The taphonomy of big-game hunting in prehistoric New Zealand.

Richard J. McGovern-Wilson

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ABSTRACT

This thesis examines patterns of bone remains from big-game hunting in New Zealand archaeological sites, and the origins of these patterns from a taphonomic viewpoint. Taphonomy, as a subdiscipline within archaeology, focuses on the events that impact upon bone remains, in the time between an animal's death and the point of analysis, and the effect of these events on the retrieval of information about the past. In spite of the importance of taphonomy to a fuller understanding of bone deposition, there has been relatively little work undertaken in this field in New Zealand, to date.

I examine the effects of two taphonomic agents, weathering (in particular subsurface, as opposed to subaerial weathering) and burning, on moa and seal remains from 17 big-game hunting sites throughout New Zealand. To establish a baseline for understanding the effects of weathering in the temperate climate zone, I conducted a three-year experiment whereby bones were exposed to a range of different weathering situations. The results suggest that subsurface weathering processes begin almost immediately with microorganisms within the soil quickly breaking down the soft tissue. An objective scale was developed for measuring the degree of weathering a bone has undergone, based on the prevalence of markers such as cracking of the diaphysis, the exposure of the underlying cancellous bone and, in the long-term, the large-scale flaking of cortical bone.

The analysis of these New Zealand wide archaeological collections provides evidence that, in the sites which I examined, taphonomic agents probably played an insignificant role in determining the fate of bones of big-game species. The taphonomic re-analysis did not alter the interpretation of the prehistory of those sites, and has not altered the interpretation of big-game hunting. The weathering of bone cannot be correlated with soil type, geographic region or with chronological age.

There are two two environmental zones which are exceptions to this. Firstly, areas of the North Island Volcanic Plateau and the West Coast of the South Island, where the high rainfall levels coupled with high soil acidity (pH <4.5) act to breakdown bone at such a rate that it does not survive to be recovered by archaeologists. Secondly, the inland basins of the South Island where pronounced freeze-thaw patterns work to destroy bone remains, which have been deposited in a landscape where soil deposition is negligible and the only protection provided to bones comes from the deposition of silt during the periodic flooding of streams or rivers, within a few decades.

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This thesis is dedicated to Peter Greenaway

Director of *Zed and Two Noughts* (ZOO)

who transformed the study of dead things into a new and artistic height

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Introduction.

TAPHONOMY

Time deals harshly with archaeological remains. The natural forces of sunshine, wind, rain, bacterial action, and erosion, together with human and animal breakage, treading and scavenging can cause objects to be pushed downward or sideways in the ground, or to be eroded even to the point of being removed completely from a site. The study of these and similar effects is called "taphonomy", from the Greek words *taphos* meaning tomb or burial and *nomos* for law or systems of law (Gifford 1981:366).

The term was coined first by a palaeontologist, Efremov (1940:85), to describe "the study of the transition (in all its details) of animal remains from the biosphere into the lithosphere, i.e. the study of a process in ... which the organisms pass out of the different parts of the biosphere and, being fossilized, become part of the lithosphere. The passage from the biosphere into the lithosphere occurs as a result of many interlaced geological and biological phenomena". The major foci of taphonomy are the events that intervene between death and fossilization and the effects of those events on the retrieval of information about the past.

Taphonomy, as a discipline within archaeology, was developed in Africa and to a lesser degree in North America as a response to the primary problem of distinguishing between bones from natural or predator kill sites on the one hand (e.g. hyaena, lion and bear) and those from cultural sites on the other (Miller 1975, Binford and Bertram 1977, Behrensmeyer 1978, Bonnischen 1979, Behrensmeyer and Hill 1980, Haynes 1980, Brain 1981, Gifford 1981, Shipman 1981, Dixon and Thorson 1984, Morlan 1984). Because taphonomy is an ecological study of the formation of death assemblages (Sivertson 1980:428, Lyman 1982a:337) it looks at many different aspects of bone remains and the processes involved in the formation of bone accumulations. From initial responses to the problem of determining the source of bone scatters, the field has grown to include a wide range of topics such as: the identification of avian predator deposits (Coy 1983:181, Craig et al. 1985); the effects of dogs, hyaenas and other scavengers on bone accumulations and the differentiation between their bone scatters and those attributable to humans (Brain 1981, Andrews 1983, Avery 1984, Hill 1984, Blumenschine 1988, Cruz-Uribe 1991); geological effects upon cultural remains, especially fluvial action and soil creep (Behrensmeyer 1990a); the effect chemical weathering has on bone preservation (Gordon and Buikstra 1981, White and Hannus 1983); the differentiation of cultural modification from weathering cracks and spiral fractures which cause pseudotools (Brain 1967, Tappen and Peske 1970, Miller 1975, Bonnischen 1979:26–34, Myers et al. 1980, Shipman 1981:173, Haynes 1983a, Johnson 1985); the distinction between cutmarks and animal gnawing (Bonnischen 1979:18–25, Archer et al. 1980, Horton and Wright 1981, Haynes 1983b); differential survival of bone classes, based on bone density, which is seen as an important variable that mediates taphonomic processes and controls the frequencies of fossil classes (Lyman 1982b); determination of the origin of unmodified bones; measuring post-depositional bone destruction through chemical and mechanical action after burial (Klein 1989, Marean 1991); and, differentiating between butchery and natural disarticulation in big-game species (Hill 1978, 1979, Hill and Behrensmeyer 1984, 1985). Gifford (1981) provides a substantial review of the development of taphonomy and the manner in which it has branched out to investigate many of these new fields. From within this broad range of topics, the major emphasis of this thesis is placed upon the action of subsurface bone weathering as the principal taphonomic agent concerning big-game hunting remains in the New Zealand context.

TAPHONOMIC AGENTS

The discussion above describes a broad range of taphonomic agents which impinge upon faunal remains following the death of an animal. There are four principal groups of agents which I consider important in the application of taphonomy to prehistoric big-game hunting, namely: animals, prehistoric peoples, archaeologists, and weathering.

Animals

The impact of animals on faunal remains, either through direct scavenging or trampling, can have serious consequences for archaeologists. Haynes (1983b) attempted to establish a set of criteria by which probable carnivore taxa responsible for inflicting damage on long bones could be interpreted. Recent ethnographic and experimental studies have raised the question of the extent to which dogs and other carnivores may have eaten up the archaeological record (Miller 1975, Hill 1976, Binford and Bertram 1977, Bonnischen 1979, Haynes 1980, Binford 1981, Brain 1981, Kent 1981, Walters 1984). Schiffer (1987:188–189) summarises a range of studies which describe some of the effects of bone processing and accumulation by large carnivores. The most important observations that have emerged from these studies are that carnivores can have significant attritional effects upon faunal assemblages, and when they do the assemblages are modified in patterned ways. In addition, dogs can have a serious effect in terms of the spatial rearrangement and dispersal of material (Schiffer 1987:70–71).

Recent reanalyses of sites of an equivocal nature, whereby either natural or cultural processes may be responsible for their formation, have revealed interesting results. A taphonomic re-analysis of Zhoukoudian (Binford and Ho 1985, Binford and Stone 1986) indicated that the faunal remains were possibly not solely the result of human occupation, but that carnivores had also been important agents in the deposition. Likewise, Dixon's work on late Pleistocene remains in the Porcupine River area in Alaska (1984), documented three major mechanisms which modify bone in patterns similar to the alterations produced by man, namely: carnivore fractures, rodent gnawing, and rock fall and rubble scarring.

Brain (1981) analysed nearly 20,000 hominid and animal bones from the classic cave sites of Sterkfontein, Swartkraans, and Kromdrai to answer the question 'Who were the hunters and who were the hunted? How did these bones enter the caves ?' He used taphonomy to answer these questions but initially he had to carry out a series of wide-ranging background studies dealing with many aspects of bone accumulation and preservation, by carnivores and humans, in a variety of open-air and cave contexts. These included looking at the diet of carnivores, bone accumulations at their lairs/dens/caves and comparison with the faunal remains recovered from supposedly human occupation sites.

In New Zealand the effects of carnivores in the creation of faunal assemblages is almost non-existent, due to the lack of mammalian predators prior to the arrival of humans, although they may have played a small role in the modification of culturally derived assemblages in prehistoric times when the Polynesian dog was introduced. Thus we have an excellent area in which to study the taphonomics of site formations — where pre-human sites (e.g. Pyramid Valley and O'Malley's Swamp, Paerau) are the result of natural processes, and cultural sites are a reflection of hunting and butchering practices only.

Prior to the arrival of the Polynesians the number of animals that could impact on faunal assemblages in New Zealand was minimal. The two most likely candidates would have been the New Zealand raven (*Palaeocorax moriorum*) and the Black-backed gull (*Larus domincanus*) which would have picked at soft tissue remaining on bones, shifting them around, and generally disturbing the spatial integrity of the remains. When the Maori arrived they brought with them two effective taphonomic agents in the form of the Polynesian rat (*Rattus exulans* — kiore) and the dog (*Canis familiaris* — kuri). The effect of the rat on the big-game remains would have been minimal, but they certainly impacted upon small-bird and probably fish remains.

The kuri may have had a significant affect on New Zealand faunal remains, both in the chewing and gnawing of bones and by shifting material around a site. So what do we know of the diet of the prehistoric dog in New Zealand? Ethnographic evidence indicates that dogs in Polynesia seem to have eaten mainly vegetable foods, such as breadfruit paste and taro (G. Forster 1977, cited in

Bay-Petersen 1984), while those in New Zealand were fed mainly on fish (e.g Crozet 1891:76). White (1889) records that their food was chiefly of rats, and native birds (quail, weka, pigeon and ground-lark). It must be remembered, however, that the ethnographic evidence relates to events in the late 18th century, especially around the north of the North Island when all the moa were gone, and the range of the seals was restricted to the south of the South Island, and so the dogs had none of the big-game on which they may have traditionally been fed.

Archaeologically it has been shown that dogs ate big-game remains, as evidenced by the state of recovered bones (Allo 1970, Kooyman 1985, Taylor 1984; also from material at Shag Mouth, Pleasant River and Pounawea (personal observation)), but coprolite studies by Byrne (1973) and Williams (1980) recorded fish bones and scales, along with plant fibres and spores, fragments of shell, along with grit and charcoal. Allo's (1970, 1971, 1979) work on the dog, and especially its dentition, found significant differences between dogs from the North and South Islands which she attributes to the differing diet. Periodontal disease, premortem tooth loss, and a greater degree of tooth wear in South Island dogs all tend to indicate that their diet may have consisted of more resistant matter (e.g. seal and moa remains, including bones), and that North Island dogs probably ate more vegetable foods.

However recent studies of the manner in which animals process the bone which they gnaw and eat suggest that it should be expected that only small bones would survive the process in a relatively intact and identifiable condition. In a series of experiments to test the survival of fish bone passing through the gut of pig, dog and human specimens, Jones (1986) found that less than 10% of the ingested bones survived passage through the animals' digestive system. This may have significant implications for the effects of dog attrition in New Zealand sites. While the fish bones were consumed whole, the bones of big-game are chewed and crushed before being swallowed. If less than 10% of whole fish bones survive, this may mean that crushed fragments of larger bones do not survive at all to be passed in faeces. In addition, we must take into account the nature of the midden material available to the dogs. Anderson (1989a:151) suggests that approximately 60–70% of the moa MNI return to sites as butchered joints, and the bones involved (femur and tibiotarsus) have industrial uses after the meat has been removed. Thus their availability to dogs may have been limited. In addition, nearly all moa bone which appears in archaeological sites is from fully matured birds where the epiphyses have fused to the diaphysis, and thus the bone is much harder than that of younger specimens. This material would be more likely to be left if other softer bone was present. In mammals we find the reverse situation, whereby the majority of animals caught are juvenile or sub-adult where the epiphyses have yet to fuse. This means that the dogs would find it easier to chew on the soft cancellous bone and this is generally what we find. Smith (pers.comm. 1991) has observed that one of the more common seal bones exhibiting dog attrition is the distal end of the radius, which results from dogs eating discarded flippers. The meat is flensed off the forelimb before it is discarded from the humerus down. Below the distal radius is waste material (for the Maori) so the dog starts at that end where there is still soft tissue present and works up. Miller (1975:212) likewise comments on the habit of predators and scavengers of preferentially chewing the soft cancellous bone rather than the compact bone. He observed that the soft cancellous bones (ribs, spinous processes of vertebrae, calcaneum etc) were generally the first parts of the skeleton to be worked on after the soft tissue had been consumed.

The full effect of dog attrition in the New Zealand situation has never been fully investigated. A study of possible significance is that by Marean et al. (1992) who presented a systematic and controlled experiment in which captive hyaenas were permitted to ravage simulated archaeological assemblages of unbroken and hammerstone-broken bones. The experiment showed that vertebrae and pelves were nearly always chosen first for consumption and all portions of vertebrae and ribs were destroyed nearly 100% of the time, while pelves and compact bone were destroyed 50–70% of the time. They continue:

> "The ends of limb-bones are destroyed frequently, but the middle shaft fragments are virtually never destroyed. This means that hominid discarded bone assemblages that have been ravaged by hyaenas will be robbed of vertebrae, ribs, pelves and compact bones, but the original number of

> limb elements will be reconstructible from middle shaft fragments. The result of hyaena ravaging is to mimic the schlepp effect. ... Selective hominid transport of limb elements is not a required explanation of this pattern [of low frequencies of vertebrae, ribs and pelves, and high frequencies of limb elements]" (Marean et al. 1992:119).

Obviously dogs in New Zealand sites would exhibit different behaviour and consumption patterns to hyaenas, but the possibility does exist that the softer elements were being consumed by dogs after the discard of these bones in a site. This may have been especially prevalent in those sites where dog gnawing is visible on the softer articular surfaces of the long bones, suggesting that dogs did have access to the discarded remains of large fauna.

Analysis of the effects of dog attrition at Twilight Beach (Taylor 1984:124) indicates that 47.0% of the seal bone showed evidence of having been modified through chewing and gnawing. The pattern of elemental survival can possibly be related to the attractiveness of the assemblage to dogs, especially the juvenile seal bones which have a thick periosteum and cartilagineous structure which are particularly attractive to carnivores, and rarely survive well in deposits. The low survival rate of the lower limb elements may be due to their having been discarded as parts of whole flippers which would have been attractive to dogs, as discussed above. Dog gnawing was present on all of the cetacean body parts, and common on most (op. cit.:156). While the dog mandibles showed no evidence of animal attrition, most of the other dog bones did show signs of damage (op. cit.:171).

The frequencies of dog bone at Mt Camel (N6/4) can be attributed to taphonomic processes, particularly dog chewing, operating on virtually complete carcasses (Nichol 1990:187). Bone from the site is heavily chewed and there are widespread and abundant toothmarks, with the effects of dog chewing clearly visible in the relative rarity of the proximal ends of longbones, particularly of humeri and tibiae. This matches carnivore damage as described by both Binford (1981) and Brain (1981). Numerous dogs at Mt Camel have also acted as quite powerful agents of attrition, and they have clearly caused considerable damage to many classes of material including dog bone, cetacean bone and fish bone.

In his major study of the Sunde Site, on Rangitoto Island, Nichol's analysis of the midden from above the ash in the large oyster lens midden (called the 'Soft Shore Midden') revealed that it contains a lot of evidence of dog damage (Nichol 1990:404). This was recorded both on bird bones and other dog bones which were found to be greatly fragmented with numerous bite marks apparent. A large bulk of the fish bone was also highly fragmented, and this is consistent with an intense level of dog attrition. Some have gritty yellow encrustations which may be an indication that they were partially digested before being passed in faeces and subsequently weathered out (ibid:407). This is consistent with the experiments conducted by Jones (1986), discussed above, and would suggest that the area may have resulted from a dog feeding station.

A further animal agent in site formation is that of natural mass deaths of animal species. In his discussion of bone clusters, Haynes (1988b) presents evidence to suggest that their association with cultural remains may not necessarily be as a result of big-game hunting by hominids, but may be the result of mass death sites, i.e. where a group of animals (of one or more taxa) died over a brief time span due to a single (natural) agency of death (op. cit.:219), or a cumulative bone site where large mammals have been exposed to numerous different predator mortality events. In both instances the remains may subsequently be scavenged by hominids, and the initial interpretations of hominids being the sole bone-collecting agency (e.g. Potts 1984) need to be re-evaluated.

People

People are certainly one of the most influential of taphonomic agents. As accumulators of bones, they introduce many variables into the process of bone deposition. Hunting strategies determine which animals are caught. Preference for animal products determines patterns of return, for although meat is generally the main product sought, bone and antler are also collected for tools, and skins and sinews for clothing. Butchery processes also influence the distribution and survival of elements and transportation impacts on these as well: small to medium animals are often returned whole to a site while the skeletal frames of larger animals are commonly left relatively intact at kill sites and their meat removed (Payne 1972:68, Sivertson 1980:428, O'Connell et al. 1992). People further damage bone during cooking and eating, during the cutting up of an animal for immediate consumption or storage, by grinding it down and altering it to make artefacts, by burning the bones, and in the tidying of rubbish.

Some bone breakage patterns are commonly associated with cultural activity, for instance, the 'crack and twist' technique for breaking bones frequently results in spiral fractures of the bone shaft (Brain 1981:140). However, it has been shown that predators can also produce similar fractures (Miller 1975, Bonnischen 1979:26–34, Myers et al. 1980, Shipman 1981:173, Haynes 1983a, Johnson 1985) and Tappen (1969, 1976) showed that fractures are likely to follow the main structural orientation of the bone which often is in a spiral fashion. The appearance of spiral fractures therefore tends to reflect more of the internal structure of the bone than the nature of the trauma the shaft has suffered (Gifford 1981:404). Break contours on living or fresh bone either follow the long axis of the collagen fibres or, if the breaks are not quite parallel to the fibre direction, the contours are irregular and splintered. In contrast, dried bones show a greater tendency to shear perpendicular to the long axis of the bone and its collagen fibres, because of the decreased shearing strength and energy-absorbing capacity of dried bone in that dimension. Dried bones that have been trampled may show what have been called columnar fractures — such fractures result in many rectangular or almost rectangular fragments of bone. Breaks parallel to and perpendicular to the long axis of the bone will often occur in bones where there are compressional stresses, such as bovine metapodials (Hill 1976:). Some differences in breakage patterns between fresh and mineralized bones include: 1) fresh bone shows negative impact scars on the lateral edge of the fragment directly below the impact point; these are not present in mineralized bones; 2) fracturing of mineralized bones produces rectangular fragments; and, 3) fresh or green bones commonly show spiral fractures, which do not occur in mineralized bone (Shipman 1981:173).

Taphonomic patterning of faunal remains in sites has been explained by the use of utility indices (e.g. Binford 1978, Lyman 1985, Jones and Metcalfe 1988, Metcalfe and Jones 1988, Grayson 1989, Marshall and Pilgram 1991). In particular, these have been used to explain the relative frequencies of skeletal parts of high food value (including the quantity and quality of bone marrow) in archaeological sites. The commonly held thread to the use of bone indices "is that human butchers will select bones for transport that tend to have high food values" (Lyman 1992:12). Furthermore, "the relationship between the volume density of skeletal parts and the utility of those parts for human consumers seems to be tightly dictated by functional anatomical principles" (op. cit.:18). In particular, the analysis suggested an inverse relationship existed between "the volume density and utility of appendicular skeletal parts, and a positive relationship between the volume density and utility of the axial skeleton" (ibid). Lyman (1992:20) concludes that faunal utility indices will only prove to be of help when they measure only the human behaviour variable, rather than a combination of different variables which may include factors "such as the probability that bone will survive attritional agents".

Previous taphonomic research in New Zealand has focused more on the cultural aspects than on the physical agents of taphonomy, such as Kooyman's (1985) work on moa hunting. Kooyman was primarily interested in body part representation as a means of distinguishing differential site types so as to characterize the make-up of kill sites versus butchery and habitation sites. He does accept that a variety of noncultural factors can alter the cultural information recorded in the original patterning of the remains (op. cit.:130) but does not describe them in detail. As a means of testing the amount of destruction the bones had undergone, due to these agents, he undertook to measure the cortical thickness of bones following Lyman's (1982) finding that bone density was a major factor in bone survival and this could be determined from cortical thickness. The results of this suggest that "If natural destruction of the bone in the archaeological sites examined was an important factor, the element representation data should fairly closely parallel the ability of bones to survive as measured by their cortical bone thickness" (ibid).

Archaeologists

Taphonomic processes continue when archaeologists excavate a site. Excavation, transportation, sorting, and cleaning phases all create damage to archaeological remains and their disposition. It is commonly accepted by archaeologists that breaks resulting from recent processes can be readily distinguished from damage inflicted in the past because they are clean and light in colour (Taylor 1984:76), but this may not always be true.

Some of the more important taphonomic factors that archaeologists bring to bear are derived from the very nature of the discipline. By excavating a site the bones are removed from their context and the integrity of the site is disturbed. The analysis of bones often results in them being broken and crushed — such as for stable isotope or trace element analysis. The sampling methods employed by archaeologists on a site are also a form of taphonomic agent. Deciding to excavate one area in preference to another, by test-pitting larger sites, by taking grab samples of faunal remains or by selectively collecting material over a certain size — these all play an important role in the life history of bones.

In many instances the need to sample a large site is driven by time and financial constraints, besides the sheer amount of work required. However, the archaeologist risks missing important information as often hunter-gatherer camp sites and temporary hunting and kill sites can range from several hundred to several thousand square metres in extent (O'Connell 1987, O'Connell et al. 1992).

> "Conventional excavation tactics at [contemporary single carcass and multiple kill] sites would often fail to capture important features of site structure and assemblage composition. Inferences about associated human activities would err accordingly. If the same scale of patterning is present at prehistoric sites, similar implications follow" (O'Connell et al. 1992:340).

In New Zealand, only Nichol (1990:Chapter 2) has discussed the problem of archaeologists as a source of taphonomic bias by examining techniques in the quantitative analysis of shell middens and he explored means of quantitatively measuring how much midden is potentially lost from a sample. By conducting experiments from a known starting point he concluded that most material is lost through crushing or the use of too large a sieve by archaeologists. This latter point is important in a country such as New Zealand where coastal middens often contain large amounts of fish and small bird bones, and where the use of sieves greater than 3mm mesh will almost guarantee the loss of information.

Weathering

Undoubtedly, however, one of the most important categories of taphonomic agents is that encapsulated by the term "weathering". Weathering is best described as the process by which bone decomposes through the breakdown of the chemical matrix as the result of physical and chemical agents working on the bone while it is lying on the ground surface or within the soil matrix. These agents include the effects of sun, wind and rain, as well as chemical attack such as the leaching of minerals to and from the immediate environment. It involves both macroscopic (cracking, flaking, fragmentation etc) as well as microscopic changes to the bone, and will ultimately result in the complete destruction of the bone unless there is a change in circumstances and the bone is either buried or fossilized. There is a distinction which must be made here between the weathering that bones undergo on or above the ground surface, i.e. 'subaerial weathering', and that which occurs below the ground surface within the soil matrix. For want of a specific term, the latter is referred to in this thesis as 'subsurface weathering'. In this thesis that term will only be used to describe that process which is occurring below the ground surface, while use of the term 'weathering' will be in reference to the more general concept of bones undergoing change due to environmental conditions, and to weathering which bones undergo on the ground surface.

In this thesis the predominant emphasis is on the subsurface weathering of bone from big game hunting sites in prehistoric New Zealand, and I discuss whether the differential recovery of bone classes in archaeological sites is naturally or culturally derived, and how this might in turn alter our perception of big-game hunting during the prehistoric period.

The most important step forward in the understanding of non-cultural taphonomic processes in New Zealand archaeology was the work by Taylor (1984) who analysed mammalian fauna from the site of Twilight Beach (N1–2/96). It was his contention that taphonomic and cultural influences on the faunal material in middens had been neglected by New Zealand archaeologists and under-utilised as a source of information, and therefore "The principal objectives of [the] analysis were to document the taphonomic and cultural factors that had influenced this bone assemblage in order to identify what could be reliably inferred from the remains about the activities of the prehistoric people there" (op. cit.:1).

There are also a number of what Taylor (1984:3) describes as physical variables which are of importance. These include the effects of such factors as weathering, animal attrition, and trampling. Taylor (op. cit.:17) dismisses trampling as irrelevant to New Zealand's prehistoric record because he sees it as being the product of herd animals. However, given the soft substrate in which the vast majority of big-game sites are to be found, the effect of human trampling on bone must be considered. He developed a means of measuring the degree of weathering observed on the bones, taken almost directly from Behrensmeyer (1978), but paid most attention to factors such as body part representation, age profiles exhibited by the remains, and animal attrition.

The analysis of the weathering evident in the Twilight Beach seal remains (Taylor 1984:120–122) resulted in three main observations: (1) there was a low incidence of the more advanced stages of weathering (splitting and flaking) which would tend to indicate that the assemblage had not been exposed to surface weathering for any great length of time. Cracking was common but he felt this was more a function of the bone drying after burial; (2) the surface bone exhibited a slightly higher degree of weathering than the excavated bone, but not significantly so; (3) variation existed within the excavated samples, in that while cracking and root damage increased with midden depth, splitting and flaking decreased. He argues that the shell in the midden above would have prevented much water percolating to the lower midden and the shell would also have neutralised any acidic properties of water that did percolate.

The cetacean remains exhibit slightly different results which can be explained in part by their different bone structure. "Cetacean bone generally consists of cancellous bone encased in a thin shell of compact bone which prevents the bone from cracking and splitting, in the manner typical of other mammal bone. Instead, weathering of the compact whale bone removes the shell, leaving the cancellous bone exposed and because of the coarse cellular nature of this bone, the physical variables were not apparent" (op. cit.:156). Therefore, only the whale vertebrae were examined for weathering as they retained the outer shell. Fifty percent of the caudal vertebrae showed evidence of weathering due to their large surface area, highly cellular structure and the unossified nature of the bone, despite their large size.

The dog remains from Twilight Beach generally showed higher rates of all forms of weathering than those of seals and this was most notable on the mandibles which all showed extensive splitting (Taylor 1984:171). It is uncommon to find damage on dog mandibles as they are the strongest and most solidly constructed element. Taylor (ibid) suggests that the high rate of splitting here may indicate that these bones were being cooked.

In his wide-ranging investigation of midden material from northern North Island archaeological sites, Nichol (1990) addressed a number of taphonomic questions. In an attempt to assess the amount of attrition and decay of fishbones in archaeological sites, Nichol (ibid:61–66) began by comparing class frequencies of material across sites. This could be achieved by 'comparing relative frequencies of different anatomical elements across a number of sites, so that the extent of the dispersion of the frequencies of different bone classes at a site can be used as a guide to the extent of attrition there' (Nichol and Wild 1984). They argue that "Clearly animal bones could be rather more durable than those of snapper without dispelling doubts about many styles of prehistoric ecology and economics, and techniques of environmental reconstructions, site seasonality and the like are seriously at risk if the numbers of bones in sites are such a poor guide to the number originally deposited" (ibid:47).

The original study (Nichol and Wild 1984) of nine assemblages of snapper bones from six sites produced potential results. In the two sets of samples from stratified middens relative dispersion of class frequencies decreased in lower layers. These results are consistent with the idea that it is percolating rainwater, with dissolved CO_2 in the form of carbonic acid, that is responsible for most of the losses to assemblages. Under these circumstances material in the upper layers of a site protects that below, and the almost impervious Rangitoto Ash which covers the Sunde site protected the assemblage beneath it best of all (Nichol 1990:68, 174; Nichol and Wild 1984).

Nichol's taphonomic analysis of fishbone from Kohika (N68/104) found that the jack mackerel remains were evidenced by vastly greater numbers of cleithrae than head bones (Nichol 1990:171–172). This was possibly due to removal of the heads in order to prevent rapid decomposition of the fish. Alternatively, the frequencies are the result of differential attrition — many of the jaws simply decayed in the ground.

Although the prehistoric Maori in New Zealand exploited a wide range of faunal resources, including fish, small-birds and shellfish, I have concentrated my research on the remains of big-game species, as these are comparable in size to some of the species in other parts of the world on which weathering analysis has been undertaken.

BIG-GAME HUNTING IN NEW ZEALAND

At the time of their arrival in New Zealand the Polynesians found a land bereft of large terrestrial mammalian fauna. In its place were two main groups of taxa that the Polynesian settlers soon adapted to big-game hunting strategies — the moas (Aves: Dinornithiformes) and various classes of sea-mammals (Note: big-game are here defined as species with live adult body weights of 20kg plus).

