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Scales of analysis: evidence of fish and fish processing at Star Carr

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Abstract

This contribution directly relates to the paper published by Wheeler in 1978 entitled 'Why were there no fish remains at Star Carr?'. Star Carr is arguably the richest, most studied and re-interpreted Mesolithic site in Europe but the lack of fish remains has continued to vex scholars. Judging from other materials, the preservation conditions at the site in the late 1940s/early 1950s should have been good enough to permit the survival of fish remains, and particularly dentaries of the northern pike (*Esox lucius* L., 1758) as found on other European sites of this age. The lack of evidence has therefore been attributed to a paucity of fish in the lake. However, new research has provided multiple lines of evidence, which not only demonstrate the presence of fish, but also provide evidence for the species present, data on how and where fish were being processed on site, and interpretations for the fishing methods that might have been used. This study demonstrates that an integrated approach using a range of methods at landscape, site and microscopic scales of analysis can elucidate such questions. In addition, it demonstrates that in future studies, even in cases where physical remains are lacking, forensic techniques hold significant potential.

Keywords: Mesolithic; Star Carr; Flixton Island, Fish remains; Seasonality; Use wear

1.0. Introduction

Figure 1: location map of Star Carr.

Grahame Clark excavated Star Carr from 1949-1951 (Clark 1954) (Figure 1). His discoveries have led to what has become known as one of Europe's most famous Mesolithic sites. This was due to the outstanding preservation of organic remains, including the discovery of a brushwood platform associated with an extensive faunal assemblage and extremely rare artefacts such as 'headdresses' made from the crania of red deer (*Cervus elaphus* L., 1758). Clark noted that:

'No remains of fish survived. Negative evidence is notoriously dangerous in prehistory, and never more so than when a substance so perishable as fish-bone is in question. Yet to judge from what was found on similar sites in different parts of northern Europe, traces might at least have been expected for the lower jaws of pike, had these been caught. It should be remembered though that the evidence for pike-fisheries among the later Maglemosian comes from sites occupied during the summer, in the early months of which the fishing was carried on with leisters in temperate Europe down to modern times. The absence of pike remains from Star Carr may therefore be a true reflection of the circumstance that the site was *abandoned during the summer months*' (Clark 1954, 16, our emphasis).

In the 1970s and 1980s a number of articles reinterpreted the evidence from Star Carr, in particular reconsidering the seasonality of the site and importantly, suggesting that the site had been occupied during the spring and summer (Carter 1998, Caulfield 1978; Jacobi 1978; Legge and Rowley-Conwy 1988; Mellars and Dark 1998). This overturned Clark's hypothesis, as set out above, and with new interpretations of summer occupation, it became even harder to account for a lack of pike at the site.

In 1978, Wheeler, wrote a seminal paper entitled 'Why were there no fish remains at Star Carr?'. Importantly, he drew attention to the fact that pike can be fished all year round, which negated the seasonality argument. Therefore, he suggested that there were probably no fish present in the lake throughout the course of site occupation. His hypothesis was that fish, attempting to colonise up the riverine systems, would not have permeated the Lake Flixton basin because the water was too fast flowing at Kirkham Gorge, located roughly 40 kilometres downstream.

However, Wheeler (1978) did not mention the presence of waterfowl, which can transport fish spawn via their feet. The Star Carr faunal assemblage contained at least seven species: white stork (*Ciconia ciconia* L., 1758), common crane (*Grus grus* L., 1758), red-breasted merganser (*Mergus serrator* L., 1758), red-throated diver (*Gavia stellata* P., 1763), great crested grebe (*Podiceps cristatus* L., 1758), little grebe (*Podiceps ruficollis* P., 1764) and a duck of similar size to the pintail (*Anas acuta* L., 1758) (Clark 1954). Thus fish could have colonised the lake via this method of passive dispersal.

The only potential (indirect) evidence for fishing is in the form of the barbed points. Clark found 190 barbed points and 1 harpoon at Star Carr (Figure 2). These were made out of red deer antler and manufactured so that they could be hafted onto wooden shafts for spearing or throwing. In some cases they may have been hafted in pairs or with the addition of a central bone point to provide a leister as has been observed at other sites in Europe: one such pairing of barbed points was observed by Clark *in situ* (Clark 1954, plate 12).

Figure 2: A range of the different types of barbed points/harpoons found at Star Carr including the harpoon in the middle (scale: 5cm).

Further evidence for the use of barbed points and harpoons related to fishing practices derives from a number of other Early Mesolithic ('Maglemosian') sites in north-west Europe: Holmegård, Lundby, Mullerup, Ulkestrup Lyng, Sværdborg, Vinde-Helsinge and Ögaarde (in Denmark) and Duvensee, Friesack 4, Friesack 27a, Hohen Viecheln and Wustermark (in northern Germany) (Aaris-Sørensen 1976; Broholm 1924; Clark 1948; Gramsch and Beran 2010; Groß 2014; Jessen *et al*. 2015; Noe-Nygaard 1995; Robson 2015; Rosenlund 1980; Schuldt 1961). In addition, fish remains were also encountered at the majority of these sites and are solely pike, or pike dominant. However, wels catfish (*Siluris glanis* L., 1758), European perch (*Perca fluviatilis* L., 1758), tench (*Tinca tinca* L., 1758), carp (Cyprinidae sp.), common bream (*Abramis brama* L., 1758), common rudd (*Scardinius erythrophthalmus* L., 1758) and European eel (*Anguilla anguilla* L., 1758) have also been identified (Aaris-Sørensen 1976; Broholm 1924; Gramsch and Beran 2010; Groß 2014; Jessen *et al*. 2015; Noe-Nygaard 1995; Robson 2015; Rosenlund 1980; Wundsch 1961).

In addition, there is a close correlation between pike remains and barbed points, similar to those found at Star Carr. For instance, at Sværdborg, Denmark, 80 upper and 64 lower pike jaw bones were found along with 274 leister prongs and 11 hooks (Clark 1952, 47). There are also sites where barbed points have been found in association with pike bones within the lake bed. Clark (1948, appendix 1) lists Calbe (Germany), Esperöds Mosse (Scania), and Kunda (Estonia). In two cases at the latter site barbed points were found impaling pike skeletons: one in the back of a large pike and the other in the skull (Clark 1952, 47).

In comparison, there is very little evidence in Britain for freshwater fishing, particularly in the Early Mesolithic. The only comparable example to the European evidence appears to derive from nearby Holderness: in 1903 an antler harpoon was found at Atwick, East Yorkshire and in 1932 further investigations were carried at the nearby site at Skipsea by Godwin and Godwin (1933, 39) who found ‘fragments of *Pinus* bark, fins of pike (*Esox lucius*) and flint artifacts’.

In the later part of the British Mesolithic evidence for fishing freshwater species exists but these specimens are not found alongside barbed points: for example a single precaudal vertebrae of a pike was found at Bouldnor Cliff on the Isle of Wight (Momber *et al*. 2011, 52) and from the Severn Estuary Mesolithic sites a total of 513 identifiable fragments of fish were found including Salmonidae (salmon family), eel and a possible cyprinid (Cyprinidae sp.) as well as coastal species (Bell 2007, 166-168).

