)**	**Morphology**
Mean	29.7	19.7	1.51	**Mean**	30.6	20.8	1.47	**Mean**	30.9	21.2	1.46
StDev	3.1	1.8	0.12	**StDev**	2.8	1.5	0.09	**StDev**	2.6	1.3	0.10
Median	29.6	19.6	1.50	**Median**	30.8	20.8	1.47	**Median**	31.1	21.2	1.46
Interquartile	4.5	2.3	0.16	**Interquartile**	4.6	2.0	0.11	**Interquartile**	3.5	1.3	0.11
Minimum	22.4	14.4	1.29	**Minimum**	23.5	18.0	1.25	**Minimum**	25.4	19.6	1.25
Maximum	37.9	24.8	2.02	**Maximum**	36.6	24.7	1.68	**Maximum**	35.1	25.1	1.65
Skew	0.1	0.2	0.78	**Skew**	-0.1	0.2	0.02	**Skew**	-0.3	1.8	-0.04
Kurtosis	-0.3	0.3	1.09	**Kurtosis**	-0.4	-0.3	0.18	**Kurtosis**	0.1	4.9	0.43
n =	223	223	223	**n =**	64	64	64	**n =**	16	16	16
Variance	9.71	3.41	0.01	**Variance**	7.99	2.27	0.01	**Variance**	6.71	1.68	0.01

Table SI-Chapter7-3.20: Summary statistics for dog whelk from contexts 13.

Context 13 Spit 3	**SH_N (mm)**	**AH_N (mm)**	**Morphology**	**Context 13 Spit 4**	**SH_N (mm)**	**AH_N (mm)**	**Morphology**	**Context 13 Spit 5**	**SH_N (mm)**	**AH_N (mm)**	**Morphology**
Mean	28.9	19.2	1.51	**Mean**	29.5	19.8	1.49	**Mean**	29.8	19.8	1.51
StDev	2.9	1.7	0.09	**StDev**	2.7	1.7	0.09	**StDev**	2.8	1.9	0.10
Median	28.5	19.1	1.50	**Median**	29.4	19.8	1.48	**Median**	29.7	19.8	1.50
Interquartile	4.1	2.0	0.11	**Interquartile**	3.8	2.0	0.13	**Interquartile**	3.9	2.6	0.13
Minimum	18.8	13.9	1.31	**Minimum**	21.8	14.8	1.21	**Minimum**	22.1	14.3	1.26
Maximum	38.0	24.0	1.81	**Maximum**	38.8	25.3	1.83	**Maximum**	37.2	24.5	1.85
Skew	0.1	-0.1	0.42	**Skew**	0.1	-0.1	0.19	**Skew**	0.0	0.1	0.41
Kurtosis	0.4	0.7	0.26	**Kurtosis**	-0.1	0.4	0.05	**Kurtosis**	-0.2	-0.4	0.11
n =	170	170	170	**n =**	438	438	438	**n =**	305	305	305
Variance	8.65	3.02	0.01	**Variance**	7.48	2.74	0.01	**Variance**	8.09	3.51	0.01

Table SI-Chapter7-3.21: Summary statistics for dog whelk from contexts 28.

Context 28 Spit 4	**SH_N (mm)**	**AH_N (mm)**	**Morphology**	**Context 28 Spit 5**	**SH_N (mm)**	**AH_N (mm)**	**Morphology**	**Context 28 Spit 6**	**SH_N (mm)**	**AH_N (mm)**	**Morphology**
Mean	27.8	19.0	1.47	**Mean**	27.0	18.7	1.45	**Mean**	27.0	19.0	1.42
StDev	3.3	2.0	0.10	**StDev**	3.2	1.9	0.11	**StDev**	3.5	2.1	0.10
Median	28.1	18.9	1.46	**Median**	27.1	18.5	1.44	**Median**	27.0	19.1	1.41
Interquartile	3.9	3.1	0.13	**Interquartile**	5.1	2.5	0.14	**Interquartile**	4.7	2.7	0.13
Minimum	19.7	13.8	1.25	**Minimum**	20.9	14.3	1.26	**Minimum**	17.4	12.4	1.25
Maximum	37.2	24.0	1.87	**Maximum**	33.9	23.2	1.77	**Maximum**	35.5	23.6	1.69
Skew	0.1	0.1	0.59	**Skew**	0.1	0.0	0.55	**Skew**	-0.3	-0.5	0.45
Kurtosis	0.0	-0.5	1.25	**Kurtosis**	-0.8	-0.1	0.23	**Kurtosis**	0.0	0.7	-0.07
n =	168	168	168	**n =**	72	72	72	**n =**	85	85	85
Variance	10.63	4.05	0.01	**Variance**	10.31	3.48	0.01	**Variance**	12.48	4.40	0.01

Table SI-Chapter7-3.22: Summary statistics for dog whelk from contexts 12, 22 and 28.

Context 28 Aggregated	SH_N (mm)	AH_N (mm)	Morphology	Context 22 Spit 6	SH_N (mm)	AH_N (mm)	Morphology	Context 12 Spit 2	SH_N (mm)	AH_N (mm)	Morphology
Mean	27.4	18.9	1.45	**Mean**	27.5	19.0	1.45	**Mean**	28.3	19.5	1.45
StDev	3.3	2.0	0.10	**StDev**	3.3	1.9	0.09	**StDev**	3.0	1.7	0.09
Median	27.8	18.9	1.44	**Median**	27.6	18.9	1.45	**Median**	28.5	19.7	1.45
Interquartile	4.4	3.0	0.13	**Interquartile**	5.0	2.9	0.11	**Interquartile**	4.0	2.2	0.13
Minimum	17.4	12.4	1.25	**Minimum**	18.3	12.7	1.24	**Minimum**	19.6	14.6	1.24
Maximum	37.2	24.0	1.87	**Maximum**	34.4	23.4	1.67	**Maximum**	35.5	23.8	1.73
Skew	0.0	-0.1	0.52	**Skew**	-0.1	-0.2	0.01	**Skew**	-0.2	-0.2	0.29
Kurtosis	-0.1	-0.1	0.65	**Kurtosis**	-0.1	0.8	0.11	**Kurtosis**	0.1	-0.1	-0.11
n =	325	325	325	**n =**	64	64	64	**n =**	249	249	249
Variance	11.13	4.01	0.01	**Variance**	10.58	3.77	0.01	**Variance**	8.99	2.86	0.01

SI-Chapter7-4: Dropped Records and Other Data Issues.

A number of records had to be dropped and these are presented in table SI-Chapter7-4.1. This is provided so that an audit trail exists between the sample sizes and derived values (such as the mean) used in this project and those published in the on-line archive.

Table SI-Chapter7-4.1: Records dropped from the downloadable archive due to data quality. The records either side of the drop record were evaluated for marginal values. The dropped records have been treated as isolated instances and not (as strict data quality methods in the absence of source data, in this case the analyst entering the record) would require which is to drop all records after the first occurrence as the association of the two values going forward cannot be guaranteed. Two possible explanations for the most of issues seem likely. Incomplete dog whelks. Samples encountered where L2 could not be recorded and the curser within Excel or column on paper were not incremented.

Context	Taxon	N	L1	L2	L1/L2	Status	Comment
13	Limpet	606	8.9	9.5	0.936842	Reject	Taller than length, following length entered as height?
13	Limpet	5479	6.9	8.2	0.841463	Reject	Taller than length, following length entered as height?
13	Limpet	5590	32	35.6	0.898876	Reject	Taller than length, following length entered as height?
13	Limpet	5910	10.2	30.5	0.334426	Reject	Taller than length, variables the wrong way round or preceeding height entered as length?
13	Limpet	7139	13.3	39.9	0.333333	Reject	Taller than length, variables the wrong way round
13	Limpet	2316	30	3.7	8.108108	Reject	>5 = very flat, this must be pathalogical or L2 should be 13.7
11	Limpet	3525	9.1	10.8	0.842593	Reject	Preceeding Height Entered as Length?
11	Dog Whelk	80	28.33	26.88	1.053943	Reject	Length only 1.45mm > than aperture. Following length entered as aperture?
13	Dog Whelk	33	16.15	17.68	0.913462	Reject	Aperture longer than shell. Shell incomplete.
13	Dog Whelk	61	28.88	29.91	0.965563	Reject	Aperture longer than shell. Shell incomplete.
13	Dog Whelk	84	16.87	19.31	0.873641	Reject	Aperture longer than shell. Shell incomplete.
13	Dog Whelk	128	16.68	16.71	0.998205	Reject	Aperture longer than shell. Shell incomplete.
28	Dog Whelk	58	32.99	31.71	1.040366	Reject	Length only 1.28mm > than aperture. Following length entered as aperture?

SI-Chapter7-5: SST Reconstructions other parts of Western Europe.

Figures SI-Chapter7-5.1 to 3 present the modelled SST curves for areas excluded from the definition of Atlantic Europe in chapter 5.

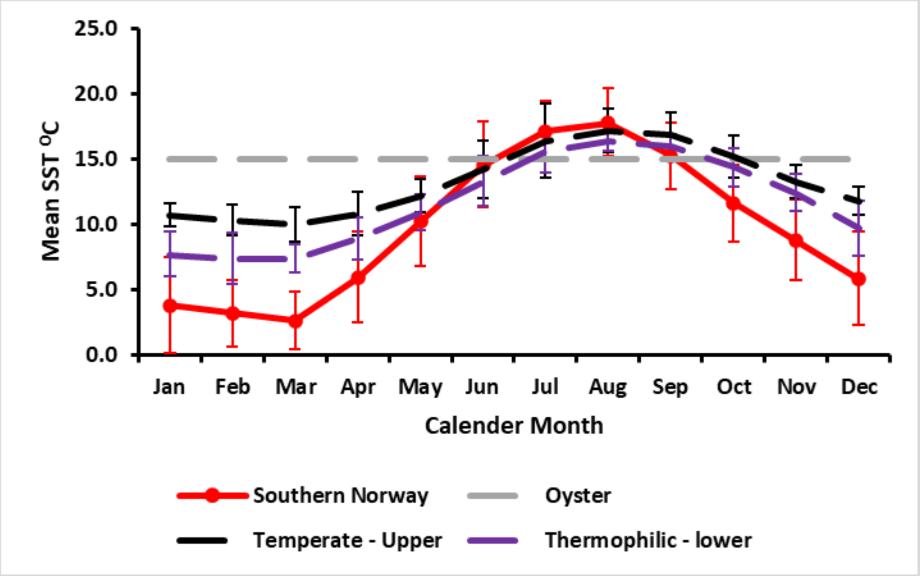


Figure SI-Chapter7-5.1: There is very little difference between the modern data presented in chapter 5 and the modelled 8.2K scenario presented here. Similar statements can be made for western Sweden and northern Denmark (data not shown).

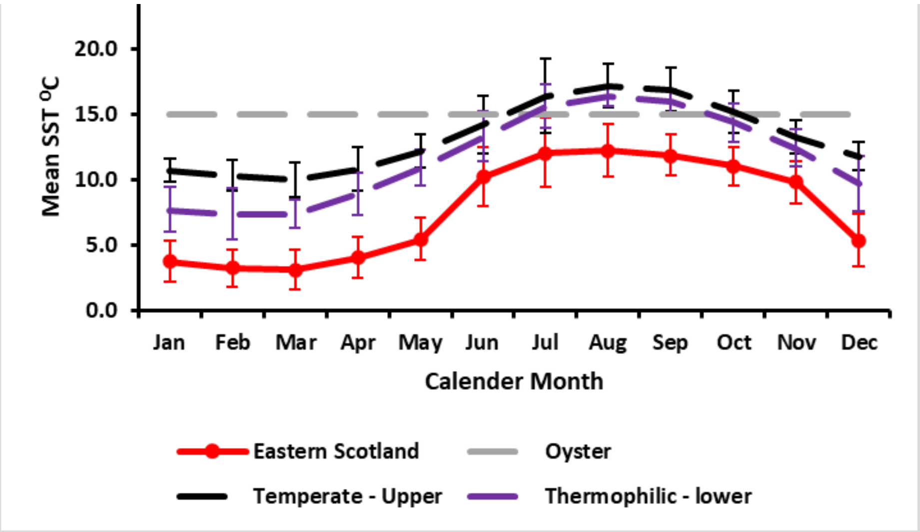


Figure SI-Chapter7-5.2: SST on the North Sea coast of Scotland generally experience slightly less winter moderation and likewise constraint on summer temperatures. The 8.2K scenario however suggests oysters would cease to be a viable resource whilst periwinkle and dog whelk would be well within limits.

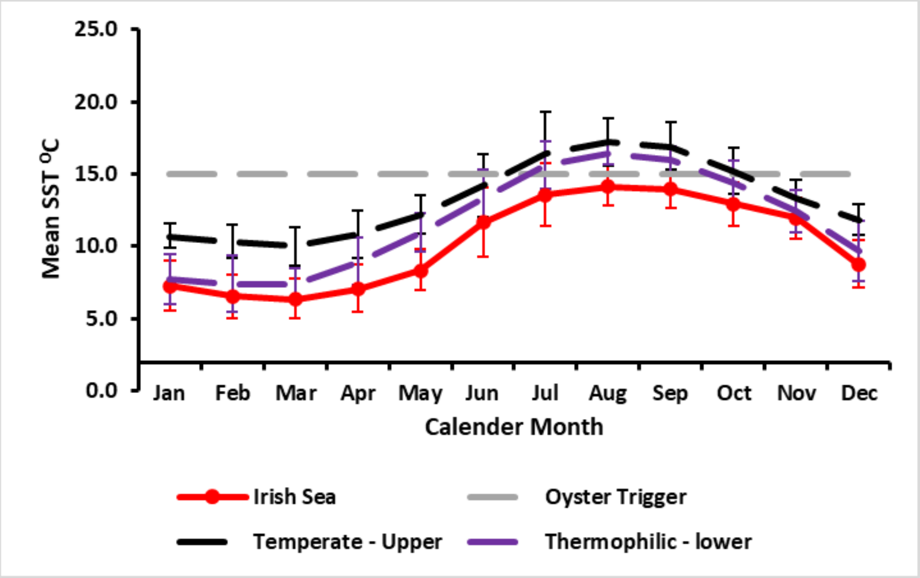
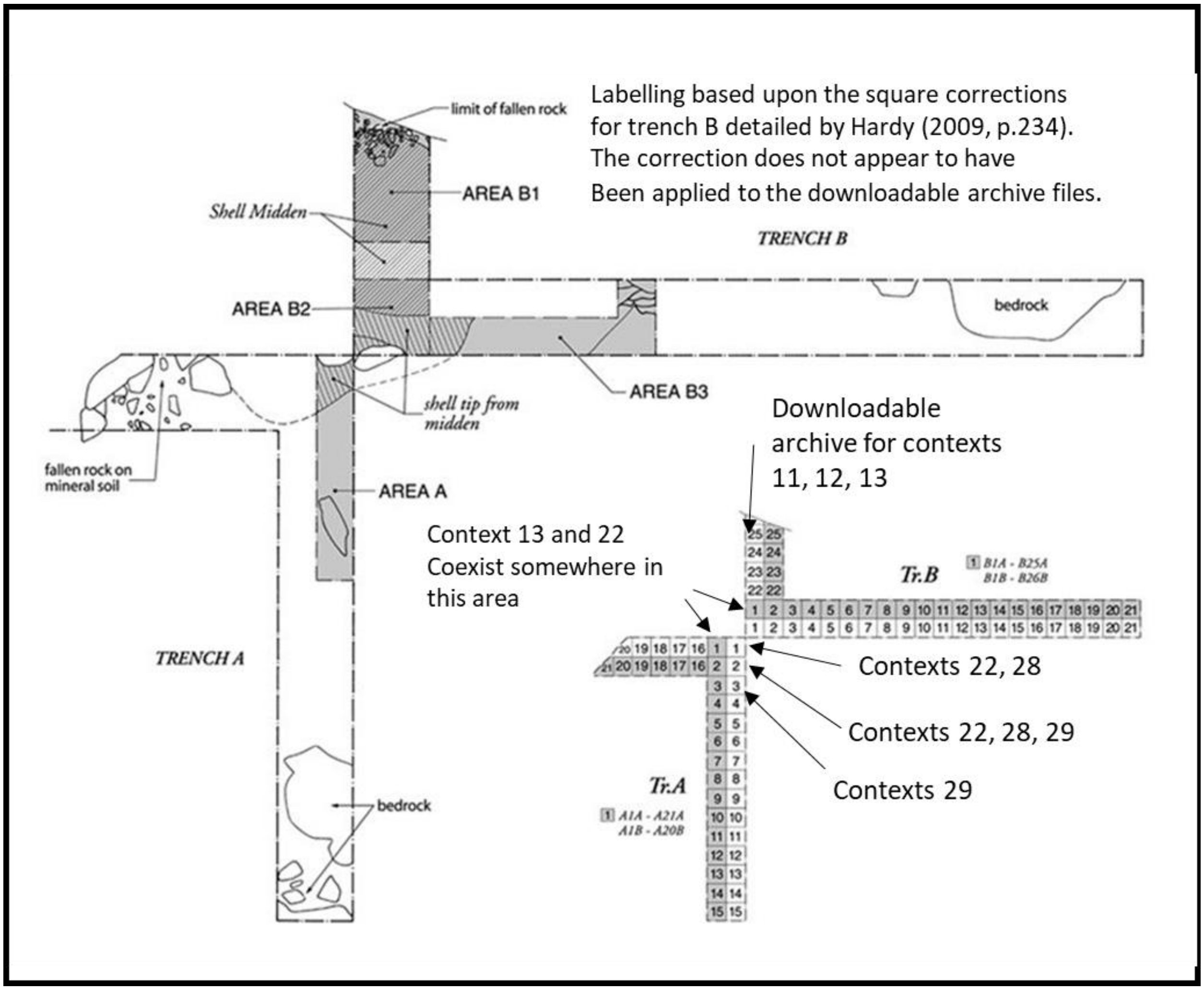


Figure SI-Chapter7-5.3: Oyster would be very marginal in this area, and the prognosis variable based upon the local environment as discussed in the main text.

SI-Chapter7-6: Stratigraphic Context for Sand Rock Shelter and other notes.



Labelling based upon the square corrections for trench B detailed by Hardy (2009, p.234). The correction does not appear to have Been applied to the downloadable archive files.

Downloadable archive for contexts 11, 12, 13

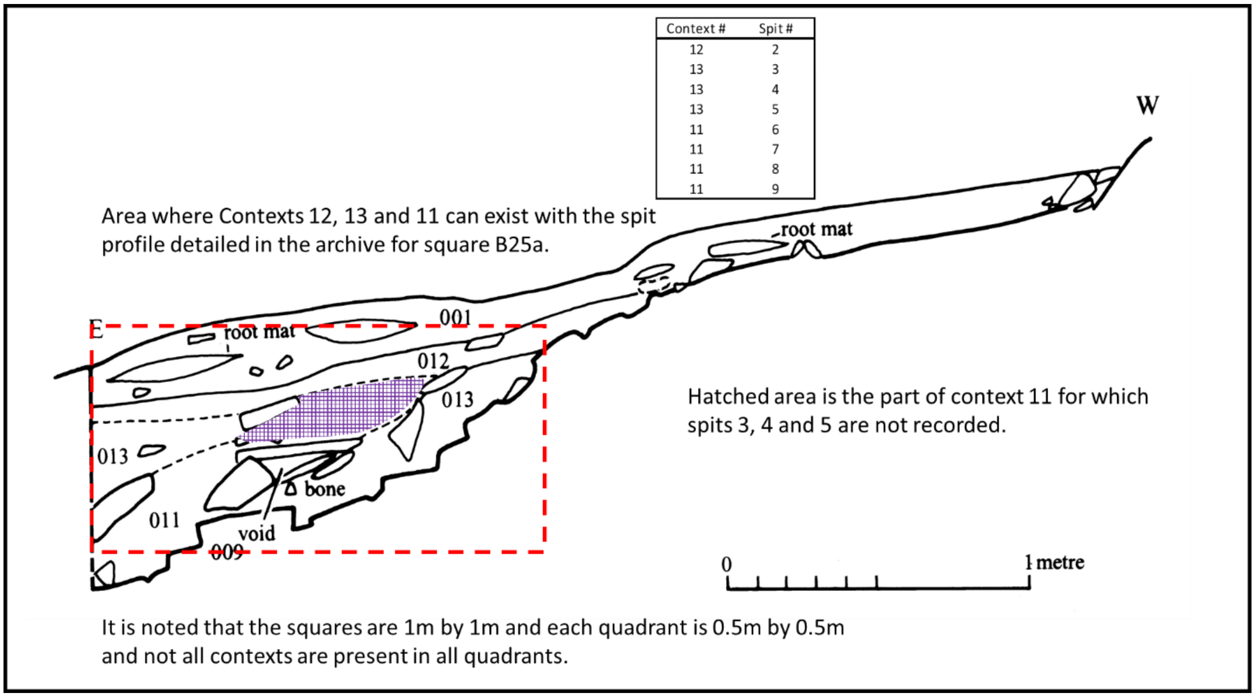
Context 13 and 22 Coexist somewhere in this area

Contexts 22, 28

Contexts 22, 28, 29

Contexts 29

Figure SI-Chapter7-6.1: Plan showing where the archive material was located prior to excavation. Adapted from Hardy (2009, Illus. 334).



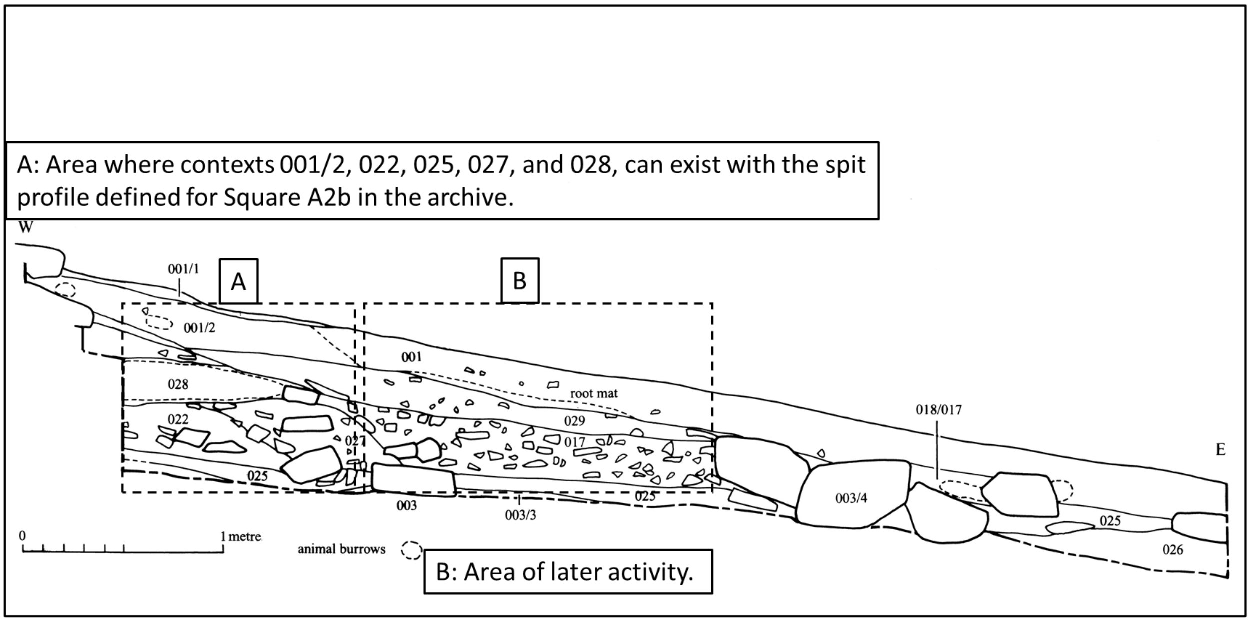
Context #	Spit #
12	2
13	3
13	4
13	5
11	6
11	7
11	8
11	9

Area where Contexts 12, 13 and 11 can exist with the spit profile detailed in the archive for square B25a.

Hatched area is the part of context 11 for which spits 3, 4 and 5 are not recorded.

It is noted that the squares are 1m by 1m and each quadrant is 0.5m by 0.5m and not all contexts are present in all quadrants.

Figure SI-Chapter7-6.2: Stratigraphic relationships in the section. The squares are 1m by 1 m and hence stratigraphy will not necessarily remain fixed in three dimensions. Adapted from Hardy (2009, SFS_FD28).



A: Area where contexts 001/2, 022, 025, 027, and 028, can exist with the spit profile defined for Square A2b in the archive.

B: Area of later activity.

Figure SI-Chapter7-6.3: Stratigraphic relationships within the section. The squares are 1m by 1 m and hence stratigraphy will not necessarily remain fixed in three dimensions. Adapted from Hardy (2009, SFS_16).

SLP and SLP are available but SWP is not, and therefore verification of size change in terms of volume could not be conducted. Generally, the length of the limpets covaries with the conicity which is consistent with the weak allometry between limpet length and limpet height whatever desiccation regime a limpet resides in.

SI-Chapter7-7: Alternative Stratigraphic Sequences at Sand Rock Shelter.

The following represent alternative stratigraphic sequences or aggregations of contexts and spits at Sand. Other are possible. Hardy (2009, p.236) states that context 28 slumped over context 22, what is not clear is whether context 22 is younger than context 28 as asserted. Younger material can slump over older material if the newer deposition becomes unstable. If it accepted that context 28 is older than context 22, it does not follow that it is necessarily much older. The biostratigraphy context 28 is very different to that of contexts 11 and 13. The sequences portrayed here and in the main text have adopting the view point of those who saw the deposits in the ground, that is context 28 is older than context 22.

Alternative Scenario 1.

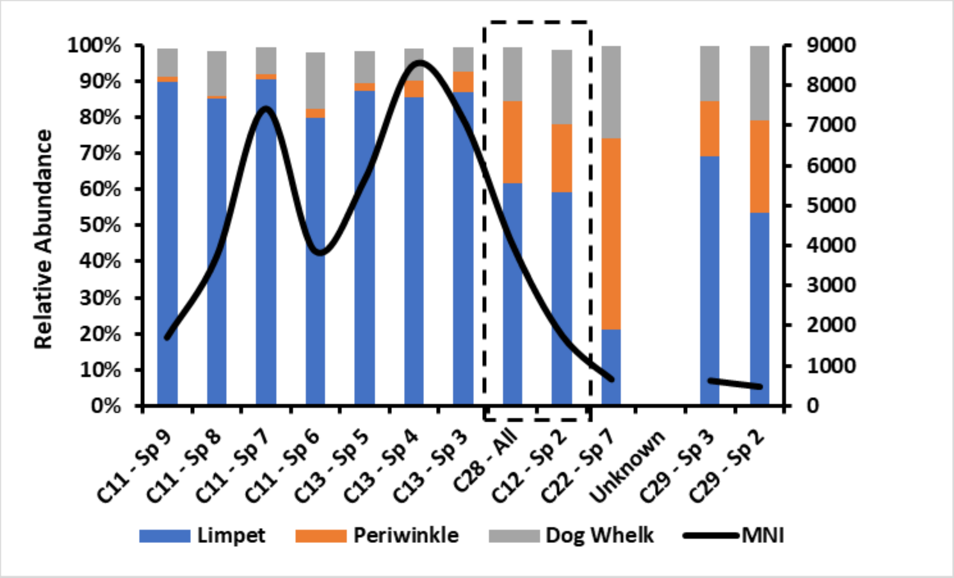


Figure SI-Chapter7-7.1: Context 28 utilised on an aggregated basis. Sequence of Context 28 and 12 could be reversed, they may even be contemporary.