Turning first to the sea mammals, the work by Smith (1985) is the most comprehensive available. To a certain extent his research centred around the exploitation of fur seals (*Arcotecphalus forsteri*) as this was the most widespread and most exploited species in New Zealand, but the Maori also exploited Hooker's sea lion (*Phocarctus hookeri*), the southern elephant seal (*Mirounga leonina*), the leopard seal (*Hydrurga leptonyx*), and several species of cetacean. Smith's research indicated that at the time of initial settlement breeding populations of fur seals were to be found throughout the country, including the far north of the North Island, the east coast of the Coromandel, Cook Strait, and the southern coasts of the South Island from Otago into Foveaux Strait. Their distribution even spread as far north as Raoul Island in the Kermadecs (Anderson 1980). By the end of the prehistoric period, their breeding range was confined to the western and southern coasts of the South Island (Smith 1985:406).

The pattern of exploitation differed for the various species. The only means of exploiting the medium to large cetaceans (pilot whales (Globicephalae) and sperm whales (*Physeter macrocephalus*)) was by scavenging naturally stranded animals — taking the teeth and some bones for industrial purposes, and the meat for immediate use. The smaller cetaceans (dolphins (*Delphinus* and *Lagenorrhyncus*)) were occasionally scavenged, but along the east coast of the South Island Smith (ibid:407) records a strong correlation between the distributions of bone harpoon points and small whale remains, suggesting they may also have been hunted with harpoons.

Seal hunting was a land-based pursuit, and it is suggested that in one third of the assemblages the fur seals were captured at seasonally occupied colonies during the late spring to early autumn (although some were invariably caught during the winter months) (Smith 1985:408). The most likely hunting technique was by stalking the animals and killing them with a blow on the snout. The representation of body parts suggests that they were butchered primarily for immediate consumption, and some parts of the body (notably the mandibles and canines) were retained for artefactual purposes. The second strategy employed in fur seal exploitation was the 'occasional opportunistic hunting' (ibid:409) of beached individuals. The elephant seal and sea leopard were probably also hunted via the opportunistic method, as were the sea lions, but given that the latter are also a colonial species, purposive hunting of sea lions was probably also undertaken. The hunting of seals made a significant contribution to the diet, with only fish matching them in overall meat, energy and nutritional yields (ibid:410).

The second taxon of big-game, the moas, were hunted throughout New Zealand from the time of initial settlement, with the most intensive exploitation occurring along the east coast of the South Island. Kooyman (1985:311) proposed that hunting was undertaken directly from habitation sites rather than from temporary hunting camps in most cases. This is indicated by the presence of low value bones in a much higher frequency than would be expected from their economic value. Hunting was close enough, however, for 20–30% of the birds to be returned as whole carcasses. Some initial butchering was completed at the kill site, with the rest of the bird being processed at the habitation site, but these kill sites are not recovered archaeologically because they represent the remains of only one or two birds, as shown by Anderson (1982).

Anderson (1989a:151), however, argues that the butchery sites were not the kill sites, and at larger sites such as Hawksburn, Kaupokonui, Wairau Bar and Rakaia Mouth, 60–70% of the MNI arriving at the site had had their heads or lower legs (or both) removed prior to their arrival. Thus while in general it appears that the butchery sites were not the hunting/kill sites, some whole carcasses were returned to these sites suggesting that there had been direct hunting from them. Kill sites represent initial butchery of only a few moa and characteristically have only a few informal stone tools.

Some of the butchery related to transportation constraints associated with large game, with the general result being the removal of the head, neck and breast, and the lower leg and foot as three separate units. Thus the pieces most commonly arriving at the habitation site were the two upper legs and pelvis (sometimes with the thoracic vertebrae attached), weighing up to 20–50kg for a medium moa. The cut mark patterns indicate that little segmentation occurred at the kill site, save that to prepare the pieces for transportation, and at the habitation site the segments tended to be cooked in the form in which they arrived (Kooyman 1985:313–314). This pattern of separating off the meatless parts of the animal at the kill site (lower legs, head/neck/breast) accords well with hypotheses based on historic and ethnographic data. The extraction of marrow was found to be a common aspect of moa processing, but Kooyman suggests that little evidence exists for the preservation of moa meat (ibid).

The hunting strategy employed in moa hunting was probably as an activity carried out by small groups or individuals using wooden spears, and possibly snares and dogs (Kooyman 1985, Anderson 1989a). The presence of a few dog gnawn bones in most sites clearly indicates the presence of dogs and if these dogs had a bone-rich diet (Anderson 1981a:17–18), the relative rarity of the gnawing would tend to indicate that either moa bone was not the source of the bone in their diet, or there were few dogs present, or they were controlled.

The archaeologically recorded hunting camps probably represent temporary kill sites where preliminary butchery of moa was performed. The ethnographic record has numerous examples of identical systems whereby mobile hunting groups range over a hunting territory, hunting within the immediate vicinity of the habitation site and shifting the camp when the local hunting became unprofitable (Kooyman 1985:319). That the Maori hunted moa on a more individual basis is interesting given that communal hunting was not unknown (for example when ducks were moulting (Phillipps 1947)) but it possibly suggests that the moa did not congregate in large groups and so communal hunting was not appropriate. The cassowary (the ratite most similar to the moa) only occasionally forms groups of more than a few individuals and perhaps moa likewise lived as solitary birds or in small groups of only a few individuals (Kooyman 1985:325).

Hunting tended to be generally non-selective and broad spectrum (Kooyman 1984) amongst species within the major habitats, but concentrated on the *Euryapteryx* assemblage (Anderson 1989a:152). In areas such as the Canterbury coast and the interior of the islands where there was limited access to other types of fauna, moa hunting proceeded into the forest-dwelling species.

THE INITIAL HYPOTHESIS

It has become apparent that faunal remains in New Zealand are affected by a number of taphonomic agents. The most important are the series of cultural influences that the Maori had on the remains — from the time an animal was killed, until its remains were deposited in a site, and the site subsequently abandoned. But in addition, a number of other processes are involved — dog attrition, trampling and weathering. In general, it was found that dog attrition can be differentiated from other taphonomic processes (such as weathering and chemical disintegration) by the tell-tale marks left by the teeth, especially the canines, as the bone was chewed.

In the conclusion to his work on the Twilight Beach mammal remains, Taylor (1984) felt that interpretation of the analysis of taphonomic processes indicated that they had had a considerable effect on the bone remains. In particular, human butchering and artefact manufacture, and dog attrition, had a marked impact on the patterning of remains observed. However, given an understanding of the diversity of the bone structure in the different species, these processes could be recognised and isolated, and the patterning of remains explained in a consistent manner. The taphonomic evidence also indicated that the site was formed over a reasonably short period of time, and the fact that there was little evidence of advanced weathering indicates that the midden had not been exposed on the surface for any great length of time.

Taylor does, however, caution that the interpretation of these results can only be preliminary because there has been a lack of systematic work undertaken on New Zealand faunal material and the effects that physical taphonomic processes can have. He feels (Taylor 1984:233) that there is a requirement for observation of these processes on fresh bones of each of the animals recorded as archaeological food sources, taking into account the differing structure of the bones of these species which may make cross-species comparisons meaningless, in order that the taphonomics can be better understood. This is illustrated by the difficulty in observing the weathering equivalent to the categories outlined by Behrensmeyer (1987), on the bones of pilot whales.

Anderson (1989a:112) highlights one of the principal outstanding short-comings of the analysis of big-game hunting in New Zealand when he states "we hardly know anything about the range of appearance or any other qualities to be expected in moa bone subjected to a variety of exposure lengths in the highly diverse weathering conditions presented by New Zealand's soils and climates". A differential reasoning for the appearance of moa bone in archaeological sites has thus arisen within New Zealand archaeology. In northern areas, it is generally argued that the occurrence of only thick-walled leg bone fragments is due to their having been imported for industrial purposes (Nichol 1990:496–505 provides a review), while in the South Island "any moa bone in a secure archaeological context constitutes *a priori* evidence of moa-hunting" (Anderson 1989a:112). In defence of this, however, "it is also fair to point out that it is the same bones chosen for industrial purposes which are least vulnerable to disappearance by rotting, trampling, gnawing etc., and their exclusive presence need not, thus, imply selection, only differential survival" (ibid).

Taylor's final comments (1984:194) regarding the weathering of bone at Twilight Beach included: "Also of note were the patterns evident in the survival of remains, particularly those of the cetaceans. Detailed consideration of these patterns in the previous chapter raised a number of issues concerning the effects of weathering and animal attrition on bone assemblages, as well as for the interpretation of human activity. Further examination of all these issues is beyond the scope of this dissertation".

Thesis objectives and outline

It is my opinion that these factors now represent the source of greatest potential value for understanding New Zealand's big-game archaeology. Until such time as we fully appreciate the natural processes which impact upon faunal remains in New Zealand sites, we cannot confidently state that the remains solely represent the practices of big-game hunting. The most important of these is bone weathering, and this thesis re-examines faunal collections from a series of big-game hunting sites from around New Zealand, to determine the role that weathering, and in particular subsurface weathering, has played in the survival of bones and whether the differential survival of bone in archaeological sites is a result of natural or cultural processes.

Chapter 2 discusses the chemical and physical structure of bone before examining the method and theory behind the breakdown of bone via a number of different processes — cultural, physical and mechanical, and chemical. This leads into a discussion of the means to measure the degree of weathering evidenced in bone remains from archaeological or natural contexts, by way of a 'bone weathering scale' (Chapter 3). The process of bone weathering, both surface and subsurface, in the temperate New Zealand environment was experimentally measured (Chapter 4); the results were applied to an archaeological case-study (Chapter 5); and then to faunal remains from big-game hunting sites from throughout New Zealand (Chapters 6 and 7) to determine whether this extensive re-analysis alters our interpretation of the archaeology of the sites (Chapter 8).

Chapter 2.

Weathering of Bone in Archaeological Sites.

INTRODUCTION

The analysis of bone and teeth from archaeological excavations provides a wide range of essential information on the taphonomic and cultural reactions that they have passed through. To avoid misinterpretations both intrinsic and extrinsic factors, which may have altered the condition of the bone prior to its being incorporated in the archaeological site and those which have interacted during the burial in the soil, have to be taken into consideration. The amount of direct sun versus shade, the amount of rainfall, the pH-value, humidity, and temperature of the soil, the transport in solution and the pressure of the surrounding earth, as well as the activity of microorganisms are the cause of such alterations. The decay of bones is connected with the transformation of hydroxyapatite to the acid calcium phosphate brushite, whose pressure of crystallization contributes to the mechanical destruction of the bone.

Bone has both structural and metabolic functions in the living individual. In addition to providing a counterforce to muscle activity and gravity, bone is vital in maintaining ionic concentrations of certain elements (e.g. calcium) at constant levels in blood serum. Bone is able to accomplish these functions because it is a complex tissue composed of a protein matrix in close chemical association with its mineral phase. In addition, bone is cellular and has a vascular and nerve supply. Living bone is dynamic — constantly undergoing surface and internal remodelling all during the life of the individual.

After death and burial, changes begin to take place as a result of several factors. Apparently, living cells are needed to maintain the relationship between protein and mineral phases. At death, this relationship begins to deteriorate. This chapter examines the structure of living bone (extrapolating from data relating to human bone to other animals), and some of the taphonomic processes which act upon the survival of faunal material in archaeological sites. In so doing, a number of issues are raised which will be examined further on in the thesis.

THE PHYSICAL AND CHEMICAL STRUCTURE OF BONE

Bone is a dynamic, cellular system made up of a complex mixture of organic and mineral components which combine both the structural and physiological functions and properties of elastic and brittle solids (such as their compressional and tensile strength as well as rigidity and hardness) (Armelagos et al. 1989:232, Price 1989a) and, as such, "it provides a strong yet resilient framework capable of self-repair" (Schiffer 1987:182–3). Bundles of collagen fibres (organic) and crystals of the calcium phosphate mineral, hydroxyapatite (hereafter abbreviated to OHA), are bound together by "an amorphous 'cement' consisting of organic and inorganic ingredients" (Hare 1980). The function of the collagen is to "provide nucleation centres for initiating the calcification of bone" (Price et al. 1985:419). Osteons are the basic structural units within the nucleation centres responsible for the formation and resorption of bone and the orientation of these structures influences some mechanical properties of bone (Schiffer 1987:183).

Mammal bone occurs in two basic tissue types: cancellous (or trabecular) bone, which is found mainly at the epiphyseal ends of long bones, in the ribs and vertebrae, and is spongy and of low density; and the compact (or cortical) bone, which makes up the diaphysis of long bones, is denser and has no macroscopic pores (Schiffer 1987:183).

The tissue consists of three major components: the organic matrix, an inorganic or mineral phase, and water. These fractions occur in the approximate proportions of 17:20:15 in fresh bone powder (Engstrom et al. 1957:28, cited in Price et al. 1985:419). The organic matrix comprises approximately 25–30% of the dry weight of bone (LeBlond and Weinstock 1976:536), with the mineral phase making up much of the balance. Almost 90% of the dry weight of the organic material is accounted for by collagen, with the remainder consisting of a variety of noncollagenous proteins (NCPs) (Table 2.1) (Hancox 1972:36, Hare 1980:209). The cement consists of a range of compounds but includes significant amounts of carbonate, citrate, magnesium and sodium, as well as a host of minor ingredients (Pritchard 1972:5). The water is contained in the lacunar and canalicular spaces of the bone and the hydration shell of the OHA (Jowsey 1977:20).

The mineralized layers of bone are arranged concentrically around the central Haversian canals. The bone mineral (OHA), which is bound to the protein fibres, is a relatively insoluble complex consisting of calcium (Ca^{++}) and phosphate $(PO_4)^{3-}$ in a ratio of approximately 2:1, and hydroxyl (OH^-) ions, along with a range of trace elements such as Na^+, K^+, Mg^{++}, Sr^{++} (Table 2.2) (McLean and Urist 1968:56, Price et al. 1985:419). The collagen molecule consists of three polypeptide (alpha) chains coiled about one another in a triple helix (Boskey and Posner 1984:34). Phosphorus comprises 15.5–16.4% of the mineral, while the amount of Ca is less certain but averages approximately 37.3% (Price 1989b:132). The unit cell for OHA is a right rhombic prism and has the formula $Ca_{10}(PO_4)_6(OH)_2$ (Posner 1969:762). *In vivo,* the OHA crystallites are in equilibrium with the body fluids which act as the reservoirs of the organic and inorganic salts required by the body (Saleeb and De Bruyn 1972).

Most of the research into bone chemistry has been conducted on human bone, but results on other mammalian material indicate that a similar situation exists (Table 2.3). Boskey and Posner (1984) show that, at least in cattle beasts, there is an increase in mineral content of cortical bone from 63% to 76.4% as the animal ages from a calf to an adult. This figure for an adult animal is similar to that quoted above. By comparison, McLean and Urist (1968:Table 2) give a figure of 70.91% of air-dried compact bone tissue for the mineral content in ox femur diaphyseal bone.

In addition, however, studies have indicated that a range of noncrystalline amorphous calcium phosphate (ACP) phases exist in bone (Table 2.4) (Hancox

Table 2.1 Components of the organic matrix of cortical bone as percentage of dry weight of organic fraction (from Price et al. 1985:420).

Primary	%	Secondary	%
Collagen	79.2–88.9		
Noncollagenous protein	4.7–9.5	Peptides	0.48–0.53
		Albumin	0.60–1.79
		Lipoprotein	0.30–0.98
		Protein polysaccharides	0.24–1.66
		Phosphoprotein	0.20
		Sialo proteins	0.36
		Glycoproteins, other associated proteins, errors, etc.	4.95–8.35
		Carboxyglutamic acid rich protein	1.00
Insoluble collagenase-resistant material and insoluble material resistant to gelatinization	1.56–4.90		

Table 2.2 Components of the mineral portion of cortical bone as percentage of dry weight (after Armstrong and Singer (1965)).

Cations	Calcium	26.70 +- 0.15
	Magnesium	0.436 +- 0.009
	Sodium	0.731 +- 0.015
	Potassium	0.055 +- 0.0009
	Strontium	0.035
Anions	Phosphorus as PO_4^{---}	12.47 +- 0.013
	Carbon Dioxide as $CO_3^{=}$	3.48 +- 0.022
	Citric Acid as Cit^{---}	0.863 +- 0.004
	Chloride	0.077 +- 0.004
	Fluoride	0.072 +- 0.003

Table 2.3 Table of the composition of various cattle bones of varying ages (from Boskey and Posner (1984)).

				Percent of dry weight			
Source	Age	Type	%H_2O	Mineral	Collagen	GAG	Lipid
Cow	calf	periosteal	*	54.0	22.2	0.38	*
		cancellous	*	52.0	19.4	0.52	1.7
		cortical	*	63.0	16.9	*	0.6
	adult	cortical	9.1	76.4	21.5	0.20	1.03

GAG - Glycosaminoglycan * - not determined

1972:48, Pritchard 1972:5) with a range of Ca/P ratios from 1.3 to 1.5. The more soluble immature phases (DCPD, OCP and TCP) occur only at the endosteal, subperiosteal, cortical and Haversian surfaces and the composition of these derives from stoichiometric values due to ionic substitutions of elements supplied from the foods and water ingested by the individual (Amjad 1984:1, Pate and Hutton 1988). They appear to precede apatite (Katzenberg 1984:16), and while these amorphous phases are similar in composition to OHA, they do not display its characteristic x-ray diffraction pattern (LeBlond and Weinstock 1972:535). Harper and Posner (1966, cited in Posner 1969:778) reported that approximately 40% of the mineral in the femurs of rat, cow, and adult human was noncrystalline. These phases become less amorphous with age as the relative proportions of the poorly crystalline OHA increases as the bone matures. The Ca/P ratio is less than 1.6 in the cartilage of growing animals, while that in bone is greater than 1.6 (McLean and Urist 1968:56). Virtually all the mineral in archaeological bone is crystalline apatite, because the amorphous calcium phosphate changes almost spontaneously in water (Waldron 1987:147). Although trace elements are present in the matrix water in an ionic form, most of the original water will be lost before the skeleton comes to archaeological attention.

Apatites are characterized by their abilities, especially in the post-mortem environment, to undergo isomorphous substitutions within the crystal lattice

Table 2.4 Calcium phosphate phases of bone mineral in order of decreasing acidity, decreasing solubility and increasing thermodynamic stability (Neuman 1980).

Formula	Chemical Name	Molar Ca/P
$Ca(HPO_4)_2H2O$	Dicalcium phosphate dihydrate (DCPD)	1.00
$Ca_4H(PO_4)_3$	Octacalcium phosphate (OCP)	1.33
$Ca_9(PO_4)_6$(var.)	Amorphous calcium phosphate (ACP)	1.3–1.5
$Ca_3(PO_4)_2$	Tricalcium phosphate (TCP)	1.50
$Ca_5(PO_4)_3OH$	Hydroxyapatite (HAP)	1.67

whereby, in the case of bone apatite, calcium may be substituted by other divalent ions such as lead, strontium, magnesium, barium, or even sodium and potassium, and the monovalent hydroxyl ion is often replaced by fluoride (McLean and Urist 1968:58–9, Hancox 1972:46, LeBlond and Weinstock 1972:536, Price 1989b:134, Pate et al. 1991:58). The phosphate group can be substituted by carbonate groups, present as $C0_3^=$, which is the third most abundant ion in bone mineral (Posner 1969: 765, Hassan et al. 1977:365). The $CO_3^=$ group cannot stereochemically substitute for the two monovalent anions (OH^- or F^-) because of its significantly larger size (McConnell 1962:257). The F^- exchange is extremely dependent on pH with only small amounts of fluoride taken up in alkaline solutions, while under more acidic conditions much more is fixed by the apatite crystals. The percentage of $CO_3^=$ increases with increasing pH and decreasing phosphate concentration (Simpson 1967:901), although in very dilute solutions the carbon dioxide content of apatite is less dependent on pH than when in a concentrated solution. Simpson (ibid) found that "with pH 8–9, a range of both geological and biological interest, apatite formed in dilute solutions had a carbon dioxide content of about 3.5 weight percent".

LeGeros et al. (1967:1411) argue that the carbonate's introduction into the apatite lattice interferes with the crystallization and has a weakening effect on the bonds in the structure which, in turn, increases both the rate of dissolution and the solubility. Most fossil bones are found to contain significant amounts of carbonate, deposited after the animal's death, which are released from the bone during acid hydrolysis (Schoeninger and DeNiro 1982:577). In spite of losing up to 90% of their collagen, fossil bones retain the concentric striation pattern of modern bones which reflects the organisation of the collagen (Hassan and Ortner 1977:132).

When bones enter the depositional environment, they are no longer subject to the biological discrimination against minor and trace elements that occurred during the life of the organism. The chemical composition of the post-mortem phase will differ from the *in vivo* values, in that it will reflect the composition of the soil solution (Pate and Hutton 1988). The fats break down rather rapidly after burial but the protein diagenesis is much slower, and in conditions where the soil is permanently frozen or where total anaerobic conditions exist, the proteins may last for thousands of years (Oakley 1969). Hedges and Wallace (1980) recovered collagen for a 700 year human skeleton, which had been contained within a saturated but not anaerobic condition. The bone had a greater proportion of soluble, nonspecific polypeptides in relation to the total organic content, and the composition of the soluble fraction closely resembled collagen on the whole. The main agents of the decay process are chemical disintegration, and biological, especially microbial, attack (Hedges and Wallace 1978). Likewise, blood and collagen have been shown to survive for up to 90,000 years (Kooyman et al. 1992, Loy and Hardy 1992).

In addition to ionic substitutions and exchanges, bone undergoes continual dissolution and recrystallization throughout the life of an individual (McLean and Urist 1968:57, Sillen 1981b).

The porous nature of bone is also conducive to infiltration by material into the vascular and cellular spaces of bone. Inspection of fossil bones by Hassan and Ortner (1977:135) using microscopic and x-ray studies found that the inclusions were of two sorts — ground water precipitates (e.g. calcite, humates and pyrite), and solid grains (e.g. quartz, hyphae, rootlets and charcoal).

The Ca/P molar ratio in modern bone is approximately 2.2 and sees little variation across the osteon (Hassan and Ortner 1977:134) while, in contrast, the fossil material generally has a much greater Ca/P ratio (approaching 2.5) toward the Haversian canals. Neuman and Neuman (1958) argue that the only ways by which the composition of apatites may vary from the theoretical Ca/P molar ratio, without affecting the structure of the lattice are, (1) by substitution of one group for another, (2) surface substitution, exchange, or adsorption, and (3) through the presence of unsubstituted defects in the internal lattice. McConnell (1962:262), on the other hand, argues that the variations can simply be explained by (1) the introduction of excess Ca, or (2) a decrease in the amount of phosphorus. Natural OHA (with a Ca/P ratio of 1.75) from Mexico has undergone substitution of 'tetrahedral hydroxyls' (H_4O_4) for the phosphate groups (McConnell 1965:425).

THE BREAKDOWN OF BONE IN ARCHAEOLOGICAL SITES

When an animal dies, and is subsequently deposited in a biological or archaeological setting, the body begins to break down and become incorporated into the surrounding matrix. The rate and manner at which this process occurs is dependent on a wide range of factors, which may be grouped together under three different categories (Figure 2.1): physical processes (the amount of rainfall, sunlight, and temperature variation, and the effects of biological attacks from scavengers, microorganisms etc.), chemical processes (implies the remains are buried and undergo diagenesis), and cultural processes (burning, trampling etc.). By their very nature these processes occur at different rates. The cultural processes occur contemporaneously with the time of burial, or postdepositionally, when the destruction of the bone is relatively quick and the results are then impacted upon by the long term, and relatively slow, physical and chemical processes.

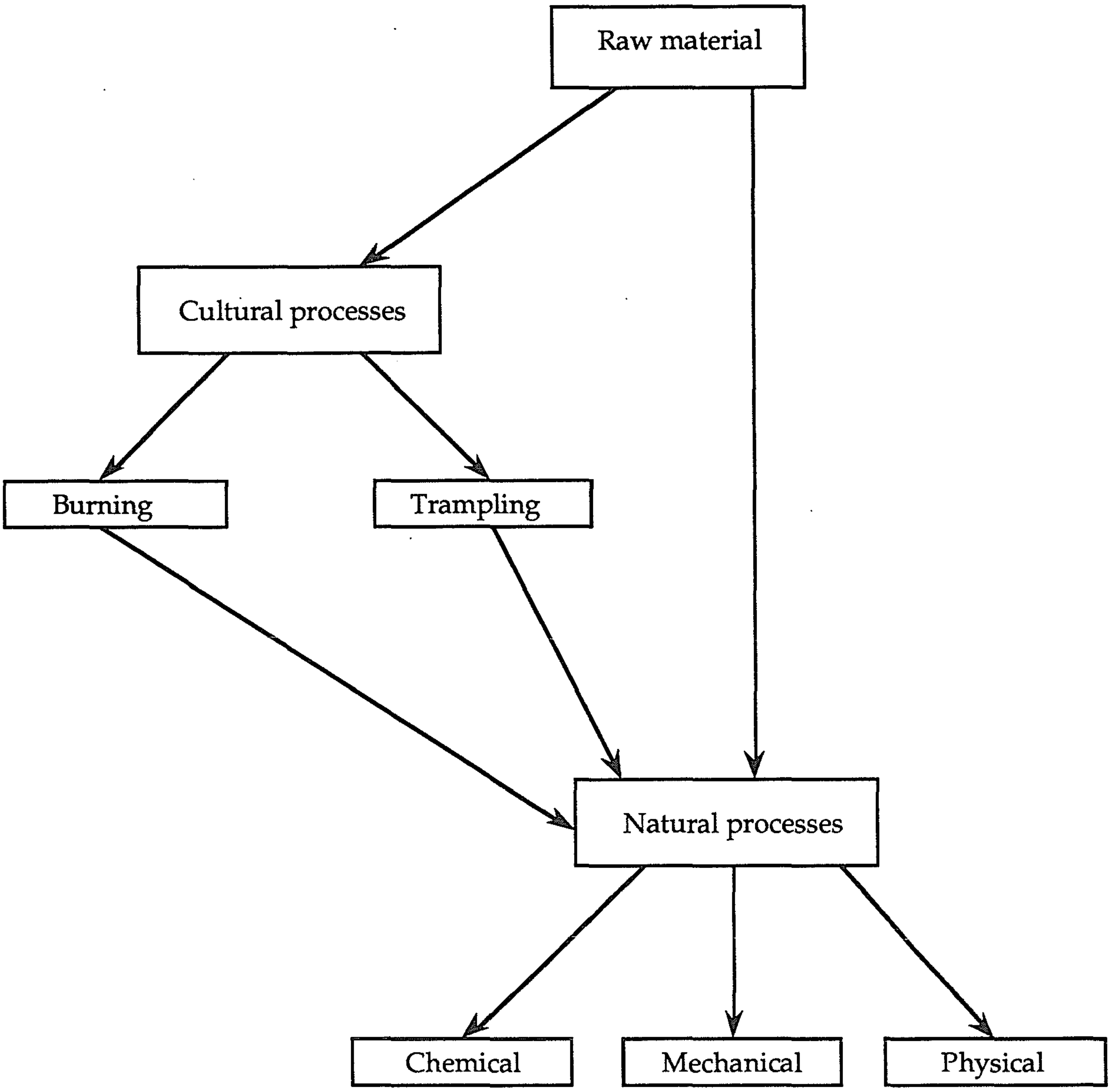


Figure 2.1 Schema of the taphonomic processes affecting bone remains.

Cultural processes

Burning.

The burning of bone in archaeological sites derives from a variety of different sources. Bones may be burned through the cooking process, refuse disposal, the deliberate use as fuel instead of wood, the setting of new fires on old bone heaps, casual discard in hearths, and through natural or accidental fires.

Brain (1981:54) conducted simple experiments with bones in the ashes of cooking fires which demonstrated stages of charring. As the collagen in fresh bone is carbonized it turns black, but with continued heating this carbon is oxidized and the bone colour changes back to white and the bone structure becomes chalky. He found that it was possible for a single bone to show a gradation from unburnt through black to white. He suggests that while cooking may have charred exposed bone, the burning of bone probably occurred more directly as a result of bones being discarded into hot ashes or when a new fire was set over the remains of an old fire. Archer (1977) and Lampert (1981) concur with this argument for the appearance of burnt bone in early Australian rockshelters, while Archer et al. (1980) and Balme (1980) suggest that the charred bones at Mammoth Cave and Devil's Lair, respectively, may have been due to broken animal bones being exposed from carcasses (which they argue were cooked whole) during the cooking process, although both the latter two studies do raise the possibility of bones having been burnt in bush fires.

