Animal Bones and Archaeology

Recovery to archive

Polydora Baker and Fay Worley

Historic England Handbooks for Archaeology

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A1 Ferry Fryston chariot burial (W Yorks) during excavation by Oxford Archaeology.
[© Diane Charlton, formerly at the University of Bradford]

Contents

Preface

This handbook provides advice on best practice for the recovery, publication and archiving of animal bones and teeth from Holocene archaeological sites (ie from approximately the last 10,000 years). It has been written for local authority archaeology advisors, consultants, museum curators, project managers, excavators and zooarchaeologists, with the aim of ensuring that approaches are suitable and cost-effective. The objectives are to

- highlight zooarchaeological considerations in project planning;
- provide recommendations for zooarchaeological recovery, assessment, analysis, reporting and archiving;
- provide guidance on minimum standards in zooarchaeological methods and their requirements.

This handbook builds on the information provided in the Historic England guidelines for environmental archaeology (Campbell *et al* 2011) but focuses on bones and teeth, as these are by far the more commonly preserved animal remains in Britain. They occur primarily in disarticulated form, as part of the waste of daily life and industrial processes, or less commonly as articulated animal burials and carcass parts. Other animal remains, for example skin, hair, feathers, soft tissues and eggshell, are excluded as they require separate specialist expertise. Worked bone objects require input from finds specialists and are also excluded.

Animal bone assemblages are found on sites of all cultural traditions, providing information about human subsistence and behaviour, ranging from what people ate, how they farmed and what they traded, to how they positioned themselves in society and their belief systems. Animal bones may be found in very large quantities, and where well preserved can present exceptional interpretative opportunities but also logistical challenges. Where present in smaller numbers, their cumulative or group value should be recognised, in particular where data are deficient or research areas are neglected.

There are varied terms in use for the study of archaeological animal bones and teeth. Throughout this document we use *zooarchaeology* without any intended bias. We also use the term *bone assemblages* to refer to archaeological animal bones and teeth. The terms *zooarchaeologist* and *animal bones expert* are used interchangeably.

This document begins with a general introduction to animal bones from archaeological sites and the information we can derive from them (Chapter 1). This is followed by a consideration of decision making at the planning stage, including current government policy and guidance (Chapter 2). Excavation and post-excavation procedures, from sampling through to archiving, are discussed in Chapter 3. Chapter 4 is a guide for practitioners that outlines requirements for undertaking and documenting various analyses. The relevance to different practitioners and key messages are presented at the start of each part. Case studies provide examples of zooarchaeological research questions and methods. A glossary describes procedural and specialist terms. Appendices include a table of scientific and common names for the animals mentioned in this handbook (Appendix 1) and a checklist of information required in order to undertake zooarchaeological assessment and analysis (Appendix 2). Sources of further advice and a list of key zooarchaeology reference resources and posters for site huts, offices and laboratories accompany this handbook (Supplements 1–4).

1
Introduction to animal bones from archaeological sites

This chapter illustrates the interpretative potential of animal bones and teeth from archaeological sites, detailed examples of which are provided in Case Studies 1–9. Interpretative potential is key to the formulation of research questions, project planning (Chapter 2), archaeological processes (Chapter 3) and zooarchaeological methods (Chapters 3 and 4).

This chapter is relevant to local authority archaeology advisors and project managers, archive curators and zooarchaeologists.

Animal bone assemblages have great potential to inform archaeological interpretations on scales ranging from an individual context or event, to site-wide, local, national and even international questions, and, of course, to investigate chronological change. In order to realise their potential, assemblages must be collected and analysed in a considered way, mindful of the impact of recovery and recording strategy on their utility. This introduction summarises some of the information potential of zooarchaeological assemblages (pp 2–5; *see* Tables 3.4 and 3.5) and the circumstances in which assemblages are likely to be found (*see* below).

Circumstances favouring preservation

Bone assemblages can represent a large proportion of an excavation's material archive, particularly at occupation sites or sites where animal carcasses were processed. Bones (including antler) and teeth (enamel, dentine and roots) have both inorganic (mineral) and organic components. They can survive well in alkaline to pH neutral environments, and anaerobic or desiccated conditions (Campbell *et al* 2011, table 2; Fig 1.1; *see* pp 39–42). Tooth enamel survives more readily than bone as it has a greater inorganic component. Burning changes the chemical composition of bones, increasing their resistance to decay.

In England, the chalk and limestone bedrock geologies of the south-central to east Midlands often provide favourable conditions, while the geochemistry of the south-east, south-west and north-west less commonly preserve skeletal tissues (Fig 1.1). Where local bedrock and superficial (drift) geologies are hostile, individual site or context conditions may allow skeletal tissues to survive, for example in deep urban stratigraphy, organic-rich deposits or shell middens.

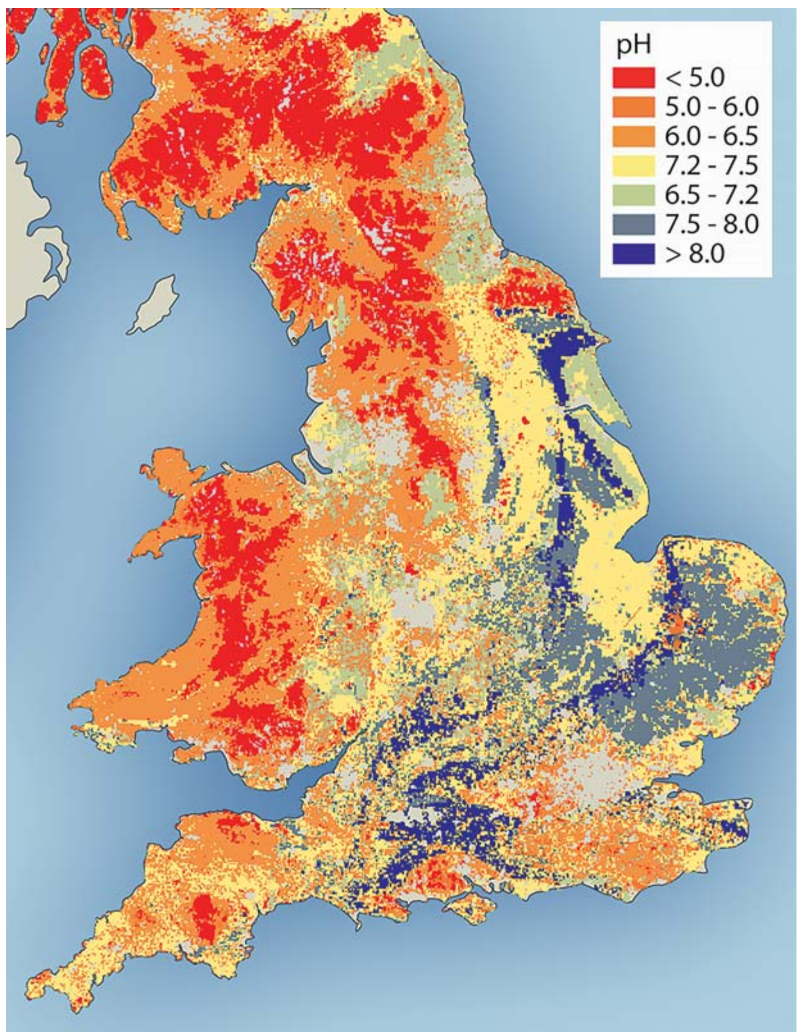


Fig 1.1
A map of soil pH. Even in acidic soils (low pH; shown here in red) local conditions may allow bone survival. [Countryside Survey data owned by NERC – Centre for Ecology & Hydrology. Countryside Survey © Database Right/Copyright NERC Centre for Ecology & Hydrology. All rights reserved]

Site-formation processes

Animal bones can become incorporated into archaeological contexts through human behaviours and natural processes (eg fluvial processes, animal burrows and dens), and usually a combination of actions. They may represent a single event or a short sequence of actions (eg High Post and Biddenham Loop bustum, Case Studies 1 and 2), or an extended series of events and processes, which might include periods of abandonment (eg Potterne and Longstone Edge, Case Studies 3 and 4). Site-formation processes can be examined through taphonomic modifications (*see* pp 39–42), including the presence of articulated bones (*see* p 18), particular animals (eg microfauna; *see* p 55) and body parts. Evidence from zooarchaeological assemblages can aid understanding of the formation processes of archaeological features and accumulation of associated materials.

Palaeoenvironments

Some animals (particularly small wild species; *see* p 55) have specific ecological requirements that restrict their habitat. Where we can be sure that they have lived and died locally, the presence of particular species (usually fish, small mammals or herpetofauna) may be taken as palaeoenvironmental proxies. In English contexts, other proxy indicators (eg invertebrates or pollen) are usually more informative than vertebrate remains. Occasionally, the presence of fauna may be used as palaeoclimatic indicators, for example some Palaeolithic small mammals and cold-adapted species. Change in animal size has been linked to climate change (*see* p 48).

Biochemical studies (using stable isotopes) of animal remains may also provide palaeoenvironmental data. For example, carbon isotope ratios may provide evidence of the degree of woodland or wetland in a herbivore's habitat (Lynch *et al* 2008).

The remains of domestic stock may be used to infer information about the landscape around a site, through their environmental tolerances (eg water requirements and preferred topography) and evidence of their husbandry and use. For example, pathological evidence on cattle bones may indicate their use in ploughing or transport; the presence of herds and flocks usually requires some form of enclosure or byre; evidence of gnawing on bones indicates the presence of scavenging animals and their access to waste.

Animal biogeography

The variety of animals inhabiting Britain is not static but incorporates introductions (natural and anthropogenic) and extinctions, as well as migrating and accidental visitors (Fig 1.2). Where they can be securely dated, the presence of species may be significant for studies of their past ranges, environmental change and trade networks. However, any study of animal biogeography must take into account the possibility that animal bones and teeth may be present as a result of disturbance to the archaeological deposit (residuality or intrusion).

In addition to variation in the presence (and abundance) of species through time, the animals themselves have sometimes changed behaviours (exploiting new habitats in response to human activity, including domestication, or environmental change) and morphology (eg animal size and shape have changed through domestication and controlled breeding). Animal biogeography may be investigated through species, age and sex data, combined with radiocarbon dating, ancient DNA (aDNA), isotopes and biometry (study of animal size and shape).

Past human behaviour

Archaeological animal bones can inform on cultural behaviours such as diet, production and provisioning, animal husbandry, butchery and crafts, and living conditions, as well as social behaviour (including social status). They most commonly represent waste from the preparation and consumption of food and from the use of other animal products, for example leather, horn and sinews. They may also represent deliberate burial or deposition of whole animals or carcass parts, for example pets, ritual offerings, casualties of disease and natural death assemblages. Some of the more commonly explored themes are introduced below.

Diet

The relative abundance of different animals can tell us about what people ate, with skeletal elements and butchery marks indicating which cuts were consumed. The age at death of the animals can inform further on the types of meat eaten. These data can be combined in the analysis of meat procurement, whether through *in situ* production and direct engagement in hunting and fishing, or

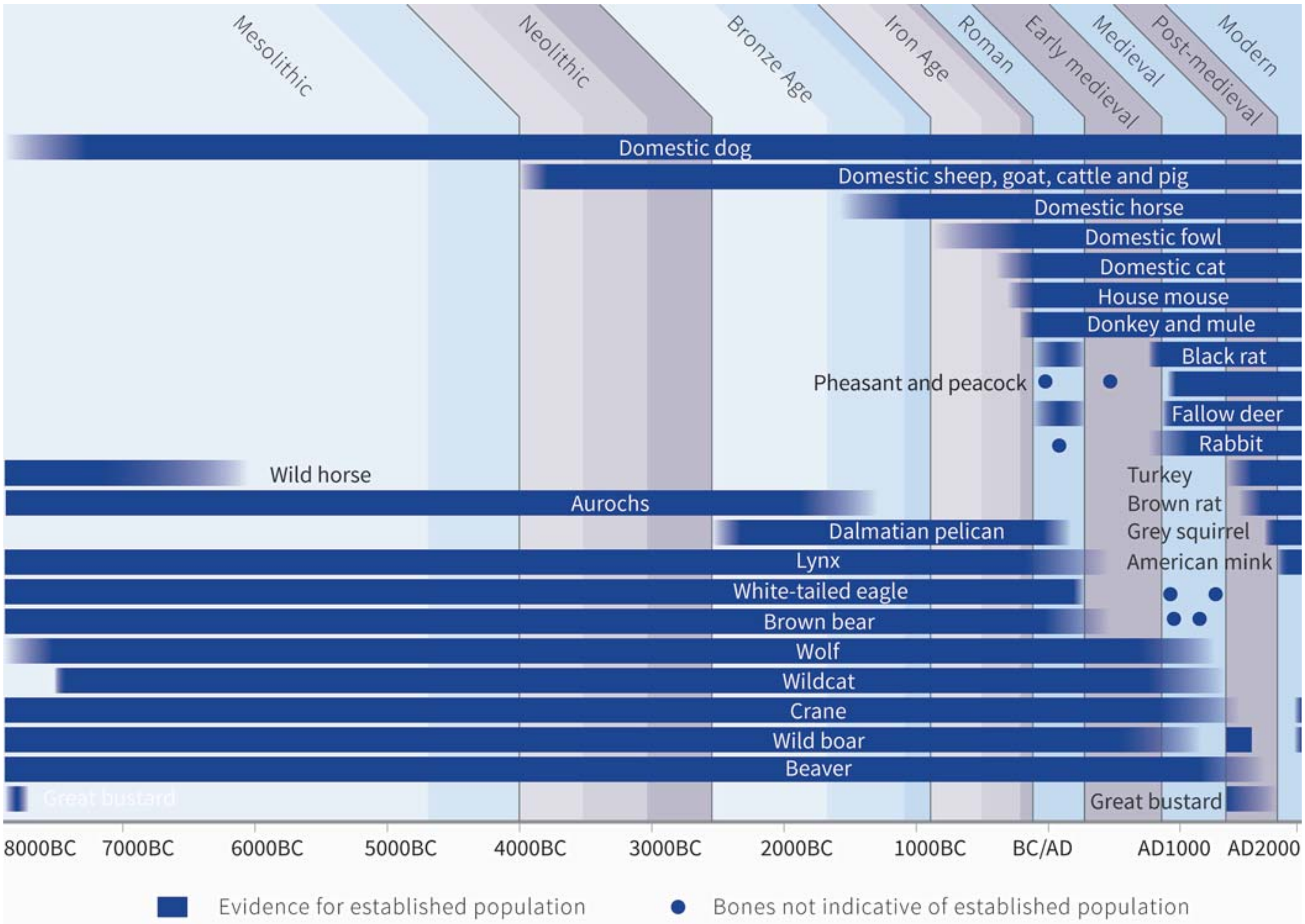


Fig 1.2
An overview of introductions and extinctions of some mammal and bird species in England during the Holocene. *See* Appendix 1 for scientific names. [Based on data from Allen 2009; Bendrey 2012; O'Connor and Sykes 2010; Yalden and Albarella 2009; archaeological period definitions from Periods list, *see* Heritage Standards nd]

through exchange in animals and carcass parts. Dietary data can provide an indication of cultural identity, including social status, as expressed through differential access to animal-based foods.

Animal management

Where animals were farmed, taxonomic identifications, biometric data, palaeopathology, aDNA and isotope analysis can inform on the process of domestication and husbandry of herds and flocks. Bone and tooth measurements can indicate the size and shape of animals and changes in husbandry (*see* pp 48–50). Non-metric variation is sometimes used to explore the isolation or mixing of populations.

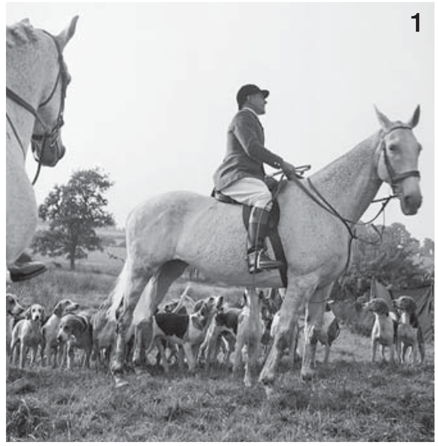
Mortality profiles and sex ratios can inform on the exploitation of livestock, whether for meat, secondary products (eg milk and wool) or traction (Fig 1.3), and can be useful for identifying on-site husbandry. These and other features may also provide evidence of social activities such as cock-fighting. Palaeopathology may elucidate aspects of individual animals' life histories. Skeletal and dental modifications may provide additional information about the use and management of livestock (eg bit wear in horses; dental microwear evidence of foddering and foraging). Isotope analysis can inform on diet composition and the movement of animals (*see* Table 3.5).

Management of wild species (eg emparkment or fishponds; Fig 1.3) may be undertaken to acquire resources and, probably more importantly, to display wealth and power. Its interpretation requires consideration of the archaeological context and animal behaviour.

Seasonality of exploitation

Seasonality data may aid our understanding of the movement and habits of early (prehistoric) populations, as well as seasonal animal management and exploitation (such as commercial fisheries) in later periods (Fig 1.3). Seasonal indicators include migratory species and those with seasonal behaviours, physiological responses and birthing

Fig 1.3
Domestic and wild animal exploitation and management. (1) Hunt in Oxfordshire; (2) unloading fish, Brixham harbour, Devon; (3) milking a nursing cow in Devon; (4) fallow deer at Richmond Park, Greater London; (5) sheep market in Cornwall; (6) peacock at Kenilworth Castle, Warwickshire; (7) newborn twin Exmoor Horn lambs, Oareford, Somerset; (8) butcher in London.
[Photo (7) John Tarlton Collection © Museum of English Rural Life; all other photos Historic England]



patterns (eg medullary bone deposition in bones of female birds during the egg-laying season; unshed antler; perinatal stock animals; developing teeth), and isotope evidence (*see* pp 22–23; Table 3.5).

Carcass processing

Tool marks can inform on the technology and organisation of butchery and bone working (*see* pp 53–55). The conformation of tool marks can indicate technology, skill of the practitioner, and existence and spread of traditions, for example the characteristic hook damage on Roman cattle scapulae (*see* Fig 4.15). The representation of skeletal elements can also inform the interpretation of carcass processing, through characteristic waste from bone, antler, horn and hide production (eg medieval furs, Case Study 5) and kitchen refuse. By tracing the technology and spatial organisation of carcass processing, culture contact and trade, diffusion and specialisation may be inferred.

Pets and pests

The direct identification of pets is most commonly deduced from their archaeological context and skeletal completeness, the careful deposition of whole animals implying a degree of affection. The unusually old age of an animal or evidence such as the assisted healing of fractures may also indicate a certain level of care during life. Depending on their ecological requirements, some exotic animals may only have survived under human confinement. As uninvited guests, commensal species (eg the house mouse, black rat and brown rat) also thrive in human settlements, evidencing the storage or transport of foodstuffs, or waste disposal.

Ritual and religion

Animals have played a central role in belief systems and ritual practices in many periods, these behaviours being intertwined with economic activities. Belief systems may be expressed through the adoption of animal totems, consumption or avoidance of particular meats, animal sacrifice and ritual deposition. The distribution of specific animals, skeletal elements and age and sex groups may provide evidence for large-scale or community acts (eg High Post, Case Study 1).

2
Planning for animal bones in archaeology

For local authority archaeology advisors and project managers

This chapter aims to promote appropriate and timely consideration of animal bones in archaeology, to assist management of costs (time and finance) and processes, and maximise information potential.

For archive curators and zooarchaeologists

Chapter 2 aims to highlight the timing and nature of their contribution to projects and project planning.

Key messages

- Zooarchaeology should be considered from project start-up to ensure that the information potential of animal bones can be realised and contribute to the project aims and objectives. This is best achieved through inclusion of a zooarchaeologist on the project team and reference to resources such as regional reviews (*see* p 87).
- Site visits by zooarchaeologists can be beneficial to site interpretation and should be anticipated in budgets.
- Methods, requirements and costs need to be defined to ensure appropriate recovery and post-excavation treatment of animal bones.
- Costs for post-excavation zooarchaeological work should be anticipated prior to fieldwork (assessment costs) and estimated through assessment (analysis costs).

In order to maximise the information available from animal bones preserved on archaeological sites (*see* Chapter 1), their recovery, assessment, analysis and archiving must be planned for at key stages of an archaeological project. Far too often, the information potential of archaeological animal bones is only considered at the end of an excavation. By this time their contribution to site interpretation may have been limited by the decisions made during the planning and excavation stages of the project. This section aims to provide a quick and easy guide to the different stages and key actions regarding animal bones when planning and implementing a project (Campbell *et al* 2011, 4, table 1).

Expert input at the planning stage is essential to ensure that appropriate information (eg data and syntheses) feeds into a project's aims, objectives and methods. Expert advice will assist in planning and costing archaeological interventions. Experts may include in-house or external specialists (eg academics, consultants or advisory bodies; technical expertise such as biochemical sampling). Appropriate time and budgets should be provided in order to allow the specialists to consult relevant advice and resources, such as regional reviews, regional research frameworks, Historic Environment Records (HERs), journals and comparative collections.

Relevant project management guidance should be read in conjunction with other planning guidance documents (Table 2.1). Key considerations for animal bones in project planning and execution are highlighted in Fig 2.1.

Starting a project

A project start-up stage generally involves the development of a project proposal or brief by the investigator, or a curator or commissioning body (Fig 2.1). This provides a broad outline of the intended investigation (CIfA 2014a, glossary). Following CIfA guidance (2014b, para 1.44.3), the brief should require investigation to advance understanding of heritage assets through clearly stated research aims, use of expert project teams (including a zooarchaeologist) and reference to relevant research frameworks. For zooarchaeology these include regional reviews of animal bone evidence (*see* p 87 and Supplement 1). Archaeological animal bones should be considered at the earliest stages of project planning.

In relation to zooarchaeology, a project brief or proposal should include

- a requirement for consideration of the potential recovery and significance of animal bones (Box 2.1; *see* also Chapter 1);
- a requirement for zooarchaeological input into the formulation of the research aims;
- a requirement for a zooarchaeologist to be identified on the project team, where bone assemblages are expected;
- a requirement for a suitable recovery strategy (with specialist visits as necessary) and post-excavation investigation and reporting, in order to address research questions with zooarchaeological data;
- a requirement for archiving any zooarchaeological reports, data and assemblages, with intended repositories identified (Brown 2007; Edwards 2013);
- a recommendation for the submission of archaeological science data in a suitable format to the HER (*see* p 37).

Table 2.1
Sectoral guidance.

Guidance	Relevance to animal bones
National Planning Policy Framework (NPPF) (DCLG 2012)	Requires developers 'to record and advance understanding of the significance of any heritage assets to be lost (wholly or in part) in a manner proportionate to their importance and the impact, and to make this evidence (and any archive generated) publicly accessible' (DCLG 2012, note 141) Defining the significance of a heritage asset is ensured through good management from project start-up to archive deposition, so that it can inform current understanding as well as future planning decisions (as required by DCLG 2012, note 169)
Management of Research Projects in the Historic Environment (MoRPHE) (Lee 2015) and Management of Research Projects in the Historic Environment, PPN 3: Archaeological Excavation (Kerr *et al* 2008)	Procedural model of good practice for project planning (including costing) and implementation, from start-up to deposition of the archive. *See* Kerr *et al* (2008) for specific stages not discussed in detail in MoRPHE (eg assessment) Defines project stages, review points (which inform decisions to continue from one stage to the next stage) and outputs (eg site reports)
Chartered Institute for Archaeologists' (CIfA) standards and guidance (CIfA nd)	Standards and procedures to be followed in all stages of archaeological investigation, including planning for and implementation of recovery and treatment of ecofacts
Standard and Guidance for Archaeological Advice by Historic Environment Services (CIfA 2014b)	Provision of archaeological advice by the heritage community regarding mainly undesignated terrestrial and marine heritage assets Emphasises that guidance must be based on up-to-date information and understanding of local, regional and national research frameworks and agendas
Heritage 2020: Strategic Priorities for England's Historic Environment 2015–2020 (Historic Environment Forum 2015)	This framework sets out the shared strategic priorities for the historic environment in England
Historic England Research Agenda (Historic England 2017)	Defines priorities for allocating expertise and resources for work carried out by Historic England and Historic England-funded projects

STAGES AND ACTIVITIES	SCOPE	ZOOARCHAEOLOGICAL CONSIDERATIONS
	INITIATING A PROJECT (pp 6–7): MoRPHE ‘start-up’ stage	
Brief, proposal, outline, research application Review point 1: decision to proceed	Outlines ‘broad requirements for work to be undertaken’ (CIfA 2014a, glossary) to ensure that it contributes to increased understanding and is appropriate (CIfA 2014b, para 1.44.4). Provides an initial statement of aims and objectives and a business case (Lee 2015).	▪ Potential recovery of zooarchaeological remains ▪ Zooarchaeological input into aims and objectives ▪ Resources, methods and associated costs ▪ Dissemination and archiving of reports, assemblages and data, including submission of zooarchaeological data to Historic Environment Records (HERs)
	PLANNING A PROJECT (p 10): MoRPHE ‘initiation’ stage	
Specification, written scheme of investigation (WSI),research proposal, project design (PD), detailed funding application Review point 2: authorise project	Sets out in detail the proposed scheme of investigation and provides a benchmark for measuring project progress and results (CIfA 2014a, glossary; CIfA 2014b, para 1.44.5). Articulates aims and objectives and business case, with risk log and costs (Lee 2015).	▪ Suitably expert zooarchaeologist identified on the project team ▪ Zooarchaeological input into aims and objectives (research questions), based on type of investigation, expected archaeology and research frameworks ▪ Appropriate zooarchaeological methods and estimated costs for execution stage (*see below*) ▪ Product descriptions (reports, data) ▪ Plans for dissemination and archiving of bone assemblage, reports and data
	CONDUCTING A PROJECT (pp 10–13): MoRPHE ‘execution’ stages	
Desk-based assessment (DBA) Review point 3	A ‘programme of study of the historic environment within a specified area or site on land, the intertidal zone or underwater that addresses agreed research and/or conservation objectives’ (CIfA 2017, 4). Animal bone experts should be consulted.	▪ Determine nature, extent and significance of the zooarchaeological resource. Useful research tools are listed in Supplement 1 and on page 87.
Fieldwork (excavation/ evaluation) Review point 3	**Field data collection** An evaluation is a limited investigation to characterise and define character, extent, quality and preservation of archaeology. An excavation may follow an evaluation, is more extensive and seeks to better understand the archaeological resource.	▪ Zooarchaeological input into recovery and recording strategy, and any revision ▪ Site visits, where necessary ▪ Advice for bone finds processing

Assessment Review point 3	**Zooarchaeological data collection** Assessment of information potential by expert animal bone specialist. Refer to checklist (*see* Appendix 2) for requirements in advance of assessment. Products include report and assessment dataset.	▪ Assess assemblage to meet aims and objectives ▪ Provide recommendations for further work based on potential ▪ Revise aims and objectives ▪ Define methods and costs for any further work ▪ Identify storage and archiving requirements
Analysis Review point 3	**Zooarchaeological data collection** Analysis of animal bones by expert animal bone specialist, including data manipulation, reporting and publication (grey literature and published reports). Refer to checklist (*see* Appendix 2) for requirements in advance of analysis. Products include report, methods statement and dataset with metadata.	▪ Identify, record and interpret assemblage to meet aims and objectives ▪ Advise on destructive sampling ▪ Consult with other project experts and peer group ▪ Comment on and contribute to project outputs (eg final reports)
Archive deposition and dissemination Review point 3	Animal bone assemblage and digital data prepared and deposited following best practice for long-term storage. Metadata must be provided.	▪ Undertake archiving tasks in consultation with project team ▪ Provide metadata (*see* p 33) ▪ Return any extracted material to assemblage (eg photography, drawing and sampling) ▪ Highlight any special treatment (eg fragile remains) ▪ Contribute to retention policy ▪ Contribute to HER submission
	FINISHING A PROJECT (p 13): MoRPHE ‘closure’ stage	
Closure	Ensure all tasks and products completed.	▪ Review achievements and lessons learnt to inform future projects

Fig 2.1
Required zooarchaeological inputs and consideration at key stages in archaeological projects. [MoRPHE, Management of Research Projects in the Historic Environment (Lee 2015)]

Planning a project

Developing the proposal or brief into a detailed project plan, also referred to as a written scheme of investigation (WSI), written specification, project design (PD) or research application, is normally commissioned by a consultant or developer in response to a planning condition, or by other organisations (eg Historic England; Fig 2.1). The WSI or PD, in conjunction with the brief, details the intended scope of work (CIfA 2014b, para 1.44.6) and should be formulated with specialist advice to ensure that research questions, recovery and post-excavation methods, and estimated costs are appropriate (AEA 1995, section 3).

In relation to zooarchaeology a WSI or PD should include

- a developed business case or project background that considers the potential presence, preservation and evidential value of animal bones, based on previous work at the site and comparative sites (eg as summarised in regional reviews, *see* p 87);
- a zooarchaeologist identified on the project team;
- detailed aims and objectives, with zooarchaeological input;
- an assemblage recovery strategy (eg sampling and hand collection, *in situ* recording methods and site visits as required);
- post-excavation methods, including anticipated destructive sampling (eg Campbell *et al* 2011; Mays *et al* 2013), and a description of expected products (eg reports and data);
- the standards that will be followed (Campbell *et al* 2011; CIfA 2014c–g, 2017; Robinson 1998; Watkinson and Neal 2001);
- provision for the preparation and deposition of a physical and data archive, with a repository and timeframe (CIfA 2014b, para 1.62; CIfA 2014g);
- provision for dissemination, ideally including submission to HERs;
- costs for all project stages (contingency arrangements should consider prior knowledge, physical context and the objectives of the project; Box 2.1).

Conducting a project

Desk-based assessment

The purpose of a desk-based assessment (DBA) is to characterise the known or potential archaeological assets (nature, extent and quality) within an area or site (CIfA 2017, 4). A DBA may represent the end product of a project or inform future projects or project stages. Its scope will vary depending on the circumstances in which it is commissioned, for example for a threatened site, research project or management plan. Animal bones may form an important part of the archaeological record and a zooarchaeologist should advise on their significance. Relevant resources (CIfA 2017, annex 1) include regional reviews of animal bone evidence (*see* p 87).

Fieldwork

Fieldwork is a data collection stage in a project and may comprise evaluation and/or full excavation (Fig 2.1). An evaluation is undertaken in order to gather sufficient information to assess the significance of the heritage asset (CIfA 2014d, paras 3.1.2 and 3.1.5), including the zooarchaeological resource (AEA 1995). The zooarchaeological requirements for evaluations and excavations are the same. Fieldwork methods must be set out in the PD and specialist advice is essential in their planning and implementation (CIfA 2014c, para 3.2.7). Site visits by the specialist may be necessary (Fig 2.2; eg High Post, Stretton Road and Lewes, Case Studies 1, 6 and 7).

A number of site factors influence the planning, cost and implementation of best practice in archaeological science (zooarchaeology), including preservation potential, site type and period, and recovery (Box 2.1).

The sampling strategy should follow best practice (*see* pp 15–17) as outlined in professional guidance (these may be referred to in in-house manuals). The methods adopted will need to consider and combine appropriately the recovery of animal bones and other ecofacts as well as artefacts (Campbell *et al* 2011). The mesh sizes used should be suitable for the retrieval of, for example, weed seeds, microfaunal remains and hammerscale (*see* Fig 3.2; eg Biddenham Loop bustum, Longstone Edge and Lewes, Case Studies 2, 4 and 7). Ideally, samples should be processed as fieldwork progresses, so that the results can highlight any modifications required to meet the research aims (eg Stretton Road and Lewes, Case Studies 6 and 7), although this will depend on the duration and scale of the project.

Animal bone assemblages from evaluations and excavations should be assessed by a competent specialist (p 12 and pp 25–29). Where an evaluation results in no further work, analysis of animal bones should be undertaken as recom-

Box 2.1

Site issues to consider while planning and implementing a project

Preservation potential

Anticipated potential and factors influencing preservation across a site must be included in project planning (Campbell *et al* 2011, 5), as this impacts on the types and costs of zooarchaeological work. Preservation of animal bones will vary depending on the local geology and hydrology of a site, and microenvironment of a context (eg pH) and assemblage composition. Data from previous investigations are invaluable in assessing the potential presence of animal bones. Where this is limited or non-existent, local geology and factors such as drainage, occupation history and known disturbance (eg plough damage) may help to assess the potential presence and probable condition (state of preservation) of animal bones. Poor preservation potential should not lead to discounting zooarchaeological evidence altogether, as preservation conditions may alter depending on local conditions (Campbell *et al* 2011, fig 2). In addition, where bones and teeth are recovered in poorer condition, they may still hold potential for addressing research questions.

Site type and period

The type of site (eg rural, urban or cave) and period (eg Neolithic, Roman or post-medieval) can to some extent help predict presence, potential, quantity and type/variability of animal bones, and aid the formulation of sampling strategies. Riverside locations in urban settings will often yield large dumps of animal bones from Roman and later periods (eg London) and areas of a Saxon town can yield rich deposits of animal bones in pits (eg Southampton; Hamilton-Dyer 2005). Animal bone groups (ABGs) are particularly common on Iron Age and Roman sites (*see* p 18). Some site types, such as temporary occupation sites, may yield small assemblages that can be important for addressing specific research questions. These small assemblages or subsets of data from multiple assemblages may be combined to address broader-scale questions (eg across London and medieval sea fishing, Case Studies 8 and 9).

Recovery (hand collection and sampling)

Recovery strategies should be informed by comparative assemblages, preservation potential, site type and period, and must ensure that research aims and objectives of the project can be addressed. For example, any project addressing the exploitation of landscapes and the role of wild resources, or the development of medieval economies (and origin and structure of commercial fisheries), would have to ensure that suitable mesh sizes are used for flotation and sieving, in order to recover the full range of species (eg birds and fish) and element types (and sizes). Similarly the organisation of provisioning and trade may only be addressed when sampling strategies ensure that a representative range, and a large enough number, of appropriate animal bones (eg for skeletal element distribution or age profiles) are recovered.

The retrieval and processing of samples may be time-consuming and labour-intensive, and must be costed appropriately to include technical equipment and trained field staff. Project budgets should allow sufficient contingency for reasonable adjustments to recover, process and investigate unexpected deposits of animal bones to meet recommended standards.

mended through assessment (Campbell *et al* 2011, 7; p 13 and pp 29–33). Where continued fieldwork or data collection is planned, the assessment should feed into recommendations regarding recovery strategies in the updated WSI/PD (eg continuation/ modification of methods and approaches; *see* pp 25–29; AEA 1995, section 9; Campbell *et al* 2011, 7) and final analysis of the complete site assemblage.

Communication and team work

During an evaluation or excavation, there should be sufficient contact between on-site staff, project managers and the specialist to ensure that sam-pling strategies and recording methods are suitable, including selection of samples for dating and biochemical analysis and documentation of animal bone groups (ABGs). Good and regular communication also ensures that unexpected discoveries are dealt with appropriately, any problems, such as delays in sample processing (sample backlogs), can be resolved quickly, and the specialist can be prepared to make site visits at short notice. Site visits by specialists benefit both the specialist (ensuring familiarity with site conditions) and project management (through monitoring and modification of recovery strategies), leading to improved understanding and enhanced reporting (eg High Post and Stretton Road, Case Studies 1 and 6).

Excavators should be informed of best practice in the recovery of animal bones by hand and through sampling, and in the excavation and documentation of articulated bones. An environmental specialist skilled in the recovery and processing of samples should be able to provide advice regarding relevant contexts, sample volumes and recording of samples. Excavators should be aware and able to record appropriate information about the samples taken, and the purpose of sampling.

