Circaea 10 (1) (1993 for 1992)

Papers from the bone taphonomy workshop at York, September 1991

An investigation into the effects on fish bone of passage through the human gut: some experiments and comparisons with archaeological material

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Summary

The survival rate and appearance of clupeid fish bones after consumption by a human is examined, and comparisons made with assemblages of clupeid bones recovered archaeologically. Several sizes of fish were ingested, on five separate occasions. While the proportion of bones surviving in a recognisable form varied, the types of skeletal elements surviving remained fairly constant. In all cases the proportions of bones surviving was very low, but the relationship between fish bone survival and fish size was not straightforward. While all bones from very small fish were lost, those from the largest fish survived less well than bones from smaller individuals. Characteristic forms of crushing and etching were observed, and these forms of damage, as well as the skeletal element distributions, are used to try to distinguish excavated assemblages of bones originating in human faeces from fish bone originating from other sources.

Introduction

Background

In recent years there have been a number of investigations into the means by which different predators may be recognised from the types of damage they inflict on bones. These studies have principally concentrated on large carnivores (Brain 1981; Binford 1981; Stallibrass 1986; 1990) and avian raptors (Mayhew 1977; Dodson and Wexlar 1979; Korth 1979; Denys 1985; Andrews 1990) as predators on large and small mammals. However, for most archaeological sites the principal accumulator of bones was probably man. At least a proportion of the smaller bones are likely to have been ingested rather than discarded before eating, and such bones would be predicted to be recovered from archaeological sites in considerable numbers.

Occasionally coprolites and pellets are recovered intact from archaeological excavations, usually from dry sites but sometimes in desiccated or mineralised form (e.g. the human coprolite from the site of 6-8 Pavement, York (Jones 1983)). Many of these appear to have been dog coprolites (e.g. Dimbleby 1968; Paap 1976; Jones 1990). Other archaeological studies of intact ancient human coprolites containing bones include reports of some containing numerous fish remains, for example those from Lovelock Cave, Churchill County, Nevada (Follett 1967; 1970). Intact human as well as dog coprolites have also been recovered from Lake Cahuilla, Coachella Valley, California (Wilke 1978). However, it is fairly unusual for whole coprolites to be identified in archaeology. More often the matrix will disintegrate, making their contents less easy to recognise. It is for this reason that investigations into criteria by which digested remains may be identified are required.

Despite the prevalence of contexts interpreted as possible cess pits during excavation, and the likelihood of a human faecal component in many, particularly urban, archaeological deposits, there have been relatively few studies of the components of modern human faeces. Considering the unpleasantness of the task, this is not altogether surprising. Examining coprolites from antiquity is much less noxious, and more socially acceptable, than studying contemporary faeces.

There is a very small literature detailing experimental work into the effects on organic materials of passage through the human gut. In 1977 Calder published one such account. Among the organic materials tested were scales of a flounder (*Rhombosolea* sp.) and a sole (*Peltorhamphus novae-zeelandiae*), shark dermal denticles (species unspecified), limpet (Calyptroeidae) radulae and periwinkle (Littorinidae) opercula. Of these, the scales were completely digested, while almost all of

Experiment No:	1	2	3	4	5	
Species ingested:	kipper	sardines	sardines	sardines	sardines	*Approx. expected no. per fish
No.	1	5	5	5	5	
*Approx. no. identifiable bones in 1 fish	80	80	80	80	80	
No. whole vertebral centra recovered	1	18	14	4	8	54
No. other bones recovered	1	6	4	1	1	26
No. eye lenses recovered	0	1	7	8	6	2
No. otoliths recovered	0	0	0	1	0	2
% survival whole fish of all bones	2.5	6.0	4.5	1.3	2.3	
% survival of whole vertebral centra	1.8	6.7	5.2	1.5	3.0	

*Table 2. Survival of fish bones through the human digestive system (excluding the 25 small herring/sprats eaten with the kipper in Experiment 1, from which no identifiable bones survived). * The expected numbers of bones in one fish (80) is based on the figures given by Jones (Wheeler and Jones 1989) to facilitate comparison with Jones' experiments. However, Jones does not detail the elements included in this figure for herring, so that the exact skeletal elements considered by him are not known. The present author considers a much greater number of head and pelvic elements (bones of the cranium, skull and pelvic region excluding spines, ribs, rays and branchial bones, etc.) to be identifiable. Otoliths and lenses are not included in the 'bone' category.*

the mollusc parts and shark denticles were recovered intact.

Jones (1984; 1986) examined the loss of bone after passage through the digestive tracts of a dog, a pig, a rat and a man, and documented the types of damage seen on the very few fragments which survived the process. Payne and Munson extracted bones after fish were fed to a dog, and these were examined by Jones (details in Jones 1984).

Objectives and approach

Undeterred by the social consequences, this author set out to augment Andrew Jones' courageous work and further investigate the effects on fish bone of human digestion. Jones himself ate only one kipper, so there was clearly a need for replication to examine the extent of variation in patterns of bone survival. The principal objective of the experiments described below was therefore to investigate whether the sorts of bones which

