



HERITAGE NEW ZEALAND
POUHERE TAONGA



Heritage New Zealand Pouhere Taonga
Archaeological Guidelines Series

Guidelines for Midden Sampling and Analysis



14 June 2014



Contents

1.	Purpose	4
2.	History of archaeozoological studies in New Zealand	5
3.	Understanding middens and their archaeological context	6
3.1.	Structure	6
3.2.	Components	7
3.2.1	<i>Molluscs</i>	7
3.2.2	<i>Crustaceans</i>	8
3.2.3	<i>Vertebrates (bone)</i>	9
3.2.4	<i>Botanical evidence</i>	11
3.2.5	<i>Coprolites</i>	11
3.2.6	<i>Other</i>	11
4.	Sampling and collection	12
4.1.	Sampling strategies	12
4.2.	Sample size and collection	14
4.3.	Information to give to faunal analysis specialists	16
5.	Identification and analysis	17
5.1.	Washing and drying	17
5.2.	Primary sorting	17
5.3.	Shell analysis	17
5.4.	Identification of bone material	18
5.5.	Quantification	19
5.6.	Size-frequency studies	20
5.7.	Presenting methods and results	20
6.	Standards	21
6.1.	Baseline standards	21
7.	Post-analysis	24
7.1.	Interpreting the data	24
7.2.	Discard protocols	25
7.3.	Storage	25
	Glossary	26
	References	27
	Further reading	29
	Acknowledgements	29

Copyright © Heritage New Zealand Pouhere Taonga 2014

Reproduction, adaptation, or issuing of this publication for educational or other non-commercial, personal purposes is authorised without the prior permission of the copyright holder(s). Reproduction, adaptation, or issuing of this publication for resale or other commercial purposes is prohibited without the prior permission of the copyright holder(s).

Cover photos:

(Left) Shell midden, Omaha Coast, Northland. *Photo, Heritage New Zealand.*

(Right) Archaeologist Karen Greig investigating an archaeological site on the southern side of Pauatahanui Inlet. *Photo, Fairfax Media New Zealand / Dominion Post.*

ISBN 978-0-908577-99-6 (online)

ISSN 1179-6413

1. Purpose

In the simplest terms, a midden is rubbish – the physical remains of domestic waste resulting from human activity. Midden deposits may represent the rubbish areas associated with living sites, or be related to temporary occupation for the purposes of collecting resources on a semi-industrial scale. Middens include faunal material, such as bone and shell, and in the New Zealand context prehistoric middens will often be dominated by shellfish remains. There is always more to a shellfish midden than just shellfish – these Guidelines stress this point and emphasise guidance for the excavation and analysis of the *whole* midden. For example, not all animal bones that end up in a midden may be the result of food preparation and other uses of animals may need to be considered.

The term *midden* encompasses all material found in these deposits, including animal bones of a range of species, environmental evidence, such as wood, charcoal, pollen and other botanical material, oven stones, artefacts, and the soil matrix in which these are located. Middens from European sites is more limited and generally consists of vertebrate remains and artefactual material only.

Middens are recovered from the vast majority of archaeological sites in New Zealand, and provides valuable insight into the lives of the former occupants of those sites. The purpose of these Guidelines is to provide advice on the kinds of questions that can be addressed through the analysis of faunal material from midden sites, the collection of midden samples in the field (why samples should be collected, how much should be collected, and how they should be collected), the type of information that should be provided to, and requested from, specialists when commissioning analyses, and guidance on the baseline methodology for faunal studies in New Zealand.

These Guidelines cover the faunal material most likely to be recovered from an archaeological site using standard collection techniques. Primary among these are shell, bone and teeth. On occasion other material of animal origin, such as scales, egg shell, hair or skin, may survive, depending on taphonomic conditions. Coprolites and micro-level components, such as pollens, starch grains, insect eggs, larvae and parasite eggs, also occur in midden deposits. These can yield important information, and require specialist analysis. Due to the specialist nature of these analyses, these components will not be considered in depth here.

These Guidelines propose a ‘baseline methodology’ for midden sampling, collection, analysis and quantification. Despite the near universality of middens in New Zealand archaeological sites, there has been limited concerted or coherent study of them. Some aspects and components of middens, particularly bones of fish, birds and mammals, have received a great deal of attention. Analysis of micro-components is being undertaken more often. However, the whole midden as a structure in its own right remains unexamined. The baseline methodology will allow for comparison between excavations by ensuring that middens are examined in the same way. The baseline methodology is not meant to be a minimum standard, nor is it a research agenda. Rather, it is a framework around which a research agenda might be built in order to examine a long-neglected aspect of New Zealand archaeology.

2. History of archaeozoological studies in New Zealand

Analysis of midden material can be used to examine a wide range of questions about the human past. This is not only about what people ate, but also the environments they were exploiting, the technology used for food procurement and processing, how food was preserved, distributed and disposed of, seasons of exploitation, human impact on the environment, adaptation to environmental changes, site formation and stratigraphy, and taphonomic processes, such as weathering and carnivore activity. Information from historic era sites, may shed light on questions of animal husbandry, butchery practices and social differentiation. Animal remains may even provide a useful relative dating mechanism in some instances, e.g., in distinguishing prehistoric from early historic Maori sites.

Faunal analysis has always played an important role in New Zealand archaeology. The first report of middens in New Zealand was by Joseph Banks, the naturalist on James Cook's first voyage, who in 1769 described "vast heaps of shells ... some appearing to be very old", which he considered to be the rubbish dumps of Maori people. In the 1840s, bones of moa and other extinct birds were found in middens associated with old Maori sites. By the 1870s, these early bone-rich deposits were being contrasted with what were thought to be more recent shell middens. The focus on remains of extinct birds continued through the first half of the 20th century. It was not until the 1960s that midden analysis began to move away from simple lists of species of birds, other animals and shells as the influence of schools of faunal analysis in California and England began to be felt.

The foundation of modern midden analysis in New Zealand was laid at that time. Methodologies were developed for identifying fish remains from archaeological sites, and for quantifying the relative abundance of shells, fish, birds and other animals. For the first time, it was demonstrated that a 'moa-hunter' diet consisted of far more than moa meat. The amount of meat obtained from fish, moa, seals, dogs and birds was estimated, and the amount of caloric energy obtained from each kind of meat was calculated. A pioneering study of crayfish mandibles showed that it was possible to demonstrate changes in the size of crayfish caught through time and thus gain an insight into the impact of Maori in the inshore zone. A similar study documented the effects of gathering on rocky shore shellfish.

Since that period, more detailed studies have been carried out on birds, fish, sea mammals, dogs and rats. Fundamental to these studies has been the quantitative assessment of relative abundance. As more data were gathered, it became possible to look for variation in fish catches, for example, from one region to another and through time in any one region. The pioneering work on crayfish has been followed by detailed studies reconstructing live fish size from archaeological bones. This approach has the potential to reveal changes in the marine environment, fishing practices and human impact on the environment. Studies of shellfish sizes have also revealed surprising differences in the size of shells taken at different periods and between past and modern shellfish populations.

There are still large areas where very few faunal analyses have been undertaken and there is great potential for further work. For a more complete review of the history and development of archaeozoology in New Zealand, see Allen and Nagaoka (2004).