Equipment and resources

Suitable staff, equipment and materials need to be resourced as part of project planning. Advice regarding sample processing, the washing of bones, marking, appropriate on- and off-site storage, care of fragile remains and archiving should be relayed to the finds and environmental staff (*see* pp 23–25).

Sample-processing equipment with appropriate mesh sizes must be provided where required. A water supply and suitable drying facilities will be essential for washing bones or processing samples. Documentation (eg sample records and index sheets) and suitable storage material (eg bags, boxes, labels and pens) must be available (*see* Table 3.6).

Laboratory work

Assessment and analysis stages of a project (Fig 2.1) include zooarchaeological data collection and manipulation. Many of the planning requirements, logistics and zooarchaeological input are similar for both stages, although the end products are of a different nature and scale (*see* details on pp 25–33). Assessment and analysis must be undertaken by a specialist with suitable expertise, as identified in the PD/WSI (CIfA 2014c, para 3.4.4; CIfA 2014f, para 3.7.3; pp 25, 29).

Assessment

An assessment of potential is the first post-excavation stage of a project (Kerr *et al* 2008, section 4.0; Lee 2015; *see* pp 25–29). Assessments facilitate effective project management by identifying the required time and costs for future work.

The assessment should consider the significance of the assemblage and its value in relation to the project's aims and objectives. It may identify research potential not originally recognised in the WSI/PD. The assessment should make recommendations regarding whether the entire assemblage or specific parts require analysis, the analytical methods (including scientific analyses, such as radiocarbon dating and isotopes, and required expertise) and costs. Detailed recording at this stage is usually neither required nor deemed best practice (*see* p 25).

It is crucial that provisional phasing, contextual descriptions and spatial distributions are provided to the specialist prior to commencing an assessment, to allow selection of relevant material (*see* Appendix 2; CIfA 2014f, para 3.5.2). Coarse-sieved and flotation samples should have been processed to ensure that, in addition to hand-collected bones, sieved bones are available

Fig 2.2
On-site discussion of the excavation strategy for bone- and find-rich deposits at Marden henge (Wilts). Inset shows the surface of the late Neolithic midden.
[Photos B Kerr]

and a representative bone assemblage (*see* Fig 3.2) can be assessed (Campbell *et al* 2011, 7).

Analysis

Analysis will include data recording and manipulation, report production and peer review (CIfA 2014f, para 3.7; Lee 2015, 10). All relevant site information, including finalised phasing, is required at the start of analysis (*see* Appendix 2). Similarly, all samples recommended for processing should have been processed and sorted by this point, so that data recording is not delayed. The analytical methods should be based on those proposed at the assessment. Variation from these may alter the costs of analysis and so should be agreed before implementation. Any material to be sampled for destructive analysis needs to be fully recorded before this takes place (Mays *et al* 2013).

The time required for recording, analysis and report preparation will have been identified at the assessment stage and should not be restricted without consultation with the specialist, as this may limit the potential of the animal bone assemblage to contribute to the project's aims and objectives. Sufficient time should also be provided for the specialist to comment on project report drafts that incorporate animal bone data (CIfA 2014f, para 3.8.5).

Communication and resources

The equipment and resources required for assessment and analysis are outlined in Table 3.6 and Appendix 2. Good and timely communication with project directors and field supervisors will ensure that the required contextual and site data (including documentation of ABGs) are correct prior to the recording of animal bones. This will prevent the need to remanipulate the data, which would require additional time and costs. Communication with other members of the project team, regarding evidence such as stratigraphy, and other environmental and cultural material, will enable integrated site interpretation. Copyright of data and reports will need to be established and ownership and authorship cited correctly.

Preparing for archive deposition

Preparing the archive for deposition is a team effort; good planning and cooperation can ensure that it is cost-effective (Edwards 2013, section 1.3, para 8.3.9). The owner or recipient repository(ies) must be identified at an early stage (in the specification; CIfA 2014b, para 1.61; CIfA 2014g, para 3.3.2) in order to determine costs and requirements, for example packaging materials, digital data storage and transport (CIfA 2014g, para 3.5; p 10 and pp 33–37). Archivists, finds staff, zooarchaeologists, conservators and other specialists should be consulted regarding storage methods and conservation needs (CIfA 2014g, para 3.4) of the physical archive and digital data (*see* p pp 33–37).

The archive must be publicly documented (as a minimum through HERs) and signposted (*see* p 37; Edwards 2013, para 8.2.3; CIfA 2014b, paras 1.56, 1.57; Lee 2015, 10, 22). Any discard prior to deposition must be undertaken following specialist advice and fully documented in the archive (*see* pp 35–36).

Closure

The closure project stage provides a means of assessing the success of a project and formally recording lessons learned, in order to inform future investigations (Lee 2015, 22–23). In terms of animal bone evidence this may include recommendations for recovery, recording, analytical methods and costs, as well as highlighting contributions to research frameworks.

3
Best practice for implementing excavation and post-excavation procedures

This chapter aims to put project planning into action. It highlights practical considerations for the recovery, post-excavation processing and archiving of animal bone assemblages. It highlights approaches and requirements for assemblage assessment and full recording (analysis), and the archiving, publication and dissemination, including through Historic Environment Records (HERs), of data and reports.

For local authority archaeology advisors and project managers

Chapter 3 aims to assist project planning, including management of costs, and to inform procedures. It also aims to assist understanding of zooarchaeological reports (assessment and analysis) and evaluation of their quality (CIfA 2014b, para 1.55).

For archive curators

Chapter 3 aims to promote best practice in submission of physical and digital zooarchaeological archives, and the signposting of archives through HERs and publications.

For zooarchaeologists

Chapter 3 aims to promote controlled and rigorous excavation and processing of zooarchaeological remains, to outline requirements for their assessment and analysis, and to promote best practice for the publication, dissemination and archiving of reports, data and assemblages.

Key messages

- Investigation of the zooarchaeological resource should be planned for throughout the life of a project, allowing its potential to be maximised, and the cost and scope of work to be managed. Seek specialist advice to inform decision making.
- Recovery, including hand collection and sampling, specialist recovery, for example of fragile remains and animal bone groups (ABGs), and post-excavation processing affect the potential and utility of an assemblage and so should follow a considered plan.
- Research questions should direct zooarchaeological methods. Select assessment and analysis methods with care and cite them in reports to allow comparability of site assemblages.
- Data are as important as interpretation. Datasets require accessibility (archiving) and explanation (metadata) to allow comparison between sites.
- Resources required for animal bone recording and reporting include reference material (skeletal and textual), equipment, site information (see the checklist in Appendix 2) and access to comparative reports.
- Potential and significance judgements depend on current understanding of the archaeological record (including zooarchaeology).
- Developing methodologies and understanding may enhance the research potential of archived assemblages and archived data.

Recovering bone assemblages

This section covers best practice in the recovery of animal bones on site, including of animal bone groups (ABGs), excavation in unusual/challenging circumstances, and decisions regarding destructive sampling of animal bones.

Excavation strategies, recovery methods (eg Payne 1972, 1975) and sampling decisions influence the make-up of animal bone assemblages, including, for example, the size of the assemblage, its chronological or spatial distribution, the animals and skeletal elements represented, and degree of fragmentation. Excavation methods can also enhance or inhibit the potential to use animal bones for radiocarbon dating deposits.

Recovery methods and sampling approaches are factors that can be controlled for during excavation and should be carefully planned, executed and recorded (Campbell *et al* 2011; *see* Chapter 2). They should relate to project aims and objectives and wider research priorities (*see* Chapter 1), informed by factors such as site characteristics and predicted bone preservation (based on prior excavation in the local area; Box 2.1). The input of an animal bone specialist and good communication between field staff and specialists, including on-site visits, are recommended (*see* below; Fig 2.1; High Post, Stretton Road and Lewes, Case Studies 1, 6 and 7).

Hand collection

Often the majority of an assemblage is collected by hand. Where hand collection is careful and thorough, it may provide sufficient data to answer a range of research questions. However, a hand-collected assemblage is often a biased assemblage because only those remains visible in the field are collected (Fig 3.1). Hand collection results in the recovery of the bones and teeth of larger species (Fig 3.2) but does not produce representative assemblages of smaller taxa (eg many birds and fish). Hand recovery also misses the smaller bones and teeth of large mammals (eg loose teeth, phalanges and foetal or neonatal bones), resulting in biased body part and age distributions. Samples are taken for processing by sieving and flotation to reduce the effect of this recovery bias. Ideally, contexts producing hand-collected bones should also be sampled (*see* below).

Animal bone collected from stratigraphically insecure contexts, for example those disturbed by animal burrows, should be clearly indicated in contextual records. Their potential can be considered at the assessment stage.

Sampling for animal bones

Sampling is used to retrieve a representative range of animal bones, including those not often recovered by hand (*see* above). Sampling for animal bones usually follows a 'systematic' or 'judgemental' strategy, or a combination of these (Campbell *et al* 2011; O'Connor 2000, 30–31), with decisions dependent on such factors as bone richness (quantity and diversity) and type and date of context (eg Stretton Road and Lewes, Case Studies 6 and 7). In particular, samples should be recovered from stratified and well-sealed deposits. There is little point in sampling mixed deposits unless the data can contribute to specific questions. Where a context is not 100% sampled, samples should usually be collected from different areas within it (scatter sampling) so that they are representative of the whole context. In order to study spatial variation within a deposit it may be advisable to use a grid pattern,

Fig 3.1
Hand-collected (1) and >4mm coarse-sieved (2) assemblages from a medieval context at Windsor Castle (Berks). [Photos F Worley]

		Mammals	Birds	Fish	Microfauna
Hand collection		Most larger bones; largest cat-size bones (long bones, skulls)	Larger long bones of large birds	Bones of large fish	
Processed whole-earth sample fractions	>10mm	Most larger bones; largest cat-size bones (long bones, skulls)	Larger long bones of large birds; largest long bones of small birds	Bones and otoliths of large fish; some bones and otoliths of medium fish	Largest bones, eg long bones and larger vertebrae of amphibians
	10–4mm	Smaller bones, loose teeth; cat-size ribs, vertebrae, phalanges, carpals and tarsals	Long bones, vertebrae, ribs, carpals of large birds; most bones of small birds	Bones and otoliths of medium fish; some bones (eg cleithra, opercular bones, skull and vertebrae) of small fish	Large bones, eg long bones and skulls
	4–2mm	Foetal or perinatal bones; cat-size teeth, smallest phalanges, carpals and tarsals	Phalanges, ribs of large birds; some bones of small birds; wing and leg bones of tiny birds	Vertebrae, otoliths and dermal bones of small fish; most eel bones and herring vertebrae	Large bones of most species
	2–1mm		Few bones (including phalanges and tracheal rings) of small and tiny birds	Bones of tiny fish; tiny diagnostic dermal bones from small, medium and large fish	Small newts and lizards, juveniles of any species
	1–0.5mm				Smallest bones and teeth of any species; slow worm osteoderms
	Flot		Least dense bones, phalanges, skull fragments, tracheal rings of small and tiny birds	Scales and least dense cranial bones and vertebrae	Least dense bones, vertebrae

Recovery: Good Possible Unlikely

Large birds: chicken size and above
Small birds: below chicken size
Tiny birds: below thrush size

Large fish: > 0.6m
Medium fish: 0.3-0.6m
Small fish: 0.15-0.3m

Tiny fish: < 0.15m
Microfauna: squirrel size and smaller

Fig 3.2
The effect of collection strategy on the nature of a recovered bone assemblage. This figure indicates examples of material recovered in each fraction and therefore the evidence lost through the use of larger meshes and hand collection (*see* Table 4.3). [Image J Vallender with P Baker, C Gleed-Owen, R Nicholson, D Serjeantson, J Williams and F Worley]

with each grid square recorded as an individual sample, and/or to sample in spits (eg Biddenham Loop bustum and Potterne, Case Studies 2 and 3).

Flotation and coarse-sieved samples

To minimise recovery bias, samples should be whole earth (Campbell *et al* 2011, 11). This means that all bones and teeth must be retained within the sample, even where visible, with the exception of fragile or fragmented bones, which may be recovered separately. Any extracted bones must be labelled with the sample number. Whole-earth samples can be processed in various ways. The method chosen will depend on the sediment type and material potentially present in the sample, including finds, and plant and animal remains, and is usually best determined at or before the time of sampling. The most common approaches are flotation and coarse sieving.

Flotation samples are generally taken for the recovery of charred plant remains, but are also effective for recovering bone assemblages, including tiny bones and teeth, variously retained in the heavy fraction and flot (Fig 3.2). The sample volume is generally 40–60 litres (Campbell *et al* 2011, 12). The mesh size for collecting the heavy residue from flotation samples should be between 0.5mm and 1mm, and the mesh size for flots is usually 250–300µm.

Monitoring the bones recovered from samples can identify whether sample volumes are sufficient to address research questions. Zooarchaeological questions relying on the interpretation of, for example, taxonomy, age, element distribution or biometry, may require sample volumes of 100 litres or more. Where flots and the smallest fractions are not required, and flotation is not cost-effective or possible, whole-earth samples may be coarse sieved (wet or dry). Wet sieving is preferable to dry sieving in most conditions as some bones may be missed if adhering sediment is not removed. Coarse-sieved samples are passed through a series of meshes, generally >4mm and >2mm, resulting in different residue fractions (Fig 3.2). Sediment can be disaggregated manually, but without forcing it through the mesh. Dry sieving is sometimes used prior to wet sieving to collect artefacts that may otherwise be damaged by water, or it may be used where water is not available and transport of large volumes of sediment is problematic.

Sorting residues

Flotation heavy residues may be passed through a stack of sieves, usually of 4mm and 2mm. Residue fractions from both flotation and coarse sieving are sorted in the same manner. Generally 100% of the >4mm and an agreed proportion of the 2–4mm fractions are sorted to recover animal bones. Any <2mm fractions and flots should be scanned or sorted under a microscope by appropriate specialists. Further sorting of the 2–4mm and <2mm fractions and flots may be recommended at later stages and so they must be retained. It is essential that the interpretation of data resulting from different fractions or a combination of flotation and coarse sieving considers any effects of the different processing methods.

Recovery from partially excavated features

As with all archaeology, recovered animal bone assemblages are only part of what was once present, and still less of what was utilised at the site. This knowledge underpins all archaeological interpretation. Where an excavation strategy leads to partial excavation of deposits (eg ditch spits or half-sectioning features without subsequent 100% excavation), the recovered bone assemblage may not be representative and its interpretative potential may be limited by sample size. Where it is suspected that unusual assemblages are present, for example those derived from structured deposition or feasting, the deposit is ideally recovered in its entirety. Where an ABG (p 18) is encountered and part of the group is retained in an unexcavated area, the excavation should be extended to recover the entire ABG. Where this is not possible, observations on the nature of continuation into the baulk should be recorded in notes, section drawings and photographs.

Documentation in the field

Documentation and labelling is essential if the specialist is to understand what and how much animal bone has been collected, how and from where it was recovered, and to locate the assemblages for examination. Advice regarding appropriate labelling is given on pp 23–24.

Records for each context should provide quantification (eg the fragment count or weight as required, and number of bags or boxes) and current location (eg box number) of the bone assemblage. For animal bones from samples, additional information must include the sample number, volume of sample, fraction and method of processing (ie wet or dry sieving, flotation and mesh sizes). Details of any specimens bagged or boxed separately (eg fragile remains) must be documented, as must further spatial information where recorded (eg grids, spits, quadrants, drawings and photographs).

Recovery from extraordinary or challenging deposits

The majority of animal bones are recovered from mixed disarticulated assemblages of domestic waste. Assemblages that do not fit this description, for example part skeletons or manufacturing waste, require special consideration in the field. Best practice dictates seeking the advice of a bone specialist at the time of discovery, and of an archaeological conservator for poorly preserved remains. The likelihood of encountering these deposits should be planned for (*see* Chapter 2; eg Karsten *et al* 2012), including recovery method and associated costs.

Animal bone groups (J Morris)

Articulated animal remains are often encountered on archaeological sites and can vary from complete skeletons to just a few elements (Fig 3.3). They are present from all periods, but are particularly prevalent on Iron Age and Roman sites (eg High Post, Case Study 1). Variability in composition and changing trends in interpretation have led to a lack of recognition in the field and confusion in the nomenclature used when reporting on these deposits. Often highly interpretative descriptions, alluding to a ritual or functional origin, are used, such as animal burial, fall victim, feasting waste and special animal deposits (Grant 1984). It is recommended that the neutral term animal bone group (ABG; also referred to as associated bone group) is used (Hill 1995; Morris 2011).

ABGs are of great evidential value. Their composition (elements present) and taphonomic alterations, such as butchery, weathering, scavenger gnawing and differential bone destruction, can all inform on the actions or events behind the deposition (Morris 2011; Morris and Jervis 2011), as can other associated remains (eg human bones or complete ceramics). ABGs provide an ideal opportunity for the investigation of metrical variation and pathological conditions within a single individual. The recovery of remains still in articulation indicates a lack of disturbance, making ABGs ideal candidates for radiocarbon dating (*see* Table 3.5).

Site visits will allow the zooarchaeologist to confirm whether body parts are missing and whether the remains have been manipulated or are in an anatomically natural position. ABGs should be planned and photographed, their location accurately recorded (eg at the base or in the fill of a ditch), and their presence noted on the context record, together with that of associated finds. Importantly, ABGs must be kept separate from the rest of the faunal material, as they cannot be securely separated in the laboratory. Following common practice for human remains, the left/right and hind/fore limbs and right/left ribs should be bagged separately. This speeds-up post-excavation work, highlights whether certain body areas are missing and allows the siding of elements such as phalanges, leading to further interpretative possibilities.

It is recommended that ABGs are assigned an identifier (eg an ABG number) that allows them to be distinguished from disarticulated bones, as they require particular attention during bone recording, quantification and interpretation.

Manufacturing waste

Animal parts are used in multiple crafts and industries (Fig 3.4) that can occur on many scales (with varying intensity and degree of specialisation). Evidence may include bone and antler cut-offs from the manufacture of objects (MacGregor

Fig 3.3
Examples of animal bone groups. (1) Complete Roman horse from Finsbury Square, London; (2) articulated Neolithic pig or wild boar carcass portion from Marden henge (Wilts); (3) early medieval fish skeletons from St Martin Palace Plain, Norwich (Norfolk).
[(1) Photo Museum of London Archaeology, (2) photo B Kerr, (3) photo M Sharp, © Norfolk Museums Service]

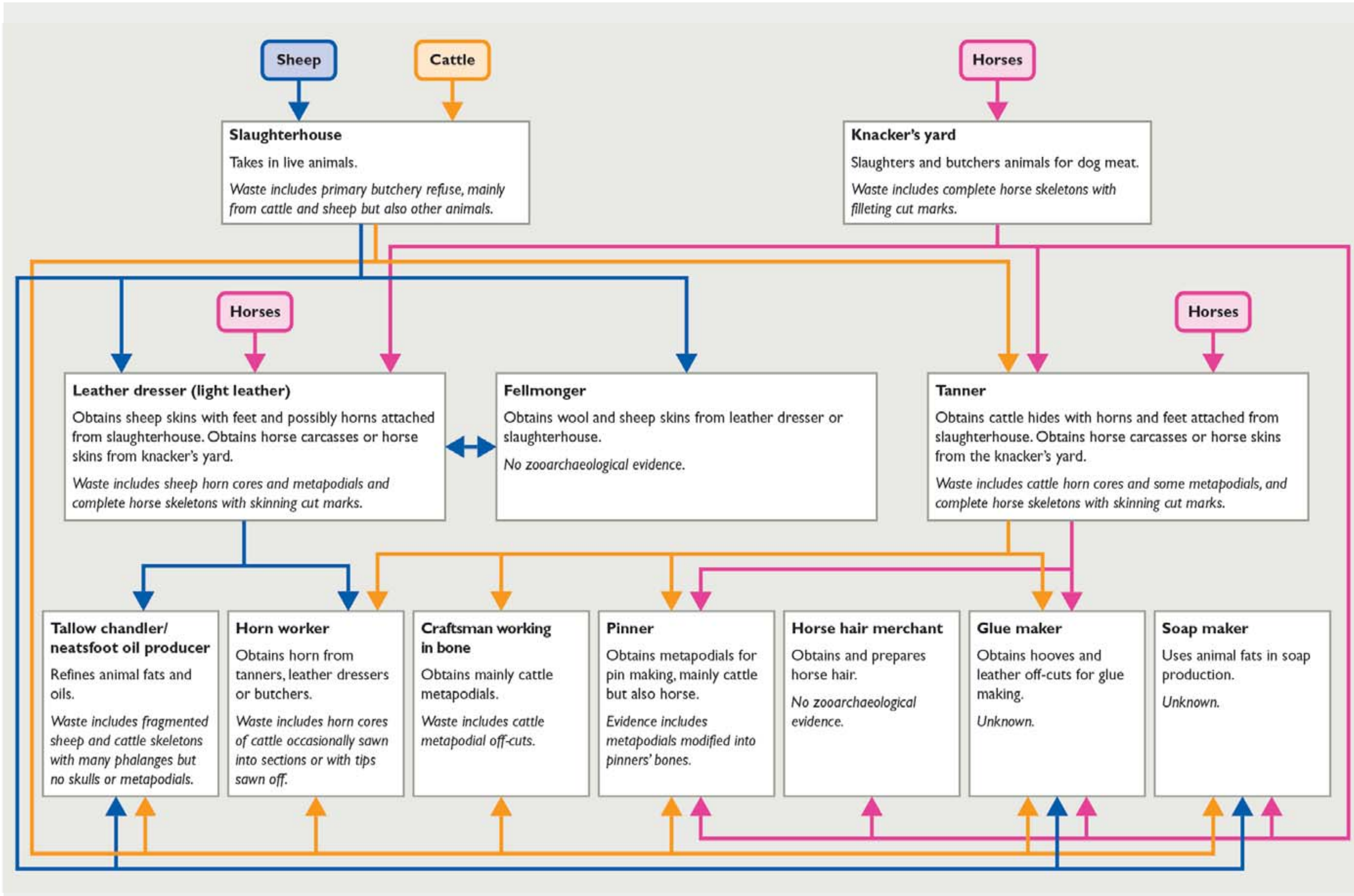


Fig 3.4
Model of animal carcass-processing industries in post-medieval towns and their zooarchaeological indicators, based on evidence from London.
[Adapted from Yeomans 2007, fig 8.11]

1985), refuse from leather production and horn working (Albarella 2003; Dungworth and Paynter 2006, 30; Yeomans 2006), waste or retained elements associated with furriery (Fairnell 2011; Luff and Moreno Garcia 1995), and intensively fragmented bones for extraction of fats and proteins (Johnstone and Albarella 2002; Maltby 2010, 287). The extraction and working of animal by-products on a domestic or industrial scale can be identified through the types and location of tool marks, bone fragmentation patterns and skeletal element distributions (eg medieval furs, Case Study 5). Bones and bone ash were used in ceramics and metal working and may be identified through specialist analysis (eg Girbal 2011).

Evidence for industrial activities may be found scattered throughout domestic waste or in discrete deposits. An interpretation of production processes can hinge on evidence of the selection of animals or animal parts. It is therefore essential that the recovered bone assemblage is representative of the material deposited. Whole-earth samples may be required to recover evidence of manufacturing processes involving bones of small animals (eg small fur-bearing species, Case Study 5). Where manufacturing waste deposits are recognised in the field, they should be documented (including photographs and plans) and recovered in their entirety to enable as complete an analysis and interpretation as possible. For example, some activities will yield an abundance of a restricted element range that can inform interpretation of the activity, but also provide population data through biometric analyses (eg Albarella *et al* 1997; Yeomans 2007). Site visits by a specialist will assist interpretation and may allow spatial information to be recognised and recorded.

Bones used as construction material

Animal bones and teeth have long been used in construction, with most available evidence dating from the post-medieval period. Bones, horn cores and teeth were used in floors, walls and boundaries as primary building material, or for repair, packing or decoration. They were also used as linings for pits, field drains and soakaways, as foundations for roads, and as pegs for roofing (Armitage 1982, 1989a, b; Hall 2012; Yeomans 2006, 2007, 2008; Fig 3.5). The study of bones used in construction allows investigation of technology, processes and procurement. Their use can be linked to local butchery, tanning or horn working. As with some industrial bone deposits (*see* above), the presence of large numbers of single bone types holds broader information potential that should be considered in the recovery and recording strategies. This is best informed by specialist advice and site visits, which may allow some initial bone recording in the field and will be especially valuable where selective recovery is undertaken.

Recovery of burnt bones

Burnt animal bone deposits may result from wild fires, accidental or deliberate building fires, burning of waste (including diseased stock), or industrial and domestic fires (eg ovens, hearths and kilns). They may also result from ceremonial

Fig 3.5
The structural use of animal bone. (1) Horn-core well lining at Prescott Street, London. Details of floors at (2) Wantage, Oxon, using phalanges, and (3) West Dean, W Sussex, using horse teeth. (4) Whale jaw arch, Chideock, Dorset. [(1) Photo LP Archaeology, (2) photo P Wilkinson, (3) photo P Baker, (4) photo P Baker]

practices such as cremation, which sometimes include animals alongside humans (eg Worley 2008; Biddenham Loop bustum, Case Study 2).

Burnt bones retain zooarchaeological potential but pose challenges for recovery. While calcined bones lack the organic component of unburnt bones and therefore survive more readily in unfavourable conditions, they are brittle and usually highly fragmented. Important information regarding identification, life history or processing (eg butchery) may only be observed on a few small fragments in an assemblage, making thorough recovery (including whole-earth sampling) crucial.

Sample processing should be undertaken with care so as not to fragment bones further. The recovery of bones from contained deposits (such as urned cremation burials) can be achieved by block lifting and subsequent excavation (following published guidance; McKinley and Roberts 1993). Thorough recovery from uncontained cremation burials (including busta) and spreads of burnt bone requires whole-earth sampling (Mays *et al* 2004). Where deposits are deep (eg over 0.1m) or cover a broad area, sampling in spits and/or a sample grid can provide further information about deposit formation, for example distribution of species or body parts (eg Biddenham Loop bustum and Potterne, Case Studies 2 and 3).

Recovery of poorly preserved and fragile bones

It is often advisable to first photograph and record *in situ*, and then block lift, poorly preserved, fragile or heavily fragmented bones (Watkinson and Neal 2001; Fig 3.6). They should be lifted on rigid boards to prevent further

Fig 3.6
The conservation of fragile late Neolithic bones from Marden henge (Wilts). (1) Poorly preserved scapula and unidentified bones *in situ*; (2) block lifted; (3) after initial cleaning; (4) reverse side after conservation showing that the group also included a pelvis; (5) illustration of the group. Conservation allowed the bones to be identified and their size compared with Neolithic domestic cattle and aurochs. [(1) Photo C Rees, (2)–(4) photos D McCormack, (5) image J Dobie]

fragmentation, and stored in cold, dark conditions at a stable moisture level. They should not be allowed to dry out, as the drying sediment adheres to the bones and then contracts, often pulling the bones apart. Wrapping in plastic sheeting will help prevent drying. If they are left wet for too long (or at too high a temperature) mould will develop, degrading and potentially contaminating the bones, and decreasing their biochemical potential. Consolidants should only be used after consideration of potential biochemical effects (Karsten *et al* 2012, 19; Mays *et al* 2013, 6) and following the advice of a conservator. Block-lifted bones should be examined by a conservator and treated as required as soon as possible. An animal bone specialist should advise whether lifting and the proposed treatment are justified by the information potential of the bones. This may require a site visit. Observation of the bones *in situ* will also allow the bone specialist to record any significant features (eg associated remains, morphology and biometric data) that may be lost on lifting.

Recovery of well-preserved remains from waterlogged and submerged sites

While animal bones from anaerobic waterlogged deposits may be very well preserved, their recovery and processing provides unique challenges. As organic materials and delicate remains (such as insects and plant macrofossils) may also be present in these deposits, an appropriate recovery strategy must be agreed by all specialists concerned. Animal bone in submerged deposits may be recovered by excavation, trawling or grab sampling. Underwater excavation should record, hand collect and whole-earth sample for bones following the same principles as land excavation (Campbell *et al* 2011), with recovery and conservation of bone considered at the planning stage (Karsten *et al* 2012).

Once brought to the surface, bone assemblages (including from marine environments) should be kept immersed in clean (tap) water and in cold dark conditions (Karsten *et al* 2012, 15; Robinson 1998) and further conservation advice sought, for example regarding desalination. Where tap water is not available, local fresh or salt water may be used temporarily (Karsten *et al* 2012, 15). Processing animal bones from waterlogged and underwater sites will require careful drying, and desalination where appropriate, to prevent fragmentation, delamination and warping (Jenssen 1987). On drying, the recrystallisation of minerals (including salts from marine water) may cause bone to fragment (Jenssen 1987). In some cases, oxidation of minerals (eg pyrite) may cause acid formation and thus severe bone degradation (Huisman 2009, 46; Turner-Walker 2009).

Exceptionally large assemblages

Contexts such as dumps, middens (eg Potterne, Case Study 3) or deep urban stratigraphy (*see* Box 2.1) may yield very large bone assemblages. These may provide rich datasets but can also incur substantial costs. Such contexts should usually be anticipated, and the scope of works and costs managed and documented through project planning (*see* pp 6–7).

The recovery strategy should be planned in advance, taking into account the impact of the methods on the utility of the assemblage to address the project's research questions. For example, thorough recovery from only part of a context can provide a broad range of data, but the data may not be representative (p 17) and may be too limited to examine variation (*see* pp 38–39). Excavating the entire context and prioritising hand collection over sampling will affect the range of data recovered (pp 15–16). Selective on-site discard is poor practice. The scope of further work is best decided through assessment (pp 25–29).

Body silhouettes (including sand stains)

In well-drained acidic deposits, such as gravels and sands, skeletal tissues rarely survive (eg Cronyn 1990, 277). However, as famously recorded in inhumations at Sutton Hoo (Hummler and Roe 1996), the decomposing organic materials, including bodies, can leave silhouette stains. One such stain at Snape cemetery was tentatively interpreted as an animal offering (Pestell 2001, 255–6). Excavators should consider animal remains in the recording and interpretation of silhouettes, and carefully sample for any surviving skeletal material, particularly in the likely region of the head, given the greater durability of tooth enamel.

Biochemical sampling

Scientific samples are taken for a range of purposes, including determining the geographic origin, short- or long-term diet, and genetic profile of an animal (eg medieval sea fishing, Case Study 9), identifying a disease (eg bovine tuberculosis), interpreting environmental conditions, or dating specimens and deposits (*see* Table 3.5; High Post, Case Study 1). Biochemical sampling is a destructive process, although for some techniques the sample size is very small and it may be possible to use the same sample for multiple techniques. In all cases thorough recording prior to sampling is essential.

Biochemical sampling is undertaken by specialist laboratories; however, zooarchaeologists and managers should be aware of the considerations for selecting appropriate bones and teeth for these techniques. Detailed guidelines for the biochemical sampling of bone assemblages may be found in a range of sources (eg Mays *et al* 2013) and should be consulted in the first instance. Prior to sampling, it is best to seek the advice of a zooarchaeologist, technical specialist, culture-historical expert, archive curator and conservator, as appropriate. Careful consideration needs to be given to the aims, suitability of samples (eg bone or tooth; element; part of specimen; required size; biological preservation; contamination or disturbance), likelihood of success and impact of the analyses on the resource (eg scarcity of specimens). An understanding of the archaeological parameters (research questions, context and methodology) and sample requirements will maximise the potential to identify suitable specimens, excavate them appropriately (eg avoid consolidants and retain integrity of ABGs; High Post and medieval sea fishing, Case Studies 1 and 9) and correctly extract and process bone samples.

Post-excavation care of animal bone assemblages

Projects must follow the requirements of the receiving repository. Guidance for processing bone assemblages is given in Watkinson and Neal (2001) and is elaborated upon here.

Cleaning

Hand-collected and dry-sieved assemblages should be cleaned as soon as possible following excavation, to facilitate their appropriate storage and ensure their readiness for assessment. Wet-sieved and floated bones usually only require drying. Animal bones and teeth are generally robust and most can be washed using tap water (but not left to soak). Highly polluted water should be avoided as the chemical components may present a health hazard and affect bone preservation. Sea water should also be avoided as dissolved salts will crystallise on drying (p 22). Fragile remains should be handled carefully, and washing or cleaning should be avoided where it may cause damage (pp 21–22).

Bone assemblages must be dry before they are bagged. They should always be dried away from direct heat or sunlight, in an aerated location. The varying structure and thickness of different parts of bones and teeth may lead to differential stresses, particularly in larger

Information	Bones and teeth	Bags and labels	Boxes
Project	✓	✓✓	✓✓
Context number (or range)	✓	✓✓	✓✓
Specimen identifier	✓	✓	✓
Sample number (or range)	✓	✓✓	✓
Fraction (or range)		✓✓	✓
Small find number (or range)	✓	✓✓	✓
Material type		✓✓	✓✓
Related action* identifier		✓	
Quantification		✓	
ABG identifier/detail		✓✓	
Box identifier			✓✓

✓ may be recorded; ✓✓ essential if applicable; *eg illustrations and specialist samples.

Table 3.1
Information often recorded on specimens, their bags and boxes.

remains, if dried rapidly. These stresses can cause bone to warp and crack or teeth to shatter, restricting their information potential. If drying is too slow, mould may make bones unsuitable for biochemical analyses and affect their long-term preservation.

Marking bones and teeth

Following cleaning, bones and teeth may be marked in line with the requirements of the receiving repository and project procedures (Table 3.1; pp 33–37). Marking greatly enhances the ease with which material from different contexts can be handled together and compared, and ensures that mistakes in bagging assemblages can be easily rectified. However, as marking is time-consuming (requiring a budget) it may not be recommended for all fragments, for example unstratified material. A specialist can advise on the approach best suited to the assemblage (such as marking where considerable comparative analysis might be anticipated). The assessment may provide an opportunity to review which parts of an assemblage should be marked.

Labels should avoid any diagnostic landmarks or features (eg muscle attachments, foramina and articular surfaces) that can assist in taxonomic, element or age determination. Specimens should not be marked if very fragile, or if a label risks obscuring a large proportion of the surface. Similarly, marking should avoid any surfaces modified through working or pathology (eg decorated or shiny surfaces). Specimens of potential use for radiocarbon and other biochemical analyses are best left unmarked to avoid contamination (Brickley and McKinley 2004).

When bones and teeth are marked, indelible Indian ink should be used following museum/archive standards (Davis and Payne 1991). A fine/medium point is recommended, to allow as small a label as possible. A thin layer of Paraloid B72 in acetone (an acrylic co-polymer) can be applied to porous bone prior to marking but only where a suitable area is available and the specimens are not required for biochemical sampling. Control of Substances Hazardous to Health (COSHH) regulations must be followed when using this substance.

Bagging and boxing

Hand-collected bone assemblages are generally bagged by context on site. Animal bone is usually packed in resealable, write-on polythene bags. It may be necessary to perforate bags to prevent build-up of condensation leading to deterioration. Perforations should be pin-prick size, to prevent loss of small specimens. Bags and boxes should not be over-packed, to avoid breakage. Acid-free paper and individual containers may be used to protect fragile specimens. Material extracted for specific purposes, such as illustration or scientific analysis, may be packed separately. Bags should be stored in low-acid cardboard boxes, with brass staples, of the size required by the final repository. Boxes should be stored in a dry, pest-free environment. It is recommended that a list detailing the contents of each box is provided to the specialist (*see* Appendix 2).

All labelling of bags, containers and boxes should follow the requirements of the repository, project procedures and advice in Watkinson and Neal (2001, 3.1), with the important addition of sample number and residue fraction for all sieved assemblages (Table 3.1). They should be labelled using permanent ink; additional waterproof labels may be placed within each bag. Ballpoint pens and pencils may be used for temporary labels but can become illegible over time.