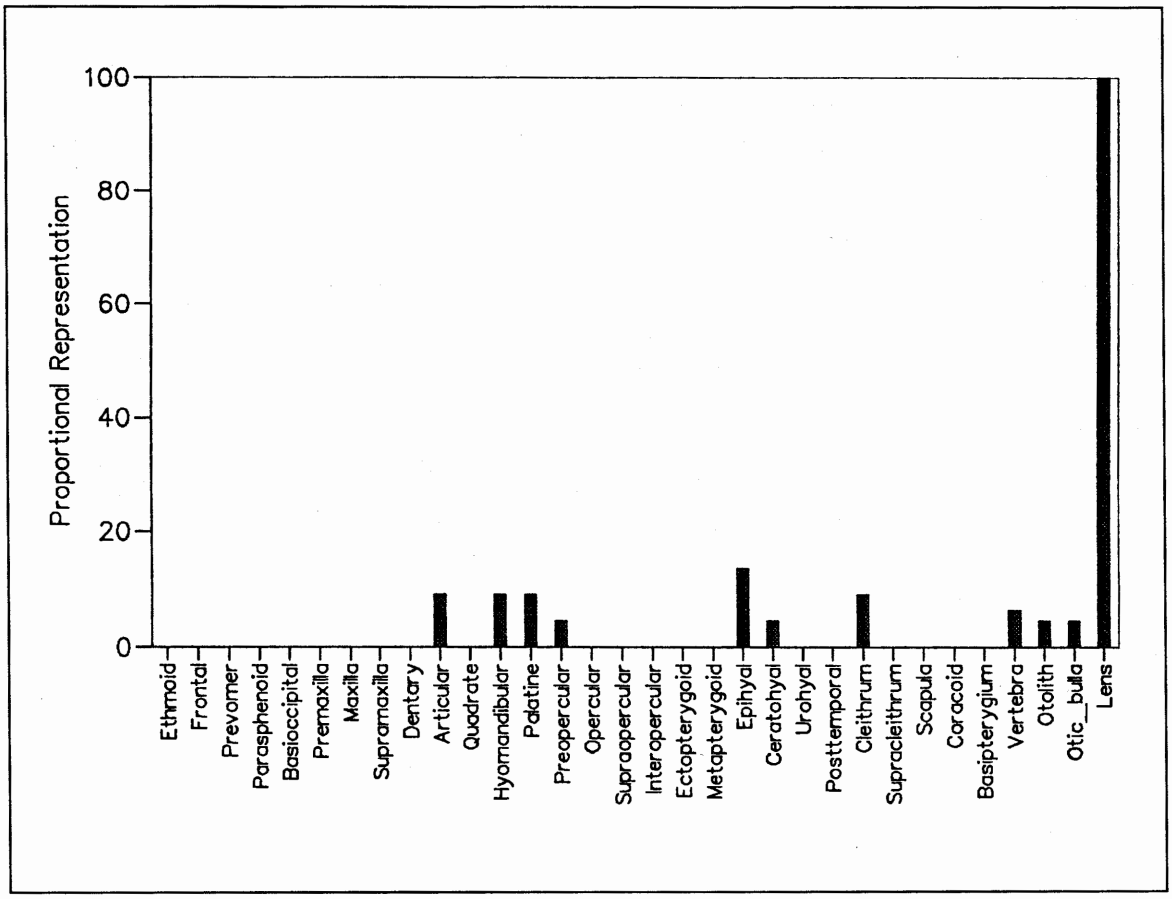

Figure 17. Proportional representation of clupeid skeletal elements after human digestion.

survive the human digestive process, and the types of damage inflicted on them, is predictable, or whether variability in digestive efficiency leads to great variation in the resulting bone assemblage. From an archaeological viewpoint, the experiment was therefore designed to assess the extent to which humans modify bone assemblages during ingestion and digestion and, secondly, to assess the potential for recognising in archaeozoological assemblages bones which have passed through the human digestive tract.

To look at the effects of human digestion on ingested fish bones a number of complete fish were eaten. Several sizes of fish were used, the limits to size and species being set by the feasibility of swallowing the bones. The digested bone assemblages were then compared with assemblages of small fish remains recovered from archaeological deposits, in an attempt to determine whether the archaeological bones had, in fact, been deposited in human faeces. Human-digested bone assemblages are elsewhere compared with assemblages of small fish bones recovered from otter spraints, seal scats, gull pellets and water-abraded skeletons (Nicholson 1991a).

Materials and methods

Whole fish, lightly cooked, were eaten by the author on five separate occasions. On the first occasion one kipper (*Clupea harengus* L. total length 300 mm) and 25 whitebait (young herrings, also *C. harengus* L. and sprats *Sprattus sprattus* (L.), of lengths from 60 mm to 80 mm) were eaten. On the subsequent occasions five sardines (*Sardina pilchardus* (Walbaum) of total lengths from 160 mm to 190 mm) were consumed. Each fish was eaten in its entirety, after frying or grilling for up to five minutes; this caused charring to the fins,

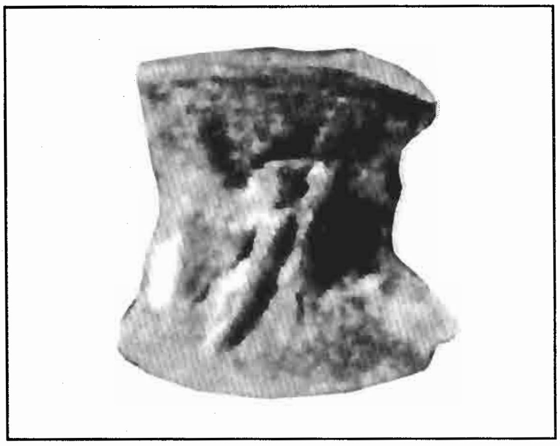

Figure 18. Detail of medio-lateral compression of a clupeid vertebral centrum as a result of chewing (x12).

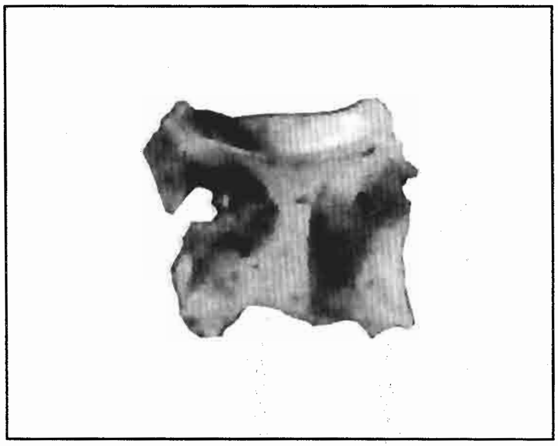

Figure 19. Detail of crenellation to the edges of a clupeid vertebral centrum caused by acid dissolution (x10).

but otherwise the bones appeared undamaged. With each fish meal, approximately 200 g of tinned sweetcorn (*Zea mays* L.) was eaten, which acted as a marker to indicate when the entire meal had passed through the gut, as recommended by Calder (1977). Bread was also consumed, as the bones (especially the kipper's head bones) were sometimes difficult to swallow. It was found that the fish heads required more mastication than the vertebrae. Many vertebrae were probably swallowed unchewed. Faeces were collected for five or six days after each sample of fish had been eaten. These faeces were soaked in warm water for up to 24 hours. Disaggregation proved to be possible without recourse to the chemicals described by Calder (*ibid.*), by passing a stream of hot water over the faeces, held in a 500 micron mesh sieve. The residue was further cleaned by moving the base of the sieve up and down in a shallow bowl of warm water. The residues were sorted either wet or after drying at 40°C. Bones were picked out using a low-powered dissecting microscope.