3. Understanding middens and their archaeological context

3.1. Structure

Middens are structures formed by particular kinds of human activity, and they should be understood as such. A range of activities create middens, and these can be understood only if the midden is excavated stratigraphically using standard archaeological field techniques. At the very least, this means cutting a trench through the midden, examining it in profile, and making a section drawing showing where the samples were taken. Taking a ‘grab sample’ is not the same as doing an archaeological investigation. The activities that structured the midden will condition the contents and hence the analysis of them. The matrix may be just as important as the contents in understanding these activities.

Among the activities that can structure a midden are waste dumping, cooking, digging earth ovens or postholes, raking out and the use of shell in ovens as a heat retainer, i.e., deposition and redeposition. These varied activities may be carried out for equally varied purposes, for instance, fire can be used for food preparation, food preservation, warmth or waste disposal. Middens may be deliberately redeposited, for instance, as the fill of storage pits. Higham’s (1990) analysis of the large midden in the 1987 ‘high dune’ excavation at Shag River Mouth (North Otago) exhibited many of these features, as has Witter’s (2009, 2013) more recent work in the dune systems near Kaiapoi.

As an example of the detailed analysis of midden structure during excavation that provides information about cultural practices, we can look at the Pegasus site at Woodend. Here Witter (2009, 2010, 2013) has observed a range of methods for the disposal of estuarine shell, including:

- ▶ The use of square-sided flax baskets (20 x 20 x 10 centimetres in size) used both to serve portions of food and to collect food scraps for discard. Middens contain fist-sized bunches of shell, which derive from the baskets that had been stacked in the midden, with the shells at all angles and fitting into one another;
- ▶ There were also piles of shell poured on the ground from a container, which were often tilted and standing on end. This was more common for cockle than pipi, and it is possible to excavate where one pile or heap of shells lap onto another; and
- ▶ Other types of lenses or layers of more flat-lying shells, which indicate other processes of gathering shells for disposal or leaving them where eaten.

Post-depositional factors also affect the structure of a midden – posts can decay and postholes infill with shell. Middens can slump downhill, they can be trampled by people

or animals who can dig into them, they can be deflated by wind or water, or they can be ploughed or otherwise damaged by heavy machinery. In order to understand the midden and the cultural activities that structured it, any or all of these factors need to be taken into account. The structure of the midden will determine the analysis.

Sometimes it is thought that there is a clear distinction between middens that result from a single episode of food processing and those that have built up slowly in the vicinity of a place where people were living for some time. However, this is an over-simplification and it is advisable to approach any midden without preconceptions about how and why it was deposited.

Although middens are primarily considered to be oriented around food remains and the results of food preparation and consumption, they may incorporate other things like artefacts and oven stones. The midden is the matrix in which such things are found. Artefacts found within the midden matrix will generally be analysed separately from the faunal component, but it is important to consider the context in which they were found. Historic middens may often contain relatively large quantities of non-faunal domestic rubbish.

Middens are not homogeneous deposits. The variation in the composition of middens can be quite marked even from adjacent samples. Ambrose (1963) and Davidson (1964) recognised that middens are structures. In almost 50 years since, there has been little or no progress in our approach to middens, apart from the Higham 1990 study quoted above, something that these Guidelines aim to address.

3.2. Components

Middens are not just collections of shells and bone – they may contain a variety of other components. The following sections consider the classes of material that may be found in New Zealand middens, and the information that can be gained from the study of these.

3.2.1 Molluscs

Marine shell is often the major component of middens, yet is frequently the most neglected in many respects. Analysis of shell rarely goes beyond what is required for basic subsistence information and usually relies on identification of only “countable” portions, leaving a lot of the shell assemblage unidentified and unquantified in any meaningful way. Marine shell can provide information on seasonality, environmental change and over-exploitation as well as subsistence,

Marine shell was used as a raw material for artefacts, less so in New Zealand than in the tropical Pacific, and shell is known to have been used for scaling fish and preparing flax fibre among other things (Harsant 1983). Such activities may leave distinctive use-wear patterns on the shell. Figure 1 shows images of shells recovered during excavations near Thames that were possibly used as tools (Phillips 2004). Minor or incidental shell can provide important information on issues such as exploitation zones and collection strategies, and its importance should not be overlooked. Shellfish gathering may be relatively selective, such as targeting larger individuals, or as mass gathering by scooping up everything. Mass gathering may be indicated by the presence of shells that

were collected dead, such as articulated bivalves still containing the estuarine mud, or gastropods with whelk-pierced holes. There may also be breakage on shells that have been opened by oystercatchers, similar to the shells shown in Figure 1 (Witter 2010). A fine-grained analysis of the shell component of a midden can help tease out the taphonomic factors that have affected it, particularly those that have fragmented the shell.

Middens also may be burned if they were mixed with flammable organic material – either accidentally or even in a deliberate manner when ovens were created in the middens. This can produce enough heat to produce patches of calcium oxide (lime).

Figure 1.
Shells possibly used as tools.
Photo, Caroline Phillips



Analysis of O^{18} isotopes in shells can reveal change in sea temperature through time, and the width of growth rings in shells can provide evidence for the season of harvest. For examples, see Higham (1996) for work on blue mussels and Samson and Edgar (1995) and Leach *et al.* (2000) for studies on tuatua.

Freshwater shell is often found in sites close to inland lakes and rivers (Campbell 2005), and can be analysed in the same way as marine shell. It should be noted, however, that freshwater mussels are very prone to weathering, and it may be difficult to recover them sufficiently whole for measurements.

Land snails can provide important palaeoenvironmental data, offering a picture of natural and human-induced habitat changes over time. Many land snails are tiny, and can be retrieved only from unsieved bulk samples.

3.2.2 Crustaceans

Most parts of crabs and crayfish do not survive well in archaeological sites. However, the mandibles (hard mouth parts) of crayfish (Figure 2) do survive and can be readily retrieved and identified.

Figure 2.
Crayfish mandibles
Photo, Foss Leach



3.2.3 Vertebrates (bone)

Most archaeologists can, and will, carry out basic shell analyses themselves with the help of a book (e.g., Morley 2004), though they should always consider seeking specialist advice. Bones are a different matter and require analysis by someone with specialist knowledge and experience. Few faunal analysts do all classes of bone. The non-specialist might separate shell from bone and other midden components (charcoal, oven stones, artefacts etc) and then pass all the bone onto one specialist who might separate out the differing bone types to pass onto other appropriate specialists.

New Zealand sites may contain a variety of **birds**, from moa to small passerines, such as tui and bellbirds, and can include birds from a wide range of habitats. Chickens are not known from pre-European sites in New Zealand, but may be a common component in domestic refuse from historic era sites, along with other introduced taxa. Bird bone is characterised by a smooth, shiny appearance and hollow shafts. Moa bones have thick walls but are still hollow inside. Non-specialists can easily mistake fragments of moa bone for mammal, or even wood. The study of bird bone may provide information not only on subsistence patterns, but on the nature of the surrounding environment – the species represented in the sample may be largely forest-dwellers, marine, estuarine etc. Bird bones can provide information on capture and processing techniques, seasonality and tool manufacture. The presence of medullary bone deposits in long bones and metatarsal spurs can provide evidence of the sex of chickens and periods of egg-laying (McGovern-Wilson 1989).