Table 3.2
Training requirements for effective recovery of animal bone during excavation.

Role	Knowledge/understanding (training) requirement
Entire project team	Excavation and recording of animal bone groups (ABGs); site sampling strategy; site documentation; when to seek specialist advice (eg distinguish animal and human bone); dealing with fragile remains; health and safety.
Finds- and sample-processing staff	Handling and processing of bones and fragile remains (eg washing, drying, marking, packing and record keeping); when to seek specialist advice.
Sample-processing staff	Sample-processing techniques and their appropriate application; recognition of animal bone types (eg presence of perinatal animals, microfauna and fish) and condition (eg brittle, soft or mineralised) in order to modify recovery strategy; when to seek specialist advice.

Training requirements

Appropriate training should be provided for excavation and post-excavation staff to ensure that recovery and curation of animal bones follow best practice. Types of training relevant to different archaeological roles are summarised in Table 3.2.

Health and safety

It is the responsibility of the project managers to ensure that staff are aware of and adhere to basic health and safety rules (eg manual handling, COSHH, hygiene and handling of animal skeletal remains and soft tissues; ICAZ 2017). Animal remains may rarely present risks of disease (eg from modern and ancient zoonoses) so their correct handling is essential. Other considerations include handling of hazardous materials and contaminated soils and bones (eg heavy metals; Environment Agency 2005).

Assessment

Why assess animal bones?

The purpose of an assessment is to determine what types of information are present in an assemblage and how these can contribute to project aims and objectives (Campbell *et al* 2011, 7), and estimate costs for this work (Box 3.1). Conducting an assessment provides the crucial opportunity to identify at an early stage the presence of key pieces of information, and any need for particular analytical approaches. It can also highlight any potential not previously recognised in the initial aims and objectives. The specialist draws on site data, comparative research and zooarchaeological conventions and techniques to identify whether part or all of an assemblage holds information potential.

Box 3.1

An assessment considers

- what is worth doing
- how to do it
- how long it will take
- how much it will cost

Approaches to assessment

A bone assessment is a clearly defined piece of work that aims to collect summary data; it does not represent the initial stage of analysis (Kerr *et al* 2008, 422; with general requirements of assessment reports also in Campbell *et al* 2011). The requirements of an animal bone assessment are summarised in Table 3.3.

Assessment tasks can be scaled to the size and complexity of an assemblage. Except for very small assemblages, an efficient approach to assessment data collection is rapid recording by context rather than bone by bone (Fig 3.7). While detailed recording may seem to represent cost-effective data collection in advance of analysis, this may not be the case. Money and time will have been wasted if the information potential is limited and detailed recording is not justified.

In the case of very large assemblages, it is not necessary to record assessment data for the entire assemblage. Given sufficient information (eg on phasing, excavation areas or different feature or context types), the specialist can select a representative subset for assessment. From this subset, it must be possible to estimate the total available data by chronological or spatial grouping relevant to the research questions. It is essential that the character (proportions of taxa, degree of fragmentation and preservation) of the entire assemblage is taken into consideration by scanning the remaining assemblage.

Assessment reports

The components of an assessment report are presented in Table 3.3. Assessment reports must be archived. Where an assessment concludes that no further analytical work is required, the assessment data and report represent the documentary record of the assemblage and should therefore be referenced in site publications, as appropriate.

Information required prior to an assessment

Key types of site and context information are required to enable the specialist to collect and present animal bone data relevant to a project's aims and objectives (*see* Appendix 2). In particular, assessment should not proceed without broad phasing of individual contexts, as bones do not provide an absolute date unless directly dated (Payne 1991). In addition, the project team should discuss any specific questions they want

Table 3.3
Components of an animal bone assessment report.

Background data	
Site data	Report should include site location, site type and date so that it can be understood as a stand-alone document. Type (eg evaluation or excavation) and date of intervention should be stated.
Stratigraphic integrity	Consideration of contamination and residuality within the assemblage based on available archaeological and finds information.
Current curation	Comment on the current storage location, quantification of boxes, nature of storage (ie whether bagged by context) and condition (ie whether washed and/or marked). This information is required to determine costs, programming and logistics of future work (ie analysis/archive deposition).
Assessment methods	
Criteria under which bones are considered: • recordable • measurable • ageable	The methods used must facilitate assessment of potential (Box 3.2) in light of the project aims and objectives. Criteria must be clearly stated, as these may vary between specialists even where standard methods and procedures exist. Detail of methods may vary with the size and complexity of assemblages. Selection of methods may be informed by those applied to comparative assemblages, current methods and theory. Assessment data should usually be recorded at the context level (ie not an inventory of every bone).
Conventions used to record preservation	
Methods for additional data required to assess potential	
Material assessed	Where only a representative proportion of an assemblage is assessed, the criteria employed to select material must be stated.
Consideration of potential and significance	
Recovery method	For some data (eg identifiable bones) it is essential that material collected by different techniques (ie hand collected or sieved fractions) is distinguished so that the information potential of individual fractions and their impact on the assemblage is understood (eg absence or lack of small fauna or small skeletal elements; *see* Fig 3.2).
Phasing and approximate date	All data should be considered by phase.
Data tables	Data should be presented by recovery method and phase, spatial grouping and other variables where relevant. Animal bone groups (ABGs) should be considered independently.

Assemblage characterisation	Numbers of identifiable/recordable (to species/part of the skeleton) bones and teeth (*see* pp 44–46). Taxa of specific interest should be distinguished (eg main domestic taxa) but other animals may be grouped (eg wild mammals and birds) to reflect the project aims and objectives.
	Numbers of ageable bones (epiphysial fusion, foetal/neonatal finds) and teeth (tooth and mandible wear stages) (*see* pp 48–50). These data may be restricted to main domestic taxa.
	Numbers of measurable bones and teeth (*see* pp 48–50). These data may be restricted to main domestic taxa.
	State of preservation of the bones.
	Other aspects may be presented quantitatively or commented on in a qualitative fashion (eg presence/absence), eg for sex distinction (*see* pp 46–48), pathology (*see* pp 50–53), non-metric traits (*see* p 53), butchery (*see* pp 53–55), craft or industrial (*see* pp 53–55) evidence (pp 18–20).
	ABGs and taxa of specific interest may be distinguished and commented upon in greater detail, to reflect the project aims and objectives.
Recommendations	
Requirement for further analysis	A clear statement as to whether the assemblage merits further analysis, referencing its potential (Box 3.2) against the project aims and objectives, other materials from the site and current state of knowledge (abundance or scarcity of comparative sites and assemblages, or cumulative or group value; eg across London and medieval sea fishing, Case Studies 8 and 9).
Comparanda	The report should identify relevant assemblages and syntheses that would serve as comparanda for analysis (*see* Supplement 1).
Proposed methods for further analysis	Methods of analysis should be specified so that their impact on time estimates, project management and required resources can be considered. Methods of analysis (pp 29–33) should take into account comparative datasets.
Proposed additional research questions	Identification of new information potential (and required methods) to feed back into project planning.
Costings/budget	
Time estimates	Costings should be presented by task (eg bone recording, data manipulation, biochemical analyses, comparative research, report writing and editing), with the number of days required for each. This allows evaluation of cost, facilitates project management (progress) and can inform future projects.
Additional costs	Where the work required includes specialist laboratories, methods and costs should be sought from the relevant specialist(s).

				COUNTABLE										AGEABLE									MEASUREABLE					
				Cattle		Sheep/goat		Pig		Bird	Fish	Other		Cattle			Sheep/goat			Pig			Cattle	Sheep/goat	Pig	Bird	Other	
Site	Context	Box	Pres	Teeth	Bones	Teeth	Bones	Teeth	Bones	Bones	All	Teeth	Bones	Mandibles	Teeth	Bones	Mandibles	Teeth	Bones	Mandibles	Teeth	Bones	All	All	All	All	All	Comments
GM/XV	Layer 5	6	PM	11																								
GM/IX	Layer 3	7	PG	48																								
GM/IX	Layer 3	7	M		2									1														
GM/IX	Layer 3	7	P		18											1												gnawing
GM/IX	Layer 3	7	PM		14											5							2					gnawing
GM/IX	Layer 3	7	PM		9								1			1												inc red deer
GM/IX	Layer 3	7	P		11		4						1															inc dog
GM/IX	Layer 3	7	P	17	1	25		1						1	7			15					2	8				
GM/X	Layer 3	23	MG					22	4			2									13				8			inc red deer
GM/X	Layer 3	23	P			1	4										4	1						4				
GM/X	Layer 3	23	PM		10											5							1					gnawing
GM/X	Layer 3	23	M		13																							gnawing

Fig 3.7
Example of an assessment spreadsheet, compiling data into context groups (A Hammon, pers comm). 'Pres' records preservation: P, poor; M, moderate; G, good. [Spreadsheet design U Albarella]

Box 3.2

What is assessing potential?

Evaluating suitability to:

- provide data to address the project's aims and objectives;
- provide data to address additional research questions not considered in the initial project planning, which may include broader research priorities (frameworks, etc).

Assessment of these qualities may be based on factors such as the following:

Contextual integrity and chronology
Is the chronological resolution of the assemblage sufficient to allow meaningful interpretation? Is the assemblage likely to include a high proportion of residual or intrusive material, and how does this affect its suitability?

Assemblage 'richness'
What primary data can be recorded? For example: species, element, age at death and sex representation; evidence of carcass processing, pathology and formation processes. In what quantities are these data available, and are they meaningful as stand-alone datasets or in comparison with those from other sites?

Contextual rarity
Does the assemblage present an opportunity to investigate zooarchaeological questions in an underrepresented social, cultural or geographical context, or improve understanding of recognised trends?

Biological rarity
Will the presence of spatially or chronologically unusual species contribute to the biogeography of that species?

Notable activity
Does an assemblage include evidence for unusual utilisation of species?

Additional utility
Can it contribute to other aspects of site interpretation, for example by providing material for radiocarbon dating or identifying specific activity areas within a site?

Examples of research themes against which to assess the potential of an assemblage can be found in Chapter 1. The potential of the whole assemblage may be different to that of its parts (eg separate contexts). Judgements of potential value will vary over time and with research questions, as they are tied to current knowledge and methodology.

the bone specialist to consider. Ideally, context and sample information should be provided digitally in tabular form, as this eases data collection and manipulation, thus saving time and money. The presence of 'unusual' deposits (eg ABGs, grave goods and industrial waste deposits) should be highlighted so that they can be assessed and their specific information potential, recording requirements and time and cost implications recognised.

Resourcing assessments

Assessments should be undertaken by expert zooarchaeologists, who have the breadth of academic knowledge and practical skills to enable informed judgements. If necessary, outside expertise should be sought, for example, for studies of fish bones or ancient DNA (aDNA) analysis. Less experienced specialists should only carry out assessments under appropriate supervision.

Analysis

What is analysis?

An analysis usually follows an assessment of a bone assemblage (pp 25–29) and realises its potential to address a project's aims and objectives. Analysis comprises the recording of primary data (the structured description of bones following a predetermined methodology; *see* p 55; Fig 3.7; Tables 3.4 and 3.5), manipulation of those data, interpretation in the light of current understanding and, finally, production of an interpretative report(s) (Fig 3.8; specification for reports can be found on p 33). Each of these stages is essential for the completion of the next. Once the analysis has begun, the specialist should be kept informed of any alteration to the essential inputs (eg phasing, methodological conventions or research question; Fig 3.8). Such alterations may necessitate revisiting earlier analysis stages and require significant additional work for the zooarchaeologist, particularly regarding derived data, such as age profiles or estimation of minimum number of individuals (MNI) (*see* pp 44–48).

Typically the nature of a bone assemblage will be considered within each phase of activity, taking into account any archaeological variables (eg activity areas, deposit types and associated finds) of relevance to the research questions. Clearly resolved chronological context grouping (phasing) is fundamental to the utility of an analysis; there is usually little potential for assemblages with coarse chronological resolution, particularly where the time span encompasses different cultural groups (eg Roman to medieval).

Selecting methods

The types of primary data typically recorded during analysis, and therefore included in a bone

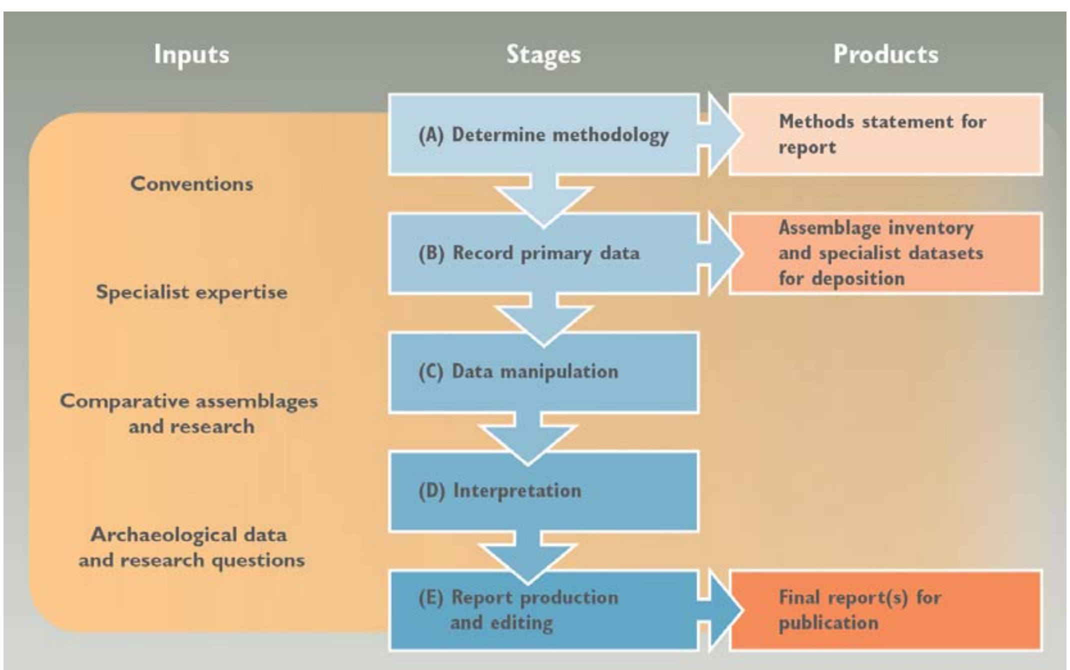


Fig 3.8
Assessment and analysis: essential inputs, stages and products.
[Image F Worley and J Vallender]

inventory, are summarised in Table 3.4 (*see* Chapter 4). This recording is required before any destructive analyses take place (pp 22–23; Table 3.5). Bone inventories usually comprise records describing individual fragments, allowing flexibility in the manipulation of data. Unless introducing a novel approach, data recording should follow published conventions. All recording methods must be clearly defined in a method statement.

The selection of methods should take into account how comparative assemblages were recorded and interrogated, and reflect intervening developments in zooarchaeology and archaeology. There may be instances when the data archive of comparative assemblages is inadequate or does not meet current standards (eg in the use of conventions). In these cases it may be appropriate to revisit the archived assemblage to apply relevant methods in order to generate a new dataset that will allow better contextualisation of the current assemblage.

Selective bone recording for analyses

The larger a phased bone assemblage is, the greater the reliability of any interpretations, conclusions and statistical analyses (*see* pp 38–39). However, it may not always be appropriate to consider all bone fragments. Via assessment, a zooarchaeologist may recommend considering only a subset (a random or systematic selection) of an assemblage in certain circumstances:

- where issues of residuality or contamination prevent some bones from being securely attributed to a useful date range;
- where the study focuses on a particular thematic or contextual research question for which only some of the bones are relevant (eg only a specific element, species, phase or deposit type);
- where a study is conducted as a pilot for a later, more in-depth, study.

Recovery (pp 15–25) and recording methods (eg *see* pp 44–46) may in themselves be selective.

Table 3.4
Typical primary data recorded during an analysis and its interpretative utility.

Data category	Data recorded for each fragment	Typical interpretative value
Provenance	Context (and find spot or associated finds, where relevant) Recovery method (including processing) Articulation with other fragments	Essential information for all meaningful interpretation.
Taxonomic identification (*see* pp 42–44)	Species (or higher taxonomic classification, eg large mammal)	Fundamental to most analyses and research questions.
Skeletal identification	Element Side (left/right/axial) Position (fore/hind) Region of element (zones/fragmentation)	Data profiles may inform potential bias in other data classes. Commonly used for quantifications; determining formation process including function; sex profiles.
Age at death and sex (*see* pp 46–48)	Age at death (bone fusion/ossification; tooth formation/eruption/attrition; incremental structures) Sex	Data profiles may inform potential bias in other data classes. Commonly used for interpretation of husbandry and hunting strategies and technologies; seasonality.
Biometrics (*see* pp 48–50)	Standard measurements	Animal size and shape; population characteristics; trade/introductions; sex profiles; species identification.
Non-metric variation (*see* p 53)	Non-metric traits (eg missing hypoconulid on bovid third molar)	Population studies (genetic pool); species identification.
Modification	Taphonomy (gnawing/part digestion; burning; trampling; *see* pp 39–42) Butchery marks (*see* pp 53–55) Pathology (*see* pp 50–53) Bit wear	Deposition and post-depositional processes (which may affect interpretation of other data classes); health; husbandry; slaughter; carcass processing.

Where selective recording is used, it is particularly important that the selection criteria are clearly recorded in a methods statement, and that the remaining assemblage is not discarded without a record (pp 33–37). Like all archaeological materials, animal bones are an irreplaceable resource and any subsampling introduces further biases into archaeological interpretation. Understanding those biases helps mitigate their effect.

Required specialist expertise

Animal bone analysis should only be conducted by a zooarchaeologist who is aware of current knowledge and theory, and skilled in practical methods. It is essential for the individual to have access to resources and peer review (Table 3.6). There are several sources of information that may assist understanding of appropriate research questions and guide selection of comparative

Table 3.5
Biochemical, microscopic and imaging analyses and their typical interpretative value. Most techniques are destructive (*see* pp 22–23; for further guidance *see* Campbell *et al* 2011; Mays *et al* 2013).

Method	Research questions and potential	Sampling notes*
Radiocarbon dating	Scientific dating of deposits or individual bones/teeth	*c* 0.5–1g sample of tooth/bone (or 2g fully calcined bone). For dating deposits, articulating bones and refitting epiphyses provide the most secure samples.
Investigation of stable isotopes Including carbon, nitrogen, strontium, oxygen, lead, hydrogen and sulphur. Material (tooth/bone) and isotope sampled depend on research question. Teeth retain chronological resolution and resist diagenetic change.	**Taphonomy**: pre-screening for sufficient collagen preservation (based on percent nitrogen method) prior to other methods (eg radiocarbon dating)	Bone drilled to yield a 5mg sample
	Animal management: interpretation of diet (eg weaning, feeding and foraging), seasonality, herding and control (eg penning, pannage and transhumance)	*c* 0.5g sample of bone/tooth; up to 50mg tooth enamel
	Human diet: animal samples provide local baseline data to inform interpretation of dietary isotopes from human bones (eg marine or fresh-water input; meat from herbivore or omnivore animals)	*c* 0.5g sample of bone/tooth
	Environment, climate, location: where animals were raised, managed and moved	*c* 0.5g sample of bone/tooth; up to 50mg tooth enamel
Investigation of biomolecules Identification of proteins and ancient DNA (aDNA)	Identification of sex, species or other genetic groups (domestication and stock management; trade), physical characteristics of animals, palaeopathology	aDNA: c 50mg–3g sample of bone or tooth (not enamel). Teeth better resist diagenetic change than bone. Proteins: for ZooArchaeology by Mass Spectrometry (ZooMS), bone/tooth dentine is drilled to yield a 5–50mg sample; microfauna can require a smaller sample.
Histology Microscopic structure	Seasonality, age at death, palaeopathology, taphonomy, species identification	Thin-section of bones, teeth and otoliths
Tooth microwear Microscopic abrasion from eating	Animal diet, seasonality	Non-destructive
Imaging Includes use of photographs, X-radiography, laser or light scans, computed tomography (CT) scans	Tooth development (ageing), palaeopathology, bone density (taphonomy), species identification, animal management and movement (using geometric morphometrics)	Non-destructive

*As a rule of thumb, samples of up to 3g may be retrieved from an area *c* 10–20mm by 10–20mm. The amount required will depend on bone structure and preservation.

assemblages. These include vertebrate regional reviews (*see* p 87), regional and temporal research agendas and frameworks, the Environmental Archaeology Bibliography (University of York 2008) and peer support through professional groups, eg the Professional Zooarchaeology Group (PZG) and International Council for Archaeozoology (ICAZ). In addition, specialist resources such as the Animal Bone Metrical Archive (ABMAP; University of Southampton 2003) may provide relevant comparative datasets (*see* Supplement 1).

Specific aspects of assemblages (eg fish bones, microfauna, bone working and biochemical studies; Table 3.5) may require additional expertise. This should be identified as early as possible, for example through site visits (*see* pp 11–12) or at assessment (pp 25–29), but may also become apparent as analysis progresses, and it can be considered at informal and formal review points (*see* Fig 2.1; Lee 2015, 20–21).

Resources required by the zooarchaeologist

To complete a bone analysis, zooarchaeologists require resources and facilities as defined in Table 3.6 and summarised in Fig 3.8. A checklist for archaeological data required prior to bone analysis is provided in Appendix 2.

It is essential that the zooarchaeologist knows the provenance of each bone and how it was collected, including whether it was from an ABG. Recovery methods bias animal bone assemblages (pp 15–25), making this information vital for

Table 3.6
Resources (excluding time) required for an animal bone analysis.

Work space requirements	Equipment requirements	Reference resource requirements
A suitable workbench • Adequate space (at least enough room to lay out all the bones from a context, together with any recording equipment) • Appropriate height for standing or sitting, and suitable seating for working for prolonged periods • The working surface should preferably be plain coloured and not textured, as small bones may get lost against a patterned or textured surface **Adequate lighting** • Natural light is ideal and may need to be supplemented by a bright desk lamp to view fine detail such as butchery marks **Stable environment** • The workspace should be protected from drafts, particularly when working with small bones, and from extremes of temperature, which may be detrimental to both archaeological bones and skeletal reference collections **Additional specialist facilities** • Additional laboratory facilities and resources may be needed (eg for X-radiography or chemical analysis)	**Magnification** • A low-power light microscope or hand lens for assessing fine detail (eg butchery marks and gnawing) **Measuring equipment** • An osteometric board and calipers for measuring bones • Flexible tapes or cord, such as fishing wire, for circumference measurements (materials that stretch should be avoided) • Weighing scales **Handling equipment** • Trays and Petri dishes (for laying out bones) • Tweezers **Consumables** • Finds bags and permanent marker pens • Packing materials for fragile specimens (eg clear plastic boxes, acid-free tissue paper, etc) • Appropriate pen and Indian ink (and acrylic co-polymer when required, p 24), if marking bones • Archive boxes as agreed with repository **Photography** • Access to photographic equipment including photographic scales **Computing** • Hardware and software, including any word processing, spreadsheet, database and statistical software • Facility for daily digital backup, ideally in managed network storage	**Skeletal reference collection** • Access to a collection, ideally including most species commonly recovered archaeologically. Specimens should include various ages, sexes and breeds, particularly species exhibiting the most morphological variation • Access to other collections for particularly difficult or unusual specimens may also be required **Reference texts** • Standard bone recording manuals/texts, particularly those specifying standard recording conventions (eg zones, tooth wear and measurements) or common species distinctions (eg sheep/goat and chicken/pheasant). Useful references are listed in Supplement 1 **Comparative data** • Access to comparative site reports and methodological papers (books, journals and online resources). Useful resources are listed in Supplement 1 and on p 87 **Site-specific data** • *See* checklist in Appendix 2

appropriate interpretation. Any additional information recorded on site (eg photographs of bones *in situ* or comments on any concentrations of bone) should also be provided.

Depending on the research questions being addressed, the specialist will need to know the context types (eg ditch fill or layer), how they are interpreted (eg backfill, primary fill, hearth, midden or topsoil) and how they relate to other contexts (stratigraphically and contextually).

Analysis should not begin until a site narrative (including chronology, location and site type) and finalised phasing by context have been provided. The phasing should be in a format that allows integration with the bone inventory (eg a digital spreadsheet). Animal bones in themselves often cannot indicate residuality or contemporaneity, so evidence regarding the integrity of each context must be provided to the bone specialist.

Each stage of the analysis process (Fig 3.8) requires time. Depending on the research questions being asked and the potential of the assemblage, data recording may represent <50% of the total time required. Ideally the same specialist(s) should conduct each stage of analysis. If the specialists involved change (eg between recording and data analysis) the process may be protracted and there is the potential for data loss.

Products of zooarchaeological research

Bone inventories/catalogues

A bone inventory is the primary record of an assemblage; it will be produced as part of data recording, often in a digital format (*see* p 55), and should be submitted to a permanent archive (*see* below, Archive deposition). Where possible, it should be made available through specialist datasets (*see* p 55; Supplement 1) and publication. As noted in other professional guidance (ICAZ 2009), recording methods and any abbreviations or codes used must be clearly defined (metadata) so that the catalogue can be reassessed and interpretations tested.

Contents of reports

Reports disseminate information obtained from an animal bone assemblage, whether documenting a small number of fragments or a large and highly informative dataset. Reports should be interpretative, addressing the aims and objectives of a project, and comprehensible as a stand-alone piece of research. They must present clearly defined methods and supporting data to allow interpretations to be critically assessed by others and the reported assemblage to be used in future inter-site analyses (Box 3.3). There are essential elements to most bone reports: an introduction (including phasing and site information), aims and objectives, methods, results (including datasets, or directing users to data held in an accessible location), discussion and conclusion. However, the report may be structured in different ways, reflecting

- the quality of the assemblage;
- the nature of the investigation (eg assessment, analysis or synthesis);
- document constraints (numbers of figures and tables, word length, etc);
- the intended audience (ie archive-only, client-only, monograph, journal paper, specialist contribution to excavation report, or focused thematic or methodological zooarchaeological research).

Photographs and illustrations, including a scale, may help convey details of the assemblage, such as spatial distributions, butchery marks or pathologies. Quantitative and descriptive data may be best presented in graphs and tables.

Maximising evidential value

Animal bone data are best used to address research questions and inform the interpretation of archaeological sites when integrated with other excavation information. This can only be achieved with good and timely collaboration between animal bone specialists and the rest of the project team. To avoid technical inaccuracy or misinterpretation, integrated interpretations should be commented upon by all relevant members of a project team prior to publication. Discoveries relevant to wider research should be highlighted.

Archive deposition

Preparation for archiving

Preparation of bone assemblages for archiving includes appropriate labelling, bagging and boxing (pp 23–24). The requirements of the repository need to be identified at an early stage of project planning so that preparations are correct and cost-effective (Edwards 2013, para 8.1.6). During the course of the project some specimens

Box 3.3

Essential information in publications (including grey literature)

Together with the inventory, reports may become the only surviving record of the assemblage, should the bones be discarded, destroyed or lost. Wherever zooarchaeological data are published it is essential that the methods used in their recording and interrogation are easily accessible, to allow comparison with other datasets.

Key information to include in a publication is outlined below.

Methods followed

- Criteria for inclusion of bone specimens (ie the bone was considered countable if it fulfilled the requirements, such as exceeding a minimum completeness threshold) or reference to published method.
- Collection method(s) for the assemblage (whether hand collected or coarse/wet sieved, including mesh sizes). Bones collected using different methods should not usually be combined in quantifications (*see* pp 44–46).
- Quantification methods, such as number of identified specimens (NISP), minimum number of individuals (MNI), minimum number of elements (MNE), etc (*see* pp 44–46), including specific criteria.
- References for standard conventions (eg zoning systems; biometric conventions and conversion factors; tooth wear recording methods; tooth wear and fusion age at death categories).
- Any identification criteria, including references (eg methods for distinguishing between morphologically similar species such as sheep and goat, horse and donkey, chicken and pheasant).
- Any variation to cited methods must be explicitly described.

Data

- Primary data (quantification of assemblage, usually presented by taxa, phase and any relevant contextual grouping).
- Sample size for summary, prevalence or derived data in text, tables and charts.
- Raw measurement data with measurement units (*see* pp 48–50). If not feasible to include raw data, the data archive must be accessible and its location signposted.
- Description of any pathological changes or carcass-processing marks, in addition to interpreted diagnoses or butchery practices (*see* pp 50–52 and pp 53–55).

Explanatory information

Any coding must be defined (eg for species, bones, fusion states and phases).

Supplementaries

- Identity of the zooarchaeologist responsible for both the practical work and report writing.
- Skeletal reference collection consulted.
- Recording database, if using a published system (eg Harland *et al* 2003) or unpublished in-house system (eg Historic England zooarchaeology database).
- Date of laboratory work and/or report (if significantly different to date of publication).
- Intended repository for assemblage.
- Statement regarding disposal of any part of the assemblage, with signposting of any relevant report (pp 35–36).

may have been extracted, for example for photography, drawing or destructive sampling. These items should be reunited with the rest of the animal bone assemblage prior to archive deposition. The animal bone assemblage should be accompanied by documentation including the reports and data (with metadata including any codes/abbreviations used), and a record of any selective recording, destructive sampling, supplementary analysis (eg X-radiography) and discarded/reburied material. Any discard prior to deposition requires zooarchaeological input (*see* below).

Transfer

Ownership of all the components of the material archive should be transferred to the final repository by means of a transfer of title agreement at the earliest possible stage during a project. Licence to copyright for all documents and digital material should also be granted to the final repository (Brown 2007, 31–34). Delivery of the project archive to the repository should take place as soon as possible after completion of work leading to final publication, and within the timeframe as specified in the written scheme of investigation (WSI) (*see* p 10). A project may not be considered closed until the archive is deposited (CIfA 2014g, para 3.6.3).

Retention and discard policies

Animal bone assemblages are an irreplaceable resource, therefore the ideal approach to their archiving is properly funded retention for the following reasons:

- Developing methods and technologies provide new means of data verification and recording, and allow new research possibilities, such as identification criteria, protein analysis, isotopes, aDNA and dating, but also quantification methods, osteometric conventions and taphonomy (see Society of Museum Archaeologists 1993). Recent re-analysis projects include assemblages from Durrington Walls (Albarella and Serjeantson 2002) and Potterne (Madgwick *et al* 2012; Case Study 3) and multi-site syntheses using new techniques (eg Sykes *et al* 2011; medieval sea fishing, Case Study 9).
- Developing theory, particularly changes in perception of which fragments have information potential, for example types of fragments counted and analysed (Outram 2001), or value of burnt bone.
- Improved understanding through characterisations of the archaeological record, including regional reviews (*see* p 88), regional research frameworks and academic research, highlight research value not previously recognised.
- It may be necessary to return to archived assemblages to record data that are comparable with more recent datasets or for syntheses (eg pp 29–30; Serjeantson 1995), given the complex issues of quantification and derived data in zooarchaeology.
- Testing previous interpretations of the evidence.
- Many archived bone assemblages are inadequately reported.

However, the current economic reality is that a discard policy may need to be imposed, for either deposition of new assemblages or rationalisation of archives (Edwards 2013, para 8.1.6). When this is the case, the following principles are important for developing a policy:

- All policies must aim to minimise loss of information.
- Policies must be developed for specific circumstances (eg site type, location and preservation conditions) with specialist zooarchaeological input.
- The impact of applying a policy to each individual assemblage should be assessed and recorded by an expert animal bone specialist, with reference to additional expertise where necessary (eg biochemical analyses and socio-cultural history; Edwards 2013, para 8.3.9). This decision may consider whether the material has been flagged as a 'key assemblage' (p 37) but should not be based solely on that judgement.

Where a discard policy is deemed suitable, the following actions should be undertaken:

- The policy must be implemented with input from an expert animal bone specialist.
- Any discarded material must be documented and that record archived together with the discard criteria. The record may include photography, quantification and description.
- Unsorted flots and residues should not be discarded before specialist reporting (assessment or analyses as appropriate) is completed.

While discard of fresh bones must follow best practice for the disposal of animals and animal by-products (Defra 2011, 6–8), archaeological animal bones do not present a health risk (unless soft tissue is present or they were recovered from contaminated soil; p 25). Generally bone assemblages can be discarded in the same manner as other finds. They may be reburied on site in excavated areas; however, this is rarely feasible as decisions regarding discard are generally taken after backfilling has been completed. Reburial must not occur within undisturbed areas of archaeological sites. If finds are reburied within an excavation, discarded material must be deposited in labelled bags (to identify it should it be rediscovered in the future) and its location three-dimensionally recorded. The option to use discarded assemblages for education and training may be considered. Archaeological bones do not make ideal reference specimens unless their taxonomic identification is secure.

Box 3.4

What makes an assemblage significant?

Significance is derived from potential (ie evidential value; Drury and McPherson 2008; *see* Box 3.2). Therefore, significance judgements are based on similar factors as assessment of potential, and also vary with developing methodology and knowledge. Significance may also be historic, such as having been associated with notable personalities or places (historic value). Significance should not be solely based on high rarity; it is important that investigations of exceptional circumstances are based on a good understanding of 'typical' practice. Significance and potential are fundamental to defining key assemblages (Fig 3.9).

Site name: *Blagdon Manor Farm*		**Organisation undertaking the work:** *Archaeological Unit X*	
Site code: *BMF08*			
Date of intervention: *November 2008*			
Grid reference: *NP 6032 5046 or 460320 750460*		*(the latter fully numeric grid ref is easier to enter into ArcGIS, for example)*	
OBJECT TYPE: eg vertebrate remains, mammal remains, small mammal remains, bird remains *Vertebrate, mammal remains*			
Material type:	**Modification state:**	**Aspect:**	**Investigative technique:**
(eg metal, wood, bone) *bone, tooth*	(anoxic, charred, mineral replaced) *mineral replaced, altered by animals*	(feature) (eg worked) *pathology*	(eg microscopy, X-radiography) *stable isotope analysis*
Method of recovery: (eg flotation, coarse sieving, specialist sampling) *hand retrieval, floatation*			
Key assemblage:		**Yes** *X*	**No**
Potential: *Large assemblage from three well-defined phases of occupation*			
Period: *Roman*			
References: *Bloggs, G. 2008 Assessment report of the site of Blagdon Manor Farm, Doggerland, Unpublished report of Archaeological Unit X*			
Storage location: *Museum of Environmental Samples*			
Notes: (PTO if necessary)			

Fig 3.9
A worked example of a form used for submitting summary data along with the full report to the Historic Environment Record (HER).
[From English Heritage nd]

Digital data storage

Once a project is complete, data should be deposited with the physical archive (pp 33–35). In addition, digital repositories can offer secure archiving of datasets, maintaining them in usable digital form and promoting their use. There are several repositories to choose from, including those developed by universities and others that are specific to archaeology, for example the Archaeology Data Service (ADS). Deposition of digital data incurs costs associated with long-term storage and care, appropriate formatting and provision of metadata. The receiving repository should be contacted as early as possible to determine requirements and costs.

Inclusion of data in Historic Environment Records

(S Warman)

Reports on all archaeological interventions, however small, should be lodged with the local HER as promptly as possible upon approval, for example by the local authority archaeology advisor (Gilman and Newman 2007). Submission of zooarchaeological information to HERs, and currently to OASIS (Online AccesS to the Index of archaeological investigationS), is usually planned with publication, dissemination and archiving considerations (eg in briefs, specifications and WSIs). The level of detail currently recorded for zooarchaeology specifically (and archaeological science in general) varies between HERs; some pilot studies incorporate a range of archaeological science data (English Heritage 2010), while others signpost the presence of an assemblage and its archive location (assemblage and report).