In this scenario (figure SI-Chapter7-7.1 to 7.6) contexts 28 and 12 reflect a change in resource procurement and deposition intensity. The case for a possible hiatus after spit 3 of context 13 remains as stated in the main text.

The situation is more volatile although repositioning context 12 as stated in the caption would support a disruption after spit 3 of context 13 and a steadily increasing level of deposition with declining exploitation of dog whelk and limpet over time.

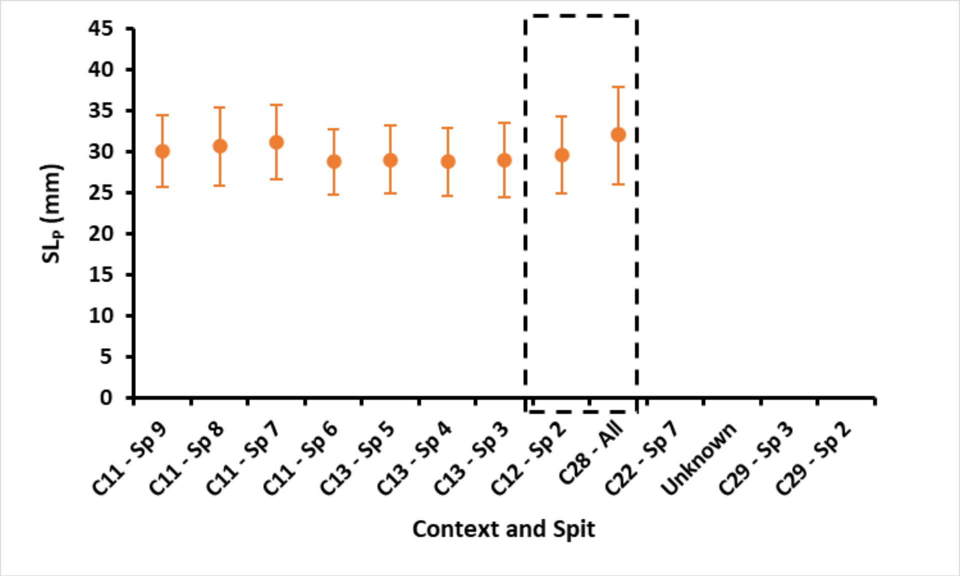


Figure SI-Chapter7-7.2: Limpet length. Unfortunately, there is no data after context 28 and the context 28 data reflects just the final spit (see below).

Limpet size is responding positively to reduced procurement pressure.

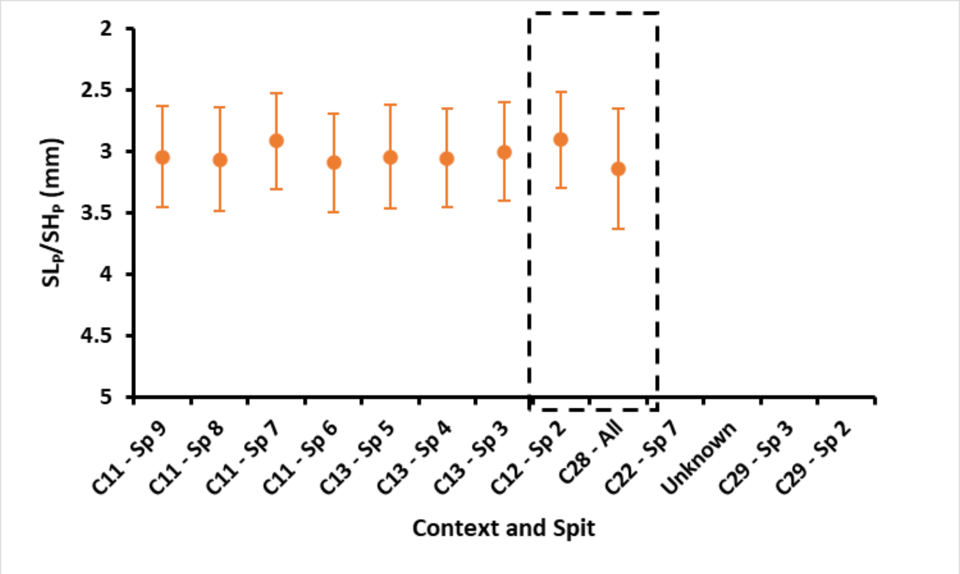


Figure SI-Chapter7-7.3: Reducing conicity in scenario 1. Unfortunately, there is no data after context 28 and the context 28 data reflects just the final spit (see below).

Decreasing conicity with increased length possibly suggests limpets are being acquired from under seaweed.

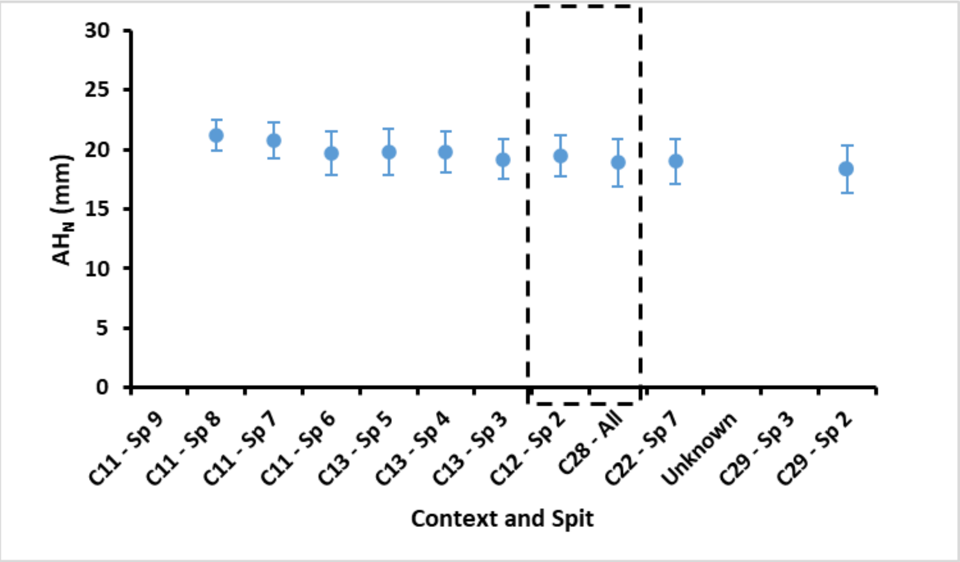


Figure SI-Chapter7-7.4: Dog whelk size in alternative scenario 1.

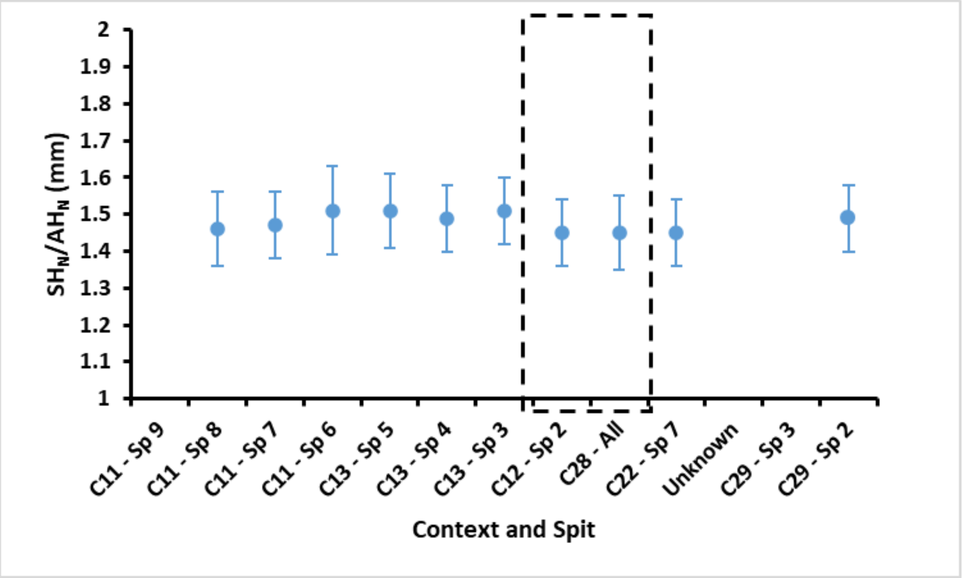


Figure SI-Chapter7-7.5: Dog whelk morphology in alternate scenario 1.

Shore energy level has increased back to context 11 levels after a period of calmer conditions. Periwinkle are getting larger which is consistent with lower procurement pressure but not increasing shore energy (see main text for a discussion).

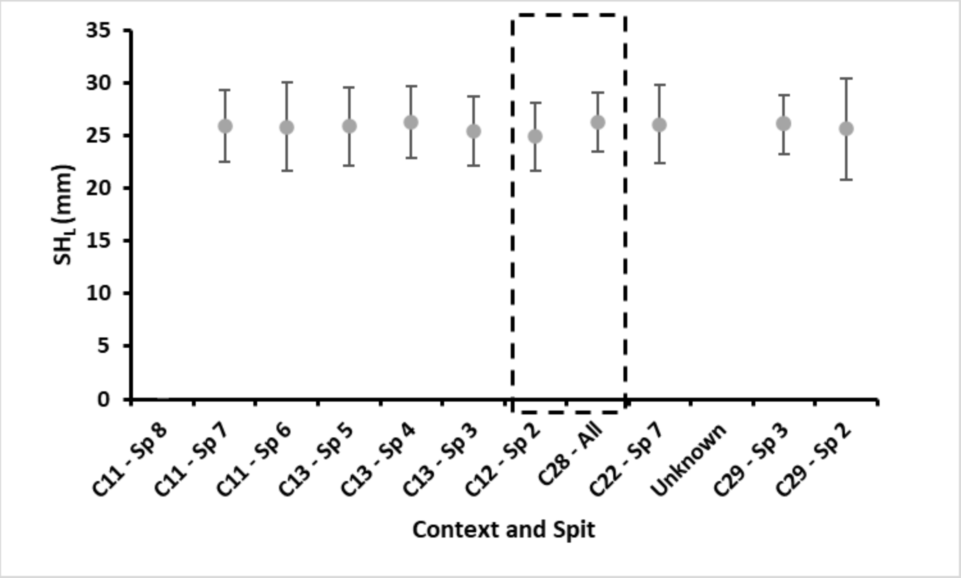


Figure SI-Chapter7-7.6: Periwinkle size in alternative scenario 1.

Alternative Scenario 2.

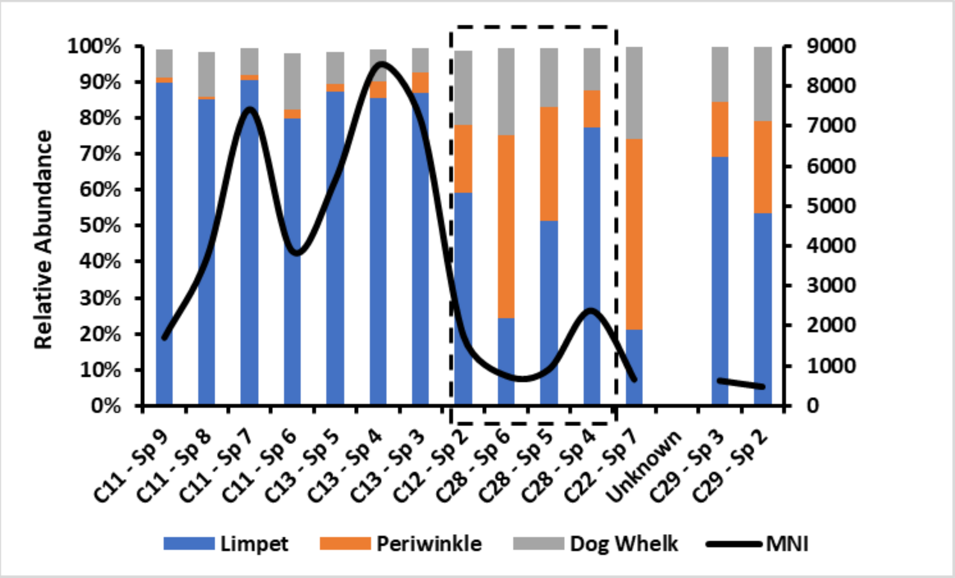


Figure SI-Chapter7-7.7: Context 28 assumed to have slid and maintained its stratigraphy. Context 12 placed with contexts 11 and 13 but it could sit between spits 4 and 5 of context 28 as shown in the main text.

In this scenario (figures SI-Chapter7-7.7 to .12) context 28 is assumed to have slid over context 22 and

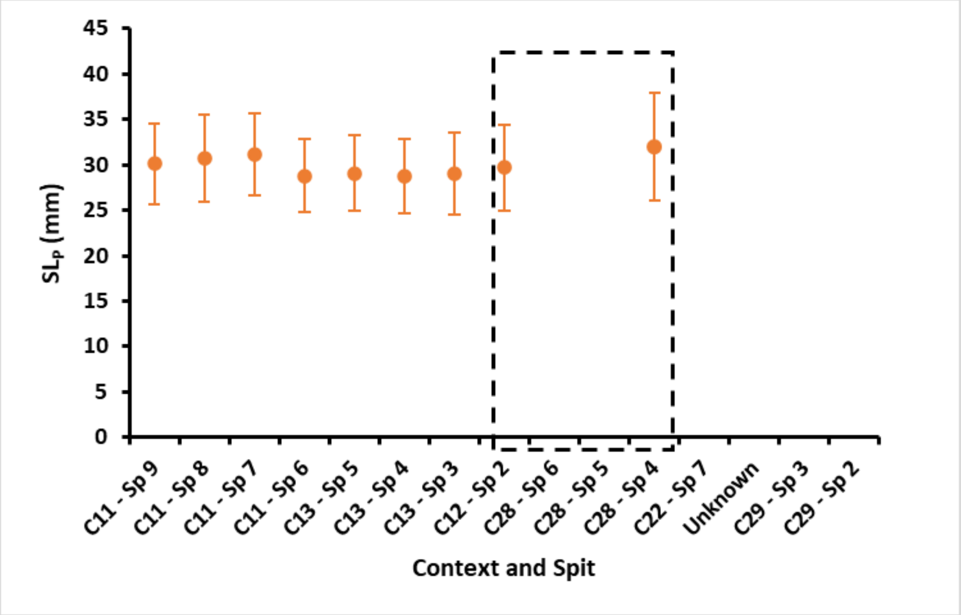


Figure SI-Chapter7-7.8: Limpet length in alternative scenario 2. It is difficult to resist the temptation to interpolate between the final two data points. Placing context 12 between spits 4 and 5 of context 28 as in the main text does not cause an anomalous picture.

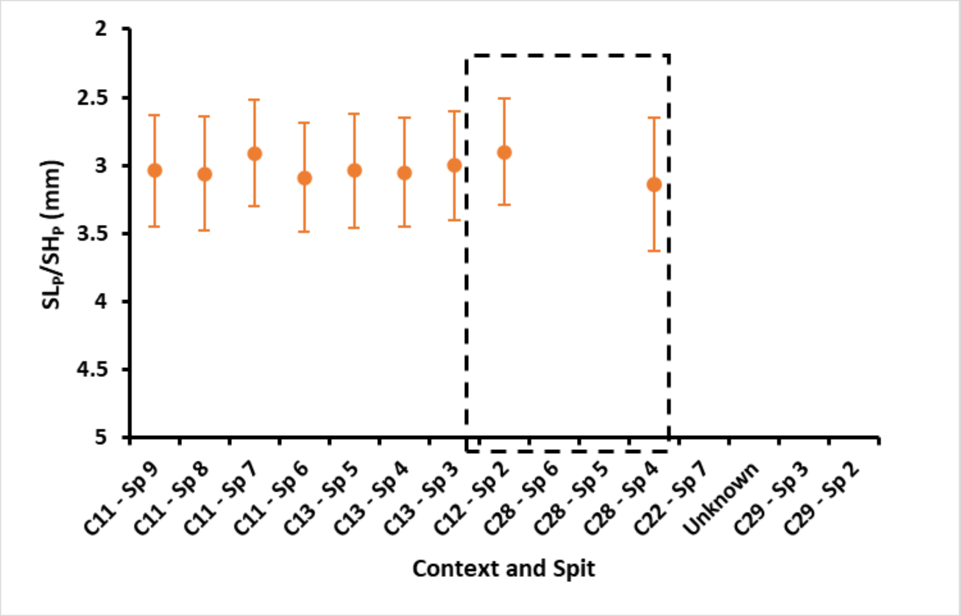


Figure SI-Chapter7-7.9: Limpet conicity in alternative scenario 2. It is difficult to resist the temptation to interpolate between the final two data points.

maintained its stratigraphic sequence. The situation is not dissimilar to the presented in the main text with a period of change. The absolute interpretation is dependent upon where context 12 is considered to sit within the sequence.

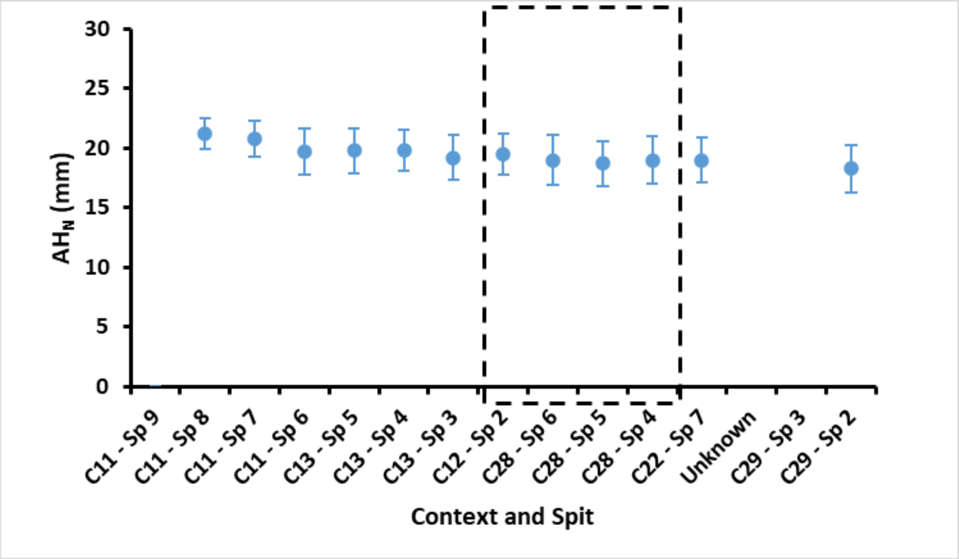


Figure SI-Chapter7-7.10: Dog whelk size in alternative scenario 2.

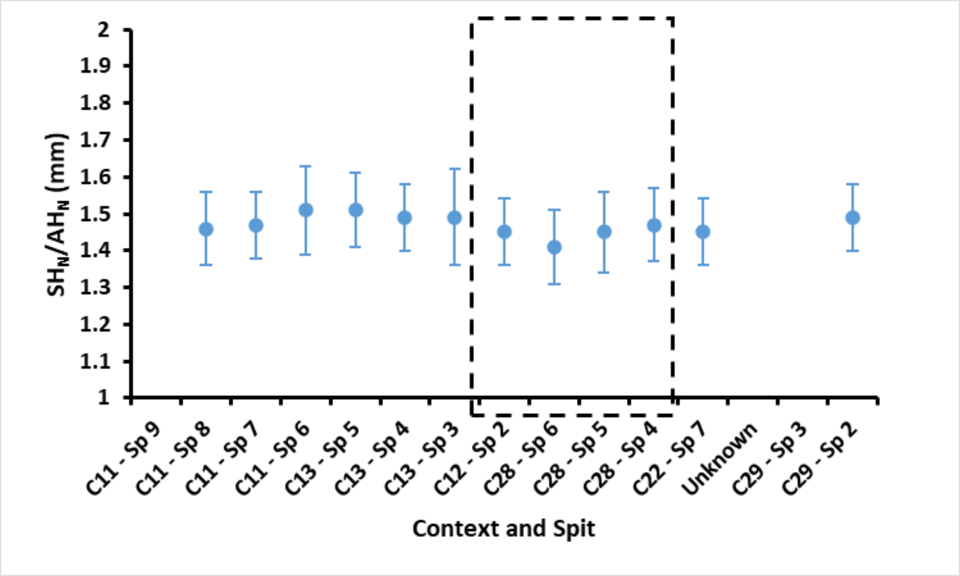


Figure SI-Chapter7-1.11: Dog whelk morphology in alternative scenario 2. Placing context 12 between spits 4 and 5 of context 28 as in the main text does not cause an anomalous picture.

As with the scenario in the main text there is a period of relatively stable dog whelk size during a period of increasing and then decreasing shore energy level, whilst the relative abundance of dog whelk increases.

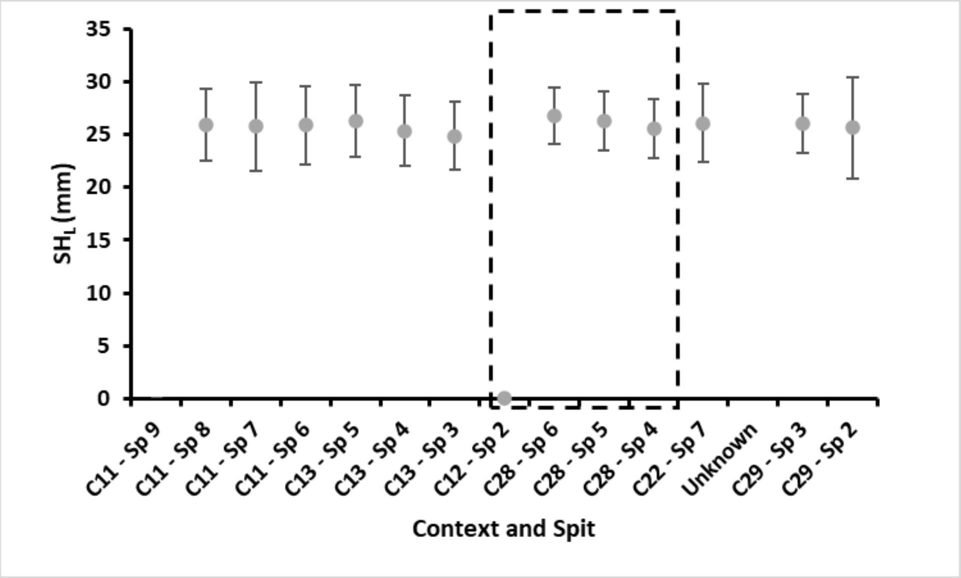


Figure SI-Chapter7-1.12: Periwinkle size in alternative scenario 2.

Periwinkle size is reducing as shore energy levels ameliorate once again suggesting in increased procurement pressure is responsible. The main issue is that absolute procurement levels are low, and periwinkle size remains greater than in context 13. Given dog whelk sizes are stable and the relative abundance of periwinkle is falling dramatically the conclusion must be that the periwinkle population lacks resilience at this point. Why is an interesting question and it is possible that the period of greater shore energy has reduced weed cover and mussel settlement and the grazers such as limpet, are maintaining the situation (Ballantine, 1961b). More availability of bare rock and mussel cover is consistent with increasing dog whelk abundance. A key point is that in this scenario context 22 constitutes a stark reversal in both periwinkle size and relative abundance.

SI-Chapter7-8: Notes on other Scottish Sites.

Drumvargie Cave.

This cave near Oban was occupied during the 8th millennium cal bp but detailed information on the faunal composition is lacking. Anderson (1898) does make ordinal statements on abundance and based upon these it appears that oyster and scallop were the 3rd or 4th or equal 3rd 4th most abundant taxa. The presence of oyster in the middens of Atlantic Scotland is rare beyond a few valves that were probably collected from the shore and may have been curated as tools or other domestic purposes. In chapters 4 and 6 (the latter in relation to West Voe) it was noted that abundance statements of visually distinctive species must be treated with caution and it is with cognizance of this that the exploitation of oyster at this site has been tentatively stated (Table SI-Chapter5-1.6-5), especially as scallops reside in the infralittoral, are mobile, and therefore are likely to have been acquired post-mortem from the shore.

An Corran.

Entry for Periwinkle Sample 36 F Minimum size greater than maximum size. It was assumed that these were the wrong way round, but it could be that the maximum should have been 33 not 23.

Entry for the standard deviation of periwinkles in sample 36G entered incorrectly compared to the others. Using the published value to convert from cm to mm generates a standard deviation which is greater than that covered by the maximum and minimum for this sample.

Sample sizes too small to deal with dog whelks.

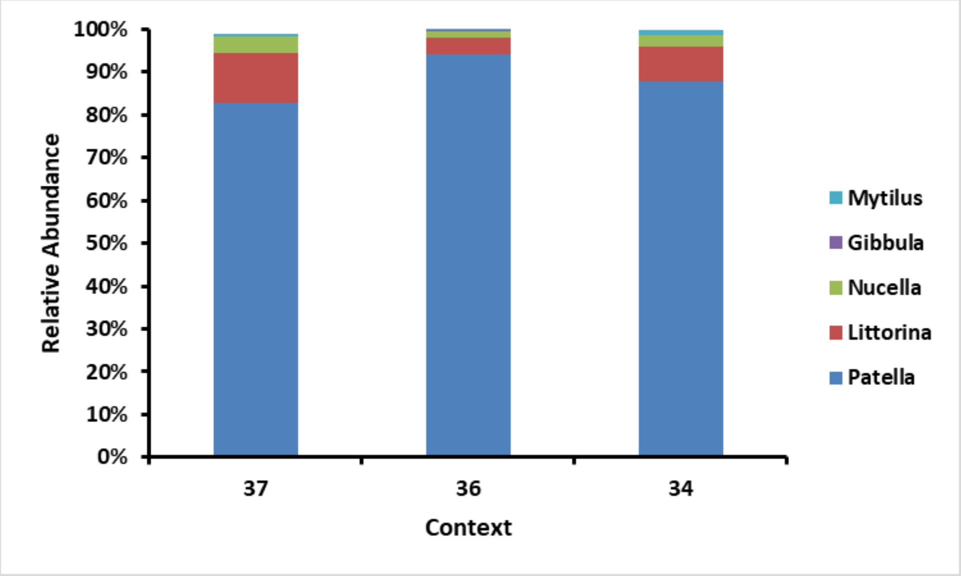


Figure SI-Chapter7-8.1: Faunal composition from the key contexts at An Corran. Data from Pickard, and Bonsall (2012).

Vertebrate assemblages very poor and not very numerous (Bartosiewicz, 2012). Features of note: Sample D context 36 contains a quantity of bird remains dominated by puffin (ibid). Red deer feature early and are then rare (ibid). Skeletal element composition, including antler, only provided at site level (ibid) which covers Mesolithic to Iron age (Saville and Hardy, 2012) and hence is of no value.

SI-Chapter7-9: Characteristics of Selected Faunal Taxa.

The following species were identified as potentially informative bioindicators.

Mammals.

The relative presence of the species preferring woodland Roe Deer, Wild Boar and Elk against red deer is utilised as a proxy for land cover. Today the distribution of the grey seal excludes the Bay of Biscay whereas the harbour seal does inhabit this area (NBA Atlas). The presence of grey seal is therefore a potential indicator of cooler marine environment.