The reason for the lack of fish remains at Star Carr has therefore remained a mystery that has intrigued scholars and members of the public alike. A possible explanation for the absence of fish remains at Star Carr could be that Clark did not sieve the sediments, meaning that small specimens may have been missed. Sieving was not a common practice at the time; peat is extremely difficult to sieve because it is highly organic and does not easily pass through a sieve and therefore it is perhaps unsurprising that this was not attempted.

Renewed research since 2004 (Conneller *et al*. 2012; Milner *et al*. 2013) has provided further opportunities to test for the presence of fish remains at the site. Initially, it was considered highly unlikely that any fish remains would be found, even with sieving, due to the extremely acidic sediments that have formed over the last couple of decades (Boreham *et al.* 2011; High *et al*. 2015). Some bone and antler has become 'jellybone': the mineral has dissolved in the acidic peat and the collagen has turned to gelatin (Milner *et al*. 2011a). Furthermore, quantities of bone and antler are extremely low when compared to Clark's faunal collection, suggesting that much of this material has completely disappeared (Milner *et al*. 2011a).

During the last four years, three different lines of evidence have at last provided definitive evidence that not only a range of fish species were present in the lake, but that they were caught and processed by humans. Significantly, these lines of evidence came from completely different scales of analyses:

1. landscape scale: coring the lake sediments for environmental and climate records
2. site scale: excavations at Star Carr and at Flixton Island Site 2
3. microscopic scale: microwear traces on flint tools from Star Carr

1.1. Background to the sites

Star Carr and Flixton Island Site 2 are two of a number of Early Mesolithic sites that have been recorded in the area around the palaeo-Lake Flixton, in the eastern Vale of Pickering, North Yorkshire, UK (Figure 3). The palaeo-lake formed at the start of the Windermere Interstadial (c. 14,700-12,800 cal BP; 12,700-10,800 cal BC), a warm phase at the end of the last Ice Age before the final cold period of the Younger Dryas (12,700-11,600 cal BP; 10,700-9600 cal BC), and it persisted as a water body until the end of the Mesolithic (c. 6000 cal BP; 4000 cal BC).

John Moore, a local amateur archaeologist first carried out investigations in the area in the late 1940s and identified 10 sites around the lake. Moore excavated a trench at Star Carr in 1948, and from 1949-1951 Grahame Clark from the University of Cambridge conducted three further seasons of fieldwork (Clark 1954). Moore also conducted fieldwork at Site 2 on Flixton Island which was published as a three-page summary at the end of the Star Carr monograph (Clark 1954).

Further work in the area has been carried out by the Vale of Pickering Research Trust since the 1980s, with the aim of mapping the extent of the lake and identifying further sites (for a full account see Milner *et al*. (2011b)). Since 2004, NM, CC and BT have been co-directing excavations at Star Carr and in 2012 the POSTGLACIAL project commenced: this is a five year, European Research Council funded project with the aim 'To implement an interdisciplinary, high-resolution approach to understanding hunter-gatherer lifeways within the context of climate and environment change during the early part of the post-glacial period (c. 10,000-8000 BC)'. In order to address this aim, further excavations have been carried out at Flixton Island Site 2 (2012-14) and Star Carr (2013-2015), in conjunction with a programme of coring lake sediments in order to reconstruct local climate and environmental change.

Figure 3: The locations of Star Carr and Flixton Island Site 2 as well as all other known Mesolithic sites within the Lake Flixton basin (lake area a reconstruction of the water at its maximum during the Holocene). Key: 1, Star Carr; 2, Ling Lane; 3, Seamer Carr Site F; 4, Seamer Carr Sites L and N; 5, Seamer Carr Site K; 6, Seamer Carr Site D; 7, Seamer Carr Site B (Rabbit Hill); 8, Seamer Carr Site C; 9, Manham Hill; 10–12, Cayton Carr; 13, Lingholme Site B; 14, Killerby Carr; 15, Lingholme Site A; 16, Barry's Island; 17, Flixton School Field; 18, Flixton School House Farm; 19, Woodhouse Farm; 20, VP Site E; 21, VP Site D; 22, Flixton Site 9; 23, Flixton Island Site 1; 24, Flixton Island Site 2; 25, No Name Hill.

2.0. Methodology

2.1. Sediment coring

Between 2010-2013, alongside the lake-edge excavations, a sediment core-based palaeoenvironmental study was undertaken as part of the POSTGLACIAL project. The preliminary results of this research were reported by Palmer *et al*. (2015). During coring, a single fish scale was identified toward the base of sediment core C (Palmer *et al*. 2015).

2.2. Excavations at Flixton Island Site 2

In 2012, excavations were carried out at Flixton Island Site 2, approximately 500 metres east of Star Carr. A programme of sieving the archaeological sediments was carried out and a 50% sample was sieved using a 4 mm mesh in order to retrieve small pieces of bone or flint debitage, which otherwise would have been missed through trowelling. As the focus was on the lakeshore deposits, where fewer archaeological remains are generally found, a very small proportion of finds were retrieved in the sieve. However, a fish vertebra was discovered in the sieve from context 1003 (Mesolithic reed peat).

2.3. Excavations at Star Carr and the flotation of the dryland deposits

During the excavations in 2008 at Star Carr, the remains of a structure were discovered on the dryland, which has become known as the 'Earliest house in Britain' (Conneller *et al*. 2012). The structure was composed of a hollow in the ground, infilled with organic rich sediment, and surrounded by postholes. It should be noted, that although significant quantities of mammal bone have been found on the dry land deposits, and in the structure itself, the preservation of the bone is generally extremely poor and most remains are unidentifiable either in terms of genus/species or in many cases element.

Sediment was sampled from the structure and processed in the laboratory using the bucket flotation method. Volumes ranged from 1.5 to 2.5 litres. A 300 μ sieve was used to collect the flot and a 1 mm sieve was used to catch the residue. Samples were dried in a drying cabinet for approximately 12 hours at 40°C. The flot was examined primarily for plant remains and the residue for other biological remains. The content of each sieve was examined a small fraction at a time under a stereomicroscope. Plant remains and any other biological remains retrieved were extracted using tweezers and stored in a sealed glass tube, clearly labelled with the site code and sample number in preparation for identification. A total of 11 fish remains were recovered from grid square I3, context 149, by ET, and analysed by HR using the modern reference collection housed at the University of York.

More recently, in 2015, excavations were carried out in the vicinity of Clark's trenches including a small area of unexcavated baulk and here two fish remains were recovered by hand during the careful excavation of context 312 (Mesolithic reed peat).

2.4. Microwear analysis

Microwear analysis is the study of traces that are visible on a tool and which develop through the course of the tool's use. Traces can vary depending on the contact material that is worked and the direction in which the tool is used. (Vaughan 1985). This is determined by comparing archaeological traces with those on experimentally used tools. It is this comparison that allows an analyst to make an informed inference about the function of artefacts (van Gijn and Little in press).