Roles and responsibilities

Local authority archaeology advisors should discuss submissions to the HER, including any animal bone reports, as early as possible with the contractor. Appropriate submission can be ensured through instructions in briefs.

The WSI should include submission of zooarchaeological information to the HER as a task. The information should comprise the final animal bone report (often included within a site report) accompanied by summary information, for example as presented in the HER archaeological science form (English Heritage nd, 3; Fig 3.9). In order to complete the form the zooarchaeologist will make a judgement regarding whether the assemblage is 'key'. This opinion may apply to the entire assemblage or subgroups; it will be based on the specialist's current understanding of its significance (Boxes 3.2 and 3.4) and should be justified under 'Potential' in the form. The decision allows curatorial staff and HER users to identify rapidly those assemblages that may hold the greatest potential.

Thesauri and terminology

Submissions to the HER must follow data standards. The key source is *MIDAS Heritage: The UK Historic Environment Information Standard* (English Heritage 2012). Terminology for inclusion of summary bone assemblage information can be found in Heritage Standards thesauri (Heritage Standards nd).

4
Practitioners' guide to good practice

For local authority archaeology advisors and project managers

This chapter aims to assist non-specialists in understanding zooarchaeological reports and datasets and evaluating their quality (CIfA 2014b, para 1.55). It also aims to promote inclusion of essential information in publications to allow critical evaluation of interpretations and future reuse of data.

For zooarchaeologists

Chapter 4 aims to promote the selection of appropriate methods for effective use (in addressing research questions and interpretation) and reuse (including synthesis) of datasets. It is supported by additional resources listed in Supplement 1, which includes commonly cited methodological manuals and conventions.

Key messages

- Zooarchaeological data are complex and methods vary depending on research questions and the nature of the assemblage (its recovery, condition and make-up).
- Access to datasets (ie raw data) and clear methods, including use of standards, conventions and quantification methods, are essential for comparability of datasets, synthetic studies and peer review.
- Interpretations must be supported by clear description of the data.

Using recording conventions and standardised terminology

Standardised terminologies should be employed to ensure that reported data are clear and unambiguous, and therefore allow comparability with other datasets. Standard terminologies include scientific names for animals (pp 42–44; *see* Appendix 1), skeletal elements and anatomical features (eg ICVGAN 2012; but anglicised schemes are also in use, eg Cohen and Serjeantson 1996; Hillson 1999), and anatomical location and direction (eg O'Connor 2000, 8–9).

Recording conventions also ensure repeatability of observations and comparison of datasets. These are particularly important for biometry (pp 48–50), bone zones (pp 44–46) and tooth attrition (pp 46–48).

Sample size and examining variation
(A Hammon, P Baker and F Worley)

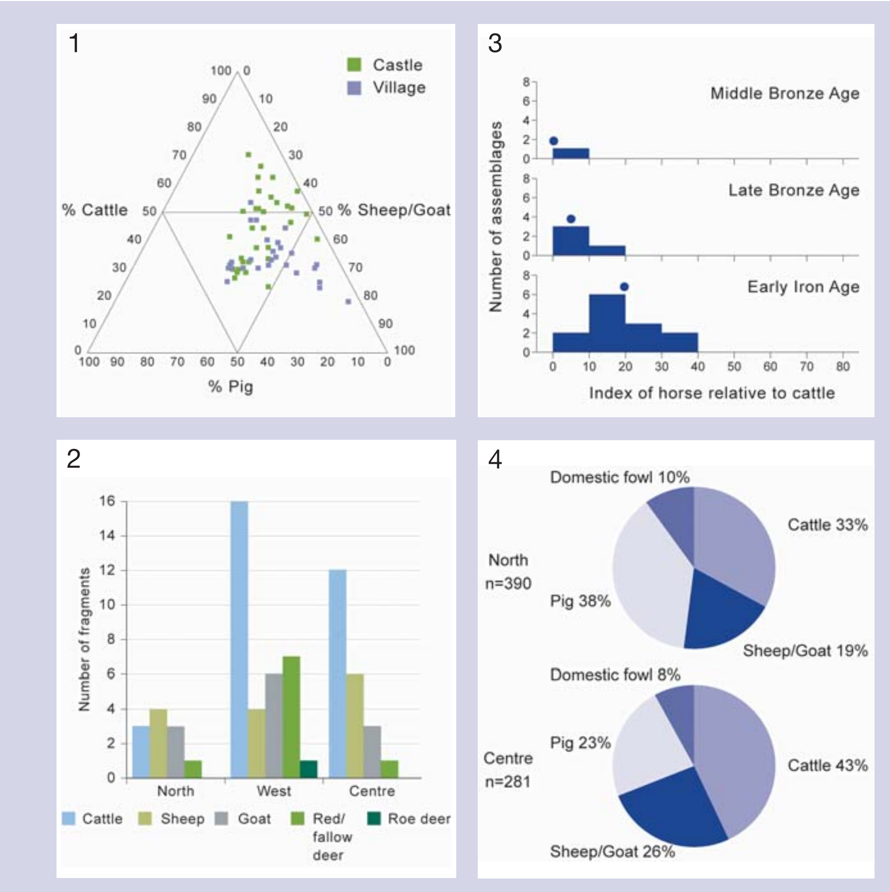
Sample size

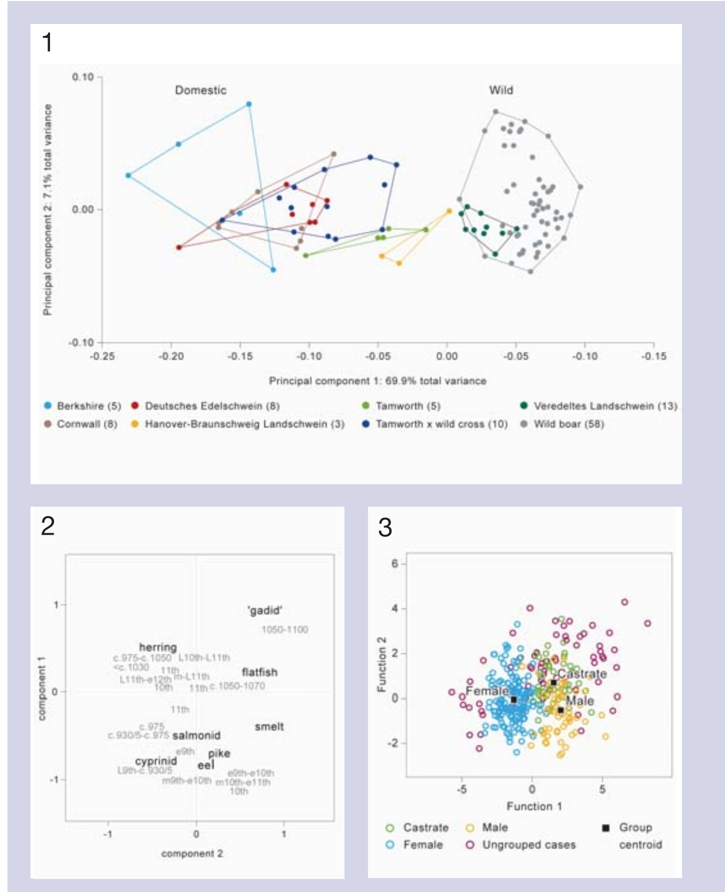
A considerable amount of work has been conducted on sample adequacy (Baxter 2003; Cochrane 2003; Hambleton 1999, 39–40; King 1978; Orton 2000; Turner 1984), although there appears to be little agreement on what constitutes acceptable sample sizes for valid interpretation and comparison. In addition, a small dataset can increase in evidential value when viewed in the light of other assemblages (ie group value or rarity, eg across London, Case Study 8). Requisite sample size is ultimately dependent upon what is being analysed and the questions being asked, and therefore sample size should always be clearly presented (*see* Box 3.3).

Examining variation

For many variables, visual display of data in graphs and diagrams will allow recognition of patterns of similarities and differences, and may suffice for interpretation (Hambleton 1999, 19). Patterns of frequency may be visualised using a range of diagrams depending on the number of categories and research question (Fig 4.1). Scatter diagrams are also often useful for visualising data, particularly for biometry (pp 48–50).

Raw data may be investigated through univariate descriptive statistics (including sample size, mean, other measures of central tendency and dispersion). Multivariate statistics, such as discriminant function analysis, have been applied to various zooarchaeological questions, includ-





ing the separation of sexes or closely related species (Fig 4.2). Apparent differences between datasets (eg variation in abundance or biometric data; Potterne and London, Case Studies 3 and 8) may be tested for their statistical significance, for instance using the Mann–Whitney U-test, Student's t-test or the chi-squared test.

The choice of statistical method will depend on the nature of the data, the size of the dataset and the research question (null hypothesis) being tested. It is advisable to seek specialist input when choosing statistical tests to ensure their correct application and interpretation.

Preservation and taphonomic evidence
(T O'Connor)

The state of preservation of excavated animal bone reflects the sequence of processes and events that occurred between the death of the animal and the time the bones are studied, and affects the diversity and detail of its information potential. For some assemblages, taphonomic evidence may outweigh the cultural or biological evidence (*see* Table 3.4; Fig 4.3; eg Potterne, Case Study 3).

Through consideration of taphonomy we aim to understand three post-mortem stages of assemblage formation:

- Biostratinomic stage: from death to incorporation in the archaeological deposit. This stage includes the cultural processes with which archaeology is mostly concerned.
- Diagenetic stage: from incorporation to excavation. Here, the main factors are hydrology and the geochemistry of the sediment.
- Sullegic stage: the processes of excavation, sampling and recovery. We have most control over this stage, and it can have considerable impact on the characteristics of the assemblage (*see* pp 15–25).

Recording taphonomic evidence

When considering which forms of evidence need to be recorded, it is useful to 'replay' the taphonomic trajectory in reverse. Suggestions of attributes to record and their information

Fig 4.1 (above left) Alternative graphical presentations of relative abundance data. (1) Tripolar plots; (2) bar charts; (3) histograms; (4) pie charts. [(1), (2) and (4) adapted from Albarella *et al* 1997; (3) adapted from Bendrey 2010]

Fig 4.2 (above) Examples of multivariate (principal components and discriminant function) analyses. (1) Pig and wild boar skull shape; (2) changing fish exploitation in medieval England; (3) post-medieval sheep metacarpal shape compared with modern Shetland sheep. [(1) adapted from Owen *et al* 2014, fig 3, © Elsevier; (2) from Barrett *et al* 2004, fig 2b, courtesy of Antiquity Publications Ltd; (3) data from University of Southampton 2003; from Popkin *et al* 2010]

Fig 4.3
Examples of taphonomic modifications. (1) Cat tooth marks on a kittiwake humerus; (2) subaerial weathering on a pig mandible on the surface of a midden; (3) marked erosion of a bone that has lain on an active, eroding land surface; (4) 'rounding' of morphology and old breaks indicating considerable transport, possibly by water, before burial; (5) weathering on a sheep metatarsal, with close-up (6) showing surface cracking, probably from subaerial weathering and secondary mineral deposition acquired during burial. [Photos T O'Connor]

potential are presented in Fig 4.4. Published conventions can aid recording and comparison of taphonomic evidence (*see* Supplement 1).

Types of taphonomic analyses

Making a thorough record of preservation and taphonomic evidence can be time-consuming and may appear to be a distraction from learning more about the animals and people's use of them. Our interpretation of the bone assemblage is likely to be more confident, and less likely to be misleading, if we understand in detail the processes that have affected it between the original living community that we seek to understand and the pile of bone fragments on the bench.

The distribution, intensity and selectivity (or ubiquity) of surface marks and modification reflect the uses that people and other animals have made of the carcass. Some examples are outlined below.

- The distribution of butchery marks shows the consistency and intensity of utilisation, for example whether more or less meat-bearing parts of the carcass were equally heavily butchered, or whether bones were consistently split to extract marrow.
- The distribution of charring may show mode and purpose of burning, for example whether bones are charred all over, suggesting domestic or refuse fires, or only partially charred, suggesting roasting (the bone within meat will not char).
- The intensity and selectivity of scavenger tooth marks will show the degree of scavenger access to the bones before burial, and may also indicate whether some elements have been preferentially destroyed.

Checking the spatial distribution of assemblages against site phase plans may be informative.

- The location of heavily tooth-marked assemblages may identify the 'home' location of dogs, or the 'safe' hideaway of rats. In either case, bones may have been moved from their original place of surface deposition.

- Assemblages with variable colour and perhaps old dry-bone fractures may be associated with areas of pit digging where reworking of material is likely.

The relative frequency of taxa and skeletal elements within the assemblages should be tested for taphonomic impacts before reaching any conclusions about carcass utilisation by people.

- Is the relative frequency of taxa or elements clearly correlated with bone robustness? For example, are elements with a high proportion of cancellous bone (such as proximal tibiae) scarce, while those with mostly thick compact bone (such as distal tibiae) abundant?
- Is the relative frequency of elements clearly correlated with the distribution of tooth marks? For example, if vertebrae appear to be underrepresented and the few surviving vertebrae show a lot of tooth marks, the underrepresentation may represent scavenger attrition rather than human utilisation.
- Do loose teeth make up a high proportion of an assemblage? If teeth are more than *c* 25% of the identifiable specimens, without associated predominance of cranial bones and mandibles, appreciable taphonomic loss of bones should be suspected.

Trajectory	Stages and potential processes		Example evidence recorded
	Sullegic stage	Recent breakage	Often irregular, non-spiral, fracture surface distinctly paler than adjacent bone
		Loss following breakage during excavation	Few specimens conjoin at fresh breaks, few teeth retained in mandibles and maxillae
		Size-biased collection (*see* pp 15–25)	Few fragments other than teeth <50mm length
		Anatomically biased collection (*see* pp15–25)	Few rib and shaft fragments
	Diagenetic stage	Consistency of colour across assemblage	Colour (hue and intensity) consistent
		Presence of characteristic secondary minerals	Minerals (eg pyrite, vivianite and calcite) present
		Breakage through settlement and compression, especially in stony sediments	Dry-bone breaks
		Differential preservation of enamel and dentine, mature and immature bones, in low pH environment	Destruction of enamel and scarcity of young bones and teeth
	Biostratinomic stage	Butchery processes (pp 53–55)	Butchery marks
		Bone working (pp 53–55)	Saw cuts
		Consumption (tooth marks)	Tooth marks (consider diameter and depth, single bite or repeated, superficial or destructive)
		Consumption (digestion; *see* Table 4.3)	Digestion (fragment edges smoothed and/or tapering, surfaces often with shallow, smooth-edged pits, fragments tend to fusiform shape)
		Fresh-bone fractures	Spiral fractures (consider any assocaition with butchery or tooth marks)
		Burning (*see* pp 20–21), implicated practice (cooking, refuse fire, etc) and fire intensity	Colour (black, blue-grey, nearly white), frequency and location of burning
		Associated bone groups (ABGs) (*see* p 18)	Deposition of whole/part carcasses
		Deposition of freshly broken/butchered material	Fragments conjoining across spiral fractures
		Subaerial weathering, showing exposure at the surface before burial	Longitudinal cracking and flaking reflecting underlying bone morphology, often only on one surface of the bone

Fig 4.4
Taphonomic stages and evidence.

Fragmentation of the assemblage may be quantified by estimating the proportion of fragments in different size classes, or in classes defined by the percentage or fraction of complete elements. For example, we might contrast an assemblage in which 55% of specimens are <25% complete with one in which 55% are >50% complete. However, as will be clear by now, it is essential to distinguish fragmentation consequent upon cultural, biostratinomic processes from fragmentation during the diagenetic stage and 'excavation damage' in the sullegic stage. Generalised analysis of 'fragmentation' without those distinctions will be uninformative at best.

Taxonomic identification

Levels of identification

Zooarchaeological taxonomic identification groups skeletal remains into hierarchical categories based on, but not restricted to, Linnaean classification. This is usually based on morphology, but biometry (pp 48–50), biochemical and histological analyses may also be used. Identifications are made within a reasonable expectation of the faunal spectra for a particular region and timescale (*see* Fig 1.2). Specialist expertise and judgement is required, informed by comparative assemblages (*see* Supplement 1).

The most specific identification possible is usually to species. In its biological definition, this is a group of animals capable of breeding to produce fertile offspring, for example domestic goat. Often particular bone morphologies are shared by more than one species, in which case specimens may only be identifiable to genus (eg Capra; goats and ibexes), family (eg Bovidae; goats, sheep, cattle, etc), order (eg Artiodactyla; even-toed ungulates) or a non-Linnaean category (eg sheep/goat, goat-sized mammal). For this reason, the term 'taxon' (plural taxa) is often more appropriate than 'species'. Identification to a broader taxonomic group is also appropriate where diagnostic characteristics are not present, for example for particular skeletal elements (commonly ribs and vertebrae) or because of fragmentation. Decisions on recording levels should be documented in the methods (*see* p 33) and metadata (p 55). Less certain taxonomic identification may be distinguished through the use of the prefix 'cf' (compare with).

Within a species, a breed (eg bagot goat; Fig 4.5) is a classification based on characteristics such as conformation, size, coat characteristics, ancestry, etc. As these characteristics cannot often be recognised in bones, and the criteria denoting breeds may be fluid over time, the term is not relevant to most archaeological assemblages and its use should be avoided in identification. Where more than one shape of animal within a species is recognised archaeologically (eg through biometry; pp 48–50) these are best referred to using terms such as 'forms', 'types' and 'varieties'.

While common names for animals are often used in reports, to meet international standards in science reporting they should be accompanied by the scientific name (Latin binomial; *see* Appendix 1). Unlike common names, the scien-

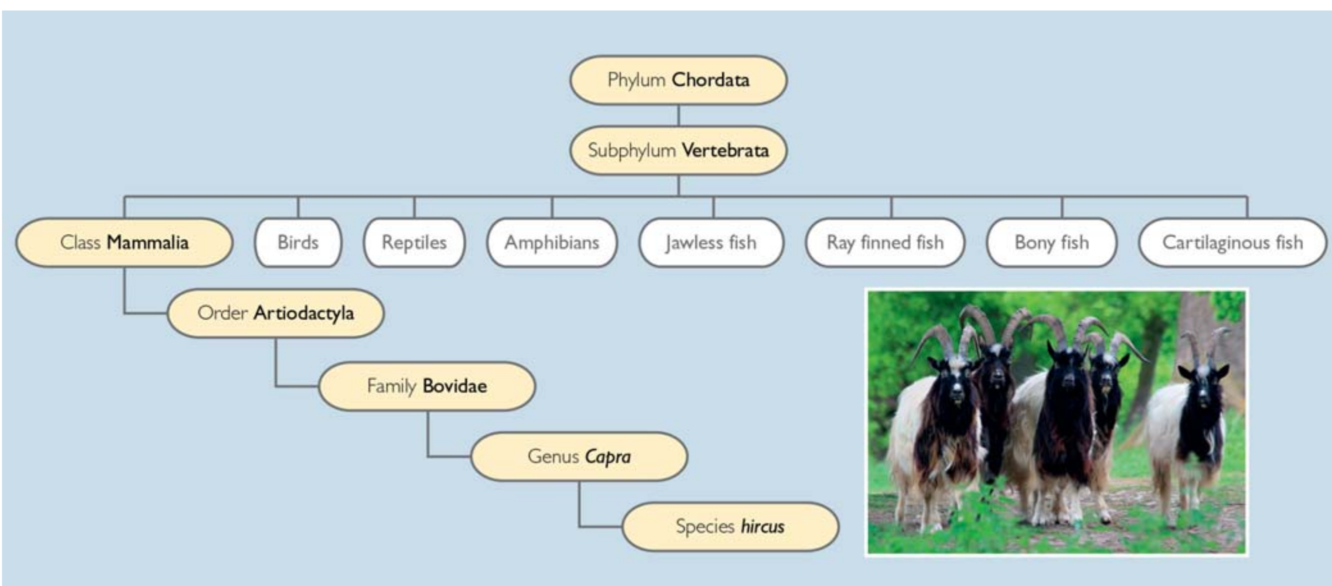


Fig 4.5
Summary Linnean taxonomy of domestic goat (Capra hircus). [Image F Worley; photo (bagot goat) Rare Breed Goats UK]

tific name is internationally recognised, unique to that species, and imparts precise biological characteristics. Use of scientific names prevents confusion, particularly when work is translated into different languages. Scientific names must be correctly italicised and capitalised (Reitz and Wing 1999, 35, 37).

Using reference resources

The fundamental basis of archaeological animal bone identification is comparison with specimens of known biological origin (element, species, age and sex; Fig 4.6). Identifications should be made with reference to expert knowledge of morphological variation within and between taxa, based on comparison with skeletal reference material, and in conjunction with published studies of reliable distinguishing characteristics.

Printed and digital manuals (*see* Supplement 1) can assist identification by presenting images of typical examples of the major bones of commonly encountered species, often highlighting the most significant differences between them. However, they have limitations compared with skeletal reference material:

- usually only a few common species are represented, inviting misidentification of more unusual taxa without due care;
- often only the major bones are illustrated, excluding some areas of the skeleton;
- bones are morphologically varied depending on factors including age, sex, life history, environment, etc;
- manuals provide limited views of each bone that may not detail aspects of interest.

The development of online virtual reference collections (*see* Supplement 1) has begun to address the limitations of two-dimensional images, through rotatable three-dimensional models. These sometimes offer virtual illumination to enhance topographical features.

Identification to taxon can depend on subtle variations in diagnostic criteria, which must be distinguished from the range of normal variation. Some commonly encountered groups of animals are particularly difficult to identify to species, including caprines (sheep and goats; these are often referred to as ovicaprines or sheep/goat), galliforms (chickens, pheasants and related species), anatins (ducks), cervids (red and fallow deer) and equids (horses, donkeys and mules). There are several published guides to aid species distinction (*see* Supplement 1). When used, these must be cited in the methods, ideally with the criteria applied and level of certainty recorded for each decision, to allow verification and comparison between datasets.

Comparative reference collections

Reference collections are subject to legislation, particularly concerning protected species and fallen livestock. Current government guidance should be sought by all who curate a collection.

The species representation in a reference collection should include those likely to be recovered archaeologically, including extinct species, and modern introductions, which may

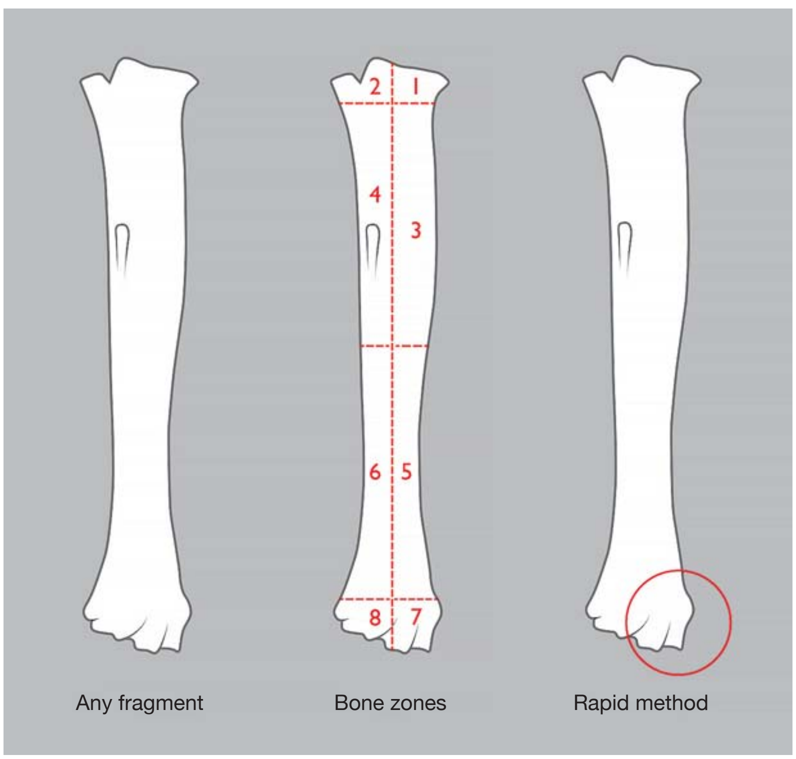
Fig 4.6
Reference collections of modern comparative material can be presented as disarticulated individual skeletons (1) or as an index collection of the same bones across species (2). Empty compartments are included in index collections to highlight additional species that should be considered. [Photos P Baker]

be intrusive in archaeological layers. The majority of archaeological animal bones from Britain are domestic species; these animals are therefore essential components of a reference collection. Wild fauna should also be represented and considered in identifications if relevant (eg deer and aurochs).

To allow observation and assessment of intraspecies variation, reference collections must aim to include individuals of varying skeletal maturity and sex (pp 46–48). Ideally, a collection should contain several individuals within each subset, particularly for species exhibiting the greatest degree of morphological or size variation. It is inadvisable to use archaeological bones as reference material as their identity and life history are usually unverifiable.

To enable ease of use and prevent degradation of a reference collection, it must include labelled (*see* p 24 for labelling bones) and disarticulated specimens, housed in an appropriate environment. Reference collections are costly to acquire and maintain, and few are comprehensive. It is therefore important that specialists consult appropriate reference collections to identify ambiguous specimens. Such collections are held at organisations including museums, universities and public bodies (eg Historic England); each may have restrictions on access and may charge a bench fee, particularly for commercial use, which should be anticipated in project planning.

Fig 4.7
A schematic representation of recording methods. Left: any fragment from any part of the bone is recorded. Centre: a fragment is recorded if >50% of any defined zone is present. Right: a fragment is recorded if >50% of only a single specific region of a bone is present.
[Image P Baker and J Vallender; bone diagram and numbered zones adapted from Serjeantson 1996]



Destructive identification techniques

Taxonomic identification can also be achieved through destructive histological or chemical analyses, such as protein analysis and ancient DNA (aDNA) analysis. Chemical or histological identification is dependent on suitable preservation, will require specialist advice and facilities, and may incur cost, which should be identified through assessment.

Destructive techniques should only be applied where the value of the resultant information outweighs the loss of the material, and after standard recording (*see* Table 3.5). Further information on destructive techniques can be found in Mays *et al* (2013).

Recording fragments and quantifying abundance

Recording systems

The selection of a recording system will depend on the nature of the assemblage and the research questions of the project. Methods should be clearly stated. While some practitioners adopt a minimalist approach to recording bone fragments, others are all inclusive or may have developed a middle-ground strategy. For example, many fragments may be identifiable to taxon but a specialist may follow a selective system, recording only a suite of elements (eg Davis 1992) and/or those that meet certain criteria (eg Serjeantson 1996; Fig 4.7). These may be referred to as 'countable' fragments. Such systems will speed up the recording by targeting certain evidence, for example species, age and biometry, but can impact some types of analyses that require a more comprehensive dataset (eg some taphonomy, butchery and pathology studies).

Archaeological bone assemblages usually comprise fragmented rather than complete elements. For this reason, recording systems must include a record of the part of the bone represented by each countable fragment. The use of published zone systems (eg Fig 4.7; *see* Supplement 1) allows comparison within and between assemblages recorded in a similar manner. They can assist in further quantification of abundance (p 45) and description of characteristics (eg location of butchery marks).

Introduction to quantification

Quantification of taxonomic and skeletal part abundance is fundamental to the investigation of the appearance and spread of animals, and their use in diet, economies, trade and social activities.

There are many methods of quantifying abundance, each with strengths and inherent weaknesses, and it is often recommended that more than one approach is used to allow a balanced consideration of the data (eg High Post, Case Study 1). The methods adopted should be appropriate to the questions asked, with concepts of validity (eg whether the technique measures the required data), reliability (replicability of the measurement) and accuracy (the 'nearness' of a measurement to the target population) being central to the choice of approach (Lyman 2008, 11–13). Compatibility with quantifications used in any comparative data should also be considered.

Approaches to quantification

When selecting a quantification method, it is useful to distinguish between primary (also called raw or fundamental) and secondary (or derived) data.

Primary data

Primary data are observable and measurable properties, for example fragment counts or weight. Fragment counts yield a raw count of specimens identified to a pre-determined taxonomic level (pp 42–44), most commonly referred to as the number of identified specimens (NISP). The strength of fragment counts is that, when the method is clear, NISP data can be directly combined and compared. However, a fragment count is influenced by a number of factors:

- inclusive/exclusive recording methods (*see* p 44);
- differential anatomy between or within taxa (eg number of foot bones, immature and mature skeletons);
- intensity of fragmentation (taphonomy, including butchery method and differential preservation);
- fragment interdependence (many fragments may derive from the same bone or animal, eg animal bone groups).

Bone weight (mass) is a replicable measure that, in combination with NISP, can inform about fragmentation by taxon. In some situations, for example deposits of highly fragmented burnt bones, weight may be the most useful quantification. Weight is influenced by individual life history, preservation (including mineralisation) and cleaning (removal of soil). Some studies have shown that there is a broad correlation between fragment count and weight (Lyman 2008, 102–3). Given that bone fragments are usually recorded individually (*see* pp 29–30) making NISP data integral to the record, weight may be a superfluous measure in many assemblages.

Derived data

Secondary data are derived through mathematical manipulation of primary data, for example estimates of the minimum number of individuals (MNI) or elements (MNE). The calculation of MNI or MNE is used to interpret the original number of animals or skeletal elements represented in an assemblage. MNI implies the presence of whole animals. Minimum numbers are derived from raw fragment counts, taking into consideration skeletal element, element part and side, with additional variables such as age, sex and size sometimes considered. Use of minimum numbers circumvents problems of differential anatomy and fragment inter-dependence. However, their serious limitation is that very different counts may be produced depending on the level of aggregation, ie whether estimates are calculated by context, area, phase or entire sites (Fig 4.8). The use of different approaches means that counts may not be comparable between datasets.

Derived quantifications can also include estimates of biomass (such as meat weight and meat utility), used to indicate resource availability (eg meat, marrow, grease and hides). Biomass may be calculated based on NISP, MNE, MNI, weight (and regression analysis) and bone size (and allometry), using conversion factors (eg total carcass or usable meat weight). It is influenced by a number of factors, including age, sex, breed, health and seasonality, which are difficult or impossible to determine for most fragments. Depending on the recording method, the use of a count or weight of identified specimens may ignore high meat-yielding elements, for example vertebrae and ribs. Biomass estimations are only comparable when based on the same method.

Selecting quantification methods

Quantification methods should target research questions. Some issues to keep in mind when

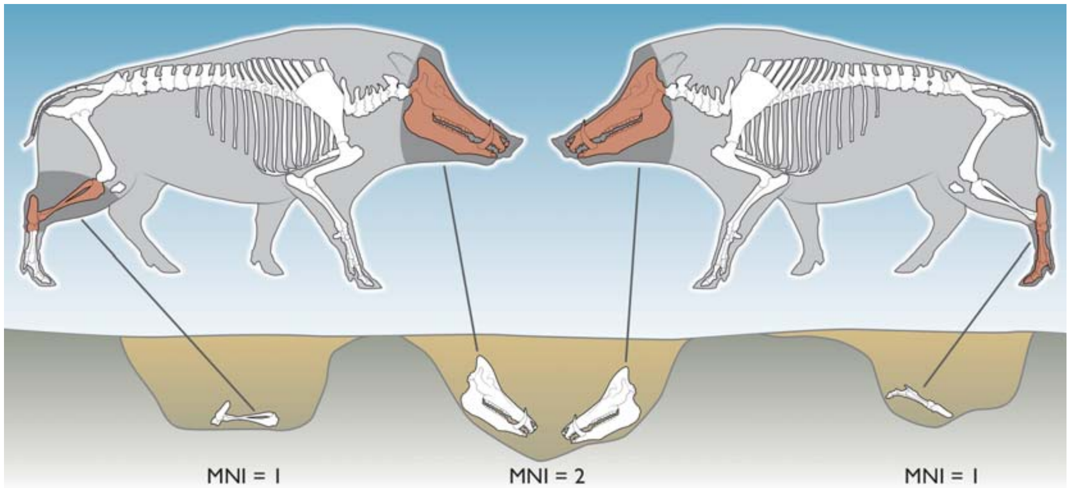


Fig 4.8
Calculating minimum number of individuals (MNI). MNI estimates are influenced by how assemblage data are grouped (eg by feature, phase or area). In this example, MNI is estimated for each pit and summing these data would provide an inflated total MNI of 4. [Image J Vallender; derived from O'Connor 2000, fig 6.2; boar skeleton illustration by M Coutureau (Inrap), © 2003 ArcheoZoo.org]

selecting methods and interpreting abundance data include the following:

Assemblage characteristics:
- site type (consumer or producer site);
- provenance (context type can have a substantial influence on what was originally deposited and what survived);
- assemblage size and taphonomy (preservation and recovery).

Cultural behaviour:
- dietary norms (edibility of animals and animal parts);
- carcass processing (tradition and technology);
- depositional practices and use of space.

Methodological considerations:
- specialist skill in identification;
- recording and quantification methods used in comparative datasets.

Publishing quantification data and methods

It is best practice to publish tables of primary data, particularly where derived data are calculated. Quantification methods (primary data and derived data) must be explicitly described, to allow reuse of data and method.

Age and sex data

Information potential

Mortality profiles (age at death) and sex data/ratios can inform on the economic and symbolic roles of animals. Where present in sufficient quantities, age and sex data can be used to identify husbandry, animal use and site provisioning, seasonality, hunting strategies, the type of meat consumed and social behaviour (*see* pp 2–5).

Principles

The size, shape, structure and/or composition of teeth and bones change as animals mature. Teeth also erupt, become worn and are lost during life. Modern studies (baseline data) have shown that these changes occur within a relatively consistent sequence and timeframe, allowing estimation of age at death of archaeological specimens, from which mortality or kill-off profiles can be constructed (Fig 4.9).

Age at death estimation uses species-specific baseline data. However, it must take into account that
- most of the baseline data for domestic species derive from modern animals, which develop more quickly than 'primitive' breeds (and thus probably archaeological animals), so they must be used as relative markers and recognised as estimated chronological ages;
- some variation in sequence and duration exists between baseline data sources, depending on the method of examination (eg X-radiography, direct visual assessment of skeletons or live animals) and recording;
- timing of maturation is influenced by sex, and can be influenced by environment, diet, husbandry and health.

For these reasons, it is essential to reference the sources of baseline data applied in an analysis, and to consider their influence in any comparative analysis.

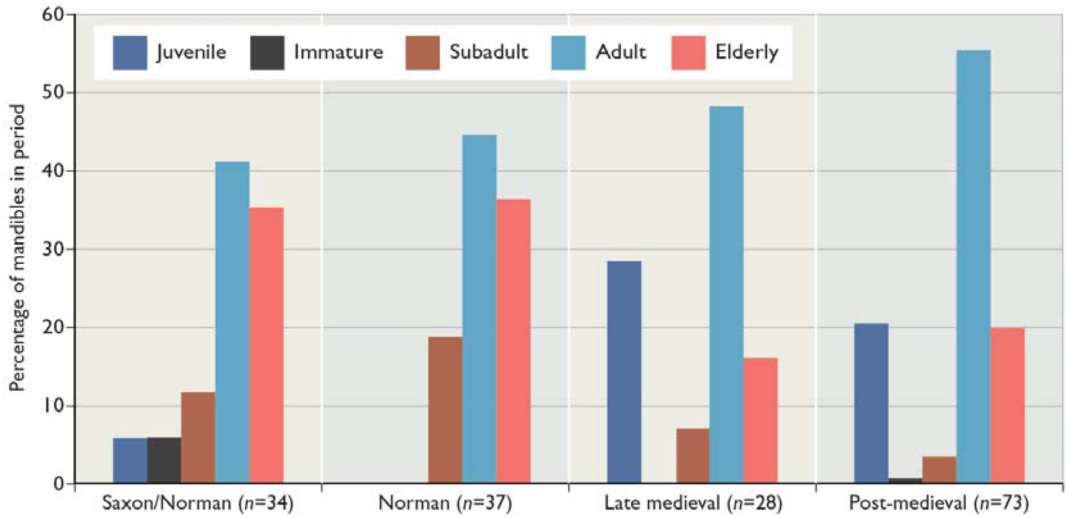


Fig 4.9
A cattle mortality profile showing an increase in culling of calves from the late medieval period onwards; this reflects a change in husbandry towards meat, and in particular veal production. [Data from Albarella *et al* 1997, table 15; mandibular tooth wear stages following O'Connor 1988]

Common methods of ageing teeth

Analysis of mandibular tooth eruption and attrition are common ageing methods for domestic mammals. Following sequential eruption, teeth become progressively more worn, and distinctive wear patterns are formed by the enamel folds and dentine. The rate of wear is variable and dependent on a number of factors including sex, diet and environment (soil ingestion). In very old animals, wear may obliterate all signs of enamel and reduce teeth to the roots.