Kooyman (1985:116–117) argues that large scale burning of bone must be due to either refuse disposal or the use of bone for fuel. While casual discard of bone into hearths was quite likely, it would not account for extensive destruction of bone through burning, as seen in the New Zealand sites of Hawksburn and Coal Creek.

> "Refuse disposal is not necessary at sites that are not reoccupied, nor at sites that are not occupied on a long term basis. ... Extensive refuse disposal is

> probably indicative of permanent occupation of a site or an area. Bone would make an acceptable fuel as it does burn quite efficiently once started. It might be used instead of, or in addition to wood for a number of reasons: a quantity is available from butchering and it might as well be used rather than being discarded; the weather is cold and all possible fuel is being used; wood is not available, either because it has been exhausted locally, it is unsuitable for burning (e.g. it is too wet), or it cannot be collected (e.g. due to bad weather); religious beliefs dictate that bone must be burnt; bone is deemed to have a particular, or better, heating quality. When bone refuse is being burned, it will probably be collected into piles ... some distance from the main habitation and working areas ... [and one would] anticipate incomplete burning at the base of the pile, at least in some instances. In New Zealand, bone used as fuel in ovens would be associated with the ovens and would be raked out in a pattern consistent with the manner in which ovens are normally cleaned out. ... Burning of bone as fuel in hearths ... would probably not result in a pattern that would indicate the specific purpose behind the burning" (Kooyman 1985:116–117).

Walters (1988) disputes the notion of bones being discarded in fires, or of refuse being burned to remove it from a site. His study of the Utopia Aboriginal people suggests that the discarding of bones in fires is 'pollution' — the fires of the Utopia people are built from hardwood *Acacia* for the purpose of cooking food only and that bones are thrown away from the hearth, the 'bones' throw' distance of Gould (1969:8, cited in Walters 1988). Obviously cultural ideals play a role in the way that different peoples relate to features such as the hearth. Walter (op. cit.) argues that the appearance of small fragments of burnt bone in Utopia sites is due to new hearths being created on living areas, but that large bones are swept or carried beyond the perimeter of the living area and are unlikely to have fires lit upon them.

When bone is burnt it can become more friable and porous, and thus more susceptible to damage from agents which destroy bone (Chaplin 1971:18). Organic matter is removed during burning, leading to a weight reduction by approximately one third, and resulting in the bone structure becoming very brittle. The amount of shrinkage in bone which Ubelaker (1989) recorded during experimental firing ranged from 1–25% depending on the density of the bone and the temperature and duration of the fire. "No shrinkages occurred until the temperature reached 700°C. There was a progression between 700 and 900°C, but higher temperatures produced no further shrinkage" (op. cit.:35). The loss of water from the hydroxyl crystals in OHA crystals, and the loss of water molecules bound to the organic material, during heating, causes the extensive cracking and warping in burnt or heated bone (Shipman et al. 1984:321). The physical characteristics of burnt bone depend on the firing temperature, whether the bone has been crushed or broken prior to burning, and the amount of fuel, ash and charcoal present (Gejvall 1969:469). Differences have been recorded in the way cortical and cancellous bone react to burning — cortical (or compact) bone cracks and breaks into pieces, while cancellous (spongy) bone "shrinks slightly during burning but in general retains its shape" (ibid).

The most readily recognisable criterion for identifying burnt bone, at the macroscopic level, is colour. Bones which have been burnt are most commonly blackened but the more heavily they have been burned the colours range through red-brown, grey and white. Shipman et al. (1984) summarise how bone passes through a continuum from unburnt bone, to "non-incinerated or smoked bone that shows blackening on the edges, to incompletely incinerated bone (blackened or dark brown in colour), to completely incinerated or calcined bone that is usually described as bluish-white or grey in colour" (Shipman et al. 1984:308). At a microscopic level, there are a variety of changes which bones undergo when they are burnt, not least a change in colour and structure. Shipman et al. (op. cit.) described five distinct stages in the burning of bone (Table 2.5) and also five stages in the changing morphology (Table 2.6).

Under the microscope, fresh bone is pale yellow in colour and has a low birefringence because of the OHA content (Coutry et al. 1989:109). As it is burnt

Table 2.5 Colour changes in the heating of bone (after Shipman et al. 1984:312–313).

Stage	Temperature (°C)	Colour range
1	20–<285	white, pale yellow, yellow
2	285–<525	reddish brown, very dark grey-brown, neutral dark grey, reddish-yellow
3	525–<645	neutral black, medium blue, reddish-yellow
4	645–<940	neutral white predominates, light blue-grey, light grey
5	940+	neutral white, medium grey, reddish-yellow

Table 2.6 Morphological changes in the heating of bone (after Shipman et al. 1984:314–315).

Stage	Temperature (°C)	Tissue appearance
1	20–<185	normal
2	185–<285	increased surface roughness
3	285–<440	glassy and very smooth
4	440–<800	frothy or fleecy appearance
5	800–940	frothy protuberances coalesce into smooth-surfaced globules or nodules

not only does the colour change, but so does the birefringence as the structural changes that accompany the loss of organic material modify the optical properties until above 650°C it has the birefringence of calcite (ibid). Not only are the optical properties affected, but changes are also apparent at the isotope level. DeNiro et al. (1985) found that changes in the $d^{13}C$ and $d^{15}N$ values of collagen are caused by mild heating, such as roasting or boiling, but more extreme heating, such as the temperatures recorded during cremation or the burning of discarded refuse, shifts the ratios by a large enough margin to render them unsuitable for dietary reconstruction. Likewise, trace element levels have been shown to be altered during firing to high temperatures (Herrmann and Grupe 1988, Grupe and Hummel 1991). While Ca/P ratios remain similar to that of native bone at lower temperatures, above 800°C the OHA crystals are modified to b-tricalcium-phosphate, undergo "shrinkage of up to 30% as a consequence of recrystallisation and crystal fusion" (Grupe and Hummel 1991:177), and exhibit a 'physiological' Ca/P ratio (Herrmann and Grupe 1988:96).

Burnt bone also shows a distinctive breakage pattern due to the high tension collagen fibres denaturing at high temperatures (Shipman (1981:177). Transverse cracks appear perpendicular to the long axis of the bone, sufficient enough to break across the shaft or, if they connect with a longitudinal split, may break away sections of the bone (ibid). The condition of the breakage surfaces distinguishes between 'postfossillization' cracks and those derived from burning — "Burned bones show a characteristic polygonal cracking pattern on subchondral surfaces; sometimes the polygonal plates curl up at the edges and fall off. This pattern is distinct from the mosaic cracking of articular surfaces produced by weathering" (Shipman 1981:177).

Trampling.

The effects of trampling by both humans and herd animals is often forgotten, and certainly under-rated, as a taphonomic factor in the accumulation of archaeological debris. Whether it is by animals or by humans undergoing their daily activities, the process disturbs previously deposited materials on or near the ground surface. In a soft substrate, such as the sand-dunes upon which most of the coastal sites in New Zealand are situated, trampling can play an important role in the accumulation history of a site. Taylor (1984:17) downplayed the effects of trampling in New Zealand because he felt that it was symptomatic of herd animals only. This section outlines a number of natural and archaeological case studies into the effects of trampling, and experiments that have been undertaken to test these in a controlled manner.

Behrensmeyer (1990a:7) defines trampling as "a physical process involving the impact of the feet of animals on the ground surface. It can mark, break, and/or bury bones that are lying upon or immediately under the surface". Hesse and Wapnish (1985:25) include it as a perthotaxic process ('those which move and destroy fragments of bone before they come to rest and are buried'), along with weathering and gnawing, and list trampling among a series of more natural variables (freeze-thaw cycles, plowing, rodent burrowing, insects, plant roots, and crustacea) that churn archaeological sites and selectively destroy the temporal and spatial data. The elements of articulated skeletons may become separated so they no longer appear to be from one individual, and primary associations between bones and archaeological remains can become so disturbed that reconstruction of the original assemblage is impossible (Olsen and Shipman 1988:536). Trampling tends to crush and bury bones of varying shapes and compositions, depending upon the substrates and can cause both isolated and multiple sets of grooves and linear marks similar to cut-marks caused by human implements in substrates with relatively medium or coarse grain size (Behrensmeyer 1990a:7). Trampling also polishes bone surfaces and causes rounding of the edges, especially in a soft substrate. Most importantly, it has been shown that trampling modifies the horizontal and vertical distribution of artefacts in archaeological sites, even to the extent of moving material across apparently undisturbed stratigraphic horizons. Finally, it sorts artefacts by size with smaller material tending to migrate downwards. Many researchers identify two types of trampling, based on the direction in which the affected material moves — described originally by Stockton (1973) as 'scuffage' (horizontal movement) and 'treadage' (vertical movement).

There are a number of variables which appear to affect the degree of bone modification through trampling in any archaeological site. These include — the weight of the trampler, and the hardness of the foot; the frequency with which the bone is trampled; the texture, grain-size and hardness of the substrate — a property which Schiffer (1987:126) terms as penetrability, and links to moisture content, chemical constituents and vegetation; the condition of the bone surface, the degree of weathering it has undergone, its moisture content and that of the surrounding substrate, and whether it is covered by periosteum or other soft tissue. Behrensmeyer (1990a:7–8) argues that the modification experienced as a result of trampling is only clearly visible on fresh or slightly weathered bones (weathering stages 0–1), and that it is often blurred by subsequent weathering, abrasion through fluvial or aeolian action, or by post-mortem diagenesis. The marks do tend to occur with greater frequency on the diaphyses and other smooth portions of the bone rather than the rougher sections such as the epiphyses.

In an archaeological assemblage there tends to be some correlation between the intensity of trampling and the occurrence of cultural materials on the ground. In the more heavily utilised areas there should be fewer items present (due to the removal of waste material to midden areas), but any material that is present will be heavily trampled. Conversely, in areas of substantial cultural buildup, such as secondary refuse areas, one would expect to find a lower degree of trampling (Schiffer 1987:126).

There have been a number of studies into the effects of trampling by both humans and large animals. These can be grouped into a number of main categories: (1) those which examine bones from palaeontological sites where trampling is probably a major cause of damage (see Olsen and Shipman (1988) for references); (2) ethnoarchaeological observations of trampling by modern groups of indigenous people (Brain 1967, Gifford and Behrensmeyer 1977, Gifford 1978, DeBoer and Lathrap 1979); (3) the effects of herd animals (Brain 1967, Behrensmeyer and Dechant Boaz 1980, Haynes 1983, 1988a, Andrews and Cook 1985, Borrero 1990); (4) experimental replications of trampling (Stockton 1973, Tringham et al. 1974, Villa and Courtin 1983, Gifford-Gonzalez et al. 1985, Behrensmeyer et al. 1986, Olsen and Shipman 1988, Nielsen 1991); and (5) archaeological sites where trampling is suspected as the main cause of disturbance of the cultural material (Stockton 1973, 1977, 1980, Cahen and Moeyersons 1977, Hughes and Lampert 1977, Siiriäinen 1977, Gifford 1978, Rosenfeld et al. 1981, Rowlett and Robbins 1982, Villa 1982, Villa and Courtin 1983, Hofman 1986, Richardson 1992).

These studies have tended to focus on two main issues — that trampling (particularly that of humans) disturbs stratigraphic sequences by producing vertical migrations of material, and trampling produces damage patterns on bones and lithics that are similar to those produced by use or butchering activities (Nielsen 1991:483). In all the cases described above, an inherent problem exists that trampling can often be masked by subsequent taphonomic factors, such as weathering, which may be of significant over-riding importance. The advantage, therefore, of experimental trampling is that all other taphonomic variables can theoretically be controlled, allowing for the fact that this control may introduce additional, unnatural conditions which cultural material may not experience in a natural setting. Olsen and Shipman (1988:536) argue that problems arise in distinguishing between traces produced on bone during trampling, and those made during butchery, and therefore that criteria need to be established for separating trampling from humanly produced cut marks.

During fieldwork in the undisturbed ranges of bison and moose, Haynes (1983) recorded the effects of scavenging and trampling on naturally occurring carcasses and skeletal remains from dated predation and death events, over the course of several seasons, as well as recording the weathering history of the bones. He found that 8% of bones show evidence of carnivore damage, in the form of spiral or green-fractures, and 5% show modifications due to trampling. There was even higher incidences of both these forms of damage (up to 50%) on the bones of smaller species.

When long bones are gnawed by carnivores, the damage is initiated at the softer epiphyses and as the cancellous bone is consumed so the shaft is exposed. The subsequent gnawing, biting and levering of the shaft sometimes creates spiral cracks through the cortical bone, and this weakening of the bone structure leaves them susceptible to fracture from trampling, "with the fracture directed at least partly along the spiralling crack lines" (Haynes 1983:105). Trampling in the wild by hooved animals generally involves either kicking the bones several centimetres, or placement of the hoof directly on the object lying on the ground. The more weathered and degreased the material is, the more brittle it becomes and so the more likely it is to fracture. Haynes (op. cit.:111) also noted that material in Stage 1-2 weathering exhibited spiral fractures similar to that which one would expect to find in green-bone remains. This type of remain is more commonly found in well shaded and moist areas such as woods or meadows, or in wet areas such as pond margins and stream crossings.

The greater percentage of the bones recorded, however, were not spirally fractured but bore the characteristic marks of advanced weathering — "multiple longitudinal cracks with rounding edges, exfoliation of the periosteal tissue, and splintering of the fracture edges" (Haynes 1983:113).

In a similar study of non-cultural elephant remains in southern Africa, Haynes (1988a) recorded proportions of spirally fractured limb bones as high as 62% in mass death assemblages at Shabi Shabi and Shakwanki. Trampling marks mimicked cutmarks made by stone tools, and tusk fragments were similar to specimens identified as artefacts (op. cit.:131). About 40% of bones on the ground surface were found to bear trampling marks in the modern elephant die-off locales, with most of them bearing only isolated incisions (op. cit.:154). The frequency of cutmark mimics, and the similarity of naturally occurring tusk fragments to 'archaeological' material leads Haynes to comment (1988a:131) that "numerous attributes of non-cultural assemblages are virtually indistinguishable from attributes that archaeologists have believed to be created by human behaviour alone".

Many of the long bones in this study had weathered for quite some period of time (up to three years), but still exhibited spiral fractures when stepped upon by elephants. The amount of protection from weathering, through the effects of thick grass, or bones lying in mud, inhibits the development of typical weathering features, and so determines the degree of longitudinal versus spiral fracturing (op. cit.:150). The less weathered the bone, either because of its age or the weathering stage it has attained, the more likely it will fracture spirally.

Brain (1967) had encountered a similar collection of pseudotools from the Kuiseb River area of South Africa. These tools showed an even polish and several were tapered to a fine point — on first glance, unquestionably cultural implements used for the preparation of skins or some similar purpose. Investigation revealed that they had been recovered from the sand surrounding a village waterhole where 460 goats gathered daily to drink. Disturbance of the sand by their hooves abrades the surface of bone fragments lying in the sand to produce a polish normally associated with human activity.

A further example of the similarity between natural and cultural modification of bone surfaces is documented by Andrews and Cook (1985) who recorded the breakup of a cow skeleton and the subsequent dispersal of the bones by trampling over a seven and a half year period. Upon recovery, the bones were examined by SEM and the marks produced by trampling of the bones on a rocky substrate, and the moving of the bones among the rocks produced a non-random pattern of incisions very similar to those left by human processing of carcasses (op. cit.:689). The main difference between trample marks and cutmarks, which Andrews and Cook (ibid) suggest can be used to determine the possible origin of the incisions, is that trampling marks were concentrated along the shafts of the long bones with a transverse orientation, while cutmarks concentrate at the articular ends of the bones. In addition they described the trample marks as being "... numerous, generally superficial, closely spaced, intersecting and of variable curvature, length and breadth" (op. cit.:681).

Matthews (1965) was among the first to recognise the problem of upwards migration of material in archaeological deposits. While he does not directly suggest that trampling was a cause, he does put it down to the daily activities of people living on archaeological deposits — the digging of postholes and pits, the movement of people, the scavenging by dogs and children, the hollowing of hearths — all serve to mix the deposit and bring older material to the surface. He assumes that this 'zone of disturbance' would affect the upper 30cm of a habitation deposit (Matthews 1965:295).

It was archaeologists working closer to home who first realised that trampling was a direct cause of the mixing of archaeological material in sites found on soft substrates. Stockton (1973, 1977, 1980) recognised a size sorting differential in action at the Shaw's Creek and several other Blue Mountain aboriginal sites in Australia. In the loose sandy floor of these sites, continuous occupation over a period of time would see a vertical displacement of cultural material with smaller items down-pressed, while the larger flakes were seemingly uplifted (Stockton 1973:115). This differential he ascribed to the effects of 'treadage', where material is depressed into the sandy floor, and 'scuffage', where the material was forced along horizontally by the action of the foot. The implications of such movement are the likelihood that abrupt cultural changes may be masked by the mixing of artefacts from adjacent levels.

This situation occurred in a site (Sassafras I) discussed by Hughes and Lampert (1977:139) whereby backed blades are found up to the surface while at the nearby site of Currarong they do not occur in levels younger than about 1500BP. This difference is explained by the nature of the substrates in the two sites and, therefore, by a vertical displacement due to trampling. At Sassafras there is a loose sandy deposit which would not have inhibited vertical movement, while in the Currarong site a capping of tightly packed shells would have ensured that there was no such movement of artefactual material.

In this discussion of the effects of trampling on archaeological deposits, there are a number of smaller studies that implicate human movement across the site in the displacement of material. Siiriäinen (1977) argues for vertical displacement, through both trampling and artefacts dropping into fine cracks in the soil, as an explanation for the distribution of artefacts he recorded. Cahen and Moeyersons (1977) undertook a systematic reassembly of worked cores from the Iron Age site at Gombe Point in Zaire, and found that vertical distances of up to 1m separated conjoining pieces from vastly different archaeological phases. While trampling is a possible reason for this movement, Cahen and Moeyersons (ibid) also conducted experiments into the alternate wetting and drying of the sediments as a secondary explanation, using simulations of oscillating water tables and the percolation of rain water from the surface. Rowlett and Robbins (1982) recorded the vertical movement of coin molds at the Iron Age hillfort site of Titelberg in southwestern Luxembourg, and found more extensive movement occurred outside the buildings (9.4% of the molds had migrated upwards) where pedestrian traffic was greatest. Likewise, Rosenfeld et al.'s (1981:7) study of the Early Man Shelter in North Queensland showed that it was meaningless to plot the location of artefacts in great detail because of the vertical and horizontal displacement produced in the loose sandy sediments.

As part of her investigations in the East Turkana region, Gifford (1978, Gifford and Behrensmeyer 1977) surface plotted the distribution of artefacts at Site 20, immediately after abandonment. There then followed three separate flooding events across the site, before it was excavated. Two hundred pieces had been surface plotted but the excavation revealed a further 1953 from the subsurface layer, averaging ca. 3cm as a maximum dimension. Trampling was seen to be the primary cause for this size-dependent sorting within the fine sand substrate, with fragments less than the 3cm dimension migrating downwards while larger material remained partially exposed on the surface. This vertical displacement had occurred after only four days' occupation of the site (Gifford 1977:81).

Gifford (ibid) proposed a number of hypotheses regarding the effects of trampling upon cultural materials, which included: "Elements below 3cm maximum dimension are highly likely to become primary refuse, while those above this size are less likely to be primary refuse"; "elements likely to be primary refuse are also likely to migrate subsurface due to trampling"; and "A subsurface trampling zone will contain a relatively higher proportion of primary refuse than will the surface zone of a site". These hypotheses will be more closely examined later in this section, in light of the results from experimental research undertaken into trampling.

Hofman (1986) linked a number of 'physiogenic and biogenic processes' to the vertical movement of items in fine silty clay river-terrace deposits, such as those in which the Cave Spring site was recorded. This movement was between distinct depositional units with very similar sedimentological compositions and this has important implications for archaeologists attempting to differentiate between archaeological levels based on changes in artefact composition. Trampling was one of only a series of postdepositional processes seen to be responsible for the vertical movement in this site — others included the shrink-swell action of the terrace sediments, collapse of decayed root structures, tree throws, burrows and galleries of both vertebrates and invertebrates, and freeze-thaw action (Hofman 1986:167).

In an interesting reanalysis of some Old World sites, Villa (1982) uses the evidence of conjoining bone and lithic fragments to show that these sites have undergone disturbance of the archaeological assemblages. The presence of undisturbed matrix or finely stratified sequences are not sufficient to rule out vertical displacement of artefacts. The failure to recognise the importance of postdepositional mixing, she argues, seriously affects the validity of studies which require a fine control over the interpretation of stratigraphic units. The displacement of material may occur even when the matrix itself has not been visibly disturbed (Villa 1982:278).

She discusses four principal sites in which conjoining of material has supported the hypothesis that there has been vertical mixing of artefacts: the sites of Gombe Point in Zaire, Meer II in Belgium, Terra Amata, and Hortus in France. Her arguments for Gombe followed Cahen and Moeyersons (1977) in which alternate wetting and drying of the sediments by an oscillating water table or percolating rainwater were the primary cause. The Epipalaeolithic site of Meer II was excavated over an area of 220m^2 with the archaeological material coming from an homogeneous sandy layer. The artefacts were distributed through a vertical depth of 35-50cm, with conjoinable pieces being recovered up to 40cm apart vertically (op. cit.:279–280).

In a reanalysis of the Terra Amata cultural material, Villa (ibid) found even more serious problems within the stratigraphic record. Conjoinable fragments were separated by up to 20-30cm vertically, 40% of the refitted pieces belonged to different cultural levels, and conjoined pieces were even dispersed through different geological layers and from stratigraphic subdivisions within some of the sediment layers (e.g. the lower sand unit). Villa attributes the vertical dispersal to a variety of factors, including: trampling, mixing by fauna, and alternate wetting and drying of the sediments by waves. She also suggests that while these factors could explain a real movement across different levels (natural and cultural) of stratigraphy, other explanations linked to the excavation strategy (e.g. misunderstood contacts between adjacent levels, excessive subdivision of the deposits) would indicate only apparent displacements (op. cit.:285). In the fourth site of Hortus, teeth and jaw fragments belonging to the same Neanderthal individuals were scattered through vertical distances of 50cm, across four or five layers (ibid).

Conjoinable pieces, therefore, are able to indicate the degree of mixing, over considerable vertical distances, which may occur in archaeological sites. This displacement, either postdepositional or contemporaneous with the time of burial, can occur without visible traces of disturbance, and can occur both within homogeneous layers, and across different geological strata. Furthermore, artefacts scattered through a considerable thickness of sediments may belong to a single occupation episode (Villa 1982:286-7).

Applying this same concept of conjoinable pieces to material from Fontbregoua Cave in southern France (a 9m+ sequence of Upper Palaeolithic, Mesolithic, and Neolithic deposits) allowed Villa and Courtin (1983) to determine vertical displacements were occurring of up to 30cm across apparently distinct cultural layers. The density of the material at Fontbregoua indicated that the site had been intensively occupied, and the scattering of conjoinable pieces over large areas, both horizontally and vertically, seems to suggest a non-localized agency of displacement in the dispersal such as trampling (Villa and Courtin 1983:272).

Recent work on the stone tools from Kenniff Cave, Central Queensland, Australia by Richardson (1992) revealed conjoined flakes "from different excavation layers [which] exhibit a maximum vertical separation of 30.4 cm, covering approximately 2500 years and a minimum vertical distance of 11.5 cm which equates to about 300 years" (op. cit.:417). This was despite the well stratified and apparently undisturbed appearance of the deposit.

To test the effects of trampling on cultural assemblages, a number of experimental replications have been undertaken. Stockton (1973, 1977) conducted a simple experiment by laying out fragments of red glass on a level sandy surface, covering them with 5cm of sand, and leaving them to be trampled for a day. Upon excavation it was found that material had been roughly sorted by weight over a depth of 16cm, with the larger material at or near the surface.

Villa and Courtin (1983) recreated the Stockton experiment but extended the trampling phase to up to 36 days, by people walking in and out of the cave during the course of the excavation, across material which was buried in light sand. Their results showed that trampling in such substrates can cause mixing of materials from two separate layers, predominantly in a zone 10-16cm deep, horizontal displacement was occurring over distances of up to 85cm, and there was a distinctive size sorting in action with smaller pieces (less than 50g) being the more mobile in a vertical displacement.

Gifford-Gonzalez et al. (1985) conducted a similar experiment in two different substrates — a compact sandy silt (loam), and medium- to fine-grained beach sand. Two people wearing moccasins or sandals walked over the scatter of obsidian debitage for two hours. This was a far more intense period of foot traffic than the experiments described above but they had set out to "subject materials and substrate to a substantial amount of treadage" (op. cit.:808). Artefacts in the loam substrate underwent minimal downward migration but tended more towards horizontal displacement. Fracture of small pieces was the dominant damage pattern. By contrast, the sandy site was an efficient trap of nearly all artefacts, and during the experiment pieces were continually vertically circulated (ibid). Most pieces migrated to 3-8cm depth with the distribution approximating a normal curve, and the dominant damage pattern consisting of edge damage on larger flakes.

Nielsen (1991) further examined the question of damage to archaeological materials, in particular pottery sherds and obsidian flakes (although bones and fragments of wood and brick were also included they are not reported upon in the results). The experiments were made on dry, hard-packed surfaces both before and after rain. All fragments underwent vertical and horizontal displacement, although the effects of treadage were minimal because of the solid nature of the substrate. The degree of damage exhibited on the flakes is sparse — most show one to three randomly distributed scars, on either surface, with a trend towards larger scars on steep edges (op. cit.:500). A few pieces in the dry substrate experiment show rows of continuous parallel scars along an edge, which could be easily misinterpreted as intentional retouch (ibid).

Behrensmeyer et al. (1986) and Olsen and Shipman (1988) conducted experiments to investigate the differentiation between trampling marks and cutmarks on bone fragments. In the Behrensmeyer et al. experiment, relatively fresh (weathering stage 0–1) bones of horse and cow were trampled in the damp sand and gravel of a stream. The trampling scratches occurred as sets of parallel, shallow marks oriented obliquely to the long axis of the bone (1986:770). Cutmarks, by comparison, are generally found on areas of ligament attachment or occur in areas unlikely to be exposed to other taphonomic processes. They do comment, however, that while it is unlikely that multiple trample marks could be mistaken for scraping or cutting marks, isolated trample marks on the areas identified above could be (ibid).

Olsen and Shipman (1988) subjected sheep and cattle bones to trampling in four different substrates (pea gravel, coarse sand, fine sand, and potting soil) by people walking barefoot over them for two hours. The results were that in all cases (except for those using potting soil) the bones exhibited a polish on the bone surface, similar to that described by Brain (1967, 1981), and fine, shallow striations of varying orientations along the diaphyses. None of the trample marks matched cutmarks in all details (especially lacking were the parallel lines within the main grooves which are commonly seen in cutmarks), but in particular the distinguishing features were the high numbers and the varying degrees of orientation exhibited by the trample marks, and their widespread occurrence on the diaphyses of long bones, rather than in places of ligament or muscle attachment where cutmarks generally occur (Olsen and Shipman 1988:549–550). In addition, the striations were extremely fine and shallow and lacked known distinguishing characteristics usually associated with cutmarks (e.g. parallel grooves within the cutmark) (ibid).

It is obvious from the work discussed above that trampling has quite possibly had a profound effect upon archaeological sites in New Zealand. The loose sandy substrate in which most of them occur would quickly and easily be affected by treadage and scuffage, and the evidence that cultural layers can be mixed, even if they are separated by up to 50cm, bears a substantial relevance to the New Zealand situation where multi-layer sites generally display very little vertical distance between cultural horizons.

Physical and mechanical processes

Weathering.

In the mid to late 1970's, fieldwork in Amboseli National Park, Kenya, by Behrensmeyer and others on the effects of subaerial weathering of mammal bones in a variety of environments, proved to be an important step in the development of taphonomy. Behrensmeyer (1978:153) defined weathering as "the process by which the original microscopic organic and inorganic components of a bone are separated from each other and destroyed by physical and chemical agents operating on the bone in situ, either on the surface or within the soil zone". More recently, Behrensmeyer has broadened this definition of weathering to being:

> "the natural decomposition of bone and tooth through physical and chemical processes operating at or near the ground surface. It involves macroscopic changes including cracking, flaking, splitting, and fragmentation, and microscopic changes including breakdown of organic compounds (chiefly collagen) and dissolution, recrystallization, and/or chemical alteration of mineral components. These changes occur progressively, starting at the time of death, and ultimately result in total destruction of bone and tooth unless circumstances such as burial or mineralization bring a halt to decomposition" (Behrensmeyer 1990a).