Identification of moa and other extinct birds is a sub-specialty of analysts, usually museum-based. Recent revisions in moa taxonomy (Bunce *et al.* 2003) means that only these specialists are sufficiently experienced and knowledgeable for undertaking this type of analysis.

Fish bone often has the appearance of being constructed of thin layers. It can also appear flaky or striated. Non-specialists sometimes mistake the ribs and spines of fish for small bird bones. The appearance of fish bone varies considerably depending on the state of preservation. The vertebrae of sharks and rays are very distinctive, and as very little of cartilaginous fish survives in the archaeological record (except vertebrae and teeth) it is important to be aware of the appearance of these bones. The tail spines of stingrays and the tooth plates of eagle rays often survive well. Elephant fish tooth plates can resemble sheep's hooves. Likewise, it is worth being able to recognise fish otoliths (hard calcareous ear parts – Figure 3), as these look more like shell than bone and generally will not be recognised as belonging to fish during initial sorting by non-specialists.

Figure 3.
Snapper otolith.
Photo, Foss Leach



It is usually possible to identify fish bone from New Zealand sites to species level, owing to the lower diversity of fish in the temperate zone compared with the tropical Pacific. The study of fish remains can provide information on subsistence patterns, fishing techniques and technology, zones of exploitation, environmental changes and seasonality. Historic period sites sometimes include introduced fish, such as trout and salmon, as well as native species.

In prehistoric sites in New Zealand, **mammal** remains will be confined to those of the small Pacific rat, domestic dog (both introduced by the first Maori settlers) and sea mammals, which are all easily distinguished from each other and human remains. Bear in mind that rabbit burrows, and rabbit bones have been found in prehistoric sites because of this. If there is any question that the bone may be human it should be treated as such until a specialist can make a positive identification. Historic sites have the potential to contain the remains of any of the animals introduced by Europeans, although generally remains will be confined to those animals that were of economic use, principally cattle, sheep and pigs, and occasionally dogs and cats. The remains of animals, such as mustelids, possum and hedgehog, have seldom been reported from archaeological contexts in New Zealand, but may have been overlooked by non-specialists.

Bones of **tuatara** are sometimes found in early sites on mainland New Zealand, and are important in documenting the former wider distribution of this animal. The jaws are relatively easy to distinguish from fish jaws. Remains of **small lizards** have seldom been found, but it is likely that they are sometimes missed during sorting of small bones.

3.2.4 Botanical evidence

Middens may contain a range of botanical evidence including charcoal, seeds, pollen and starch grains. Depending on the nature of the depositional environment, items such as wood or plant fibres may also survive. These can provide evidence of the surrounding environment and changes in that environment, and may show evidence of horticultural activities. Flotation is generally the best method for the recovery of many botanical items, especially seeds and small charcoal fragments, including carbonised bracken rhizome bark. Analysis of micro-components usually requires specialist knowledge and equipment to prepare and examine samples.

3.2.5 Coprolites

Coprolites (faeces) are occasionally present in midden sites, although they may go unrecognised. In New Zealand prehistoric sites, both human and dog coprolites are found, and are very difficult to distinguish from one another. Coprolites can provide valuable dietary information, and information on the health of an individual or population through examination of parasites preserved within them. Coprolite analysis is a specialised task, but it is important that archaeologists recognise coprolites when they find them. Pre-European dog coprolites are probably more common than human, and can be used to gain an insight into dog diet and husbandry. Irwin *et al.* (2004) provide a good overview of the information that can be gained from coprolites.

3.2.6 Other

Middens also have the potential to contain the remains of miscellaneous items, such as **eggshell**. While there is little or no record of eggshell, other than that of moa, being found in New Zealand middens, this is more likely to be because it is not being sought. As with many of the smaller midden components, eggshell is likely to be lost through sieving. For **micro-components**, such as pollens, starch grains, insect eggs and larvae, and parasite eggs, unsieved bulk samples have to be taken. Size requirements and other collection details should also be discussed with the appropriate specialists. **Insects** are also likely to be present in middens, but likewise have been mostly overlooked in the New Zealand context. Consequently, suitable methods of collection and analysis, along with the associated specialist knowledge, have not been developed to date in this country.

4. Sampling and collection

4.1. Sampling strategies

Most excavations undertaken within the context of development-driven archaeology are constrained in terms of both time and money. To a lesser extent, this can be true for research-based archaeology. It is therefore necessary to employ a sampling strategy in order to collect material for analysis. It is important to give careful consideration to sampling, so that the most appropriate strategy for the particular site is used. This involves having clearly identified research aims before beginning work, as well as the flexibility to vary research aims and strategies as the archaeology of the site unfolds during excavation. The need for a well-defined research strategy is as important for development-driven archaeology as it is for pure research, although the level of complexity of the questions to be answered will undoubtedly vary.

The first consideration is: *What is it that we want to know?* For example, when considering faunal remains, some of these questions may be relevant for analysis:

- ▶ Which species were being targeted at this site?
- ▶ What types of environments were people exploiting?
- ▶ What techniques were people using to gather shellfish/catch fish/hunt birds?
- ▶ What evidence is there for dog husbandry in pre-European times and domestic species in the historic period?
- ▶ Was occupation seasonal or year-round, temporary or permanent?
- ▶ If seasonal, was the site returned to in successive years, or is it a single occupation site?
- ▶ Is there evidence for change through time in target species and environments?
- ▶ Are there any changes in size frequency or distribution for shellfish and fish?
- ▶ Are such changes due to over exploitation? Or to environmental changes? Or natural recruitment cycles?
- ▶ What are the age/sex ratios of domestic animals or wild animals, such as seals?
- ▶ Is there evidence of butchery? Differential disposal? Preservation of food, such as drying?
- ▶ Is there any evidence about social status of the site's inhabitants?
- ▶ Which taphonomic factors are at play, and how might they influence the preservation and interpretation of the material?

In development contexts, the nature of the work being undertaken will affect the sampling strategy used. The approach taken during monitoring of trenching for utilities where there are no known sites will differ from that where the monitoring is for large-scale earthworks, and the approach taken for the investigation of an already-recorded site will differ again.

The advantages and disadvantages of three common sampling methodologies (random, judgement and systematic) are summarised in Table 1. A *random* sampling strategy is not likely to be useful where the location and nature of sites is unknown because this

could miss deposits completely. In reality, *judgement* or *systematic* samplings are likely to be those most often employed in these situations – deposits are either selected for sampling when encountered because they look ‘good’, or a decision may be made to take samples at set intervals, regardless of appearance. If questions for answering include those pertaining to intra-site variability, then a *systematic* approach should be employed over a *judgement* one. Conversely, if the aim is to answer the most basic of subsistence questions, a single, decent-sized sample from a rich context may suffice. A *combination* approach may be most useful in many instances.

Sampling methodologies need to be recorded explicitly in the field and described in the final report.