The eruption and wear of individual teeth is used to derive the wear stage or age of mandibles following multiple schemas (*see* Supplement 1); equivalencies between conventions are required to compare assemblages (eg Hambleton 1999, 64–67). In sheep, isolated teeth may also be assigned to age categories based on their wear (Payne 1988).

Less common methods of ageing include crown height, which in Britain is primarily used for equid teeth, cementum increments (annual growth rings) and tooth crown and root development. Cementum can indicate an accurate age and possible season of death, but is destructive, time-consuming and expensive. Crown and root development can be used to identify the age of young animals. Where teeth are secured in complete jaws, tooth roots and developing crowns may be examined through either X-radiography or deliberate breakage of the bones. These methods have time and equipment costs.

Common methods of ageing bones

In foetal/perinatal animals, ossification of bone is largely incomplete and bone shape is ill-defined. Foetal bones are difficult to identify to species, even with the aid of guides (*see* Supplement 1) and reference material. Nonetheless, their presence is important for identifying on-site husbandry and animal management, and seasonality of occupation. Because of their small size, perinatal bones are generally recovered through sieving.

Some skeletal elements are formed from several parts, which fuse in sequence, allowing estimation of age at death (Fig 4.10). The timing and duration of fusion events can vary substantially with species, sex, diet, environmental conditions, castration and breeding (eg Popkin *et al* 2012). Fusion can only be used to assign restricted age ranges in younger animals as it is predominantly complete by early adulthood.

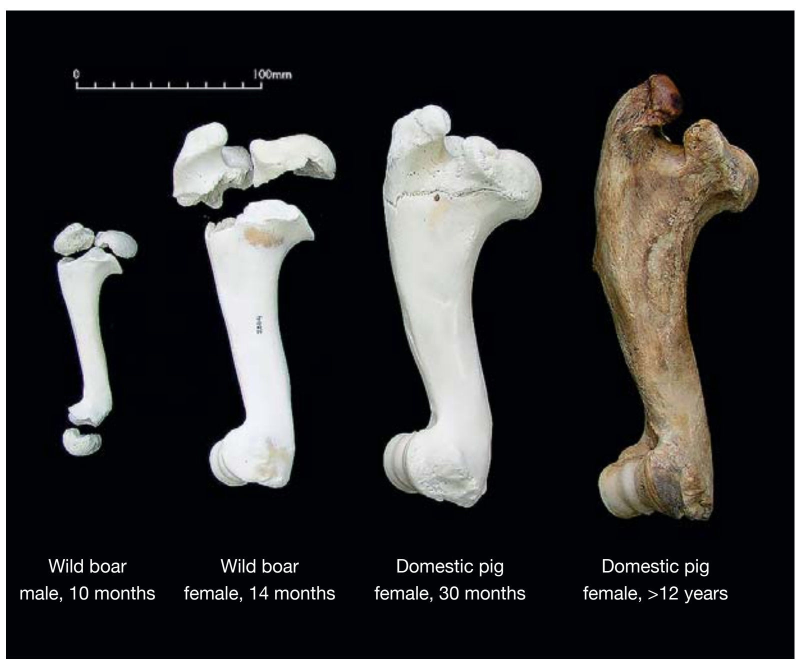


Fig 4.10
Pig and wild boar humeri showing the sequence of bone fusion.
[Photo P Baker]

Growth rings and bone microstructure have been shown to vary with age (Dammers 2006). Their use as an ageing method is complicated by variation with sex, taxon and preservation. Histological analysis is destructive and incurs cost.

Sexing animal bones and teeth

Male and female skeletons are often dissimilar and can be separated. In some cases, castration can blur the distinction between males and females, allowing recognition of castrates but complicating sex identification (Popkin *et al* 2012). Given a sufficiently large sample size, it may be possible to quantify the prevalence of sexual traits:

Skeletal characteristics that may differ include:

- element morphology (eg pelves, canines and horn cores);
- the presence of discrete elements or features (eg baculae and medullary bone);
- osteometric variation (*see* p 49).

Impact of recovery

Interpretation of sex or age ratios should take into account taphonomic biases. Very young bones and teeth are more susceptible to damage and loss than adult specimens (pp 39–42). Many of these, together with some small sexually diagnostic elements, are susceptible to recovery bias, for example foetal bones, small deciduous teeth, unfused epiphyses and baculae are predominantly recovered through sieved samples (*see* pp 15–25; *see* Fig 3.2).

Excavation of fragile or fragmented elements (eg mandibles with teeth and associated unfused bones) should retain their association in order to permit age at death and sex estimation of individual specimens (eg mandible wear stage and sex) and minimise double counting in derived profiles (eg fusion groups and male/female ratios). Like animal bone groups (ABGs; *see* p 18), recognising associated unfused bones in the field informs on deposit formation processes (ie lack of disturbance) and thus facilitates the selection of radiocarbon samples (*see* pp 22–23).

Publishing age at death and sex data

It is good practice to publish raw data along with any derived age estimates (eg fusion groups and mandibular wear stages) and sex ratios, to allow comparative analysis. It is also essential to reference methods and diagnostic criteria, including definitions of individual states (eg ‘fusing’ and ‘erupting’) and age categories (eg ‘subadult’ and ‘early fusing’) to avoid ambiguity.

Metrical recording and analysis (A Hammon)

A range of factors can influence size and shape: species, breed, sex, age of the individual, nutritional status and pathology. For the majority of assemblages most specimens are too fragmented to provide measurements. Careful consideration must be given to which measurements are recorded and analysed, taking into account project aims and objectives, wider research questions and the peculiarities of individual assemblages.

Information potential

Animal size and shape can inform on the following.

- Species identification. The metrical separation of species may confirm or supplement morphological criteria (*see* Supplement 1).
- Domestication. The process(es) of domestication often led to a decrease in size of the species involved, for instance Neolithic cattle are generally smaller than aurochs, their wild relation.
- Climate change and environmental conditions. Individuals from the same species are generally larger in colder climates because of the necessity to conserve rather than dissipate heat: the Bergmann effect (Davis 1987, 68–72). Changes in habitat may affect species size; in Britain, red deer have decreased in size through the Holocene, as a result of progressive deforestation (Staines 1991, 497; Yalden 1999, 104–5).
- Breed development. Certain traits have been encouraged through selective breeding (eg larger and more robust individuals to increase meat yields). Selective breeding is evident during the early Roman period in southern Britain (Albarella *et al* 2008; Hammon 2008, 89–92; Fig 4.11) and the Agricultural Revolution (Albarella and Davis 1996; Thomas 2005; Thomas *et al* 2013), whereas other periods show no change in animal size (Hammon 2011). Noticeably large bones may also denote

animals imported to breed with indigenous stock (Albarella *et al* 2008; Fig 4.11).

- Sex profiles. Metrical data often demonstrate a bimodal distribution in sexually dimorphic species, commonly interpreted as representing males and females. Measurement ratios may also show male and female distributions, for example in cattle metacarpals (Howard 1963). Although the presence of different populations and castrated males complicates the picture, the method's validity has recently been confirmed with aDNA (Davis *et al* 2012; Telldahl *et al* 2012).
- Over-hunting. In certain circumstances over-hunting may lead to a size decrease in a population (eg Coltman *et al* 2003; Magnell 2004).

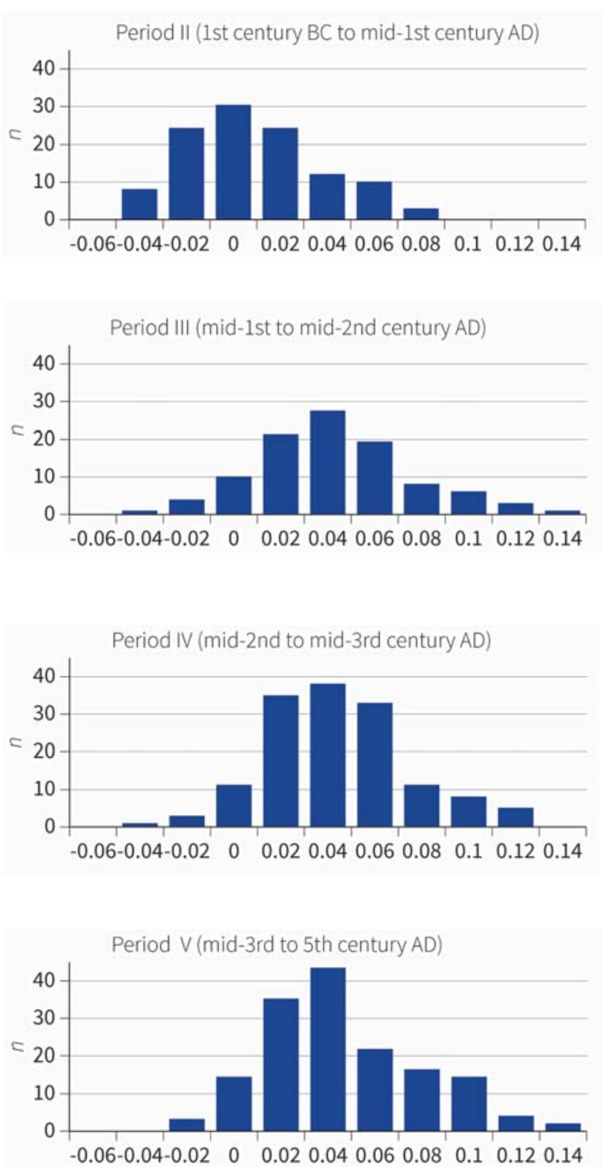


Fig 4.11
Comparison of cattle size by phase at Elms Farm (Essex), using the log-ratio technique for width measurements. [Adapted from Johnstone and Albarella 2002, fig 39]

Measurement methods

Measurements should be recorded to a precision of 0.1mm. Most measurements are taken using vernier-style callipers or an osteometric measuring box for larger specimens. The latter method is not as accurate as using callipers, although the percentage error may not be significant on larger measurements. Non-linear (eg circumference) measurements must not be taken using elastic material.

Measurements must be recorded in a consistent manner to minimise intra- and inter-observer error, and enable comparative analysis. Various conventions have been published to facilitate this (*see* Supplement 1), the mostly widely used being von den Driesch (1976).

Which specimens should be measured?

Generally, only skeletally mature specimens (ie those that have fully fused or ossified) should be measured. Measurements of skeletally immature bones may be recorded (eg to estimate age at death of particular specimens) and should be clearly denoted in raw data. To ensure accuracy, measurement anchor points should not be abraded. Only if noteworthy should degraded specimens be measured (and indicated as approximate measurements). Measurement conventions should allow comparison with other datasets, and thus the specialist should be familiar with developing methods (*see* select conventions in Supplement 1).

Analysis of biometric data

Given sufficient data, individual measurements may be plotted on bar charts or histograms to allow identification of population characteristics. Assuming a size overlap exists between the sexes of a species, an even distribution might indicate an equal ratio of males and females, whereas a skewed distribution might denote the predominance of one sex over the other. An even distribution with a few large outliers might suggest the presence of imported stock (Fig 4.12) and a bimodal distribution could infer the presence of two different populations of a single species. It is important to consider the possible effect of pooling measurements from closely related species (eg it is normal practice to combine sheep and sheep/goat measurements where goats are not identified in an assemblage), which

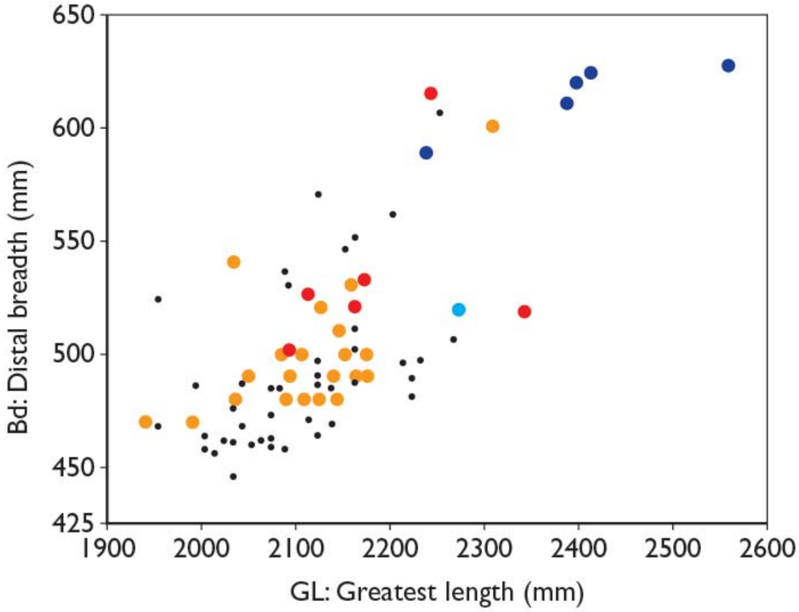


Fig 4.12
Scatter diagram showing cattle breed development and variation during the Roman period, as illustrated by the shape: greatest length compared with distal breadth of metatarsals.
[Adapted from Albarella 1997, fig 5]

creates larger datasets but may skew results. Scatter diagrams of two measurements from the same skeletal element (bivariate analysis) creates a shape index that can also be used to infer sex and/or population (Fig 4.12).

The log-ratio technique combines measurements from different elements (but taken in the same axis, eg post-cranial length, depth or breadth measurements) to form larger datasets (Davis 1996; Simpson *et al* 1960, 356–8). This method calculates the logarithm of the ratio between a measurement and its standard. There are only a few published standards (eg Albarella and Payne 2005; Davis 1996). Many researchers choose their own standard from the material under study, for example selecting measurements from a particular phase to allow direct comparison with the remainder of the assemblage (eg Fig 4.11; London, Case Study 8).

Publishing results

Selected biometrical data should be presented in the text of unpublished and published reports using a combination of figures (diagrams and graphs) and tables. Where summary biometrical data are presented, they should include the number of cases, minimum value, maximum value, mean, standard deviation and occasionally the coefficient of variation. Raw data, ie measurements from individual specimens, should be available to allow other researchers to conduct inter-site analyses and syntheses.

Archiving measurements

Raw measurement data must be deposited along with the project archive (*see* pp 33–37). Animal bone regional reviews (*see* p 87) summarise trends in biometric data and can be used as a starting point for identifying archived datasets. Animal bone measurements are increasingly being made available online, in individual project datasets (eg the Danebury Environ Roman Programme sites; University of Oxford 2008) and combined metric archives (eg University of Southampton 2003; *see* Supplement 1). Contributing metric data to national datasets should be considered in project planning.

Recording pathology
(R Thomas and F Worley)

Information potential

The goal of animal palaeopathology is to explore the relationships that exist between environment, human behaviour and disease and injury in animals. Studies of pathology can shed light on themes such as hunting practices, domestication and the intensification of animal husbandry, animal management, zoonotic disease and attitudes to animals. Palaeopathological investigations can operate at different scales of analysis, from reconstructing the biography of individual animals (eg Fabiš 2005) to exploring the health consequences of environmental change (eg Van Valkenburgh 2009).

Pathologies likely to be encountered

Many disease processes will not affect bones and will be invisible to zooarchaeologists. There are, however, four broad classes of pathology that are regularly encountered in archaeological material: injury (trauma); joint disease; infection and inflammation; and metabolic disturbances. Tumours (neoplasia) and birth defects can also affect the skeleton, but these are less frequently observed. The areas of the body commonly affected are the mouth and extremities. A selection of specific disorders that can be recognised in each of these broad groups, along with the interpretative potential, are summarised in Table 4.1; examples of pathologies are shown in Fig 4.13.

Approaches to recording

The study of skeletal pathology begins with the identification and analysis of visible alterations to bone (ie gross lesions), although particular conditions may be investigated further using specialist techniques, including radiography, microscopy and aDNA analysis.

Generic guidance on recording animal pathology is provided by Vann and Thomas (2006) and O'Connor (2000, 108–110); specific methods have been developed for some lesions (*see* Supplement 1). Systematic recording and reporting of pathologies is essential for three reasons:

- to draw attention to pathologies that are absent, as well as those that are present;
- to highlight the full range of lesion manifestations, not just the spectacular cases;
- to allow the calculation of lesion prevalence, which in turn facilitates intra- and inter-site comparisons and the identification of spatial and temporal trends.

All lesions should be described before they are diagnosed. All bone pathologies are formed by a combination of bone formation and bone destruction; consequently, it is possible for different conditions to produce similar lesions. Furthermore, there are many lesions that are not presently diagnosable, but a detailed, accurate description can permit future interpretation. Key variables to be recorded include:

- precise anatomical location;
- size and shape of lesion;
- nature and appearance of bone formation and/or destruction.

Wherever possible, precise descriptive terminology should be employed. Annotated illustrations (photographs, radiographs and line drawings) are helpful in supporting written descriptions.

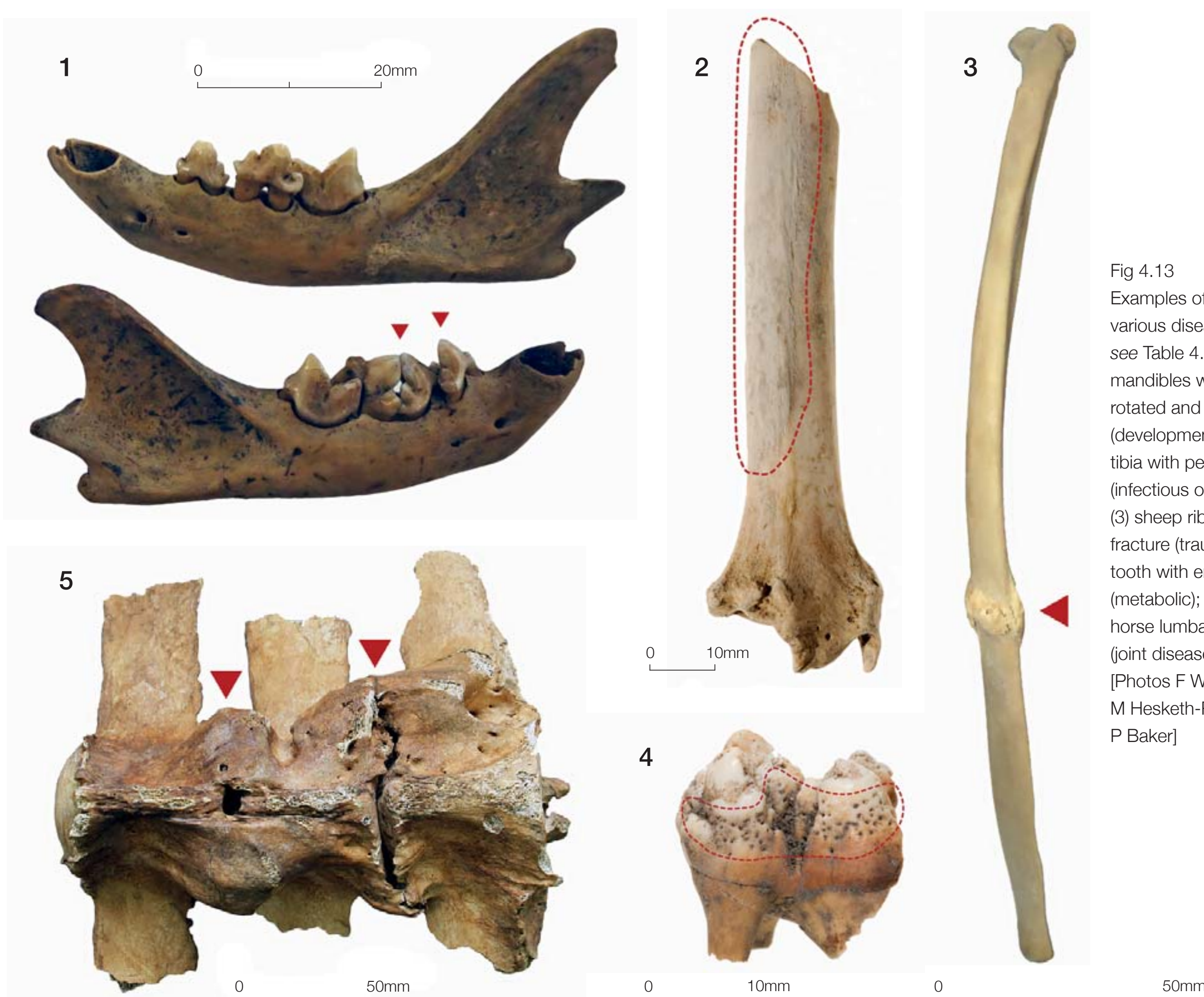


Fig 4.13
Examples of pathologies in various disease categories, *see* Table 4.1. (1) Cat mandibles with impacted, rotated and repeated teeth (developmental); (2) sheep tibia with periostosis (infectious or inflammatory); (3) sheep rib with healed fracture (traumatic); (4) pig tooth with enamel hypoplasia (metabolic); (5) ankylosed horse lumbar vertebrae (joint disease).
[Photos F Worley, I Leonard, M Hesketh-Roberts, G Ayton, P Baker]

Table 4.1
Categories of disease, example conditions and their interpretative potential.

Disease category	Example conditions	Interpretive potential
Trauma	Fracture Dislocation Haematoma Bit wear Incisional wound	Human-induced (eg through slaughtering, hunting, polling, non-accidental injury, aggressive handling, surgical intervention and management practices) Inter- and intra-species interactions (eg mating fights and predation) Accidental Pathological (ie secondary fractures of bone following primary pathological changes in the skeleton, such as neoplasia or osteoporosis)
Joint disease	Non-specific arthropathy (osteophytosis, lipping/ broadening of articular surfaces) Osteoarthritis Spavin (osteoarthritis and ankylosis of the tarsals) Navicular bone disease (horse) Infectious arthritis Articular osteochondrosis Spondylosis Ankylosing spondylitis	Age-related degeneration (influenced by sex, body mass and inherited predisposition) Activity and husbandry (eg riding, traction, shoeing, housing and surfaces) Foot conformation Localised trauma
Metabolic bone disease	Rickets Osteomalacia Osteoporosis Growth disturbances (eg enamel hypoplasia and lines of arrested growth) Toxicosis	Feeding and managing animals (eg starvation and malnutrition; confinement and weaning) Physiological (ie related to age or hormonal cycles) Heavy metal poisoning Environmental stress and change
Infection and inflammation	Systemic infection (tuberculosis, brucellosis, actinomycosis) Localised bone inflammation Osteomyelitis Periostitis Periodontal disease Pododermatitis (foot rot) Avian osteopetrosis	Management and husbandry (eg density and proximity of animals, hygiene of animal husbandry and grazing) Localised trauma Disease evolution and dispersal
Developmental	Absent, supernumerary or abnormally sized bones and teeth Deviations in alignment of the spine and limbs Proportional or disproportional dwarfism Cranial perforations	Spontaneous mutation Inherited (and possibly selected) trait Presence of teratogenic agents

Diagnosing pathology

Once lesions have been described, it is possible to think about cause. Where lesions occur in disarticulated remains, it may only be possible to classify a lesion into a broad class of pathology. However, with thorough recovery of an ABG, the distribution of lesions across the skeleton can permit a more specific diagnosis. All diagnoses must be differential: all possible causes of the lesions must be excluded before a firm diagnosis can be suggested. The terminology of diagnoses should follow veterinary protocol (eg Thompson 2007).

Making sense of pathology

Key things to think about when interpreting pathology are

- lesion frequencies can vary between and within taxa (eg as a result of age, sex, body mass and inherited predisposition);
- animals will exhibit more lesions with age (including degenerative changes);
- lesions occurring early in life may no longer be visible as a result of bone remodelling;
- connecting bone lesions with symptoms is difficult and some lesions may not have affected animal behaviour or productivity;
- many observed lesions are a result of chronic illness (bones are generally not affected by diseases that cause rapid death or diseases that are overcome by the immune system);
- pathology can affect the preservation of bones, for example bone affected by osteoporosis is fragile whereas some conditions lead to more robust bone (sclerotic lesions).

Recording non-metric traits
(R Thomas and F Worley)

Historically, non-metric traits have appeared alongside pathology in animal bone reports. However, non-metric traits represent normal anatomical variation rather than a response to disease. Such traits are discontinuous, congenital or predilected at birth and may be inherited. Commonly reported non-metric traits include:

- the absence of the mandibular second premolar in cattle, sheep and some deer (Fig 4.14);
- the absence of the third cusp (hypoconulid) in the mandibular third molar in cattle, sheep and some deer (Fig 4.14);
- the position of the mental foramen;
- the position of the major nutrient foramen;
- the absence of horn cores (naturally polled) in sheep, goats and cattle.

The interpretative potential of these traits remains open. Nevertheless systematic reporting of trait expression and prevalence has the potential to provide useful information regarding gene flow and can occasionally assist in speciation (eg the position of the mental foramen in sheep and goats).

Recording butchery and bone working
(M Maltby)

Information potential

A key goal in animal bones studies is to understand how humans exploited animal carcasses, including the use of primary and derived products (eg skin, fur, meat, marrow, grease, sinews, glue, bone, horn and antler). Questions regarding the processing of each of these products can include the following.

- How consistently and intensively were carcasses of different species processed?
- Were the various processes carried out by specialists (and operating on what scale)?
- Were discrete locations selected for processing and/or deposition of resulting waste?
- What types of implements were used (eg flint scrapers, metal cleavers or saws)?
- Were the products prepared for immediate use or stored?
- Do the products represent finished items or an intermediate stage in processing?
- Were the products traded?

These aspects of carcass processing can help explore broader economic and social aspects of

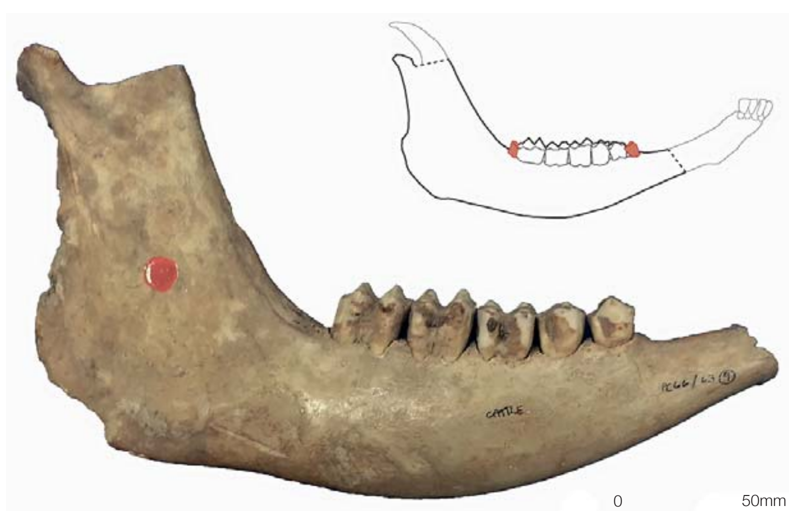


Fig 4.14
A cattle mandible with absent second premolar and third molar hypoconulid. Inset shows a mandible with a standard tooth row.
[Photo R Thomas; illustration adapted from Pales and Garcia 1981, fig 22]

Fig 4.15
Butchered scapulae.
(1) Roman cattle scapulae from Elms Farm (Essex), showing characteristic 'hook damage'; (2) pig scapula from a late Neolithic context at Marden henge (Wilts) showing fine cut marks characteristic of flint tools.
[(1) Photo U Albarella, (2) photo F Worley]

human behaviour, through chronological intra- and inter-settlement variations. For example, characteristic butchery on cattle scapulae (Fig 4.15) or filleting marks on cattle long bones from Roman military or large civilian settlements probably reflects the presence of specialist butchers (Maltby 2007; Seetah 2006b). To realise its information potential, butchery and bone-working evidence must be considered in conjunction with the relative abundance of skeletal elements (pp 44–46), ABGs (*see* p 18) and taphonomic evidence (pp 39–42). Analysis of bone, horn and antler working should involve collaboration with a finds specialist.

Approaches to recording

Prior to examining bones for processing marks, it is essential that they are clean. Hand-held lenses or microscopes may be required to recognise marks.

All processing marks need to be described before they can be interpreted. However, there is no manual that provides a comprehensive guide to recording method or mark interpretation. The most comprehensive discussion and descriptions of the various stages of butchery can be found in Seetah (2006a; *see* Supplement 1). Most current methods record the following information, which should be regarded as the minimum required:

- location(s) of the mark(s) on the bone (eg joint surface, shaft, proximal, lateral or zone);
- the direction of the mark(s) on the bone (eg medio-lateral);
- the angle of the marks inflicted on the bone (eg vertical, oblique or skim);
- the nature/severity of the mark(s) (eg shallow, deep or cut through);
- implement(s) used (eg saw, large blade edge, fine blade edge, point of blade, cleaver or file).

It is also useful to note whether a particular mark lies close to where a bone has been broken and where multiple marks have been inflicted, as these may provide evidence for the sequence of processing.

Butchery marks can be recorded diagrammatically (either digitally or on prepared forms) or using a coding system to describe the location, nature and frequency of the marks. Photography is often employed to document unusual or the more common and 'classic' butchery traces. Three-dimensional imagery is potentially an effective, but less commonly used, recording method.

Interpretation and quantification

Carcass-processing records can be grouped into types of mark observed (eg cleaver marks, scoop marks, axially split bones, transversely chopped vertebrae, cut marks; Figs 4.15 and 4.18) and placed into interpretative categories (including killing, evisceration, skinning, disarticulation, meat removal, marrow removal, pot sizing, splitting, horn working, antler working and bone working). These classifications can be quantified (eg Maltby 2007; Seetah 2006a). Interpretation of frequency should recognise that some types of processing will leave more evidence than others (Dominguez-Rodrigo and Yravedra 2009) and consider the implications of taphonomy, recording and quantification methods employed (Otárola-Castillo 2010).

Recording bones of birds, fish and microfauna

The majority of British bone assemblages comprise predominantly domestic mammal bones. Consequently, many zooarchaeologists may be most familiar with larger mammals. Birds, fish and the small wild vertebrate fauna of Britain have particular zooarchaeological considerations. Their potential and methods of study are presented in Tables 4.2 and 4.3.

Compiling an animal bone inventory

Structuring data

Assemblages of animal bone can result in large and complex datasets. Collating data in a database or spreadsheet can expedite data manipulation, minimise transcription errors and omissions and, with appropriate metadata, provide an unambiguous and informative archive for future research and dissemination.

A database can speed up data entry by providing pick lists (eg fusion stages) including convention prompts (eg illustrations of tooth wear stages with citation). Programmed reporting (structured views of data) can aid interpretation, for example prevalence (such as sexed pig canines) across variables (such as phase, feature type and taxon) or derived calculations (pp 44–46).

Various and diverse systems for bone inventories are used in zooarchaeology today, a few of which are published (*see* Supplement 1). Systems may be stand-alone or incorporated into wider excavation databases, and may require adaptation to particular research questions or to facilitate divergent or developing recording methodologies. Consistency in design can allow direct comparisons across datasets, while data from different systems can be compared with reference to their metadata.

Variables and field types

Different types of bone analysis (*see* Tables 3.4 and 3.5) will have varying recording requirements (variables/attributes and field types). For example, assessment data are often recorded at a context level (*see* p 25) while analysis data are recorded in more detail and by bone fragment. When designing a data structure, it may be useful to consider the following questions:

- What types of data do your methods generate, for example text, numeric, ranked category (such as poor, moderate, good), presence/absence, image and spatial data?
- Does your design allow you to query your data appropriately and efficiently? Considerations may include the following:
  - How will you integrate phasing and contextual data into your dataset?
  - How will you quantify your data (eg will you count records or manipulate a numeric field)?
  - How will you account for ABGs and isolated teeth in quantifications?
  - How will you distinguish absence of data, lack of recording and null values (particularly for true/false data)?
- Can you implement restricted word lists (controlled vocabulary) to standardise nomenclature, avoid typographic errors and produce a simpler and more manageable dataset? Coding may be used to speed and standardise data entry, but requires transcription and thorough metadata. Supplementary free text may be required for additional notes.
- Are your naming conventions for objects (eg tables and queries) clear?

Metadata

Metadata (data about data) are crucial to enable reuse of your data, whether archived in hardcopy or digitally, and is a requirement of deposition (ADS 2015). Metadata allow others to understand what has been recorded and the recording method. It is particularly important that metadata include the purpose of each table, names and descriptions of each field included, and the relationships between tables. It is essential to cite references for any conventions used (eg criteria for species identification and measurements), and define abbreviations, codes and any in-built calculations (eg MNE or MNI). Advice on metadata for digital archives is presented in ADS (2015).

Table 4.2
Bird, fish and microfauna (herpetofauna and small mammals): evidential potential and methods.

Aspect	Herpetofauna (amphibians and reptiles) (C Gleed-Owen)	Small mammals (J Williams)
Species diversity	The extant native herpetofauna includes seven amphibian species and six reptiles. Additional species have been identified zooarchaeologically (Beebee *et al* 2005; Gleed-Owen 2000).	There are over 40 species of squirrel-size and smaller mammals present in Britain today (The Mammal Society 2012), including introduced and vagrant species. Other species, identified archaeologically, are no longer present.
Potential	Small mammals and herpetofauna are sensitive environmental indicators that can inform environmental reconstructions, but their potential for palaeoenvironmental reconstructions is complicated where assemblages are derived from predators (Table 4.3). Some species are generalists; others are restricted to certain habitat types and climates, especially the rare, introduced or extinct species. Their archaeological presence can inform understanding of biogeography.	
	Herpetofaunal remains are most useful at reflecting local environment and climate, eg juvenile amphibians indicate proximity of standing water bodies. Herpetofauna also hold information on seasonality and predators. They can have an economic significance, as a human food resource, which might be indicated by an over-representation of frog or toad limb bones (eg Gleed-Owen 2006). They also give insights into biogeography and modern conservation issues.	Some small mammal species are habitat-specific, but many Holocene species tend to live in a broad range of environments, so provide less detailed palaeoclimatic or environmental information. Small mammals can also provide information on the use and abandonment of sites.
Identification: taxa and element (including recording method) (pp 42–44)	The anuran (frog and toad) skeleton is dominated by the limbs and cranium, all of which are diagnostic. Many elements are identifiable to species, and most to genus. The newt, lizard and snake skeleton is dominated by the vertebral column, and individual vertebrae are usually diagnostic to species. Snake vertebral morphology changes through the column, and confusion is possible in the cervical region. Lizard and newt crania also have diagnostic elements. Tortoise, turtle and terrapin remains are larger than other herpetofauna; the carapace and plastron are diagnostic to species. Siding should be attempted where possible, eg limbs and girdles in anurans, jaws in lizards.	Most small mammal identification is carried out using the molar teeth of mice, voles or rats, and the mandibles of shrews. It is possible to identify some long bones to species, but molar teeth are almost always the most commonly identified element and thus used to calculate MNI (pp 44–46). Few specialists will try to identify post-cranial bones to species, and this level of detail will only pay dividends in scant assemblages or where crucial to specific research questions. In most cases siding is only relevant to calculating MNI, and therefore in most cases can be limited to teeth.
Identification: age and sex (including recording method) (pp 46–48)	Size is a good gauge of age. Maturity is reached at 3–4 years for most species. Fused epiphyses and girdles are a sign of old age in anurans. Sexing is possible in several adult anuran elements (especially humeri) and, together with age or size classification, may assist MNI calculations.	The sex of some small mammal bones may be determined, based on biometry and morphology. However, the evidential value of this information is limited.
Identification: resources required	Skeletal reference material is invaluable and recommended for all practitioners. Several published and unpublished identification keys/guides are useful for specific groups of microfauna (*see* Supplement 1).	
Quantification (pp 44–46)	In herpetofaunal assemblages, presence/absence is the most useful indicator, but relative abundance is informative in large assemblages. Anuran MNI is straightforward on recognisable axial elements (eg sacra) or sided elements (eg limbs and ilia), taking into account sex (in anuran forelimbs) and size. For snakes, the vertebrae are too numerous (and separation too esoteric) to make MNI worthwhile. Newts and lizards can be recorded by MNI but their remains are usually too scarce to make it worthwhile. In small, completely sampled features, the counting and siding of all skeletal elements can demonstrate the presence of partial or whole skeletons (Gleed-Owen 2004). NISP is theoretically proportional to MNI in all species groups, and has been demonstrated for anurans (Gleed-Owen 2006).	NISP counts are recommended for all species, for comparing relative abundance over time and between features. MNI can be worthwhile on the best preserved elements, although it is usually directly proportional to NISP. In small, completely sampled features, the counting and siding of all skeletal elements can demonstrate the presence of partial or whole skeletons.
Biometry (pp 48–50)	Shape indices can be useful in taxonomic identification of, for example, water frog (eg pool frog) versus brown frog (eg common frog) ilia (Gleed-Owen 2000).	