Birds.

The auk family are utilised as a proxy for SST, the guillemot’s range extends to the Channel Islands, whereas the razorbill’s does not (NBN Atlas). They also lack resilience due to low fecundity, laying a single egg per season. The family is semi- precocial, so the vulnerable period for both juvenile and parent on the nest is reduced. The young cannot fly when the male takes them from the nest.

Fish.

Sea Bream (sparidae) are utilised as a proxy for minimum SST and estuarine habitats.

Cod family (gadidae) are utilised as a proxy for maximum SST. Experience thermal stress at SST exceeding 16^{o}C and this can be seen in their otoliths (Høie *et al*, 2009, pp.320-321; Neat *et al*, 2008; Grønkjær, 2016; Igrens *et al*, 2020). The range of pollack, pout, pouting and poor cod extends to the Channel Islands, those of Atlantic cod and saithe do not (NBN Atlas). Significant mortality of gadidae was recorded during the winter of 1963 (SST -1.5^{O}C) (Crisp *et al*, 1964).

Crustaceans.

Furrowed crab: Rocky substrates (Hayward and Ryland, 2012).

Risso's crab: Mixed substrates (Hayward and Ryland, 2012).

Harbour/Sandy swimming crab: sandy substrates (Hayward and Ryland, 2012).

Velvet swimming crab: Rocky substrates (Hayward and Ryland, 2012).

Edible crab: Rocky substrates and semi exposed shores (Hayward and Ryland, 2012; Pickard and Bonsall, 2009), high mortality during the winter of 1963 (SST -1.5^{O}C) (Crisp *et al*, 1964). Soft substrates are required for spawning and migrations in excess of 35km have been observed (Bennett and Brown, 1983). Fertilisation internal, larvae planktonic for around 2 months (Bennett, 1995). Upper thermal tolerance of 21^{O}C to 31^{O}C (Cuculescu, *et al*, 1998). This aspect is only material for individuals resident in the intertidal and shallow infralittoral zones.

Shore crab: Mixed substrates and sheltered shores preferred (Hayward and Ryland, 2012; Pickard and Bonsall, 2009). Upper thermal tolerance of 31^{O}C to 35^{O}C (Cuculescu, *et al*, 1998).

Spider crab: Prefers warmer water, very high mortality during the winter of 1963 (SST -1.5^{O}C) (Crisp *et al*, 1964).

Molluscs

Common periwinkle:

Resilient during the winter of 1963 (SST -1.5^{O}C) (Crisp *et al*, 1964)

Prefers weed cover (Hayward and Ryland, 2012).

Intertidal down to 60m (Hayward and Ryland, 2012).

Prefers low exposure shores, can extend range slightly by seeking cover in fissures or mussel beds which constrains size (Ballantine, 1961a).

Will migrate down the shore in response to extreme temperatures (high or low), resistant to freezing (Aarset, 1982).

Fertilisation internal. Fertilised eggs are then broadcast (Chase and Thomas, 1995; Fish, 1972).

Planktonic stage lasts up to seven weeks (Chase and Thomas, 1995; Fish, 1972).

Spawning recorded at SST ≥ 5^{O}C (Chase and Thomas, 1995).

Dog Whelk:

Resilient during the winter of 1963 (SST -1.5^{O}C). (Crisp *et al*, 1964).

Prefers reasonably exposed shores and avoids extremes at either end of the range (Ballantine, 1961a). Can extend range slightly by seeking cover in fissures which constrains size.

Prefers bare rock (Ballantine, 1961a).

Intertidal mainly but can be found less frequently down to 40m (Hayward and Ryland, 2012).

Morphology changes in response to shore exposure (Palmer, 1990).

Fertilisation internal. No planktonic phase. Dispersal of adult during life usually less than 5m.

Spawning recorded at SST ≥ 9.5^{O}C (Largen, 1967).

Thick Top Shell:

Total mortality during the winter of 1963 (SST -1.5^{O}C). Crisp *et al*, 1964).

Prefers reasonably exposed shores and avoids extremes at either end of the range (Ballantine, 1961). Can extend range slightly by seeking cover in fissures which constrains size.

Prefers bare rock (Crothers, 2001).

Intertidal only (Hayward and Ryland, 2012)

Morphology changes subtly in response to shore exposure (Antunes da Costa, 2015). Although Cabral (2020, p.13) puts this down to abrasion of the spire during life which is greater on exposed shores with abrasive sand sediments.

Broadcast spawner, with external fertilisation within the water column. Critical population density required to support external fertilisation (Crothers, 2001).

Planktonic stage less than 10 days (Crothers, 2001).

Temperature profile based upon modern distribution according to the NBN Atlas.

Peppery Furrow Shell:

Total mortality during the winter of 1963 (SST -1.5^{O}C) Crisp *et al*, 1964.

Prefers sheltered estuarine environments, inhabits sands and especially muds (Hayward and Ryland, 2012).

Shallow burrower.

Intertidal only.

Temperature profile 6-15 C in north wales (Araújo Santos, 2012); consistent with the distribution recorded in the NBN Atlas.

Not tolerant of freezing, vulnerability increased due to preference for low salinity environments.

External fertilisation. Broadcast spawner. Planktonic stage 30 days. Juvenile development 3 times faster at 23°C than at 18°C (Araújo Santos, 2012) Critical population density required to support efficient broadcast spawning and external fertilisation.

Temperature profile based upon modern distribution from the NBN Atlas.

Chequered Carpet Shell:

Total mortality during the winter of 1963. Crisp *et al*, 1964.

Shallow burrower in sand, muddy gravel or clay (Carter, 2003).

Low intertidal zone and shallow sublittoral 10s of metres. (Hayward and Ryland, 2012).

Confined to the English Channel coast between 1873 and 1967. Colonisation of Scotland commenced in 1979, probably enabled by the summer of 1976.

Common Cockle

High mortality in 1963, total in some locations (Crisp *et al*, 1964). Low freezing resistance.

Shallow burrower, in sand, mud or muddy gravel (Hayward and Ryland, 2012).

Intertidal and just into the infralittoral < 10m (Hayward and Ryland, 2012).

Vulnerable to mortality due to dislodgement or smothering during storms. Mass local mortalities are observed frequently (Burden *et al*, 2014).

Not tolerant of freezing, vulnerability increased due to preference for low salinity environments.

Planktonic stage up to 5 weeks (Burden *et al*, 2014).

Critical population density required to support efficient broadcast spawning and external fertilisation.

Spawning triggers at around 13°C (but fertilisation can occur at >5°C), but other factors probably involved (Tyler-Walters, 2007).

***Ensis ensis*.**

Extremely high and widespread mortality in the winter of 1963, tens of thousands washed up at St. Andrews (Crisp *et al*, 1964)

Broadcast spawner (Holme, 1954).

Planktonic stage 20 days (Assumed from *E. siliqua*)

Deep burrower (Henderson and Richardson, 1994).

Fine sand; can tolerate some silt, on sheltered shores.

Low intertidal to shallow sublittoral 10s of metres (Hayward and Ryland, 2012; Holme, 1954).

***Ensis magnus*.**

Extremely high and widespread mortality in the winter of 1963, tens of thousands washed up at St. Andrews (Crisp *et al*, 1964)

Broadcast spawner (Holme, 1954).

Planktonic stage 20 days (Assumed from *E. siliqua*)

Deep burrower (Henderson and Richardson, 1994).

Fine sand, but can tolerate coarser grades, on sheltered shores (Holme, 1954)

Low intertidal to shallow sublittoral 10s of metres (Hayward and Ryland, 2012, Holme, 1954).

***Ensis siliqua*.**

Extremely high and widespread mortality in the winter of 1963, tens of thousands washed up at St. Andrews (Crisp *et al*, 1964)

Broadcast spawner (Holme, 1954).

Planktonic stage 20 days (Da Costa *et al*, 2008)

Deep burrower (Henderson and Richardson, 1994).

Fine sand on sheltered to semi exposed shores (Holme, 1954).

Low intertidal to shallow sublittoral 10s of metres (Hayward and Ryland, 2012; Fahy and Gaffney, 2001; Holme, 1954).

European Oyster.

Very high to total mortality of entire beds in some regions of the UK during the winter of 1963 (SST -1.5^{O}C) (Crisp *et al*, 1964).

Can succeed on both moderately exposed and sheltered estuarine shores (Sloan, 1993).

Low in the intertidal zone and down to 80m (Hayward and Ryland, 2012).

Larviparous, the sperm are broadcast, fertilisation internal. Incubation up to 21 days, followed by planktonic phase of up to 14 days (Gross and Smythe, 1946).

Spawning and juvenile development requires water temperatures of 15^{o}C or more (McGonigle *et al*, 2016; Gross and Smythe, 1946).

Spawning success highly dependent upon population density (Crothers, 2001).

Red Lipped Rock Shell.

Northern limit Cantabrian Spain (recently reported for the first time on the French side of the English Channel) (Pezi *et al*, 2019).

Fertilisation internal. Fertilised eggs are then broadcast (Ayari *et al*, 2017).

Planktonic stage up to 3 months (Ayari *et al*, 2017).

Other Species for general information.

Patella vulgata.

Broadcast spawner (Henriques *et al*, 2017).

Fertilisation in the water column ((Henriques *et al*, 2017; Orton and Southward, 1961).

Planktonic larval stage 2 weeks (Henriques *et al*, 2017).

Population density a factor in successful spawning Crothers (2001).

Inhabits intertidal zone, possibly just into the infralittoral < 5m Hayward and Ryland (2012).

Vulnerable to combinations of high temperatures and calm sea conditions. (Orton, 1933)

Mussel

Broadcast spawner

Locally high mortalities in the winter of 1963 (Crisp *et al*, 1964), yet tolerant of freezing (Aarset, 1982).

Firm substrates.

Mid intertidal zone to shallow sublittoral 10s of metres.

SI-Chapter8.

SI-Chapter8-1: Stable Isotope Analysis of Saithe Otoliths – Methods.

Selection of Specimens

As described in chapter 6 the otoliths were speciated but delineation between Saithe and Pollack primarily to ensure the samples used in isotope analysis were as consistent as possible, given speciation of small juvenile specimens within gadidae is problematic. The biometric criteria provided by Harkonen (1986) and a Boolean approach applied. Any otolith that fell into the Atlantic cod range was rejected, even if it also fell within the range of Pollack and or saithe. Very few specimens (due to size) registered as false for Pollack and true for Saithe or vice versa. A specimen also had to be from the anterior end and ≥50% complete (see main text) as this ensured the widest point was included. The otoliths were also filtered based upon condition as described in the main text, carbonised, eroded or very eroded specimens were rejected.

The results obtained are potentially altered if the aragonite recrystalises into calcite due to diagenesis. These small otoliths could not yield sufficient material to support the stable isotope assay and an XRD analysis of crystalline structure. The author selected a number of otoliths in different preservation categories and after manually reducing the entire otolith to powder the author evaluated the crystalline structure using (X-ray diffraction) XRD within the Materials Analysis Laboratory of the Archaeology Department. The twin peak signature of 2θ (Braggs law) for aragonite is completely swamped, to the point of not being visible, by the magnitude of single peak of calcite; such swamping occurs prior to the composition reaching 25% calcite to 75% aragonite. Otoliths in good condition were aragonite as expected, as were those classified as eroded. Two specimens in the very eroded category returned a result that indicated that at least 25% of the otolith had inverted to calcite Plates SI-Chapter8-1 and 2 at the end of the chapter. It is for this reason that only otoliths in good condition were utilised as stated above.

In the contexts from TNB2 and context 14 of TNB1 and PMS the number of otoliths that remained after the above filtering was limited and otoliths chosen to address the following criteria. Firstly, a number of very small specimens were selected (OW ≤ 1.8mm) as these would indicate temperatures shortly after spawning and when aggregated possibly highlight changes in the timing of spawning. Secondly the very limited number of the largest otoliths were targeted as these generally fell within the 'hole' within Mellars and Wilkinson (1980)'s modern data. Finally, otoliths were targeted where OW was consistent with an OL of between 6 to 7 mm, as based upon the author's analysis of the data in Mellars and Wilkinson (1980), this size range is where the ambiguity between summer, autumn, winter and spring fishing exists in different growth regimes. The remaining budget was assigned by selecting otoliths from other size classes.

Otolith Preparation

The chosen samples were encapsulated within clear EPO-SET Resin combined with EPO-FLOW Hardener using silicon baking moulds and allowed to cure in a fume cupboard for 72 hours. The use of silicon bakeware negates the need for a release agent.

Once cured, the encapsulated otoliths were examined under magnification and the widest point etched onto the resin surface using a fine surgical scalpel. The otoliths were then sectioned by the author in the Thin Section Laboratory in the Earth Sciences Department. The sectioning was conducted at an offset from the etched mark and performed on a water lubricated saw to minimise the heating of the sample. Once sectioned the specimens were ground back to the etched mark by the author using a lapping wheel, again water lubricated, in the Thin Section Laboratory.

Sampling

The micromill is not water lubricated and the rpm was therefore reduced to 5% following (Dias et al, 2019) to minimise heating and therefore possible recrystallisation. To avoid undue mechanical stress due to the reduced RPM, the plunge speed was reduced to 54µms^{-1}. This measure also addresses qualitatively some of the differences between micromilling and hand milling asserted by Waite and Swart (2015). The milling was conducted to a depth of 150µm.

The samples were milled by the author on an ESI/New Wave Micromill in the Sir Kingsley Dunham Paleoclimate Laboratory. After a number of evaluations (on modern mollusc shell) and given the generally unknown territory the incremental analysis of such small otoliths constitutes, the samples were drilled vertically using a Brasseler scriber H1621.11 tungsten carbide fine tipped drill bit, the smallest available in the laboratory. The shaved transect approach utilised by Hufthammer *et al*, 2010 and the Earth Sciences team on speleothems, was unsuitable for otoliths of this size and a minimum aliquot size of 50µg. The placement of milling locations is described in the main text. A key point was that four overlapping aliquots were required to achieve the target weight of 70-100 µg, although often less material was recovered. These were defined as a single pass on the micromill and the aliquot was recovered once all the locations that formed an aliquot had been automatically milled.

Each aliquot was recovered manually, weighed to six decimal places under vacuum on a stabilised weighing table, and then transferred to and sealed in a new vial. The recovery instruments were then cleaned with acetone and the otolith cleaned with a high pressure air gun. If necessary, any stubborn debris was displaced using a fine pointed tool and then the air gun reapplied. The next aliquot was then milled.

Stable Isotope Assay

Carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) isotope ratios were measured in the carbonate (CO_3) component of saithe otoliths. The samples were grouped into groups within 10µg within each batch. The vials were then flushed with helium (grade 4.5) and CO_2 was liberated by reaction with 99% ortho-phosphoric acid for 2 hours at 70°C. The resultant gas mix of helium and CO_2 was transferred through a Thermo Fisher Scientific Gasbench II in which a gas chromatographic column separated the CO_2 from the gas mixture and then passed into a Thermo Fisher Scientific MAT 253 gas source mass spectrometer for isotopic analysis.

The following international reference materials were analysed within each group of samples within in batch, NBS 18 (calcite, n=2), IAEA-CO-1 (marble, n=2) and LSVEC (Lithium Carbonate, n=2). In addition, an internal standard, DCS01 (calcium carbonate, n=2) was also analysed. Repeated analysis of both international and internal standards yielded an analytical precision better than 0.n‰ (1 s.d.) for $\delta^{13}C$ and 0.4‰ (1 s.d.) for $\delta^{18}O$[15]. Normalisations and corrections were made using IAEA-CO-1 and LSVEC, with all $\delta^{13}C$ and $\delta^{18}O$ values reported relative to the Vienna PeeDee Belemnite (VPDB) standard. $\delta^{18}O$ was additionally reported relative to the Vienna Standard Mean Ocean Water (vsmow) standard for comparison purposes. On the advice of Professor Colin MacPherson, the results were adjusted following Kim *et al*, 2007) by adding 0.38‰ to correct for the difference in fractionation between aragonite and calcite during acid dissolution.

Factors Potentially Influencing the Integrity of the Results.

A number of factors can potentially alter the stable isotope ratios in carbonates. One has already been considered above and prompted the evaluation by XRD to assess where aragonite to calcite inversion had occurred due to diagenesis. Waite and Swart (2015) provide a somewhat dystopian outlook (to which Werner Heisenberg would readily relate) by suggesting that the very act of sampling will alter stable isotope ratios randomly, and even possibly when inversion does not occur. This does not appear to have been a concern for other researchers and Dr. James Baldini of the Earth Sciences department stated that in their own test evaluations they had not been able to confirm the phenomenon in a non-inversion scenario. The research cited above appears to be fundamental to the use of oxygen isotopes from mollusc shell otoliths and other marine organisms via milling, possibly dictating the utilisation laser ablation, which the author understands comes with its own set of challenges.

The other primary influence on the stable isotope composition of the sample is the cultural treatment and post depositional histories of the samples, whether they are otoliths or molluscs shells. Have the samples passed through the digestive tract of a human or another species? Have the samples been exposed to other treatments, especially during food preparation? Were the specimens simply discarded

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[15] See the main text. The highly moderated oceanic environment from which the fish originated meant that the author rejected samples with an analytical precision of >0.2‰ (1 SD).

and then left exposed to chemical processes as the flesh surrounding them decomposed? These are just some of the scenarios to be considered.

These scenarios have been explored experimentally. Disspain *et al* (2016) adopted a novel approach to experimental design, as despite each fish they purchased having two otoliths they compared results between different fish, having subjected the otoliths from one fish to one of the treatments (baking, boiling, decomposition) and established a statistical difference in the isotopic composition. Little else needs to be said regarding the lack of value in this result. Andrus and Crowe (2002) utilised a more conventional interpretation of the scientific method and assessed the different treatments using one otolith from each fish as a control whilst subjecting the other to one of the treatments. They concluded no change was observed other than from very high temperatures due to actual burning. In the otoliths analysed in this project the major evidence for post-depositional treatment is staining of the outer layers due to the decomposition of the fish head following discard onto the midden. There is no reason to consider the stable isotope values are altered in such circumstances based upon the results above (ibid).

Quality Control.

As discussed in the main text some samples were rejected. Samples that collapsed clearly presented an issue in terms of inter-aliquot contamination and were rejected. Out and out failure, such as those due to a faulty septum was automatically identified by the technical team prior to the results of a batch being issued. Other samples were identified by the technical team as requiring caution as the automatic quality control checks placed the measured profile were more than one standard deviation outside the control standards. These were reviewed by the author, in each case such results represented an outlying value, yet not beyond the range of a possible result, for oxygen. Such cases always reflected a high, but not impossibly so, summer temperature. The carbon values associated with such specimens were always unreconcilable with other results. All the samples flagged as requiring caution were rejected by the author.

Table SI-Chapter8-1.1: XRD evaluation to check condition versus inversion to calcite.

	Condition	Inverted
Good	12	0
Eroded	13	1
V Eroded	8	1

SI-Chapter8-2: Review of Methods Utilised.

The author would revise the way the otoliths are encapsulated in resin to reduce the loss of samples and therefore intra-otolith sequences due to collapse during milling. With confidence that small otoliths can yield useful information, the author would revise the way the specimens are milled to create greater resolution whilst generating samples of sufficient mass, this will come with a cost in terms of the time investment to conduct such milling due to need to precisely define the concentric paths for the mill to follow using a shaving approach (figure SI-Chapter8-1). Unfettered by personal circumstances, the author would seek to assay isotope samples on a mass spectrometer with an optimal sample weight around 50µg.[16] However, the revised, if more time consuming, approach to milling may negate the need for this last measure.

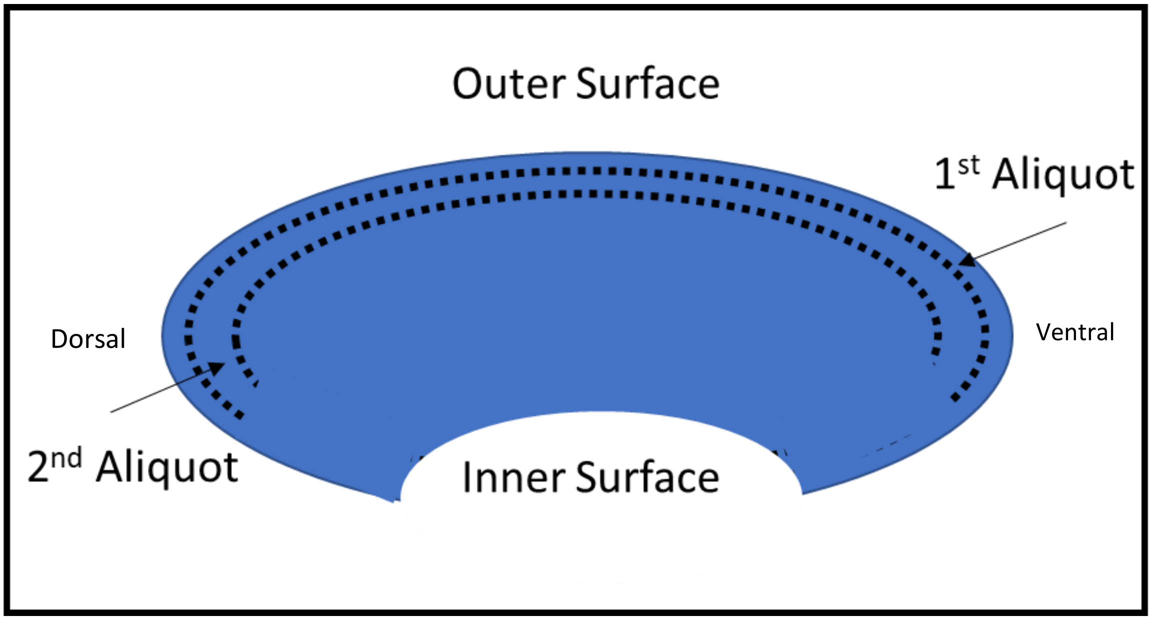

Figure SI-Chapter8-2.1: Conceptual model of the revised sampling of otoliths utilising the capability if the micromill to continuously follow a defined path on the sample. The difference in the rate of aragonite deposition per unit time on the outer surface compared to the ventral and dorsal edges does require further consideration.

SI-Chapter8-3: Oronsay Biometrics.

The taxonomic composition of the Oronsay middens in terms of the three major species of mollusc are provided by Jones (1984) but MNI counts are not provided. The number of dog whelk siphonal canals is provided and where this value is >0 the relative abundance of dog whelk was utilised to reconstruct the total MNI count for a stratigraphic unit.

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[16] This is not a criticism of the equipment utilised, the use of which the author will always remain indebted to the Earth Sciences department, but the equipment is optimised for a different task in assaying samples from speleothems or dentition, where the sample sizes are much larger in terms of mass. 50µg as utilised in the cited literature was the absolute minimum for the configuration utilised.

The mean values for otolith length are not provided for Caisteal nan Gillean II. The means (purely to facilitate a similar method of presentation as other middens) were estimated from the data available in Mellars and Wilkinson (1980). The relative abundance of each bin was utilised with the total number of otoliths to calculate the number of otoliths in each bin. The distribution of otoliths was assumed to be normal within each bin and the mean value to coincide with the centre point of the bin. This data was then used to create a crude estimate of the weighted mean for otolith length in each stratigraphic layer.

The otolith distributions from Caisteal nan Gillean II are presented in figures SI-Chapter8-2 to 5.

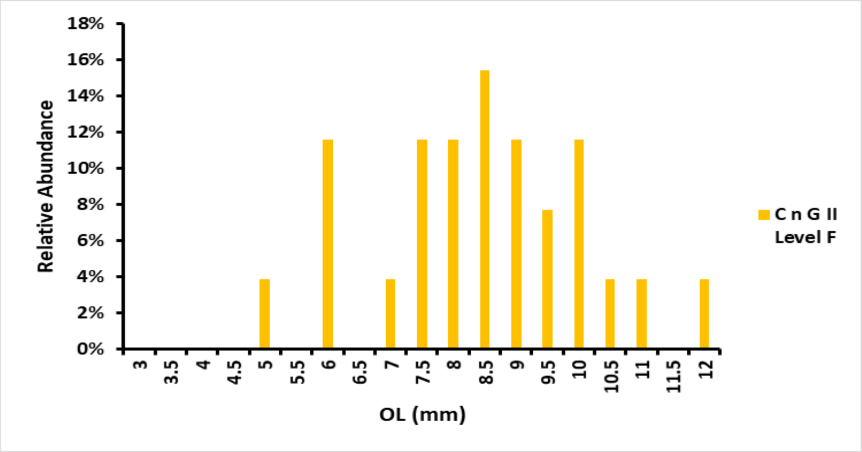

Figure SI-Chapter8-3.1: Otolith lengths from Caisteal nan Gillean II Level F.

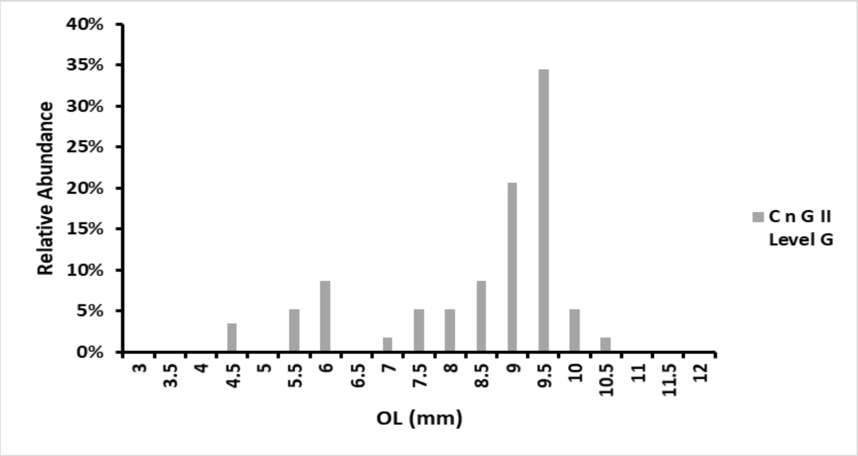

Figure SI-Chapter8-3.2: Otolith lengths from Caisteal nan Gillean II Level G.

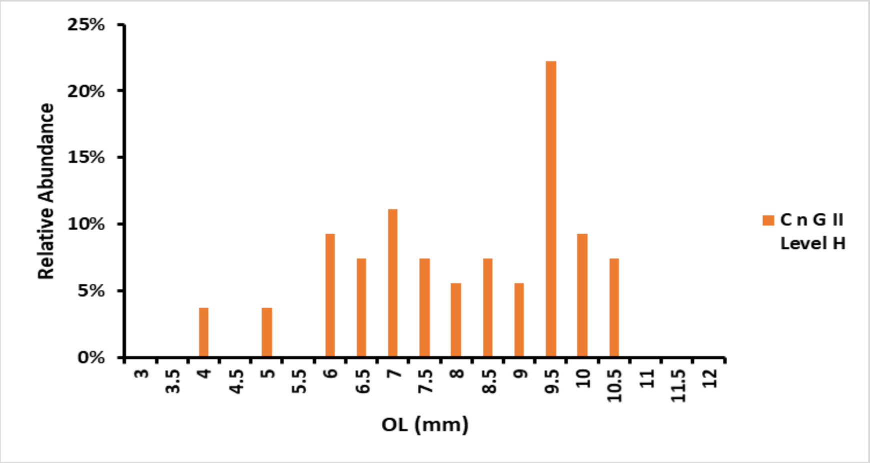

Figure SI-Chapter8-3.3: Otolith lengths from Caisteal nan Gillean II Level H.