The Amboseli bone assemblage provides a modern analogue for taphonomical processes which Behrensmeyer et al. (1979) suggest can then be extrapolated to fossil assemblages derived from surfaces, prior to fluvial transport. Johnson (1985:184) describes weathering as a "dessication and chemical process that leads to changes in the physical properties and chemical structure of the bone" which, in turn, influence the manner in which a bone fractures.

Weathering was found to be dependent on local conditions of soil chemistry, temperature, exposure to sunlight, and humidity, and changed the appearance of bones exposed on the ground surface. Behrensmeyer (1978) devised a scale (running from 0 to 5) for qualitatively measuring the degree of weathering evident on bone specimens. This scale passes from fresh to totally disintegrated bone and although it describes a continuum of change (from initial longitudinal cracks to deeper cracking, exfoliation and eventually disintegration), the individual categories as described appear to characterize stages that the bone passes through in the breakdown cycle. The rate at which disintegration occurred was found to be relatively constant, for this particular environment, and enabled Behrensmeyer (ibid) to propose a timeframe within which weathering stages correlated with years since death. Thus, for example, she suggests that bones exposed continuously on the surface reach weathering stage 3 by the time they are 3–5 years old (Behrensmeyer 1978:157), and that bones in Stages 0, 1, and 2 have lain exposed for less than 3 years.

Hare's (1980) work on amino acid racemization shows a correlation between the weathering stages and the progressive breakdown of the amino acids within bone. This would tend to support the interpretation that there is an association between temperature and moisture fluctuations at the soil surface with bone weathering at Amboseli.

Variations in the weathering within skeletons, and within individual bones, have been documented and occur for a number of reasons. The variations can be the result of differential levels of sunlight on the bones (caused by shade patterns from surrounding vegetation), the effects of local carnivorous scavengers, bacteria, soil acids associated with plant decomposition, insects, and seasonal areas of standing water (Behrensmeyer 1978, Gifford 1981). It is also believed that cycles of hot-cold, wet-dry, and freeze-thaw contribute to weathering (Miller 1975, Schiffer 1987:158). In some cases, bones in moist environments were recorded with more weathering on the lower than upper surfaces due to the buildup of salts in the weathering cracks which forced bones apart. Patterns of shallow grooving on surfaces in contact with the ground were interpreted as the result of dissolution by acids associated with the growth and decay of roots or fungus (Behrensmeyer 1978:154). Bones of smaller mammals were found to weather much faster, as did those of fish, birds and reptiles, due to the basic structural differences of these latter groups (Gifford 1981:417). It was also found that within an individual, bones with a high surface area to volume ratio also weathered at a faster rate. Shipman (1981:41, 100) links bone damage to the responsible processes at a more general level. For example, cracking, crumbling, and exfoliation are caused by weathering, whereas aeolian transport leads to pitting. Carbonic acid secreted by roots in contact with the bone causes dendritic etching of the bone (Schiffer 1987:273). The exfoliation of diaphyseal cortical bone is caused by severe dessication of the bone while it is exposed on the surface and this often results in delamination along the longitudinal split line axis (Johnson 1985:184).

Microorganisms play an important role in the destruction of interred bone, in addition to the general environmental influences described above (Piepenbrink 1986, Grupe and Piepenbrink 1988, 1989). Fungi actively penetrate through the hard tissues, but they also leach the tissue of dead bone by extensive excretion of secondary metabolites. In addition, soil metals can be carried into the bone specimen where they become fixed to the mineral matrix within a short time (Grupe and Piepenbrink 1989:293).

Although Behrensmeyer (1978) was the first to attempt to qualitatively measure the rate of bone weathering, work in describing the process of bone disintegration had been undertaken previously by Brain (1967), Isaac (1967) and Miller (1975). Brain (1967) examined the differences between dry and humid climates on bones, allowing fresh bones to weather under varying conditions (some fully exposed to the sun, others in partial shade, some covered by leaves) at sites in Pretoria and at the Transvaal Museum's Desert Research Station, 70km inland from Walvis Bay. The latter area receives less than half an inch of rain a year, and he found that bones from this site exhibit two particular characteristics: they have bleached chalky surfaces and they often have dessicated tissue adhering (Brain 1967:97). A similar situation was observed among bones collected from a Hottentot village near to the research station (ibid).

Isaac (1967) describes an experiment initiated in 1958 to test the theory that bone weathering may also be a factor in the destruction of evidence of dietary and economic factors, even in areas of dry climate and alkaline soil conditions. Over a period of 7 years the skeleton of a sub-mature goat and a few cattle bones were observed in natural conditions. The bones were protected from scavenger disturbance and by the end of the period the bones had deteriorated to such an extent that if they had been subjected to regular animal trampling, nothing but small fragments would have survived (Isaac 1967:40).

Miller (1975) describes the deterioration sequence for bones in the Colorado Desert in southern California — a sequence that includes the effects of scavengers in the initial removal of the soft parts, invertebrates such as worms and bacteria, and the physical action of the weather through wind scouring, and dessication. Cracks appear in the bones in a relatively short period of time, even before the periosteum is completely removed. Within a year 25% of the periosteum is gone, the bones are bleached white and the cracks in the long bones go through to the marrow cavity. After four years there are numerous longitudinal and transverse cracks and exfoliation of the bone surface is beginning to occur (Miller 1975:216). The organic material is generally removed after about 18 years, and bones were recorded from animals that have died over 30 years previously, although in a very highly weathered state.

In a further study from semiarid parts of East Africa, Gifford (1978, Gifford and Behrensmeyer 1977) recorded bones from a campsite in the East Lake Turkana region which had been occupied in 1957–58. The bones were extremely fragile and deeply invaded by weathering cracks, but remained identifiable. Subsurface bones were less heavily weathered, although leached of organic content. Thus it appears that bones of medium-sized mammals on local land surfaces will endure for up to 20 years before total disintegration, with subsurface material less decomposed than surface components of the same assemblage.

In a series of studies of natural accumulations of elephant bones, Haynes

(Conybeare and Haynes 1984, Haynes and Stanford 1984) observed that bones which lie on the ground surface in southern Africa are subjected to weathering at rates much higher than the rates recorded in Canada and other temperate and subarctic regions. Factors which affect this rate of disintegration include whether the bones are lying in wet substrates or protected environments such as shaded pond edges, and these bones tend to exist in a fresher state for much longer than the bones that lay in the open channel of the Shabi Shabi river which were the subject of his study (Conybeare and Haynes 1984). Differential weathering within single bones produces a range of fracture patterns whereby, for example, the wet lower parts might fracture spirally when trampled while the drier upper portion might crack linearly and splinter (Haynes and Stanford 1984:228). The spirally fractured parts are similar to those described by Morlan (1980) as derived from fresh, or green-bone, fragmentation.

A number of studies have taken the Behrensmeyer (1978) method and applied it to a description of fossil material from both cultural and natural situations. Shipman et al. (1981) examined 606 specimens from the Fort Ternan site, Kenya, for evidence of weathering and found that 68% were either very fresh or showed only microscopic signs of weathering — corresponding to weathering stages 0 and 1 of Behrensmeyer (1978). Only 3% were weathered to Stage 4, and thus they concluded that the assemblage was only briefly exposed to weathering prior to deposition within the geological sediments.

Potts (1986) applied the method to assemblages from five archaeological levels from Bed I Olduvai Gorge, dated 1.85–1.70ma (Leakey 1971, Hay 1976 – cited in Potts 1986:25). In this study he found that the condition of the bone varied over the surface of the specimen, and so recorded a wide range of surface features. The patterns of bone decomposition associated with subaerial weathering, which he recorded, include: both small- and large-scale cracking, mosaic-pattern cracking, exfoliation, and friable/splintered bone. He also recorded characteristics not attributable to subaerial weathering such as surface abrasion, friability, and scorings that were the effects of other taphonomic factors (for example, plant roots, soil chemistry, particle abrasion) (Potts 1986:27). Thus it was possible to determine the degree to which patterns of weathering were masked by other processes and led to the conclusion that the results suggested that a period of several years was involved in the accumulation of each assemblage.

Andrews and Ersoy (1990) went even further back in time and applied the method to the Miocene collection of bones from Pasalar, Turkey. The edge-rounding on the bones are symptomatic of bones which have been weathered for some time on the ground surface and then abraded, in this case probably by a flood which transported the sediments to the fossil site where they were mixed together and then deposited. The assemblage included both 'fresh' and weathered bones and, in most cases, the bones were only in weathering stage 2 or 3 and the degree of abrasion only slight (Andrews and Ersoy 1990:391). The more weathered the bone, the longer they had been exposed on the surface, perhaps for several years, but it is not possible to estimate the period of exposure because of the subsequent abrasion.

Tuross et al. (1989) undertook a molecular study of weathered bones to examine the sequence of protein degradation and "to demonstrate correlations between bone weathering stages and protein preservation in order to provide guidelines for sample selection for future biochemical analysis of fossil bone" (Tuross et al. 1989:262). During the fossilization process there is replacement of the inorganic mineral component and destruction of the organic components, but the rate and mechanism of the process are poorly understood. Two wildebeest carcasses, an adult and a juvenile, were the subjects of 10-year longitudinal studies during which time they underwent natural weathering in Amboseli Park, Kenya. They provided evidence for marked changes in both the organic and inorganic phases of the bone, which corresponded to weathering stages described at a macroscopic level. The remains were visited yearly and a rib collected for analysis during each visit.

Both carcasses showed evidence for progressive increase in the OHA crystal size and protein degradation over the 10-year period. The 10 years of surface weathering had altered the extractability of collagen, indicating changes within the protein. The increase in OHA crystal size "may reflect a tendency of crystals to enlarge *in situ* once the organic matrix begins to breakdown, without the addition of external minerals" (op. cit.:162). At a macroscopic level, the bones had weathered to Stages 3–4 in the adult wildebeest, and Stage 5 in the juvenile (on the Behrensmeyer (1978) scale).

This study shows that both micro- and macroscopic changes in bone proceed simultaneously, and that NCPs and collagen alpha chains are preserved at their original molecular weight even under relatively severe environmental conditions. It is interesting to note, however, that observations of buried versus surface components, during this study, reveal that even shallow burial can retard the weathering process, as can the effects of shading to a lesser degree. Bones recovered from subsurface positions remained at Stage 1 while those on the surface reached Stage 4, even though both derived from the same animal and had therefore been deposited at the same time. This would tend to suggest that surface exposure, and particularly sunlight, has a strong influence on the weathering at a macroscopic level.

In spite of the widespread support that the Behrensmeyer (1978) model has received from archaeologists and palaeontologists, Lyman and Fox (1989) criticise it for a number of shortcomings. The most important, they argue, is that one cannot directly estimate the time that has elapsed since the death of an animal simply by measuring the degree of weathering exhibited by the remaining skeletal elements. Furthermore, one cannot necessarily infer the relationships between prehistoric weathered bones and their exposure and accumulation histories based on the documented correlations between years since death, weathering stages, and depositional habitat (Lyman and Fox 1989:293). Behrensmeyer's (1978:153) definition of weathering suggests that it is a continuous process involving both mechanical and chemical changes to a bone's integrity as a discrete object.

The definition of weathering implies that the process starts once the bone is exposed to the weathering agents, i.e. once the soft tissues detach from the bones. Immediately, therefore, we find an additional variable in the Behrensmeyer (1978) model, because the manner in which hide, muscle tissue, etc. are removed controls how quickly after death exposure and weathering begin. The definition also makes it clear that bones continue to weather in subsurface contexts, albeit at a much slower rate. Many researchers assume exposure, and therefore weathering, ends once a bone is buried, a fact which Lyman and Fox (1989:295) attribute to Behrensmeyer's statement (1978:154) that buried bones of a carcass "frequently show no signs of weathering even when exposed parts are in Stage 4 or 5".

While accepting the potential that Behrensmeyer's observations had for describing the breakdown of modern animal carcasses, in the case of prehistoric assemblages, Lyman and Fox (op. cit.:311) argue that her model, which they present in equation form (Equation 1 below), should be represented by the more complex form in equation 2.

$$WS = f(YD) \qquad (1)$$

where WS = weathering stage and YD = years since death

$$WS = f(YD, SE, TX, ME, ED, AH) \qquad (2)$$

where SE = skeletal element, TX = taxon
ME = depositional environment
ED = exposure duration, AH = accumulation history

Two of the variables (SE and TX) can be controlled during analysis, as can weathering if we presume that the weathering stages only characterize subaerial weathering. While the most weathered bone has obviously been exposed the longest, Lyman and Fox (ibid) suggest that even controlling for SE, TX, ME, and WS does not necessarily allow one to be able to distinguish the "three kinds of taphonomic time — AH, ED, YD —" from weathering data. This is because

> "Each animal represented by a bone assemblage may have died at a different time, and each bone of each carcass may (1) have been exposed for a different duration, (2) have

> been accumulated at a different time, (3) have been deposited in a different microenvironment, (4) represent a different skeletal element each with its own unique weathering rate, and (5) represent a different taxon with its own unique weathering rate" (Lyman and Fox ibid:312–3).

Thus, while Behrensmeyer's data reflect a correlation between the age of a carcass and the degree of weathering experienced by that carcass, it does not take into account other taphonomic factors which affect the duration of assemblage formation. Those taphonomic factors which affect weathering rates, such as ME, SE, TX and the agents of exposure and burial, can only be partially controlled and may significantly alter the relationship between weathering stages and the years since death. In fact, Lyman and Fox (ibid) conclude that were they "to significantly enlarge Behrensmeyer's (1978) original control sample of 52 carcass observations by study of all bones of, say, 200 carcasses of various taxa, the correlation of weathering stage with YD would decrease remarkably due to within and between carcass variation in AH, ED, SE, TX, and ME".

A similar conclusion had earlier been reached by Bunn and Kroll (1987) who felt that because the different bones of a carcass accumulate at the same point in time and the exposure time, as measured by the weathering stages, ranges from months to years, a wider set of factors were at work than simply accumulation time. These include "different orientation on the ground, coverage by hide or connective tissue, partial burial and reexposure in loose sediment, and position relative to patches of vegetation or shade trees" (op. cit.:97) which affect the weathering stages present in a bone assemblage. Thus, they suggest, "the weathering data ... measure the process of burial more directly than they measure the process of accumulation" (ibid).

Despite these criticisms, Behrensmeyer's work is very important because it focused attention on the fact that faunal remains are affected by a multiplicity of factors, of which weathering is but one, between the time of death, and deposition, and their subsequent recovery. Behrensmeyer's scale was developed to record weathering on intact bones from whole or near complete carcasses derived from recent accumulations. The extension to archaeological and palaeontological assemblages must be treated with caution because the time depth associated with such bone accumulations may mask the defining characteristics of the weathering stages.

Freeze-thaw.

Freeze-thaw cycles, or cryoturbation, can pose a major threat to archaeological sites in either high altitude or high latitude areas, where the ground freezes seasonally to varying depths (Wood and Johnson 1978:334, Schiffer 1987:213). Frost heave characteristically uplifts strata and material in sites, but the rate varies according to factors such as soil texture, soil moisture, thermal conductivity of the artefact in relation to the surrounding matrix, shape and orientation of the artefact, and the rate of freezing (Wood and Johnson 1978:339-341).

While the effects of cryoturbation upon archaeological sites in New Zealand are likely to be very slight, it is anticipated that freeze-thaw cycles will have a marked effect upon bone remains lying on the surface. This will be especially a problem in areas such as parts of the Volcanic Plateau in the North Island, and Central Otago and the Mackenzie Basin in the South Island.

Miller (1975) conducted experiments with tibiae and metapodials of freshly killed cattle to test the effects of rapid freezing and thawing. The bones were cleaned of all soft tissues and were taken straight from the slaughter house to the deep freeze. Thirty tibiae and nine metapodials were kept in the deep freeze and maintained at a temperature of -20°C for three weeks. At this point 15 tibiae and 5 metapodials were removed and placed outside in sunlight at temperatures ranging from 10–24°C where they were allowed to thaw and dry. The remaining bones were dried indoors at 24°C. In both cases, Miller (ibid:219) observed cracks appearing parallel to the longitudinal axis of the bone within 12 hours. Drying of the bones continued for 72 hours and observations made during this time showed that while many cracks were only surface cracks to 1mm depth, many of the cracks went through the compact bone to the marrow cavity.

In a series of experiments to determine the effects of freezing-thawing upon the breakdown of soft tissue, Micozzi (1986) found that previously frozen-thawed animals showed predominantly decay (aerobic decomposition) in the field, while freshly killed animals showed predominantly putrefaction (anaerobic decomposition). These two forms of tissue loss subsequently dictate the rate of disarticulation of the animal, and are governed by a wide range of interrelated environmental factors which include: "morphology and physical condition of the organism before death; the location of the remains in soil, or standing, or running water; the temperature, humidity, soil pH, ground cover, season and a host of other vegetational and climatic factors; and, often, the actions of insects and carnivore scavengers" (ibid:954).

Hill (1978, 1979) and Behrensmeyer (Hill and Behrensmeyer 1984, 1985) have proposed sequences of natural disarticulation, but Micozzi (1986:959) argues that these studies are ambiguous because they did not differentiate between the activity of decay organisms and other intrinsic factors and those of predator-carnivores. He suggests that freezing-thawing is one of a series of physical and biological agents that accelerate the rate of disarticulation.

Based on the results of these two series of experiments, one can argue that the cumulative effects of 400–500 years of freeze-thaw cycles upon moa bones lying exposed must have been quite considerable, especially in central basins of the South Island. Micozzi's (1986) work would suggest that the freeze-thaw cycle accelerated the disarticulation of any moa carcasses, while Miller's experiments (1975) would suggest that major structural changes (cracking through the cortical bone to the marrow cavity) were initiated within 72 hours.

Chemical processes

From the moment a bone is deposited on a site and enclosed within a soil matrix it begins to interact with the surrounding environment and undergo diagenesis, or chemical weathering. The term diagenesis is a general term for any kind of alteration or change to the original bone matrix and involves the processes of "dissolution, precipitation, mineral replacement, recrystallisation and ionic substitution" (Pate and Hutton 1988:730, Krueger 1991). "The primary mechanisms of post-mortem diagenesis in bone mineral are (1) precipitation of separate mineral phases, e.g. calcite, in small voids and fractures, (2) ionic exchanges between the soil solution and calcium phosphate lattice positions, and (3) recrystallisation and crystal maturation involving the conversion of micro-crystalline [OHA] to a larger, well-crystallized geological apatite" (Pate and Hutton 1988:730). The most important variables which determine the rate at which these reactions occur are soil pH, organic mater content, temperature, abundance and distribution of rainfall, and local groundwater movement (Henderson 1987, Pate and Hutton 1988).

Water is one of the most important agents of decay and its principle action is by leaching (Henderson 1987:46). Variations in the effect of water on diagenesis are caused by relative humidity, rainfall levels and drainage (Salomon and Haas 1967, Garland 1987). Bones from a humid environment are "susceptible to physico-chemical changes more so than those from a dry environment" (Garland 1987:121) and the entry of ground-water into the protein-mineral bond hydrolyses the protein component such that the mineral is removed by the percolating ground-water. Salomon and Haas' (1967) study of bones from Israeli sites revealed that

> "bones from the dry climate zone of the Dead Sea were well preserved histologically, showing their Haversian systems and lacunae after almost 6000 years ... [while] more recent bones from a humid area were much more depleted of their organic and inorganic matter, but their microstructure, including their Haversian systems, were well preserved. These bones showed changes in the form of 'granular bodies' which are interpreted as the result of physicochemical interaction with the soil in which they were buried" (op. cit.:747).

Preservation of bone mineral has been found to be better in soils with a neutral or slightly alkaline pH, and is worse in soils which are acidic in their pH (Keeley et al. 1977, Gordon and Buikstra 1981, White and Hannus 1983, Henderson 1987, Waldron 1987). The action is one of dissolution of the inorganic matrix by acids present in the soil, which leaves the organic material susceptible to leaching by water (Henderson 1987:46). Middens with a high concentration of wood ash also tend to have higher alkaline conditions (Schiffer 1987:146). In forests decaying organic matter lowers the soil pH and thus reduces the survival probabilities of bone near the surface, while tree roots secrete humic acids which etch artefacts such as bone (op. cit.:150, 183).

Gordon and Buikstra (1981:569) found that the correlation between soil pH and bone preservation was significant ($r = -0.92$, $p < .00001$) and that as soil pH decreased so the destruction of bone material increased. White and Hannus (1983) were able to determine that the weathering of OHA in bone is initiated by organic and carbonic acids formed by the microbial decomposition of collagen, which initially is dependent upon water and oxygen present in the soil matrix, but becomes more predominant in acid soils. Watson's (1967) analysis of skeletal material from termite mounds in Zimbabwe, found that bones were preserved within the alkaline environment of the termite mound, but completely dissolved in the surrounding acidic soils. In a further study of farm animals that had been buried in a range of soil types, he found that those buried in acid soils on vlei margins with occasional high water tables were among the most susceptible to decay (op. cit.:699).

Pate and Hutton's (1988) analysis of the chemical data for a soil profile at the archaeological site of Roonka in the Lower Murray River basin of South Australia, revealed that soil pH played a dominant role in determining the availability of various elements (Al, Fe, Mn oxides and hydroxides; Ca and Mg phosphates; Ca, Mg, K and Na carbonate, sulphate and chloride salts) for ionic substitutions in archaeological bones (op. cit.:731). They found that with the dominance of calcium and bicarbonate soluble ions in the Roonka Flat dune soils, calcite was the expected predominant secondary mineral phase in the archaeological bone in Trench A (op. cit.:736). The "calcite precipitates along fractures and in voids created by decaying organic material" (ibid) and is often contaminated by Mg, Sr, Mn, and other ions from the soil solution.

The effect of temperature upon bone preservation varies greatly with latitude, season and depth of burial. There is a two-fold increase in the rate of reaction with every 10°C rise in temperature (Von Endt and Ortner 1984:249, Henderson 1987:47), and bones buried in the tropics will decay faster than those buried in higher latitudes. Likewise, seasonal variations will see different rates of decay at particular times of the year.

Rottländer (1976) studied the effect of micro-organisms, and in particular the bacteria *Clostridium histolyticum*, on the decomposition of bones. The decomposition of meat surrounding the bone is accelerated by the presence of the bacterium, the growth of which is governed by temperature and the presence of moisture which also determine the dissolution rate of inorganic material and apatite. Hence, he argues (op. cit.:86), there are good reasons to relate good bone preservation to a cold and/or dry climate.

Another important chemical change in bone is the progressive loss of organic compounds — "the older the fossil bone, the less organic matrix it contains and consequently the fewer total amino acid residues per gram of bone" (Hare 1980:209–210). This arises because the amino acids which make up the collagen and other proteins undergo hydrolysis and if there is sufficient water present the free amino acids will be leached from the bone. In a constant environment the rate of protein degradation should be constant, as measured by the loss of nitrogen from protein collagen as it degrades into its constituent amino acids during bone decomposition (Lynch and Jefferies 1982). The rate of nitrogen degradation, however, is rarely constant because of the effects of variables such as solute concentrations, temperature, soil pH, micro-organisms and water on the rate of protein decay. In experiments on the racemization of amino acids, Hedges and Wallace (1978:384) determined that the sensitivity of laboratory racemization rates to temperature, and of collagen breakdown and extraction to pH, suggests that buried bone may well contain valuable information about the burial environment.

The process of bone fossilization, subsequent to its deposition in a site, involves a number of post-mortem changes — in particular, carbonate substitution (Cook 1951, Cook et al. 1961). Hassan et al. (1977) found that the change involves the removal of endogenous carbonate and its replacement by exogenous carbonate into internal crystal PO_4^{3-} sites.

A number of authors have undertaken experimental laboratory work to investigate the effects of the three main variables — pH, moisture and temperature — on bone survival rates. Rotlländer (1976) determined that fresh, dried bone showed a weight loss of about 35% on ignition which is mainly due to the loss of protein. Hare (1980) undertook experiments which controlled temperature, moisture conditions and pH. Water is necessary for the hydrolysis of amino acids and if excess water is present, varying amounts of leaching can occur in addition to the hydrolysis and racemization. Hare (op. cit.) heated bone samples in varying amounts of water and found that the amount of protein leached varied from little or none in samples under anhydrous situations, through to 95% leaching of the protein in the situation where the water was changed frequently to ensure that the bone fragments were always in contact with fresh water (op. cit.:213). Protein loss was more rapid for smaller bone fragments and the protein loss curves appeared to follow a curve with three distinctly different rates (ibid). The survival of bone in a natural environment is dependent upon the mechanical strength and hardness of the bone, and if the organic matrix is weakened through racemization and leaching of the amino acids, the hardness and strength will decrease. Hare recorded that

> "as water reacted with the protein in the bone fragments, the fragments became progressively chalkier and easier to break apart. Samples that had been leached extensively were generally easy to crush and cut. In the early stages of the reactions where collagen was still present, the fragments when dissolved in acid would show the intact pseudomorphic ghosts of the bone fragments. Bone strength and hardness appeared only slightly less than that of fresh bone material. As the reactions progressed, the pseudomorphic ghosts looked progressively less intact until there was no longer any pseudomorph left — only a few scattered fragments of organic material. At this stage there was substantially less strength and hardness left in the bone fragment. The fragments were somewhat chalky and easily crushed with the fingers" (Hare 1980:218).

Ortner et al. (1972) also investigated the effects of controlling pH, water and temperature in the laboratory by subjecting bones to conditions of neutral pH and excess water, which are a rare occurrence at any archaeological site as very few experience neutral soil conditions or have soils that are saturated during the entire year. They determined (op. cit.:519) that water was a necessary requirement for the reactions associated with protein degradation and that increasing the temperature and decreasing the pH will accelerate the rate of decay.

Von Endt (1980) undertook experiments to determine the effect of bone volume on the degradation of bone protein by subjecting samples of cow bone, cut into 1, 2 and 4mm cubes, to a constant volume of water heated to 120°C for varying lengths of time up to 4 hours. The amino acid analysis of the solution indicated that protein was lost from the bone at an inversely proportional rate to bone size.

SUMMARY

It is apparent from this review of the literature that the survival of bone in natural and archaeological sites is dependent upon a wide range of factors, including: both subaerial and subsurface weathering (Table 2.7), trampling, the degree of burning the bone experienced, and carnivore gnawing. In particular, it is clear that there is a distinction between the agents acting upon bones deposited on the ground surface, and those buried within a depositional matrix, and the processes that the bones pass through in their disintegration (Table 2.7). While bones undergoing either subaerial or subsurface weathering are acted upon by different agents and go through different processes, there are a range of microscopic processes which are common to both as part of the disintegration of the bone complex. These include the breakdown of organic compounds, and the dissolution, recrystallisation, and chemical alteration of the mineral components.

To date, the majority of the research into bone weathering has been been directed towards subaerial weathering and most researchers identify some, or all, of the following as the end products of weathering: cracking, flaking, splitting and fragmentation, mosaic-pattern cracking, crumbling, and exfoliation. There has been little research into the processes of subsurface weathering, but some of this

Table 2.7 Taphonomic agents involved in subaerial and subsurface weathering.

Agents	
Subaerial	Subsurface
Amount of sun vs. shade	Insects
Wind	Micro-organisms
Rainfall	Growth of roots and fungus
Humidity	Pressure of surrounding earth
Transport in solution	Chemical - soil pH
Scavengers	temperature
Insects and micro-organisms	moisture content
Temperature	organic content
Cycles of hot-cold, wet-dry, and freeze-thaw	leaching and chemical activity
Vegetation cover	

research has identified features such as surface abrasion, friability, and scoring of the bone surface as being specific to subsurface weathering. To assert these as the end-products of subsurface weathering, given the paucity of detailed research into this field, is 'jumping-the-gun' somewhat.

In this thesis, while I intend to focus on the effects of both subaerial and subsurface weathering, and burning, on bone in the temperate New Zealand environment, and to investigate the effects of temperate zone soil conditions on bone survival, the primary focus of the thesis will, by necessity, be on the effects of subsurface weathering on bone condition. This is because of the very nature of the environments in which most big-game sites in New Zealand are to be found, the coastal sand-dune systems, which means that the length of post-depositional time that bones spend on the ground surface can often be very short before they are buried within the soil matrix. More importantly, however, the bone collections which form the data-base for this thesis were derived from archaeological sites and so I must work on the assumption that the primary form of weathering which they have undergone, is subsurface weathering.

Chapter 3.

The Formation of a Bone Weathering Scale

The survey of bone weathering processes, and previous investigations of them, prompts a number of questions in regard to the New Zealand situation. These are:

1) What is the effect upon bone survival rate of New Zealand's temperate climate, with the shorter sunshine hours and greater rainfall levels ?