Birds (D Serjeantson)	Fish (R Nicholson)
Approximately 200 species of resident and migratory birds are regularly found in English archaeological deposits, although small songbirds are only rarely present in anthropogenic assemblages.	There are over 200 species of fish found in British waters, and additional species may have been imported in different periods (eg Locker 2007). Fish can be found in almost all aquatic habitats; species may vary with geographical area, water type (fresh water, salt water or estuarine), depth and quality. Most species of relevance are bony fish (Osteichthyes), as other classes of fish rarely preserve archaeologically (Wheeler and Jones 1989, 14), although a few elements of cartilaginous fish (Chondrichthyes) are commonly found, ie the bony dermal denticles from rays (especially thornback) and calcified vertebral centra.
Bird bones are rare on prehistoric sites but from the Roman period onwards they are common, with most originating from food remains. Domestic and wild bird bones are informative about foods eaten, trade links, household wealth, ritual activity, hunting technology, seasonality, feather collection, husbandry and breed development (eg across London, Caste Study 8). Bird bones from prey assemblages (eg raptor pellets) provide evidence of the local environment; they may help to identify the particular predator and from this inform on site disuse/abandonment (eg Longstone Edge, Case Study 4).	Fish remains are most common in coastal middens and on urban sites, and can reflect both human behaviour (eg fishing techniques, food preparation and consumption, trade, wealth and ritual) and the natural environment. Occasionally cultural deposits can also be found in submerged sites (eg shipwrecks; Coy *et al* 2005). Fish bones can provide information about the waters fished and the techniques and technology used in their capture. Changes in species abundance or size may indicate changes in water temperature and/or quality as a result of climate change or human action (O'Connor 1988). The bones of migratory species can provide evidence of seasonal occupation at a site, or of a change in economic focus towards seasonal fishing. Preserved fish (dried, salted, pickled or smoked) and fish products (eg garum and other fermented fish sauces) have been widely traded and their production or consumption may be identified archaeologically (Bateman and Locker 1982). Stable isotope research is helping to identify the movement of fish (Barrett *et al* 2011; Geffen *et al* 2011; Orton *et al* 2011; medieval sea fishing, Case Study 9).
Some avian families, such as ducks, waders and thrushes, include species whose skeletal elements are almost identical in shape and which overlap in size; in this case it may be impossible to identify bones beyond family level. The skeletal elements that survive best and can most reliably be identified to taxon are the coracoid, humerus and tibiotarsus, followed by the ulna, femur and carpometacarpus. Other elements either survive less well or are less easily identified. It is useful to assign elements to the categories 'certain' or 'probable', as uncertain identifications can still provide evidence for bird exploitation. Siding and the recording of bone 'zones' are recommended *(see below*).	Most skeletal elements can be identified at least to family, but the skeletal diversity within fish means that no single suite of skeletal elements can be used to identify all taxa. Bones from some taxa (eg salmonids and sea breams) may be difficult to identify to species. The most diagnostic bones in most bony fish are usually the paired jaw bones (the dentary and premaxilla) and siding should be attempted where possible. Fin elements are usually undiagnostic but the dorsal or anal fin spines of a few fish are readily identifiable, as are some dermal structures. Pharyngeal bones from wrasses and cyprinids (carp family) are robust and usually identifiable to species, but hybridisation within the cyprinids can occur (Cowx 1983). A few fish have distinctive scales, but as scales from archaeological deposits are usually fragmented, their identification is only possible with considerable experience.
Bird bones cannot be aged as securely as those of mammals because only a few have fusion points; instead, bones of immature birds are porous. Furthermore, most species are skeletally mature by the time they leave the breeding site, although there are exceptions. Maturation of galliform bones is slower than with some other groups, which means that chickens can be aged fairly closely through recording bone maturity (ossification and fusion) and length. Galliforms can be sexed from the spur on the tarsometatarsus, generally present only in males. The presence of medullary bone occurs only in female birds and only during the egg-laying period. Some avian species show sexual size dimorphism, with males generally larger than females, although raptors and owls show the reverse pattern.	Age at death and seasonality may be determined from incremental growth in otoliths, scales and some bones, but interpreting the growth patterns requires considerable experience and rings are often obscure in archaeological material. Age is also reflected in size relative to individuals of the same species; however, it is rarely possible to assign specific ages based on fish size, as growth rate is highly related to external variables such as food availability.
Access to a comprehensive reference collection is essential given the range of potential species. These are available in a few key institutions, eg the Natural History Museum and Historic England. Some resources are available to assist with identification (see Supplement 1) and a detailed overview of methods and potential is provided in Serjeantson (2009).	Identification of fish remains requires access to a comprehensive reference collection; this is particularly essential for new practitioners. Small fish bones, otoliths and scales require the use of a magnifying lens or microscope. A review of fish anatomy, bone identification and recording is given by Wheeler and Jones (1989). Useful guides for the identification of selected elements from a wide range of northern European taxa are listed in Supplement 1. Published papers are useful for specific groups of species. Digital identification guides are also available (*see* Supplement 1) but should not be used on their own.
MNE and MNI can be calculated as well as NISP, provided side and bone zones have been recorded. The distribution of the main anatomical elements can show whether wings were collected for feathers or bones for tools. They may also show how and where food was prepared or eaten.	NISP counts are most commonly used to indicate the relative abundance of taxa. Presence/absence by sample can be useful for large assemblages. MNI has limited use as vertebrae may be the most common, or only, bones present for some taxa, and are difficult to use for MNI calculations. Recording of a suite of skeletal elements and separation of vertebrae into regions of the spine is essential in order to identify processed fish or processing activities (Enghoff 1996; Locker 2000a).
Major elements should be measured following von den Driesch (1976). Additional measurement conventions have been developed (*see* Supplement 1). Analysis of size assists with taxonomic identification and may give a sex ratio in sexually dimorphic species (eg chickens). The evolution of domestic bird breeds can be established by analysis of bone morphology.	Fish size may be estimated by comparing archaeological bones to fish of known size or reconstructed more accurately by measuring selected bones or otoliths using published conventions (eg Morales and Rosenlund 1979). Seasonal exploitation can be investigated through the statistical analysis of biometrical data (Wheeler and Jones 1989).

Table 4.3
Bird, fish and microfauna (herpetofauna and small mammals): taphonomic processes, including sampling (see pp 39–42).

<table>
<tr><th>Aspect</th><th>Herpetofauna (amphibians and reptiles)
(C Gleed-Owen)</th><th>Small mammals
(J Williams)</th></tr>
<tr><td rowspan="2">Assemblage accumulation (biostratinomic stage)</td><td colspan="2">Understanding accumulation processes for microfauna is critical for accurate interpretations of past environments or establishing patterns of site use or abandonment. Did the microfauna die of natural causes, were they present on site during human occupation (ie as commensal species) or do they derive from predator or human activity?

A variety of predators (birds and mammals) feed on microfauna, either regurgitating or excreting remains that can become incorporated into archaeological deposits. If predation is the accumulation mechanism, it is useful to know which predator(s) is responsible, in order to
• gauge the likely ‘provenance radius’, ie the distance within which microfauna were predated, and therefore the environments that might be represented;
• understand prey selection biases, as the presence/absence or frequency of microfaunal species may be a function of prey selection rather than representative of the presence or abundance of any given species within the local area.</td></tr>
<tr><td>Predation is a major agent of accumulation. Digestive damage is the most recognisable taphonomic clue for predation of herpetofauna. It presents as longitudinal reduction of long bones, rounding of corners, general thinning, and exposure of cancellous bone at articulations.

In reptiles, whose most numerous bones are vertebrae, predation is usually reflected by digestive damage. In amphibian bones additional evidence for predation includes crushing, splintering, predator tooth marks (reptilian or mammalian) and other breakage (Fig 4.16). Clean breaks can be predatory or post-mortem, but crushing and splintering inflicted at death are distinct. Complete absence of digestive damage and breakage is a reliable indicator of natural death through pitfall, etc.</td><td>Predator activity can be determined from bone breakage and the digestion of teeth (Fig 4.17) and the (epiphyseal) ends of long bones (Andrews 1990). However, absence of predatory damage does not necessarily indicate a natural death assemblage. Prey remains from one of the most common small mammal predators, the barn owl, very rarely exhibit signs of digestion (although it is more pronounced in nest deposits; Williams 2001). For archaeological sites with only a limited number of small mammal bones, it can therefore be difficult to differentiate between barn owl-accumulated material and natural deaths.</td></tr>
<tr><td>Diagenetic taphonomy (diagenetic stage)</td><td>Cranial and post-cranial remains preserve equally well in anurans and lizards, while cranial preservation is poor in newts and snakes. Severe weathering can remove smaller species and elements from an assemblage, therefore affecting its evidential value.</td><td>It is rare to find complete cranial elements as the skull is very fragile; however, principal limb bones readily survive. Molar and incisor teeth are the most robust items, and are usually identifiable even where bones are fragmented. Guides for taphonomic analysis of small mammals are available (see Supplement 1).</td></tr>
<tr><td>Recovery (sullegic stage), see Fig 3.2</td><td colspan="2">Microfauna are recovered though sieving (see Fig 3.2). Wherever possible, contexts containing visible microfaunal remains should be sampled in their entirety; material subsampled in the field will make subsequent analysis more difficult and less valuable. A single bone or tooth can be useful in identifying the presence of a species, with potentially interesting environmental, archaeological or biogeographical implications.

Inappropriate sieve size can impact significantly on specimen counts (NISP/MNI) and affect taphonomic interpretations (particularly in the case of small mammals). The minimum sieve mesh size must be 0.5mm, in order to recover taxonomically diagnostic loose teeth. A 1.0mm mesh can result in the loss of some small amphibian bones and the smallest mouse molars. A 2.0mm mesh results in the loss of a range of small mammal teeth, bones from small newt and lizard species, and juveniles of any microfaunal species (see Fig 3.2).</td></tr>
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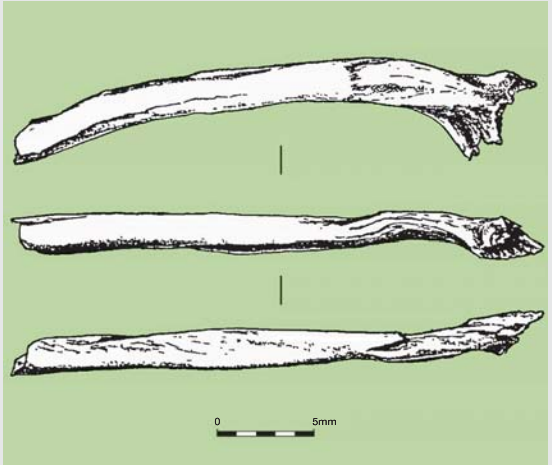


Fig 4.16 (right)
Common toad ilium with healed fracture from Three Holes Cave (Devon) interpreted as evidence of crunching by a predator: amphibians can survive severe trauma and their bones may exhibit impressive recovery. [Adapted from Gleed-Owen 1998, fig 6.20]

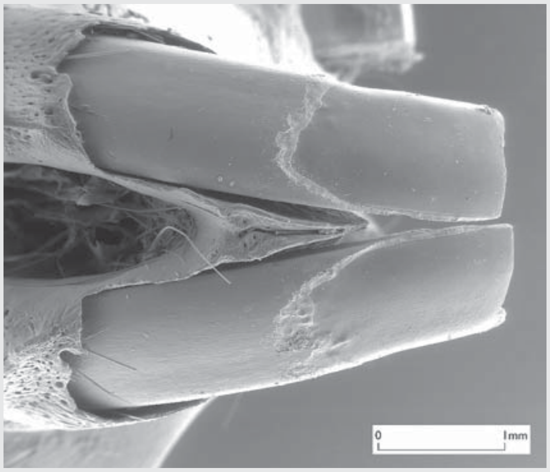
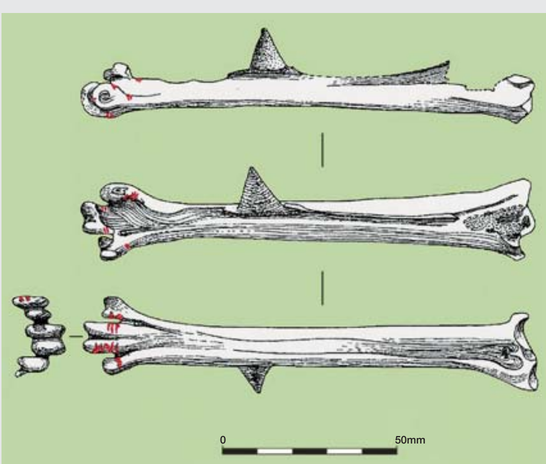


Fig 4.17 (far right)
Scanning electron microscope (SEM) image showing digestion of field vole incisor enamel. [Museo Nacional de Ciencias Naturales, Madrid; European Commission Human Potential Programme, BIODIBERIA; project number A94]

Birds (D Serjeantson)	Fish (R Nicholson)
Human butchery and consumption are confirmed by cut marks (Fig 4.18), restricted areas of burning, and sometimes by types of break through the leg and wing bones or by traces of human chewing. Natural deposits can be recognised by the presence of songbirds, and from the parts and preservation of the prey skeleton. Owl pellet material is characterised by the presence of small birds together with small mammals and herpetofauna. Some raptors may leave beak marks. Traces of digestion on small bird bones may help to distinguish pellet remains from human food waste. Dog, cat and rodent gnawing are also sometimes seen, and semi-digestion on larger fragments may also be evident.	Usually archaeological fish bone accumulations result from human activities: food preparation, consumption or processing of fish for export. Characteristic distortion and corrosion of fish bones is commonly seen in cess pit deposits (Jones 1986; Nicholson 1993), clearly demonstrating that these fish had been eaten (Fig 4.19). Predators and scavengers may leave accumulations of remains, and fish bones may also be present in discarded fish guts. Abandoned buildings and caves may contain accumulations of bones from fish brought in by animals or dropped in their faeces (Wheeler and Jones 1989, 78). Otter holts, for example, may contain significant accumulations of fish remains. Larger bones may show characteristic distortion and marks caused by chewing, but small bones may pass through the gut of otters and into the spraint completely undamaged (Nicholson 2000). Fish assemblages from submerged sites may be very well preserved but require careful taphonomic investigation in order to determine whether the assemblage is naturally or culturally derived. Occasionally, falling water levels may cause mass mortality. Fish may be stranded on sites as a result of flooding, or the drying up of ditches or channels, but this kind of event is unlikely to result in large collections of bones in a single locality. Bone preservation may result from a rapid accumulation of silt covering the remains; otherwise weathering and scavenging are likely to result in the scattering and loss of bones.
As with mammals, the relative survival of parts of the skeleton is density dependent. Wing and leg bones survive best.	Fish bones from different taxa vary in size and in physical and chemical composition, and this affects their survival before and after burial. The skeleton of sharks and rays are made of ossified cartilage, which is rarely preserved, although their calcified vertebral centra, teeth and dermal denticles are often found. Smaller bones are most likely to survive in waterlogged sediments or where remains have become mineralised (eg cess pits).
Sieving is necessary for the retrieval of bones of most birds (*see* Fig 3.2). Where sieving is not carried out, only the larger elements of birds from the size of a chicken upwards may be recovered. Articulated remains should be collected and labelled as an ABG (*see* p 18).	To realise the potential of fish remains, careful sampling and sieving is essential as an adjunct to hand collection (Campbell *et al* 2011, case study 2). Large whole-earth samples (100 litres; *see* p 17) may be necessary to provide adequate numbers of fish bones, particularly for prehistoric and Roman deposits. A 2mm mesh is adequate in most circumstances but a finer mesh may occasionally be needed, particularly for urban sites where organic preservation is good. Residue sorting time can be reduced if subsamples are scanned first. Articulated remains should be collected and labelled as an ABG (*see* p 18).



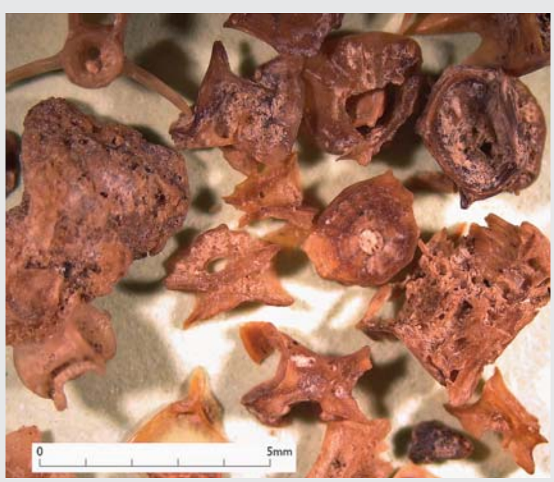


Fig 4.18 (far left)
Eleventh-century peacock bone with cut marks suggesting removal of feet, recovered from Carisbrooke Castle (IoW). [Illustration D Webb]

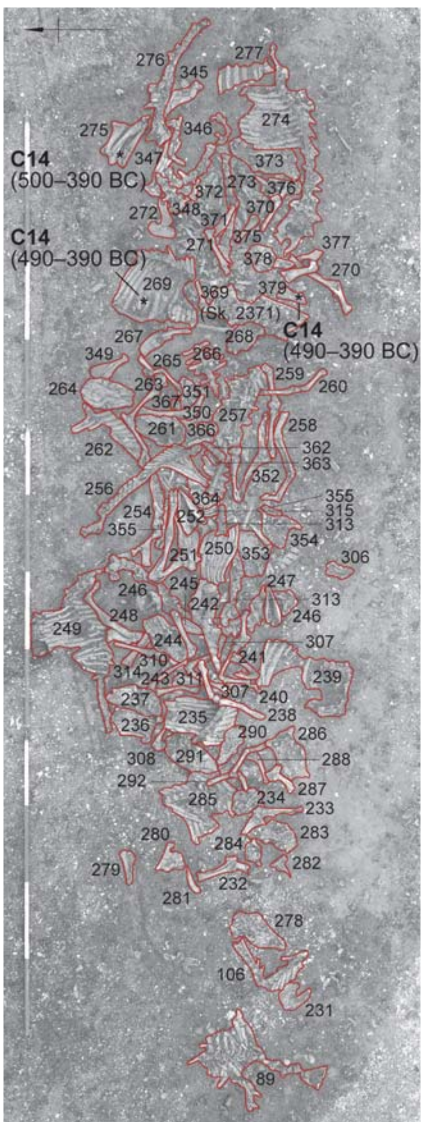
Fig 4.19 (left)
Fish remains recovered from a post-medieval cellar fill on the site of the Ashmolean Museum extension, Oxford (Oxon): the majority of bones show clear evidence of corrosion and distortion consistent with chewing and deposition in faeces. [Photo R Nicholson]

Case Study 1: **High Post, Wiltshire** (L Higbee)

Keywords: animal bone groups (ABGs); biochemistry; communication/site visits; quantification/statistics; site formation

Excavations by Wessex Archaeology at High Post, near Salisbury (Wilts) in 2008–9 (Powell 2011), revealed part of an early Iron Age hilltop enclosure and late Romano-British features. A large deposit of articulated animal bones (animal bone groups; ABGs), was spread over an area of *c* 2m by 15m, within a shallow elongated depression roughly parallel with the inside of the enclosure ditch. The deposit would originally have been covered by a bank, the existence of which was suggested by a band of unweathered chalk. ABG deposits of this type represent short-lived episodes of deposition, unlike the general refuse that accumulates at most archaeological sites.

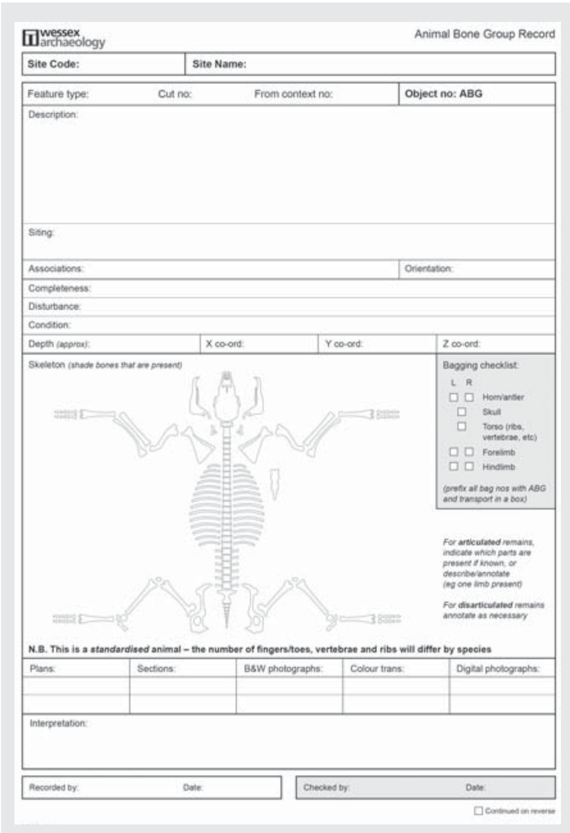
Fig CS1.1
Animal bone deposit 2536 after cleaning and showing animal bone groups (ABGs) individually numbered and ready to be lifted.
[Photos Wessex Archaeology]



The ABG deposit did not show up on the geophysical survey and was barely clipped by one of the evaluation trenches, therefore it was only once the topsoil was stripped as part of the main excavation that the deposit was identified and a suitable recovery strategy formulated. The adopted strategy benefited from the direct input of a zooarchaeologist who was able to visit the site on several occasions. The main purpose of the initial visit was to provide advice and training to field staff on recovery and recording protocols, and that of later visits was to define individual ABGs so that they could be lifted separately. The strategy worked well and was subsequently used when more of the ABG deposit was revealed in a watching brief.

Careful cleaning of the deposit allowed the zooarchaeologist to define individual ABGs and assess any spatial patterning on site. Once fully exposed, the deposit was photographed and planned at an appropriate scale, with overhead shots of its full extent proving particularly useful during the analysis stage and providing images for publication (Fig CS1.1). Once defined, each individual ABG was assigned a unique identifying number from the object register; the ABGs were annotated on to the plan and surveyed. A pro forma sheet (Fig CS1.2), similar to those commonly used to record human skeletons, was completed for each ABG before it was lifted and bagged separately. The bags were clearly labelled with all the relevant contextual information, including the unique identifying ABG number. These recovery methods ensured that the contextual security of each ABG was maintained as an integral part of the site archive.

Detailed analysis of the deposit (Higbee 2011) indicated that it contained 155 separate ABGs representing the remains of at least 25 cattle, 5 sheep, a pig and a horse, estimated to represent a total of 7,450kg of meat. The preservation state, degree of articulation and lack of scavenger gnaw marks indicated that the animal carcasses were buried fairly soon after they were butchered. The cattle were all too old to have been slaughtered for prime beef (Fig CS1.3); although some were cows and probably had been used for dairy, most were males and may have been used for traction. All carcass parts were present in the deposit (Fig CS1.4) and the butchery evidence indicated that they had been skinned and


wessex archaeology

Animal Bone Group Record

Site Code:	Site Name:

Feature type: | Cut no: | From context no: | Object no: ABG

Description:

Siting:

Associations: | Orientation:

Completeness:

Disturbance:

Condition:

Depth (approx): | X co-ord: | Y co-ord: | Z co-ord:

Skeleton (shade bones that are present)

Bagging checklist:
L R
☐ ☐ Horn/antler
☐ Skull
☐ Torso (ribs, vertebrae, etc)
☐ ☐ Forelimb
☐ ☐ Hindlimb
(prefix all bag nos with ABG and transport in a box)

For articulated remains, indicate which parts are present if known, or describe/annotate (eg one limb present)

For disarticulated remains annotate as necessary

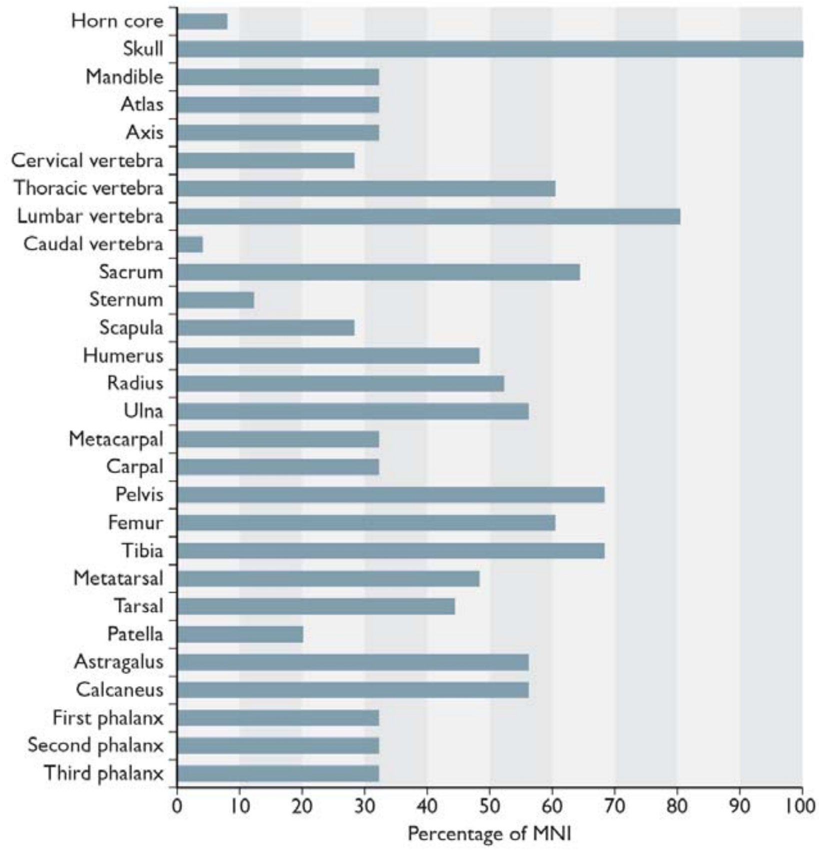
N.B. This is a standardised animal – the number of fingers/toes, vertebrae and ribs will differ by species

Plans:	Sections:	B&W photographs:	Colour trans:	Digital photographs:

Interpretation:

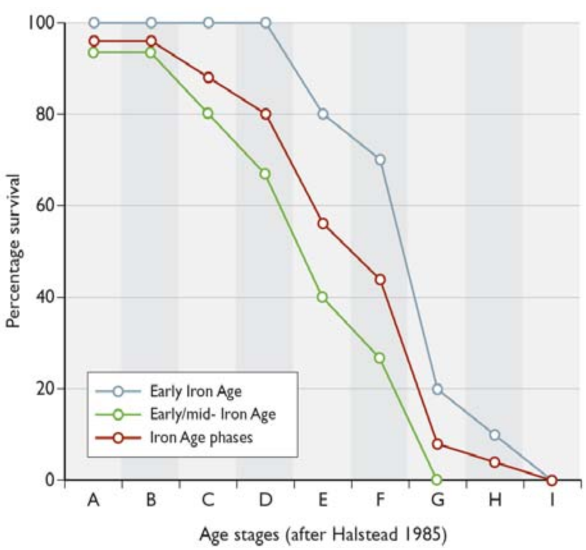
Recorded by: | Date: | Checked by: | Date:

☐ Continued on reverse



roughly divided but not processed into small meat joints. The skulls were detached; the limbs, with feet attached, were disarticulated at the shoulder or hip; the torso was divided into large racks. The overall scale of the deposit, the large size of the meat joints and other characteristics suggested that it contained the remnants of a communal feast, perhaps even one associated with the construction of the enclosure.

Radiocarbon samples were selected from both the animal bone deposit and the primary fill of the enclosure ditch, with the aim of establishing whether there was a relationship between the animal bone deposit and the construction of the earthwork. The short-lived depositional episodes represented by the ABGs offered immense potential to refine the chronology of the site. Complete bones in good condition were chosen



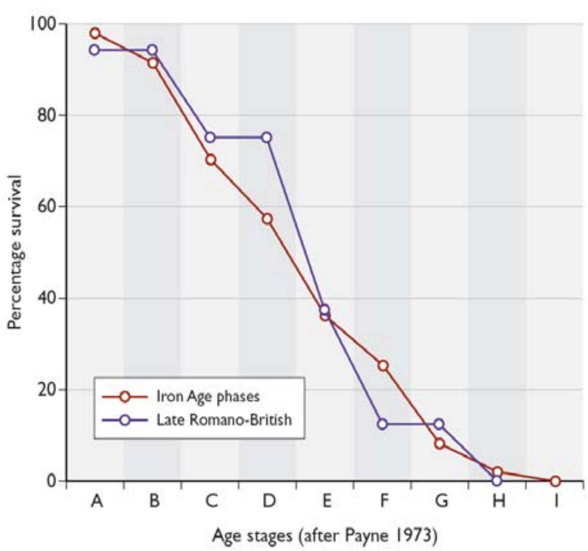


Fig CS1.2 (above, left) Wessex Archaeology's pro forma animal bone group (ABG) recording sheet.

Fig CS1.3 (above) Cattle mortality profiles based on mandibles from the early Iron Age deposit 2536 (n = 10) and other early/mid-Iron Age contexts (n = 15). [Adapted from Higbee 2011, fig 31]

Fig CS1.4 (far left) Cattle element representation in early Iron Age animal bone deposit 2536 (MNI = 25). [Adapted from Higbee 2011, fig 30]

Fig CS1.5 (left) Sheep mortality profiles based on mandibles from Iron Age (n = 46) and late Romano-British (n = 17) contexts. The Iron Age data include a single mandible from an animal bone group (ABG) deposit. [Adapted from Higbee 2011, fig 33]

Table CS1.1
Relative frequency of livestock species by number of identified specimens present (NISP), minimum number of elements (MNE), minimum number of individuals (MNI) and meat weight estimate (MWE) by period. MWE based on 275kg for cattle, 37.5kg for sheep and 85kg for pig. [After Higbee 2011, table 14]

	Early/mid-Iron Age	Late Romano-British
NISP		
Cattle	34%	43%
Sheep/goat	62%	54%
Pig	4%	3%
Total NISP	*1,360 specimens*	*600 specimens*
MNE		
Cattle	32%	53%
Sheep/goat	63%	44%
Pig	5%	4%
Total MNE	*930 specimens*	*600 specimens*
MNI		
Cattle	32%	31%
Sheep/goat	63%	66%
Pig	5%	4%
Total MNI	*60 individuals*	*29 individuals*
MWE		
Cattle	76%	76%
Sheep/goat	21%	22%
Pig	4%	3%
Total MWE	*6,905kg*	*3,273kg*

from the ditch to ensure that the material sampled was unlikely to be residual. The radiocarbon dates (following Bronk Ramsey 2009; Reimer *et al* 2009; cited in Barclay and Stevens 2011) are listed below.

ABG deposit

- 2420±35 BP (NZA-31064), corrected to 500–390 cal BC
- 2380±30 BP (SUERC-32316), corrected to 490–390 cal BC
- 2355±30 BP (SUERC-32315), corrected to 490–390 cal BC

Primary fill of the enclosure ditch

- 2330±30 BP (SUERC-32317), corrected to 410–370 cal BC
- 2310±30 BP (SUERC-32318), corrected to 410–350 cal BC

The results of Bayesian modelling indicated that the animal bone deposit predated the construction of the enclosure ditch by a relatively short period (Barclay and Stevens 2011, 86–91). The animal bone deposit was therefore interpreted as the remains of a communal feast associated with the foundation and construction of the enclosure, during which it was sealed beneath up-cast (ie the bank) from the digging of the ditch.

Short-lived depositional events have a biasing effect on general economic trends, as certain species, carcass parts or ages are likely to have been selected for reasons other than availability or economics. The unusual nature of the High Post deposit puts it outside the sphere of everyday activities and for this reason it was excluded from any discussion about the wider economy of the site. Economic interpretation of the information obtained from bones and teeth from other contexts, however, indicated that, apart from a slight increase in the age at which sheep were slaughtered, there was in fact very little difference in the exploitation of livestock species between the early/mid-Iron Age and late Romano-British period (Fig CS1.5; Table CS1.1).

Case Study 2: Biddenham Loop (Great Denham) bustum, Bedfordshire

Keywords: burnt bone; funerary; sampling/recovery; site formation

Bustum burials offer the opportunity to investigate a single cremation event and a more complete burnt debris assemblage than the selected or 'token' assemblage usually deposited in other types of cremation feature. Unlike many crematory traditions in Britain, Roman bustum burials combined the pyre site and grave site. At sites such as Biddenham Loop, Great Denham (Beds) (Luke 2015), the cremation pyre was constructed above a pit, into which pyre debris and human remains fell as the pyre burnt. Additional grave goods were then added to the assemblage before the pit was filled in.

The Biddenham Loop site was excavated in 2007–8 by Albion Archaeology. Careful excavation of the bustum (Fig CS2.1) allowed the positioning of the deceased and goods on the pyre, and unburnt goods in the grave, to be considered in a similar way to the analysis of inhumation burials. The bustum pit was subject to thorough whole-earth sampling following the recommended procedure (McKinley and Roberts 1993). This recovery method reflects the fragmentary nature of burnt remains and their potential to retain valuable information. This effort was rewarded by a more thorough appreciation of the funerary activities leading to the archaeological assemblage.

Research has shown that cremation pyres sometimes included animals or animal parts, perhaps offered as food, possessions, companions and/or protectors for the deceased in his or her transformative journey associated with the funeral rite, and perhaps representing the individual's position in life. The Biddenham Loop bustum included the burnt remains of a dog and a domestic fowl. The inclusion of the latter is relatively common in Roman cremation rites, but burnt dogs have been found infrequently in England. Excavation of the burial in horizontal spits and vertical segments (Fig CS2.2) allowed the human osteologist (N Powers) and zooarchaeologist (M Maltby) to determine that the deceased (an adult male) was probably laid on the pyre in an extended position, with an adult dog placed at his feet (the burnt dog bones being found in segment 7; Fig CS2.2). The dog was probably a complete carcass when burnt, as most regions of the skeleton were identified within the assemblage of burnt bones. Two calcined chicken bones were also recovered from the same area. Some of the cremated human bones were gathered and put into an urn, which was placed in the grave. A second ceramic vessel was placed at the foot end of the grave. Analysis of charcoal and nails found in the bustum demonstrated that the burnt timbers may have included decorated wooden furniture (Duncan and Challinor cited in Luke 2015), possibly a couch. The thorough archaeological recovery of burnt bones and the retention of their spatial distribution have allowed interpretation of aspects of this individual's funerary ceremony, including the use of animals and presentation of his pyre to any assembled mourners Fig CS2.3).