Table 1. Common sampling methodologies (after English Heritage 2002)

Sampling Method	Description	Advantages	Disadvantages
Random	Areas to be sampled are selected in a statistically random manner	Mathematically rigorous	Can completely miss important deposits if used on its own
Judgement	Samples are taken from obviously ‘rich’ deposits	Can be cost-effective as only ‘good’ deposits are targeted	Highly subjective. What constitutes a ‘good’ context may not be apparent to the excavator. Biases result in favour of highly visible material, i.e., a lens containing a large and distinctive snapper bone will be more ‘attractive’ than a lens containing a small mackerel bone
Systematic	Samples are taken using a predetermined systematic approach, such as a grid	Ensures entire site is considered, able to be re-evaluated during excavation	Unusual contexts may be missed

4.2. Sample size and collection

It is probably best, at the outset, to have an idea of how the data are to be analysed and presented in the report. This includes anticipating the type of graphs or tables to be used, and how the deposits are to be shown on a plan. It is also important to note that small sample sizes do not provide reliable data, particularly in terms of species richness, nor are they suitable for statistical analyses.

Depending on the skills and experience of the field archaeologist, if middens are encountered unexpectedly or turn out to be different from what was initially allowed for in the research/sampling strategy, it may be necessary to revise the strategy. It is advisable (if possible) to discuss sampling with a faunal specialist who may be analysing the collection before taking any samples. Once the size and complexity of a midden is better understood through excavation, the sampling strategy can be refined, especially around issues such as sample size.

Samples can be collected either as ‘bulk’ unsieved samples, i.e., the entire matrix and all its contents are retained, or they may be sieved on-site to reduce the amount of material needing to be transported and stored. In some situations, material may be further sorted on-site to remove components that are not relevant to the particular research questions being posed. Regardless of the approach used, the amount of material taken should always be noted, and where on-site sieving and sorting has been undertaken, the original volume before sieving should be recorded so that issues of density etc can be addressed.

It is useful to take samples consistently using a standard-sized vessel, such as a 10 litre bucket. If measuring shell for size-frequency analysis where, at a minimum, 100 whole shells of one species are needed (see below), even 10 litres may not be enough to ensure enough whole shell is collected for measurement. Choose a standard-sized collection vessel that ensures the sample is sufficiently large to give valid results.

Ensure that the bucket is, in fact, the correct size, e.g., 10 litres, as most cheap buckets are 9.6 litres and lidded paint pails are around 11.5 litres. To ensure that each sample is the same size they should all be ‘packed and level’, i.e., drop the bucket on the ground from 10 to 20 centimetres a few times to pack the midden into it (assuming there is no fragile bone material present). It should also be noted that 10 litres in a bucket will not be equivalent to 10 litres in situ, and the difference will vary from situation to situation.

The total number of samples to be taken depends on the research questions being asked and the site being investigated. A single sample will not indicate anything about variation in the midden, let alone the cultural factors responsible for that variation. A number of random samples will highlight variation, but it might be better to use a systematic strategy, such as sampling stratigraphic units in 50 millimetre spits, or a strategy targeting a range of different lenses of midden to explain variation more constructively. On the other hand, a single sample from an eroding midden is better than no sample at all.

On-site sieving and sorting will inevitably result in the loss of some data, and it is always desirable to take a bulk sample for later analysis if possible, even if this is not included in the initial analysis. A sieved and sorted sample is no longer a midden sample – it is an assemblage of items such as fish bones, bird bones and shellfish. This is particularly

important for the collection of very small items such as land snails or seeds and other micro-components. Specific requirements for the collection of samples for specialised analysis, e.g., DNA, should be discussed with specialists before work begins, to ensure that samples are properly collected and stored.

Material should ideally be sieved at no greater than 3 millimetre mesh, as the loss of small bones (such as fish otoliths and rat bone) and even shell at greater mesh sizes is considerable. Using a 2 or 3 millimetre sieve, however, is a relatively slow process. A 5 or 6 millimetre mesh is usually more than twice as fast – an important consideration in a contract situation. The preliminary use of a fine sieve, however, may be used to test for the possibility of small bones or micro-debitage. In some contexts, where small vertebrates are likely to occur infrequently and are not of interest in terms of research objectives, the use of 6 millimetre mesh sieves is perfectly acceptable, but in these instances it must always be remembered that absence of particular taxa from the sample does not necessarily equate to absence from the site. Sieve size must always be reported with the results of faunal analysis. If the facilities are available, wet sieving can greatly speed up the sieving process, especially using a high velocity nozzle.

Hand collection of faunal remains should never be used on its own, as this will bias the sample towards large and/or easily recognised taxa. However, in some situations where very large bones, such as moa or domestic cattle, are involved it may be desirable to collect these separately from the remainder of the material. This will often be a departure from a random or systematic sampling strategy when the larger bone is taken from a wider area than the predefined sample points. Archaeologists generally want to collect all moa bone (and formal artefacts etc), so such a departure is frequently necessary. Removing a large moa femur from a 10 litre sample is equivalent to removing 2 or 3 litres. So, in the interests of establishing guidelines, the moa bone should be calculated into the sample. Similarly, when shell midden in a large and complex site consists largely of one or two species, hand collection of unusual shells (and other material), not included in quantitative analysis, may extend our understanding of the range of environments that the people responsible for the midden were exploiting.

Decisions about what to identify should not be made during excavation. On-site discard protocols should be used only for material that can be easily recorded on-site, and only in consultation with whoever will be undertaking the later analysis of that class of material.

Samples should be bagged and clearly labelled with all provenance information using indelible ink. It is imperative that all workers follow the same labelling system to ensure consistency and reduce the risk of provenance information being misunderstood. If lidded buckets are used to retain bulk samples, these should likewise be clearly labelled and properly sealed. 10 litre samples can be quite heavy, so large, heavy (250 micron) plastic bags sealed with cable ties are recommended. Provenance data or sample number can also be cable-tied onto the bag.

It is important to record details pertaining to the nature of samples taken whilst in the field. These details include density of material, compaction, matrix (e.g., sand, silt, clay etc, including colour and consistency), relationship of the sample to archaeological

features (e.g., oven scoop, rake out, midden dump etc), any unusual features such as paired shells or concentrations of small bones, and the reason the sample was chosen. Soil samples should be taken for pH analysis, including control samples from the immediate site surrounds.

4.3. Information to give to faunal analysis specialists

Whilst basic information can be derived from an assemblage alone, the more information that is given to the specialist(s) about the site and the collection strategies, the more they will be able to give about the assemblage in return. The types of information that can/should be provided include:

- ▶ Basic site information – location, site number, environment. Ideally the specialist should be provided with a copy of any preliminary report and a draft of the archaeology section of the final report.
- ▶ Excavation details, when, by whom, total area excavated, number of units, size, number of layers, i.e., the archaeology of the site.
- ▶ Information on recovery methods – sampling strategy (including size of samples), screen sizes, any on-site discard.
- ▶ Observations relating to perceived density of faunal material across the site. Were faunal remains concentrated in particular areas, or near particular features, and how has this influenced sampling?
- ▶ Any artefacts relating to subsistence, e.g., fish hooks, harpoons, bird spears or artefacts made from animal products.
- ▶ Has the assemblage undergone any other division, e.g., primary sorting to class? Who is analysing the other material – it is not uncommon, when the primary sort has been undertaken by a non-specialist, for the specialist to find material belonging to another class within a sorted sample. This will need to be sent on to the correct specialist.
- ▶ Specific questions to address.
- ▶ Inventory of bag numbers, and explanation of provenance system.
- ▶ Bagging protocol (many specialists will have their own system of bagging, so if you wish your own system to be used, it is important to make this clear from the outset).
- ▶ Units for analysis, i.e., which excavation units, layers or features should be aggregated for analysis of minimum numbers and other measures.