Results and discussion

Of all the complete fish eaten, very few bones survived the digestive process. Details of the recovered fragments are given in the appendix and summarised in Table 2. Figure 17 illustrates graphically the proportional representation of skeletal elements recovered, based on the pooled results from all the fish ingested.

The proportional representation of skeletal elements (PR) has been calculated using the method given by Dodson and Wexlar (1979, table 1) and is based on the numbers of bones surviving compared with the expected number:

$$PR = \frac{F_o}{F_t \ x \ MNI} \ x \ 100$$

where F_o = the number of recovered bones, otoliths or lenses (for each skeletal element); MNI = the minimum number of individuals, by the most frequent bone; F_T = the expected number of the element in one individual.

The minimum number of individuals (MNI) is calculated in the conventional way, from the most commonly represented bone in the assemblage. It should be noted that this figure *is* a minimum; the most commonly represented bone will probably have suffered some loss too.

The extremely low numbers of bones which survived digestion are of similar proportions to those reported by Jones (1986) and Wheeler and Jones (1989, 73-4). Most bones were damaged and, of those identified, many would not have been identified to species had I not known what was swallowed. None of the whitebait bones survived in any form. Figure 17 illustrates the extent of bone loss, expressed as the proportional representation

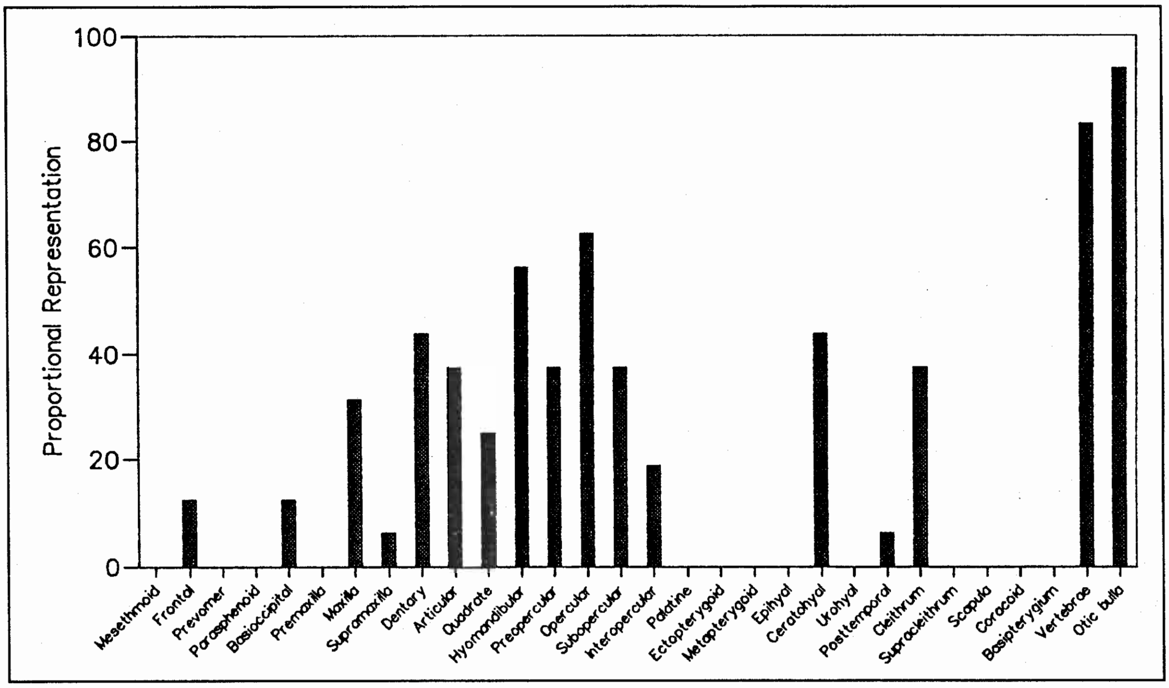

Figure 22. Proportional representation of clupeid skeletal elements from Queen Street, Newcastle-upon-Tyne, England.