Identifying fish within prehistoric assemblages is recognised as difficult due to their vulnerability of the traces and a frequent lack of distinction from other animal processing activities (van Gijn 1986, 23). However, experimental work replicating different aspects of fish processing, such as filleting, gutting and scaling (see García Díaz and Clemente Conte 2011; van Gijn 1986) has enabled similar traces to be identified on archaeological lithic assemblages (Clemente *et al*. 2010; Högberg 2009). Recent research has even identified fish microwear traces on Neanderthal stone tools (Hardy and Moncel 2011), showing that fish processing tools have great antiquity.

3.0. Results

3.1. Sediment coring

The scale recovered from the sediment core had a characteristic ctenoid form and was identified by DS as a scale from a perch. The scale was identified at c. 17.1 m.a.s.l around 705 cm below the current ground surface. The deposits in which it lay are carbonate-rich lake sediments (Palmer *et al.*'s lithofacies 2a), associated with the Windermere interstadial (equivalent to the European Bølling/Allerød chronozone and dating between c. 14,700-12,800 cal BP, or 12,700-10,800 cal BC). The scale sat within the earliest sediments of this interval and reflects the presence of fish within the lake soon after the commencement of climatic warming. Fish scales of Lateglacial age are relatively uncommon finds within sediment cores in the UK, being first reported for Esthwaite Water in the English Lake District by Pennington and Frost (1961), and this chance find was not repeated in any other samples.

3.2. Flixton Island Site 2 and Star Carr ichythoarchaeological results

A total of 14 fish remains have been recovered from Flixton Island Site 2 and Star Carr (Table 1). Two of the remains were vertebral fragments that could not be determined to species. The following provides a brief summary of these data.

Taxon/skeletal element	*Esox lucius*	*Esox lucius*/ Salmonidae	Cyprinidae	*Perca fluviatilis*	Unidentifiable	**Totals**
Lake Flixton						
Ctenoid scale				1		**1**
Flixton Island Site 2						
Caudal vertebra	1					**1**
Star Carr						
Caudal vertebra			2			**2**
Posterior abdominal vertebra	1					**1**
Pharyngeal tooth			2			**2**
Premaxilla	1					**1**
Rib			1			**1**
Tooth		3				**3**
Vertebral fragment				1	2	**3**
Totals	**3**	**3**	**5**	**2**	**2**	**15**

Table 1: Represented skeletal elements of the various taxa found during the excavations and in the post excavation processing of bulk samples from Flixton Island Site 2 and Star Carr and also the ctenoid scale from the sediment core.

Although neural and haemal spines were absent, the bone recovered from Flixton Island Site 2 was a caudal vertebra which was identified by HR and AKGJ as pike (Figure 4). The total length (hereafter TL) of the pike was estimated as a function of bone size according to the methods as set out by Morales and Rosenlund (1979) utilizing the regression equations as stated by Zabilska (2013). The size of the vertebra, 12.1 mm across the greatest medio-lateral breadth of the centrum, corresponded to that of an individual approximately 815 mm in TL. Since adult pike normally range from 400 to 1000 mm in TL (Davies *et al*. 2004), this falls well within that range.

The vertebra was sent to Oxford Radiocarbon laboratory for direct AMS radiocarbon dating but unfortunately failed to produce a date due to a lack of collagen. However, a sample of willow (*Salix* sp.) from the same level was successfully dated to 9170-8570 cal BC (95.4% probability: OxA-X-2495-12, 9480 ± 90 BP). This date is contemporary with the dates yielded for Star Carr.

Figure 4: SEM image of the pike caudal vertebra from Flixton Island Site 2.

All of the fish remains recovered from the bucket flotation method were less than 1 cm in size, and all but one was calcined. It is likely that the one that was not visibly calcined had been subjected to some burning in order for it to have survived in this dryland context.

Although largely incomplete, a premaxilla that could not be sided was identified as that of pike. This specimen was calcined and was dark grey, almost black, in colour. Comparison with modern specimens suggested that it derived from an individual that was less than 200 mm in TL.

Three isolated teeth were identified as likely to derive from Salmonidae: however, it must be noted that salmon and pike have very similar teeth and there is the possibility that these also belonged to pike. If they are Salmonidae there is a possibility that these remains could have belonged to either the anadromous brown trout (*Salmo trutta* L., 1758) or Atlantic salmon

(*Salmo salar* L., 1758). All specimens were calcined, ranging from light grey almost white to dark grey in colour.

A fragile, isolated pharyngeal tooth was identified as deriving from Cyprinidae (carp and minnow family). It was not possible to identify the specimen to species level. The specimen was calcined and was dark grey in colour. Although neural and haemal spines were absent, two caudal vertebrae were identified as Cyprinidae. The specimens were calcined and were light grey, almost white and white in colour respectively. It was not possible to estimate the TLs, although they derived from an individual that was less than 200 mm in TL by comparison with modern specimens. In addition, one rib was identified as Cyprinidae. The specimen was incomplete, as only the proximal end was present.

In addition, one vertebra was identified as that of perch. The specimen was incomplete, as only half of the vertebral centrum was present. It was calcined, and was light to dark grey, almost black in colour. It was not possible to estimate the TL, although it derived from an individual that was less than 100 mm in TL based on comparison with modern taxa.

In 2015, excavations at Star Carr yielded a further two fish remains. Although fragile, the first specimen, an isolated tooth with a portion of the pharyngeal bone was identified by HR as deriving from Cyprinidae. It was not possible to identify the specimen to the lower species level or estimate the TL. The second bone, a posterior abdominal vertebra (Figure 5) was identified by HR as pike. The TL of this specimen was estimated according to the criteria outlined above (Morales and Rosenlund 1979; Zabilska 2013). The size of the vertebra, 11.4 mm across the greatest medio-lateral breadth of the centrum, corresponded to that of an individual approximately 873 mm in TL.

3.3. Evidence that fish had been processed at Star Carr from microwear analysis

The current programme of microwear analysis of flint tools from Star Carr is the first since Dumont's studies (Dumont 1983, 1988). Microwear analysis of the flint in and around the structure has only just begun. Two flints with fish processing polish have already been identified a short distance from the structure (Figure 6). Neither of the tools (92184 and 91949) are retouched. One (92184) is classified typologically as a fragment; the other (91949) is a proximal blade fragment. The fish processing polish are presented in Figure 7.

The two tools from Star Carr were taken to the Laboratory for Artefact Studies at Leiden University to be blind tested by three experienced microwear analysts. None of the analysts knew the original identification was fish processing. After independently analysing tool 91949, two analysts identified the wear traces as resulting from fish processing; the other said ‘possibly fish processing’. The test was repeated for tool 92184, with two analysts identifying fish processing and the third saying the polish was ‘indeterminate’. When presented with the conclusions from the other two analysts, this third analyst accepted that fish processing was a strong possibility.

Figure 5: Photograph of the pike vertebra in situ.

Fish processing traces consist of randomly distributed lines of matt, dull polish often described as having a corrugated appearance (Figure 7a) sometimes located away from the edge (van Gijn 1986). Edge damage in the form of small flake scalar scars, which form a repeated but irregular appear along the edge of the flint, are visible on some tools (van Gijn 1986; Högberg 2009). Lately, analysts have observed another feature to fish polish: areas where fish scales adhering to the surface of the tool have prevented polish forming, resulting in rounded, scalar areas of unpolished surface (García Díaz 2014, 98; see also Figure 7c).