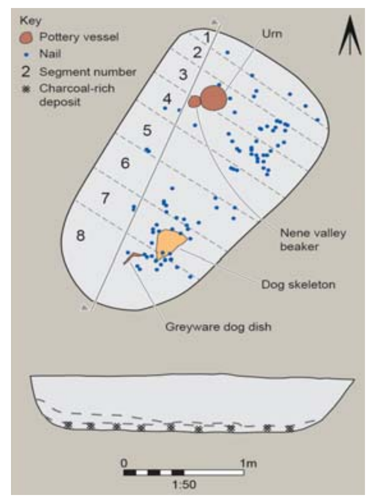


Fig CS2.1 (above, top) Biddenham Loop bustum under excavation. [Photo Albion Archaeology]

Fig CS2.2 (above) Post-excavation plan and section showing the division of the lower fill into eight segments, each 100% sampled, and the position of the finds. [Image Albion Archaeology]

Fig CS2.3 (left) Interpretative reconstruction of the Biddenham Loop bustum. [Illustration C Marshall; reproduced here with permission of Albion Archaeology]

Case Study 3: Taphonomy and depositional history at Potterne, Wiltshire (R Madgwick)

Keywords: archive reuse; quantification/statistics; sampling/recovery; site formation; taphonomy

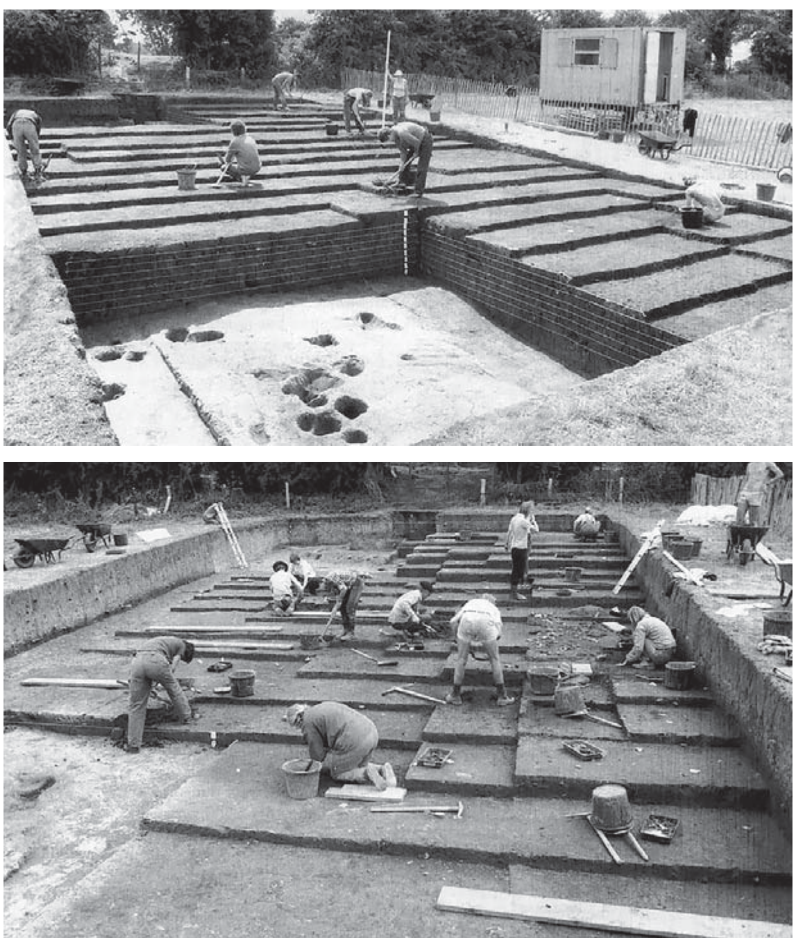
Fig CS3.1 (below) Photographs of the Potterne midden (Wilts) under excavation in 1984, demonstrating the 0.1m spit/m^2 strategy. [From Lawson 2000, plates 6 and 7]

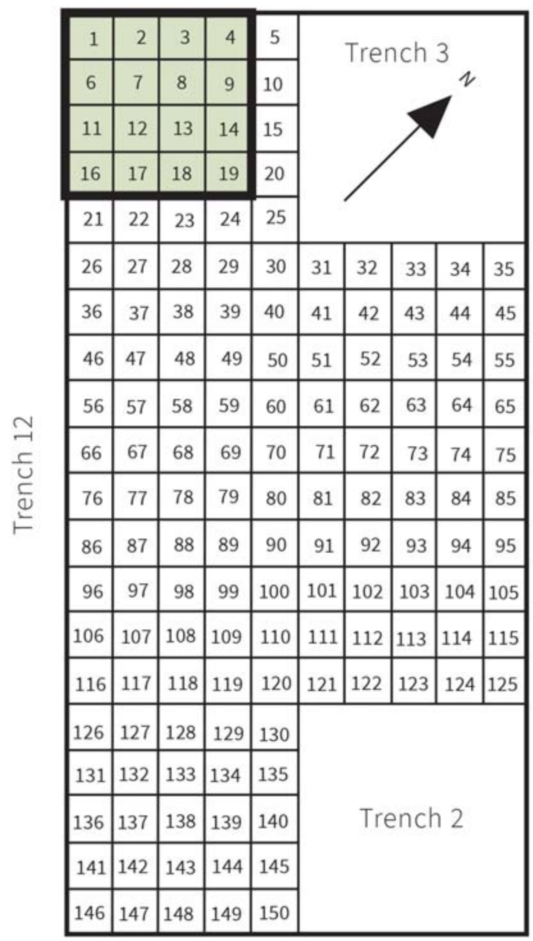
Fig CS3.2 (below, right) Schematic diagram of trenches 2, 3 and 12, with square numbers noted. The 16m^2 sample area is highlighted. [From Potterne archive, produced by A Lawson, adapted by R Madgwick]

Taphonomic data can enhance the interpretation of site formation, and are particularly useful for bone-rich deposits where stratigraphy is obscured. The late Bronze Age/early Iron Age midden of Potterne (Wilts; excavated 1982–5, coordinated by Wessex Archaeology) represents a vast accumulation of cultural debris, covering approximately 3.5ha with deposits up to 1.5m thick. Accumulations were artefact-rich and dominated by a homogeneous black earth matrix. Stratigraphy could rarely be observed and therefore much of the excavation was conducted using arbitrary 0.1m spits and 1m squares (Figs CS3.1 and CS3.2) to impose spatial control over the deposits. Compositional differences in the bone assemblage and soil micromorphological analyses provided limited insights into the sequences of deposition (Locker 2000a; Macphail 2000). A novel study based principally on ceramic type distribution and bone fragmentation suggested a continuous, gradual build-up of the midden over time (Reilly *et al* 1988) but this was not an entirely satisfactory explanation for such thick deposits.

A pilot study was carried out on a 4m by 4m square of the midden to assess the potential of using evidence of weathering, gnawing, trampling and fracture freshness to shed light on depositional histories. The study area (Fig CS3.2) represented 1% of the total midden area. It had 1.4m–thick deposits, with the basal spit (1.31–1.4m) containing no bone and the uppermost three spits (up to 0.3m below the topsoil) being heavily plough-affected. All bones from spits 4–13 (0.31–1.3m) were re-analysed incorporating a suite of taphonomic variables.

For all modifications, each spit was compared with every other spit using multiple pairwise





Taphonomic variable	Susceptible taxa	Susceptible elements
Weathering	Cattle, horse	Mandible, long bones (excluding fibulae), pelvis, scapula
Gnawing	Cattle	Long bones (excluding fibulae), pelvis, scapula, astragalus, calcaneum
Trampling	Cattle	Not applicable
Fracture freshness index (FFI)	Not applicable	Femur, humerus*

*Femur and humerus are susceptible to low FFI scores.

Table CS3.1
Summary results of a statistical study on suscep-tibility, using binary logistic regression models. The table shows element and taxon categories that are significantly more frequently affected by modifications in a sample of approximately 25,000 identifiable specimens from British archaeo-logical sites (Madgwick 2011; Madgwick and Mulville 2012).

comparisons to identify statistically significant differences. Simple tests of difference were used: chi square for variables recorded as pre-sent/absent (eg gnawing and trampling) and Mann–Whitney for those with ordinal stages (eg weathering and fracture freshness). The analysis identified many significant differences between spits. It was then necessary to assess whether any variation in composition of the bone assemblage between spits could explain these significant differences. Previous research has demonstrated that certain elements and species are more likely to exhibit modification because of their structural properties, even when subjected to the same depositional history (Madgwick 2011; Madgwick and Mulville 2012; Table CS3.1).

Multiple pairwise tests were used to identify whether variation in modification between spits could be accounted for by assemblage composi-tion, or was the result of genuine differences in depositional history. In some spits, composition could not account for the patterns of modifica-tion, and therefore significant differences were considered to be evidence of variation in the accumulation process, including phases of intense accumulation, periods of hiatus and times of disturbance. A simplified summary of this is presented in Fig CS3.3. While the sequence of deposition may vary across the midden, this proof-of-concept study demonstrates the potential of the method for reconstructing site-formation pro-cesses and phases of accumulation in thick deposits, using simple statistical tests.

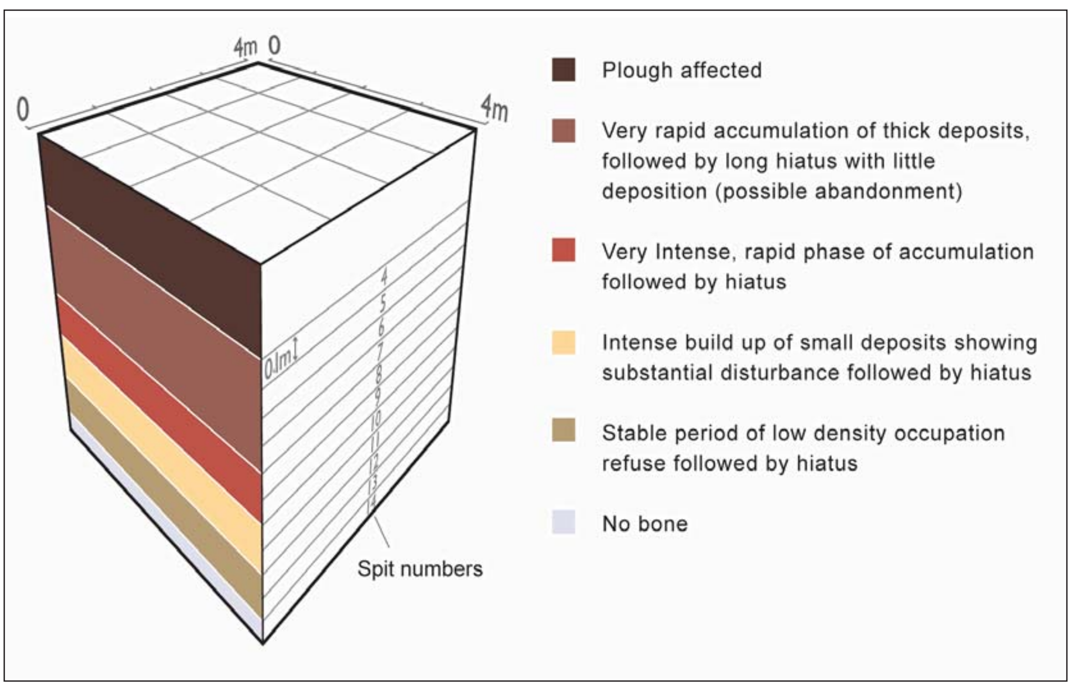


Fig CS3.3
Schematic diagram of the sample area highlighting and briefly describing phases of deposition as recognised in the 14 recorded 0.1m spits. [Illustration J Vallender, after Madgwick 2011]

Case Study 4: Longstone Edge barrows, Derbyshire

Keywords: funerary; sampling/recovery; site formation; small mammals

In 1996, two adjacent Bronze Age bowl barrows were excavated on the escarpment at Longstone Edge (Derbs) by English Heritage (Last 2014). Quarrying, 19th-century excavations and modern construction had caused considerable damage to the monuments (Fig CS4.1). Stabilisation works on the quarry edge were predicted to cause further disturbance, prompting an archaeological intervention.

The excavation aimed to understand mound construction, burial practice and use of space around the monuments. The animal bone assemblage was of particular interest with regard to environmental reconstruction and mound taphonomy (use and abandonment). Contexts with human remains, or significant artefact or palaeoenvironmental assemblages, were 100% sampled, and floated or wet sieved over 0.5mm, 1mm, 2mm and 4mm residue meshes, ensuring the recovery of the smallest microfaunal elements (*see* Fig 3.2).

Barrow 1 in particular proved to be a complex monument with a lengthy history of activity before the main mound was constructed. Microfauna comprised *c* 80% (volume) of the fills of the early Bronze Age cist grave 1; they were also abundant in later pre-mound layers, and present in the Barrow 2 grave. Water vole and field vole contributed 80–90% of the number of identified microfaunal specimens (NISP), with small numbers of other small mammals, herpetofauna and fish probably deriving in part from local background fauna (Andrews and Fernandez-Jalvo 2012). Similar accumulations of small animals noted in other barrows have been variously interpreted as hibernating or prey animals, or remains from human consumption or ritual activity. At Longstone Edge, analysis of species diversity, and of bone breakage and digestion (*see* p 55), indicated that two main predators were responsible for the accumulations, the short-eared owl, producing low levels of modification, and the Eurasian eagle-owl, effecting greater change.

The high diversity of the microfauna suggests an environment of mixed woodland and open country. Both identified owl species would have hunted across open land on the tops and slopes of the escarpment. As ground-nesting species, they would have been vulnerable to any disturbance from human activity, suggesting that the site was not routinely visited by people. Additionally, the quantity of bone shows that owls occupied the site over several years, indicating strongly that there was a lengthy period when the cist was not covered by a mound (Andrews and Fernandez-Jalvo 2012, 49). Finally, the evidence for Eurasian eagle-owl contributes to the ongoing debate about its past distribution and extinction (Yalden and Albarella 2009, 58).

Fig CS4.1
(1) Schematic diagram of Barrow 1, Longstone Edge (Derbs); (2) Barrow 1 during excavation; (3) damage to Barrow 2.
[(1) Illustration C Evans, photos Historic England]

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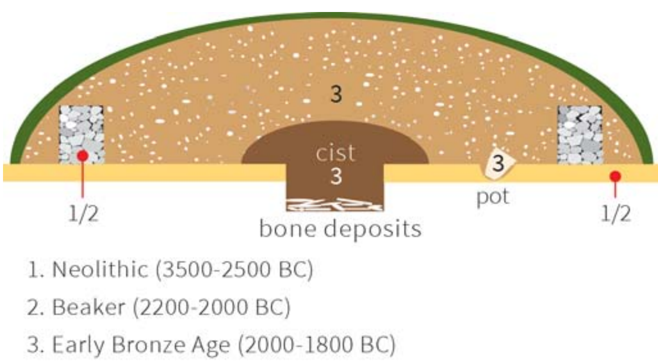

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Case Study 5: **Medieval furs** (E Fairnell)

Keywords: butchery; by-products; sampling/recovery; urban; site formation; small mammals

Archaeological evidence of fur and fur processing is rare in Britain. However, for every pelt used, an animal will have been skinned, and those animal remains can be recognisable within the zooarchaeological record. Zooarchaeological data can reveal evidence of the species involved, the process of skinning, as well as the end product.

The abundance of one fur-bearing species, the cat, increases in medieval urban bone assemblages, for example in Winchester (Hants; excavated in the 1970s and 1980s by the Winchester Museums Service; Maltby 2010; Serjeantson and Smith 2009, 149–50) and elsewhere (Fairnell 2011; Rielly 2006). Cats may have been encouraged within settlements to help control vermin, or increasingly considered as pets, but the zooarchaeological evidence indicates that the expanding urban feral cat population also provided an accessible source of pelts (Luff and Moreno Garcia 1995).

Cat skulls are repeatedly found with cut marks, taken as indicative of skinning (Fig CS5.1). Very often such cut marks are associated with assemblages that contain whole or partial cat skeletons, as found in Winchester (Serjeantson and Smith 2009, 149–50; Fig CS5.2). The combination of element representation and butchery mark evidence suggests that cat carcasses were deposited after the pelts had been removed, with particular care taken to skin out the head.

Fig CS5.2 includes data from the Bedern, York (Bond and O'Connor 1999; Scott 1985) as an interesting contrast to the data from Winchester. At first glance the number of identified specimens (NISP) of red squirrel from the Bedern suggests deposition similar to that of cats at Winchester. However, compared with the cat carcasses, the squirrel is represented only by lower limb elements, particularly metapodials and phalanges, with one cut mark on a tarsal. All the squirrel bones were recovered in a sieved sample, without which the species, and its implication for medieval furriery, may not have been recognised. No squirrel was identified at Winchester even though sieving took place, and very little cat was found at the Bedern in sieved or hand-collected assemblages (Fig CS5.2). The anatomically skewed deposit of squirrel in York is not unique, a similar one having been described from London (Rielly 2006), but it is striking. While the combination of cut marks and carcass deposition at Winchester suggests relatively frequent skinning of cats, the squirrel deposit at York seems to be an isolated episode. Rather than the initial skinning of a carcass, the element distribution in the Bedern squirrel deposit is more indicative of a later stage in pelt processing (Bond and O'Connor 1999), perhaps even a final garment that was adorned with the feet and tails of squirrel.

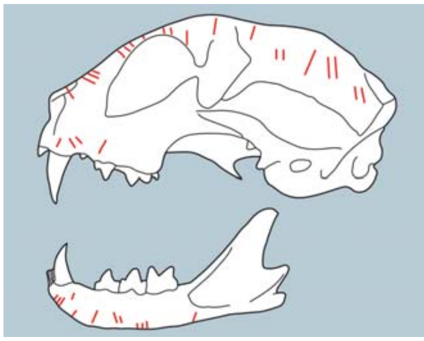


Fig CS5.1
Summary compilation of cut mark location on cat skulls and mandibles from Winchester (Hants). [Data from Serjeantson and Rees 2009, figs 5.52 and 5.53, and element outlines adapted from von den Driesch 1976, figs 17b and 24]

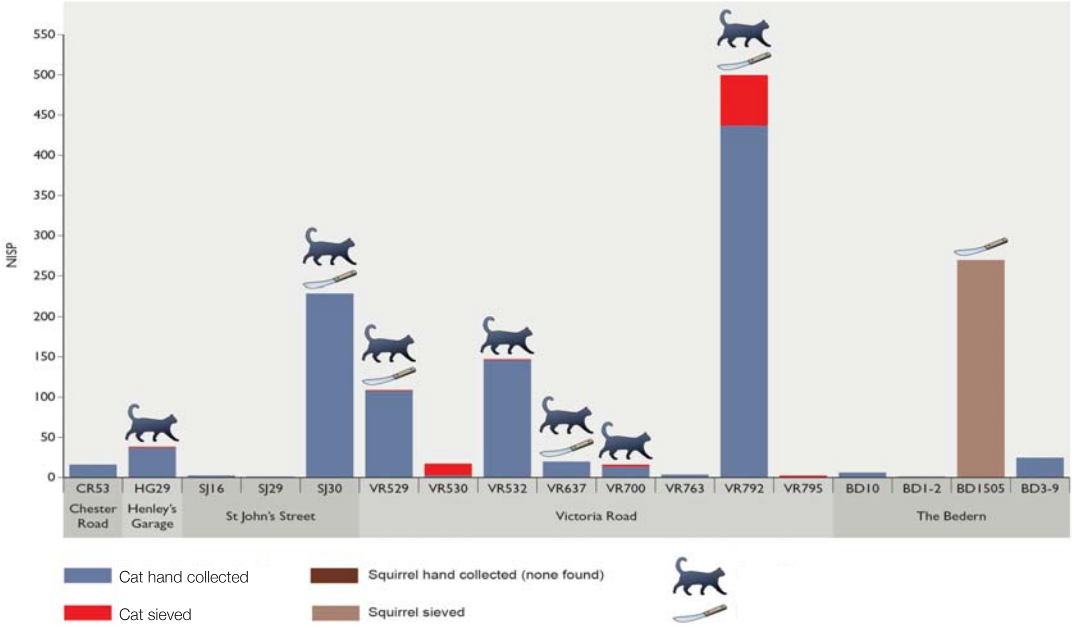


Fig CS5.2
Number of identified specimens (NISP) of cat and squirrel bones from sites in medieval Winchester (Hants) and the Bedern (York). [Data from Bond and O'Connor 1999; Scott 1985; Serjeantson and Rees 2009]

Case Study 6: Stretton Road, Great Glen, Leicestershire (J Browning)

Keywords: communication/site visits; economy; on-site feedback; sampling/recovery

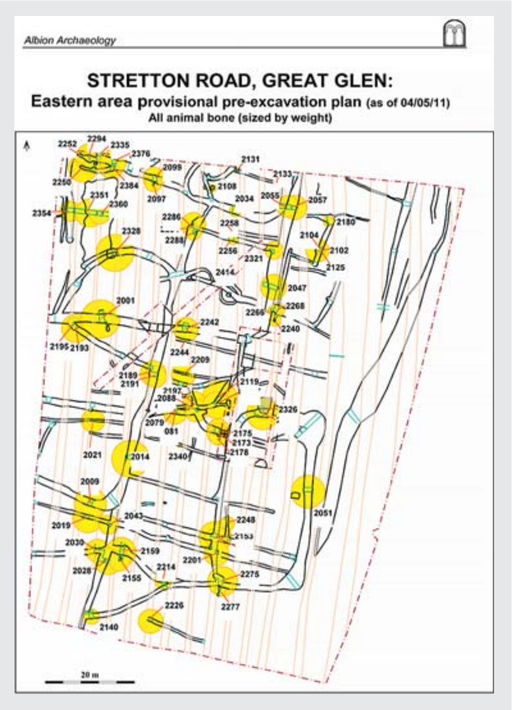


Fig CS6.1 (right)
Example document used in on-site planning meetings to inform excavation strategy and target bone recovery. [Image Albion Archaeology]

In 2011, Albion Archaeology excavated a Romano-British rural farmstead, located at Stretton Road approximately 6 miles from *Ratae Corieltauvorum* (Roman Leicester, Leics; Luke *et al* 2015). The supply of meat to the town and its economic relationship with the countryside is inadequately understood (Knight *et al* 2010; Monckton 2006, 277); suitable faunal assemblages, excavated under modern conditions, are rare and, where they exist, are often small and poorly preserved. The significance of the farmstead and its potential to provide evidence for the provisioning of the Roman town was recognised from the outset.

A University of Leicester Archaeological Services (ULAS) zooarchaeologist was consulted at an early stage of the project, ensuring the availability of an animal bones specialist during excavation; a dialogue was maintained by email. The zooarchaeologist was invited to site meetings with the English Heritage Science Advisor (SA), consultant (CgMs) and county council planning archaeologist. An excavation strategy was agreed, in which sections were excavated from ditches and gullies at points along their length, while discrete features were half-sectioned. In addition to hand recovery, whole-earth samples were taken to retrieve small bones and charred plant remains. Site visits provided the opportunity to see the features from which the bones were recovered, to evaluate the preservation of bones processed during excavation, and to discuss observations with site staff.

Fig CS6.2
Excavation of animal bones at Stretton Road (Leics). [Photo Albion Archaeology]

The zooarchaeologist emphasised the need for a large assemblage to compare with the urban material from Leicester. Previous experience had shown that fragmentation was high in the local clay soils, resulting in a large proportion of undiagnostic fragments; increasing the quantity of bone collected could help counter this effect. Enclosure ditches yielded reasonable quantities of bones (Figs CS6.1 and CS6.2). The SA therefore recommended the extension of excavated sections to ensure hand recovery of sufficient material for analysis. Although this meant further work for the excavation team, it was agreed to target sections that had already produced relatively rich assemblages, including potentially identifiable bones and ageable mandibles. This approach was possible because samples were processed and bone frequency recorded as the excavation progressed, with this information regularly relayed for discussion at site meetings (Fig CS6.1).

Increasing the recovery of bones from the ditches ensured a sufficient assemblage size to explore provisioning mechanisms. For example, domestic species representation was similar to local Iron Age sites and contrasted with sites in Roman Leicester, which have greater species diversity. This diversity is possibly attributable to larger assemblage sizes and better preservation, but may also suggest a more varied diet in the towns than at Stretton Road and therefore a wider provisioning network. For cattle, there was an emphasis on older animals, similar to the urban sites. However, adult sheep were also more prevalent, providing a contrast with the younger animals seen at some town sites in this period.

The active dialogue between the specialists and the excavators benefited both parties. The excavation team was able to access advice and feedback on their collection strategy, including information regarding how the faunal remains would contribute to regional research. In turn, the zooarchaeologist gained a better understanding of the site and provenance of the bones, and ensured their appropriate recovery.

Case Study 7: Prehistoric and historic Lewes, East Sussex

(L Allott and G Ayton)

Keywords: communication/site visits; economy; fish; on-site feedback; sampling/recovery; urban

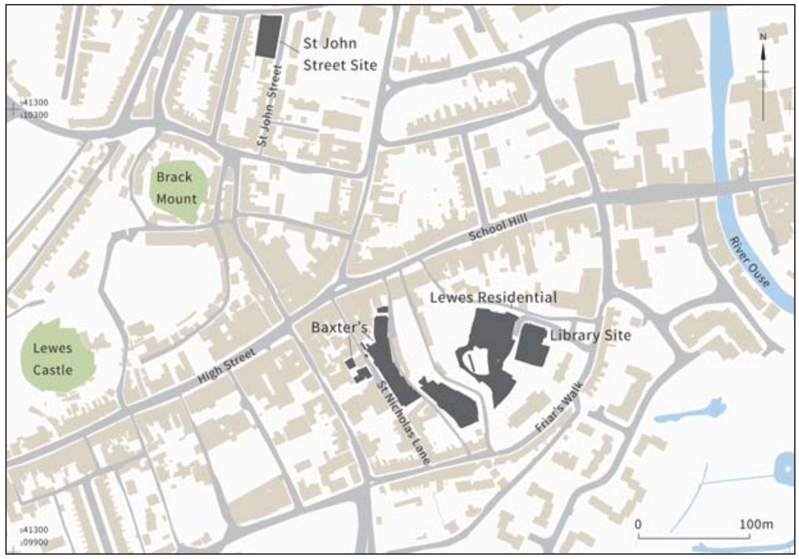


Fig CS7.1
Map of Lewes (E Sussex) showing the location of sites. [Image Archaeology South-East, based on Ordnance Survey open data. Crown copyright and database right 2014]

Excavations in 2008 by Archaeology South-East (ASE) at the Lewes Residential site, Lewes (East Sussex), revealed unique evidence of middle to late Iron Age occupation, as well as new evidence for medieval and post-medieval activity (Swift forthcoming). It was of prime importance to fill knowledge gaps relating to phases of land use that were underrepresented or absent elsewhere in the town, as well as to place the site within its wider downland setting. Sampling aimed to gather spatial and temporal data from a broad range of ecofact classes that could be used to explore patterns of farming, food processing, supply and consumption, as well as industrial activities such as tanning and brewing, and to gain an understanding of health, hygiene and living conditions.

The sampling strategy was developed initially for the written scheme of investigation (WSI) and refined on site through discussions with the English Heritage Science Advisor, county archaeologist, and ASE site supervisors and environmental archaeologist. This ensured that the experience and knowledge from sampling at other excavations in Lewes, in particular Baxter's printworks (Fig CS7.1), was drawn upon. The data suggested that abundant faunal, botanical and artefact remains might be present in medieval and post-medieval features, and also highlighted the importance of sampling in addition to hand collection of faunal remains to maximise retrieval of smaller elements and species.

Sampling was primarily undertaken using whole-earth samples (40 litres or 100% of smaller features) with retention of subsamples (up to 10 litres) for specialist processing and analyses. Stratified samples were taken from large features with superficially homogeneous fills. A total of 161 samples was taken from 158 contexts including a range of feature types (quarry, storage, refuse and cess pits, ditches, post-holes and wells) from across the site (Fig CS7.2), the fills of which could be compared and contrasted.

The mammal and bird bone assemblages recovered from the samples included evidence of neonatal pig and domestic fowl, remains not commonly collected by hand. The neonatal remains suggest that pigs may have been bred within the town and, alongside the evidence for domestic fowl, imply that the inhabitants were partially self-sufficient (assemblages analysed by G Ayton). Furthermore, over 93% of the fish assemblage was retrieved from the samples. A total of 9,848 identifiable fish bones was analysed by D Jacques, providing information regarding fishing techniques, consumption, processing and industry.

Bones recovered from samples contributed towards the overall interpretation that in the medieval period the area was primarily a quarry, and secondarily used as a dumping ground for domestic and other waste. This interpretation is further supported by botanical evidence in which cereals and remains of native wild fruits are prominent.

Sampling also aided retrieval of smaller artefact classes that are otherwise easily missed or under-represented, including bone objects (such as combs), small metal objects (eg copper alloy mounts) and smaller fragments of better represented artefact classes (such as glass and ceramics). Analysis of these finds helped to refine site dating.

Fig CS7.2
Excavations at Lewes Residential site, Lewes (E Sussex). [Photo Archaeology South-East]

Case Study 8: Chicken biometry in medieval and post-medieval London (M Holmes)

Keywords: archive reuse; biometry; quantification/statistics; synthesis/group value

The analysis of 1,469 individual chicken bone measurements from 68 largely urban sites (Fig CS8.1) was included within Thomas *et al*'s (2013) study of domestic livestock size and shape change in medieval and post-medieval London.

The study methodology addressed a number of issues. First, residuality and redeposition are significant problems on urban sites. Here, their effects were limited by only including securely dated, undisturbed contexts. Second, only small datasets were available at most sites and for each phase (Table CS8.1); individually, these were too small to compare. The use of log-scaling (Meadow 1999) allowed pooling of data from each measurement plane (length, depth and breadth; Thomas *et al* 2013, table 2). A Mann–Witney test was used to compare the log-scaled data, as the datasets comprised uneven sample sizes with a non-standard distribution. Third, it was necessary to identify the proportion of hens and cockerels in each sample to understand the origins of size change; this was achieved using measurements of the tarsometatarsus combined with the presence of sexually diagnostic spurs and spur scars (Sadler 1991; West 1985). Finally, some confusion may arise between the bones of domestic fowl and other galliforms and potentially bias biometric data. However, as few other galliform species (six bones) were identified from any of the sites, it was considered safe to assume that their influence was minimal.

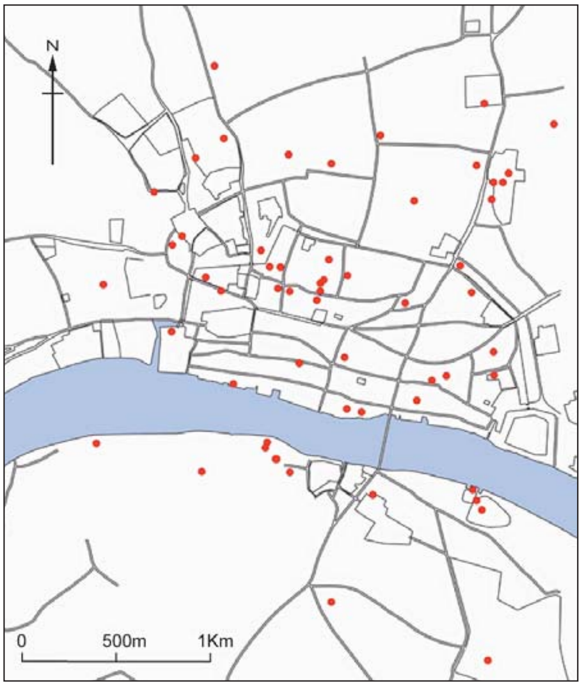


Fig CS8.1
Location of the London sites. Six additional sites are not shown, five of which lie within 1km of the illustrated area. Merton Priory is *c* 10km to the south-west.
[Image J Morris]

Table CS8.1
Chicken bone measurement dataset by phase. For phase definitions *see* Fig CS8.2.

Phase	A	B	C	D	E	F	G	H	Total
Number of sites	21	28	22	24	10	6	13	8	68
Total number of measurements	302	442	241	209	57	38	80	90	1,459
Minimum measurements/site	2	1	1	1	1	1	1	1	1
Maximum measurements/site	118	118	85	50	20	19	25	56	181
Mean measurements/site	14.4	15.8	11.0	8.7	5.7	6.3	6.2	11.3	21.5
Median measurements/site	6	11	4	4	3	3.5	4	4.5	6.5
Mode measurements/site	2	1	2	2	2	NA	9	2	2
Standard deviation	26.0	22.4	19.2	11.3	5.9	6.8	6.3	18.5	33.8
Standard error	5.7	4.2	4.1	2.3	1.9	2.8	1.7	6.5	4.1
Sample variance	674.1	501.8	367.5	127.9	35.3	46.3	39.6	342.2	1,145.5

NA, not applicable.

Findings of particular interest included the following:

- Statistically significant size changes occurred between phases A (1220–1350) and B (1340–1500) (Fig CS8.2) and between subphases B1 (1340–1450) and B2 (1400–1500). These came in the wake of the Black Death, when more livestock became accessible to the peasantry, bringing greater opportunity for selective breeding. Combined with this, the increase in the proportion of cockerels in phase B (1340–1500) may partially explain the apparent size increase at this time (Fig CS8.3).
- Another increase in size occurred in phase H (Fig CS8.2). Documentary evidence suggests that farmers were beginning to use selective breeding to produce larger animals more suited to meat and secondary products. However, the dearth of data from the later 17th century onwards means it is not known to what extent selective breeding explains the observed size changes, or whether new stock importation also played a part. This highlights the need for increased data collection to aid understanding of post-medieval animal husbandry.
- The site of Merton Priory, situated outside the city, produced the largest dataset (127 bones), of which nearly all dated to phase A. Chickens from this site were smaller and more robust than those from other sites. They are considered to reflect a distinct type of domestic fowl.