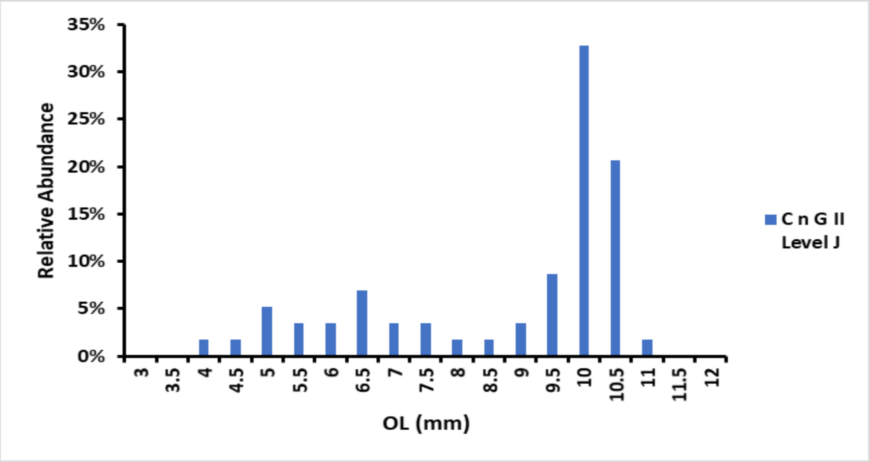

Figure SI-Chapter8-3.4: Otolith lengths from Caisteal nan Gillean II Level J.

SI-Chapter8-4: Summary Statistics and Statistical Test Outcomes.

Otolith Length

Table SI-Chapter8-4.1: Statistical test results for Caisteal nan Gillean II otolith length for all otoliths. Kolmogorov-Smirnov test.

J v H	C n G II	
Max	0.25718	
J (n =)	58	
H (n =)	54	
Sig	0.276839	
H_0	Fail to Reject	
H v G	C n G II	
Max	12	
H (n =)	54	
G (n =)	58	
Sig	1.29361	
H_0	Reject	@ 0.001
G v F	C n G II	
Max	0.205076	
G (n =)	58	
F (n =)	26	
Sig	0.32098	
H_0	Fail to Reject	
J v F	C n G II	
Max	0.545564	
J (n =)	58	
F (n =)	26	
Sig	0.462589	
H_0	Reject	@0.001

Table SI-Chapter8-4.2: Statistical inference test output for Priory and Cnoc Coig for OL for specimens designated as 1st year by Mellars and Wilkinson (1980).

Priory	Mean	SD	n
1	7.07	0.515	25
2	7.41	0.437	59
Confidence	0.05		
DF	82		
Critical	0.00274		
t.test			
	s^2	0.212702	
t statistic	3.089221		
H_0	Reject		

Priory	Mean	SD	n
2	7.41	0.437	59
3	7.65	0.459	66
Confidence	0.05		
DF	123		
Critical	0.003422		
t.test			
	s^2	0.201386	
t statistic	2.984968		
H_0	Reject		

Priory	Mean	SD	n
3	7.65	0.459	66
4-7	8.08	0.736	16
Confidence	0.05		
DF	80		
Critical	0.00411		
t.test			
	s^2	0.272746	
t statistic	2.954704		
H_0	Reject		

Priory	Mean	SD	n
1	7.07	0.515	25
4-7	8.08	0.736	16
Confidence	0.05		
DF	39		
Critical	7.19E-06		
t.test			
	s2	0.37156	
t statistic	5.175412		
H_0	Reject		

C. Coig	Mean	SD	n
Below Midden	6.47	0.811	197
Within Midden	6.72	0.516	356
Confidence	0.05		
DF	551		
Critical	1.18E-05		
t.test			
	s^2	0.405507	
t statistic	4.421163		
H_0	Reject		

Table SI-Chapter8-4.3: Statistical inference test output for Cnoc Silgeach and Cnoc Coig pit 6 for OL for specimens designated as 1st year by Mellars and Wilkinson (1980).

C. Coig (6)	Mean	SD	n	C. Silgeach	Mean	SD	n
17	6.64	0.406	39	B28	5.5	0.952	29
18	6.14	0.524	11	B29	5.18	0.901	31
Confidence	0.05			Confidence	0.05		
DF	48			DF	58		
Critical	0.001446			Critical	0.186218		
t.test				t.test			
	s2	0.187699			s^2	0.857423	
t statistic	3.380518			t statistic	1.337693		
H_0	Reject			H_0	Fail to Reject		
C. Coig (6)	Mean	SD	n	C. Silgeach	Mean	SD	n
18	6.14	0.524	11	B29	5.18	0.901	31
19	8.14	0.709	10	B30	5.24	0.819	30
Confidence	0.05			Confidence	0.05		
DF	19			DF	59		
Critical	5.23E-07			Critical	0.786659		
t.test				t.test			
	s2	0.382626			s^2	0.742476	
t statistic	7.399964			t statistic	0.271886		
H_0	Reject			H_0	Fail to Reject		
C. Coig (6)	Mean	SD	n	C. Silgeach	Mean	SD	n
19	8.14	0.709	10	B30	5.24	0.819	30
20	6.97	0.395	18	B31	5.81	0.776	25
Confidence	0.05			Confidence	0.05		
DF	26			DF	53		
Critical	6.16E-06			Critical	0.011103		
t.test				t.test			
	s2	0.276021			s^2	0.639704	
t statistic	5.646402			t statistic	2.63169		
H_0	Reject			H_0	Reject		
C. Coig (6)	Mean	SD	n	C. Silgeach	Mean	SD	n
20	6.97	0.395	18	B31	5.81	0.776	25
21	6.91	0.75	17	B32	5.2	0.436	13
Confidence	0.05			Confidence	0.05		
DF	33			DF	36		
Critical	0.76715			Critical	0.0129		
t.test				t.test			
	s2	0.353104			s^2	0.464816	
t statistic	0.298557			t statistic	2.616611		
H_0	Fail to Reject			H_0	Reject		
C. Coig (6)	Mean	SD	n	C. Silgeach	Mean	SD	n
17	6.64	0.406	39	B28	5.5	0.952	29
21	6.91	0.75	17	B32	5.2	0.436	13
Confidence	0.05			Confidence	0.05		
DF	54			DF	40		
Critical	0.086253			Critical	0.286211		
t.test				t.test			
	s2	0.282662			s2	0.691442	
t statistic	1.747401			t statistic	1.08091		
H_0	Fail to Reject			H_0	Fail to Reject		

Table SI-Chapter8-5.4: Summary Statistics for OL from the Oronsay Middens. Data from Mellars and Wilkinson (1980)

Cnoc Silgeach		1st Year	
	n	Mean	St.dev
B28	29	5.5	0.952
B29	31	5.18	0.901
B30	30	5.24	0.819
B31	25	5.81	0.776
B32	13	5.2	0.436
Cnoc Coig		Column 6	
	n	Mean	St.dev
17	39	6.64	0.406
18	11	6.14	0.524
19	10	8.14	0.709
20	18	6.97	0.395
21	17	6.91	0.75
Priory		1st Year	
	n	Mean	St.dev
1	25	7.07	0.515
2	59	7.41	0.437
3	66	7.65	0.459
4-7	16	8.08	0.736
Cnoc Coig		1st Year	
	n	Mean	St.dev
Below Midden	197	6.47	0.811
Within Midden	356	6.72	0.516

Limpet Length

Table SI-Chapter8-4.5: Statistical testing output for SL_P from the Oronsay middens. Data from Jones (1984).

Priory	Mean	SD	n
1	30.74	5.224596	129
2	31.03	4.656522	112
Confidence	0.05		
DF	239		
Critical	0.651754		
t.test			
	s^2	24.68943	
t statistic	0.451895		
H_0	Fail to Reject		

Priory	Mean	SD	n
2	31.03	4.656522	112
3	31.75	5.67253	119
Confidence	0.05		
DF	229		
Critical	0.294482		
t.test			
	s^2	27.09079	
t statistic	1.050747		
H_0	Fail to Reject		

Priory	Mean	SD	n
3	31.75	5.67253	119
4	32.02	4.866374	164
Confidence	0.05		
DF	281		
Critical	0.667871		
t.test			
	s^2	27.24932	
t statistic	0.429525		
H_0	Fail to Reject		

Priory	Mean	SD	n
4	32.02	4.866374	164
5	30.73	4.01995	101
Confidence	0.05		
DF	263		
Critical	0.026252		
t.test			
	s2	20.82168	
t statistic	2.235072		
H_0	Reject		

Priory	Mean	SD	n
5	30.73	4.01995	101
6	32.02	4.272236	120
Confidence	0.05		
DF	219		
Critical	0.022563		
t.test			
	s2	17.29675	
t statistic	2.297009		
H_0	Reject		

Priory	Mean	SD	n
6	32.02	4.272236	120
7	32.73	5.295998	159
Confidence	0.05		
DF	277		
Critical	0.230183		
t.test			
	s2	23.83938	
t statistic	1.202536		
H_0	Fail to Reject		

Priory	Mean	SD	n
7	32.73	5.295998	159
8	33.99	3.865876	122
Confidence	0.05		
DF	279		
Critical	0.027661		
t.test			
	s2	22.36511	
t statistic	2.213657		
H_0	Reject		

Priory	Mean	SD	n
8	33.99	3.865876	122
9	33.1	5.237939	190
Confidence	0.05		
DF	310		
Critical	0.10731		
t.test			
	s2	22.56048	
t statistic	1.615085		
H_0	Fail to Reject		

Priory	Mean	SD	n
9	33.1	5.237939	190
10	32.12	4.86999	183
Confidence	0.05		
DF	371		
Critical	0.062322		
t.test			
	s2	25.61149	
t statistic	1.869634		
H_0	Fail to Reject		

Priory	Mean	SD	n
1	30.74	5.224596	129
10	32.12	4.86999	183
Confidence	0.05		
DF	310		
Critical	0.017377		
t.test			
	s2	25.19483	
t statistic	2.391479		
H_0	Reject		

C. Coig - 6	Mean	SD	n	C. Coig - 10	Mean	SD	n
17	27.34	5.196152	48	9	29.57	4.583939	125
18	28.46	5.031153	125	10	29.83	4.136726	125
Confidence	0.05			Confidence	0.05		
DF	171			DF	248		
Critical	0.19564			Critical	0.638207		
t.test				t.test			
	s^2	25.77632			s2	19.0625	
t statistic	1.299153			t statistic	0.470786		
H_0	Fail to Reject			H_0	Fail to Reject		

C. Coig - 6	Mean	SD	n	C. Coig - 10	Mean	SD	n
18	28.46	5.031153	125	10	29.83	4.136726	125
20	29.34	4.360333	125	11	30.47	4.360333	125
Confidence	0.05			Confidence	0.05		
DF	248			DF	248		
Critical	0.140732			Critical	0.234986		
t.test				t.test			
	s2	22.1625			s2	18.0625	
t statistic	1.477792			t statistic	1.190505		
H_0	Fail to Reject			H_0	Fail to Reject		

C. Coig - 6	Mean	SD	n	C. Coig - 10	Mean	SD	n
20	29.34	4.360333	125	11	30.47	4.472136	125
21	28.61	3.913119	125	12	30.56	4.360333	125
Confidence	0.05			Confidence	0.05		
DF	248			DF	248		
Critical	0.164846			Critical	0.872146		
t.test				t.test			
	s2	17.1625			s2	19.50625	
t statistic	1.393069			t statistic	0.1611		
H_0	Fail to Reject			H_0	Fail to Reject		

C. Coig - 6	Mean	SD	n	C. Coig - 10	Mean	SD	n
21	28.61	3.913119	125	9	29.57	4.583939	125
Premidden	26.47	3.132092	109	12	30.56	4.360333	125
Confidence	0.05			Confidence	0.05		
DF	232			DF	248		
Critical	0.000324			Critical	0.081434		
t.test				t.test			
	s2	12.75099			s2	20.0125	
t statistic	3.650257			t statistic	1.749543		
H_0	Reject			H_0	Fail to Reject		

C n G I	Mean	SD	n
1	31.02	4.929503	120
2	30.1	4.572614	108
Confidence	0.05		
DF	226		
Critical	0.146779		
t.test			
	s^2	22.69443	
t statistic	1.456006		
H_0	Fail to Reject		

C n G I	Mean	SD	n
2	30.1	4.572614	108
3	30.38	4.509878	110
Confidence	0.05		
DF	216		
Critical	0.649439		
t.test			
	s2	20.62126	
t statistic	0.455177		
H_0	Fail to Reject		

C n G I	Mean	SD	n
1	31.02	4.929503	120
3	30.38	4.509878	110
Confidence	0.05		
DF	228		
Critical	0.30679		
t.test			
	s2	22.40636	
t statistic	1.024277		
H_0	Fail to Reject		

C n G II	Mean	SD	n
E	29.61	4.137221	46
F	31.77	4.583939	125
Confidence	0.05		
DF	169		
Critical	0.005664		
t.test			
	s^2	19.97513	
t statistic	2.802495		
H_0	Reject		

C n G II	Mean	SD	n
F	31.77	4.583939	125
G	32.57	5.25476	125
Confidence	0.05		
DF	248		
Critical	0.200805		
t.test			
	s2	24.3125	
t statistic	1.282671		
H_0	Fail to Reject		

C n G II	Mean	SD	n
G	32.57	5.25476	125
H	32.57	5.031153	125
Confidence	0.05		
DF	248		
Critical	1		
t.test			
	s2	26.4625	
t statistic	0		
H_0	Fail to Reject		

C n G II	Mean	SD	n
H	32.57	5.031153	125
J	33.2	5.366563	125
Confidence	0.05		
DF	248		
Critical	0.339239		
t.test			
	s2	27.05625	
t statistic	0.957518		
H_0	Fail to Reject		

C n G II	Mean	SD	n
E	29.61	4.137221	46
J	33.2	5.366563	125
Confidence	0.05		
DF	169		
Critical	6.22E-05		
t.test			
	s2	25.68904	
t statistic	4.1073		
H_0	Reject		

C. Sligeach	Mean	SD	n
28	29.58	4.603998	92
29	31.96	4.136726	125
Confidence	0.05		
DF	215		
Critical	9.01E-05		
t.test			
	s^2	18.8412	
t statistic	3.991551		
H_0	Reject		

C. Sligeach	Mean	SD	n
29	31.96	4.136726	125
30	31.77	4.472136	125
Confidence	0.05		
DF	248		
Critical	0.727612		
t.test			
	s^2	18.55625	
t statistic	0.348697		
H_0	Fail to Reject		

C. Sligeach	Mean	SD	n
30	31.77	4.472136	125
31	30.44	3.913119	125
Confidence	0.05		
DF	248		
Critical	0.012983		
t.test			
	s^2	17.65625	
t statistic	2.502318		
H_0	Reject		

Table SI-Chapter8-4.6: Summary statistics for SL_P for the Oronsay middens data from Jones (1984).

Priory			
	n	Mean	St.dev
1	129	30.74	5.224596
2	112	31.03	4.656522
3	119	31.75	5.67253
4	164	32.02	4.866374
5	101	30.73	4.01995
6	120	32.02	4.272236
7	159	32.73	5.295998
8	122	33.99	3.865876
9	190	33.1	5.237939
10	183	32.12	4.86999

Priory			
	n	Mean	St.dev
1	129	30.74	5.224596
2	112	31.03	4.656522
3	119	31.75	5.67253
4-7	544	31.98801	4.76468
8	122	33.99	3.865876
9	190	33.1	5.237939
10	183	32.12	4.86999

Cnoc Silgeach			
	n	Mean	St.dev
28	92	29.58	4.603998
29	125	31.96	4.136726
30	125	31.77	4.472136
31	125	30.44	3.913119

Cnoc Coig	Pit 6		
	n	Mean	St.dev
17	48	27.34	5.196152
18	125	28.46	5.031153
19			
20	125	29.34	4.360333
21	125	28.61	3.913119
Premidden	109	26.47	3.132092

Cnoc Coig	Pit 10		
	n	Mean	St.dev
9	125	29.57	4.583939
10	125	29.83	4.136726
11	125	30.47	4.472136
12	125	30.56	4.360333

CNG I			
	n	Mean	St.dev
1	120	31.02	4.929503
2	108	30.1	4.572614
3	110	30.38	4.509878

CNG II			
	n	Mean	St.dev
E	46	29.61	4.137221
F	125	31.77	4.583939
G	125	32.57	5.25476
H	125	32.57	5.031153
J	125	33.2	5.366563

Limpet Conicity

Table SI-Chapter8-4.7: Statistical testing output for limpet conicity from the Oronsay mideens. Data from Jones (1984).

Priory	Mean	SD	n
1	3.16	0.4543127	129
2	3.19	0.4233202	112
Confidence	0.05		
DF	239		
Critical	0.598206		
t.test			
	s^2	0.1937674	
t statistic	0.527687		
H_0	Fail to Reject		

Priory	Mean	SD	n
2	3.19	0.4233202	112
3	3.04	0.4363485	119
Confidence	0.05		
DF	229		
Critical	0.00863		
t.test			
	s^2	0.1849712	
t statistic	2.649206		
H_0	Reject		

Priory	Mean	SD	n
3	3.04	0.4363485	119
4	3.15	0.5122499	164
Confidence	0.05		
DF	281		
Critical	0.05901		
t.test			
	s^2	0.2321651	
t statistic	1.895817		
H_0	Fail to Reject		

Priory	Mean	SD	n
4	3.15	0.5122499	164
5	3.15	0.5024938	101
Confidence	0.05		
DF	263		
Critical	1		
t.test			
	s2	0.2586357	
t statistic	0		
H_0	Fail to Reject		

Priory	Mean	SD	n
5	3.15	0.5024938	101
6	3.22	0.438178	120
Confidence	0.05		
DF	219		
Critical	0.269878		
t.test			
	s2	0.2196256	
t statistic	1.106144		
H_0	Fail to Reject		

Priory	Mean	SD	n
6	3.22	0.438178	120
7	3	0.3782856	159
Confidence	0.05		
DF	277		
Critical	1.04E-05		
t.test			
	s2	0.1641076	
t statistic	4.491025		
H_0	Reject		

Priory	Mean	SD	n
7	3	0.3782856	159
8	3.16	0.4418144	122
Confidence	0.05		
DF	279		
Critical	0.001228		
t.test			
	s2	0.1656953	
t statistic	3.265804		
H_0	Reject		

Priory	Mean	SD	n
8	3.16	0.4418144	122
9	3	0.4135215	190
Confidence	0.05		
DF	310		
Critical	0.001296		
t.test			
	s2	0.1804458	
t statistic	3.246579		
H_0	Reject		

Priory	Mean	SD	n
9	3	0.4135215	190
10	3.17	0.4058325	183
Confidence	0.05		
DF	371		
Critical	7.48E-05		
t.test			
	s2	0.1679094	
t statistic	4.005524		
H_0	Reject		

C. Coig (6)	Mean	SD	n	C. Coig (10)	Mean	SD	n
17	3.16	0.484974	48	9	3.06	0.447214	125
18	3.13	0.559017	125	10	3.08	0.447214	125
Confidence	0.05			Confidence	0.05		
DF	171			DF	248		
Critical	0.743789			Critical	0.723974		
t.test				t.test			
	s^2	0.291254			s2	0.2	
t statistic	0.327369			t statistic	0.353553		
H_0	Fail to Reject			H_0	Fail to Reject		

C. Coig (6)	Mean	SD	n	C. Coig (10)	Mean	SD	n
18	3.13	0.559017	125	10	3.08	0.447214	125
20	3.12	0.447214	125	11	3.07	0.447214	125
Confidence	0.05			Confidence	0.05		
DF	248			DF	248		
Critical	0.876023			Critical	0.859828		
t.test				t.test			
	s2	0.25625			s2	0.2	
t statistic	0.156174			t statistic	0.176777		
H_0	Fail to Reject			H_0	Fail to Reject		

C. Coig (6)	Mean	SD	n	C. Coig (10)	Mean	SD	n
20	3.12	0.447214	125	11	3.07	0.447214	125
21	3.19	0.447214	125	12	3.1	0.447214	12
Confidence	0.05			Confidence	0.05		
DF	248			DF	135		
Critical	0.217095			Critical	0.824674		
t.test				t.test			
	s2	0.2			s2	0.2	
t statistic	1.237437			t statistic	0.221969		
H_0	Fail to Reject			H_0	Fail to Reject		

C. Coig (6)	Mean	SD	n	C. Coig (10)	Mean	SD	n
21	3.19	0.447214	125	9	3.06	0.447214	125
Premidden	3.1	0.417612	109	12	3.1	0.447214	12
Confidence	0.05			Confidence	0.05		
DF	232			DF	135		
Critical	0.114661			Critical	0.767717		
t.test				t.test			
	s2	0.188083			s2	0.2	
t statistic	1.583537			t statistic	0.295958		
H_0	Fail to Reject			H_0	Fail to Reject		

C n G I	Mean	SD	n
1	3.02	0.438178	120
2	3.01	0.415692	108
Confidence	0.05		
DF	226		
Critical	0.860227		
t.test			
	s^2	0.18291	
t statistic	0.176286		
H_0	Fail to Reject		

C n G I	Mean	SD	n
2	3.01	0.415692	108
3	3.04	0.524404	110
Confidence	0.05		
DF	216		
Critical	0.640587		
t.test			
	s2	0.224373	
t statistic	0.467537		
H_0	Fail to Reject		

C. Silgeach	Mean	SD	n
28	3.16	0.479583	92
29	3.04	0.447214	125
Confidence	0.05		
DF	215		
Critical	0.059545		
t.test			
	s^2	0.212698	
t statistic	1.89417		
H_0	Fail to Reject		

C. Silgeach	Mean	SD	n
29	3.04	0.447214	125
30	3.06	0.447214	125
Confidence	0.05		
DF	248		
Critical	0.723974		
t.test			
	s^2	0.2	
t statistic	0.353553		
H_0	Fail to Reject		

C. Silgeach	Mean	SD	n
30	3.06	0.447214	125
31	3.28	0.447214	125
Confidence	0.05		
DF	248		
Critical	0.000129		
t.test			
	s^2	0.2	
t statistic	3.889087		
H_0	Reject		

C n G II	Mean	SD	n
E	3.08	0.40694	46
F	3.01	0.447214	125
Confidence	0.05		
DF	169		
Critical	0.354122		
t.test			
	s^2	0.19084	
t statistic	0.929178		
H_0	Fail to Reject		

C n G II	Mean	SD	n
F	3.01	0.447214	125
G	3.12	0.782624	125
Confidence	0.05		
DF	248		
Critical	0.173684		
t.test			
	s2	0.40625	
t statistic	1.364382		
H_0	Fail to Reject		

C n G II	Mean	SD	n
G	3.12	0.782624	125
H	3.02	0.447214	125
Confidence	0.05		
DF	248		
Critical	0.216019		
t.test			
	s2	0.40625	
t statistic	1.240347		
H_0	Fail to Reject		

C n G II	Mean	SD	n
H	3.02	0.447214	125
J	2.96	0.447214	125
Confidence	0.05		
DF	248		
Critical	0.289876		
t.test			
	s2	0.2	
t statistic	1.06066		
H_0	Fail to Reject		

TableSI-Chapter8-4.8: Summary statistics for limpet conicity from the Oronsay middens. Data from Jones (1984).

Cnoc Coig		Pit 6	
	n	Mean	St.dev
17	48	3.16	0.484974
18	125	3.13	0.559017
19			
20	125	3.12	0.447214
21	125	3.19	0.447214
Premidden	109	3.1	0.417612

Cnoc Coig		Pit 10	
	n	Mean	St.dev
9	125	3.06	0.447214
10	125	3.08	0.447214
11	125	3.07	0.447214
12	125	3.1	0.447214

Cnoc Silgeach			
	n	Mean	St.dev
28	92	3.16	0.479583
29	125	3.04	0.447214
30	125	3.06	0.447214
31	125	3.28	0.447214

Priory			
	n	Mean	St.dev
1	129	3.16	0.454313
2	112	3.19	0.42332
3	119	3.04	0.436348
4	164	3.15	0.51225
5	101	3.15	0.502494
6	120	3.22	0.438178
7	159	3.00	0.378286
8	122	3.16	0.441814
9	190	3.00	0.413521
10	183	3.17	0.405832

CNG I			
	n	Mean	St.dev
1	120	3.02	0.438178
2	108	3.01	0.415692
3	110	3.04	0.524404

CNG II			
	n	Mean	St.dev
E	46	3.08	0.40694
F	125	3.01	0.447214
G	125	3.12	0.782624
H	125	3.02	0.447214
J	125	2.96	0.447214

Dog Whelk.

Table SI-Chapter8-4.9: Statistical testing output for AH_N from the Oronsay middens. Data from Jones (1984).

C. Silgeach	Mean	SD	n	Priory	Mean	SD	n
28	19.5	1.85731	44	1	19.68	2.0139513	15
29	19.59	1.525647	44	2	18.93	1.5697771	18
Confidence	0.05			Confidence	0.05		
DF	86			DF	31		
Critical	0.804435			Critical	0.238298		
t.test				t.test			
	s^2	2.8886			s^2	3.1830774	
t statistic	0.248376			t statistic	1.202438		
H_0	Fail to Reject			H_0	Fail to Reject		
C. Silgeach	Mean	SD	n	Priory	Mean	SD	n
29	19.59	1.525647	44	2	18.93	1.5697771	18
30	19.07	1.478716	26	6	18.95	1.7246449	11
Confidence	0.05			Confidence	0.05		
DF	68			DF	27		
Critical	0.16801			Critical	0.974641		
t.test				t.test			
	s^2	2.275762			s^2	2.653163	
t statistic	1.39349			t statistic	0.032083		
H_0	Fail to Reject			H_0	Fail to Reject		
C. Silgeach	Mean	SD	n	Priory	Mean	SD	n
30	19.07	1.478716	26	6	18.95	1.7246449	11
31	19.18	1.117721	13	7	19.99	1.859032	15
Confidence	0.05			Confidence	0.05		
DF	37			DF	24		
Critical	0.814723			Critical	0.159428		
t.test				t.test			
	s^2	1.882611			s^2	3.2553333	
t statistic	0.236014			t statistic	1.452081		
H_0	Fail to Reject			H_0	Fail to Reject		
C. Silgeach	Mean	SD	n	Priory	Mean	SD	n
28	19.5	1.85731	44	1	19.68	2.0139513	15
31	19.18	1.117721	13	7	19.99	1.859032	15
Confidence	0.05			Confidence	0.05		
DF	55			DF	28		
Critical	0.558768			Critical	0.664707		
t.test				t.test			
	s2	2.969535			s2	3.756	
t statistic	0.588256			t statistic	0.438056		
H_0	Fail to Reject			H_0	Fail to Reject		

C. Coig (6)	Mean	SD	n
17	18.94	1.683746	14
18	19.08	2.014249	23
Confidence	0.05		
DF	35		
Critical	0.829024		
t.test			
	s^2	3.60324	
t statistic	0.217575		
H_0	Fail to Reject		

C n G I	Mean	SD	n
1	18.73	1.369306	30
2	19.1	1.669401	29
Confidence	0.05		
DF	57		
Critical	0.355158		
t.test			
	s^2	2.322951	
t statistic	0.932213		
H_0	Fail to Reject		

C. Coig (6)	Mean	SD	n
18	19.08	2.014249	23
20	19.86	1.67332	70
Confidence	0.05		
DF	91		
Critical	0.06872		
t.test			
	s2	3.103938	
t statistic	1.842084		
H_0	Fail to Reject		

C n G I	Mean	SD	n
2	19.1	1.669401	29
3	18.9	1.301076	32
Confidence	0.05		
DF	59		
Critical	0.601898		
t.test			
	s2	2.212034	
t statistic	0.524497		
H_0	Fail to Reject		

C. Coig (6)	Mean	SD	n
20	19.86	1.67332	70
21	18.9	2.062208	23
Confidence	0.05		
DF	91		
Critical	0.026852		
t.test			
	s2	3.151202	
t statistic	2.250114		
H_0	Reject		

C n G II	Mean	SD	n
E	19.32	1.641646	22
F	20.2	2.009179	12
Confidence	0.05		
DF	32		
Critical	0.177074		
t.test			
	s^2	3.156244	
t statistic	1.380257		
H_0	Fail to Reject		

C. Coig (6)	Mean	SD	n
21	18.9	2.062208	23
17	18.94	1.683746	14
Confidence	0.05		
DF	35		
Critical	0.951603		
t.test			
	s2	3.726126	
t statistic	0.061131		
H_0	Fail to Reject		

Table SI-Chapter8-4.10: Summary Statistics for dog whelk from the Oronsay middens. Data from Jones (1984).