2) What effect does alternate wetting and drying, or heating and cooling (the freeze-thaw cycle) have ?

3) What effect do microorganisms and other biological factors have ?

4) In the process of diagenesis/weathering, what effect do the different soil environments, from the coastal sand-dunes, to the volcanic loams of the central North Island, and the riverine silt of the inland South Island basins have ? This includes both the effects which soil acidity and the composition of the ground water have on the organic matrix and the subsequent leaching of organic and mineral components.

5) Given that burning weakens the overall structure of the bone, how does this impact upon its survival ?

Two hypotheses can be formulated in relation to these questions: (1) that bone will survive longer and in better condition when it has been deposited in a sand matrix; and (2) the greater amount of burning that the bone undergoes, the more brittle it will become and subsequently the time it will survive will decrease. As a corollary to the second hypothesis, it is anticipated that more highly burnt material may reach a point of stable equilibrium with its surrounding matrix over time, and with subsequent exposure to the elements it will undergo rapid breakdown.

The essential prerequisite to investigating these questions is the development of a suitable bone weathering scale.

The first attempts to understand the problem of weathering in bone assemblages were made by Isaac (1967) who undertook experiments to observe changes through time in bones by setting out cleaned bones in a controlled situation. Later studies have continued this work but, in addition, have worked with naturally occurring carcasses in situ to observe variations caused by micro-environmental conditions (Behrensmeyer 1978), and have studied long-term changes in naturally occurring carcasses for which the animal's time of death was recorded (Miller 1975, Behrensmeyer 1978, 1990b, Gifford 1980).

The results of this work have revealed that break-down of collagen and separation of small-scale structural components in bone cause changes in physical appearance, at both macroscopic and microscopic levels. At the extremely basic level there are often changes in the chemical composition of the organic and mineral phases of the bone and in the crystal structure of the mineral component. Different micro-environmental conditions cause variation in rates of change and there is evidence that rates of change of weathering vary within the same skeleton depending on whether bone was forming or resorbing at time of death, and also among skeletons, depending on species, body size, age since birth, and physiological state (Behrensmeyer 1990a).

The bench-mark study of patterns of weathering in animal bone, and thus the work which underlies mine, was initiated by Behrensmeyer in Amboseli National Park, Kenya, in 1975, as part of a larger research project to determine the effects of natural taphonomic processes on modern animal bones and carcasses. Amboseli was chosen for a long term study because it had a higher number of dead animals per scavenger, and thus more bone scatters available for study, than other areas (for example, the Serengeti). A method of describing the degree of weathering evident on the bones was developed (Behrensmeyer 1978), and applied to bone scatters on the ground surface — some of which were studied for 15 years. Among the results Behrensmeyer (1990b) found that there was a body-size effect between wildebeest and elephant, and juvenile animals weathered faster than adults. There was slower weathering evident on material that was partially buried in a swamp where the water and vegetation lent some protection, and there was a differential weathering rate between upper and lower surfaces of individual bones with the upper surfaces appearing at least one or two stages more advanced. Based on the results of these long-term studies, in which the bones were examined annually, Behrensmeyer devised a schema for estimating the minimum length of time a bone had been lying on the surface. Results from the most exposed situation at Amboseli showed that, on average, it took two years to reach stage 2, four years to reach stage 3, six years to stage 4, and nine years to stage 5. Lyman and Fox (1989) question Behrensmeyer's (1978) results, and conclude that while bone weathering data can provide important taphonomic information, the data does not "necessarily reflect the duration of bone assemblage formation because (1) they are not structured to do so, and (2) many taphonomic factors are involved in the formation of an assemblage of weathered bone, some of which cannot be controlled in analysis of bone weathering data" (Lyman and Fox 1989:293).

In extending these results to the archaeological and palaeontological world, and perhaps in reply to Lyman and Fox's criticisms, Behrensmeyer (1990a) envisages a number of problems which could arise: sub-surface alteration of the bone surfaces prior to fossilization may alter the appearance of bones and make original weathering difficult to determine, and cracking and flaking can occur due to post-depositional compacting. In addition, a number of environmental variables can affect bone modification prior to burial. At the micro-environmental level these can include exposure to fluctuations in light, temperature and moisture, freezing, heating (from merely being boiled to burning of the bone itself), vegetation, soil chemistry, the depth of burial, and submergence in water. Macro-environmental conditions refer to variations in overall climate and vegetation which may exert large-scale effects on weathering.

WEATHERING IN THE HIGHER LATITUDES

It is important to remember that the work undertaken by Behrensmeyer in Amboseli, and subsequent studies such as that by Gifford (1981), was in the highly specialised ecological and climatic zone of equatorial Africa (2°S) where the plains habitat experiences wide fluctuations in terms of wind, temperature and rain. The direct application of their results, and even the methodology, to higher latitudes does not automatically follow and nor do the results of studies undertaken in the central plains of North America or Greenland.

There are very few examples of taphonomic analysis in high-latitude environments. Morlan (1980) analysed material from the high Arctic, while Borrero (1990) studied the taphonomics of guanaco bones (*Lama guanicoe*) from Cabo San Pueblo, Tierra del Fuego (Argentina). The latter study perhaps has more significance to the New Zealand situation given a closer similarity of conditions, in comparison to those in the Arctic. Borrero (op. cit.) noted that while gnawing by foxes produced limited damage, the trampling by guanacos disarticulated skeletons, produced vertical migration of both the small and dense bones, and fractured the more heavily weathered bone. A high correlation existed between weathering stage and the damage sustained by trampling (op. cit.:365). Trampling also produced spiral fractures of the fresh bones in a limited number of cases. The important point he notes in conclusion (ibid:370) is that "the patterns ... are not dependent on a single general variable (the "environment"). The interactions that produce bone assemblages on land surface [sic] are instead complex and must be specified".

In their analysis of muskox skeletons in Jameson Land, East Greenland, Noe-Nygaard and Larsen (1990) used weathering to distinguish between material which was discarded immediately and that which was involved in the butchery process. The climate is very arid so there is not enough moisture to freeze and subsequently crack the bones. In her analysis, six stages of weathering, each with seven parameters, were measured at four levels of presence (-/0/+/++). The results showed that taphonomic changes in the Arctic were so slow that one cannot measure accurately the pre-burial age. Indeed data reconstructed from other regions cannot be applied. Palaeo-ecological and economic conclusions are very hard to derive when a bone (for example, sample #22, dated to A.D. 1200) exhibits stage 5 weathering on its upper surface, while the lower surface is only stage 2–3 and could easily appear 400 years younger.

An important issue now arises in the adaptation of taphonomic analyses to the New Zealand situation. The previous studies, described above, were undertaken in very different climatic and ecological zones — equatorial Africa, southern South America, and the Arctic Circle. How might we now apply them to the New Zealand situation ? New Zealand lies at the centre of the global water hemisphere and for the most part has distinctive maritime climates which means that it is affected to a far greater extent by weather patterns which develop outside the region, in response to oceanic and atmospheric conditions, before they sweep through the southern ocean and across New Zealand. Thus there is a far greater variability in climatic variables such as the temperature range (on a month to month basis rather the diurnally as at Amboseli), the amount of sunlight hours, the amount of rainfall, and patterns in the freeze-thaw cycle. More important, because the country covers a wide range of latitudes, with the far north of the North Island extending close to the sub-tropical zone, while the south of the South Island is firmly planted within the temperate zone, there is a significant climatic variation from north to south. This is likely to have a significant impact on the survival rate of bones on the surface of archaeological sites, prior to their incorporation within a burial matrix.

WEATHERING SCALES USED IN PREVIOUS TAPHONOMIC RESEARCH

There have been a number of studies of the process of bone weathering, in a range of different ecological settings, which are based on the use of ordinal scales to describe the degree of weathering present in faunal remains. The following section discusses some of these studies, and in particular their weathering scale, as a means of developing a specific weathering scale for describing the state of bones recovered in New Zealand archaeological sites. The discussion of the development of weathering scales follows two separate lines — firstly, I discuss the weathering scales developed to study bones affected by subaerial weathering, as this is the primary focus of most research to date (although many researchers use the Behrensmeyer (1978) weathering scale rather than developing new scales), and secondly, I examine weathering scales which have either been developed specifically for describing buried bones, which have undergone subsurface weathering, or which have been derived from the Behrensmeyer (1978) scale and adapted to the study of buried bones. The discussion is ordered by date of publication (for convenience), and in most cases the actual details of the weathering scales are quoted verbatim.

Subaerial weathering scales

In a study of cattle and horse remains on a ranch in the Tierra Blanca Mountains of the Colorado Desert, southern California (where the annual temperature ranges from -12 to 54°C and rainfall is less than three inches per annum) Miller (1975) describes the effects of weathering upon bone in a desert environment. Miller was primarily interested in the study of cracks and fractures, in bones, that could be mistaken for human modification of the bone. The weathering of bone is seen as only one process in the alteration of bones which may resemble human activity.

Because weathering, *per se*, was not his main interest, the description he gives of the phases through which bones pass as they weather is not as rigorous as later work in this field (e.g. Behrensmeyer 1978). The stages he describes, which are based on years since death, give an indication only of the breakdown of cattle and horse bones in this particular environment, over a period of up to 34 years after death (op. cit.:217–218). When an animal dies, removal of the soft parts by predators soon follows and then deterioration and modification of the bone by animal gnawing, wind scouring and by weathering begins to occur. His description of the weathering process follows:

Animals dead for less than one year — "less than 5% of the periosteum removed from the still articulated bones with not more than one small longitudinal crack per long bone". Bones scattered by scavengers generally lack most of the periosteum, are sun-bleached and have many longitudinal cracks.

Animals that have been dead for one year — "about 25% of the periosteum is gone; exposed portions of the bone are ... bleached to a brilliant white"; and there are from two to three longitudinal cracks per bone which penetrate into the marrow cavity.

Animals that have been dead for two years — transverse cracks begin to appear.

Animals that have been dead for four years — the periosteum is totally removed; some long bones still articulated; all exposed bone thoroughly bleached with many transverse and longitudinal cracks going into the marrow cavity; exfoliation beginning; bone surface slightly powdery.

Animals that have been dead for 18 years — most of the organic material gone; bones had started to change colour from brilliant white to a dull greyish colour; exfoliation advanced, with many cracks and splinters produced.

Animals that have been dead for between 31 and 34 years — "showed severe deterioration, a dull gray colour, many cracks and splinters, and bone so badly weathered it is doubtful if fossilization could take place" (Miller 1975: 217–218).

Although Miller (ibid) claims to have recovered bones of horses from 1840's stage routes, "they were in such a poor state of preservation that it would have been difficult to collect them". As a general rule, he suggests that bone exposed for over 20 years would be too weathered to be mistaken for artefacts.

Behrensmeyer's work in the Amboseli Basin of Kenya (Behrensmeyer 1978) focused attention on the survival and weathering of bone remains lying exposed on the ground surface, and has been discussed in detail earlier in this chapter. Here I wish to present in detail the ordinal scale which she developed from observations of bones deposited in six major habitat zones, namely "swamp, dense woodland, open woodland, plains, bush, and lake bed" (op. cit.:151) as this is one which formed the basis of my own weathering scale. Behrensmeyer's scale categorized the observable weathering of bones into six stages, recognized from descriptive criteria, which provide "a basis for the investigation of weathering rates and processes" (op. cit.:150). The scale is presented below:

> "Stage 0 — Bone surface shows no sign of cracking or flaking due to weathering. Usually bone is still greasy, marrow cavities contain tissue, skin and muscle/ligament may cover part or all of the bone surface.
>
> Stage 1 — Bone shows cracking, normally parallel to the fiber structure (e.g. longitudinal in long bones). Articular surfaces may show mosaic cracking of covering tissue as well as in the bone itself. Fat, skin and other tissue may or may not be present.
>
> Stage 2 — Outermost concentric thin layers of bone show flaking, usually associated with cracks, in that the bone edges along the cracks tend to separate and flake first. Long thin flakes, with one or more sides still attached to the bone, are common in the initial part of Stage 2. Deeper and more extensive flaking follows, until most of the outermost bone is gone. Crack edges are usually angular in cross-section. Remnants of ligaments, cartilage, and skin may be present.
>
> Stage 3 — Bone surface is characterized by patches of rough, homogeneously weathered compact bone, resulting in a fibrous texture. In these patches, all the external, concentrically layered bone has been removed. Gradually the patches extend to cover the entire bone surface. Weathering does not penetrate deeper than 1.0–1.5mm at this stage, and bone fibers are still firmly attached to each other. Crack edges usually are rounded in cross-section. Tissue rarely present at this stage.
>
> Stage 4 — The bone surface is coarsely fibrous and rough in texture; large and small splinters occur and may be loose enough to fall away from the bone when it is moved. Weathering penetrates into inner cavities. Cracks are open and have splintered or rough edges.

> Stage 5 — Bone is falling apart in situ, with large splinters lying around what remains of the whole, which is fragile and easily broken by moving. Original bone shape may be difficult to determine. Cancellous bone usually exposed, when present, and may outlast all traces of the former more compact, outer parts of the bones" (Behrensmeyer 1978:151).

Behrensmeyer provided the following guidelines to aid in deciding into which category a bone should be placed:

> "1) the most advanced stage which covers patches larger than 1cm square of the limb's surface is recorded.
> 2) whenever possible shafts of limb bones, flat surfaces of jaws, pelves, vertebrae, or ribs are used, not edges of bones or areas where there is evidence of physical damage (e.g. gnawing).
> 3) all observers must agree concerning the stage before it is recorded" (ibid:152).

The bones described in my work are all derived from archaeological contexts and so would tend to be more fractured (due primarily to cultural practices such as marrow extraction) than large complete African mammal bone. Thus, in some cases an area smaller than 1cm square may necessarily have to be considered when describing the most advanced weathering present. Another point she raises is that larger skeletal material is easier to categorize and that small, compact bones "weather more slowly than other elements of the same skeleton and do not exhibit all the diagnostic characteristics of the weathering stages" (ibid). She notes that when categorizing a skeleton it is advisable to examine a number of different bones to assess the most advanced weathering. This last point is not really applicable to the archaeological situation as it is only rarely that bones are recovered that can clearly be shown to have been articulated prior to their discard and interment in a site, or have been derived from the same individual. Therefore, every bone described in my project will be examined individually and its weathering independently assessed. A further limitation to the use of Behrensmeyer's weathering scale is that it is really only applicable to mammals with a body weight greater than 5kg (ibid). My application of the methodology to moa remains poses no problem in that regard, given that the major leg bones are very similar in structure and density to mammalian bone and the live-weight of moas is estimated to fall in the range 20kg – ca. 200kg (Anderson 1989a:Table 5.1), but the limitation may reduce the usefulness of her scale when examining remains of juvenile individuals.

In his taphonomic study of the faunal remains from Twilight Beach (N1+2/976) in northern New Zealand, discussed in Chapter 1, Taylor (1984) established a weathering scale which included four stages of weathering adapted from Behrensmeyer's (1978) six stages to suit the New Zealand material and conditions. The effect of this reduction is twofold; firstly, the ability of the scale to distinguish finer variations in weathering is limited — each of Taylor's stages describes a phase the bones pass through (fresh, hair-line cracks, splitting, exfoliation) rather than being points on the continuum — and, secondly, it reduces the degree of subjectivity because there are fewer categories into which bones can be placed.

Stage 1 was for bone showing no evidence of physical signs of damage due to weathering, i.e. it could be considered 'fresh'. The next three stages were seen as separate variables, and were described as follows:

Stage 2: Cracking — "cracks are visible on bones as thin black lines perpendicular to the bone surface and orientated to the long axis of the bone" (Taylor 1984:82). Sometimes called hair-lines or hair-cracks, these cracks generally appear shortly after the bone is exposed even before all the periosteum has been removed. They are probably part of the natural drying process that bones undergo.

Stage 3: Splitting — "this ... is a continuation of the cracking process, and can be identified when the cracks have widened and extended right through the bone to the marrow cavity" (ibid). While he admits this is probably an arbitrary division of a continuous process, he claims the distinction is readily observable and permits the identification of separate stages in a related process (ibid).

Stage 4: Exfoliation — this stage occurs when the laminar surface of the bone begins to flake off or the bone surface starts to powder (ibid:84).

In describing their work in Jameson Land, East Greenland, Noe-Nygaard and Larsen (1990) detailed the establishment of a set of weathering categories in which six stages, each with seven parameters, were measured at four levels of presence (-/0/+/++) for muskox skeletons.

Subsurface weathering scales

Gordon and Buikstra (1981) sought to establish a correlation between the degree of bone preservation and soil pH in two Woodland mortuary sites in southern Illinois. They examined the degree of bone preservation of the skeletal remains and 'scored' them according to the following six categories:

> "Category 1, Strong Complete Bone: Skeletal elements are whole and undamaged. There is no evidence of postmortem destruction of osseous material which is not directly referable to local root, micro-organism, or burrowing mammal activity. For immature individuals, ossification centers are present and recoverable. All classes of skeletal data may be collected.
>
> Category 2, Fragile Bone: Bony elements may be fragmentary, but they are completely reconstructible. External surfaces may show some etching. Articular surfaces of long bones and surfaces of sternum, vertebrae, and other cubical bones show superficial destruction. Essentially all classes of standard osteological descriptive data can be collected; however, microstructure studies could be severely limited. In immature individuals, epiphyseal ossification centers are eroded, but diaphyses are reconstructible.
>
> Category 3, Fragmented Bone: Skeletal elements are generally cracked and fragmented. Most units are identifiable and reconstructible with copious labour and skill. Bone surfaces are heavily etched and cracked. Articular ends of long bones, vertebrae, and other trabecular bone may not be reconstructible. The skull is

> reconstructible to the point that most standard descriptive measures of the vault are possible; however, the face may not be observable. Data classes such as the length of long bones and many forms of pathology (e.g. degenerative joint disease) are severely limited.
>
> Category 4, Extremely Fragmented Bone: Skeletal elements are severely fragmented and many may not be recognizable. One cannot consistently collect any osteometric data or observe pathological changes. Nonmetric variants may be scored, but the battery of observations is frequently incomplete. Determinations of age at death and sex of adult skeletons may not always be possible.
>
> Category 5, Bone Meal/Ghost: Bones are reduced to a powdery substance which will not hold shape without support from the soil or chemical preservatives. Fragmentary tooth crowns may still be recoverable; however, even these are fragile. Bone outlines may be present as stains only. No forms of osteological data can be consistently collected" Gordon and Buikstra (1981: 568–569).

By examining remains from soils of varying acidity, and ignoring the localized effects of roots and rodents, Gordon and Buikstra (op. cit.) attempted to predict (on the basis of soil acidity) the likely degree of bone preservation. The most important feature of their work, in relation to the current project, was that the weathering was diagenetic in character, i.e. they were describing bones which had been buried. In notes to their weathering scale they make an interesting point that "although preservation had been scored at convenient intervals, there is an underlying continuity to 'preservation', and this variable will be treated as continuous for analytical purposes" (Sokal and Rohlf 1969: 12 cited in Gordon and Buikstra 1981).

The Todd et al. (1987) examination of faunal remains recovered during the Princeton-Smithsonian excavations at the Horner site showed bone conditions ranging from poor (generally) to excellent (rarer). Some of the northern areas of the site were quite shallow (bones less than 30cm below ground surface) and the bones showed fairly extreme weathering/deterioration in addition to evidence of damage by sage and grass roots (op. cit.:63). Although they were unable to determine whether the generally poor condition of the bones was due to "pre-burial weathering or post-depositional deterioration" (ibid:65), it is most probably a combination of the two. Two of the most common element groups which are represented in the faunal collection from the Princeton-Smithsonian excavations (astragali and metapodials) were described for their surface condition via a modified version of Behrensmeyer's (1978) scale. This is presented below in

Table 3.1 Weathering stages for the Horner site bones derived from the Princeton-Smithsonian excavations (from Todd et al. 1987:64).

Stage	Compact bone	Cortical bone [a]
1	Unweathered, articular surfaces intact with no surface cracking	Unweathered
2	Articular surfaces intact with some surface cracking	Limited surface weathering; some longitudinal cracking
3	Articular surfaces exhibit some deterioration, but more than 50% of the surface remains intact	Light surface flaking, deeper cracking
4	Intact articular surfaces restricted to a few small "islands"; less than 50% of articular surfaces remain intact	Patches of fibrous bone with moderate flaking and cracking
5	No articular surface area remains intact	Deep cracking and extensive surface flaking
6	Bone severely deteriorated; large areas of fibrous bone exposed	Bone falling apart

[a] after Behrensmeyer (1978)

Table 3.1, with the main modification to Behrensmeyer being the renumbering of her stages '0-5' as stages '1–6' (i.e. Behrensmeyer's codes were all increased by one). An additional stage (0) was added to describe unweathered, greasy bones.

Todd et al. (ibid) utilised two separate sets of codes, as shown in Table 3.1, because they documented different rates of surface alteration during subaerial weathering between cortical bone (e.g. metapodials) and articular surface bone and the more compact bones (e.g. carpals, tarsals, astragali etc.).

In addition, "since differences in weathering stages on surfaces of an individual element can provide some indication of the subaerial positional stability of a bone, ... the weathering stages on both the most severely weathered and least weathered surfaces of the metapodials were recorded" (op. cit.:67). The weathering of the metapodials ranged from lightly (Stage 2) to extremely (Stage 6) weathered and in every case the most extreme stage occurred on the posterior surface, while weathering on the anterior surface does not exceed Stage 4 (ibid). While they were unable to explain why the posterior surface of the metapodials was the side exhibiting the greatest degree of weathering, the marked difference in weathering recorded on opposite surfaces of the bone does suggest that the bones were in a quite stable position prior to burial. The weathering would have been more uniform had they been subjected to continual or repeated movement during their subaerial weathering phase. By comparison, only the most extreme weathering stage was recorded for the astragali with Stage 4 being the most common category. They suggest that further studies "of the ranges, rates, and indications of weathering on a variety of skeletal elements is needed" (ibid) in order to explain the different levels of weathering recorded between cortical and dense compact and articular surface bone.

In general, the weathering of material from the Horner site was described as moderate to heavy. Todd and his co-workers assumed that many of the bones actually present in the excavations may have reached Stages 5–6 since only the better preserved bones were retained after the excavation, with the greater percentage being discarded in the field. The advanced weathering of this material suggests that it may have remained exposed on the ground surface for a relatively long time prior to burial (ibid).

In his analysis of the faunal remains from the 1989 excavations at Head-Smashed-In Buffalo Jump, Kooyman (1990) utilised the Todd et al. (1987) modified Behrensmeyer scale to describe the weathering of his material. One problem encountered during the recording of the weathering was that some specimens lacked cortical bone on either (or both) the upper or lower surface, with the underlying cancellous bone exposed (Kooyman 1990:22). No weathering stage was recorded for these bones which would be fine if they were deposited in the site in this condition, but the removal of the cortical surface may have been due to weathering processes within the substrate in which they were buried and exclusion of them from the analysis of the weathering in the site greatly underestimates the extent of weathering experienced by the remains. In continuing excavations it is intended to examine the sediments immediately surrounding bones in which the cancellous bone is exposed to recover small bone 'chips' which would indicate post-depositional weathering (B. Kooyman pers.comm. 5/3/92).

All Behrensmeyer's weathering stages were represented in the remains with a normal distribution around weathering stage 4. This quite advanced weathering state suggests, at first glance, that the bones were exposed to surface weathering for quite some time prior to burial. In describing differences in the weathering of upper and lower surfaces, 40% showed greater upper surface weathering, while 44% exhibited relatively equal weathering on both surfaces (Kooyman 1990:31). This suggests that either there is no difference in the rate of weathering between surfaces, or the material was disturbed during the phase of subaerial weathering. In spite of this difference in the weathering of upper and lower surfaces, the difference in weathering stages observed was either none or one in 86% of the cases (ibid). Rapid burial is probably not the cause of this lack of any great difference in the weathering between surfaces. Rather, Kooyman (op. cit.:36) suggests that the well aerated, sandy soil may have allowed subsurface weathering to continue in a similar fashion to that experienced in subaerial weathering. The fact that so many of the bones recovered in subsequent excavations lacked cortical bone, and the sediment surrounding them contains bone 'chips', is indicative of extensive degradation occurring within the post-depositional phase, in addition to the weathering experienced prior to burial (B. Kooyman pers.comm. 5/3/92).

In their seminal paper on the chemical weathering (i.e. diagenesis) of bone in archaeological sites White and Hannus (1983) proceed one step further than Gordon and Buikstra (1981) by discussing the breakdown of the OHA molecules in bone through the action of organic and carbonic acids formed by the disintegration of collagen. In aerobic weathering, of the kind described by Behrensmeyer (1978), the organic collagen weathers more rapidly than the bone mineral (OHA). However, under certain conditions within the soil, this inorganic matrix will also deteriorate. Bone for their study was recovered from three archaeological sites in South Dakota and subjected to chemical analysis, as well as being rated for three characteristics — "weathering (on a scale increasing from 1 through 8), porosity (1 increasing through 4), and charcoal amount in surface (0, few, or many black flakes)" (White and Hannus 1983:318). While details of the rating scales were not given, correspondence with Everett White (pers.comm. 17/10/91) established that the "bone weathering was measured by a relative scale that was at least very subjective" (my emphasis added). He further commented that while most people can determine the difference between fresh bone, which is unweathered, and that which is very weathered, the determination of intermediate stages is dependent on what the observer imagines they can identify.

> "The weathering stages form a continuum that grades from one stage to another. There is no philosophical basis for separating a continuum into discrete units so it is pointless to say one separation is better than another. If one is reasonably intelligent more discrete units will become apparent as you study the continuum. It is just that your mind has been able to assimilate and integrate the details that you are observing" (ibid).

If we re-interpret Behrensmeyer's (1978) categories with this thought in mind, it could be suggested that rather than being clear cut stages which exist as easily measurable points, as many people have assumed, she saw them as convenient intervals along the continuum with which to correlate against 'time since death'. Behrensmeyer (op. cit.:153) herself recognized the somewhat arbitrary nature of the divisions which were being imposed upon a natural continuum, but felt that "the success of the scheme has been indicated by the ease with which new observers recognize the stages, and there may be some 'natural' component in the classification. This could reflect the fact that bones spend relatively longer periods within each stage than between them". There is no getting away from the fact, however, that these are arbitrary divisions based upon the subjective viewpoint of the observer(s).

While this should not be construed as a criticism of the use of weathering scales as a means to describing the physical breakdown of bones, *per se*, it is intended to serve as a reminder that the weathering of bone is dependent upon a range of local environmental factors and that the description and measurement of this weathering is both pertinent to those environmental conditions and the subjective view of the observer who is describing the bone conditions. The rate of bone disintegration in soil is dependent upon temperature (both soil and air), moisture levels, and soil chemistry (especially the pH). Surface weathering is affected by such factors as the amount of sunshine hours, vegetation cover, and rainfall. Changing any of these variables will alter the rate of bone weathering so it is very difficult to automatically apply a weathering scale developed for one set of environmental and climatic conditions, and with the subjective bias of the person who developed that scale, to a collection of bone remains in a different regime and expect comparable results. Every weathering scale has two inherent deficiencies — it is applicable only to one climatic/environmental type, and there is the built-in bias of the observer. To overcome these, people working on bone weathering have developed their own scales for measuring the breakdown of bone, as discussed above in this section. Often they are simply modifications of a previous study (Behrensmeyer (1978) is an oft-used base for developing a new scale) to suit a new set of variables. Two studies which utilised the same scale are those of Todd et al. (1987) and Kooyman (1990) but both were examining bones from a similar environment on the midwest plains of North America and so effectively nullified one of the in-built biases of this methodology.

A WEATHERING SCALE FOR THE NEW ZEALAND SITUATION

Taking into account the foregoing arguments regarding the use of weathering scales, I decided to develop my own scale to describe the condition of bones recovered from New Zealand archaeological sites. The scales currently available for describing bone weathering were developed in southern California (Miller 1975), equatorial Africa (Behrensmeyer 1978), the mid-west plains of North America (Todd et al. 1987), and the more temperate climate of the Illinois Basin (Gordon and Buikstra 1981), which all experience different climatic and environmental conditions to those found in the temperate high-latitude oceanic climes of southern New Zealand. The inherent subjectivity in all these scales can be partially overcome by developing well defined classes and explicit criteria for placing material within each class. A bone weathering scale must also suit the nature of the assemblage as different bones within an animal and from different species weather at different rates and in different ways.