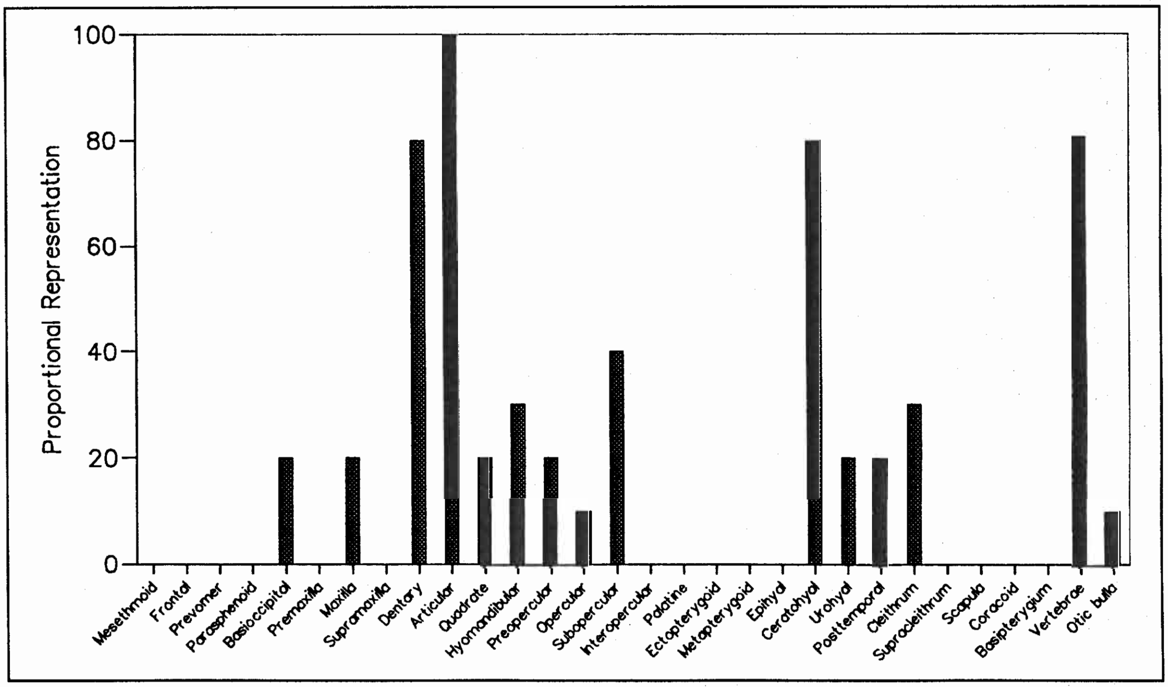

Figure 23. Proportional representation of clupeid skeletal elements from Crown Court, Newcastle-upon-Tyne, England.

of skeletal elements; thus the recovered assemblage is treated as if it were from an archaeological sample in which the number of individuals would be calculated as a minimum (MNI) rather than known in advance. The range of potentially identifiable skeletal elements listed in Figure 17 is based upon those bones which this author considers identifiable among the Clupeidae, and includes a greater number of skeletal elements than considered by Jones (see Table 2). Because of the small numbers of bones which survived, and the relatively low numbers of fish ingested, only very crude conclusions may be drawn about the relative survival rates of different parts of the skeleton, by calculating the percentage rates for vertebrae and for the entire skeleton as a unit (Table 2).

Of all the parts of the skeleton, for the species used in these experiments, the eye lens was by far the most resilient element. Unfortunately, as eye lenses are not calcified their survival in all but exceptional sediments is unlikely. Lenses might also be misidentified as seeds. Thus concentrations of eye lenses cannot be used as a diagnostic feature of deposits containing human faecal material.

The destruction of almost all head bones indicates that it may not be possible to say whether complete fish were consumed from assemblages of bones contained in faecal material. The lower survival rate for the larger kipper (herring) when compared with the sardines may result from the greater amount of mastication necessary to enable swallowing of the kipper bones. As all whitebait bones were lost, chewing clearly does not provide the whole explanation for differences in survival, however. Bone size must also play a part, as may the extent of calcification, which will be related both to fish species and age. The survival of scale fragments is contrary to the results given by Calder (1977) who found that no fish scales survived digestion.

Most of the vertebrae recovered were crushed: the most common form of damage was compression and breakage of the struts supporting the two articulating facets (Fig. 18). This commonly resulted in the two halves being separated. Many fragments of the centrum rim were also recovered. Several vertebrae were stained black or dark brown. These specimens commonly exhibited extreme acid dissolution, causing crenellation and rounding to the edges of the articulating facets (Fig. 19). Erosion causing smooth crenellated edges was also observed on other fragments, not all of them identifiable. There was no obvious correlation between extent of bone erosion and the length of time before the bone was passed in the faeces. Complete, unstained and uneroded vertebrae were recovered with stained and eroded specimens.

Evidently the efficiency of the digestive system varies, even in one individual. As only fish of the Clupeidae were consumed in these experiments it would be useful to use fish of other families and to compare the results. Eel, *Anguilla anguilla* (L.), and stickleback, *Gasterosteus aculeatus* L., bones are commonly found in deposits where human faeces are suspected, and other small fish could also potentially be consumed whole. It is to be expected that the efficiency of the digestive system will vary between individuals and depending on the health of the individual. Other variable factors must also include the extent of chewing, itself influenced by the number and condition of teeth, and the amount of 'padding' surrounding the bone when consumed. Preparation techniques, such as boiling, roasting and drying may also affect the extent to which bones will be digested. Archaeological deposits containing faeces are frequently identified by the presence of abundant intestinal parasite eggs (see below), and heavily parasitised individuals may digest food in a different way from healthy individuals. Stomach upsets would also be likely to reduce the efficiency of digestion. The experiment described here only provides a starting point; ideally many more experiments should be undertaken, using a number of different individuals, to establish the variation in digestive function.

Do different mammalian digestive systems affect bone differently?

Inevitably, in the absence of extensive experiment replication a cautious approach must be taken when attempting to identify the consumer from an assemblage of apparently chewed and digested bone. Considering the experiments which have been performed by this author (Nicholson 1991a) and by Jones (1984; 1986; and Wheeler and Jones 1989, 70–2), however, certain traits may be suggested.

When small (120 mm) complete herring and small complete plaice (*Pleuronectes platessa* L., 130 mm) were offered to rats Jones found that all bones were completely ingested; none were present in the faeces. A larger herring (270 mm) was also offered to the rats, and had some remains not been removed from the cage to prevent excessive decomposition and smell, Jones felt all these bones would have been ingested, too. A pig eagerly ate a large fresh herring (255 mm) and mackerel (*Scomber scombrus* L., 355 mm), producing only seven identifiable fragments per fish in its faeces. No descriptions of damage to the bones were given. A dog consumed a large herring (273 mm) and haddock (*Gadus morhua* L., 325 mm), lightly fried. Nine identifiable herring bones and ten haddock bones were passed in the faeces, most exhibiting damage from chewing.