In short, specialists can produce no more than a table of identifications if they are not given the relevant information that provides the context of the assemblage.

5. Identification and analysis

5.1. Washing and drying

It may not always be necessary to wash samples before sorting and this will depend on the matrix, e.g., material from sandy matrices may not require much in the way of further cleaning, although it is often beneficial to re-sieve the samples to remove any dry sand or soil. A sub-sample of the matrix could be retained for analysis of micro-components. The purpose of sieving is to remove the matrix and retain the macro-components, but the matrix is an essential part of the original deposit and deserving of its share of the analysis. Material that is not relatively clean after drying should be wet sieved and dried again to remove as much of the matrix as possible. Wet deposits may need to be wet-sieved on site.

Samples should be completely dried before any sorting takes place and the dry sample weighed. Bone material may warp if dried too quickly, so care must be taken to ensure this does not happen.

5.2. Primary sorting

The first step in midden analysis is to place like with like, sorting into categories, such as shell, bone, stone, charcoal, seeds etc. Following this, the bone will need to be further sorted into class (bird, mammal, fish, reptile etc). While some archaeologists will have had some training in faunal analysis, and be capable of undertaking the initial sort into classes, further identification and analysis is best done by specialists.

The level of identification required will be dictated by the questions to be answered. The following provides some basic information about each faunal class, but those with no training in faunal analysis should sort only the shell from the bone, particularly if the original midden has a high diversity. Bone analysis specialists will be able to sort the bone assemblage into classes.

Material should be re-bagged and re-labelled at each step, ensuring that the original provenance information is always retained, both on the bag and in the site database.

5.3. Shell analysis

Shell, for the most part, is relatively straightforward, to the point that many archaeologists are able to undertake basic identification with the use of a good reference book for the more common and easily recognised species (e.g., Morley 2004). It is also relatively easy to build up one's own reference collection of shells. It should be possible for an archaeologist to identify and quantify the main food shells in a sample, seeking specialist help only in confirming identifications of uncommon shells, which are often 'incidental' in the midden, i.e., not collected as food. Incidental shells can still provide useful environmental information. A basic methodology for shellfish analysis is presented in the following section.

5.4. Identification of bone material

Identifications of bone to taxonomic level below class should be undertaken only by specialists. Standard methodology is to sort the material first to element, then to the lowest taxonomic level possible. For some classes, only certain elements may be selected for identification to taxa, e.g., the standard method of fish bone identification in New Zealand is to identify only the dentary, premaxilla, maxilla, articular and quadrate, and certain ‘special’ bones (Leach 1997). While this is generally sufficient for answering basic questions of relative abundance of different taxa, it is not possible to address questions relating to butchery, differential disposal or preservation of body parts using this method. Furthermore, taxa with small or fragile mouth bones may be under-represented. Identification of additional bones in fish is not difficult, although comparative collections in New Zealand are not generally organised to facilitate this. The decision of whether this should be undertaken will depend on the research questions. In the case of mammals and birds (Leach 1979), it is the norm to identify a far wider range of body parts, with the majority able to be identified to species level.

Taxonomic identifications should be made only to the lowest level that can be assigned with certainty. This will usually be species, however, in some situations it may only be possible to identify to genus or family level. If a taxonomic identification is tentative this must be stated clearly.

Following taxonomic identification, the material should be re-bagged. It is common practice to use a separate bag for each sided element identified to a taxon within a provenance. For example, all right quadrates belonging to snapper from Provenance A would be bagged together. Material from different provenances must never be mixed when bagging identified specimens, even if the assemblage is to be considered as a single unit for data analysis. The original provenance information for the material should be written on the bag, along with the element, taxonomic and quantitative information. Some specialists will use a code system if the provenance information is lengthy. This is acceptable so long as the original provenance information is on the outer bag containing all specimens from that provenance.

Other things that might be recorded include taphonomic indicators, such as burning, weathering, dog or rodent gnawing.

Once a taxonomic identification is made, the data must be recorded. Excel spreadsheets are ideal for this and the pivot table function in Excel is a simple way to produce cross-tabulated calculations of Number of Identified Specimens Present (NISP) and Minimum Number of Individuals (MNI) (see the next section for a discussion of these terms).

The level of analysis required, and the data needed, will depend to a large extent on the questions being asked. This should be discussed with the specialist(s) undertaking the analyses, so it is clear what the requirements are. Seemingly unimportant information in terms of the questions posed can have a profound effect on interpretations. For example, some juvenile fish inhabit different ecological zones than their adult counterparts, so size

may be an important consideration in determining the zone of exploitation and capture methods. In situations where material will not be retained post-analysis, it is particularly important to record as much detail as possible about the nature of the material, even if this is qualitative.

5.5. Quantification

Quantification is the process of aggregating the data produced from the identification of faunal remains in ways that are meaningful and enable research questions to be addressed. Different methods of quantification provide measures of different things, so it is important that an appropriate method of quantification is used.

There are a number of ways of quantifying faunal remains, the most common being the use of weight or counts such as NISP, MNE (Minimum Number of Elements) and MNI. These all produce different results that mean different things for the analysis.

NISP is a fragment count of all identifiable specimens, both complete and fragmentary, in a given taxonomic category. NISP is sometimes used erroneously in shellfish quantification when what is actually being reported is MNE, i.e., where only countable portions have been used for identification.

MNE is the minimum number of elements, i.e., a single bone from a vertebrate, one valve of a bivalve shellfish, or the apex, aperture or operculum (where present) of a gastropod. The count is made by determining the minimum number of elements that could account for the material present. In order to avoid inflated counts, faunal analysts will often use the presence of particular diagnostic markers, for instance, the hinges of bivalves, or elemental portions of bones (such as proximal end, distal end etc) on which to base the count. It is important to be explicit about the methodology used in generating MNEs, as different methods may result in different results. The use of MNE is particularly valuable for identifying differential body part representation for vertebrates, which may reflect butchery practices, differential disposal or taphonomic issues, such as differential preservation.

MNI counts are generated from MNE, i.e., you can not calculate MNI without first calculating MNE. This is usually done by counting the most common element, or sided element as is generally the case with bone, for each taxon.

Considerable debate exists as to the best method of quantifying faunal remains (Grayson 1984; Lyman 2008). Weight is not generally considered to be an accurate measure for addressing questions of relative taxonomic abundance because of the variability in weight of various elements (shell or bone) between species (Mason *et al.* 1998). It is Heritage New Zealand's recommendation that it not be an acceptable measure.

Issues surrounding the use of NISP counts are primarily related to the differential fragmentation between taxa. NISP counts can be affected where differing numbers of elements are identified for different taxa within a class, and obviously NISP data for

separate classes of fauna, e.g. fish and shellfish, are not even remotely comparable. NISP can also be affected by the skill level of the person doing the identifications – different people may arrive at entirely different results, which can have major implications if the data are used for comparative purposes by other researchers.