Priory			
	n	Mean	St.dev
1	15	19.68	2.013951
2	18	18.93	1.569777
3			
4			
5			
6	11	18.95	1.724645
7	15	19.99	1.859032
8			
9			
10			

CNG I			
	n	Mean	St.dev
1	30	18.73	1.369306
2	29	19.1	1.669401
3	32	18.9	1.301076

CNG II			
	n	Mean	St.dev
E	22	19.32	1.641646
F	12	20.2	2.009179
G			
H			
J			

Cnoc Silgeach			
	n	Mean	St.dev
28	44	19.5	1.85731
29	44	19.59	1.525647
30	26	19.07	1.478716
31	13	19.18	1.117721

Cnoc Coig		Pit 6	
	n	Mean	St.dev
17	14	18.94	1.683746
18	23	19.08	2.014249
19			
20	70	19.86	1.67332
21	23	18.9	2.062208
Premidden			

Cnoc Coig		Pit 10	
	n	Mean	St.dev
9	23	18.76	1.870374
10	0	0	0
11	6	20.2	1.812622
12	6	19.48	1.004291

Periwinkle.

Table SI-Chapter8-4.11: Statistical testing output for SHL from the Oronsay middens. Data from Jones (1984).

Priory	Mean	SD	n
1	27.34	2.6208396	53
2	26.44	2.5719642	54
Confidence	0.05		
DF	105		
Critical	0.075883		
t.test			
	s^2	6.7406914	
t statistic	1.792806		
H_0	Fail to Reject		

Priory	Mean	SD	n
2	26.44	2.5719642	54
3	25.85	4.1079192	30
Confidence	0.05		
DF	82		
Critical	0.42054		
t.test			
	s^2	10.243537	
t statistic	0.809552		
H_0	Fail to Reject		

Priory	Mean	SD	n
3	25.85	4.1079192	30
4	24.38	1.96	4
Confidence	0.05		
DF	32		
Critical	0.490206		
t.test			
	s^2	15.653119	
t statistic	0.69802		
H_0	Fail to Reject		

Priory	Mean	SD	n
4	24.38	1.96	4
5	25.72	1.3095801	14
Confidence	0.05		
DF	16		
Critical	0.123548		
t.test			
	s2	2.1137375	
t statistic	1.625687		
H_0	Fail to Reject		

Priory	Mean	SD	n
5	25.72	1.3095801	14
6	26.13	2.4859204	22
Confidence	0.05		
DF	34		
Critical	0.574402		
t.test			
	s2	4.4726706	
t statistic	0.567054		
H_0	Fail to Reject		

Priory	Mean	SD	n
6	26.13	2.4859204	22
7	25.53	2.7624808	17
Confidence	0.05		
DF	37		
Critical	0.480848		
t.test			
	s2	6.8074757	
t statistic	0.712134		
H_0	Fail to Reject		

Priory	Mean	SD	n
1	27.34	2.6208396	53
7	25.53	2.7624808	17
Confidence	0.05		
DF	68		
Critical	0.017039		
t.test			
	s2	7.0482118	
t statistic	2.445978		
H_0	Reject		

C. Coig (6)	Mean	SD	n
17	23.78	2.719559	10
18	22.62	3.992668	6
Confidence	0.05		
DF	14		
Critical	0.498454		
t.test			
	s^2	10.44793	
t statistic	0.694958		
H_0	Fail to Reject		

C. Coig (6)	Mean	SD	n
18	22.62	3.992668	6
20	25.1	2.712932	46
Confidence	0.05		
DF	50		
Critical	0.051728		
t.test			
	s2	8.21814	
t statistic	1.993048		
H_0	Fail to Reject		

C. Coig (6)	Mean	SD	n
20	25.1	2.712932	46
21	25.24	2.686466	11
Confidence	0.05		
DF	55		
Critical	0.878153		
t.test			
	s2	7.334018	
t statistic	0.154026		
H_0	Fail to Reject		

C. Coig (6)	Mean	SD	n
17	23.78	2.719559	10
21	25.24	2.686466	11
Confidence	0.05		
DF	19		
Critical	0.23131		
t.test			
	s2	7.301842	
t statistic	1.236583		
H_0	Fail to Reject		

C. Coig (10)	Mean	SD	n
9	24.21	2.433105	37
10	23.66	3.222158	47
Confidence	0.05		
DF	82		
Critical	0.391065		
t.test			
	s2	8.423241	
t statistic	0.86225		
H_0	Fail to Reject		

C. Coig (10)	Mean	SD	n
10	23.66	3.222158	47
11	24.56	2.829541	23
Confidence	0.05		
DF	68		
Critical	0.258005		
t.test			
	s2	9.613594	
t statistic	1.140679		
H_0	Fail to Reject		

C n G I	Mean	SD	n
2	22.3	2.72125	68
3	21.54	2.6	16
Confidence	0.05		
DF	82		
Critical	0.31393		
t.test			
	s2	7.287176	
t statistic	1.013232		
H_0	Fail to Reject		

C n G II	Mean	SD	n
E	21.68	3.55176	6
F	23.27	2.204541	6
Confidence	0.05		
DF	10		
Critical	0.373451		
t.test			
	s^2	8.7375	
t statistic	0.931674		
H_0	Fail to Reject		

C n G II	Mean	SD	n
F	23.27	2.204541	6
G	26.47	2.776274	13
Confidence	0.05		
DF	17		
Critical	0.024218		
t.test			
	s2	6.870141	
t statistic	2.473647		
H_0	Reject		

Table SI-Chapter8-4.12: Summary statistics for SHL for the Oronsay middens. Data from Jones (1984).

Priory			
	n	Mean	St.dev
1	53	27.34	2.62084
2	54	26.44	2.571964
3	30	25.85	4.107919
4	4	24.38	1.96
5	14	25.72	1.30958
6	22	26.13	2.48592
7	17	25.53	2.762481
8			
9			
10			

CNG I			
	n	Mean	St.dev
1			
2	68	22.3	2.72125
3	16	21.54	2.6

CNG II			
	n	Mean	St.dev
E	6	21.68	3.55176
F	6	23.27	2.204541
G	13	26.47	2.776274
H			
J			

Cnoc Coig		Pit 6	
	n	Mean	St.dev
17	10	23.78	2.719559
18	6	22.62	3.992668
19			
20	46	25.1	2.712932
21	11	25.24	2.686466
Premidden			

Cnoc Coig		Pit 10	
	n	Mean	St.dev
9	37	24.21	2.433105
10	47	23.66	3.222158
11	23	24.56	2.829541
12	4	24.18	1.72

SI-Chapter8-5: Stable Isotope Assay Outcomes.

Table SI-Chapter8-1: Stable Isotope Assay output.

Status	Tranche	Batch	Group	Assay No.	Otolith	Sample	Sample	Modelled length	Weight (µg)	∂^{13}C	sd	∂^{18}O	sd	^{13}C^{12}C	^{18}O/^{16}O	^{13}C^{12}C	^{18}O/^{16}O	^{18}O/^{16}O
						Id	Width							v-pdb	v-pdb	v-pdb	v-pdb	Aragonite
																		0.38
Caution > 1 σ	1	3	2	31	C11OT0003	A	2.1	5.75	71	34.01	0.05	27.18	0.06	-1.82	1.53	-1.75	1.59	1.21
Accept	2	4	2	39	C11OT0004	B	0.72	1.93	152	36.03	0.05	32.67	0.09	-3.17	1.81	-3.00	1.85	1.47
Accept	2	4	2	34	C11OT0004	E	1.27	3.22	188	36.19	0.04	32.67	0.08	-3.01	1.81	-2.84	1.85	1.47
Accept	2	4	2	32	C11OT0004	D	1.73	4.73	156	36.27	0.06	32.29	0.09	-2.93	1.43	-2.76	1.47	1.09
Accept	2	4	1	17	C11OT0004	C	2.3	6.26	196	37.16	0.03	32.6	0.09	-2.04	1.74	-1.90	1.78	1.40
Accept	2	2	3	33	C11OT0004	A	3.05	8.25	81	38.11	0.03	32.37	0.08	-1.03	2.05	-0.94	2.20	1.82
Accept	1	3	2	32	C11OT0005	A	1.68	4.81	71	33.68	0.05	26.82	0.08	-2.15	1.17	-2.08	1.22	0.84
Accept	2	2	3	34	C11OT0007	B	0.52	1.56	80	35.61	0.05	31.94	0.08	-3.53	1.62	-3.38	1.76	1.38
Caution > 1 σ	2	4	1	19	C11OT0007	D	0.9	2.42	125	35.75	0.08	31.07	0.06	-3.45	0.22	-3.27	0.24	-0.14
Accept	2	2	4	43	C11OT0007	C	1.4	4.00	77	36.77	0.04	31.77	0.08	-2.37	1.45	-2.25	1.58	1.20
Accept	2	4	1	16	C11OT0007	A	2.1	5.83	137	37.1	0.04	32.12	0.06	-2.10	1.26	-1.96	1.29	0.91
Accept	2	4	1	20	C11OT0008	B	0.71	1.91	128	35.41	0.04	32.84	0.07	-3.79	1.98	-3.60	2.02	1.64
Accept	2	1	2	20	C11OT0008	D	1.17	3.25	98	36.16	0.03	32.13	0.08	-2.97	1.72	-2.82	1.83	1.45
Accept	2	1	4	44	C11OT0008	C	1.72	4.65	85	36.26	0.06	31.84	0.09	-2.89	1.58	-2.77	1.72	1.34
Accept	2	1	4	43	C11OT0008	A	2.3	6.18	88	36.57	0.04	31.31	0.1	-2.58	1.05	-2.46	1.17	0.79
Caution > 1 σ	1	1	3	40	C11OT0014	A	2.31	6.20	87	33.67	0.04	27.06	0.08	-2.15	1.60	-2.10	1.65	1.27
Reject-LS VEC σ	1	2	1	7	C11OT0015	A	2.27	6.34	56	33.49	0.04	26.26	0.1	-1.97	1.24	-2.01	1.36	0.98
Accept	1	3	2	39	C11OT0021	A	1.86	5.80	74	33.41	0.06	26.95	0.09	-2.42	1.30	-2.34	1.36	0.98
Accept	2	3	3	35	C11OT0045	B	0.67	1.75	106	34.03	0.06	32.44	0.06	-5.18	1.96	-4.98	2.08	1.70
Accept	2	3	4	39	C11OT0045	C	1.32	3.49	114	34.73	0.04	32.38	0.06	-4.48	1.90	-4.29	2.01	1.63
Accept	1	1	2	20	C11OT0045	A	1.78	4.81	50	31.61	0.05	27.11	0.09	-4.36	1.60	-4.24	1.64	1.26
Reject-LS VEC σ	1	2	2	28	C11OT0051	A		4.38	61	32.45	0.08	25.95	0.07	-3.02	0.93	-3.06	1.04	0.66
Accepted	1	3	1	9	C11OT0054	A		4.97	66	33.49	0.07	27.13	0.07	-2.34	1.48	-2.26	1.54	1.16
Reject-LS VEC σ	1	2	1	16	C11OT0061	B	0.77	2.28	58	33.45	0.07	25.83	0.09	-2.01	0.81	-2.05	0.92	0.54
Accept	1	1	3	43	C11OT0061	C	2.35	6.18	88	33.96	0.04	27.14	0.08	-1.86	1.68	-1.81	1.73	1.35
Accept	1	3	1	10	C11OT0061	A	3.08	8.49	66	33.49	0.05	27.07	0.09	-2.34	1.42	-2.26	1.48	1.10
Failed	1	2	4	69	C11OT0063	A			85	32.62	0.03	25.17	0.08	-2.85	0.15	-2.89	0.24	-0.14
Reject-LS VEC σ	1	2	1	17	C11OT0084	A	2.08	5.67	58	33.56	0.05	25.83	0.09	-1.90	0.81	-1.94	0.92	0.54
Accept	1	1	2	26	C11OT0086	A	1.84	4.94	53	32.67	0.05	27.1	0.07	-3.29	1.59	-3.20	1.63	1.25
Accept	1	1	4	52	C11OT0087	A	2.43	6.63	95	34.88	0.05	26.54	0.05	-0.94	1.08	-0.90	1.13	0.75
Caution > 1 σ	1	3	1	17	C11OT0098	A		4.92	68	34.41	0.04	26.95	0.05	-1.42	1.30	-1.36	1.36	0.98
Accept	2	3	4	40	C11OT0205	B	0.35	1.05	110	36.89	0.04	32.4	0.07	-2.31	1.92	-2.18	2.03	1.65
Accept	2	2	4	39	C11OT0205	G	0.87	2.42	77	35.76	0.04	31.82	0.07	-3.38	1.50	-3.23	1.63	1.25
Accept	2	4	1	15	C11OT0205	F	1.51	4.00	116	36.23	0.03	32.1	0.04	-2.97	1.24	-2.80	1.27	0.89
Accept	2	4	2	33	C11OT0205	E	1.97	5.43	170	37.49	0.04	32.42	0.09	-1.71	1.56	-1.58	1.60	1.22
Accept	2	4	1	18	C11OT0205	D	2.47	6.77	161	38.27	0.06	32.93	0.09	-0.93	2.07	-0.82	2.11	1.73
Accept	2	4	1	21	C11OT0205	C	2.97	8.14	131	37.37	0.04	32.46	0.09	-1.83	1.60	-1.70	1.64	1.26
Accept	2	1	2	21	C11OT0205	A	3.35	8.86	104	36.98	0.07	31.98	0.04	-2.15	1.57	-2.02	1.67	1.29
Reject-Collapse	1	2	1	14	C14OT0009	B			58	31.05	0.05	25.67	0.09	-4.42	0.65	-4.48	0.76	0.38
Accept	1	1	1	9	C14OT0009	C	1.13	3.65	46	33.23	0.07	26.44	0.1	-2.73	0.93	-2.64	0.96	0.58
Failed	1	2	4	58	C14OT0009	A			79	30.7	0.05	21.22	0.16	-4.77	-3.79	-4.83	-3.83	-4.21
Reject-LS VEC σ	1	2	1	15	C14OT0029	A	1.32	3.81	58	35.75	0.07	30.97	0.06	-3.38	0.75	-3.25	0.84	0.46
Accept	2	2	2	15	C14OT0029	A			58	32.83	0.05	25.92	0.1	-2.64	0.90	-2.68	1.01	0.63
Accept	1	1	2	27	C14OT0117	A	1.46	4.11	54	33.53	0.1	26.69	0.09	-2.43	1.18	-2.35	1.21	0.83
Accept	2	2	4	45	C14OT0123	B	0.58	1.45	81	34.58	0.04	31.63	0.07	-4.57	1.31	-4.39	1.44	1.06
Reject-LS VEC σ	1	2	2	29	C14OT0123	A	1.64	4.54	62	32.97	0.06	26.07	0.09	-2.50	1.05	-2.54	1.17	0.79
Reject-Collapse	2	2	2	16	C14OT0139	B	0.51	1.37	58	34.3	0.1	30.89	0.09	-4.84	0.67	-4.67	0.76	0.38
Accept	1	3	1	22	C14OT0139	A	1.49	3.92	71	33.05	0.08	26.58	0.08	-2.78	0.94	-2.70	0.98	0.60
Accept	2	3	1	13	C14OT0250	B	0.51	1.40	51	35.47	0.09	31.21	0.09	-3.67	1.20	-3.56	1.35	0.97
Reject	1	1	2	23	C14OT0250	B			51	32.75	0.08	27.7	0.09	-3.21	2.18	-3.12	2.23	1.85
Accept	1	3	1	42	C14OT0250	D	1.12	2.98	75	33.41	0.07	27.44	0.07	-2.42	1.79	-2.34	1.85	1.47
Accept	1	2	3	47	C14OT0250	C	1.69	4.57	76	33.52	0.07	26.48	0.08	-1.94	1.46	-1.98	1.59	1.21
Accept	2	3	6	60	C14OT0250	A	2.32	6.58	68	36.93	0.07	31.58	0.09	-2.17	1.20	-2.06	1.29	0.91
Reject	1	3	1	13	C14OT0250	A			68	34.15	0.07	27.26	0.08	-1.68	1.61	-1.61	1.67	1.29

Status	Tranche	Batch	Group	Assay No.	Otolith	Sample Id	Sample Width	Modelled length	Weight (µg)	$\partial^{13}C$	sd	$\partial^{18}O$	sd	$^{13}C^{12}C$ v-pdb	$^{18}O/^{16}O$ v-pdb	$^{13}C^{12}C$ v-pdb	$^{18}O/^{16}O$ v-pdb	$^{18}O/^{16}O$ Aragonite
																		0.38
Caution > 1 σ	2	2	1	10	C14OT0256	B	0.6	1.80	57	34.5	0.08	30.77	0.09	-4.64	0.55	-4.48	0.64	0.26
Accept	2	2	2	17	C14OT0256	A	1.88	5.29	62	35.58	0.08	30.72	0.07	-3.55	0.50	-3.42	0.59	0.21
Reject-LS VEC σ	1	2	2	30	**C14OT0256**	A			62	32.87	0.08	25.67	0.1	-2.60	0.65	-2.64	0.76	0.38
Accept	1	2	1	13	C14OT0259	A		5.83	103	37.42	0.06	31.63	0.05	-1.71	1.22	-1.59	1.31	0.93
Accept	1	2	4	45	C14OT0267	B	0.54	1.64	85	35.44	0.07	31.93	0.1	-3.71	1.67	-3.57	1.81	1.43
Reject				67	C14OT0267	B			85	33.28	0.05	26.68	0.04	-2.18	1.66	-2.22	1.80	1.42
Accept	1	2	4	63	C14OT0267	C	1.36	3.71	83	33.04	0.05	26.62	0.09	-2.43	1.60	-2.47	1.74	1.36
Accept	1	3	2	29	C14OT0267	A	2.15	5.91	71	33.16	0.06	26.71	0.05	-2.67	1.06	-2.59	1.11	0.73
Caution > 1 σ	2	3	2	20	C14OT0300	A			46	36.8	0.09	30.07	0.11	-2.33	0.06	-2.25	0.17	-0.21
Accept	1	2	3	53	C2OT0023	A	1.44	3.92	2	5.42	33.3	0.06	26.9	-2.12	1.83	-2.16	1.97	1.59
Reject-LS VEC σ	1	2	1	18	C2OT0037	A	1.12	3.03	59	31.69	0.05	26.07	0.06	-3.78	1.05	-3.83	1.17	0.79
Caution > 1 σ	1	1	1	14	C2OT0052	A			50	31.56	0.07	25.46	0.13	-4.41	-0.05	-4.29	-0.03	
Accept	2	2	1	7	C2OT0060	B	0.48	1.40	60	34.97	0.03	31.01	0.09	-4.16	0.79	-4.02	0.88	0.50
Accept	1	3	1	11	C2OT0060	A	1.44	3.84	68	32.41	0.06	26.67	0.09	-3.42	1.03	-3.33	1.07	0.69
Accept	2	2	4	40	C2OT0068	A	1.27	3.57	80	35.36	0.05	31.88	0.1	-3.78	1.56	-3.62	1.69	1.31
Accept	2	2	1	8	C2OT0073	A	0.95	2.66	64	36.56	0.06	31.09	0.08	-2.57	0.87	-2.46	0.97	0.59
Accept	2	4	2	41	C2OT0080	C	2.01	5.43	115	37.34	0.02	32.37	0.05	-1.86	1.51	-1.72	1.55	1.17
Caution > 1 σ	2	3	2	18	C2OT0080	A	2.79	7.49	53	37.63	0.07	31.04	0.08	-1.50	1.03	-1.43	1.17	0.79
Caution > 1 σ				35	C2OT0094	A			120	35.38	0.04	32.54	0.09	-3.82	1.68	-3.63	1.72	1.34
Accept	2	4	2	36	C2OT0102	B	0.75	1.96	164	35.81	0.03	32.84	0.08	-3.39	1.98	-3.21	2.02	1.64
Caution > 1 σ	2	1	3	34	C2OT0102	A			85	35.78	0.08	30.4	0.09	-3.37	0.14	-3.24	0.23	-0.15
Accept	2	3	6	61	C2OT0110	B	0.53	1.34	66	35.76	0.06	31.64	0.09	-3.35	1.26	-3.21	1.35	0.97
Caution > 1 σ	2	3	1	7	C2OT0110	A			45	36.45	0.07	30.67	0.09	-2.69	0.66	-2.60	0.79	0.41
Failed	1	2	3	54	C2OT0158	A			79	29.73	0.05	21.54	0.08	-5.74	-3.47	-5.81	-3.50	
Reject-LS VEC σ	1	2	1	11	C2OT0202	A	1.54	4.16	58	32.82	0.07	26.22	0.09	-2.64	1.20	-2.69	1.32	0.94
Accept	1	1	1	10	C5OT0003	B	0.57	1.58	47	30.91	0.09	26.79	0.08	-5.06	1.28	-4.93	1.31	0.93
Failed	1	2	4	68	C5OT0003	C			85	30.73	0.03	23.44	0.1	-4.74	-1.57	-4.80	-1.54	-1.92
Accept	1	2	4	61	C5OT0003	A	1.92	5.13	80	32.75	0.06	26.11	0.09	-2.72	1.09	-2.76	1.21	0.83
Caution > 1 σ	2	1	2	22	C5OT0004	B	0.69	1.99	102	38.19	0.06	31.54	0.07	-0.94	1.13	-0.84	1.22	0.84
Accept	1	3	1	14	C5OT0004	A	2.09	5.72	68	35.22	0.1	26.75	0.07	-0.61	1.10	-0.56	1.15	0.77
Accept	1	3	1	15	C5OT0006	B	0.6	1.45	68	31.56	0.09	27.22	0.05	-4.27	1.57	-4.17	1.63	1.25
Reject-LS VEC σ	1	2	2	32	C5OT0006	C	1.08	2.82	65	31.79	0.08	25.52	0.08	-3.68	0.50	-3.73	0.60	0.22
Accept	1	3	2	33	C5OT0006	A	1.95	5.26	72	33.57	0.09	27.03	0.09	-2.26	1.38	-2.19	1.44	1.06
Accept	2	3	2	17	C5OT0011	B	0.53	1.40	51	35.92	0.06	30.47	0.08	-3.22	0.46	-3.12	0.58	0.20
Accept	2	4	2	40	C5OT0011	E	0.9	2.34	138	37.01	0.04	31.89	0.04	-2.19	1.03	-2.05	1.06	0.68
Accept	2	1	3	36	C5OT0011	D	1.67	4.35	86	37.31	0.05	31.27	0.1	-1.84	1.01	-1.74	1.13	0.75
Accept	2	1	1	10	C5OT0011	C	2.36	6.37	95	38.05	0.04	32.58	0.06	-1.08	2.16	-0.98	2.29	1.91
Accept	2	1	2	17	C5OT0011	A	3.14	8.65	97	37.85	0.06	31.48	0.09	-1.28	1.07	-1.17	1.16	0.78
Accept	1	1	1	16	C5OT0014	B	0.45	1.64	50	31.52	0.07	27.49	0.11	-4.45	1.97	-4.33	2.02	1.64
Reject-LS VEC σ	1	2	2	24	C5OT0014	D	0.93	2.50	60	31.59	0.08	26.33	0.1	-3.88	1.31	-3.93	1.44	1.06
Accept	1	3	2	38	C5OT0014	C	1.48	3.89	74	32.55	0.05	27.1	0.09	-3.28	1.45	-3.19	1.51	1.13
Accept	1	2	3	48	C5OT0014	A	2.07	5.64	76	32.53	0.08	25.96	0.07	-2.94	0.94	-2.98	1.05	0.67
Caution > 1 σ	1	1	1	11	C5OT0021	B			47	32.32	0.04	26.58	0.07	-3.64	1.07	-3.54	1.10	0.72
Accept	1	1	1	7	C5OT0021	E	0.82	2.09	45	32.54	0.1	26.86	0.09	-3.42	1.35	-3.33	1.39	1.01
Accept	1	1	2	24	C5OT0021	D	1.26	3.30	51	33.15	0.1	27.08	0.07	-2.81	1.57	-2.72	1.61	1.23
Accept	2	2	3	30	C5OT0021	C	1.7	4.46	80	36.11	0.05	31.35	0.07	-3.03	1.03	-2.89	1.15	0.77
Reject	1	2	4	62	C5OT0021	C			80	32.86	0.05	26.26	0.07	-2.61	1.24	-2.65	1.36	0.98
Accept	1	1	3	41	C5OT0021	A	2.26	6.10	88	33.37	0.06	26.29	0.07	-2.46	0.83	-2.40	0.87	0.49
Accept	1	2	3	52	C5OT0028	B	0.5	1.21	78	31.98	0.07	26.48	0.09	-3.49	1.46	-3.54	1.59	1.21
Accept	1	3	2	35	C5OT0028	C	1.31	3.33	73	33.56	0.07	26.94	0.09	-2.27	1.29	-2.20	1.35	0.97
Accept	1	3	2	34	C5OT0028	A	2.2	6.45	73	33.97	0.04	26.65	0.08	-1.86	1.01	-1.79	1.05	0.67
Caution > 1 σ	2	3	5	52	C5OT0029	B			70	35.82	0.06	31.32	0.09	-3.29	0.94	-3.15	1.02	0.64
Accept	1	3	2	36	C5OT0029	A	2.01	5.45	73	33.69	0.08	26.7	0.08	-2.14	1.06	-2.07	1.10	0.72
Accept	1	1	4	48	C5OT0032	D	0.95	2.52	91	31.63	0.04	26.94	0.06	-4.20	1.48	-4.12	1.53	1.15
Caution > 1 σ	2	4	1	12	C5OT0032	C			135	35.69	0.05	32.09	0.09	-3.51	1.23	-3.33	1.26	0.88
Accept	1	3	1	20	C5OT0032	A	2.13	5.69	70	33.49	0.07	27.06	0.09	-2.34	1.41	-2.26	1.47	1.09
Accept	1	1	2	25	C5OT0035	B	0.74	1.96	53	31.73	0.1	26.91	0.06	-4.23	1.40	-4.12	1.44	1.06