Although not located within the structure, the fish processing tools were located a short distance from it and are from the same context as the calcined fish remains from within the structure. Due to taphonomic processes such as bioturbation and the palimpsests of activity on the dryland, we cannot be sure that the tools and fish remains are contemporary. Future microwear analysis of the flint assemblage from within the structure will determine whether a contextual relationship exists between the remains and tools. As this analysis is ongoing it also remains to be seen if future microscopic studies of the flint assemblages from other areas of the site will reveal similar evidence for fish processing tools.

Figure 6: Structure at Star Carr showing the distribution of finds. Key: triangle, location of fish remains within the structure; stars, lithics exhibiting fish processing traces.

Figure 7: Flint 92184 (above) and 91949 (below), both of which display fish processing polish. All micrographs 20x.

4.0. Discussion

4.1. The earliest evidence of fish in Lake Flixton

A particularly significant discovery of this research is that the evidence of perch in the lake originates in the Windermere interstadial, roughly between 2000-4000 years before settlement commenced at Star Carr. Native to Britain, perch are presently distributed across the northern Palearctic, with the exception of the Iberian Peninsula, central Italy and the Adriatic basin (Freyhof and Kottelat 2008). They occur across a diverse range of habitats, including estuarine lagoons, lakes and medium-sized streams, spawning in NW Europe in early spring when water temperatures reach a minimum of c. 10°C (Gillet and Dubois 2007; Hokanson 1977) and the photoperiod conditions increase. As opportunistic feeders, they prey on a wide range of aquatic invertebrates, with larger individuals becoming piscivorous once they reach 120 mm in length (Freyhof and Kottelat 2008).

The spread of *Perca fluviatilis* across Europe after the last Ice Age has been documented using molecular techniques (Nesbø *et al.* 1999). This suggests that perch found in modern day western Europe dispersed along the major river systems centred around the Vistula, Elbe, Rhine Rhône, Saône and Thames, with British perch originating from a southern glacial refugium, probably located in France although the exact position remains unclear (Nesbø *et al.* 1999). A similar southern French refugium has been suggested for other freshwater taxa today found in Britain, such as barbel (*Barbus* sp.) (Persat and Berrebi 1990), chub (*Leuciscus cephalus* L., 1758) (Durand *et al*. 1999) and brown trout (García-Marín *et al*. 1999), with the molecular data implying rapid northward expansion through northern European riverine systems since the last Glacial Maximum in the UK. Here, it is suggested that the presence of perch in Lake Flixton during the early Windermere interstadial could indicate colonisation through the Derwent river system.

4.2. The fish trophic system in Lake Flixton

This research also demonstrates the presence of pike, known from a number of Early Mesolithic sites in Denmark. Pike can be found throughout Asia, eastern North America and the majority of Europe. In Britain, it is the largest predatory freshwater fish, and consumes invertebrates, lesser fish, aquatic birds, amphibians and small mammals. Although it occurs in lakes to larger ornamental ponds and from canals and slow flowing rivers to streams, it can also reside in bogs as well as brackish lagoons and shallow, protected bays (Davies *et al*. 2004). It has a high tolerance to changes in pH and is capable of surviving in polluted waters, including those with low oxygen content (Noe-Nygaard 1995). Whilst it is a solitary carnivore, it is not territorial, often congregating in shoals to rest. Aided by its camouflaged appearance, it hides in submerged vegetation, where it lurks near its prey. Mating takes place between March and April when pike congregate and seek shallow water; it is during this time when they can almost be caught by hand (Noe-Nygaard 1995). Both the presence of perch and pike in Lake Flixton indicates a mature water body with an established trophic system.

Five of the fish remains have been identified to Cyprinidae. Although these specimens could not be identified to the species level, other species routinely identified in contemporaneous European faunal assemblages include the following: bream, white bream (*Abramis bjoerkna* L., 1758), Crucian carp (*Carassius carassius* L., 1758), common carp (*Cyprinus carpio* L., 1758), roach (*Rutilus rutilus* L., 1758), rudd and tench. Cyprinidae are, in general, lower down in the trophic level hierarchy, compared to perch and pike, and mainly feed on benthic invertebrates, including worms, molluscs and insect larvae (Maitland and Linsell 2009).

Although we cannot be 100% certain at the present that we have trout or salmon, it is important to discuss them in case further discoveries prove their presence. Both are anadromous species (migrate from the sea into freshwater to spawn) (Wheeler and Jones 2009). During their spawning runs, they can often become concentrated, albeit sometimes for a short period, making them abundant and prime targets for fishing. Atlantic salmon enter freshwater from the sea and migrate upstream at different times throughout the year. Whilst this is largely dependent upon the flow of the river and the water temperature, they arrive at the spawning grounds from November through February (Mills 1971). Here they are extremely vulnerable to predation since they are in shallow waters and occupied by spawning.

4.3. Fishing and consumption

Apart from the barbed points, there is no other evidence of fishing gear, such as nets, hooks, or traps, found at any of the sites along the former lake edge. However, some suggestions can be made as to the possible techniques that might have been used. Since pike are known to congregate within the littoral zone of a lake during their spawning period in the spring, they could have been more easily exploited at this time (Noe-Nygaard 1995). The pike may also have been attracted to some of the food waste, such as bones, which were deposited at the lake margins and from these areas it may have been possible to spear the pike using the barbed points found at the site. However, it should be noted that the barbed points found in the lakeshore deposits are not hafted and are therefore unlikely to have been lost during fishing activities. In addition, it is possible that bows and arrows were used or blows via clubs, and then collected (Aaris-Sørensen 1976).

Clark (1952, 48) recounts how Lapps spear pike from boats by targeting them when they sun themselves in the upper part of the water body. The use of boats is well established at this time, since people used the islands on the lake and presumably accessed them by boat. Clark (1954) also found what he thought was a wooden paddle at Star Carr: this is very thin but broken at both ends so difficult to estimate its full length. It has sometimes been dismissed as a paddle due to its thinness, however, paddles of this shape are known to be favoured in some place for navigating through reeds. Boats and paddles are also well documented for the Mesolithic across Europe.

As well as spearing fish in the day, Clark describes how the Lapps also enticed fish to the surface of the water at night by burning dry wood at the prow of the boat. An argument for night fishing has been suggested for pine tapers found on Irish Midland waterways linked to night-time fishing/eeling activities (Little 2009). At Star Carr, numerous burnt birch bark rolls have been found and analysed (Figure 8). Experiments have shown that plain rolls of bark burn for only a matter of minutes because the lack of oxygen in the middle of the roll suffocates the fire. However, if strips of bark are positioned within the rolls the torches burn for longer though tend not to survive as a burnt roll (Figure 9). Research is ongoing to determine whether the birch bark rolls from Star Carr could have been used for torches.

Figure 8: Birch bark roll with evidence of burning from Lake Flixton.