By developing my own scale I could allow for New Zealand climatic and soil conditions; I would be describing nodes on the weathering continuum which I believed I could see as meaningful separations; I would be describing the remains primarily from one class of animal (moas); and thus I would be able to undertake a comparative study of faunal remains from a number of archaeological sites around the country. In developing a weathering scale to describe the state of bones which may have experienced either subaerial or subsurface weathering (or both), I took a similar approach to that of Todd et al. (1987) and Kooyman (1990) because of the nature of the bones which it must describe. As archaeologists we study bones which are the end-product of a whole range of taphonomic variables, and so we can only assume the processes that bones have gone through prior to their recovery in an excavation. The majority of big-game sites in New Zealand are found in the coastal sand-dunes, where bones can experience a range of depositional conditions across a single site — some bones will be buried immediately after their disposal on a site, some will lie exposed on the surface for a period of time before they are buried, some will be buried for some time and then will be uncovered. The sandy matrix of these sites often results in bones passing through phases of burial and exposure, until a time is reached when there is sufficient matrix built up to ensure permanent burial until they are recovered by archaeologists. Thus it was felt that a weathering scale for the New Zealand situation had to be developed which was broad-based enough to describe the condition of archaeological bones which have been through an unknown taphonomic history, and which have undoubtedly been subjected to both subaerial and subsurface weathering.

My weathering scale borrows heavily from existing scales described in the literature and is as follows:

Stage 1 — unweathered or fresh bone. No physical damage due to weathering observed although there may be some erosion of the processes due to abrasion as the result of trampling.

Stage 2 — the ends of exposed bones and the articulating surfaces either flaking or granular, thus exposing the underlying cancellous bone. Fine hair-line cracks are starting to appear along the diaphysis.

Stage 3 — longitudinal cracking and splitting of the diaphysis starting to occur, following the fibre structure of the bone; articular surfaces exhibit up to 50% loss of the surface; the diaphysis shows occasional pitting and erosion of the bone surface which may be due to chemical wear.

Stage 4 — the splitting and flaking of the diaphysis are more severe with the splits through to the marrow cavity, and the cortical surface of the bone starting to flake off. The articular epiphyseal surfaces retain less than 50% of the surface bone.

Stage 5 — extreme weathering with large areas of cancellous bone exposed on the epiphyses, cracking and splitting of the diaphyseal cortical bone very advanced and accompanied by severe exfoliation. Elements can fracture or flake during hand examination.

After examining a large number of bones, it became apparent that it was not always possible to satisfactorily place a bone into a discrete unit. As a rule, in deciding what stage to record for a particular bone, I followed Behrensmeyer's (1978:152) convention whereby "the most advanced stage which covers patches larger than 1cm square of the limb's surface is recorded", but I found it more helpful to record this as being intermediate between the two stages, i.e. '2/3' means that areas of Stage 3 are more extensive than Stage 2 but do not cover the whole bone. This reflects the fact that the categories/stages used in weathering scales are simply arbitrary divisions imposed upon a natural continuum by the observer. Bones which have lain exposed on the ground surface for some length of time tend to become bleached, primarily from the sun, with a white 'chalky surface' and so I also recorded whether bones were sun-bleached by the addition of an asterisk (*) to the weathering category.

While I was recording the weathering categories, I also recorded the degree of burning evident on the bones so that I examine what effect, if any, burning had on the bone structure and, therefore, ultimately on the weathering of the bone and its subsequent survival through time. The stages adopted for describing the burning phases were more clear-cut and can be described as follows:

Stage 1 — unburnt, clean fresh bone.

Stage 2 — partly burnt or charred. Bones in this category were slightly burnt and much of the bone retained its fresh appearance.

Stage 3 — burnt black

Stage 4 — burnt white or grey, indicating a longer period spent directly in the fire during which the bone matrix was in a reduction reaction, probably at quite a high temperature.

Stage 5 — unburnt bone but differing from Stage 1 in that the bone was stained or discoloured (generally black) from having been deposited in a soil with a high proportion of charcoal. This is likely to occur around the edges of fires or hearths where the bone is mixed with oven rakeout which, while not burning the bone, does discolour it.

As with the recording of the weathering stages, I also recorded combinations of burning stages, i.e. '3/4' where part of the bone has been burnt white/grey while the remainder is black.

OUTLINE OF RESEARCH DESIGN

It has been shown that probably the most important factors in bone weathering are the amount of moisture and pH (subsurface) and the amount of direct sunlight and rainfall (subaerial) received by the bone.

In order to investigate these and other taphonomic factors in New Zealand I adopted the following strategy. Firstly, I conducted a series of controlled experiments in bone weathering to examine the role that soil and climate play in the survival of bones in New Zealand archaeological sites. This enabled me to construct a series of criteria by which we can measure subsurface weathering, based on the Behrensmeyer example, in the archaeological material.

Secondly, once the basic characteristics of subsurface weathering in the local environment had been determined, the results were applied to an archaeological case study. This consisted of an analysis of the moa remains from the Shag Mouth site, excavated in 1988, to extend the investigation of subsurface weathering into the archaeological past. I also investigated the spatial patterns (vertical and horizontal) of weathering within the assemblage. This provided evidence with which to test long-term accumulation (based on Behrensmeyer's (1990a) theory that an assemblage with highly variable weathering may indicate long-term attritional accumulation of bones).

Thirdly, I looked at the broader question of bone weathering and survival rates in New Zealand sites by examining assemblages of big-game from a range of sites around the country. In addition to measuring the weathering patterns evident in the assemblage each site was visited to collect both micro- and macro-environmental data which might have had a bearing on the survival of bone. A number of gradients were closely investigated during the course of the study — notably north/south, inland loam versus coastal dunes in the North Island, and coastal sites versus the dry interior in the southern South Island.

Chapter 4.

Experimental Weathering in a Temperate Environment.

This chapter describes a series of experiments conducted as a case study in experimental subsurface weathering to examine the effects of New Zealand's temperate climate, especially that experienced in the south of the country, on the survival of bones. These experiments examined subsurface weathering processes during a three year cycle in which sets of bones were subjected to different environmental situations to test the effects of soil type and pH, moisture levels and temperature on bone survival.

Climatic records were kept throughout the duration of the experiment so that the effects of prevailing weather patterns could be examined, and to allow correlations to be made between the stages reached in bone weathering in this study with those from previous studies. Soil analysis was undertaken to measure the effects of pH on bone diagenesis, and to determine the levels of ionic activity in the soil. These measurements were taken prior to the bones being introduced into the soil matrix and then again following their recovery, on the premise that any apparent change in ionic levels was possibly a measure of the degree of leaching of both organic and mineral compounds from the bone structure.

In addition, experiments were conducted into the breakdown of bone due to freeze-thaw cycles, in a replication of Miller's (1975) original experiments.

The results of this study provide a baseline for the application to an archaeological case study, the Shag Mouth site in North Otago, and to a New Zealand wide study of the taphonomics of big-game hunting sites.

EXPERIMENTAL WEATHERING

Methodology

In order to understand the processes which impact upon bone survival, a series of different soil situations was investigated to test the subsurface weathering in New Zealand conditions. Given that moa are an extinct order, and therefore fresh bone is not available similar to that found in moa-hunting sites, a comparative study was undertaken with cattle (*Bos taurus*) bones. This species was chosen as being the most similar to the structure of moa bones, with the long leg bones comprising a diaphysis of thick cortical bone and large epiphyses of cancellous bone. While it is accepted that there are most probably differences in the microscopic structure of the bones of moa and cattle, and probably also in properties such as the density, it was considered that they would not be so significantly different as to mask long-term weathering patterns in bones of this size — which is what these experiments were designed to test. In the early prehistoric period moa were the prime big-game species hunted, and are the large species most commonly represented in archaeological sites. It is the survival rate of moa bones, in particular, that this experiment was attempting to model, and is the justification for using cattle bones in the weathering experiments. The other big-game species hunted in prehistoric New Zealand, in particular the fur seal and sea lion, have a completely different type of bone structure which is highly cancellous without large marrow cavities in the centre of the diaphysis. This difference in bone structure between sea mammals and moa and cattle bones means that there can be no direct extrapolation of the results of the weathering experiments described in this chapter to seal bones, and this remains as a study that will be required in the future.

The bones were obtained fresh from a local butcher, from animals that had been killed within the previous 24 hours. The bones had been stripped of excess flesh, but still retained some soft tissue in the form of sinews, cartilage, fat and such like. The bones were stored in a freezer until required for the experiments.

In addition, a sample of moa bones from sites of known radiocarbon age was included within each matrix. The samples consisted of whole bones, proximal or distal halves, fragments of long bone diaphyses, and fragments of burnt bone. The intention was to study what effect renewed weathering had on the bones, given that the environmental conditions present in each case were being carefully monitored.

Prior to the bones being buried a range of measurements was taken: including weight (g), length (mm), and, where applicable, width of the proximal epiphysis, width of the mid-shaft, width of the distal epiphysis, and shaft thickness. The weight was taken on a Mettler P11 balance, the length on a standard osteometric board, and the other measurements with a pair of Mitutoyo dial callipers.

Two hypotheses were proposed in Chapter 1 for examination — (1) that bone will survive longer and in better condition when it has been deposited in a sand matrix; and (2) the greater amount of burning that the bone undergoes, the more brittle it will become and subsequently the time it will survive will decrease. In examining the second hypothesis, the assumption was made that more highly burnt material may reach a point of stable equilibrium with its surrounding matrix over time, and that during subsequent exposure to the elements it will undergo rapid breakdown. The experimental work described in this chapter initiates the testing of these hypotheses. It is followed up in subsequent chapters with the analysis of subsurface weathering in archaeological cases.

Five different matrix situations were located for the experiment. These were:
a) a silty loam overlying a clay horizon,
b) a coastal sand dune, with some scattered vegetation on it,
c) the roof of a building on the Otago University campus,
d) a container of soil from matrix a) which was located in the Anthropology Department and in which I attempted to accelerate the weathering procedure,
e) a container of sand from matrix b) which was located in the Anthropology Department and in which I attempted to accelerate the weathering procedure,

The first two were selected to represent conditions in New Zealand archaeological sites. The silty loam (described in detail later in this chapter) is similar to that found at river mouths in which large moa-hunting sites, such as Waitaki Mouth and Rakaia Mouth, are situated. The vast majority of midden sites in New Zealand are to be found in the coastal sand dune system, and situation b) was chosen for that reason. The only difficulty foreseen was the different classes of vegetation existing between the modern day environment and that in the past. Sand dunes today are usually covered with introduced plant species — marram grass, lupins, English broom (and occasionally pinetrees) — and how these affect the soil chemistry, in comparison with the prehistoric vegetation cover, is uncertain. The third situation, the roof of a building, was set up so as to measure solely the climatic effects and not those of the burial matrix. Bones that are discarded on the ground surface in an archaeological site are affected not only by the weather patterns, but also by the chemistry of the ground surface they are in contact with. In this experiment it was the intention to only measure climatic effects — such as those due to rainfall, the amount of sunshine on the bones, and temperature variations.

The final two types of soil matrix were containers of silty loam and sand, respectively, housed in an environment kept at a constant 28°C and which had approximately 1.5L of water poured into each container every week. The intention was to accelerate the weathering process by raising the temperature and keeping the soil matrix surrounding the bones in a constantly moist condition.

The bones that were interred in each soil matrix are described in Table 4.1. It was intended that each set of bones would comprise one each of the major leg bones, ribs, vertebrae, and portions of bone. With the beef bones this included a leg bone sawn in half (with a hacksaw) from which the proximal end was kept in one piece, while the distal end was smashed to simulate the breaking of bone for marrow extraction. The sets of moa bones likewise included complete leg bones and proximal and distal portions, as well as fragments of long bone shafts and burnt material. These were included to determine whether they would undergo further weathering given, in the case of the shaft fragments, that they exposed the marrow cavity and the edges to the full effects of environmental variables and, in the case of the burnt fragments, that these were bones whose internal structure may have been altered through heating and had established a new equilibrium with the surrounding environment.

This experiment into the effects of subsurface and subaerial weathering on long-term

Table 4.1 A full list of the bones buried in each soil matrix.
Notes: c = complete, L = left, R = right, th = thoracic (vertebra), ce = cervical (vertebra), sm = smashed, p = proximal, d = distal.
A full description of the matrix types is given in the text.

Bone type			Matrix type		
	Soil	Sand	Surface	Accel. soil	Accel. sand
Beef					
femur	c L	c L	c R	c R	c R
	p 1/2 R	p 1/2 L	p 1/2 L		
	d 1/2 R	d 1/2 L	d 1/2 L		
	(sm)	(sm)	(sm)		
tibia	c L	2 c L	c L	c L	c R
				p 1/2 R	p 1/2 R
				d 1/2 R	d 1/2 R
				(sm)	(sm)
humerus	c L	-	c L	c R	c R
vertebrae	2	2	3 th	2	2
ribs	2	2	2	2	2
Moa					
femur	c L	c L	c L	c L	c R
	d L	d 1/2 R	p R, d R	d R	p L
tibiotarsus	c L	c R	c L	c L	c R
	d L	p R		p L	d L
tarsometa.	c L	c L	c R	c L	c R
vertebrae	2	2 ce	2	th, ce	2 th
shaft frags.	4	4	4	4	4
burnt frags.	10	10	10	10	10

bone survival was initiated prior to the formation of the bone weathering scale, described in the previous chapter. Thus the condition of the bones prior to their being buried in the various soil matrices was not recorded. It can be assumed, however, that the cattle bones, which were obtained fresh from the butcher, were in Stage 1 weathering, and the moa bones were most probably in Stages 1 or 2. When the bones were recovered at the end of the three-year period, details of the weathering stage were recorded and these are presented in the results section of this chapter, along with graphs showing the change in weathering stage status during the course of the experiment.

The situation chosen for the soil matrix was my vegetable garden at 68 Nairn Street, Dunedin. The soil is a very friable silty loam overlying a clay base which appears at approximately 30–50cm depth. A 1m^2 pit was dug and the bones laid out such that they were not touching their nearest neighbour (Figure 4.1). Ten soil samples

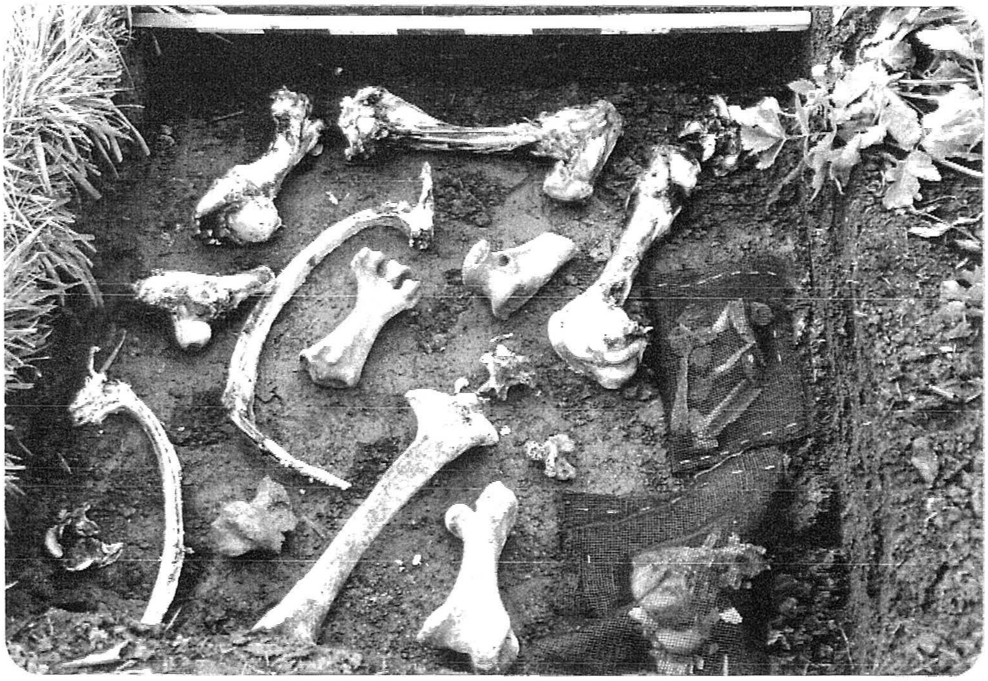


Figure 4.1 Placement of the bones in the soil matrix situation, 68 Nairn St.

(weighing approximately 100g each) were taken from the level at which the bones were buried (Figure 4.2), and were later analysed as described below. Soil was also taken for the accelerated soil situation from that remaining once the bones were covered and from the garden around this site. The garden is fully exposed to the elements, with no trees above it to stop any rainfall and it receives full day sun.

When the bones were recovered at the end of the experiment a further series of soil samples were taken — four from immediately above the bones, and four from immediately below the bones. All were within 5cm of the bones, and were taken from approximately the middle of the four quadrants (running anticlockwise with Number 1 in the NW quadrant).

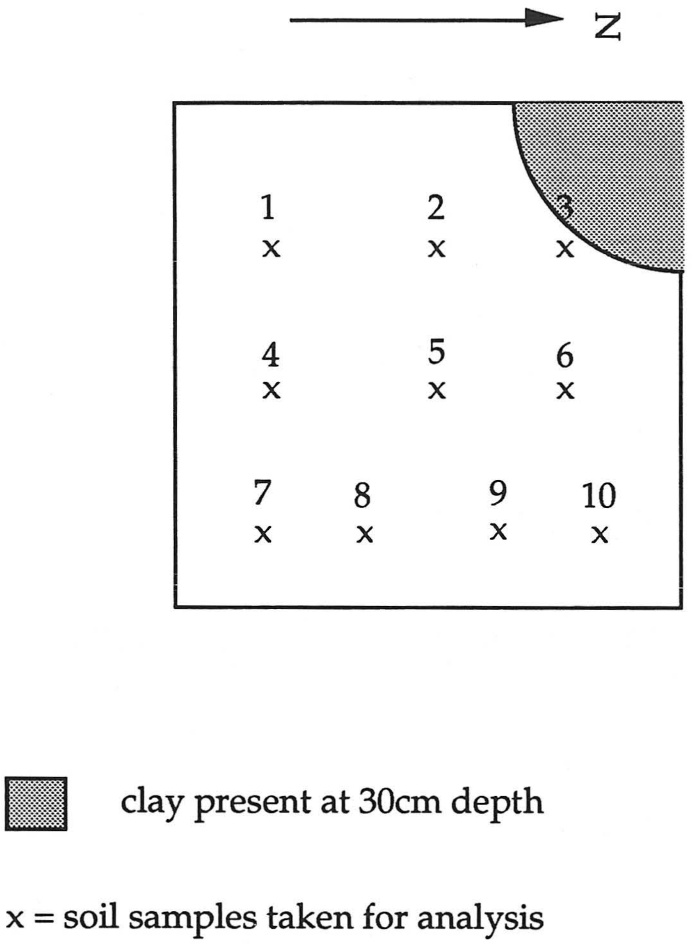


Figure 4.2 Location of the soil samples taken from the soil situation, 68 Nairn St.

The second burial site was in a sand matrix at Warrington Beach, north of Dunedin. The beach consists of a large sand spit with Blueskin Bay tidal estuary on the inland side, and the open ocean on the seaward. The spit was formerly covered by lupins and other introduced species (such as marram grass), and had a large number of pine trees on the northern half. The site chosen was approximately half way along the spit, on the crest of a high dune in the centre of the sand spit. The vegetation present included low lupin bushes and ground cover (grass), and there were a number of pines within 30m radius from the site. The bones were buried in an 80 x 100cm pit, at a depth of 45cm (Figure 4.3). Ten sand samples were recovered for sub-

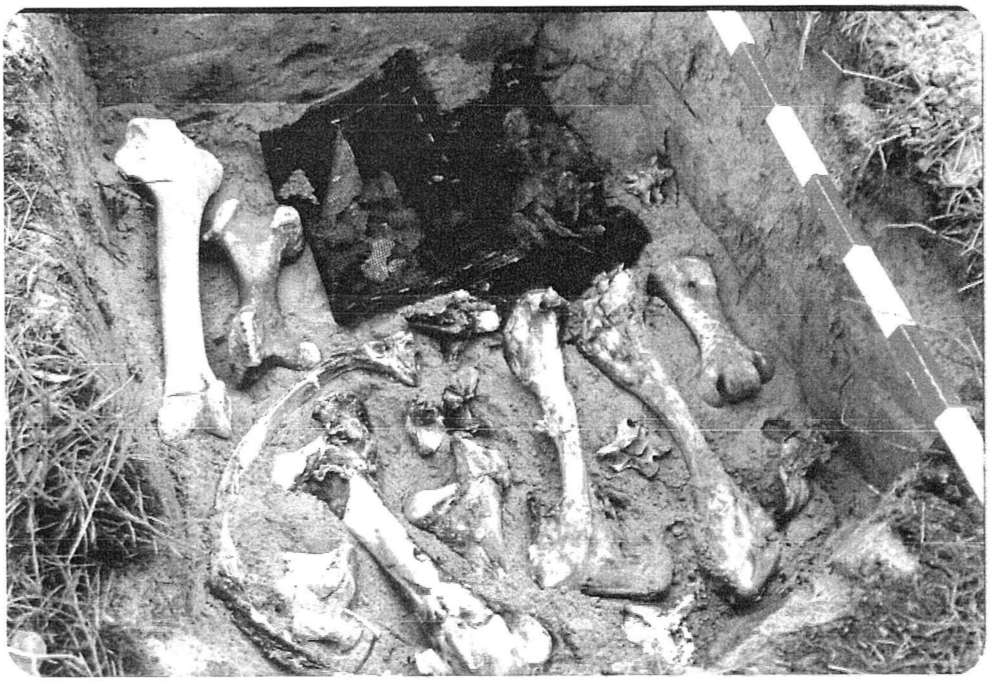
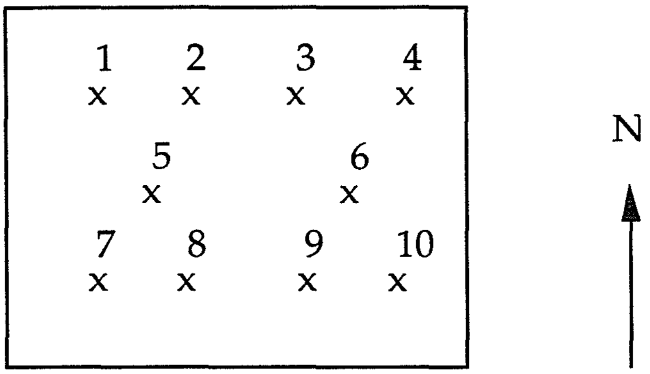


Figure 4.3 Placement of the bones in the sand matrix, Warrington Beach.

sequent analysis (Figure 4.4). A second pit was dug immediately to the east of the one containing the bones and the sand removed from the site for use in the accelerated sand situation.

When the bones were recovered at the end of the experiment a further series of soil samples were taken — four from immediately above the bones, and four from immediately below the bones. All were within 5cm of the bones, and were taken from approximately the middle of the four quadrants (running anticlockwise with Number 1 in the SE quadrant).



x = soil samples taken for analysis

Figure 4.4 Location of the soil samples taken from the sand situation, Warrington Beach.

The third experimental situation was intended to replicate conditions encountered from climatic variables only — rainfall, sunshine levels, wind, frost etc, without the added effects incurred from placement on the ground surface. To this end the bones were placed on the flat roof of the Burns Building, on the Otago University campus. The roof is a large flat expanse exposed to the elements year round and provided the ideal situation. To ensure that the bones remained on the roof and were not blown off by the often extreme wind gusts which sweep across the roof, they were placed

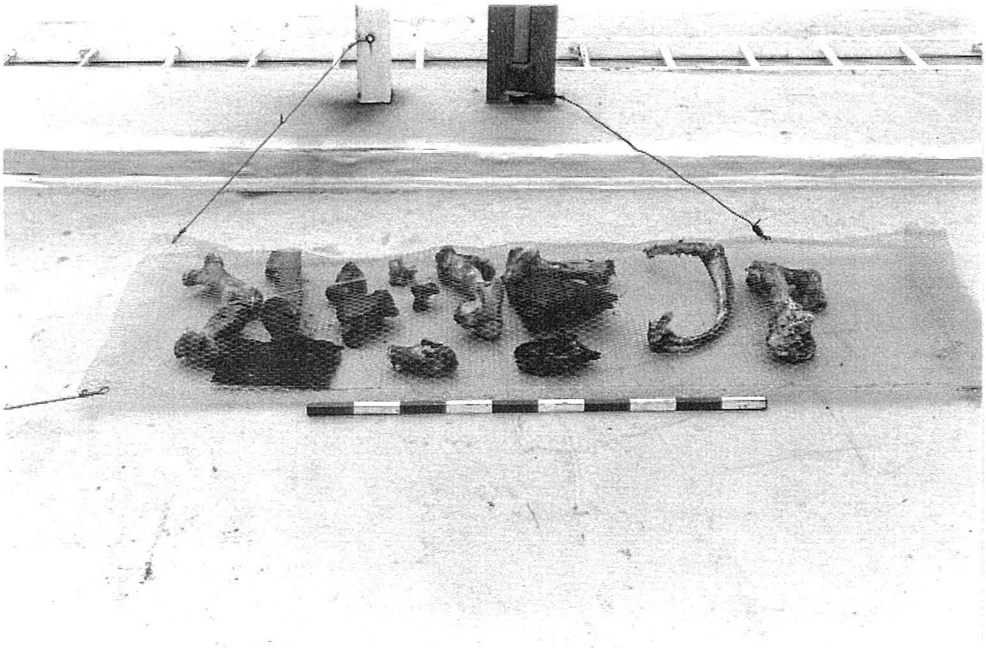


Figure 4.5 The bones for the third experimental situation, on the roof of the Burns Building, Otago University.

inside a 1m x 2m 'envelope' of chicken wire which was tied down at the four corners (Figure 4.5).

The final two soil matrices used in this experiment were soil and sand respectively which were kept in 50L plastic barrels, into which the bones had been placed, in the 'Bugroom' of the Anthropology Department, University of Otago. This room houses tanks of dermestid beetle colonies used in the preparation of comparative skeletal material for the Department's comparative collection and is, therefore, maintained at a constant 28°C and < 60% humidity. The soil and sand were collected from close proximity to the pits dug for the bones at Nairn Street and Warrington Beach, as described above. It was anticipated that with the constant warm temperature and by maintaining a high water content (the barrels had approximately 1.5L of water added weekly) the weathering process could be accelerated. Ortner et al. (1972) demonstrated that soil pH, ground water and temperature were the major factors determining the rate of nitrogen decay in bone, and that in a condition of increased temperature and excess water there will be an acceleration in the rate of decay.

Soil samples were not taken from these two matrices prior to the bones being added to the barrels as the soil and sand had already been sampled for the first two matrix situations described above. When the bones were removed from the barrels at the completion of the experiment, two bulk soil samples were taken - in each case one was from approximately one third of the way down the barrel, and the second from two thirds down.

The experiments were run over a period of three years, during which time it was considered their soft tissues would break down completely and the initiation of subsurface weathering would begin. Periodically the bones would be exhumed and examined so that the process of weathering which the bones were undergoing could be closely watched.

While the soil experiments were running, records were kept of the monthly weather patterns in Dunedin, especially: the amount of rainfall (mm), mean monthly temperature (°C), mean minimum and maximum temperatures (°C), mean grass minimum temperature (°C), and the number of sunshine hours. This information was collected from records taken at the Musselburgh Pumping Station by the New Zealand Meteorological Service, published monthly in the *Otago Daily Times (ODT)*, of which a copy of the original data is held by the Geography Department, University of Otago.

This data was collected so that patterns in the bone weathering could be examined in relation to macroscopic variations in the prevailing weather patterns. In addition, it allowed for the comparison of subsurface weathering evident on the bones from this experiment with results obtained in other studies.

A number of different soil analyses were undertaken on the samples recovered from each of the soil matrices, as described above. The samples were taken prior to the bones being buried, and from immediately adjacent to the bones when they were lifted. The analysis included soil pH, moisture content, organic content, and base cation determination. The first allows a classification of the acidity of the soil, described by Gordon and Buikstra (1981:569) as a strong predictor of the preservational state of bones, while the next three describe certain characteristics which affect bone survival and the leaching of elements into and out of the bones during diagenesis. By taking samples prior to and following the burial process, it allowed for an examination of changes in soil composition as ionic material was either uplifted or deposited from the soil to the bone.