Status	Tranche	Batch	Group	Assay No.	Otolith	Sample Id	Sample Width	Modelled length	Weight (µg)	$\partial^{13}C$	sd	$\partial^{18}O$	sd	$^{13}C^{12}C$	$^{18}O/^{16}O$	$^{13}C^{12}C$	$^{18}O/^{16}O$	$^{18}O/^{16}O$
														v-pdb	v-pdb	v-pdb	v-pdb	Aragonite
																		0.38
Failed	1	2	4	64	C5OT0035	D			84	29.63	0.04	22.24	0.1	-5.84	-2.77	-5.91	-2.78	-3.16
Accept	1	3	2	30	C5OT0035	C	1.36	3.68	71	32.22	0.06	27.08	0.07	-3.61	1.43	-3.52	1.49	1.11
Accept	2	1	2	18	C5OT0035	A	2.03	5.77	102	36.42	0.07	31.68	0.08	-2.71	1.27	-2.57	1.36	0.98
Accept	2	3	5	53	C5OT0042	A	1.39	3.79	66	34.93	0.02	31.74	0.1	-4.18	1.36	-4.02	1.45	1.07
Accept	2	2	3	31	C5OT0045	A	1.43	3.95	84	34.74	0.07	31.77	0.09	-4.41	1.45	-4.23	1.58	1.20
Accept	1	2	4	65	C5OT0050	B	0.68	1.88	84	31.9	0.07	26.61	0.07	-3.57	1.59	-3.62	1.72	1.34
Accept	2	1	2	19	C5OT0050	C	1.43	3.79	97	35.99	0.05	31.61	0.07	-3.14	1.20	-2.99	1.29	0.91
Reject-LS VEC σ	1	2	2	26	C5OT0050	A	2.23	6.02	2.68	4.28	33.1	0.04	26	-2.32	0.99	-2.37	1.11	0.73
Accept	1	3	1	19	C5OT0056	D	0.88	2.44	69	31.7	0.03	27.31	0.1	-4.13	1.66	-4.03	1.72	1.34
Accept	2	3	3	32	C5OT0056	C	1.44	4.19	112	35.16	0.04	31.77	0.08	-4.04	1.30	-3.87	1.39	1.01
Accept	1	1	4	37	C5OT0056	A	2.05	5.75	92	36.28	0.08	31.41	0.09	-2.87	1.15	-2.75	1.27	0.89
Reject				49	C5OT0056	A	2.05	5.75	92	32.93	0.07	25.86	0.07	-2.90	0.40	-2.83	0.44	0.06
Accept	1	1	4	38	C5OT0062	A	2	5.64	89	35.74	0.07	31.2	0.09	-3.41	0.94	-3.27	1.06	0.68
Accept	2	3	2	19	C5OT0064	B	0.57	1.72	51	35.4	0.07	31.31	0.1	-3.74	1.30	-3.63	1.46	1.08
Accept	1	1	3	42	C5OT0064	A	2	5.34	88	34.5	0.05	26.52	0.06	-1.32	1.06	-1.28	1.11	0.73
Caution > 1 σ	2	3	3	33	C5OT0078	D			109	34.6	0.05	32.42	0.08	-4.61	1.94	-4.42	2.05	1.67
Accept	2	1	4	42	C5OT0078	B	0.66	1.69	88	35.49	0.05	32.06	0.06	-3.66	1.79	-3.52	1.94	1.56
Caution > 1 σ	2	3	5	54	C5OT0078	A			68	35.8	0.06	30.31	0.1	-3.31	-0.07	-3.17	-0.01	-0.39
Accept	2	3	1	8	C5OT0087	B	0.66	1.91	48	34.45	0.06	31.53	0.09	-4.69	1.52	-4.57	1.68	1.30
Reject-LS VEC σ	1	2	2	27	C5OT0087	A	1.85	5.02	61	32.45	0.04	26.16	0.07	-3.02	1.14	-3.06	1.26	0.88
Accept	2	4	1	13	C5OT0097	B		1.25	153	36.41	0.02	32.75	0.1	-2.79	1.89	-2.63	1.93	1.55
Accept	2	2	3	32	C5OT0097	D		3.20	83	37.54	0.05	31.76	0.07	-1.60	1.44	-1.49	1.57	1.19
Reject	2	2	2	19	C5OT0097	C			63	14.14	0.02	19.9	0.06	-25.05	-10.30	#####	-10.53	-10.91
Accept	2	3	3	34	C5OT0097	A		7.12	108	37.26	0.07	31.62	0.09	-1.94	1.15	-1.82	1.24	0.86
Reject-LS VEC σ	1	2	1	9	C5OT0156	B	0.55	1.96	57	31.42	0.05	26.59	0.06	-4.05	1.57	-4.11	1.70	1.32
Accept	1	2	1	12	C5OT0156	D	1.09	3.01	48	32.17	0.09	26.23	0.07	-3.79	0.72	-3.69	0.75	0.37
Reject-LS VEC σ	1	2	1	10	C5OT0156	C	1.77	4.78	57	32.45	0.08	25.92	0.06	-3.02	0.90	-3.06	1.01	0.63
Accept	1	3	1	16	C5OT0156	A	2.46	6.58	68	33.99	0.06	26.9	0.09	-1.84	1.25	-1.77	1.31	0.93
Caution > 1 σ	2	3	1	9	C5OT0173	A			46	35.62	0.07	29.96	0.1	-3.52	-0.05	-3.42	0.05	-0.33
Caution > 1 σ	2	3	1	10	C8OT0001	D	0.94	2.66	52	36.1	0.08	31.72	0.08	-3.04	1.71	-2.94	1.88	1.50
Accept	2	1	1	11	C8OT0001	C	1.66	4.38	102	36.85	0.05	32.23	0.05	-2.28	1.81	-2.15	1.93	1.55
Accept	2	2	4	41	C8OT0001	A	2.65	6.98	80	37.21	0.09	31.45	0.07	-1.93	1.13	-1.82	1.25	0.87
Failed	1	2	3	49	C8OT0006	A			77	29.59	0.04	21.77	0.1	-5.88	-3.24	-5.96	-3.27	-3.65
Caution > 1 σ	2	1	1	12	C8OT0007	D	1.22	3.22	102	35.9	0.06	31.36	0.1	-3.23	0.95	-3.07	1.04	0.66
Accept	2	3	5	55	C8OT0007	C	1.81	5.02	70	36.58	0.07	31.74	0.09	-2.53	1.36	-2.41	1.45	1.07
Accept	2	2	1	9	C8OT0007	A	2.23	6.10	64	36.51	0.07	31.33	0.09	-2.62	1.11	-2.51	1.21	0.83
Accept	1	1	1	15	C8OT0065	B	0.43	1.24	50	32.3	0.04	26.93	0.11	-3.66	1.42	-3.56	1.46	1.08
Failed	1	2	3	43	C8OT0065	C			76	31.22	0.02	22.61	0.08	-4.25	-2.40	-4.31	-2.40	-2.78
Accept	1	2	3	51	C8OT0065	A	1.92	5.24	78	32.84	0.06	26.02	0.06	-2.63	1.00	-2.67	1.12	0.74
Caution > 1 σ	2	2	4	42	C8OT0025	A			75	36.28	0.06	30.4	0.08	-2.86	0.08	-2.73	0.17	-0.21
Accept	2	1	1	7	C8OT0043	B	0.58	1.56	95	35.97	0.04	32.23	0.05	-3.16	1.81	-3.01	1.93	1.55
Accept				37	C8OT0043	D		3.06	200	36.67	0.04	32.62	0.08	-2.53	1.76	-2.38	1.80	1.42
Accept	2	1	2	23	C8OT0043	C		4.57	99	36.8	0.06	32.24	0.06	-2.33	1.82	-2.20	1.94	1.56
Accept	2	3	1	11	C8OT0043	A		6.07	48	36.72	0.05	30.96	0.07	-2.42	0.95	-2.33	1.09	0.71
Accept	1	3	1	7	C8OT0052	B	0.52	1.58	66	32.4	0.07	27.47	0.08	-3.43	1.82	-3.34	1.88	1.50
Caution > 1 σ	2	3	4	41	C8OT0052	C			113	35.68	0.05	32.08	0.08	-3.52	1.61	-3.37	1.71	1.33
Accept	2	1	1	8	C8OT0052	A	1.72	4.83	98	36.03	0.05	31.49	0.11	-3.10	1.08	-2.95	1.17	0.79
Accept	2	3	6	62	C8OT0008	B2	0.46	1.29	68	34.97	0.05	32.83	0.09	-4.14	2.44	-3.98	2.57	2.19
Caution > 1 σ	2	1	1	9	C8OT0008	B1	0.61	1.58	102	35.37	0.04	32.35	0.06	-3.76	1.93	-3.59	2.05	1.67
Accept	1	3	1	18	C8OT0008	D	0.98	2.74	69	32.51	0.07	27.65	0.09	-3.32	2.00	-3.23	2.06	1.68
Accept	1	1	3	39	C8OT0008	C	1.79	4.81	86	32.7	0.07	26.74	0.08	-3.13	1.28	-3.06	1.33	0.95
Reject-LS VEC σ	1	2	1	12	**C8OT0008**	A	2.53	7.28	58	33.1	0.05	26.53	0.08	-2.37	1.51	-2.41	1.64	1.26
Accept	1	1	2	21	C8OT0074	B	0.61	1.61	51	32.24	0.08	27.46	0.09	-3.72	1.94	-3.62	1.99	1.61
Accept	1	1	1	8	C8OT0074	C	1.41	3.89	46	32.59	0.08	27	0.11	-3.37	1.49	-3.28	1.53	1.15
Reject-LS VEC σ	1	2	1	8	C8OT0074	A	2.04	5.45	57	32.55	0.07	26.09	0.06	-2.92	1.07	-2.96	1.19	0.81
Accept	2	1	3	35	C8OT0077	A	1.15	3.25	88	36.44	0.06	31.97	0.07	-2.71	1.71	-2.59	1.85	1.47
Caution > 1 σ	1	2	4	59	C8OT0121	B			80	29.82	0.09	25.78	0.1	-5.65	0.76	-5.72	0.87	0.49

Status	**Tranche**	**Batch**	**Group**	**Assay No.**	**Otolith**	**Sample**	**Sample**	**Modelled length**	**Weight (µg)**	**$\partial^{13}C$**	**sd**	**$\partial^{18}O$**	**sd**	**$^{13}C^{12}C$**	**$^{18}O/^{16}O$**	**$^{13}C^{12}C$**	**$^{18}O/^{16}O$**	**$^{18}O/^{16}O$**
						Id	**Width**							**v-pdb**	**v-pdb**	**v-pdb**	**v-pdb**	**Aragonite**
																		0.38
Accept	2	3	1	12	C8OT0127	B	0.61	2.52	53	35.78	0.06	31.25	0.1	-3.36	1.24	-3.26	1.39	1.01
Accept	1	3	2	37	C8OT0127	A	1.39	3.76	74	33.62	0.09	26.78	0.06	-2.21	1.13	-2.14	1.18	0.80
Accept	2	2	2	18	C8OT0133	A	1.28	3.49	60	36.63	0.06	31.66	0.08	-2.50	1.44	-2.39	1.55	1.17
Failed	1	2	3	50	C8OT0137	A			77	29.02	0.08	19.22	0.12	-6.46	-5.78	-6.53	-5.90	-6.28
				8	C8OT0159	A	1.5	4.22	66	32.68	0.07	26.6	0.09	-3.15	0.96	-3.06	1.00	0.62
Accept	2	2	1	11	C8OT0160	A	1.12	2.95	58	36.09	0.06	31.41	0.08	-3.04	1.19	-2.92	1.29	0.91
Accept	2	4	1	14	C8OT0174	B	0.58	1.48	119	36	0.04	32.93	0.1	-3.20	2.07	-3.03	2.11	1.73
Accept	2	2	4	44	C8OT0174	D		3.12	78	36.32	0.07	32.33	0.05	-2.82	2.01	-2.69	2.16	1.78
Accept				38	C8OT0174	C		4.75	169	36.35	0.04	32.66	0.07	-2.85	1.80	-2.69	1.84	1.46
Accept	2	2	3	35	C8OT0174	A		6.37	84	36.52	0.03	31.95	0.08	-2.62	1.63	-2.49	1.77	1.39
Accept	1	3	2	40	C8OT0177	B	0.63	1.67	75	32.56	0.06	27.37	0.08	-3.27	1.72	-3.18	1.78	1.40
Reject-LS VEC σ	1	2	2	25	C8OT0177	C	1.41	3.73	61	32.32	0.04	26.75	0.06	-3.15	1.73	-3.20	1.87	1.49
Accept	1	2	3	45	C8OT0177	A	2.1	5.67	76	34.22	0.05	25.94	0.06	-1.24	0.92	-1.27	1.03	0.65
Reject-LS VEC σ	1	2	2	31	C8OT0182	B	0.64	1.69	65	31.17	0.06	26.62	0.1	-4.30	1.60	-4.36	1.74	1.36
				50	C8OT0182	C	1.21	3.22	93	32.76	0.05	26.77	0.08	-3.07	1.31	-3.00	1.36	0.98
Accept	1	2	3	46	C8OT0182	A	1.92	5.10	76	33.24	0.05	26.31	0.1	-2.22	1.29	-2.27	1.42	1.04
Accept	1	2	4	60	C8OT0187	B	0.62	1.75	80	32.61	0.06	27.02	0.08	-2.86	2.00	-2.90	2.15	1.77
Accept	1	1	4	51	C8OT0187	C	1.22	3.25	93	33.48	0.04	27.48	0.08	-2.35	2.01	-2.29	2.08	1.70
Accept	1	3	1	21	C8OT0187	A	2.15	5.77	71	33.01	0.07	27.22	0.09	-2.82	1.57	-2.74	1.63	1.25
Caution > 1 σ	2	3	2	21	C8OT0233	B			50	34.92	0.16	27.42	0.12	-4.22	-2.58	-4.11	-2.59	-2.97
Reject-LS VEC σ	1	2	2	22	**C8OT0233**	A	1.47	4.06	59	33.75	0.07	25.66	0.09	-1.71	0.64	-1.75	0.75	0.37
Accept	2	3	6	59	C8OT0240	B	0.68	1.88	72	35.3	0.05	32.14	0.08	-3.81	1.76	-3.66	1.86	1.48
Accept	1	3	2	41	C8OT0240	A	1.62	4.46	75	32.55	0.06	27.1	0.09	-3.28	1.45	-3.19	1.51	1.13
Reject-LS VEC σ	1	2	1	13	C8OT0265	B	0.49	1.29	58	32.07	0.06	26.63	0.11	-3.40	1.61	-3.45	1.75	1.37
Accept	1	1	1	13	C8OT0265	C	0.97	2.61	49	33.05	0.08	26.3	0.1	-2.91	0.79	-2.82	0.82	0.44
Failed	1	2	4	66	C8OT0265	A			85	28.08	0.07	19.27	0.09	-7.40	-5.73	-7.48	-5.84	-6.22
Failed	1	2	2	23	C8OT0315	A			60									
Reject				49	C8OT0358	A			77	29.59	0.04	21.77	0.1	-5.88	-3.24	-5.96	-3.27	-3.65
Accept	1	3	1	12	C8OT0377	A	1.12	3.17	68	31.63	0.09	27.29	0.09	-4.20	1.64	-4.10	1.70	1.32
Accept	1	3	1	44	C8OT0387	A	1.52	4.30	76	33.68	0.05	25.86	0.08	-1.78	0.84	-1.82	0.95	0.57
Accept	1	1	2	22	C8OT0390	A	1.33	3.73	51	33.84	0.06	26.71	0.07	-2.12	1.20	-2.04	1.23	0.85
Accept	1	1	2	28	C8OT0401	A	1.62	4.32	55	33.26	0.08	27.11	0.06	-2.70	1.60	-2.62	1.64	1.26

SI-Chapter8-Plates

Plate SI-Chapter8-Plate-1: Outer surface of otolith OT0311. Condition is very eroded. >25% inversion to calcite from aragonite. ©M.J.Evans

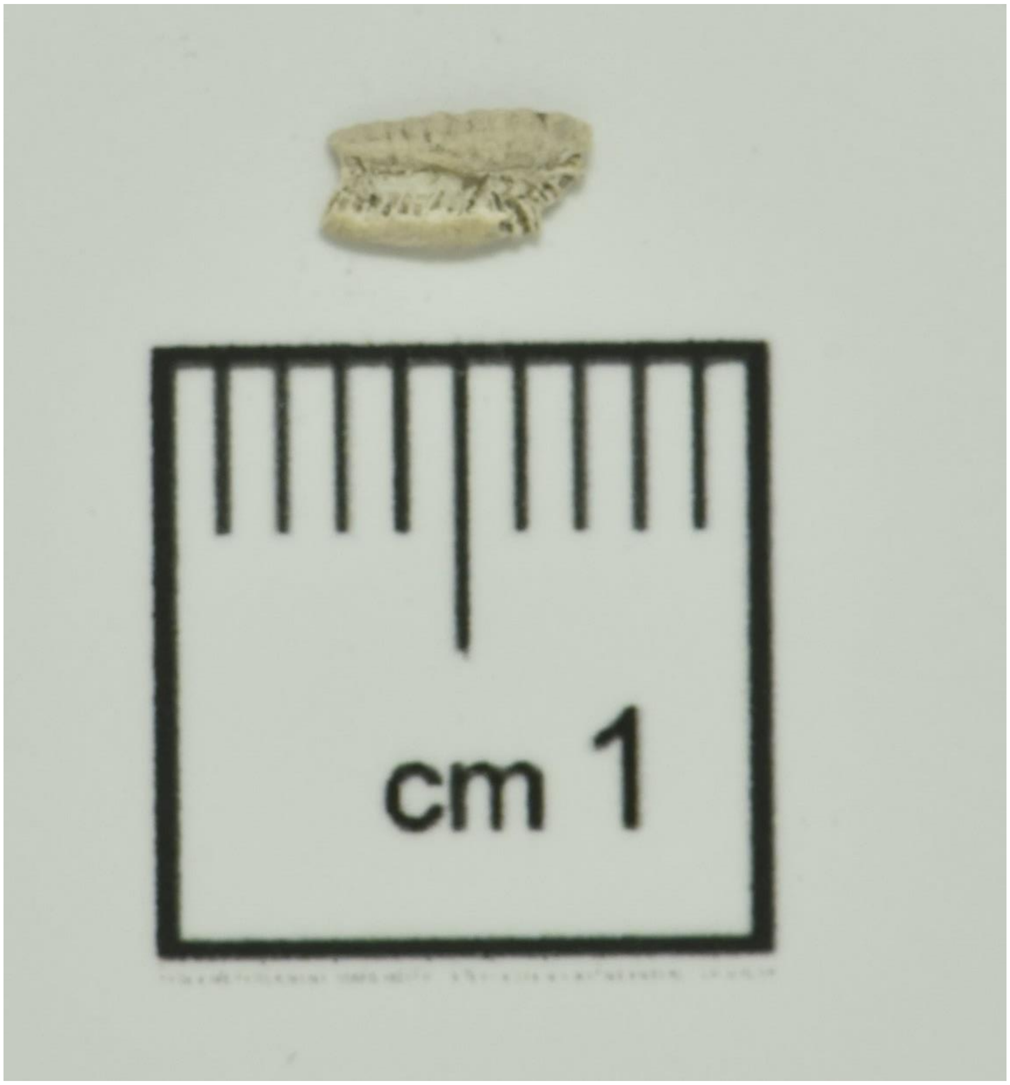

Plate SI-Chapter8-2: Inner surface of otolith OT0311. Condition is very eroded. >25% inversion to calcite from aragonite. ©M.J.Evans

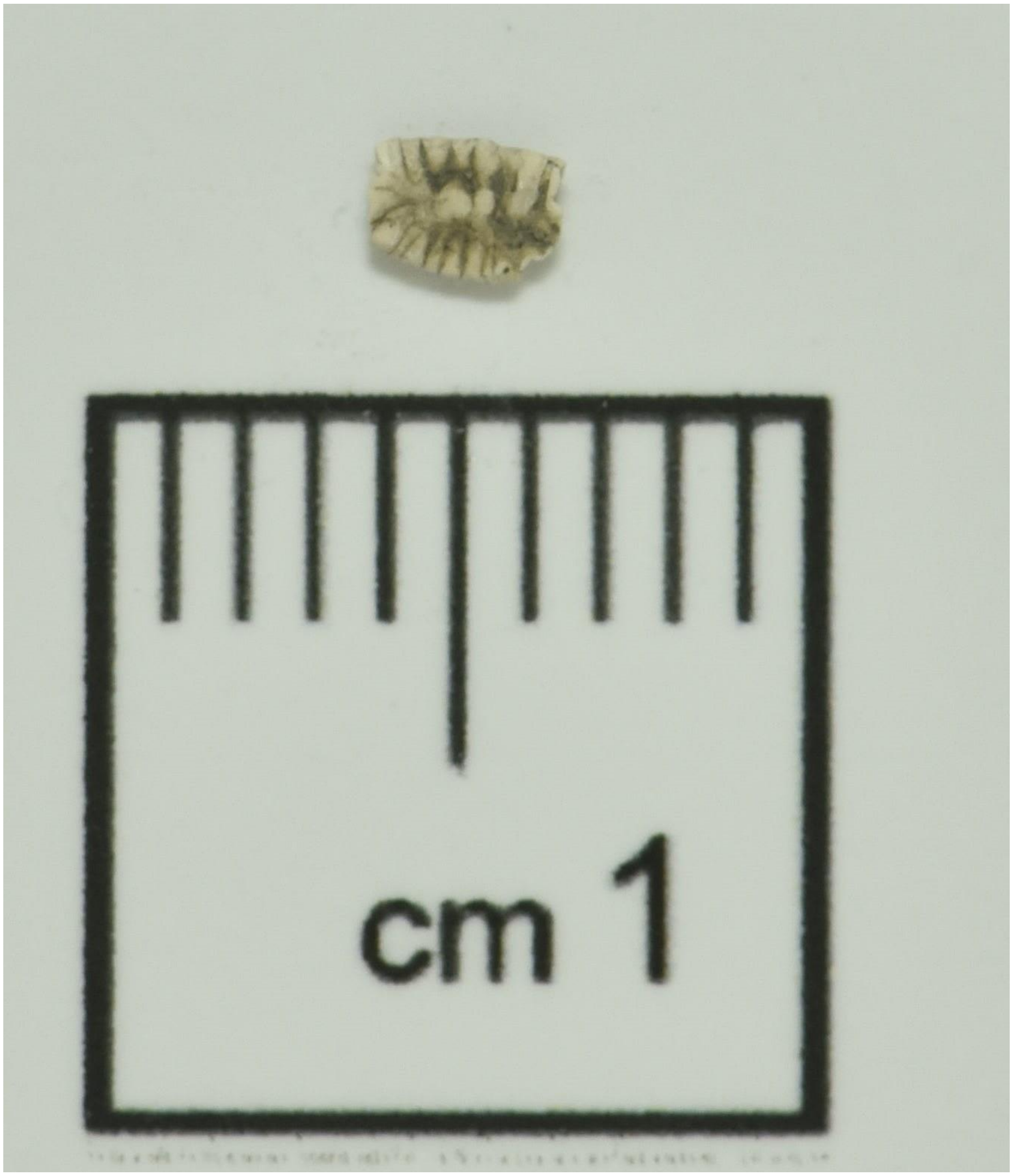

Plate SI-Chapter8-3: Outer surface of otolith OT0177. Condition is eroded. No inversion of aragonite to calcite detected. ©M.J.Evans.

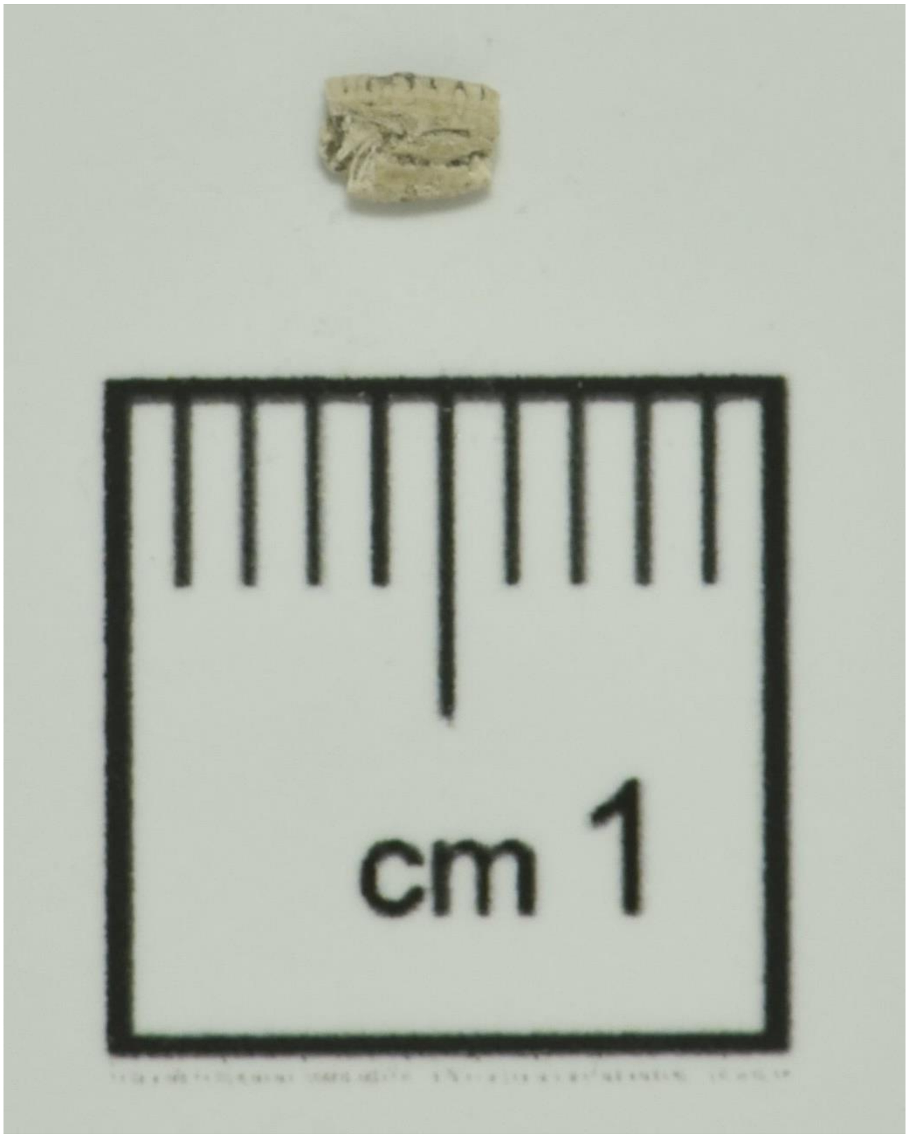

Plate SI-Chapter8-4: Inner surface of otolith OT0177. Condition is eroded. No inversion of aragonite to calcite detected. ©M.J.Evans.