Etching of the centrum facet of one herring vertebra is illustrated in Wheeler and Jones (1989, 73) and is similar to that observed by this author on some human-digested vertebrae. Two red snappers (*Lutjanus campechanus*) of about 450 g were fed to a dog by Payne and Munson (Jones 1984). Even for this relatively robustly-boned fish over 80% of the ingested bones were lost and, of those surviving, most were chewed and broken, and some etched and corroded. Of all the elements, the eye lens survived best, as also found by this author after human digestion. To summarise this evidence, given the small numbers of bones surviving digestion in pig, dog and man, and the extensive damage inflicted to most bones on ingestion by all these animals, it seems unlikely that in the absence of other evidence (such as associated parasite eggs) the mammal responsible for small numbers of chewed and etched fish bones can be identified with any degree of certainty.

By contrast, this author has also examined fish bones from contemporary otter (*Lutra lutra* (L.)) spraints from Scotland and Shetland (details in Nicholson 1991a), and found remarkably little damage to the fish skeleton. Although the number and species of fish consumed was not controlled, it was clear that as far as small fish (of under about 150 mm) are concerned almost no discernible loss of bone occurs with digestion. All bones of the skeleton were present, including otoliths, and signs of chewing and etching were restricted to a relatively small proportion of bones (often less than 30% of vertebrae appeared to have been chewed). Bones from larger fish were generally much more heavily chewed, and usually at most only one or two of these larger bones were present in a single spraint. Presumably the difference relates to the otter's ability to swallow small fish in their entirety, with minimal mastication, while large fish are treated with more care. Bones from grey seal (*Halichoerus grypus* Fabricius) droppings, also examined by the author (Nicholson 1991a), frequently displayed very extensive corrosion, but again otoliths seem to survive particularly well, even when from small fish such as sand eels (Ammodytidae).

Archaeological material

Having established that fish bones sustain considerable loss and damage during chewing and passage through the human gut, archaeological material from supposed cess pits from two sites—Viborg Søndersø and Thetford Redcastle Furze—was examined to see whether the fish bone exhibited similar features.

(a) Viborg Søndersø

Fish bones were recovered from waterlogged richly organic layers with a faecal component, excavated from beneath structures of Viking Age date at Viborg Søndersø, Denmark (D. E. Robinson, pers. comm.). The bones were recovered from two soil samples of wet weights 458 g and 375 g. These samples were sieved to 500 microns and the residues sorted using a low-powered binocular microscope. Further details are given in Nicholson 1991b.

In total, 201 bones were examined from context 1677, and 143 bones from context 1682. The faecal component in these deposits was inferred from the botanical remains and from the presence of eggs from the whipworm *Trichuris trichiura* (L.), a human gut parasite (Robinson and Boldsen 1989).

The fish species represented included eel *Anguilla anguilla*, herring *Clupea harengus* and possibly sprat *Sprattus sprattus*, flounder *Platichthys flesus* (L.), perch *Perca fluviatilis* L., bleak *Alburnus alburnus* (L.), possibly dace *Leuciscus leuciscus* (L.) and other cyprinids not further identified. With the exception of some of the herring bones (from individuals between 300-350 mm length) and the flounder dermal denticles (representing fish of at least 400 mm long), all bones were from fish of less than 150 mm total length. (Total length was estimated by comparison with bones from modern fish of known length.)

Context 1677

Eel	24 vertebrae (8 crushed/chewed).
Herring	2 otic bullae (charred), 1 basioccipital, 22 vertebrae (3 crushed/chewed).
Perch (small)	1 interopercular, 2 preoperculars, 1 prevomer (charred), 1 articular (crushed), 1 quadrate, 1 scale, 5 spines, 73 vertebrae (13 charred, 9 crushed/chewed).
?Perch (small)	1 infrapharyngeal.
Bleak	1 premaxilla.
?Dace	1 dentary.
Cyprinid	15 vertebrae (2 charred)
Unidentified	1 epihyal, 1 basioccipital, 46 vertebrae (12 charred, 8 crushed), 1 hypural, about 70 spines, rays, ribs and 150 fragments.

Context 1682

Eel	2 epihyals, 30 vertebrae (14 crushed/chewed).
Herring	1 mesethmoid, 28 vertebrae (1 charred, 3 crushed).
Clupeid	46 vertebrae (2 ?crushed).
Perch	2 spines.
?Perch (small)	2 vertebrae (1 charred, both crushed/chewed).
Cyprinid (small)	6 vertebrae (1 charred).
Flounder	2 dermal denticles.
Unidentified	1 eye lens, 1 ceratohyal, 2 hyomandibulars, 1 cleithrum, 1 postcleithrum, 18 vertebrae (2 charred, 13 crushed/chewed), about 40 rays, spines, ribs and 50 fragments.

Table 3. Fish remains from Viborg Søndersø, contexts 1677 and 1682.

A small number of bones appeared charred, as indicated by a black peeling layer seen under the light microscope and confirmed under the scanning electron microscope. Only slight charring was observed, consistent with burning during cooking rather than resulting from rubbish disposal. Both assemblages also included a proportion of vertebral centra distorted in a manner consistent with chewing prior to swallowing, but most bones were complete (Table 3). The number of bones was too small to draw firm conclusions about the representation of skeletal elements; however, it is worth noting that a very limited range of bones was present. No bones appeared to have been partly dissolved or etched. Complete centra included a number from very small (under 100 mm total length) herring or sprat. The survival of these bones through the gut seems unlikely given the results of the experiments detailed above. No bones from the small clupeids (whitebait) survived digestion in the experiment although, as discussed above, it might be postulated that digestive disorders could affect the extent of bone destruction.

Without many more experiments it is not possible to state with certainty that undistorted, complete tiny clupeid vertebrae could not withstand digestion, but the results of these experiments indicate that it is unlikely. It appears, therefore, that while a faecal component was present, many of the fish remains from Viborg Søndersø probably represent table waste, and/or fish discarded at the food preparation stage—possibly from the guts of larger fish.

(b) Thetford Redcastle Furze

Fish bones were also recovered from excavations at Thetford Redcastle Furze, Norfolk, England. The bones had been recovered from samples of sediment which had been wet-sieved through 1 mm mesh (further details in Nicholson, forthcoming).