The main problem with MNI stems from the aggregation of units – different results are arrived at depending on whether counts are generated for the assemblage as a whole, or for stratigraphic units. MNI counts generally should not be generated on the basis of arbitrary spits, as this will result in over-estimation, although if the research strategy calls for comparisons between squares or spits then this needs to be made explicit. The use of stratigraphic units is preferable, as this will enable questions of change through time to be addressed. However, if stratigraphic information is not available the area or site can be considered as a single unit. Expressing MNI counts for separate stratigraphic units can result in arbitrarily reduced overall numbers because it cannot allow for the potential for conjoined bone fragments spread across the boundaries of stratigraphic units.

Quantification is not a simple case of counting, and that of vertebrate remains should be done by the specialists undertaking the analysis of those remains, who should be aware of the problems inherent in the various quantification methods. The methodology used should be explicitly stated in the methods section of faunal reports, so that it is clear how the data were arrived at.

5.6. Size-frequency studies

Size-frequency diagrams are a very useful way of examining change through time in the exploitation of particular species. In the case of a bivalve, such as pipi or cockle, a sample of at least 100, or preferably 200, whole shells are measured according to a defined method. Much larger samples (several thousand shells) give increasingly reliable diagrams. In the case of a fish species, measurements of specific bones are used to estimate the live length and weight of the fish from which each archaeological bone has come. The resulting histogram presents the range distribution of sizes for each sample.

Although most archaeologists will not feel qualified to undertake this kind of study, it is important to be aware of the possibilities and to retain sufficiently large samples of whole shells for use in future studies of this kind. While the measuring of bones and shells is not difficult when following standardised methods, the interpretation of the resulting data is not a straightforward matter, as there are many factors that influence growth rates (Leach *et al.* 2009). For these reasons, size-frequency studies are often best left to more in-depth studies of faunal remains.

5.7. Presenting methods and results

The need to be explicit about the methods used in all aspects of faunal analysis cannot be over-emphasised. A lack of detail in this area can render the data almost, if not completely, useless to other researchers for the purposes of comparative analysis. Full details of the methods used in sorting, identification and quantification should always be given. It is not sufficient merely to state that “standard techniques” were used, as what is considered “standard” varies quite considerably. If a reference to the techniques used

cannot be provided, a full explanation must be given. Details of the reference collections used should be given, including taxonomic lists (where possible) so that it can be seen whether taxa are truly absent from the assemblage or if there is a possibility they were not identified due to gaps in the reference collection. Such information can be included as appendices in reports.

If Excel has been used to record the data, pivot tables and then charts can be easily produced for inclusion in reports. Where possible, the raw data should also be included as an appendix. This allows the data to be manipulated in other ways by other researchers if desired, e.g., when a site has been considered as a single unit for reporting purposes, but where it is also possible to look at intra-site variability.

6. Standards

6.1. Baseline standards

One of the main goals of these Guidelines is to ensure compatibility of analysis and reporting between sites and investigators. At present this is generally not the case in New Zealand, which can make the comparison of results difficult or impossible. Baseline standards for the sampling and analysis of midden are required. Leach (1986) proposed a system for fish bone analysis that has become the standard for New Zealand and much of the Pacific, so comparisons can now be made between assemblages. Something similar is required for other midden components, although Leach (1979) proposed a successful method for bird bones, as shown by McGovern-Wilson (1986). Of course, we can expand on the Leach methodology as our research interests dictate, and the Leach minimum standard might be superseded in future by something that builds on it, but does not negate its core methodology. The same should apply to any other proposed midden standards.

The following standards have been developed as guidelines for archaeologists carrying out work in accordance with Heritage New Zealand authority conditions, and as a step towards a more consistent approach.

Sampling

While a 'one size fits all' approach is not appropriate when considering sampling strategies, to address basic questions such as the main species present and an indication of relative abundance the following guidelines should be adopted:

- ▶ For small shell middens (less than approximately 2 cubic metres), with little or no apparent variation in structure and composition, a 10 litre sample may suffice. If the midden is larger, then several 10 litre samples from different places should be taken.
- ▶ For midden where there appears to be evidence of different events, or varying deposition, samples should be taken from any observable layers and, depending on the overall size and structure, from different areas. A systematic strategy should be used in such cases.

- ▶ Judgement (or hand-picked) samples can be taken from places where there appear to be variations in the composition of the midden or unusual items.
- ▶ More complex analyses, such as reconstructing size-frequency diagrams, are likely to require large samples to obtain the necessary quantities to make the analysis statistically viable. For example, for bivalve shell reconstructions, between 100 and 200 measurable whole valves of one side only are required.
- ▶ In cases where middens have a high proportion of bones, large samples should be taken. Such sites are relatively uncommon and are likely to yield important information. It may be necessary, if the site is very large, to carry out some sieving in the field to reduce the size and weight of samples being returned to the laboratory. If sieving is done in the field, it is important that unsieved (bulk) samples of 20 litres or more are also taken for subsequent fine-grained processing in the laboratory.

Shellfish

The following section outlines a basic methodology for the analysis of shellfish. For the purposes of analysis, shell is generally broken into two groups – countable and uncountable. This division is based on the presence or absence of landmark features, such as hinges for bivalves and apices, apertures or opercula (where present) for gastropods. These are: a) more readily identifiable to taxon; and b) robust and generally survive well in archaeological deposits. Differences of opinion exist as to whether so-called “uncountable” shell needs to be identified to taxa. However, not doing so means that the assemblage cannot be used to assess taphonomic issues, such as fragmentation, both within the assemblage as a whole and between species. Relying only on countable portions may also mean some species are overlooked completely, or noted only as “present”. The problem with attempting to identify all shell as far as possible, particularly for large assemblages, is that it is time-consuming. One solution to this is to undertake a fuller analysis of a sub-sample that can then be used to assess taphonomic issues. In most cases the identification and quantification of countable portions only will be sufficient to address the research questions at hand.

The following steps can be used for analysis of all material or for just countable portions:

- ▶ Sort the material into rough taxonomic groupings by placing items that look similar to each other together;
- ▶ If only using countable portions, it is important to also keep aside any shell **not** represented by countable portions, so this can be noted as present within the assemblage;
- ▶ Careful observation of the material should be made during sorting to identify any potentially modified material or artefacts;
- ▶ Identify the specimens to the lowest taxonomic classification possible, using reference specimens and/or books (NB: uncountable fragments, if used, may be able to be identified only to family or genus level – it is important not to over-identify); and
- ▶ Quantify the material following the steps given below.

If all material has been identified to taxon, NISP is generated by counting all pieces within each taxonomic category as far as possible. However, MNE/MNI derived from countable

portions may provide a better indication of relative abundance than NISP. Unidentified material should also be counted as a separate category. In addition, each category should be weighed. If the decision has been made that only countable portions be identified to taxon, and to produce MNE and MNI numbers, the following procedures should be used:

Bivalves

- ▶ Count all complete (more than half) hinges for each taxon;
- ▶ Count all half hinges, divide by 2 (NB: do not count shells where less than half the hinge is present);
- ▶ Add these figures together to provide MNE, divide MNE by 2 to produce MNI; and
- ▶ Weigh each taxon.

Gastropods

- ▶ Count apices or apertures (it may be necessary to determine which gives the higher count). As apertures are subject to breakage it is advisable to use the inner edge, which is also the anterior edge of the columella, as the basis of the count (Szabo pers. comm.). Opercula should be counted if present. Both of these counts provide an MNE;
- ▶ For gastropods with no operculum MNE = MNI;
- ▶ For gastropods with an operculum, use whichever MNE is higher (shell or operculum) for the MNI; and
- ▶ Weigh each taxon.