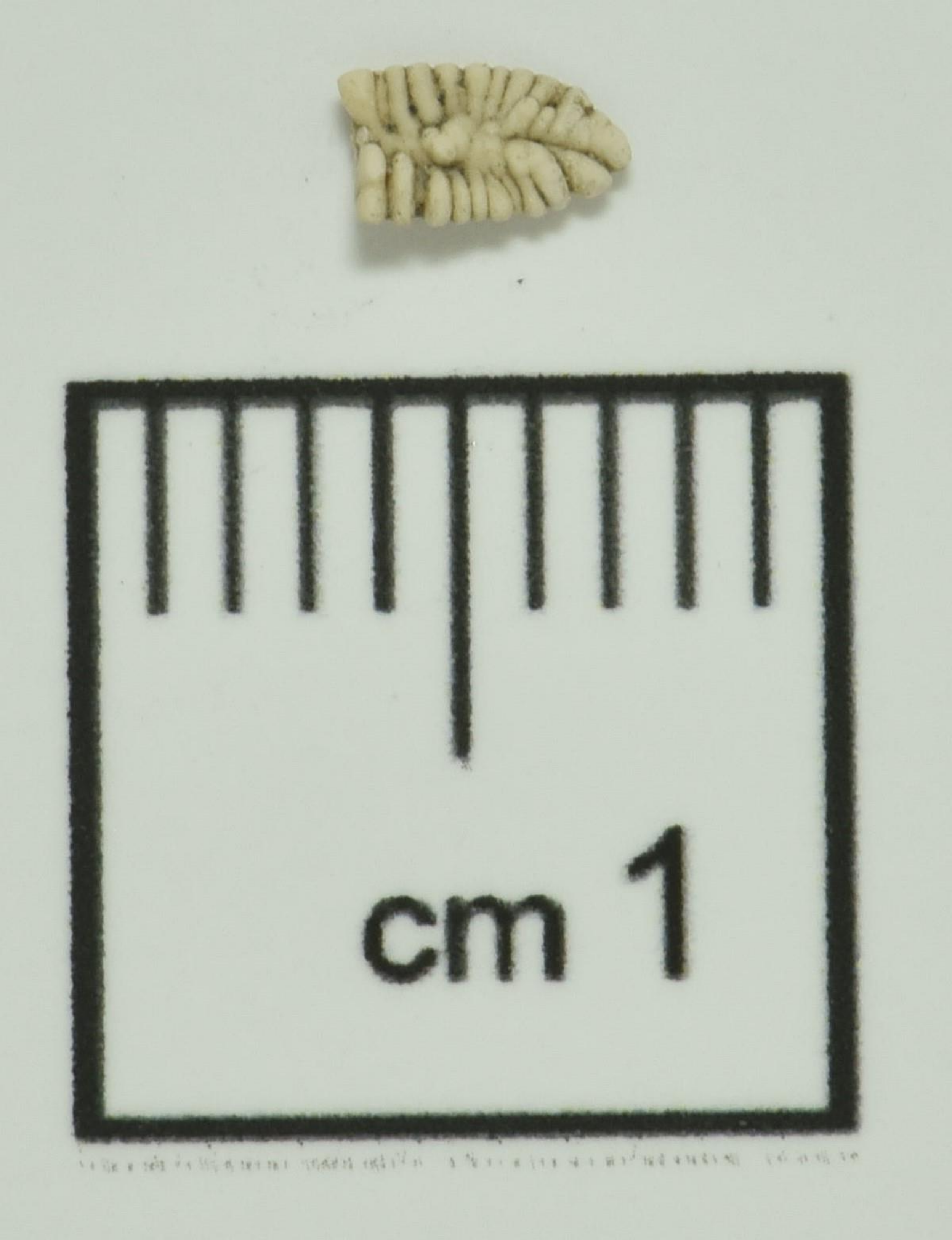

Plate SI-Chapter8-5: Outer surface of otolith OT0102. Condition is good. No inversion of aragonite to calcite detected. ©M.J.Evans.

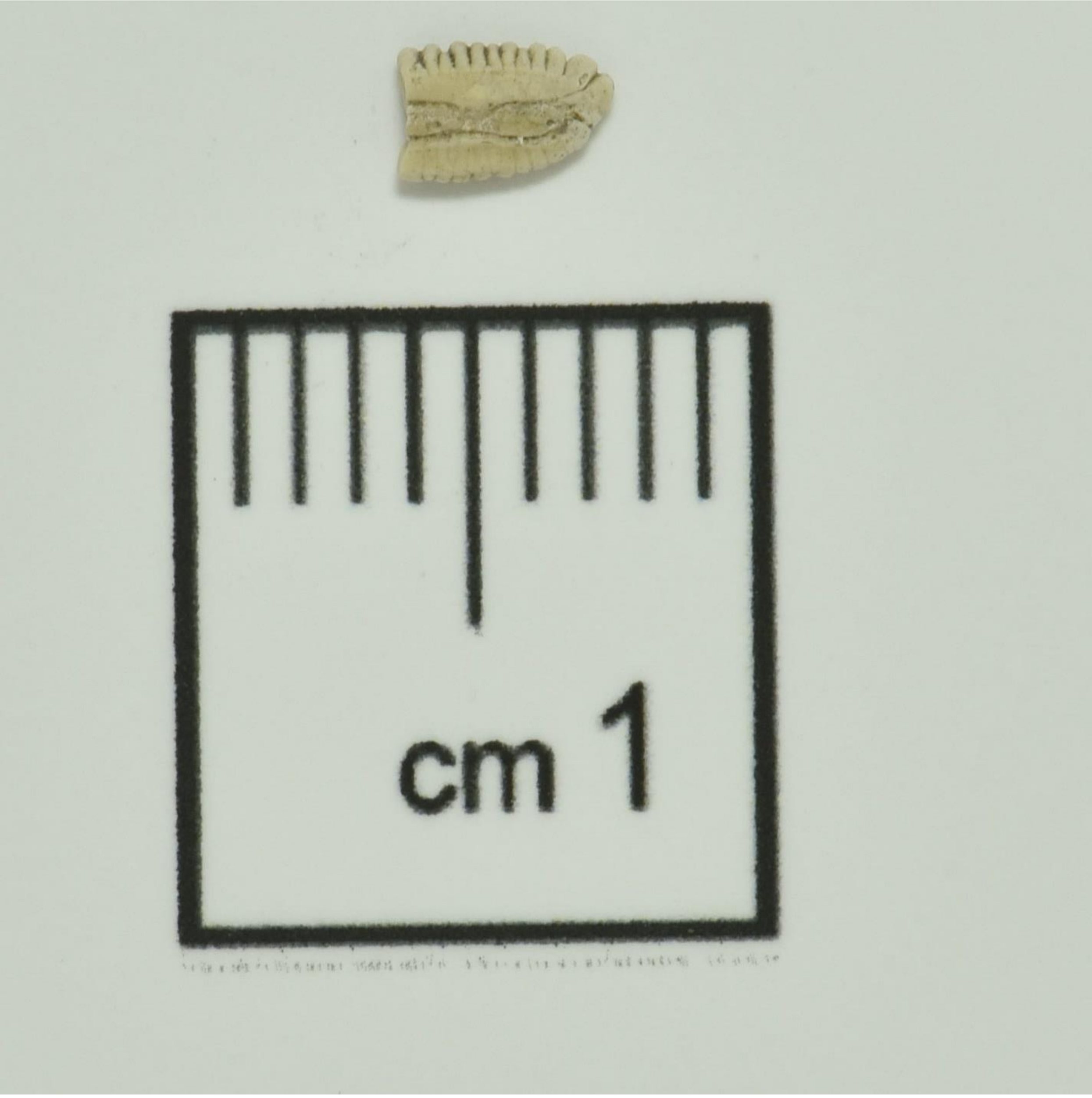

Plate SI-Chapter8-6: Inner surface of otolith OT0102. Condition is good. No inversion of aragonite to calcite detected. ©M.J.Evans.

SI-Gen-1

Introduction.

The site of West Voe, as discussed at more length elsewhere in this volume, is significant both in terms of its geographic position at the ‘crossroads’ between the open Atlantic and the North Sea, and its chronological position during what is generally accepted as the period of the Mesolithic to Neolithic transition in north-western Europe. Given that there are good grounds, as with the Western Isles (Serjeantson, 1990), for anticipating an impoverished terrestrial mammalian fauna, and probably a complete absence, the question of what economic strategies were adopted naturally presents itself. Given access to Shetland necessitates maritime navigation over a considerable distance understanding whether the occupation was all year round or a seasonal ‘commute’ can but extend our knowledge of the overall role of Scotland’s remoter islands during the period. Tackling such questions is a welcome opportunity to extend the archaeological record of the period geographically as well as our knowledge of coastal hunter-gatherers in general. Additionally, the analysis of the invertebrate remains permits an understanding of the environmental conditions prevailing at the time of occupation to be developed. The analysis was conducted against the project archive which had already been subjected to a degree of post-excavation processing, including sorting by species. The archive of faunal remains is limited to the >4mm fraction and therefore it was this that was examined. This chapter therefore brings together the results of fresh analysis and the presentation and discussion of the analyses provided with the archive. Time constraints dictated that a sub-set of samples were selected to provide the material for the fresh analysis. The analysis was conducted in June 2018 and October 2018.

The site can be characterised as representing two distinct phases of human activity. The initial phase lies below a deposit of naturally deposited (Gilmore and Melton, 2011) and archaeologically sterile sand (context 408), with the later phase lying above this natural sand deposit (ibid). It should be noted however that the composition of this later deposit has limited analytical potential, although its composition is of significance in the context of Scottish archaeology. This latter phase will be considered first, prior to moving on to the lower phase which lends itself more to the usual analytical methods.

The latter midden.

Physical inspection of the archive confirmed that the final episode of mollusc deposition was entirely of cockle (*Cerastoderma edule*), represented by both whole and fragmented valves. At the time of writing this composition is unique within the archaeology of Mesolithic Atlantic Scotland, both in terms of the extensive exploitation of this species, and its monospecific character. The cockle is well known to tolerate wide ranges of salinity variation and is often found in estuarine environments. It is therefore notable that even at the sites associated with the estuarine environments of the Forth Valley the presence of cockle is minimal, and some level of biodiversity is observed (Sloan, 1993). The only other known instance of extensive cockle exploitation is at the site of Morton B on the Firth of Tay on the North Sea coast (Coles, 1971). However, at Morton B an extensive suite of molluscs is exploited, including various bivalves, both living within the substrate (infaunal) and living on the substrate (epifaunal), as well as the epifaunal gastropods typical of Atlantic Scotland's Mesolithic middens (ibid). Given time and resource constraints further analysis was not carried out for two reasons. Firstly, there is no biometric analysis available from Morton B to support a comparative analysis of specimen sizes and population structures. Secondly, repeating the analysis performed by Coles (1971) to establish relative flesh yields at West Voe would be a fruitless exercise as cockles clearly constitute 100% of the yield.

The earlier Midden.

It was clear from an initial inspection of the archive, that in contrast to the later midden, the lower midden exhibited taxonomic variation stratigraphically, accompanied by a level of biodiversity. It was also clear that the potential for quantitative analysis existed if the samples for analysis were selected carefully. Therefore, a number of samples from various contexts were selected and these are detailed in table 1. This should be used in conjunction with the stratigraphic information provided by **xxxxx in chapter n** of this volume. The research objectives are straight forward, firstly, to understand the which resources were exploited. Secondly, to understand how subsistence strategies may have varied over time, whilst also elucidating the nature of the human - environment interaction during the period of occupation. The information and conclusions within this chapter should be utilised in conjunction with the data presented by Milner **(chapter n) and Nicholson (chapter n).**

Methods.

Sample Selection.

Samples were selected where the total number of molluscs would permit a meaningful quantitative analysis. Once this filter had been applied samples were sought that were horizontally adjacent or stratigraphically adjacent and provided coverage from both the north and south of the ‘cut feature’ (context 483). Unfortunately, the preservation and fragmentation levels in some samples demanded compromise, this being particularly true when seeking samples that as a group were adjacent in both the horizontal and vertical planes. A consequence is that no data will be presented from contexts 412/413, 413/412 and 413 (see chapter n). Comparison was made with Sand Rock Shelter, An Corran Rock Shelter, Ulva Cave, Nether Kinneil. These sites were created in different chronological periods and none of them were concurrent with West Voe (table 2), therefore direct comparisons require care, but for contextualising West Voe's mollusc assemblage they are extremely useful.

Quantification

A key question regarding any faunal assemblage is the relative importance of different species to the people who collected them, and by implication the role played by each species within the exploitation strategy. The first step to establishing the above is to establish the relative abundance of each species. This was established using the usual method employed at European midden sites, which involves establishing the minimum number of animal units (MAU) present. When dealing with molluscs the author considers NISP to be too sensitive to variation in the robustness of different species. Shell weight is even more problematic for the same reason, and the deposits at West Voe (as will be discussed) support this view point. The gastropods were quantified by counting apexes as the non-repeating element (NRE). Bivalves were sorted into left hand valves (LHV) and right valves (RHV) and each quantified using the umbo as the NRE for a valve. An estimated MAU was determined using the greater of LHV or RHV within a given sample. The number of oysters was small enough to consider gross size differences and generate a minimum number of individuals (MNI), this was not the case for mussel and therefore to maximise the comparative potential both taxa are reported as MAU. The exercise was repeated when pooling samples at context level. It is assumed that the oysters measured during the earlier analysis (see below) had been returned to the bags of mixed LHV and RHVs within each context. Crabs were identified using reference specimens and quantified as NISP, whilst also recording the presence of the claws (the propodus and dactylus).

Composition

The composition of a sample was determined by the relative abundance using the MAU values generated. This provides a view of relative abundance by the number of organisms, it does not directly reflect economic significance due to the difference in flesh yield of different species, as well as in their nutritional content. A simple experiment was conducted to compare the volume available for soft body tissue from an average sized oyster (LHV) and average sized limpet. In each case the shell was filled with water and the weight recorded.

Biometric Analysis

A key question when considering human procurement is the structure of the population they procure as this may reveal the impact humans are having upon the environment. In the case of limpets, it may also indicate the character of the shore being exploited.

Mollusc populations are known to be sensitive to both environmental conditions as well as predation levels, including that by humans. In some species the morphology of the organism is known to vary in response to environmental conditions. The limpet is an excellent example of an organism that exhibits environmental plasticity and whilst its geometrically simple morphology makes it particularly suitable for biometric analysis, the difficulty in identifying different species from archaeological shell remains does complicate the process. The common limpet (*Patella vulgata*) alters its shape in response to desiccation risk (Baxter, 1983). it has also been suggested that limpets also adjust their shell shape in response to the wave energy of the shore (Bailey and Craighead, 2003), although Baxter (1983) did not reach this conclusion. Experimental analysis has shown that limpets possess sufficient adhesive force to make mitigation against hydrodynamic forces by changes in shell shape unnecessary (Denny, 2000). It is assumed here that the vast majority, if not all, the influence on the shell shape of the limpets is a response to desiccation stress. The length, width and height (figure 1) of the limpets were measured using digital callipers to the nearest 0.1mm. From these measurements the base eccentricity (length/width) and conicity (length/height) of each shell were calculated. With periwinkles the length and aperture height (figure 2) were recorded with digital callipers to the nearest 0.1mm. For oysters the biometric data provided with the project archive (Cowie, n.d.) was utilised. Whilst the preservation of mussel in the quantities observed is unusual and provides a welcome insight as to their possible contribution at other sites, the fragmentation levels prevented biometric analysis and therefore a qualitative assessment was made.

The detailed analysis of the seasonality of oyster procurement and the age at death of the oysters is presented elsewhere in this volume (Milner, Chapter n). The biometric data available for the oysters is aggregated at the level of midden block. Individual specimen numbers had not been assigned and hence unpacking the data to establish inter-context variation was not possible. Given the results obtained for taxonomic composition the biometric data available at the midden block level does provide for a reasonable view of the dynamics of oyster procurement during the earlier phases of deposition.

To provide context for the site's assemblage a comparative analysis was made with other middens. As only summary statistics are available for some sites the comparison was made by amending the boxplot program as follows. The horizontal bar within the box depicts the mean. The extent of the box depicts the standard deviation, the whiskers two standard deviations, with those specimens lying beyond two standard deviations being shown as outliers.

Results

Composition

The variation in midden composition is presented in figure 3. Which indicates that oysters are not the numerically dominant species. It should be noted that when the 17 samples analysed are considered individually there is one instance (S.210) where oyster dominates and two others (S.38, S.78) where it is the most abundant taxon but at a relative abundance of less than 50%. Compositional comparisons with the Forth Valley middens are not possible as Sloan (1993) only provides data based upon weight. Clearly the exploitation of oyster at significant levels is restricted to the initial deposits represented by contexts 401, 436 and 466, beyond which exploitation appears to be minimal and probably opportunistic. In general, limpets and mussels dominate the assemblage. The general trends observed at the level of context are discernible at the sample level, but the data is noisy. The sample sizes, in terms of excavated litres, that result from the intersection of midden block and context, are small. The shells they contain are very large and robust, the noisy nature of the data at sample level is probably due to individual deposition events being resolved, at least in part. The resolution of such events is also observed in some of the Danish (Andersen *et al*, 1993) and South American middens (Godino *et al*, 2011).

A significant contribution from mussel is atypical within the region's archaeology with many analysts, including the author, putting this down to taphomomic and diagenetic causes. Where conditions are suitable mussels have been preserved in quantity at a limited number of sites in Norway, Spain, as well as the Forth Valley (Sloan, 1993). The numerical dominance of limpet is typical of the majority of the middens from the Atlantic façade of Europe and especially so at higher latitudes. What is significant is the very low abundance of periwinkle and even more so dog whelk (figure 4). Only one specimen of dog whelk was encountered during the analysis, and atypically it was in pristine condition and 100% complete. Even allowing for the issue of mussel preservation the assemblage can only be considered a compositional anomaly within the archaeology of the Mesolithic of Atlantic Scotland. What is also evident is that as oyster exploitation declines overtime, mussel exploitation increases but then deceases eventually leaving the final stages of the lower midden made up of almost entirely limpet (figure 3). A depositional sequence is strongly suggested; context 401 then 436, accompanied by a size reduction in oyster, then context 466 and 401/414 with possibly some concurrency, then a sequence of 414, 414/480, 480/414, 480. Unfortunately oyster age at death is not available for context 401 and size at death is not available for contexts 401, 436 and 466 as stratigraphic units, which prevents a definitive depositional and therefore acquisition model being derived.

The other gastropods.

Based upon the data from Sand Rock Shelter and Ulva Cave the periwinkles are small and the dog whelk above average in size. A few specimens of top shell (*Gibbula spp.*) are also present. Fragments of the habitually sublittoral common whelk (*Buccinum undatum*) are also present The paucity of gastropods, other than limpet, is not inconsistent with them being inadvertent transports on oyster shells or seaweed.

The other bivalves

Beyond the epifaunal oysters and mussels the exploitation of infaunal bivalves within the middens of the northern Atlantic façade, rarely comprises of more than a few isolated fragments within the midden; the notable exception being the site of Morteneses in Arctic Norway (Bjerk, 2007). In this regard the composition of the earlier midden at West Voe is typical of those encountered elsewhere. The fragmented specimens of pullet carpet shell (*Venerupis corrugata*) are small, as are the fragmented valves of razor clam (*Ensis spp.*). At the sample level there was nothing to suggest other than the remains of one or two fragmented valves.

The crabs.

Crabs are a very minor and intermittent component of the assemblage and only the shore crab (*Carcinus maenas*) was present and the specimens were small, typical of specimens that are found whilst ‘rock pooling’ today. When present in a sample only a few fragments are present. The larger specimens of shore crab and the edible crab (*Cancer paguras*) observed at other Scottish sites (Anderson, 1895; Milner, 2009) are absent.

Biometric analysis.

At times it seems as if the archaeological record rebels against attempts to interrogate it, and West Voe was one of those times. Where contiguous horizontal or vertical sequences could be found that contained a sufficient quantity of molluscs, the sequence was broken due to fragmentation levels resulting in inadequate quantities of measurable limpets (table 1). Future analysis, especially of limpet will require a less direct approach, probably using shell thickness to reconstruct length at death.

The oysters.

It is obvious at first sight that the oysters are large, and that their shells are extremely thick in most cases (image ?). The thickest oysters also exhibit twisting and skewing in terms of shell shape and thickness, often with extreme levels observed on one half of the valve compared to the other. It appeared as if many of the irregular out growths probably aligned with the contours in the substrate upon which the oyster resided. This is a relative differentiation as the majority of valves are thick overall. The first significant observation that can be made is that the Oysters south of context 438 are significantly smaller than those from the north (figure 3) (p=0.nnn using a Kolmogorov-Smirnov test), this reduction in size occurs in conjunction with the reduction in abundance already presented in figure 1.

Oyster assemblages from the Atlantic façade of Scotland are rare (non-existent?), and those of the estuarine systems of the North Sea coast, although often identified, are lost without formal analysis, especially of the molluscs. The exception is Nether Kinneil and to a lesser degree Inveravon in the Forth Valley (Sloan, 1993); hopefully new data will be forthcoming from the ongoing excavations at Tarradale on the estuary of the Beauly. Figure 4 compares the size structure of the oyster populations from West Voe and Nether Kinneil. The periods covered by the samples compared almost certainly reflect very different durations of deposition, and in the case of the Forth Valley, may be a composite of exploitation over several archaeological periods. Clearly the oysters at West Voe are relatively large, yet both the West Voe population and the that from the Forth Valley exhibit a basically normal distribution. A simple linear transformation of -20mm applied to the West Voe assemblage aligns the distributions generally, for the mode, and both tails. The distributions are then statistically indistinguishable at $p=0.001$ using a Kolmogorov-Smirnov test. The implication is that both assemblages probably reflect the exploitation of the entire populations of oysters considered to be of edible size over albeit two vastly different periods of exploitation.

The Limpets

It was obvious at initial inspection that the limpets were huge. The population structures for the limpets are summarised in figure ? The extremely large size of the limpets was further emphasised by a specimen, whose lower portion had clearly been lost, still exceeding 50mm in length (excluded from the quantitative analysis) and that a number of detached apexes exhibited extremely thick shell at the apex >10mm, in one case 11.6mm thick. The mean height of a limpet in Sand's context 11 is only 10.05mm, which puts the above into perspective. Importantly, at some sites the longest limpets are also relatively flat, whereas at West Voe the limpets are very conical. There is a positive allometry between shell height and shell length, that is larger limpets are relatively taller. To explore this aspect of limpet morphology height was compared with length at West Voe and Sand Rock Shelter, for all limpets greater than or equal to 40mm in length. Figure ? demonstrates that this principle holds strong for the West Voe assemblage, for specimens over 40mm in length a major influence on height is the length and the best fitting model is linear ($R^2 = 0.54$). At Sand Rock Shelter the length (>40mm) of the limpet has a much weaker influence on height and the best fit model is logarithmic ($R^2 = 0.34$), factors other than size are the major influence on shell height. No significant differences are observed in limpet length between contexts, unfortunately fragmentation excluded context 436 from this exercise. Inter-sample comparisons were also inhibited by sample sizes of measurable limpets. Inter-sample variation could be observed between samples 203 and 202 where a significant ($p<0.0000$ using a Student's t.test) reduction in mean size from 46.4mm to 45.7 mm is observed

The above result is consistent with the ecological studies of Ballentine, (1961); Baxter, (1983). Whilst it is true that limpets are flatter on the lower shore than higher on the shore, a more nuanced interpterion of this physical characteristic is required. Firstly, the higher shore can be some distance down the shore from the high-water strand line when rock outcrops are present. Secondly, a rocky shore is typically very heterogeneous (Ballantine, 1961) and locations offering a benign desiccation environment can be found at various levels on the shore, due to the orientation of the rock surfaces, presence of weed cover and rock pools. As a consequence, heterogeneous environments in terms desiccation risk can also be found in close proximity at the same level on the shore (ibid) and this is reflected in the morphology of the respective 'local' populations. The result obtained suggests that the limpets from West Voe were obtained from a homogenous environment that presented a relatively uniform level of desiccation risk and there appears to be little or no diversification in the nature of the environment being exploited. In contrast the people at Sand Rock Shelter were procuring their larger limpets from environments that presented lower levels of desiccation risk. The possible inferences that can be made from these results will be discussed later.

The Mussels

The preservation of mussels provides a welcome insight into the possible importance of mussels elsewhere, where preservation conditions have usually been unfavourable. A qualitative assessment indicates that a significant proportion of the mussels are large and have thick shells and very robust umbones (image ?). It can also be stated that the mussel assemblage does exhibit greater variation in size between the very large and small compared to the limpets or oysters.

Discussion

Every midden is to some degree unique in terms of its specific composition and this extends to the population structures of those taxa exploited. However, this variation exists within what might be considered as an overall 'signature composition' for a given area. Based upon the work of Sloan (1993) this principle holds true for the middens of the Forth Valley. It is also true for the middens of North West Scotland where limpets numerically dominate, and periwinkle and dog whelk vie for second or third place in terms of relative abundance; accompanied by abundant (extremely in some cases) fish bone. In the latter area we also observe limpet assemblages which have mean sizes between 28 and 32mm and the range of limpet size goes from <20mm to >50mm. In the west Coast middens we also observe a paucity of both oyster and infaunal bivalves, including the cockle. Clearly West Voe has a character of its own. The only real attributes shared with the Forth Valley middens is a non-trivial exploitation of oyster (in the lowest levels), and a paucity of fish bone. The use of shell weight by Sloan (1993) does present issues, but it can be tentatively suggested that a paucity of dog whelk and periwinkle and abundance of mussel are also possibly shared attributes. The only characteristics shared with the west coast middens is the high abundance/dominance of limpet in the upper phases of the lower midden; noting, however, that the population structure is completely different. The lower midden's composition can be best summarised as initially similar to the estuarine middens of the North Sea which then transforms into an impoverished version of the typical West Coast middens.

What is striking is the size and age of the oysters and the size (and presumably age) of the limpets. The interpretation of West Voe's lower midden is fairly straight forward. The ecosystem being exploited had not been exploited by humans for at least a decade or more, if at all (see also Milner, chapter?). Upon arrival in the area (on the island?) the population sought large oysters, mussels and limpets, the latter from a very specific and homogeneous environment. Based upon my own field observations such specimens were probably mainly found on flat, horizontal and smooth rock surfaces, and therefore were easy to locate, thus reducing search time. It is also worth noting that the whilst the oyster shells are large and very thick this is not reflected in terms of the volume available internally for the actual organism. The large size and robustness of the oyster shells cannot be used to infer a correspondingly larger amount of oyster flesh. After a period of time the human population either exhausted the supply of such oysters or changes to the environment reduced their availability and hence focus on mussel and limpet increased. Over time the availability of large mussels also reduced, and greater reliance on limpets was a necessary adjustment. It is during this period of heavier reliance on limpet that an intensification of seabird and seal exploitation is observed (Worley, chapter?; Nicholson, chapter?).