Clark (1952, 48) further mentions that the Lapps also catch pike using dragnets between two boats. Although nets have not been found at Star Carr, there are a large number of birch bark rolls some of which have not been burnt, and from ethnographical analogues, it can be demonstrated that they can be used as net floats (Figure 10).

Figure 9: experimental torch made from a birch bark roll.

Figure 10: Picture of birch bark rolls used as net floats (from The National Museum of Finland).

The site has yielded a tantalising glimpse of fish processing, and presumably consumption, from the use-wear traces on two flint tools. What is interesting is that this has taken place near to the structure where the calcined fish remains have been found. Future analysis will help to determine whether there is further patterning to these processes; however, the nature of the remains means that we will not be able to say how extensive fish consumption was.

Excluding the scale recovered from the sediment core, a total of 14 fish remains have been recovered from two archaeological sites located within the palaeo-Lake Flixton basin: Flixton Island Site 2 and Star Carr. In comparison with contemporaneous Maglemose sites in southern Scandinavia the assemblage is small. However, we believe that there are several reasons as to why so few have been recovered, and in particular from Star Carr: (1) Clark did not sieve the sediments; (2) the increase in the acidity of the sediments since the 1950s is likely to have destroyed any fish remains due to their delicate nature; (3) fish bones may have been deposited on the dry land and it is highly likely that they would not have survived unless burnt, as found in the structure; (4) we have previously demonstrated that ca. 5% of the site has been excavated, and so the possibility exists that fish remains (and possibly associated technology) may be present elsewhere on the site, possibly around the lake edge or discarded in the deeper deposits further into the lake as has been noted elsewhere in southern Scandinavia, such as Ringkloster (Andersen 1998).

5.0. Conclusion

This paper has yielded a number of important conclusions:

1. The evidence demonstrates that different species of fish were available in the lake during the Early Mesolithic and that these were exploited by the inhabitants of Star Carr. This data significantly adds to our understanding of Early Mesolithic economy in Britain.
2. The research demonstrates the importance of conducting flotation on sediments from dry land deposits and particularly from contexts such as structures. Although bone from this part of the site is generally very poorly preserved, the fish bone has been subjected to heating (in all likelihood it was thrown on a fire) which has meant that it has survived normal destructive taphonomic processes.
3. The application of use-wear analysis is of great importance for Mesolithic sites where faunal evidence is lacking. It holds the potential to uncover archaeological

information that is invisible to the naked eye, and answer economic questions that would otherwise remain unanswered.

4. By 3D plotting all artefacts using a Total Station and mapping using GIS important spatial relationships come to light that otherwise might be missed: the current evidence suggests people were processing the fish outside the structure, and then possibly cooking or consuming it within the structure before throwing the bones on a fire.

In sum, fish and fish-processing activities would have remained a mystery for Star Carr if it were not for the multi-scalar approach applied to the study of artefacts and the palaeoenvironment. Thus we believe the importance of combining micro- and macro-methods is critical when investigating hunter-gatherer settlement sites.

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References cited

Andersen, S. H. 1998. Ringkloster. Ertebølle Trapper and Wild Boar Hunters in Eastern Jutland. *Journal of Danish Archaeology*, 12, 1994-1995, 13-59.

Aaris-Sørensen, K. 1976. A zoological investigation of the bone material from Sværdborg I–1943. *Arkæologiske Stud,* 3, 137-148.

Bell, M. 2007. *Prehistoric Coastal Communities: The Mesolithic in western Britain*. York: Council for British Archaeology, CBA Report 149.

Boreham, S., Conneller, C., Milner, N., Taylor, B., Needham, A., Boreham, J., and Rolfe, C. J. 2011. Geochemical Indicators of Preservation Status and Site Deterioration at Star Carr. *Journal of Archaeological Science*, 38(10), 2833–57.

Broholm, H. C. 1924. Nye Fund fra den ældste stenalder. Holmegård-og Sværdborg fundene. *Årbøger fra nordisk oldkyndighed og historie*, 1-144.

Carter, R. 1998. Reassessment of Seasonality at the Early Mesolithic Site of Star Carr, Yorkshire Based on Radiographs of Mandibular Tooth Development in Red Deer (*Cervus elaphus*). *Journal of Archaeological Science,* 25(9), 851–856.

Caulfield, S. 1978. Star Carr – an alternative view. *Irish Archaeological Research Forum,* 5, 15-22.

Clark, J. G. D. 1948. The Development of Fishing in Prehistoric Europe. *The Antiquaries Journal,* 28(1-2), 45–85.

Clark, J. G. D. 1952. *Prehistoric Europe: the economic basis*. London: Methuen.

Clark, J. D. G. 1954. *Excavations at Star Carr: An early Mesolithic site at Seamer near Scarborough, Yorkshire.* Cambridge: Cambridge University Press.

Clemente, I., García, V., Ramos, J., Domínguez-Bella, S., Pérez, M., Vijande, E., Cantillo, J. J., Soriguer, M., Zabala, C., and Hernando, J. The Lithic Tools of the La Esparragosa Site (Chiclana de la Frontera, Cádiz, Spain, fourth Millennium BC): A Methodological contribution to the Study of Lithic Tools for the Consumption of Fisch. *Ancient Nets and Fishing Gear*, 275-285.

Conneller, C., Milner, N., Taylor, B., and Taylor, M. 2012. Substantial settlement in the European Early Mesolithic: new research at Star Carr. *Antiquity*, 86(334), 1004-1020.

Davies, C., Shelley, J., Harding, P., McLean, I., Gardiner, R., and Peirson, G. 2004. *Freshwater fishes in Britain – the species and their distribution*. Colchester: Harley Books.

Dumont, J. V. 1983. An interim report of the Star Carr microwear study. *Oxford Journal of Archaeology,* 2(2), 127–45.

Dumont, J. V. 1988. *A Microwear Analysis of Selected Artefact Types from the Mesolithic Sites of Star Carr and Mount Sandel*. Oxford: Archaeopress, Volume 187.

Durand, J. D., Persat, H., and Bouvet, Y. 1999. Phylogeography and postglacial dispersion of the chub (*Leuciscus cephalus*) in Europe. *Molecular Ecology*, 8, 989–997.

Freyhof, J., and Kottelat, M. 2008. *Perca fluviatilis*. The IUCN Red List of Threatened Species. Version 2015.2. www.iucnredlist.org. Downloaded on 18 August 2015.

García-Marín, J.-L., Utter, F. M., and Pla, C. 1999. Postglacial colonisation of brown trout in Europe based on distribution of allozyme variants. *Heredity*, 82, 46–56.

García Díaz, V. 2014. Flint, stones and bones: raw material selection, typology, technology and use-wear analysis. In E. M. Theunissen, S. M. Beckerman, D. C. Brinkhuizen, V. García Díaz, L. Kubiak-Martens, and D. C. M. Raemaekers (Eds.) *Synthesis-A mosaic of habitation at Zeewijk*, 85-117. Amersfoort: Nederlandse Archeologische Rapporten 10.