Shell with no countable portions

- ▶ Count fragments of each taxon to give NISP; and
- ▶ Weigh each taxon.

Unidentified

- ▶ Weigh.

Sorted shell should be weighed by species and the unidentified residue also weighed. The ratio of residue to unidentified shell, for instance, is a degree of the fragmentation of the assemblage. Stone and charcoal should also be weighed.

Fish

Leach's (1986) methodology for the identification of fish remains provides the minimum requirements for fish bone.

Bird and mammal

Identification of bird and mammal remains should follow a similar procedure. Individual bones should be identified, sided where appropriate, and the portion present recorded. Bones should be carefully examined for evidence of gnawing by dogs or rats, weathering, burning and working (cutting, sawing and drilling). A specialist will sometimes be able to estimate age at death of animals based on the presence of granulated bones or fusion of the epiphyses of long bones. This information is important in interpretation of the husbandry of dogs and the hunting of birds and sea mammals. Bird and mammal identifications should be presented in terms of NISP, MNE and MNI, collated for each relevant stratigraphic or area context, and then summed for the whole site.

These procedures apply equally to both prehistoric and historic period assemblages, although in the latter, MNI is less useful than MNE as a measure of relative abundance for large animals because in the historic period meat tended to be acquired as butchery units rather than complete animals. Another useful quantification method is the minimum number of butchery cuts (MNBC). If MNBC is used, it is crucial that the report contains drawings showing how the butchery cuts were defined (or references to such drawings). Research undertaken in Australia recently indicated variability within the definition of butchery cuts in the United Kingdom in the 20th century (Colley 2006). It is likely that the same variability existed in the 19th century in New Zealand, particularly because some butchery undoubtedly would have been carried out by people who were not butchers by trade. In order to better understand butchery techniques in 19th century New Zealand, it is important that the location of butchery cuts on bones is recorded.

Good examples of the reporting of bird and mammal bone can be found in McGovern-Wilson *et al.* (1996), and Smith (1988, 1996).

7. Post-analysis

7.1. Interpreting the data

The interpretation of archaeozoological data is not always a simple matter of taking “taxa exploited + environment usually found in + likely method of capture”. This simplistic approach can lead to erroneous interpretations. Ideally, interpretations should be done by, or in consultation with, the specialist who undertook the analysis, as they are likely to have a good understanding of the ecological zones and likely capture/collection methods involved. It is important to consider the nuances that can alter interpretations. It is normal practice that archaeozoologists will provide a report to the project archaeologist that gives the results of the faunal analysis, as well as detailed interpretation.

Relative abundances do not always correlate directly to the most important environmental zone of exploitation either, i.e., it cannot be assumed that the most numerous species = most important zone. For example, mudflats are dominated by large single-species beds of bivalves, whereas rocky shore gastropods are represented by a greater number of species, but will be more dispersed, i.e., not colonial. The rocky shore may be a very important collecting zone, but is likely to be represented by lower numbers of a greater array of species (Szabo pers. comm.).

Taphonomic factors must also be considered in interpretation – what factors are at play, and how might they have affected the assemblage? For example, acidic soils will affect the survival of bone material, with small or fragile bones being more affected than large bones (McGovern-Wilson 1993). Shell will also survive better than bone in these circumstances due to its alkaline nature. Is absence a true absence, or is there another possible explanation for it?

7.2. Discard protocols

Whilst it is always desirable to retain all material recovered from an archaeological site, this is not always possible due to a lack of suitable storage facilities. Museums are generally unwilling to store midden material. However, the potential for future analysis of assemblages should be carefully considered before any material is discarded. Even in situations where a very thorough analysis has been undertaken, it is not possible to anticipate what further questions may be addressed in the future with new methods and techniques.

It is particularly important to retain bone, including as yet unidentified bone, wherever possible. The amount of bone from prehistoric sites is usually manageable, but for some historic sites, discard of some bone may be necessary.

New Zealand middens often contain large amounts of shell. It is possible to reduce the shell component considerably by discarding all left (or right) bivalves and perhaps by discarding identified, but uncountable fragments, once they have been weighed. However, samples should always be kept. Where possible, samples retained should be sufficiently large for size-frequency measurements. Retained samples might also be used for other analyses such as dating, investigation of seasonality, and oxygen isotope studies to examine past water temperatures. Prior to any discard it is important to ensure that none of the shells are artefacts.

If a decision is made to discard material, then the final report must state what was discarded and the rationale for the decision.

7.3. Storage

Archaeological faunal remains are often very fragile in nature, and proper curation is important if they are to be stored long term, to prevent deterioration and damage. It is imperative that all material is completely dry before being placed into long-term storage. Even slight dampness will eventually result in the material becoming mouldy. Bags must be both well sealed and well labelled, as must boxes. Bone and other fragile material should not be packed too tightly, and should be put into sturdy cardboard boxes. Heavy bones should be packed separately to smaller, more fragile bones to avoid crushing. A full inventory of the material, preferably in both paper and electronic form, should be placed with the material. Copies of specialist reports can also be stored with the material.

Many institutions will have guidelines for the curation of material for long-term storage, and as these may differ between institutions it is important to check with the intended storage facility as to their requirements prior to lodging material.

Glossary

Archaeozoology – the study of animal remains from archaeological sites. Also known as zooarchaeology (US)

Bulk sample – in the context of these Guidelines, a bulk sample is one which is unsieved and from which nothing has been removed

Coprolite – fossilised faeces

Countable portion – part of shell or bone containing landmark feature(s) that can be used for quantification

MNBC – minimum number of butchery cuts

MNE – minimum number of elements

MNI – minimum number of individuals

NISP – number of identified specimens

Otolith – a calcareous deposit found in the inner ear of vertebrates, used in fish identification

Taphonomy – the study of environmental and cultural processes affecting animal remains after death