The assemblages considered here were recovered from five contexts: 795 (dated to the early Saxon period), 565 and 1677 (late Saxon), 1719 and 1720 (medieval, probably fourteenth century). All but the first were considered possibly to have been cesspits by the excavator (P. Murphy pers. comm.), and bones from context 565 were covered in a calcareous concretion presumed to be mineralised faeces.

Context 795

Eel	6 vertebrae (1 crushed/chewed);
Unidentified	4 vertebrae.

Context 565

Eel	62 vertebrae (8 crushed/chewed, 10 burnt or charred), 1 prevomer.
Herring	71 vertebrae (4 charred, 14 crushed/chewed), 1 basioccipital, 1 cleithrum, 1 interopercular, 1 otic bulla.
Unidentified	1 tooth, 1 parasphenoid, 20 vertebrae, 11 fragments.

Context 1677

Eel	1 vertebra.
Herring	4 vertebrae.
Unidentified	1 vertebra, 1 fragment.

Context 1719

Eel	8 vertebrae (3 crushed/chewed), 1 cleithrum.
Herring	15 vertebrae (1 burnt, 7 crushed/chewed), 1 otic bulla.
Clupeidae	11 vertebrae (2 crushed/chewed).
Stickleback	2 spines, 3 basipterygia, 1 skull fragment.
Cyprinidae (small)	2 vertebrae.
?Perch (small)	2 vertebrae.
Unidentified	2 vertebrae, 17 fragments.

Context 1720

Eel	2 vertebrae (crushed/chewed).
Herring	11 vertebrae (2 charred).
?Ruffe	1 otolith.
Stickleback	2 spines, 6 basipterygia.
Unidentified	1 cleithrum, 8 fragments.

Table 4. The fish remains from Redcastle Furze, contexts 795, 565, 1677, 1719, and 1720.

Species included eel *Anguilla anguilla*, herring *Clupea harengus*, Clupeidae (probably small herring or sprat), stickleback *Gasterosteus aculeatus*, Cyprinidae (not further identified), and possibly ruffe *Gymnocephalus cernuus* L. and perch *Perca fluviatilis*. Apart from the herring and eel bones, the bones were from fish of under 150 mm total length. Table 4 details the bones recovered, and the numbers of charred and crushed or chewed bones. Each of these contexts contained a proportion of bones crushed in a manner consistent with the damage observed after passage through the human gut. No bones appeared to have been etched in the way seen in some of the bones from the digestion experiments detailed above. However, a very limited range of samples from contexts 1719 and 1720 with herring bones were also examined for parasite eggs. Both deposits were found to contain eggs of the human whipworm *Trichuris trichiura* (Nicholson, forthcoming), supporting the conclusion that these contexts were cesspit fills, and that therefore at least a proportion of the fish bones had passed through the human gut. The similarity in the condition of the fish bones from the other contexts listed above indicates that these too had originated in faeces. Bones from other contexts at Redcastle Furze did not appear crushed, although similar species and sizes of fish were represented.

Discussion

As the experiments into human digestion have only concerned fish of the Clupeidae, comparisons of body part abundance can only properly be made with similar species recovered archaeologically.

In both the Viborg and Thetford assemblages, fish remains from contexts not interpreted as containing faeces were few, so no comparisons between the fish components of probable cesspit and non-cesspit origin could be made. The relatively low numbers of clupeid remains recovered also limits the possibilities for comparison between the archaeological and experimental material.

Herring remains are, however, frequently recovered from archaeological deposits where they do not appear to have arrived in faeces. Two sites which produced herring remains for which an origin in 'cess' was not suspected are the sites of Queen's Street and Crown Court, Newcastle-upon-Tyne, England. Clupeid bones were recovered by wet sieving large (usually 60 l) samples through a 1 mm or a 0.5 mm mesh. The deposits were of mixed origin, but most of the herring remains from Queen Street were recovered from waterlogged deposits interpreted as medieval urban refuse tips. Further details of the deposits and fish bone from them are given by Nicholson (1988; 1989).

Statistical comparisons were not feasible owing to the low numbers of clupeid bones recovered during the experiments and from Viborg and Thetford. The proportional representation of skeletal elements is illustrated by Figs. 20-3 for all the archaeological assemblages, for which the results from all contexts have been pooled.

Perhaps the clearest difference between the Newcastle assemblages when compared with the other bone groups was in the lack of chewed bones from the former. This in itself suggests that the Newcastle bones were not deposited in faeces. Additionally, the recovery of a very restricted range of bones from the material from Viborg and Thetford was reminiscent of the results from the experimental series, and was not in keeping with the trend observed for the Newcastle assemblages. The Viborg and Thetford material included a much greater proportion of vertebrae than in the experimental assemblage, however. This trend is apparent even when the small clupeid vertebrae from Viborg were excluded (as they may not have been consumed, see above). Several explanations are possible. The heads may have been discarded elsewhere, if fish were beheaded for the table, for example. Alternatively, crushed head bones may have been recognised from the experimental material (as all bone remains must have come from the ingested fish), but not from the archaeological material (where small, crushed bones may have been overlooked or classed as unidentifiable). It is also possible that the few surviving head bones were preferentially destroyed after burial. As head bones from herring are thin and fragile, their destruction in preference to vertebrae is likely (as shown in further experiments detailed in Nicholson 1991a), and chewed bones would probably be more at risk than complete bones. Given the small sample sizes further interpretation is unjustifiable; it is the gross differences between the Newcastle assemblages when compared with the other groups (from Viborg, Thetford and the experimental series) which provide the clearest evidence for different depositional origins. The presence of parasite eggs from the human whipworm indicates that in the case of the bones from Thetford and Viborg the consumer was probably *Homo sapiens*.