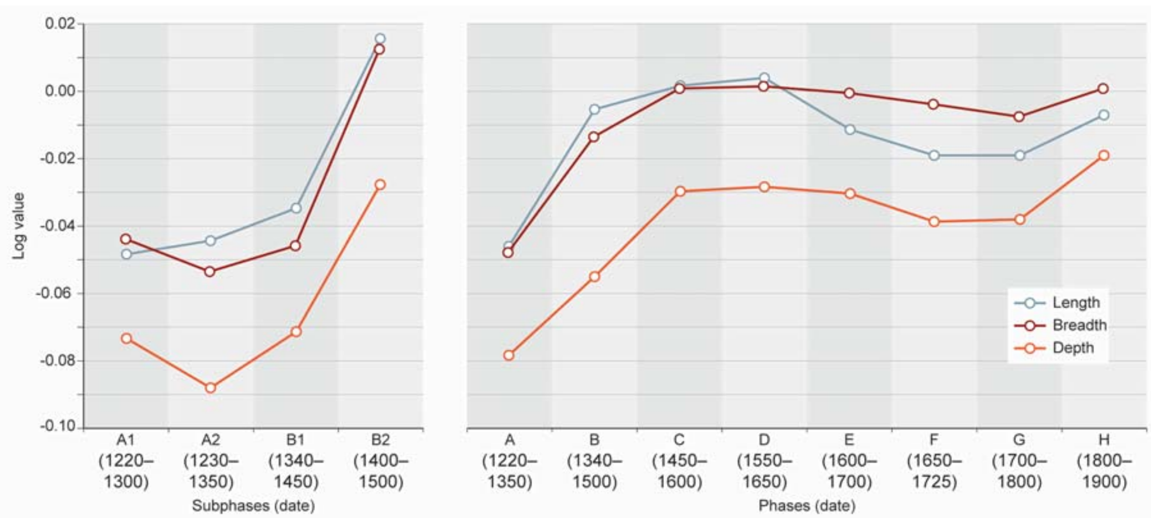


Fig CS8.2 (left)
Mean log-scaled chicken post-cranial bone measurements by phase. A reference skeleton (Warren-Ranger hybrid domestic hen) served as the standard.
[Data from Thomas *et al* 2013, table 11]

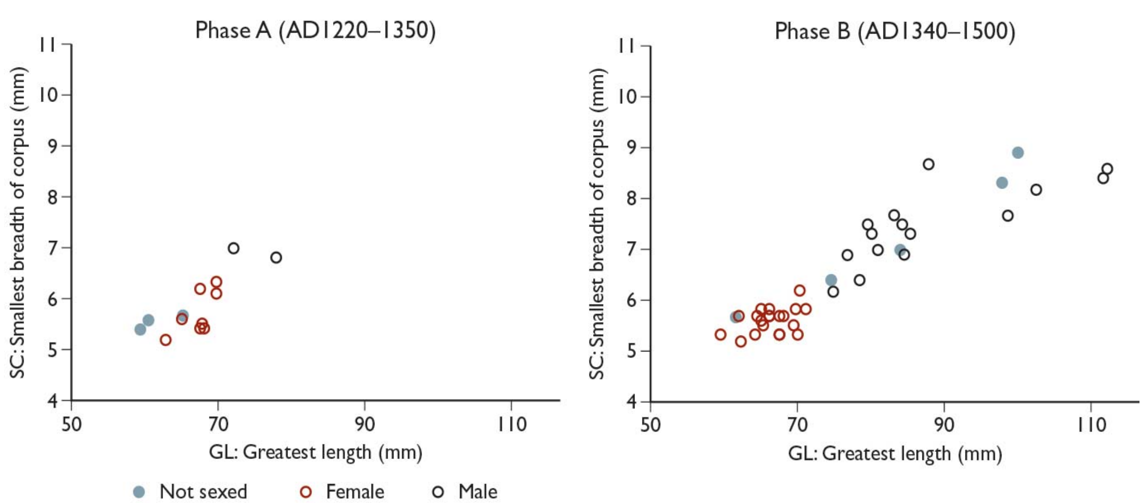


Fig CS8.3
The use of chicken tarsometatarsus measurements combined with the presence/absence of a spur or spur scar to give an indication of the proportion of hens and cockerels.
[Image M Holmes]

Case Study 9: The medieval sea fishing revolution (J Barrett and D Orton)

Keywords: archive reuse; biochemistry; economy; fish; quantification/statistics; synthesis/group value

A change from consumption of fresh-water to marine fish in medieval England was first proposed during the flourishing of UK environmental archaeology in the 1980s (eg Jones 1988). By 2004, primary research on carefully recovered material had produced enough data to sustain synthesis on a national scale. By comparing 127 sieved fish bone assemblages dating between AD 600 and 1600 it was discovered that the shift to marine fishing was both widespread (albeit

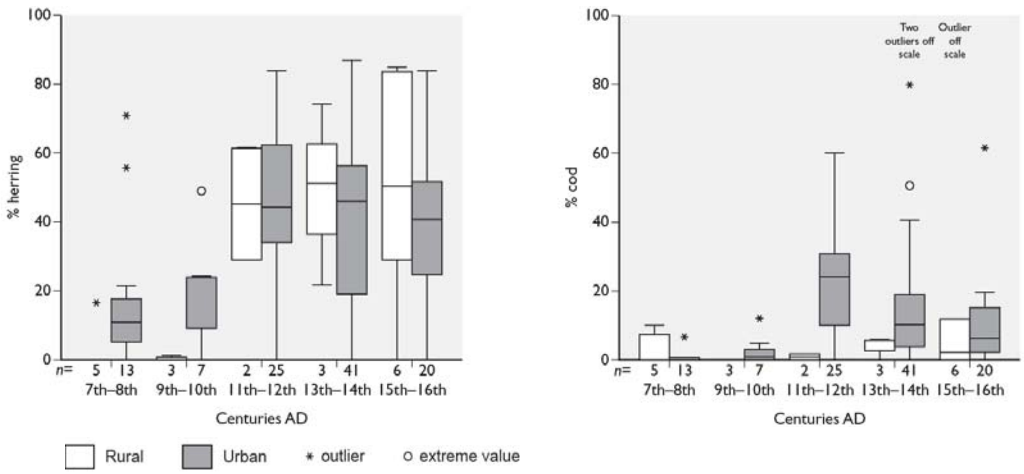


Fig CS9.1
Boxplots showing the chronological distribution of herring and cod in urban and rural medieval settlements (based on number of identified specimens, NISP). [Adapted from Barrett *et al* 2004, fig 7, courtesy of Antiquity Publications Ltd]

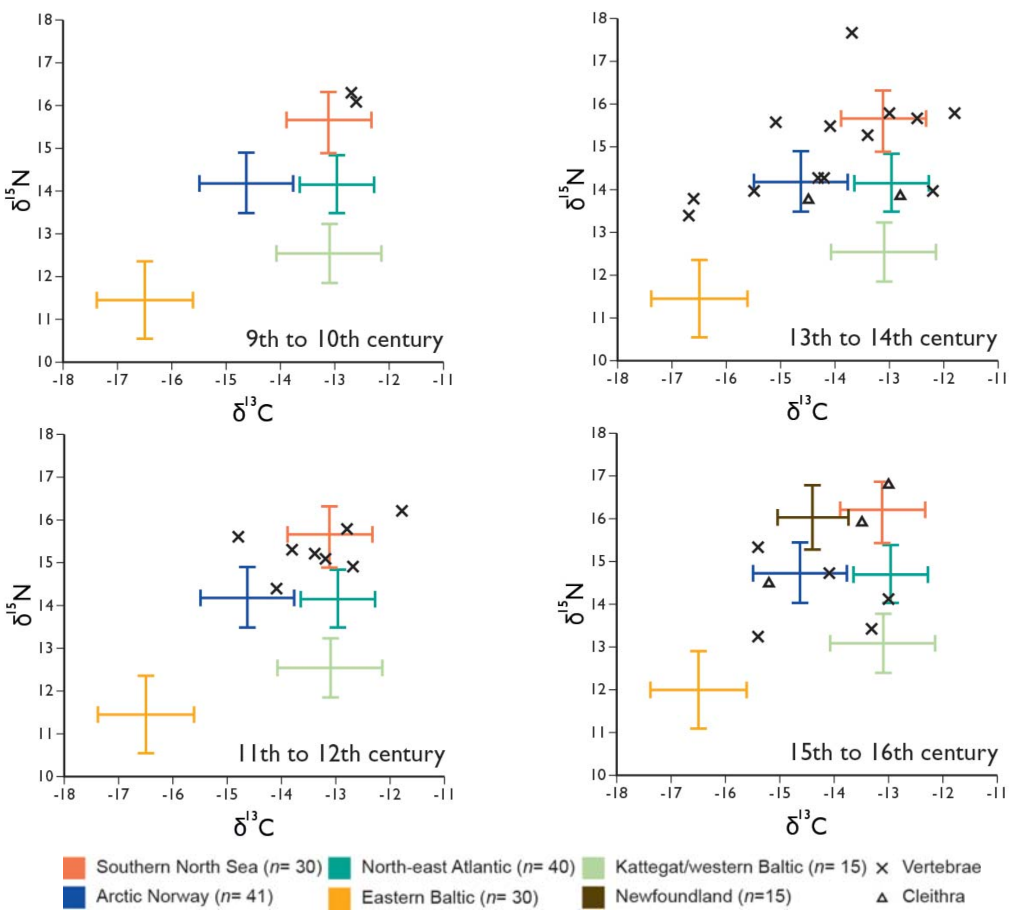


Fig CS9.2
Isotope ($\delta^{13}C$, $\delta^{15}N$) values for cod target bones (vertebrae and cleithra) from London, superimposed on the mean values and error bars (showing one standard deviation) for control skull bones from different regions. Newfoundland is considered an additional potential source in the 15th to 16th century. [Adapted from Barrett *et al* 2011, fig 5 © Elsevier]

not universal) and rapid, with a particularly clear transition in the decades around AD 1000, dubbed the ‘fish event horizon’ (Barrett *et al* 2004; *see* Fig 4.2). Herring consumption increased significantly and cod family fish, including cod itself, took on a new importance, first in towns and later spreading to the countryside (Fig CS9.1).

Comparative archaeological and historical research suggests two potentially overlapping scenarios to explain the shift: the start of long-range trade and a demand-led intensification of local marine fishing (Barrett *et al* 2004, 2011). Archived fish bone assemblages were investigated to explore these scenarios. Bulk stable isotope ratios of carbon, nitrogen and sulphur were used to detect whether cod bones represent local catches or preserved imports such as stockfish, and (with less certainty) to assign them a probable region of catch (Fig CS9.2). As most fish were decapitated prior to drying in the Middle Ages, archaeological skull bones (‘controls’) can be used as proxies for local signatures whereas post-cranial bones (‘targets’) such as vertebrae and cleithra might be from either local or imported cod. The ratio of locally caught cod to imported stockfish in an assemblage can therefore be assessed by comparing the $\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$ values of heads and bodies (Barrett *et al* 2008; Nehlich *et al* 2013).

Preliminary results based on 171 control and 129 target specimens suggested that the revolution in sea fishing first resulted from a demand-driven intensification of local fishing. By the 13th to 14th centuries the requirements of growing urban populations outstripped the capacity of supplies from the southern North Sea. Marine fisheries thus began to expand, with fish procured over increasingly long distances (eg from Arctic Norway, Iceland and the Northern Isles of Scotland to London; Fig CS9.2 and CS9.3; Barrett *et al* 2011; Orton *et al* 2014). In collaboration with the University of Hull, ancient DNA is being used to investigate when procurement first extended beyond Iceland, for example to Newfoundland. Preliminary results from the genetic study of 272 medieval and post-medieval cod bones suggest that this occurred in the mid-16th century.

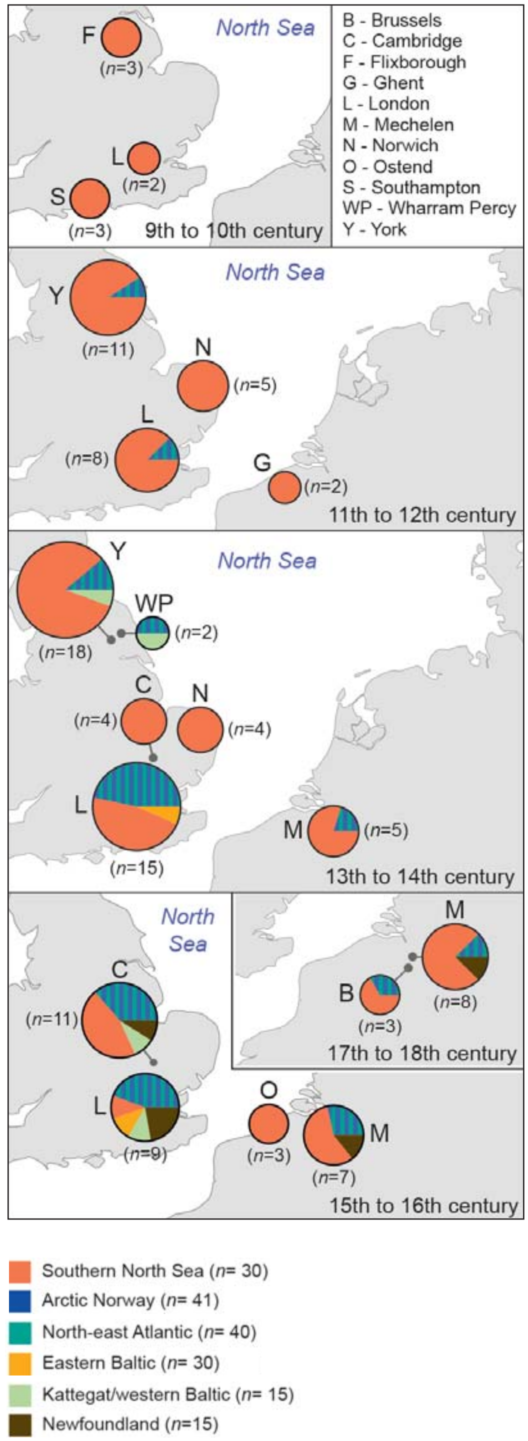


Fig CS9.3
Local (southern North Sea) and imported cod bones in England and Flanders based on discriminant function analysis of $\delta^{13}C$ and $\delta^{15}N$ measurements on 129 archaeological fish bones (vertebrae and cleithra). [Adapted from Barrett *et al* 2011, fig 4 © Elsevier]

Appendix 1: Scientific names for species mentioned in text

The taxonomy of all species is under constant review by specialists. The names used in this table reflect those used in the Historic England zooarchaeology reference collection and the National Zooarchaeology Reference Resource (NZRR; Fairnell and Orton 2017), along with common alternatives.

Common name	Scientific name (genus and species)	Scientific* family and relevant animals	Scientific* order
Mammal species			
Aurochs	*Bos primigenius*	Bovidae: cattle, goats and sheep	Artiodactyla
Beaver	*Castor fiber*	Castoridae: beavers	Rodentia
Black rat/ship rat	*Rattus rattus*	Muridae: mice, rats and voles	Rodentia
Brown bear	*Ursus arctos*	Ursidae: bears	Carnivora
Brown hare	*Lepus europaeus*	Leporidae: rabbits and hares	Lagomorpha
Brown rat/common rat	*Rattus norvegicus*	Muridae: mice, rats and voles	Rodentia
Cat	*Felis catus*	Felidae: cats	Carnivora
Cattle	*Bos taurus*	Bovidae: cattle, goats and sheep	Artiodactyla
Common shrew	*Sorex araneus*	Muridae: mice, rats and voles	Rodentia
Dog	*Canis familiaris*	Canidae: dogs, foxes and wolves	Carnivora
Donkey	*Equus asinus*	Equidae: horses, donkeys and mules	Perissodactyla
Elk	*Alces alces*	Cervidae: deer	Artiodactyla
Fallow deer	*Dama dama*	Cervidae: deer	Artiodactyla
Field vole	*Microtus agrestis*	Muridae: mice, rats and voles	Rodentia
Goat	*Capra hircus*	Bovidae: cattle, goats and sheep	Artiodactyla
Grey squirrel	*Sciurus carolinensis*	Sciuridae: squirrels	Rodentia
Horse	*Equus caballus*	Equidae: horses, donkeys and mules	Perissodactyla
House mouse	*Mus musculus* or *Mus domesticus*	Muridae: mice, rats and voles	Rodentia
Ibex	*Capra ibex*	Bovidae: cattle, goats and sheep	Artiodactyla
Lynx	*Lynx lynx*	Felidae: cats	Carnivora
Mule	*E. caballus* × *E. asinus*	Equidae: horses, donkeys and mules	Perissodactyla
Pig	*Sus domesticus* or *Sus scrofa*	Suidae: pigs	Artiodactyla
Rabbit	*Oryctolagus cuniculus*	Leporidae: rabbits and hares	Lagomorpha
Red deer	*Cervus elaphus*	Cervidae: deer	Artiodactyla
Red squirrel	*Sciurus vulgaris*	Sciuridae: squirrels	Rodentia
Sheep	*Ovis aries*	Bovidae: cattle, goats and sheep	Artiodactyla
Water vole	*Arvicola terrestris*	Muridae: mice, rats and voles	Rodentia
Wild boar	*Sus scrofa*	Suidae: pigs	Artiodactyla
Wildcat	*Felis silvestris*	Felidae: cats	Carnivora
Wild horse	*Equus ferus*	Equidae: horses, donkeys and mules	Perissodactyla
Wolf	*Canis lupus*	Canidae: dogs, foxes and wolves	Carnivora

Common name	Scientific name (genus and species)	Scientific* family and relevant animals	Scientific* order
Bird species			
Barn owl	*Tyto alba*	Tytonidae: barn owls	Strigiformes
Chicken/domestic fowl	*Gallus domesticus or Gallus gallus*	Phasianidae: chickens, grouse, partridges, pheasants, quails, turkeys	Galliformes
Crane	*Grus grus*	Gruidae: cranes	Gruiformes
Curlew	*Numenius arquata*	Scolopacidae: sandpipers and snipes	Charadriiformes
Dalmation pelican	*Pelecanus crispus*	Pelecanidae: pelicans	Pelecaniformes
Eurasian eagle-owl	*Bubo bubo*	Strigidae: owls	Strigiformes
Great bustard	*Otis tarda*	Otididae: bustards	Otidiformes
Kittiwake	*Rissa tridactyla*	Laridae: gulls and terns	Charadriiformes
Mallard	*Anas platyrhynchos*	Anatidae: ducks, geese and swans	Anseriformes
Peafowl: peahens and peacocks	*Pavo cristatus*	Phasianidae: chickens, grouse, partridges, pheasants, quails, turkeys	Galliformes
Pheasant	*Phasianus colchicus*	Phasianidae: chickens, grouse, partridges, pheasants, quails, turkeys	Galliformes
Short-eared owl	*Asio flammeus*	Strigidae: owls	Strigiformes
Song thrush	*Turdus philomelos*	Turdidae: thrushes	Passeriformes
Sparrowhawk	*Accipiter nisus*	Accipitridae: eagles, hawks and kites	Accipitriformes
Turkey	*Meleagris gallopavo*	Phasianidae: chickens, grouse, partridges, pheasants, quails, turkeys	Galliformes
White-tailed eagle/ sea eagle	*Haliaeetus albicilla*	Accipitridae: eagles, hawks and kites	Accipitriformes
Fish species			
Black sea bream	*Spondyliosoma cantharus*	Sparidae: porgies	Perciformes
Carp	*Cyprinus carpio*	Cyprinidae: carps and minnows	Cypriniformes
Cod	*Gadus morhua*	Gadidae: cods and haddocks	Gadiformes
Eel	*Anguilla anguilla*	Anguillidae: eel	Anguilliformes
Goldsinny/ goldsinny wrasse	*Ctenolabrus rupestris*	Labridae: wrasses	Perciformes
Herring	*Clupea harengus*	Clupeidae: herrings, sardines and shads	Clupeiformes
Roker/thornback skate/ thornback ray	*Raja clavata*	Rajidae: skates	Rajiformes
Salmon	*Salmo salar*	Salmonidae: salmons and trouts	Salmoniformes
Reptile species			
Slow worm	*Anguis fragilis*	Anguidae: slow worm	Squamata
Amphibian species			
Common frog	*Rana temporaria*	Ranidae: frogs	Anura
Common toad	*Bufo bufo*	Bufonidae: toads	Anura
Pool frog	*Rana lessonae*	Ranidae: frogs	Anura

*The scientific term for family may be cited in an anglicised version by omitting 'ae'; anglicisation of the scientific term for order is subject to varying modification.

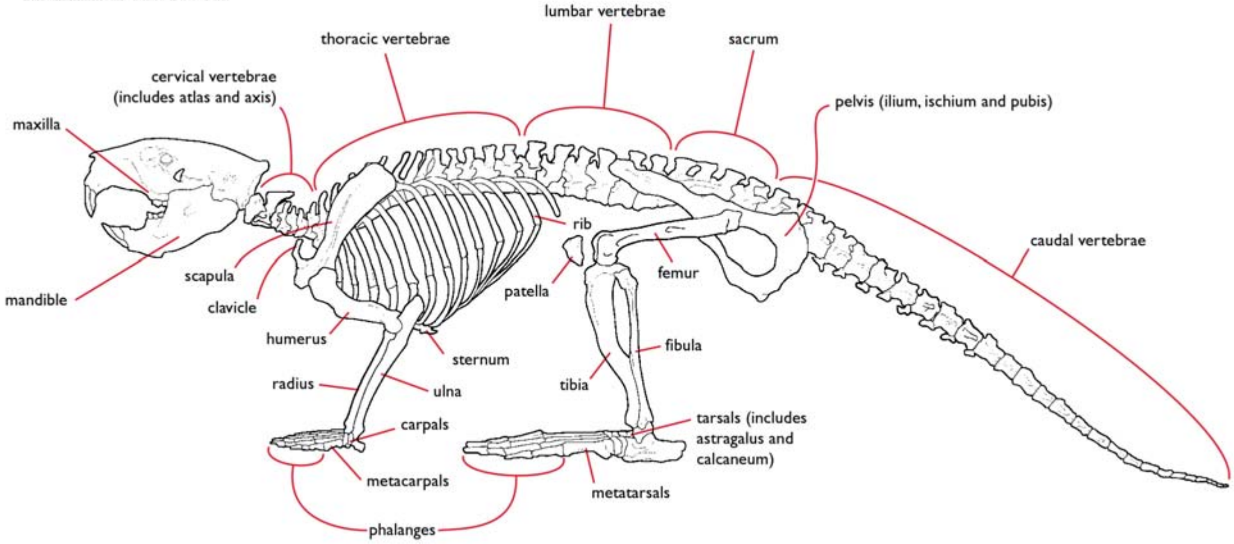
Appendix 2: Assessment and analysis information checklist

Assessment	Analysis	Data required
		1 Site narrative to include
☐	☐	Site location
	☐	Local geology (bedrock and/or soil type and pH)
☐	☐	Site type and interpretation
☐	☐	Site chronology
	☐	Size of excavated area(s)
	☐	Labelled plan of excavated features, by phase if appropriate
	☐	Intra-site functional variation, including key stratigraphic groups
☐	☐	Site disturbance (eg ploughing or erosion)
☐	☐	Information on any existing site reports (and bone reports)
☐	☐	Information about any worked bone or bone artefacts not sent to the zooarchaeologist
☐	☐	Any images or comments on the animal bone assemblage *in situ*
		2 Interpretative context index (DIGITAL) to include:
☐	☐	Context numbers for entire excavation
☐	☐	Whether animal bone was recovered, with quantification (eg number of bags)
☐	☐	Phase
	☐	Context type (eg layer or fill)
☐	☐	Context interpretation (eg post-hole fill)
☐	☐	Group number
	☐	Direct stratigraphic relationships
	☐	Identity of parent feature type and feature number (if a fill)
☐	☐	Assessment of context integrity (eg evidence for residual pottery or sealed layer)
	☐	Materials recovered other than animal bone
		3 Sample index (DIGITAL) to include:
☐	☐	Volume of each sample
☐	☐	Sample type/method of processing
☐	☐	Volume processed
☐	☐	Reason for sampling
		4 Additional documentation including:
	☐	A copy of the bone assessment report (and any other previous reports), with any associated data and recommendations
☐	☐	The research questions that are to be addressed by bone assessment or analysis
☐	☐	Up-to-date project documentation (project proposal, project design, etc), including excavation methods
		5 Box lists to include:
☐	☐	Identity of contexts represented in box and number of bags of animal bone from each context
☐	☐	Identity of samples represented in box and number of bags of animal bone from each fraction
		6 Whether or not the animal bones themselves are marked, their bags should indicate:
☐	☐	Site/event
☐	☐	Context number
☐	☐	Sample number
☐	☐	Small find number
☐	☐	Skeleton number (or equivalent)
☐	☐	Fraction

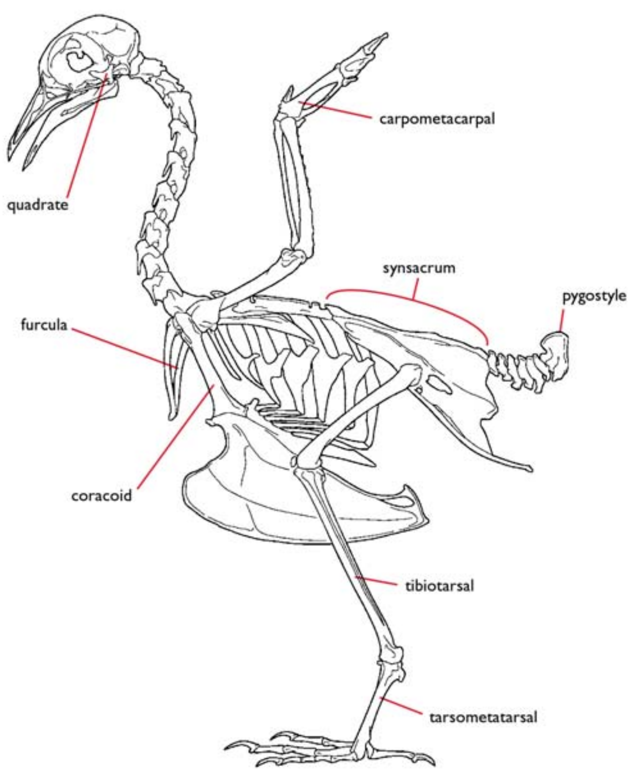
Appendix 3: Anatomical location of bones commonly cited in zooarchaeological reports

Bones are only labelled in the bird and amphibian diagrams if their name or presence differs from the mammal skeleton. Alternative naming systems may also be used. Fish skulls have a complex arrangement of bones and are not presented here. For fish bone names *see* University of Nottingham (2011).

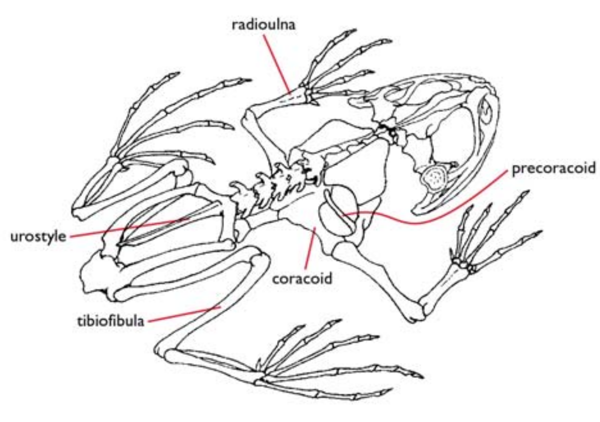
Mammal skeleton



Bird skeleton



Anuran skeleton



[Mammal and bird skeleton diagrams by M Coutureau (Inrap), © 2003 and 2005 ArcheoZoo.org; amphibian skeleton diagram by I Livingstone, © BIODIDAC, Licence: Creative Commons Attribution-NonCommercial 4.0 International Licence. Images adapted for use by V Griffin].

Glossary

Anatomical position of commonly reported bones is illustrated in Appendix 3.

ABG animal bone group, also sometimes referred to as associated bone group or articulated bone group; used for partial or whole skeletons with bones in their anatomical position (*see* p 18)

aDNA ancient deoxyribonucleic acid (DNA); DNA from archaeological bones

allometry how traits scale with each other, eg the relationship between an individual bone measurement and body size during growth

anaerobic conditions lacking oxygen, thus halting or slowing microbial decay

analysis a particular stage of zooarchaeological study, usually occurring after an assessment (*see* pp 29–33); the term analysis is also used more generally for the process of methodical study in order to answer research questions

ankylosis/ankylosed an abnormal union of bones leading to immobility of joints

anthropogenic resulting from human activity

Anura/anuran amphibians that lack a tail (eg frogs and toads)

assessment a particular stage of zooarchaeological study that considers the assemblage's potential and identifies further work (*see* pp 25–29)

avian relating to birds

axial relating to the mid-line of the body (eg vertebrae) as opposed to the right or left side

baculum (plural **baculae**) penis bone, found in males of some species

bimodal used to describe datasets showing the presence of two groups

biochemical relating to the chemical composition of biological tissues

biogeography the study of the temporal and geographical distribution of animals

biometry the measurement of skeletal structures and the study of resulting data (*see* pp 48–50); the term osteometry is also sometimes used

bit wear the abrasion of teeth as a result of wearing of a bit

bustum (plural **busta**) Roman cremation tradition combining the pyre and grave site

calcined a burnt state typically characterised by white-grey coloured bone

cancellous bone a bone structure found within some cavities, eg articular ends of long bones; also called trabecular or spongy bone

cementum a bone-like substance deposited on tooth roots and occasionally crowns

cleithrum (plural **cleithra**) a bone of the pectoral (shoulder) girdle in fish; butchered cleithra may assist in the identification of dried fish (eg stockfish)

collagen a protein making up 95% of the organic component of bone

commensal species wild or feral animals exploiting human settlement for food, water or shelter

compact bone a dense bone structure that forms the shafts and outer surface of bones

dentine a continually deposited bone-like substance located within the tooth crown and root, surrounding the pulp chamber

dermal denticles plate-like scales found in the skin of sharks, rays and chimaeras (cartilaginous fish); the teeth of these fish are modified dermal denticles

desiccated a condition in which moisture has been removed

diagenetic/diagenesis physical, biological and chemical processes following deposition

distal term used to indicate away from the body in limb bones

enamel a largely inorganic tissue covering the outer surface of the tooth crown

epiphysis (plural **epiphyses**) the part of a bone that develops separately from the main part and eventually fuses to it as the animal matures (*see* pp 46–48)

evidential value the potential to 'yield evidence about past human activity' (Drury and McPherson 2008, 7)

fauna/faunal relating to animals

flotation a method of processing environmental samples with water (*see* p 17); flot is the fraction that floats

fluvial relating to the action of rivers or streams

foetal developmental stage prior to birth

foramen (plural **foramina**) a small hole in a bone for the passage of blood vessels or nerves, such as mental foramina in mandibles

geometric morphometrics a statistical analysis of shape using the position of bone features

habitat the location in the environment in which an animal lives, including physical and biological resources

hammerscale micro-residue from iron smithing, comprising black flakes and spheres, typically a few millimetres across

herbivore an animal that feeds on plants; in British bone assemblages herbivores commonly include cattle, sheep, deer and horses, and small animals such as rabbits, hares and voles

heritage asset 'A building, monument, site, place, area or landscape identified as having a degree of significance meriting consideration in planning decisions, because of its heritage interest. Heritage asset includes designated heritage assets and assets identified by the local planning authority (including local listing)' (DCLG 2012, 52)

herpetofauna amphibians and reptiles

histology the study of the microstructure of animal tissues

historic environment 'All aspects of the environment resulting from the interaction between people and places through time, including all surviving physical remains of past human activity, whether visible, buried or submerged, and landscaped and planted or managed flora' (DCLG 2012, 52)

Holocene the current warm period following the last glaciation; archaeologically this represents the Mesolithic to modern times (as illustrated in Fig 1.2)

horn core the cranial projection situated inside the horn covering/sheath; present in male and female bovids (eg cattle, sheep and goats) except where naturally polled (hornless)

ilium (plural **ilia**) a part of the pelvic bone

isotopes forms of the same element (eg carbon, nitrogen and oxygen) with the same chemical properties but different atomic mass (ie they contain equal numbers of protons but different numbers of neutrons)

large mammal a term used for classifying fragments the size of cattle, horse and red deer

lipids organic compounds including fats, oils and waxes

local authority archaeology advisor advises the local authority planning team; this role is also known as planning archaeologist, development control archaeologist, county archaeologist and curator

marine relating to the sea or salt-water environments

mass the amount of material in an object measured in kilograms (kg), grams (g), milligram (mg), etc; the term weight is commonly used when referring to mass

medium mammal a term used for classifying fragments the size of sheep, pig and medium–large-sized dog

medullary bone a granular deposit of calcium laid down in female bird bones during the laying season that acts as a supply for egg development

metadata the structure and definitions of data (*see* p 55)

microfauna a term used within vertebrate zooarchaeology to classify the smallest vertebrates; in Britain it is usually used to include amphibians, reptiles and small mammals (as in this document), and sometimes small birds and fish; as the term has no agreed definition, it should be defined whenever used

microwear abrasion on tooth enamel surfaces, used to determine the nature of management, eg diet, foraging versus foddering

mortality profile the distribution of animal age-at-death data

natural death assemblage the accumulation of animal remains through natural processes, eg small mammals trapped in pits

neonatal age stage for newborn animals

non-metric trait minor skeletal variations that are predetermined at birth and may be expressed in one or more forms (discontinuous variation)

omnivore an animal that consumes animal- and plant-derived foods; in British bone assemblages omnivores commonly include pigs and small mammals such as rats and mice

operculum (opercular bones) bones that cover and protect the gills in fish

osteoderm bony scales found in the skin of some reptiles; generally diagnostic to species in British assemblages

osteometry/osteometric the measurement of skeletal structures and the study of resultant data (*see* pp 48–50); the term biometry is also sometimes used

otoliths ear-stones formed of calcium carbonate found in the inner ear of fish

pathology/palaeopathology modification to animal tissues/archaeological animal bone as a result of disease or injury

perinatal age stage around the time of birth (prior to or shortly after)

proximal term used to indicate towards the body in limb bones

proxy an indicator that can be used to represent the value or conditions of something else

scientific dating a method of dating that provides an absolute date or date range, eg radiocarbon dating

skeletal element specific bone or tooth

small mammal a term used to refer to mammals the size of squirrels or smaller

spur/spur scar a bony growth or corresponding scar on the tarsometatarsus, found in galliform birds, usually in males; colloquially known as a cockspur

stockfish preserved fish, usually cod or similar fish, prepared by air drying (and sometimes salting); generally the head is removed

taxonomic/taxonomy/taxon/taxa attribution to an animal or animal category (*see* pp 42–44)

teratogenic agent a chemical or biological agent causing malformation of an embryo or foetus

transhumance a form of livestock management that takes advantage of the seasonal availability of pasture; it typically involves movement between lowlands and highlands

trophic level the position in a food chain occupied by a group of animals

vertebrate an animal with a vertebral column forming part of an internal bony skeleton

zoonosis/zoonotic a disease transmitted between animals and humans

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1: Key reference resources

2: Excavating animal bones (poster)

3: Processing animal bone assemblages (poster)

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Regional reviews of animal bone assemblages and datasets

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Animal Bones and Archaeology: Recovery to Archive aims to promote high professional standards in zooarchaeological practice, from planning excavations through recovery, reporting and archiving. Written for archaeology advisors, field archaeologists and zooarchaeologists, this handbook outlines the potential of animal bones from archaeological sites, highlighting the importance of archaeological methods and promoting understanding of zooarchaeological reports and datasets. The concepts and processes discussed are illustrated by case studies from across England. The volume is supported by posters for use in the field and laboratory, and a supplementary bibliography of assemblage syntheses and technical resources. Originally published as *Animal Bones and Archaeology: Guidelines for Best Practice* (English Heritage 2014), this handbook was written in collaboration with specialists from the academic, public and private sectors in the UK. It is considered a standard resource on university reading lists, laboratory benches and office bookshelves.

Historic England zooarchaeologists Polydora Baker and Fay Worley have backgrounds in the academic and commercial archaeology sectors. Their research interests focus on UK animal bone assemblages but span the Holocene from the North Atlantic through to the Mediterranean. In addition to providing specialist research, advice and training, they manage the Historic England Zooarchaeology Reference Collection and administer the Professional Zooarchaeology Group.

> *This is a monument to collegiality and makes me proud to be a zooarchaeologist.*
> Naomi Sykes, Lawrence Professor of Archaeology, University of Exeter

> *This is a superb resource and the presentation format is particularly effective for reaching many different audiences.*
> Kitty Emery, Associate Curator of Environmental Archaeology, Florida Museum of Natural History

> *It will make readers see that there’s a lot more to animal bones in archaeology than they’d imagined and much of it has relevance to other techniques in archaeological projects.*
> Jane Corcoran, Science Advisor, Historic England

Historic England Handbooks for Archaeology