García Díaz, V., and Clemente Conte, I. 2011. Procesando pescado: reproducción de las huellas de uso en cuchillos de sílex experimentales. In A. Morgado, J. Baena Preysler, and G. González (Eds.) *La Investigacíon Experimental aplicada a la Arqueolicía*, 163-169. Málaga: Imprenta Galindo.

Gillet, C., and Dubois, J. P. 2007. Effect of water temperature and size of females on the timing of spawning of perch *Perca fluviatilis* L. in Lake Geneva from 1984 to 2003. *Journal of Fish Biology*, 70, 1001–1014.

Godwin, H., and Godwin, M. E. 1933. British Maglemose harpoon sites. *Antiquity*, 7(25), 36-48.

Gramsch, B., and Beran, J. 2010. Spätaltsteinzeitliche Funde von Wustermark, Fundplatz 22, Lkr. Havelland. *Veröffentlichungen zur brandenburgischen Landesarchäologie*, Band 41/42 – 2007/2008, 95-142.

Groß, D. 2014. *Welt und Umwelt frühmesolithischer Jäger und Sammler. Mensch-Umwelt-Interaktion im frühen Holozän in der mitteleuropäischen Tiefebene*. Unpublished PhD Thesis: Christian-Albrechts-Universität zu Kiel.

Hardy, B. L., and Moncel, M-H. 2011. Neanderthal Use of Fish, Mammals, Birds, Starchy Plants and Wood 125-250,000 Years Ago. *PloS One* 6, e23768.

High, K., Milner, N., Panter, I., and Penkman, K. E. H. 2015. Apatite for destruction: Investigating bone degradation due to high acidity at Star Carr. *Journal of Archaeological Science*, 59, 159-168, 10.1016/j.jas.2015.04.001.

Högberg, A., Puseman, K., and Yost, C. 2009. Integration of Use-Wear with Protein Residue Analysis—a Study of Tool Use and Function in the South Scandinavian Early Neolithic. *Journal of Archaeological Science*, 36, 1725-1737.

Hokanson, K. E. F. 1977. Temperature requirements of some percids and adaptations to the seasonal temperature cycle. *Journal of the Fisheries Research Board of Canada*, 34, 1524–1550.

Jacobi, R. 1978. Northern England in the eighth millennium bc: an essay. In P. Mellars (Ed.) *The early postglacial settlement of Northern Europe*, 295-332. London: Duckworth.

Jessen, C. A., Pedersen, K. B., Christensen, C., Olsen, J., Mortensen, M. F., and Hansen, K. M. 2015. Early Maglemosian culture in the Preboreal landscape: Archaeology and vegetation from the earliest Mesolithic site in Denmark at Lundby Mose, Sjælland. *Quaternary International*, 378, 73-87, doi:10.1016/j.quaint.2014.03.056.

Legge, A., and Rowley-Conwy, P. 1988. *Star Carr revisited: a re-analysis of the large mammals.* London: Centre for Extra-Mural Studies.

Little, A. 2009. Fishy settlement patterns and their social significance: a case study from the northern Midlands of Ireland. In S. McCartan, R. Schulting, G. Warren, and P. Woodman (Eds.) *Mesolithic Horizons: Papers Presented at the Seventh International Conference on the Mesolithic in Europe, Belfast 2005*, 698–705. Oxford: Oxbow Books.

Maitland, P. S., and Linsell, K. 2009. *Guide to freshwater fish of Britain and Europe*. London: Philip's.

Mellars, P., and Dark, P. 1998. *Star Carr in context: new archaeological and palaeological investigations at the Early Mesolithic site of Star Carr, North Yorkshire*. Cambridge: MacDonald Institute.

Mills, D. M. 1971. *Salmon and trout: a resource, its ecology, conservation and management*. Edinburgh: Oliver and Boyd.

Milner, N., Conneller, C., Taylor, B., Koon, H., Penkman, K., Elliott, B., Panter, I., and Taylor, M. 2011a. From Riches to Rags: Organic Deterioration at Star Carr. *Journal of Archaeological Science,* 38(10), 2818-2832.

Milner, N., Lane P., Taylor, B., Conneller, C., and Schadla-Hall, T. 2011b. Star Carr in a Postglacial Lakescape: 60 Years of Research. *Journal of Wetland Archaeology*, 11(1), 1–19.

Milner, N., Taylor, B., Conneller, C., and Schadla-Hall, R. T. 2013. *Star Carr: Life in Britain after the Ice Age*. York: Council for British Archaeology.

Momber, G.,Tomalin, D., Scaife, R., Satchell, J., and Gillespie, J. 2011. *Mesolithic occupation at Bouldnor Cliff and the submerged prehistoric landscapes of the Solent.* York: Council for British Archaeology Research Report 164.

Morales, A., and Rosenlund, K. 1979. *Fish bone Measurements: an attempt to standardize the measuring of fish bones from archaeological sites*. København: Zoologisk Museum.

Nesbø, C. L., Fossheim, T., Vollestad, L. A., and Jakobsen, K. S. 1999. Genetic divergence and phylogeographic relationships among European perch (*Perca fluviatilis*) populations reflect glacial refugia and postglacial colonization. *Molecular Ecology*, 8, 1387-1404.

Noe-Nygaard, N. 1995. *Ecological, Sedimentary, and Geochemical Evolution of the Late-glacial to Postglacial Åmose Lacustrine Basin, Denmark.* Oslo: Scandinavian University Press.

Palmer, A. P., Matthews, I. P., Candy, I., Blockley, S. P. E., Macleod, A., Darvill, C. M., Milner, N., Conneller, C., and Taylor, B. 2015. The evolution of Palaeolake Flixton and the environmental context of Star Carr, NE. Yorkshire: stratigraphy and sedimentology of the Last Glacial-Interglacial Transition (LGIT) lacustrine sequences. *Proceedings of the Geologists Association*, 126(1), 50-59, 10.1016/j.pgeola.2014.10.002.

Pennington, W., and Frost, W. E. 1961. Fish vertebrae and scales in a sediment core from Esthwaite Water (English Lake District). *Hydrobiologia,* 17, 183–190.

Persat, H., and Berrebi, P. 1990. Relative ages of present populations of *Barbus barbus* and *Barbus meridionalis* (Cyprinidae) in southern France: preliminary considerations. *Aquatic Living Resources*, 3, 253–263.

Robson, H. K. 2015. *Identification, preliminary analyses and interpretation of the fish remains from the early Holocene site, Friesack IV*. Unpublished report: University of York.

Rosenlund, K. 1980. Knoglematerialet fra bopladsen Lundby II. In B. B. Henriksen (Ed.) *Lundby-holmen: Pladser af Maglemose-type i Sydsjælland*, 128-142. København: Nordiske Fortidsminder Serie B in quarto 6.

Schuldt, E. 1961. *Hohen Viecheln: ein mittelsteinzeitlicher Wohnplatz in Mecklenburg*. Berlin: Akademie-Verlag.

Van Gijn, A. L. 1986. Fish Polish, Fact and Fiction. *Early Man News,* 9-10-11, 197–218.