Conclusion

This study has confirmed the very extensive loss of bone which occurs due to passage through the human digestive system. From a whole ingested fish of size around 400 mm, only about 3% of bones survived. For very small fish these experiments have demonstrated that it is likely that no bones will survive the digestive process. After digestion a proportion of the bones show characteristic etching, crushing, and staining which may be recognised on archaeologically recovered specimens. This, as well as the very limited range of skeletal elements which appear to withstand passage through the gut of most mammals, provides good evidence for a faecal origin for bone assemblages. Determining the consumer is a more difficult task, however, as other mammals also damage bones to a similar degree. As far as possible caution must be used, and other evidence, such as the presence of gut parasite eggs, sought. In certain cases the size of the ingested bones may provide a clue; common sense would suggest that humans are unlikely to have swallowed very large bones. Considering the number of small fish bones likely to have been lost as a result of human digestion, interpretations involving quantification or estimation of meat weights which are drawn from assemblages of bones from contexts where a 'cess' component is suspected should not be attempted.

Acknowledgements

Many thanks to Allan Hall and Harry Kenward and to an anonymous referee for their constructive comments on this paper, and to Bone Jones for inspiration!

References

Andrews, P. (1990). *Owls, caves and fossils.* London: Natural History Museum Publications.

Binford, L. R. (1981). *Bones: ancient men and modern myths.* New York: Academic Press.

Brain, C. K. (1981). *The hunters or the hunted? An introduction to African cave taphonomy.* Chicago: University Press.

Calder, A. M. (1977). Survival properties of organic residues through the human digestive tract. *Journal of Archaeological Science* **4**, 141–52.

Denys, C. (1985). Nouveaux critères de reconnaissance des concentrations de microvertébrés d'après l'étude des pelotes de chouettes du Botswana (Afrique australe). *Bulletin de la Musée Nationale d'Histoire Naturelle de Paris* (4th series), **7**, 879-933.

Dimbleby, G. W. (1968). *Appendix 1. Interim report on environmental investigations,* pp. 250-1 in Cotton, M. A. and Frere, S. S., Ivinghoe Beacon Excavations 1963-5. *Records of Buckinghamshire* **17**.

Dodson, P. and Wexlar, D. (1979). Taphonomic investigations of owl pellets. *Paleobiology* **5**, 275–84.

Follet, W. I. (1967). Fish remains from human coprolites and midden deposits obtained during 1968 and 1969 at Lovelock Cave, Churchill County, Nevada. *University of California Research Facility* **10**, 163-75.

Follet, W. I. (1970). Fish remains from human coprolites and midden deposits obtained during 1968 and 1969 at Lovelock Cave, Churchill County, Nevada. *University of California Archaeological Survey Reports* **70**, 94-115.

Jones, A. K. G. (1983). *A coprolite from 6-8 Pavement,* pp. 225-9 in Hall, A. R., Kenward, H. K., Williams, D. and Greig, J. R. A., Environment and living conditions at two Anglo-Scandinavian sites. *The Archaeology of York* **14**(4), 157–240 + plate I + microfiche 1. London: Council for British Archaeology.

Jones, A. K. G. (1984). *Some effects of the mammalian digestive system on fish bones,* pp. 61-5 in Desse-Berset, N. (ed.), 2nd fish osteoarchaeology meeting. *C.N.R.S. Centres de Recherches Archéologiques. Notes et Monographies Techniques* **16**. Editions du C.N.R.S.

Jones, A. K. G. (1986). *Fish bone survival in the digestive tract of pig, dog and man: some experiments,* pp. 53-61 in Brinkhuizen, D. C. and Clason, A. T. (eds.), Fish and Archaeology. *British Archaeological Reports, International Series* **294**. Oxford.

Jones, A. K. G. (1990). *Coprolites and faecal concretions,* pp. 242-5 in Bell, M. (ed.), Brean Down Excavations 1983-1987. *English Heritage Report* **15**. London: English Heritage.

Korth, W. W. (1979). Taphonomy of microvertebrate fossil assemblages. *Annals of the Carnegie Museum of Natural History* **48**, article 15.

Mayhew, D. F. (1977). Avian predators as accumulators of fossil mammal material. *Boreas* **6**, 25-31.

Nicholson, R. A. (1988). *The fish remains,* pp. 138-47 in O'Brien, C., Bown, L., Dixon, S. and Nicholson, R., The Origins of the Newcastle Quayside. Excavations at Queen Street and Dog Bank. *Society of Antiquaries of Newcastle-upon-Tyne, Monograph Series* **3**.

Nicholson, R. A. (1989). *The fish remains,* pp. 189-96 in O'Brien, C., Bown, L., Dixon, S., Donel, L., Gidney, L. J., Huntley, J., Nicholson, R. and Walton, P., Excavations at Newcastle Quayside: the Crown Court Site. *Archaeologia Aeliana* (5th series) **17**.

Nicholson, R. A. (1991a). *An investigation into variability within archaeologically recovered assemblages of faunal remains: the influence of pre-depositional taphonomic processes.*

Unpublished D.Phil. thesis: University of York.

Nicholson, R. A. (1991b). *The fish remains from Viborg Søndersø.* Unpublished report submitted to D. Robinson, Nationalmuseets, København.

Nicholson, R. A. (forthcoming) The fish remains and parasites from Thetford Redcastle Furze. *East Anglian Archaeology.*

Paap, N. (1976). Coprolites: preliminary results of the investigation of prehistoric faeces from Westfriesland (Province of North Holland, The Netherlands). *Berichte Rijksdienst voor het Oudheidkundig Bodemonderzoek,* 127-32.

Robinson, D. and Boldsen, I. (1989). *Botanical analyses from Viborg Søndersø.* Unpublished report, Nationalmuseets, København.

Stallibrass, S. M. (1986). *Some taphonomic effects of scavenging canids on the bones of ungulate species. Some actualistic research and a Romano-British case study.* Unpublished Ph.D. thesis, University of Sheffield.

Stallibrass, S.M. (1990). *Canid damage to animal bones: two current lines of research,* pp. 151-66 in Robinson, D. E. (ed.), Experimentation and reconstruction in environmental archaeology. *Symposia of the Association for Environmental Archaeology* **9.** Oxford: Oxbow Books.

Wheeler, A. and Jones, A. K. G. (1989). *Fishes.* Cambridge: University Press.