What is perplexing is that at no point does the population appear to have sought out the usual gastropods typical of other middens, and likewise crabs and fish (Nicholson, Chapter?). They also appear to have been reluctant to search out the longer but flatter limpets usually concealed by sea weed or resident in rock pools. Why would this be the case? The other key question relates to the references above to time. How long can a limpet population support focused harvesting of its largest individuals. Based upon the analysis of Baxter (1982) and Ballantine (1961) the procured population at West Voe, if a single procurement ‘episode’, would remove *circa* 85% of the available limpet biomass. At first glance very efficient, yet of questionable sustainability based upon the experiments of Borges *et al*, (2016), which under different harvesting regimes observe a size reduction within a maximum of 18 months. The key to understanding the limpet exploitation may reside in the similarity West Voe exhibits with the Pleistocene middens of Cantabrian Spain (Gutiérrez-Zugasti, 2011, table 1, p.8). In both cases low intensity procurement to provide dietary and nutritional variation is probably the *modus operandi*.

Why are the people at West Voe making so little use of the gamut of marine resources available, especially fish, crabs and gastropods? The exploitation of gastropods is arguably associated with the acquisition of fish (and crabs) at most other sites, excluding the Pleistocene sites discussed above. Therefore, the paucity of the gastropods and fish (and crabs) at West Voe does make for a coherent pairing. A lack of preservation of fish bone is unlikely to be material given the preservation of marine mammal bone, the bone of small bird taxa and especially mussel shell. This leaves two main candidate explanations as to why a population on a remote island in the North Atlantic (that almost certainly had no terrestrial mammal fauna during the Mesolithic) adopted such a limited approach to the exploitation of marine resources. The first is quite simply that they did not need to, other sources of subsistence were available, apparently at other locations. What these other resources are, by definition, is not revealed by the midden deposits. This may suggest a specific site function for West Voe as a specialist location where large oysters and limpets could be readily acquired, at least for a time. The alternative is that they were unable to do so, lacking the raw materials to build fish/crab traps or nets and therefore eliminating the need for bait species or 'bait sized' specimens of limpet.

Conclusion

A number of conclusions can be drawn or at least entertained. The site is significant as it provides an insight on how prehistoric people can affect previously unexploited littoral ecosystems, which is a very welcome extension to the archaeological record. The very specific character of the assemblage is unique and yet internally consistent with the under exploitation of other taxonomic groups at the site. Unfortunately, the available data does not resolve between the 'they did not need to' or 'they were unable to' hypotheses. What is undeniable is that prehistoric people will continue to surprise us in that in some places, at certain times, they simply do not do what we expect them to, in this case employ the marine resource exploitation strategies observed elsewhere. Inevitably, we do not know what the actual extent of the midden was or how much may have been lost to us. The excavated volumes are small and the specimens they contain large and robust, and it is probable that they record a snapshot of a relatively short period of deposition. This is further supported by the frequent occurrence of refits of ancient breaks within the bird bone assemblage (per sobs.) and the inter-sample variation observed both in terms of limpet length and taxonomic composition. The later exploitation of cockle is also unique in its mono-specific nature and based upon the evidence presented elsewhere clearly originates from a different archaeological period, where a very specific need or preference for an element of shellfish within the diet persisted.

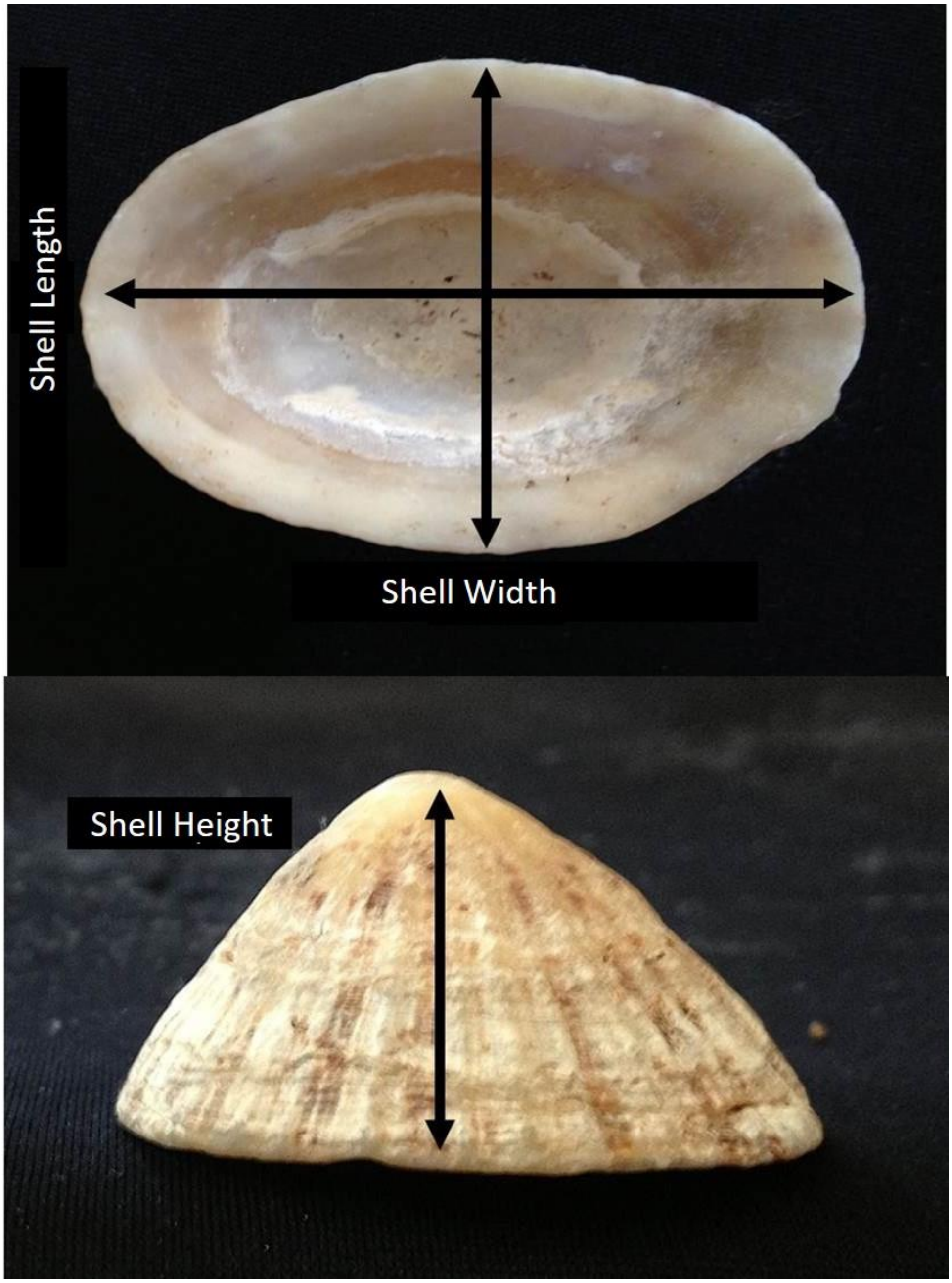

Figure 8 - Patella metrics

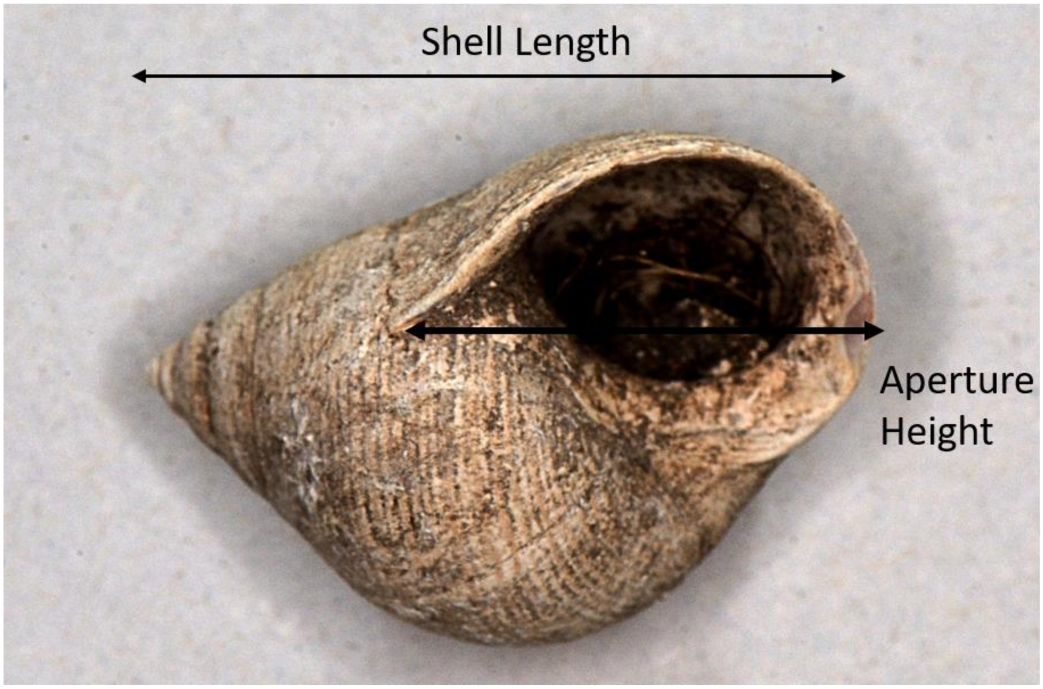

Figure 9 - Periwinkle metrics

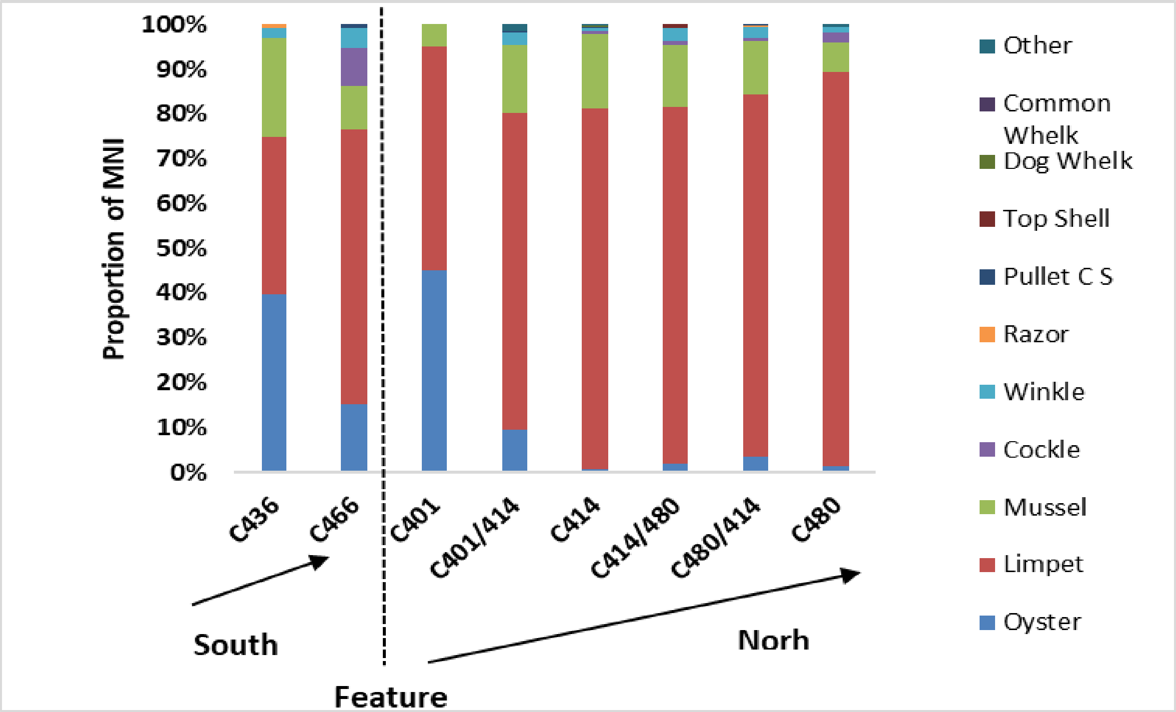

Figure 10 – Relative Abundance (Intra-site) See table 1 for sample sizes for West Voe.

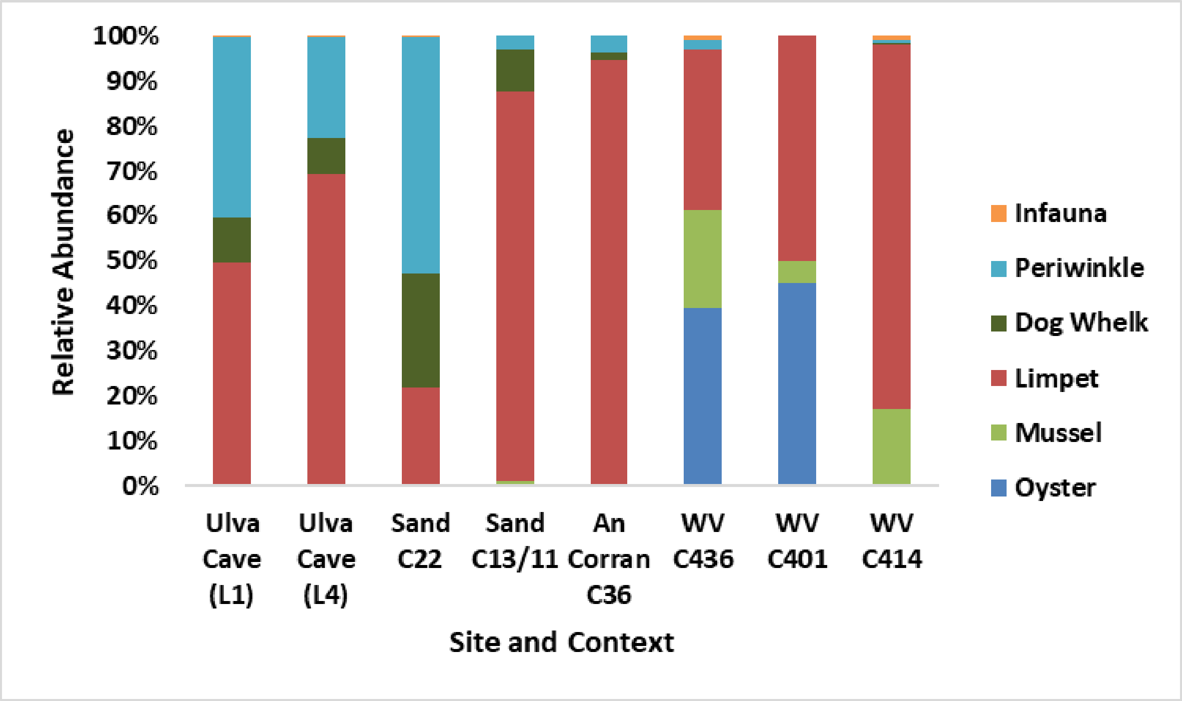

Figure 11 Comparative Composition (MAU). See table 1 for sample sizes for West Voe

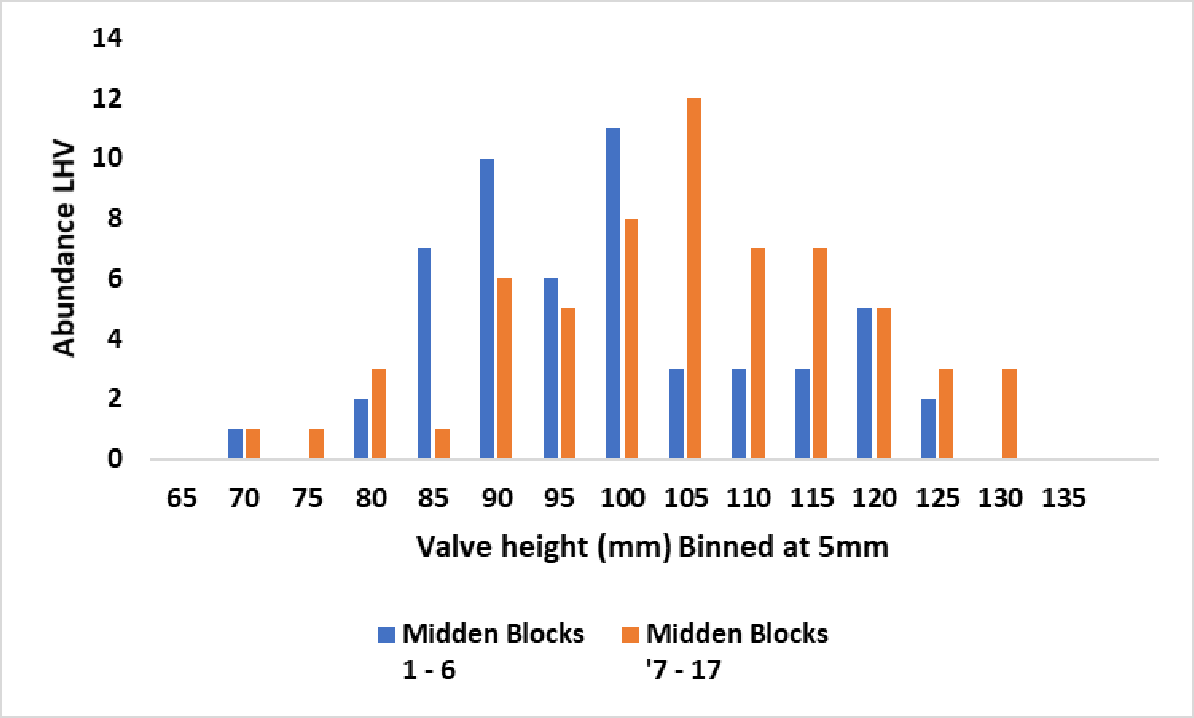

Figure 12 - Oyster size comparison either side of the feature 483. Data from archived mollusc report.

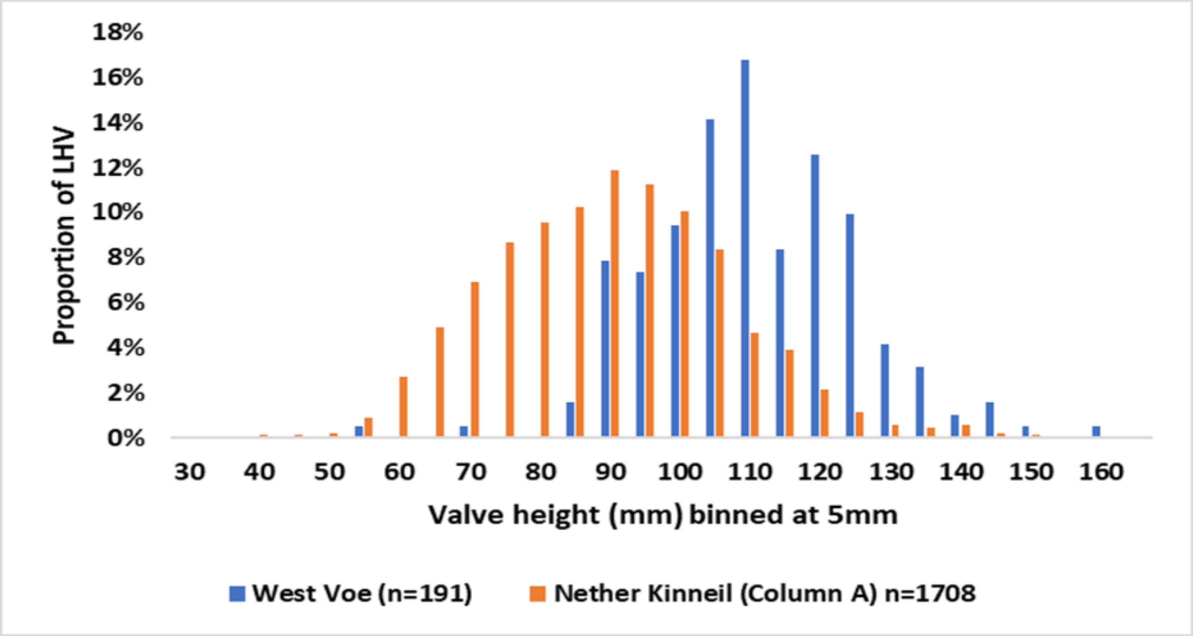

Figure 13 – Comparison of West Voe with Nether Kinneil. Data from the West Voe Archive and Sloan (1993).

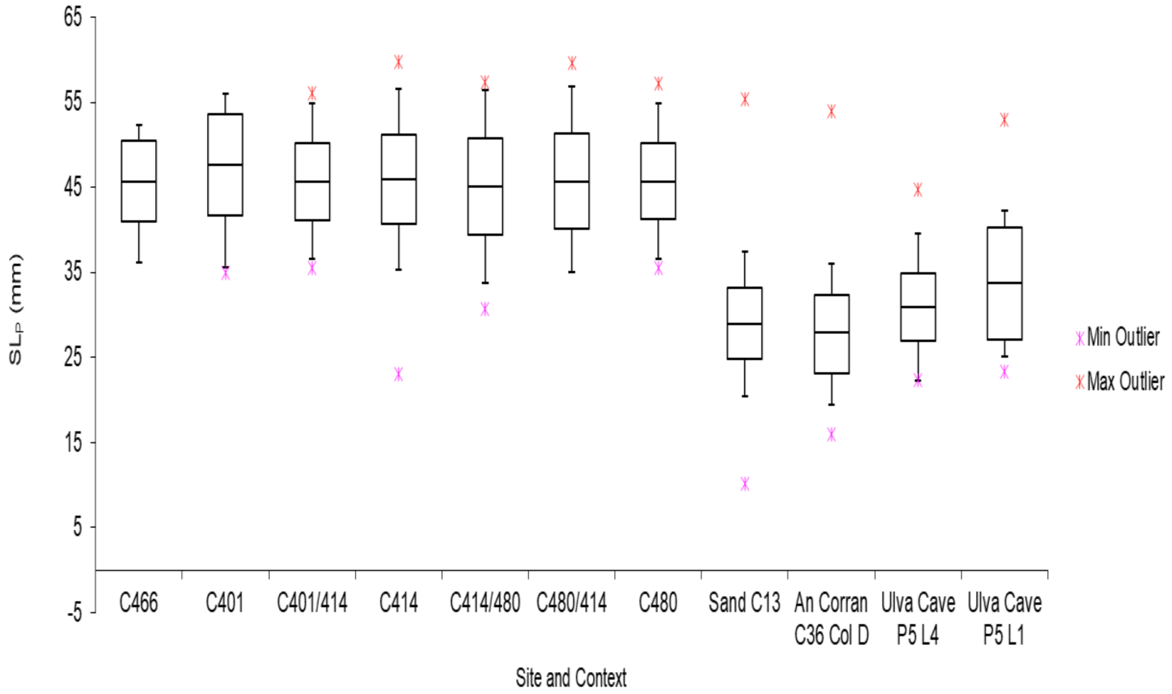

Figure 14 - Comparison of limpet length (SL_P). Comparative data from Milner (2009), Pickard and Bonsall (2012) and Russel *et al* (1995). NB. Some anomalous data entries for Sand Rock Shelter have been dropped. In these cases, it was unclear whether the height and length belonged to the same specimen or whether an entry was missing. Therefore, a simple transposition of the height and length could not be guaranteed to produce a valid result.

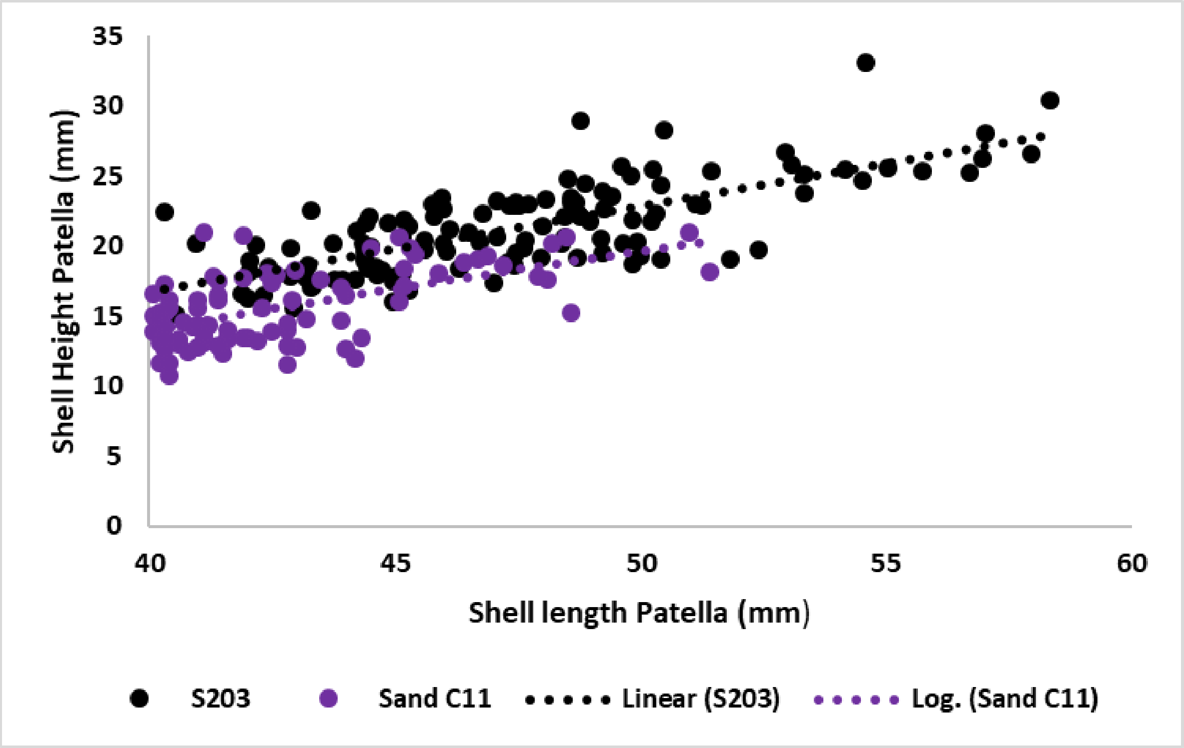

Figure 15 - Comparative Patella Conicity where shell length >= 40mm. Data for Sand Rock Shelter from Milner (2009).

Table 6 – Samples Subjected to fresh analysis

Midden Block	Context	Sample	MAU all taxa (n)	Quantity Measurable Patella n (%)
2	436	38	96	2 (6)
2	466	36	62	4 (11)
3	466	32	70	10 (21)
Feature	483			
16	401	213	39	17 (71)
17	401	210	23	3 (43)
13	401/414	71	67	26 (70)
13	401/414	78	43	13 (93)
14/15	401/414	79	286	101 (44)
13	414	51	182	82 (64)
15	414	202	166	67 (48)
17	414	203	327	168 (60)
12	414/480	57	221	90 (51)
12	480/414	75	66	15 (32)
13	480/414	49	139	51 (45)
14	480/414	74	381	126 (40)
18	480	204	91	7 (9)
19	480	207	80	25 (36)

Table 7 - Comparative Sites

Site	Context		Approx Date Ky Cal BC	Source
Sand Rock Shelter	11/13	N/A	7.0 to 6.3	Ashmore and Wickham-Jones, 2009
Sand Rock Shelter	22	N/A	5.6 to 5.3	Ashmore and Wickham-Jones, 2009
An Corran Rock Shelter	36	N/A	6.6 to 3.8	Saville and Hardy, 2012
Ulva Cave	Column P	L1	6.6 to 6.3	Russel *et al*, 1995
Ulva Cave	Column P	L4	4.7 to 4.4	Russel *et al*, 1995
Nether Kinneil	Column H	N/A	Neolithic	Soane (1993)