Van Gijn, A., and Little, A. in press. Tools, Use-Wear and Experimentation: Extracting Plants from Stone and Bone. In K. Hardy, and L. Kubiak-Martens (Eds.) *Wild Harvest: Plants and People in the Pre-Agricultural and Non-Agricultural World*. Oxford: Oxbow.

Vaughan, P. 1985. *Use-Wear Analysis of Flaked Stone Tools*. Tucson: University of Arizona Press.

Wheeler, A. 1978. Why Were There No Fish Remains at Star Carr? *Journal of Archaeological Science,* 5, 85-89.

Wheeler, A., and Jones, A. K. G. 2009. *Fishes*. Cambridge: Cambridge University Press.

Wumdsch, H. H. 1961. Die Fischreste. In E. Schuldt (Ed.) *Hohen Viecheln: ein mittelsteinzeitlicher Wohnplatz in Mecklenburg*, 70-74. Berlin: Akademie-Verlag.

Zabilska, M. 2013. Srodowiskowe i kulturowe uwarunkowania rybołówstwa ludów wybrze**ży** Bałtyku w V-IV tysiącleciu przed Chrystusem na przykładzie osady w Dąbkach, stan. 9 (gm. Darłowo), cz. 1. Unpublished PhD thesis: Nicolaus Copernicus University.