The soil analyses followed standard procedures, which had been adopted by Dr. Richard Morgan (Geography Department, University of Otago) for classes in soil science taught in that department. The pH analysis is after Allen (1974:23–25) and Allen et al. (1986:291–292) using a 1:2.5 mixing ratio of soil:deionised water. Likewise, the moisture content of the soils and the loss-on-ignition, an estimate of the organic carbon in the soil, were determined after Allen (1974:21–23) and Allen et al. (1986). In the organic determination, the muffle furnace was heated to 450°C to ensure that water of hydration was not also driven out. The analysis of the base cations (Ca^{2+}, Na^{+}, Mg^{+}, K^{+}) was carried out by the leachate method, using 1M ammonium acetate, pH 7.0, and atomic absorption spectrophotometry (Hitachi Z-6100 Polarized Zeeman AAS) as described by the New Zealand Soil Bureau (1972).

From the original soil samples, approximately 5g was removed for determination of moisture content. The remaining sample was air-dried at 20°C for 2-3 days, large stones and roots were removed, and it was then passed through a 2mm mesh sieve with any aggregates placed in a pestle and mortar to gently break them down. Approximately 20g of this sieved and dried material was used for the pH analysis, 5g for base cation determination, and 1g of the oven-dried soil (used for the moisture content determination) was subsequently used for the organic content measurement.

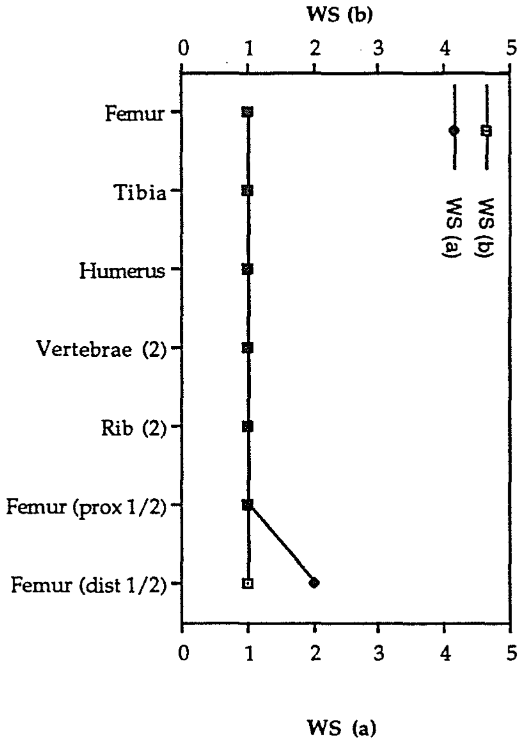
Results

Bone weathering.

At the end of the experimental period the bones were recovered and soil samples taken as described above. In all cases the bones had undergone some degree of weathering (Figures 4.6–4.10) — from partial loss of the periosteum in the case of the bones in the accelerated soil situation to total loss of the periosteum, disarticulation of the elements, and invasion by fine root hairs in the case of the bones buried in the sand at Warrington Beach.

As the bones were recovered from the soil matrix many of the cattle bones had a layer of black organic material adhering to them which was the organic remains of the soft tissue. The beef bones in general had lost the periosteum, and many had started to disarticulate, with the epiphyses separating from the shafts (due in part to the bones being derived from sub adult animals). There was evidence of pitting due to root action, and small holes in the bones were probably due to microfaunal activity. The distal femur that had been broken to simulate marrow extraction was slightly more weathered than the other bones in this matrix (Figure 4.6). The surface of the bone was quite pitted and the cortical bone was wearing thin in places exposing the cancellous bone beneath.

The moa bones were all clean and in good condition and as a general pattern they exhibited some minor cracking of the diaphysis of the long bones, and exposure of the cancellous bone on the epiphyses, especially edges of the condyles (Figure 4.6). The tarsometatarsus had a large crack running dorso-ventrally across the medial



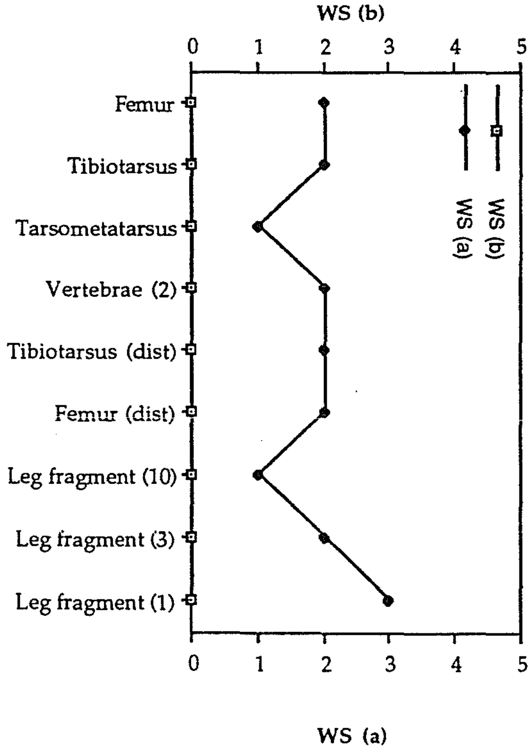


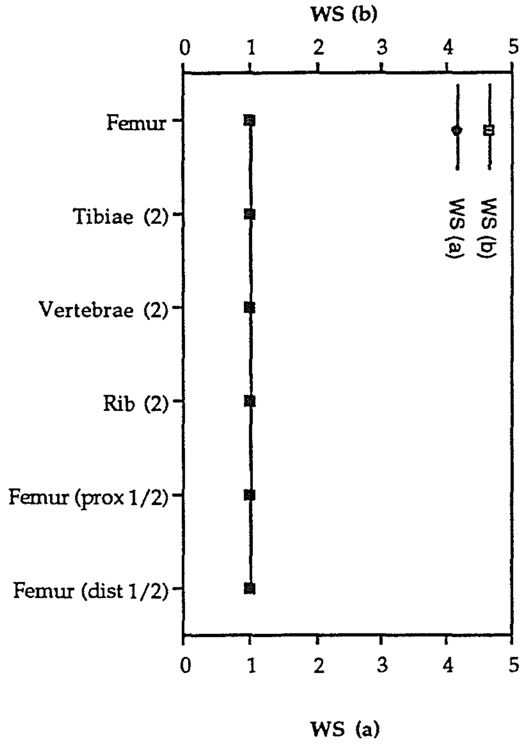
Figure 4.6 A breakdown of the weathering stages in the cattle (top) and moa (bottom) bones in the soil matrix, before ('WS (b)') and after ('WS (a)') the weathering experiment.

trochlea. The shaft fragments and smaller burnt fragments generally showed little change. The shaft fragments showed some fine cracking and in one instance flaking of the cortical bone, while two of the burnt fragments had developed deep cracks across them. This perhaps suggests that small burnt fragments had reached a state of equilibrium and that further interment did not affect their structure.

During excavation of the sand matrix to recover those bones it was recorded that the sand immediately surrounding the beef bones was more darkly stained than the remaining sand, suggesting a buildup of organic material in the sand following the breakdown of the soft tissues. Most of the beef bones had started to disarticulate, although the larger elements retained their epiphyses, and while most of the periosteum had broken down some bones had small areas of dried tissue present. In general the bones bore little evidence of weathering (Figure 4.7), and many had a greasy appearance to them. The larger of the two complete tibiae had a porous appearance at the mid-diaphysis which may be due to either plant/microorganism action or to the age of the animal (immature/subadult), as did the proximal half section of the L femur.

The moa bones generally had a large covering of fine root hairs, and had undergone continued weathering especially on the epiphyses where the underlying cancellous bone was often exposed (Figure 4.7). Many of the larger elements had fine longitudinal cracks along the shafts and, in the case of the tarsometatarsus, across the trochleae. The dorsal surface of the shaft of the tarsometatarsus had a small area of extreme pitting with much of the outer cortical bone flaking away. The smaller shaft and burnt fragments showed little evidence of further change, apart from two that had large transverse cracking.

It is the bones that had lain exposed on the surface of the Burns Building that are the most interesting, and which show the greatest amount of change. The beef bones are nearly all covered with the blackened, dried up remains of the periosteum which appears to have shrivelled and dried from exposure to the elements but has not broken down (Figure 4.8). As a result, the bones were all still articulated and in places where the bone was visible through the remains of the soft tissue it appeared to be bleached, sometimes with a green lichen present, and starting to crack



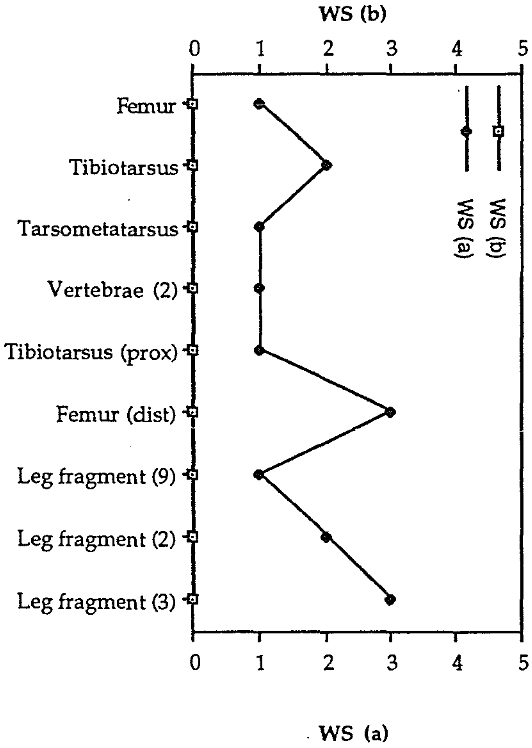


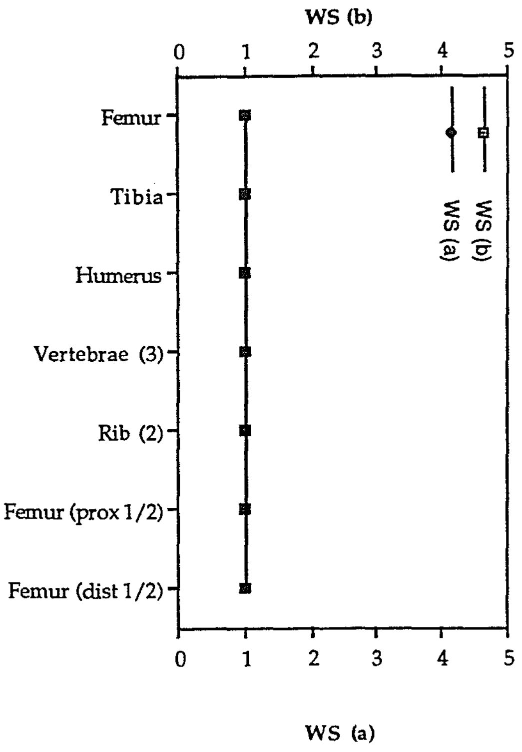
Figure 4.7 A breakdown of the weathering stages in the cattle (top) and moa (bottom) bones in the sand matrix, before ('WS (b)') and after ('WS (a)') the weathering experiment.

longitudinally. The three thoracic vertebrae, which were interred as an articulated set, had disarticulated and the epiphyses were separating from the main body of the bone.

The moa bones had all been bleached white by the sun on the surface facing uppermost, while the lower surface of many had green lichen/moss growing on it. Many are in advanced stages of weathering (Figure 4.8), suggesting that the equilibrium that had been reached within the bone structure while they were interred, had been upset by this subsequent exposure to the weather. This has important implications for archaeological sites which are accidentally or intentionally disturbed and bones brought to the surface, for example in relation to Teviotdale's comments about the Waitaki Mouth site (Teviotdale 1939:168), where the vast amounts of bone which were brought to the surface when the site was ploughed, appeared to break down and disintegrate within only a short number of years.

The long bones exhibit long, and often deep, longitudinal cracks along the diaphyses and on the majority the cortical bone is flaking away. On the epiphyses there are large areas of exposed cancellous bone, the trochleae of the tarsometatarsus and the proximal articulating surface of both this bone and the tibiotarsus have deep cracks. The two vertebrae are starting to disintegrate with large deep cracks across them and a majority of the surface area consists of exposed cancellous bone, features also present on the proximal R femur. The smaller shaft fragments had advanced to various degrees of weathering, while the burnt fragments on the whole appeared to be unaffected, although one fragment had several deep transverse cracks across it.

The bones in the two matrices where an attempt was made to accelerate the weathering showed surprising results in that, if anything, the weathering process had been inhibited, or at least slowed down, in comparison to the bones buried in the natural soil matrix situations (Figures 4.9 and 4.10). A reason for this may be that there was an accumulation of water within the container which created a situation approximating anaerobic conditions, which would have the same effect of inhibiting the weathering process. At the time when the bones were recovered, however, the matrices were both relatively dry, such that if anaerobic conditions had existed they



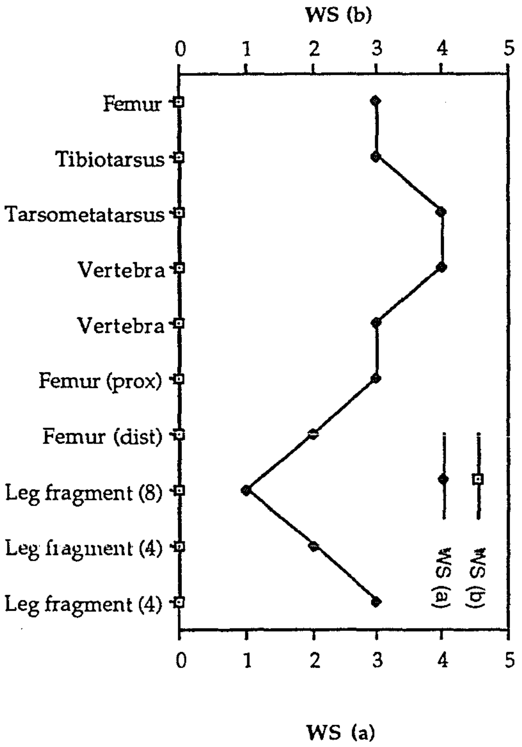
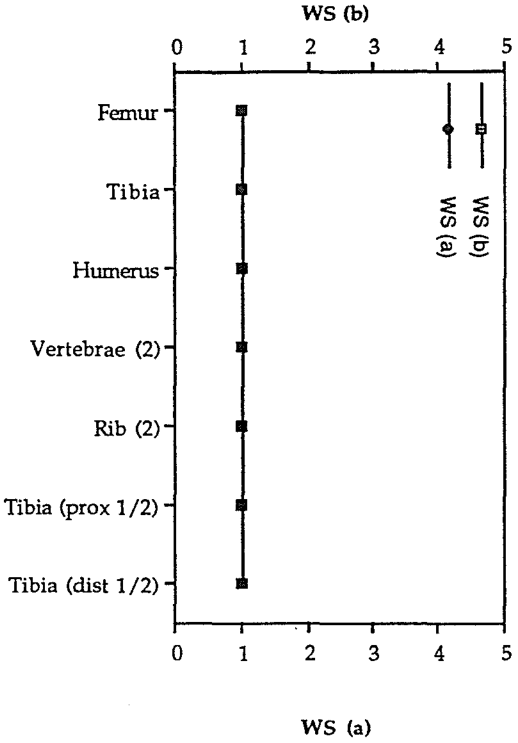


Figure 4.8 A breakdown of the weathering stages in the cattle (top) and moa (bottom) bones in the surface condition, before ('WS (b)') and after ('WS (a)') the weathering experiment.

were not in evidence at the conclusion of the experiment. The beef bones recovered from the 'accelerated' soil matrix had all lost some of their soft tissues, but most still retained fragments of dried tissue, and nearly all were stained a yellowish-black colour. Disarticulation was initiated on the ribs and vertebrae, with the epiphyses separating, but the long bones still retained periosteum on the epiphyses which inhibited the disarticulation of those fragments. The ribs had a porous appearance to them, possibly due to the age of the animal from which they derived, and the vestiges of soft tissue were in the form of a brown-black 'scaly' material. The distal tibia which had been smashed to simulate a bone broken for marrow extraction had lost all of its periosteum (thus the tarsals had disarticulated) and a number of the broken shaft fragments had longitudinal cracks.

The moa bones generally bore little evidence of continued weathering (Figure 4.9), although some elements had wear on their epiphyses which exposed the underlying cancellous bone or fine longitudinal cracking along the diaphysis. This cracking is surficial only and does not penetrate through to the marrow cavity. The L femur had areas of surface pitting and flaking on the shaft with large areas of cancellous bone exposed on the both epiphyses. The tarsometatarsus had cracking along the dorsal surface of the shaft and on the articulating surface of the trochleae. As in the other matrices described above, the smaller shaft and burnt fragments did not weather to any great extent apart from some fine cracking, and flaking of the cortical bone in one instance.

The beef bones in the 'accelerated' sand matrix were slightly more weathered than those in the 'accelerated' soil (Figure 4.10), but not as far advanced as those buried at Warrington Beach. Most had lost the majority of the soft tissue, but the more complete leg bones still retain more than 50% which inhibited disarticulation. Where the periosteum is still present it tends to be dried and often flakey and black. Separation of the epiphyses from the diaphysis has occurred on the smaller elements (ribs and vertebrae). In addition, these smaller elements have a porous appearance where the bone is exposed through the dried periosteum. Nearly all the beef bones are black in colour which is probably due to fat/grease in the bone structure which has begun to denature. The complete R humerus had a thick yellow coat of grease



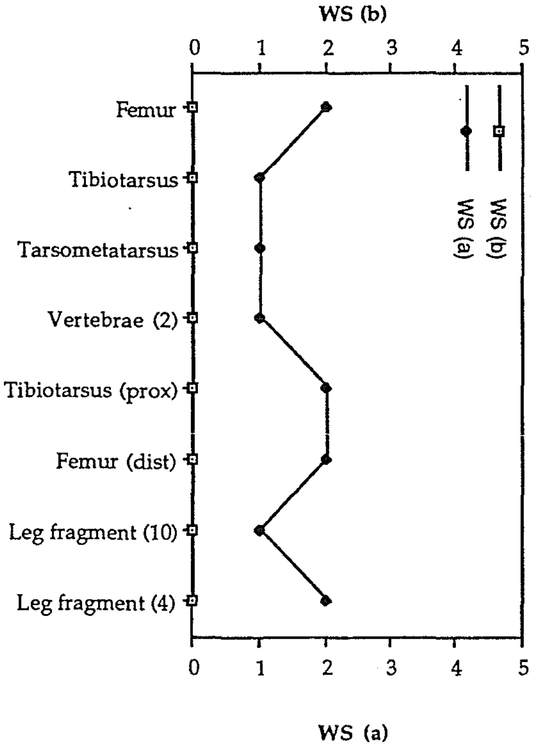
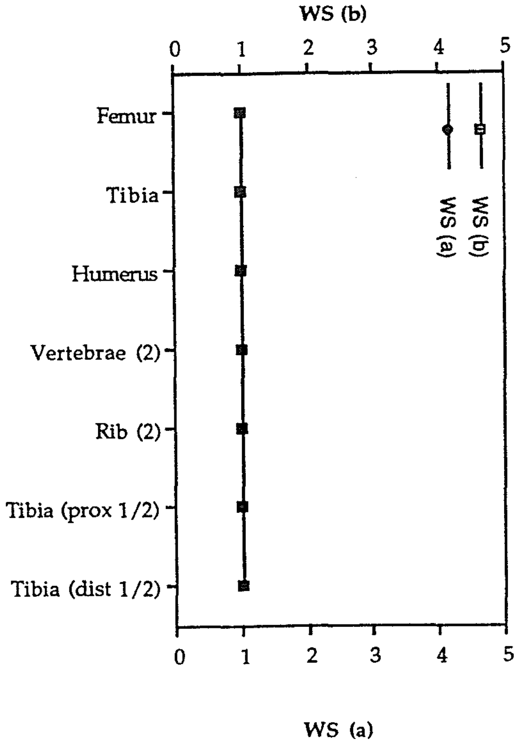


Figure 4.9 A breakdown of the weathering stages in the cattle (top) and moa (bottom) bones in the 'accelerated' soil matrix, before ('WS (b)') and after ('WS (a)') the weathering experiment.



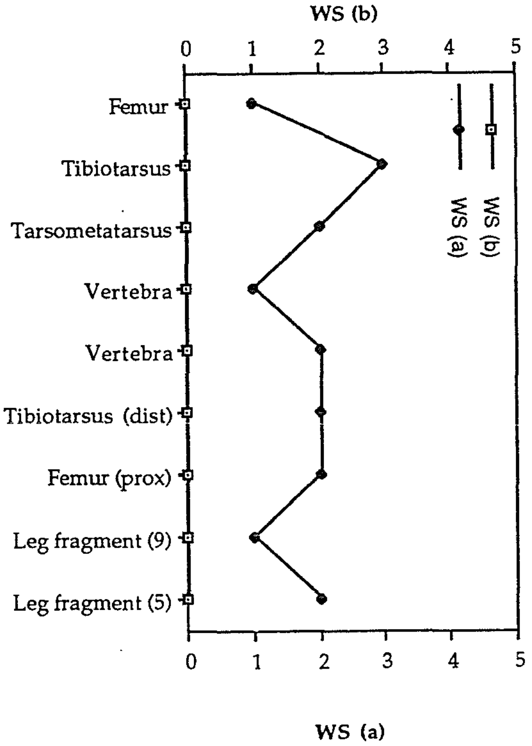


Figure 4.10 A breakdown of the weathering stages in the cattle (top) and moa (bottom) bones in the 'accelerated' sand matrix, before ('WS (b)') and after ('WS (a)') the weathering experiment.

along one side of the shaft. Some of the shaft fragments from the smashed distal tibia show evidence for the beginnings of 'circular delamination' where the layers of cortical bone are peeling apart.

The moa bones show some evidence of continued weathering, with the exposure of the cancellous bone on the epiphyses (especially along the edges of the condyles), and fine longitudinal cracking on the diaphysis. The complete R tibiotarsus has one large crack along the anterior surface of the shaft which penetrates almost to the marrow cavity. The proximal L femur has large cracks appearing on the proximal articulating surface which may be due to the bone drying out after it was removed from the sand matrix. The shaft and burnt fragments all show varying degrees of wear — from a few fine cracks to three or four large, deep cracks across the surface.

Weather patterns.

The changing Dunedin weather patterns during the duration of these experiments are described below in Table 4.2 and Figures 4.11 to 4.15. The information considered to be of primary importance for the determination of the effects of weathering on bone survival are: the amount of rainfall (mm), the mean monthly temperature (°C), the mean monthly minimum and maximum temperatures (°C), mean monthly grass minimum temperatures (°C), and the number of sunshine hours.

The readings for rainfall and sunshine hours are two factors which were discussed in the previous chapter as being important to the survival of bone. Material that is buried, and which undergoes diagenesis, is likewise affected by moisture levels, and the temperature of the surrounding matrix. For that reason mean daily temperature, minimum/maximum daily temperatures, and mean grass minimum temperatures were recorded.

During the three years that the experiments were running a number of features in the local weather patterns were highlighted by the meteorological office which may have had some effect on weathering rates. The weather for September and October

Table 4.2 Weather data for the study period of 1988-1991 (derived from the climatological data supplied to the *Otago Daily Times* by the Musselburgh Pumping Station).

Month	Rainfall (mm)	Mean daily max T (°C)	Mean T (°C)	Mean daily min T (°C)	Mean grass min T (°C)	Sunshine hours
J '88	61.7	10.4	6.9	3.4	0.2	102.0
A	40.4	11.9	8.0	4.1	0.7	130.5
S	12.6	14.8	10.7	6.6	3.6	129.5
O	27.0	17.0	12.6	8.2	4.9	151.8
N	39.9	17.4	13.4	11.7	9.5	152.6
D	61.2	19.8	15.8	11.7	9.5	238.8
J '89	55.0	.	16.4	.	.	184.0
F	48.0	17.8	14.6	11.4	9.5	123.0
M	81.0	17.4	13.8	10.2	6.7	124.0
A	31.0	15.2	11.9	8.5	5.1	106.0
M	39.0	12.3	9.4	6.4	3.5	89.0
J	95.0	10.6	7.1	3.5	-0.4	85.0
J	.	.	.	.	.	.
A	35.0	11.4	8.2	4.9	1.7	121.0
S	20.0	12.9	9.7	6.5	3.8	145.0
O	96.0	14.6	11.5	8.5	5.8	136.0
N	.	.	.	.	.	.
D	100.0	17.4	13.4	10.0	8.0	155.0
J '90	33.5	19.7	15.6	11.5	9.4	205.1
F	43.9	20.5	16.5	12.6	10.6	170.9
M	18.0	18.5	14.3	10.1	7.3	121.0
A	62.3	16.1	12.0	8.0	5.1	107.0
M	48.0	13.6	9.8	6.1	2.8	96.0
J	20.8	11.0	7.8	4.6	1.4	73.7
J	34.3	9.7	6.7	3.6	0.6	114.5
A	136.9	10.8	7.7	4.5	1.6	117.9
S	19.0	11.9	8.7	5.4	2.6	134.2
O	95.6	14.3	10.5	6.7	4.1	157.5
N	42.4	15.9	12.3	8.6	6.3	158.8
D	55.3	17.7	14.2	10.6	8.6	220.4
J '91	77.1	18.3	14.8	11.4	10.3	123.6
F	178.3	17.9	14.3	10.6	9.1	126.1
M	49.3	16.6	13.9	11.2	9.5	152.7
A	98.8	14.3	11.1	7.9	5.3	109.7

M	33.0	12.9	9.5	6.0	2.9	110.7
J	52.0	8.8	6.0	3.1	0.5	83.8
J	38.1	8.9	5.3	1.6	-1.7	134.4
A	123.8	11.9	8.1	4.2	1.2	99.2
S	54.3	12.3	9.4	6.4	3.7	102.1
O	41.0	14.6	10.9	7.1	4.4	138.3

(.) = data missing

1988 was the warmest and driest for the respective months for more than 25 years. This resulted, in part, from warmer-than-average sea temperatures around New Zealand and the anti El Niño (or La Niña) in the South Pacific (*Evening Post* 2.11.88). By the end of the year, 1988 was the ninth warmest year on record (*ODT* 7/1/89:1), a result subsequently confirmed in a report from London which stated that, globally, 1988 was the warmest for at least 100 years (*ODT* 2/2/89:1).

This pattern of warm, dry weather continued through into 1989, and it was reported (*ODT* 13/6/89:1) that the 12 month period from June 1988 to May 1989, with a mean temperature of 13.4°C (1.4° above average), was the warmest in New Zealand since records started in 1853.

Weather patterns in New Zealand are affected by two different cycles — La Niña and El Niño. The summer of 1988/89 was under the influence of the La Niña and this produced consistent and predictive weather. The remainder of 1989 was a phase between the two states so the weather tended to be very changeable (*ODT* 6/1/90:5). As a result of this, the Dunedin weather alternated between hot, dry northwesterly winds coming across the mountains, and cold, wet, southwesterlies from the ocean.

The evidence of this changeability was seen during the remainder of 1989, where June was milder and wetter (38% more rainfall) than usual (*ODT* 7/7/89), August was drier and warmer (*ODT* 11/9/89), September drier and milder — caused by high pressure systems to the east of the South Island which caused more northeast

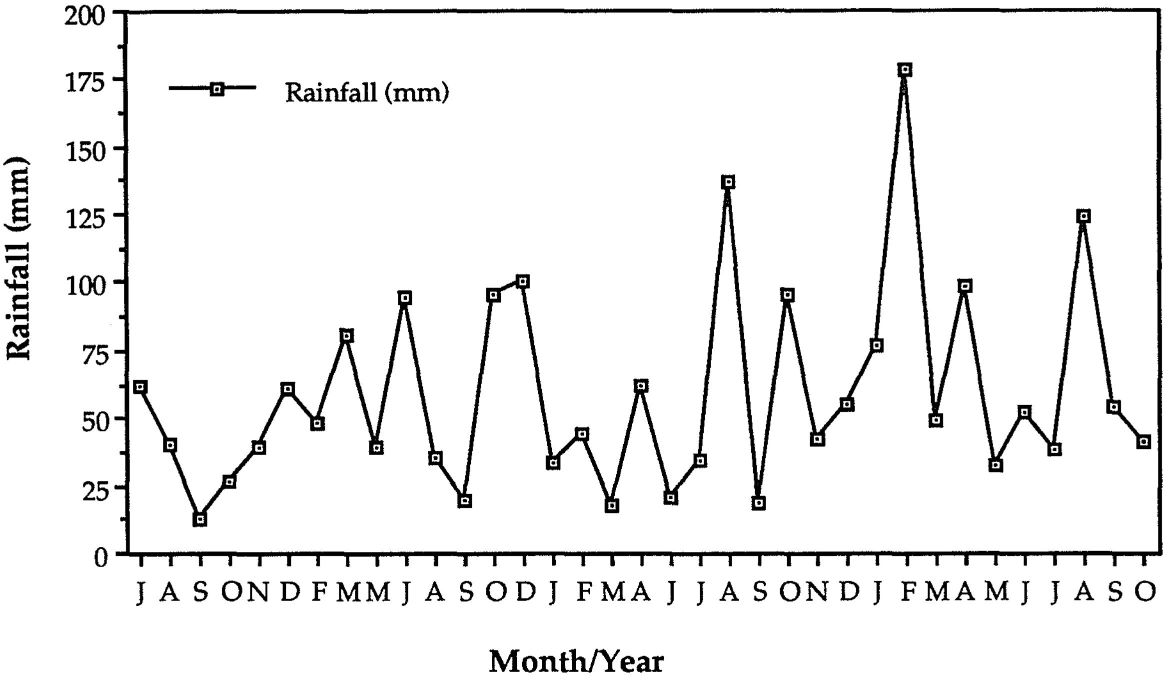


Figure 4.11 Rainfall levels for the 1988–1991 study period.