Uncountable portion – piece of shell or bone not exhibiting landmark features

References

- Allen, M. and L. Nagaoka. 2004. "In the footsteps of Von Haast ... the discoveries something grand"; the emergence of zooarchaeology in New Zealand. In Furey, L. and S. Holdaway (eds.) *Change Through Time. 50 Years of New Zealand Archaeology*. New Zealand Archaeological Association Monograph 26: 193–214.
- Ambrose, W. 1963. Shell dump sampling. *New Zealand Archaeological Association Newsletter* 6(3): 155–159.
- Bunce, M., T.H. Worthy, T. Ford, W. Hoppitt, E. Willerslev, A. Drummond and A. Cooper. 2003. Extreme reversed sexual size dimorphism in the extinct New Zealand moa *Dinornis*. *Nature* 425: 172–175.
- Campbell, M. 2005. The archaeology of kakahi (*Hyridella menzeisi*). *Archaeology in New Zealand* 48(3): 101–112.
- Colley, S. 2006. A preliminary beef cuts typology for nineteenth century Sydney and some methodological issues. *Australasian Historical Archaeology* 24: 47–54.
- Davidson, J. M. 1964. Concentrated shell middens. *New Zealand Archaeological Association Newsletter* 7(2): 70–78.
- English Heritage. 2002. *Environmental Archaeology: A guide to the theory and practice of methods, from sampling and recovery to post-excavation*. Centre for Archaeological Guidelines. London: English Heritage.
- Grayson, D.K. 1984. *Quantitative Zooarchaeology: Topics in the Analysis of Archaeological Faunas*. Orlando: Academic Press.
- Harsant, W. 1983. Historical evidence of the use of unmodified shell tools in New Zealand. In Bulmer, S.E., R.G. Law and D.G. Sutton (eds.) *A Lot of Spadework to be Done*. New Zealand Archaeological Association Monograph 14: 151–172.
- Higham, T.F.G. 1990. The seasonal factor at Shag Mouth. Unpublished MA thesis, Department of Anthropology, University of Otago.
- Higham, T.F.G. 1996. Shellfish and seasonality. In Anderson A.J., B. Allingham and I.W.G. Smith (eds.) *Shag River Mouth: the Archaeology of an Early Southern Maori Village*. Canberra: ANH Publications, pp. 245–253.
- Irwin, G.J., M. Horrocks, L.J. Williams, H.J. Hall. M.S. McGlone and S.L. Nichol. 2004. Evidence for diet, parasites, pollen, phytoliths, diatoms and starch grains in prehistoric coprolites from Kohika. In Irwin, G. (ed.) *Kohika. The Archaeology of a Late Maori Lake Village in the Ngati Awa Rohe, Bay of Plenty, New Zealand*. Auckland: Auckland University Press, pp. 217–238.
- Leach, B.F. 1979. Maximising minimum numbers: Avian remains from the Washpool midden site. In Anderson, A. (ed.) *Birds of a Feather*. Oxford: NZAA Monograph 11 and BAR International Series 62, pp. 103–121.
- Leach, B.F. 1986. A method of analysis of Pacific island fishbone assemblages and an associated data base management system. *Journal of Archaeological Science* 13(2): 147–159.
- Leach, B.F. 1997. *A Guide to the Identification of Fish Remains from New Zealand Archaeological Sites*. New Zealand Journal of Archaeology Special Publication.

- Leach, B.F., A. Budec-Piric, J.M. Davidson and M. Robertshawe. 2000. *Analysis of Faunal Material from an Archaeological Site at Raumati Beach Near Wellington*. Museum of New Zealand Te Papa Tongarewa, Technical Report 35.
- Leach, B.F., J.M. Davidson, K.J. Miller, K. Greig and R. Wallace. 2009. *Salvage Excavation and Analysis of Faunal Material from an Archaeological Site (R27/24) at Pauatahanui Inlet Near Wellington*. Museum of New Zealand Te Papa Tongarewa, Technical Report 40.
- Lyman, R.L. 2008. *Quantitative Paleozoology*. Cambridge: Cambridge University Press.
- Mason, R.D., M.L. Peterson and J.A. Tiffany. 1998. Weighing versus counting: Measurement reliability and the California school of midden analysis. *American Antiquity* 63: 303–325.
- McGovern-Wilson, R. 1986. Small bird exploitation: An archaeozoological approach to the study of fowling in Southern New Zealand. Unpublished MA thesis, Department of Anthropology, University of Otago.
- McGovern-Wilson, R. 1989. First record of medullary bone from an archaeological context in New Zealand. In Sutton, D. (ed.) *Saying So Doesn't Make It So*. Auckland: NZAA Monograph 17, pp. 109–115.
- McGovern-Wilson, R. 1993. The taphonomy of big-game hunting in prehistoric New Zealand. PhD Dissertation, Department of Anthropology, University of Otago.
- McGovern-Wilson, R.J., F.M. Kirk and I.W.G. Smith. 1996. Small bird remains. In Anderson A.J., B. Allingham and I.W.G. Smith (eds.) *Shag River Mouth: The Archaeology of an Early Southern Maori Village*. Canberra: ANH Publications, pp. 223–236.
- Morley, M. 2004. *Seashells of New Zealand*. Auckland: New Holland Publishers (NZ) Ltd.
- Phillips, C. 2004. *Archaeological Investigation of Midden T12/1184, Rennie Street, Tararu*. Unpublished report to New Zealand Historic Places Trust.
- Samson, J. and P. Edgar. 1995. The seasonal factor at Papamoa Beach (U14/1717). In R. McGovern-Wilson (ed.) *Archaeological Investigations and Monitoring for Stage 4 of the Development at Royal Palm Beach Estate, Papamoa*. Unpublished report to Hawridge Developments and NZHPT, Appendix 2, pp. 49–82.
- Smith, I.W.G. 1988. *Bones from Auckland's First Gaol: Faunal Analysis at the National Bank Site (R11/1595) Queen Street, Auckland*. Auckland: Department of Conservation, Science and Research Internal Report 18.
- Smith I.W.G. 1996. The mammal remains. In Anderson A.J., B. Allingham and I.W.G. Smith (eds.) *Shag River Mouth: The Archaeology of an Early Southern Maori Village*. Canberra: ANH Publications, pp. 185–199.
- Szabo, K. 2009. Personal Communication.
- Witter, D. 2009. 3 ½ years of fieldwork – archaeology at Pegasus. *Archaeology in New Zealand* 52(3): 171–182.
- Witter, D. 2010. Email communication to R. McGovern-Wilson in response to a draft of these Guidelines.
- Witter, D. 2013. Shellfish disposal methods on the North Canterbury coast. *Archaeology in New Zealand* 56(3): 164–173.

Further reading

- Allen, M. and L. Nagaoka. 2004. “In the footsteps of Von Haast ... the discoveries something grand”; the emergence of zooarchaeology in New Zealand. In Furey, L. and S. Holdaway (eds.) *Change Through Time. 50 Years of New Zealand Archaeology*. New Zealand Archaeological Association Monograph 26: 193–214.
- Classen, C. 1998. *Shells*. Cambridge: Cambridge University Press.
- Davis, S. 1995. *The Archaeology of Animals*. London: B.T. Batsford.
- Leach, B.F. 1997. *A Guide to the Identification of Fish Remains from New Zealand Archaeological Sites*. New Zealand Journal of Archaeology Special Publication.
- Leach, B.F. 2006. *Fishing in Pre-European New Zealand*. New Zealand Journal of Archaeology Special Publication/Archaeofauna 15.
- Meehan, B. 1982. *Shell Bed to Shell Midden*. Australian Institute of Aboriginal Studies, Canberra.
- Lyman, R.L. 1994. *Vertebrate Taphonomy*. Cambridge: Cambridge University Press.
- O'Connor, T.P. 2000. *The Archaeology of Animal Bones*. Stroud: Sutton Publishing.
- Orton, C. 2000. *Sampling in Archaeology*. Cambridge: Cambridge University Press.
- Reitz, E. and E. Wing. 1999. *Zooarchaeology*. Cambridge: Cambridge University Press.
- Russell, N. 2012. *Social Zooarchaeology: Humans and Animals in Prehistory*. Cambridge: Cambridge University Press.
- Stine, J.K. 1993. *Deciphering a Shell Midden*. New York: Academic Press.

Acknowledgements

Heritage New Zealand Pouhere Taonga gratefully acknowledges the assistance of Janet Davidson, Matthew Campbell, Karen Greig, Ian Smith, Katharine Watson, Rick McGovern-Wilson and Yolanda Vogel in the preparation of these Guidelines, and Foss Leach and Caroline Phillips for the use of photographs.