Appendix

Fish remains recovered after ingestion by a human

Experiment 1

Fish ingested: 1 kippered herring, total length 300 mm; 20 small clupeids, total lengths 60-80 mm

Day 1	No remains.
Day 2	1 crushed vertebra, 3 vertebral fragments - all from the kipper.
Day 3	1 otic bulla, 2 vertebral fragments - all from the kipper.
Day 4/5	No remains.

Experiment 2

Fish ingested: 5 sardines, total lengths 170-185 mm.

Day 1	1 crushed vertebral centrum, 3 scale fragments
Day 2	1 eye lens, 2 cleithrum fragments, 1 ? pre-opercular fragment, 1 articular, 1 stained hyomandibular fragment, 2 palatines (1 acid etched), 1 complete vertebral centrum, 8 laterally crushed vertebral centra, 1 acid etched and stained vertebra, 11 vertebral fragments, 11 scale fragments, 2 branchiostegal rays, about 30 unidentified fragments
Day 3	4 crushed, stained and etched vertebral centra, 8 medio-laterally crushed, etched and stained vertebrae, 12 etched and stained vertebral fragments, 4 scale fragments, 20 unidentified fragments
Day 4	20 unidentified fragments
Day 5	No remains.

Experiment 3

Fish ingested: 5 sardines, total lengths 170-190 mm.

Day 1	1 eye lens, 1 complete vertebral centra, 2 laterally crushed vertebrae, 1 vertebral fragments, 2 unidentified fragments
Day 2	5 eye lenses, 2 crushed epihyals, 1 crushed ceratohyal, 1 stained articular, 1 cleithrum fragment, 2 complete vertebral centra, 1 etched and stained vertebral centra, 16 vertebral fragments, 6 scale fragments, about 50 unidentified fragments
Day 3	1 eye lens, 1 complete, crushed vertebral centra, 2 acid eroded and stained vertebral centra, 3 vertebral fragments, 3 scale fragments, 17 unidentified fragments
Day 4	1 etched vertebral centra fragment
Day 5	No remains.

Experiment 4

Fish ingested: 5 sardines, total lengths 180-190 mm.

Day 1	2 crushed vertebral centra, 2 vertebral fragments, 1 scale, 3 unidentified fragments
Day 2	2 eye lenses, 1 crushed vertebral centrum, 1 etched and stained vertebral centrum, 2 vertebral fragments, 1 etched epihyal, 1 otolith fragment
Day 3	4 eye lenses, 1 vertebral fragment, 3 unidentified fragments
Day 4	2 eye lenses, 1 unidentified fragment
Day 5	No remains.

Experiment 5

Fish ingested 5 sardines, total lengths 170-180 mm.

Day 1	2 crushed vertebral centra, 1 complete vertebral centrum, 3 vertebral fragments, 3 scale fragments, 2 unidentified fragments
Day 2	4 crushed vertebral centra, 2 complete vertebral centra, 4 eye lenses, 16 vertebral fragments, 1 torn hyomandibular, 10 scale frags, about 50 unidentified fragments
Day 3	1 crushed, etched and stained vertebra, 5 vertebral frags, 2 eye lenses, 7 unidentified fragments
Day 4	No remains.
Day 5	No remains.

Final disk version received September 1992

[Editors' note: we apologise to the author for the delay in publication of this contribution, which was only in part beyond their control!]

Notes, enquiries and correspondence

To the editors of *Circaea*:

Congratulations to James Greig on his well-researched etymological discussion on what to call organic pit-fills (*Circaea* **8**, 70–3). Unfortunately we are often stuck with terms that have no basis and I would plump for *cesspit*. I still cannot bring myself to speak or write his other term *s--t*, which is not surprising when one considers that my parents were brought up in Edwardian times and my grandparents in the Victorian period.

But I have found that etymological aspects can throw important light on archaeological and historical studies, and Allan Hall's aside (*ibid.*, 73) is an example. I looked up *shive* (refuse from hemp or flax) in my *Dictionary of Textile Terms* and found it listed as *shives*: 'woollen trade term for all vegetable matter found entangled in wool'—an interesting example of the way in which a meaning can change with the context. This 524-page dictionary published by the now defunct *Textile Mercury* has no date and no pretension to be other than a glossary, but it cannot have been published later than about 1950 and is fast becoming for me an encyclopaedia of textile history.

Michael Ryder, *4 Osprey Close, Lordswood, Southampton, SO1 8EX, U.K.*

Book notices

Hurry, J. B. (1973). *The woad plant and its dye.* Clifton, New Jersey, U.S.A: Augustus M. Kelley (reprint of the 1930 edition published in London for Oxford University Press by Humphrey Milford). 328 pp., 17 pls., 11 figs. £25.00.

This book is a remarkable monograph dealing with all aspects of *Isatis tinctoria*—including the botany, cultivation, and multifarious uses of the plant, the extraction of the famous blue dye, and the economic importance of woad in Europe in the Middle Ages. The first edition (of 1930) has now been faithfully reprinted in the U.S., giving it a new lease of life, the only (small) failure in reproduction being to lose the colour originally used in Plates I and XVI.

The original title page bore the attribution 'by the Late Jamieson B. Hurry'; the author, sadly, died before seeing the completion of his work. He was a evidently a remarkable man for, as the memoir by a friend, Warren R. Dawson, records, Hurry was by profession a general practitioner, having trained as an obstetric physician and then as a ship's surgeon. His interests were wide—something almost *de rigeur* in a professional man born in the middle of the last century—and one aspect of this can be illustrated by reference to a series of monographs he wrote on *Vicious Circles—Vicious Circles in Disease, ...of Neurasthenia*, and *...in Sociology*, then *Poverty and its Vicious Circles*, not to mention his *Nursing on a Provident Basis.* Another series of publications relates to Reading Abbey and show his interest in history, and he combined history and medicine in works such as *Imhotep, the Vizier and Physician of King Zoser and afterwards the Egyptian God of Medicine.* At his home in Reading he established an 'educational garden', bringing together economic plants from all over the world, making this and a museum of plant products freely available to visitors. And it was his interest in economic botany which 'found its last expression in the admirable monograph of the history and use of Woad'.