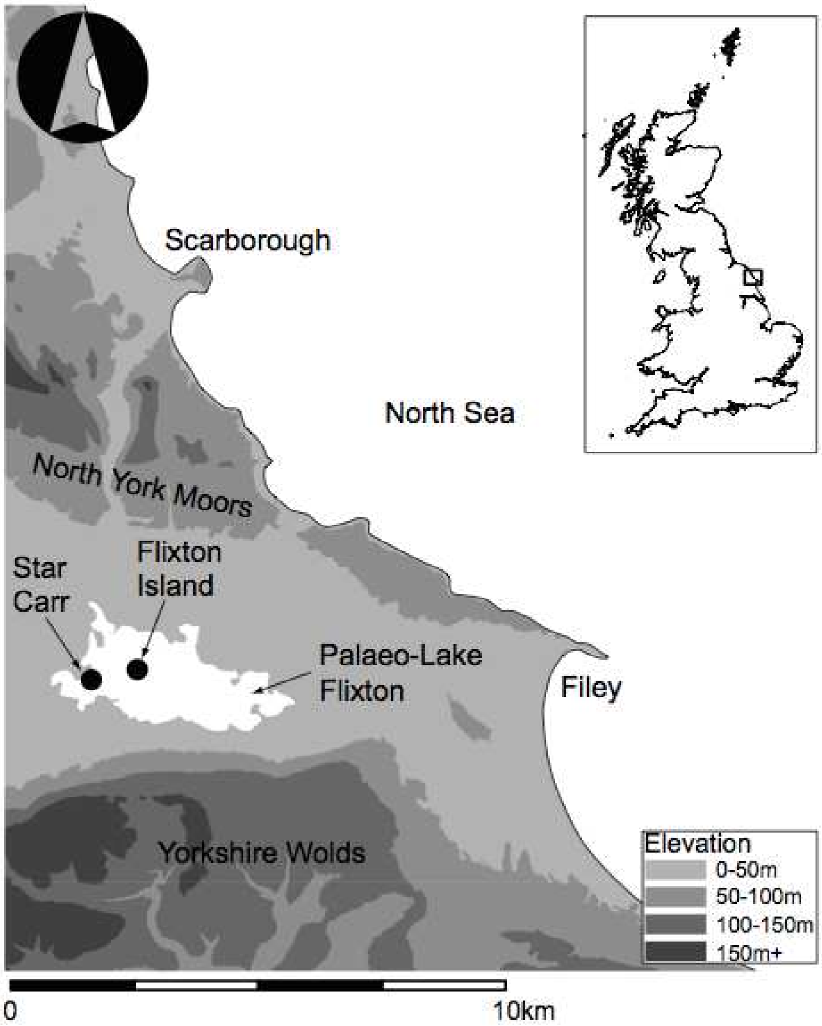

Figure 1

Figure 2

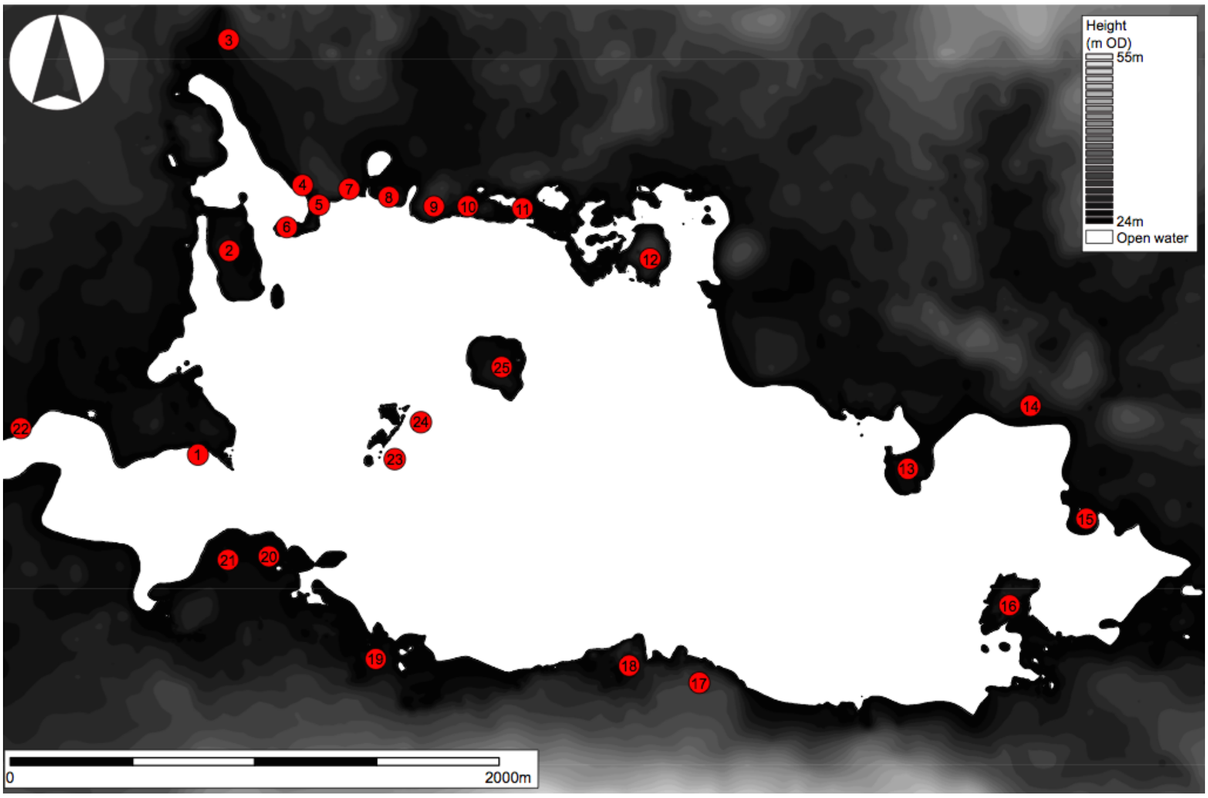

Figure 3

Figure 4

Figure 5

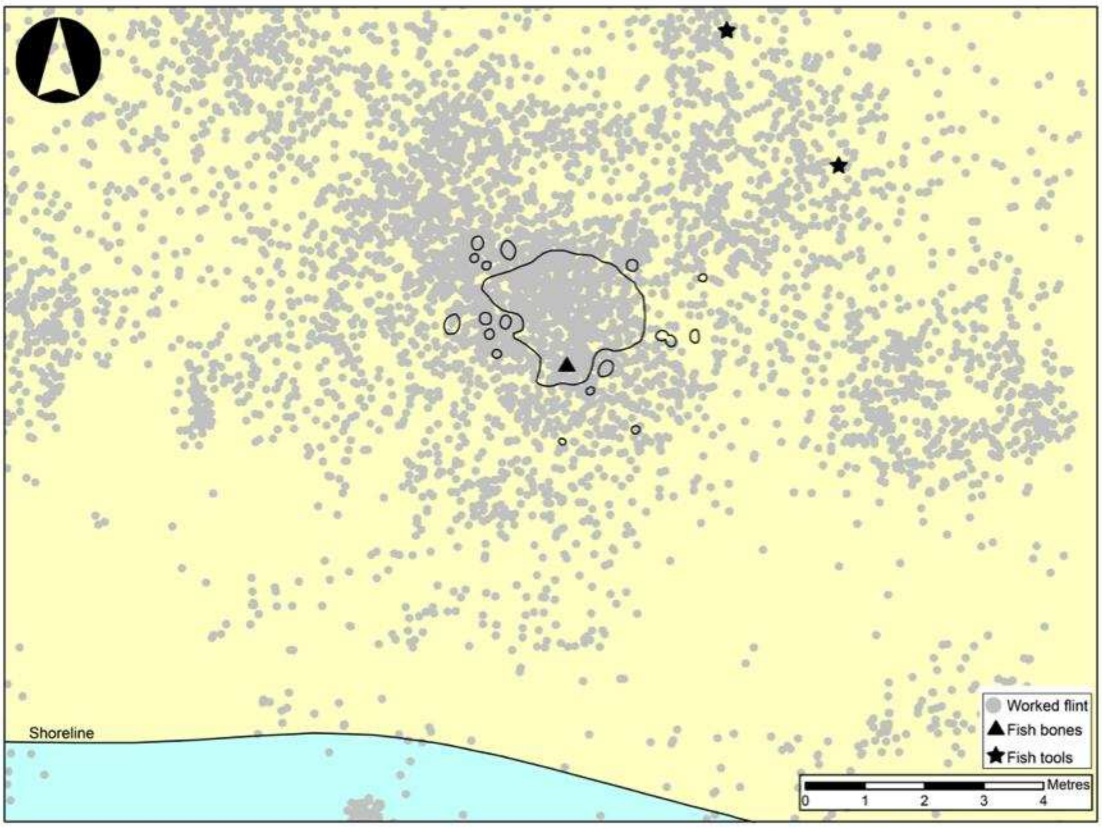

Figure 6

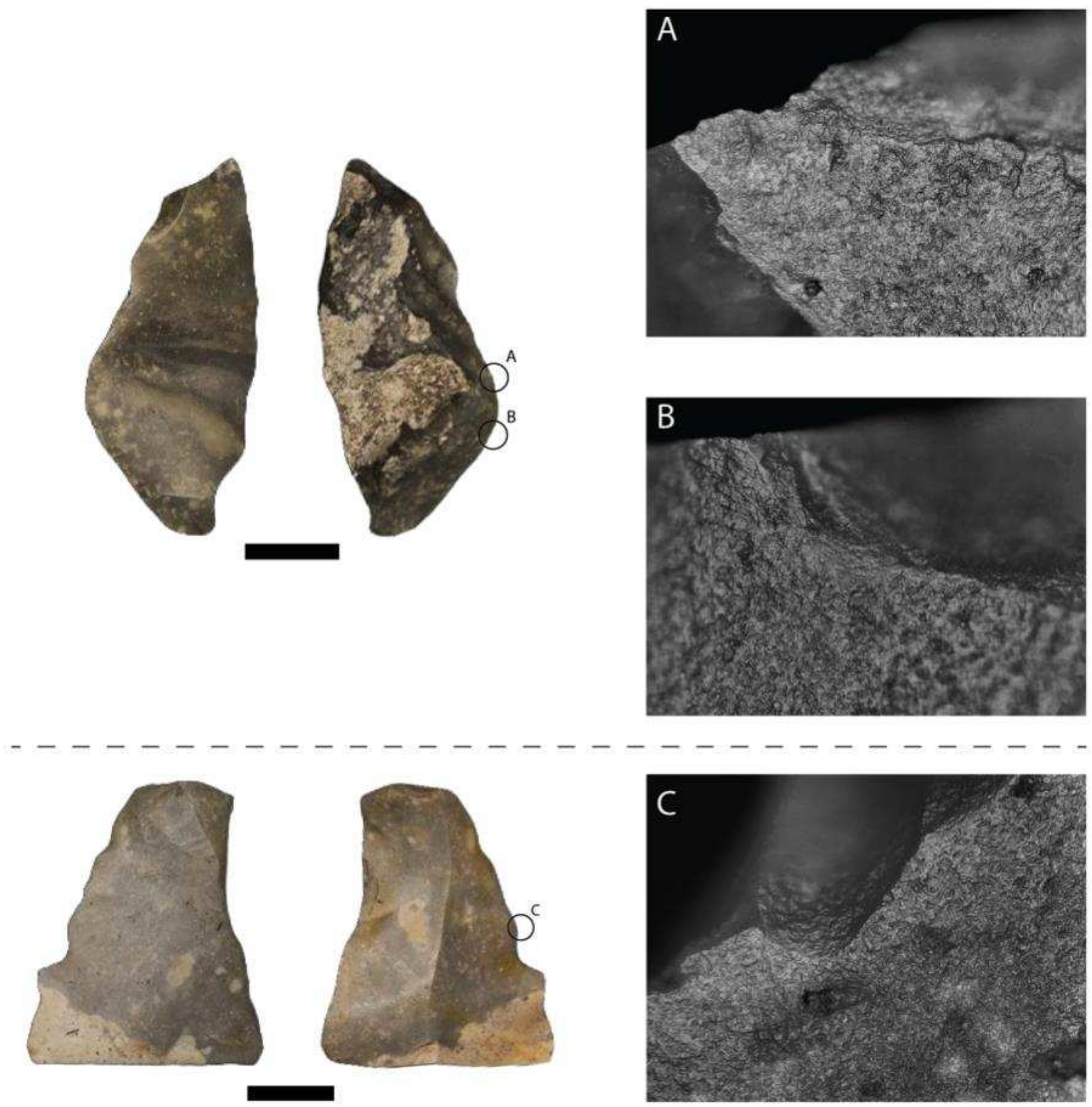

Figure 7

Figure 8

Figure 9

Figure 10