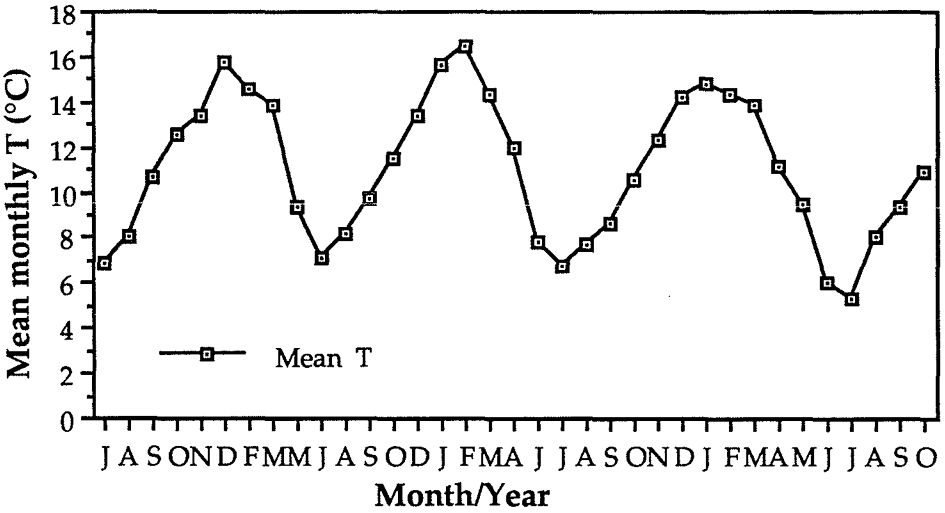


Figure 4.12 Mean monthly temperatures in the 1988–1991 study period.

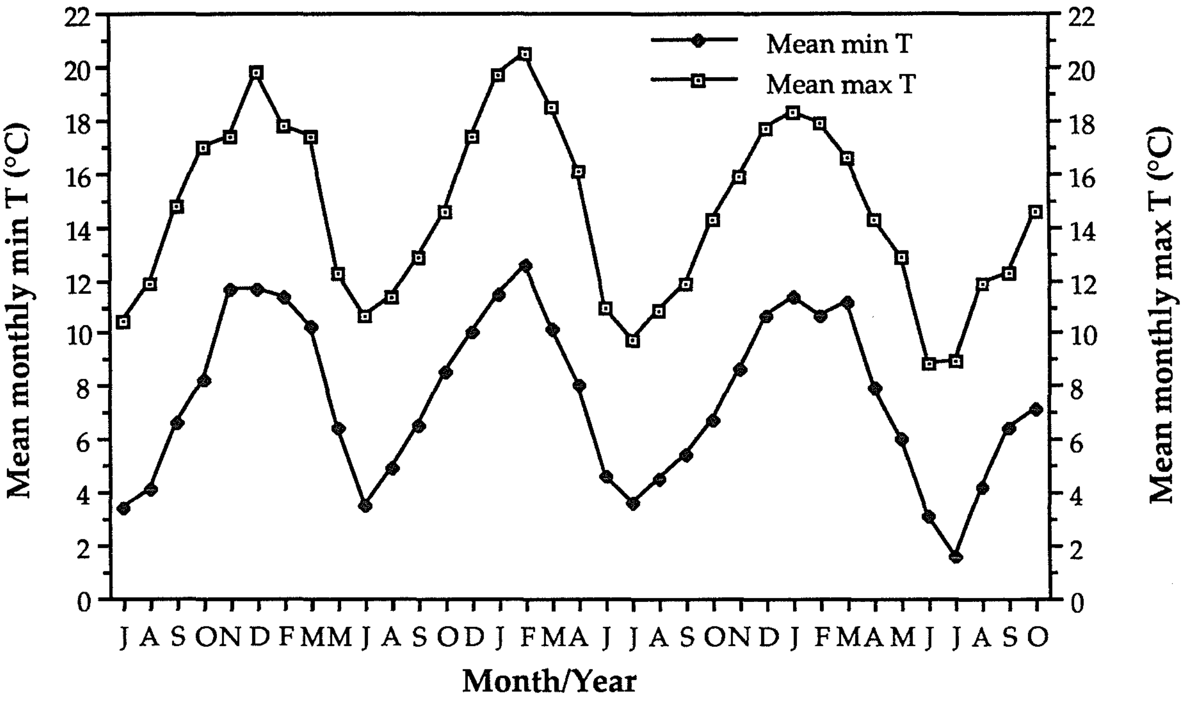


Figure 4.13 Mean monthly minimum and maximum temperatures in the 1988–1991 study period.

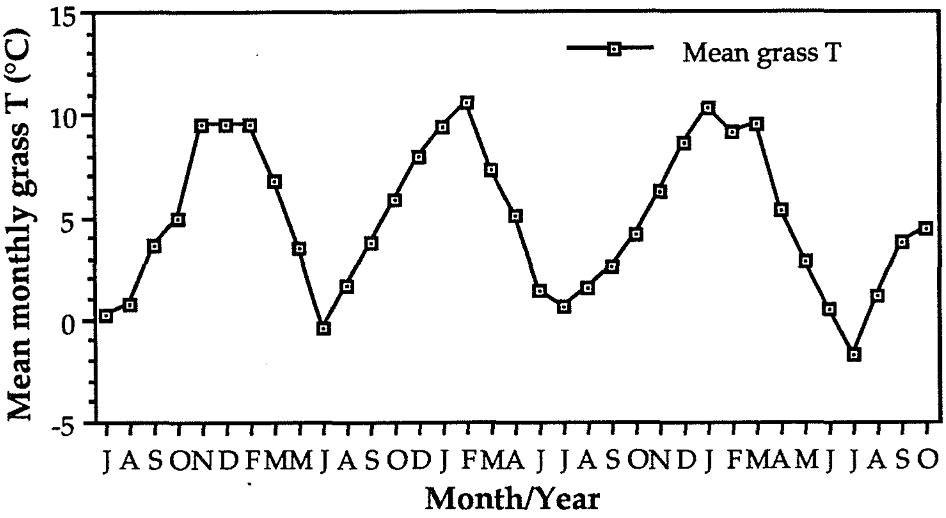


Figure 4.14 Monthly grass minimum temperatures in the 1988–1991 study period.

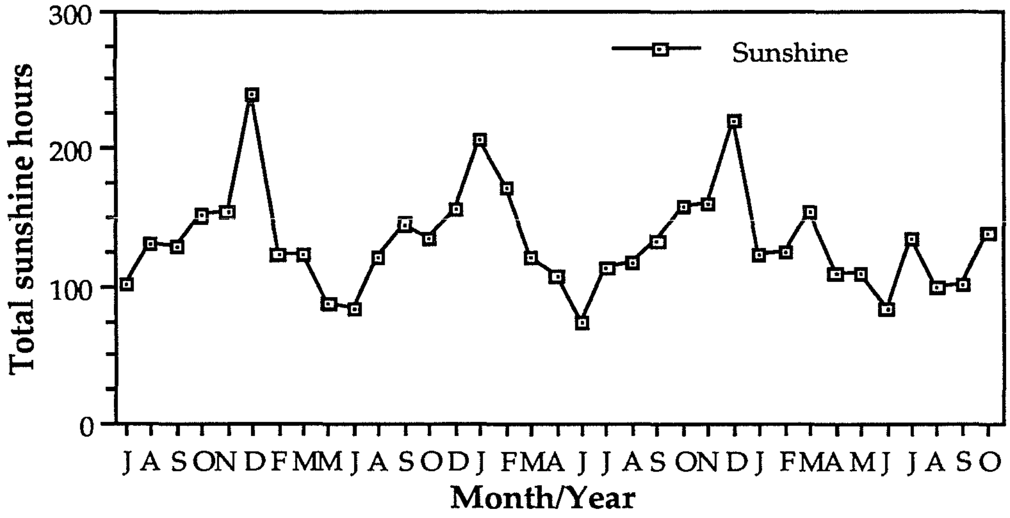


Figure 4.15 Total monthly sunshine hours in the 1988–1991 study period.

winds and fewer from the southwest — than normal (*ODT* 7/10/89:10), and October wetter (+ ca. 33% more rain), milder and less sunny than a normal October (*ODT* 7/89:27). Likewise, December rainfall was 35% above average, while mean temperatures were slightly below average (*ODT* 5/1/90:5).

Temperatures going into 1990 were above average by around 1°C bringing drier summer weather. In February this resulted in the highest mean daily grass minimum temperature of 10.6°C being recorded since 1947 (*ODT* 6/3/90:5). In April 1990 Dr. Neil Cherry, a Lincoln University meteorologist, reported (*ODT* 28/4/90:10) that the values of the southern oscillation index showed that the next El Niño event was likely to appear earlier than expected. This generally brought more westerly weather over the country, with cooler and windier conditions, and drought likely in the east and north.

If a drought can be equated with reduced rainfall, then the El Niño effects predicted by Dr. Cherry were clearly in evidence in southern New Zealand by the middle of 1990, where June was the sixth consecutive month with a greater than average mean daily temperature (*ODT* 4/7/90:2). While the western regions of the South Island were abnormally wet, the east coast had received as little as 20% of the usual rainfall. Since 1984 there had been 41 'warm' months (0.5°C or more above normal) and only seven 'cold' months (ibid).

The winter of 1990 was warmer, wetter and cloudier than usual in most areas, to the extent that this was the seventh warmest winter on record since 1853 (*ODT* 13/9/90:3). While rainfall was low in the south, it was wetter than usual over the remainder of the country. August was the month in which the two and a half year drought was broken in northern parts of Otago (*ODT* 4/9/90:3), with Oamaru receiving 285mm of rain (compared to the August average of 40mm) and Dunedin recording 137mm (average 55mm) (Figure 4.11), the wettest August on record. Following the heavy rains of August, however, September was very dry (19mm rain recorded in Dunedin) to the extent that many places in Otago recorded only 20% of their average rainfalls (*ODT* 6/10/90:15). This was primarily due to the lack of easterly winds as the westerly airstream regularly switched from the northwest to the southwest and any showery weather was quickly followed by dry warm weather.

October was very similar and although November started sunny and mild it gradually deteriorated. There were very dry conditions in Southland and the inland South Island basins, and while the temperature was above average for the country as a whole, in Dunedin it was cooler than normal (*ODT* 5/12/90:13, 2/1/91:14). Through December into January the westerlies continued and it was generally cold due to a large number of depressions to the south of the country which brought cold, showery weather to the east coast. The pattern was typical of an El Niño event but the southern oscillation index value was close to 0, so it was unlikely that this was the reason for the cool, unsettled summer (*ODT* 10/1/91:1).

February was unusually wet (the second wettest in 73 years — *ODT* 6/3/91:10) due to a slow moving rain band and a lack of anticyclonic conditions. Thus while northern parts of the country were generally drier than usual, coastal Otago received above average rainfalls (see Figure 4.11) with the heaviest being a 24 hour period on the 17th/18th when 108.6mm fell in Dunedin. March brought more settled weather to Dunedin, generally dry and sunny (*ODT* 5/4/91:5), but then April was colder, cloudier and wetter than average due to frequent spells of southwesterly winds (*ODT* 3/5/91:5). Values of the southern oscillation index had been negative since February, and forecasters were predicting a major El Niño event with cooler, drier and windier conditions than normal (*ODT* 13/5/91:12).

The cold, and relatively dry winter months (*ODT* 5/6/91:5, 3/7/91:11, 3/8/91:11) confirmed the predicted El Niño weather pattern had arrived, with the associated southwesterly winds bringing dry conditions to eastern regions of the country (*ODT* 20/8/91:10). August was somewhat wetter than average (*ODT* 4/9/91:5), despite the strengthening El Niño, but by September the rainfall had decreased again to be only slightly above average in a month which was "persistently dull and cloudy in Dunedin" (*ODT* 4/10/91:5).

The Mount Pinatubo eruptions in August had a marked effect on New Zealand's weather, with temperatures predicted to be 1°C below average in spring, and 0.5–

1°C below average in summer, with the likelihood that this would continue into the autumn of 1992 (*ODT* 30/8/91:1). This was certainly the case during November, the coldest in 50 years, when the national average temperature was 1.4°C below average (Dunedin down 1.6°C), probably due to volcanic dust in the upper atmosphere and a weak El Niño event (*ODT* 4/12/91:10). The changeable and persistent cold south-westerlies also ensured that there were long sunny spells, interspersed with showery periods, resulting in Dunedin rainfall being only 65% of normal (ibid).

What, then, does this mean in terms of the weathering experiments ? As discussed previously, two of the important variables involved in the weathering of bone (both above and below the ground surface) are moisture levels and temperature. In examining the changing patterns of Dunedin weather, therefore, this must be kept in mind. In the first two-thirds of the study, Dunedin was experiencing an unusually protracted period of warm, dry weather with mean monthly temperatures up to 1.4°C above average, and rainfall levels well below normal. The decreased rainfall levels may have produced times when the soil substrate dried out, so as to markedly slow or even inhibit continued decay of the soft tissue and bone matrix. During the latter part of the study, rainfall had increased and mean monthly temperatures had decreased, by comparison with the earlier period, and this change can be seen in Figures 4.11 and 4.12. In addition, the mean monthly minimum and maximum temperatures had decreased during the latter part of the experiment (Figure 4.13) and sunshine hours were likewise down (Figure 4.15) although this was probably due to volcanic dust in the upper atmosphere from the Mount Pinatubo eruptions, especially in the period August to October 1991. Through all these changes, however, the mean monthly grass minimum remained relatively stable on a month-by-month comparison, although during the winter months of 1990 the temperature did dip lower than during the previous winters (Figure 4.14). Thus while the decay rate would increase with increased soil moisture, this would be offset slightly by the decreasing soil temperature.

The interactions between subsurface bone weathering and climatic patterns are obviously very complex and it is probably difficult to link these weather patterns with a bone's taphonomic history. The breakdown of the periosteum and bone structure will probably continue at all times, but the rate of decay would increase as the temperature of the surrounding matrix increased, i.e. during the summer months, and when this coincided with increased moisture levels, as occurred during October to December 1989 and February 1991. I would assume that activity will tail off significantly as ground temperatures reduced to around, and below, 0°C. High rainfall periods during the winter may not necessarily increase the rate of decay due to the low ground temperatures often recorded during those months. Ortner et al. (1972:519) were able to show that "even slight differences in mean annual temperature can have a significant effect on the rate of nitrogen decay in bone", while Henderson (1987:47) states that as a general rule "the rate of chemical reactions [in the break-down of the bone structure] is nearly doubled by a 10°C rise in temperature". Examination of Figure 4.14 (above) reveals that there exists a temperature difference of that magnitude between summer and winter records in the Dunedin area. Furthermore, Henderson (ibid) relates preservation of bones to latitude, depth of burial and season, with rates of decay faster in the tropics than in the temperate latitudes, and with seasonal variations having a marked effect on rates of decay during the year.

Thus, I feel that during this experiment the bones probably underwent a cyclical weathering pattern — with the physical process of diagenesis constantly in action, but with the rate of decay increasing and decreasing in response to rainfall levels and the temperature of the surrounding matrix.

The situation would have been slightly different for the bones in weathering situation 'c' (on the roof of the Burns Building). Here, the grass temperature is immaterial and the decay of these bones was due to the effects of sun, rain and wind. The combined effects of all three helped to quickly bring the bones into a more advanced state of decay than those buried in the soil matrices. The roof is very exposed to wind from all quarters, but especially that from the south, and this would have acted to dry the bone as the wind and sun acted in conjunction with one another. The monthly variation between the minimum and maximum daytime temperature was generally in the order of 7.0°C (Table 4.2 and Figure 4.13) and this may have also played a role in the breakdown of the bone structure. On a day-to-day basis during the winter months, the temperature often dips below 0°C for quite protracted periods of hours, which is not reflected in the monthly averages given in

Table 4.2, and the effect that partial freezing has on bone structure must also be considered. The effect of freeze-thaw cycles on bone survival is discussed in detail later in this chapter.

Suffice it to say, however, that the rate of decay of these bones appears to be on a par with that recorded by Behrensmeyer (1978). The cattle bones are at the equivalent of Behrensmeyer's Stage 2 — starting to crack longitudinally, and the outer cortical bone is partially flaking. Behrensmeyer (op. cit.:157) places a time factor of 'years since death' on this stage as being from two to six years, and it is interesting that the cattle bones in the current experiment have progressed this far along the path of decay given the difference in latitudes between Amboseli at 2°S and Dunedin at 46°S. This is a very interesting result because, within the time-frame of the experiments I undertook, it provides some confidence that Behrensmeyer's results could be applied universally and that bones in the first few years of weathering appear to act in a similar manner in equatorial and temperate environments. Due to the relatively short time-span of my experiment it is difficult to predict the results over a longer period, for example 10 years.

The weather patterns recorded for the Amboseli Basin differ markedly from those of Dunedin. The basin, on the northwest side of Mt. Kilimanjaro, Kenya (Figure 4.16), is a semi-arid savannah environment with scattered *Acacia* and *Commiphora* woodland and brushland (Western 1975), formed around a Pleistocene age lake which dried out in the Recent epoch (Western and Van Praet 1973). Rainfall in the basin averages 350–400mm per annum, and while the lakebed is dry for most of the year, periods of heavy rain do bring occasional inundations (Behrensmeyer 1978:150). The vegetation mosaic which has developed supports a diverse range of fauna which concentrate during the dry season when water flows from Mt. Kilimanjaro (Western and Van Praet 1973). The soils of the basin are generally alkaline in nature (Behrensmeyer 1978:150).

While the weather patterns recorded at Amboseli are relatively specific due to the nature of the basin, they do follow the general patterns of the East African Equatorial Zone (Griffiths 1972, Nieuwolt 1977, Rudloff 1981). There is little variation in the mean monthly temperature through the year, with the warmest

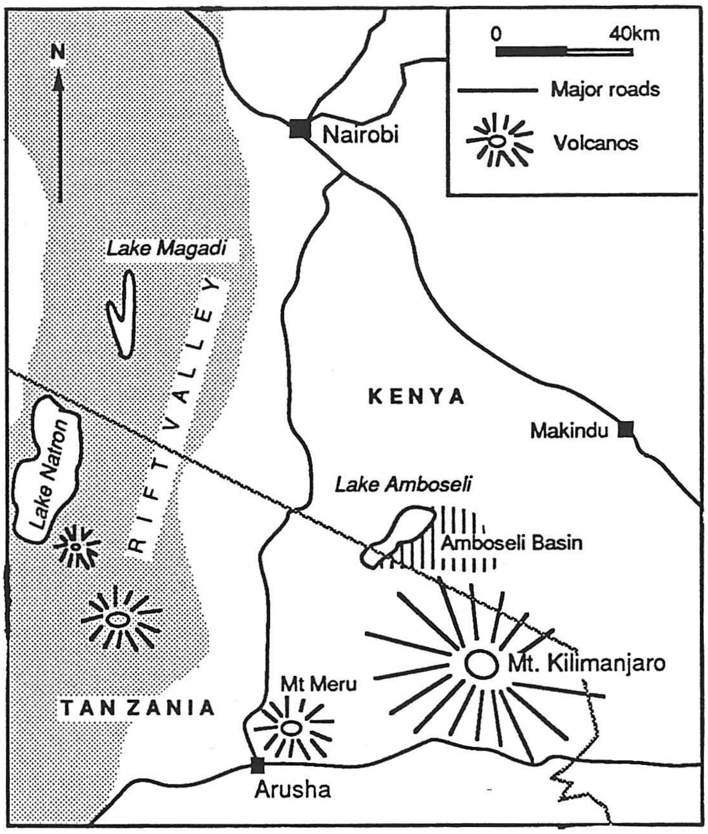


Figure 4.16 Map of southern Kenya showing the general location of the Amboseli Basin, and Makindu (from Behrensmeyer 1978).

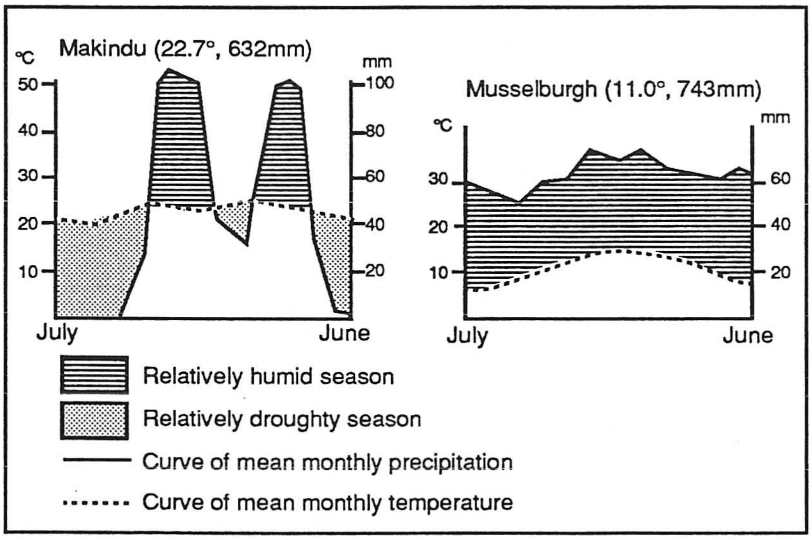


Figure 4.17 Comparison of the Makindu and Musselburgh climate charts (from Walter et al. 1975).

Table 4.3 Temperature and rainfall readings from Makindu climate station, Kenya (from Rudloff 1981:375).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
tx	32	34	34	33	31	30	29	30	31	32	31	30	34°C
t	23	24	25	24	23	21	20	21	22	23	23	23	23°C
tn	14	15	16	16	14	12	11	11	11	13	15	15	10°C
p	40	28	78	112	31	2	0	0	1	29	168	120	609mm
dp	3	2	5	8	4	1	0	1	1	3	10	11	49 days

Notes: tx = mean monthly temperature maxima
t = mean monthly temperature
tn = mean monthly temperature minima
p = amount of precipitation in mm
dp = number of days with at least 0.2mm precipitation

period mainly in March and the coldest months being July–August (Griffiths 1972:319). There are two periods of greatest rainfall, March–April and November–December, which are due to the movement of the convergence zone across the equator (Griffiths 1972:325, Nieuwolt 1977:158). The closest weather station to Amboseli is located at Makindu, approximately 100km to the northeast, and rainfall and temperature figures are presented above (Table 4.3), along with climate diagrams for both Makindu and Musselburgh, Dunedin, for a comparison of the two climatic regimes (Figure 4.17).

Soil analysis.

The results of the soil analysis for the experimental weathering are presented in Table 4.4, with a summary presented in Table 4.5 and Figures 4.18 to 4.21. In the figures, the before and after levels of the various soil variables are presented, and it

Table 4.4 Soil chemistry results for the experimental weathering.

Sample No.	Provenance	Date	pH	M.C. (%)	O.C. (%)	Base Cations (me%) K^+	Mg^+	Na^+	Ca^{2+}(1)	Ca^{2+}(2)	Ca^{2+}(3)
1	68 Nairn St, initial 1	8/8/88	6.97	.	.	0.37	0.41	1.36	21.96	.	21.96
2	68 Nairn St, initial 2	"	7.04	.	0.36	0.38	0.46	1.00	22.86	.	22.86
3	68 Nairn St, initial 3	"	7.07	.	.	0.35	0.25	0.59	14.81	.	14.81
4	68 Nairn St, initial 4	"	7.06	.	0.30	0.34	0.47	0.85	.	2.11	23.21
5	68 Nairn St, initial 5	"	7.01	.	0.36	0.26	0.44	0.58	.	2.19	24.09
6	68 Nairn St, initial 6	"	6.93	.	.	0.35	0.42	0.61	24.17	.	24.17
7	68 Nairn St, initial 7	"	7.10	.	.	0.27	0.48	0.94	.	1.94	21.34
8	68 Nairn St, initial 8	"	6.94	.	0.35	0.24	0.46	0.56	.	1.74	19.14
9	68 Nairn St, initial 9	"	7.02	.	0.29	0.24	0.39	0.45		1.60	17.60
10	68 Nairn St, initial 10	"	6.80	.	.	0.30	0.41	0.58	21.68	.	21.68
11	Warrington Beach, initial 1	"	5.24	.	.	0.05	0.19	0.46	0.35	.	0.35
12	Warrington Beach, initial 2	"	5.30	.	.	0.06	0.14	0.53	0.26	.	0.26
13	Warrington Beach, initial 3	"	5.30	.	.	0.02	0.17	0.34	0.45	.	0.45
14	Warrington Beach, initial 4	"	5.28	.	.	0.05	0.18	0.48	0.28	.	0.28
15	Warrington Beach, initial 5	"	5.43	.	.	0.05	0.18	0.70	0.39	.	0.39
16	Warrington Beach, initial 6	"	5.43	.	0.04	0.04	0.15	0.34	0.29	.	0.29

Table 4.4 (ctd.)

17	Warrington Beach, initial 7	"	5.33	.	.	0.01	0.15	0.27	0.23	.	0.23
18	Warrington Beach, initial 8	"	5.34	.	.	0.01	0.12	0.33	0.26	.	0.26
19	Warrington Beach, initial 9	"	5.24	.	.	0.02	0.14	0.25	0.24	.	0.24
20	Warrington Beach, initial 10	"	5.12	.	.	0.01	0.16	0.27	0.25	.	0.25
21	68 Nairn St, above bones 1	30/8/91	6.79	2.15	.	0.39	0.78	0.56	.	2.52	27.72
22	68 Nairn St, above bones 2	"	6.86	2.31	0.52	0.45	0.88	0.50	.	3.46	38.06
23	68 Nairn St, above bones 3	"	6.81	2.06	0.49	0.31	0.63	0.67	.	1.66	18.26
24	68 Nairn St, above bones 4	"	6.81	2.09	0.53	0.34	0.66	0.49	.	1.62	17.82
25	68 Nairn St, below bones 1	30/8/91	6.82	2.23	0.47	0.53	0.72	0.41	.	1.59	17.49
26	68 Nairn St, below bones 2	"	6.81	2.12	0.49	0.50	0.77	0.42	.	1.71	18.81
27	68 Nairn St, below bones 3	"	6.52	1.88	0.41	0.27	0.65	0.57	.	1.72	18.92
27	68 Nairn St, below bones 4	"	6.57	2.13	0.45	0.37	0.66	0.35	25.64	.	25.64
37	Warrington, above bones 1	29/8/91	4.85	0.12	0.16	0.07	0.28	0.24	0.91	.	0.91
38	Warrington, above bones 2	"	4.85	0.13	0.18	0.08	0.26	0.24	0.64	.	0.64
39	Warrington, above bones 3	"	4.91	0.24	0.27	0.08	0.35	0.30	0.83	.	0.83
40	Warrington, above bones 4	"	4.37	0.18	0.19	0.06	0.21	0.20	0.61	.	0.61
41	Warrington, below bones 1	29/8/91	4.59	0.19	0.21	0.01	0.15	0.20	0.41	.	0.41
42	Warrington, below bones 2	"	4.66	0.11	0.17	0.02	0.14	0.14	0.28	.	0.28
43	Warrington, below bones 3	"	4.53	0.17	0.24	0.02	0.13	0.09	0.26	.	0.26
44	Warrington, below bones 4	"	4.39	0.16	0.16	0.05	0.15	0.14	0.40	.	0.40
61	Accel sand, top 1/3, No. 1	20/9/91	5.23	0.14	0.08	0.23	0.28	1.07	1.07	.	1.07

Table 4.4 (ctd.)

62	Accel sand, top 1/3, No. 2	"	5.09	0.08	0.18	0.25	0.37	1.20	1.36	.	1.36
63	Accel sand, btm 1/3, No. 1	20/9/91	5.43	0.27	0.08	0.09	0.16	0.38	1.08	.	1.08
64	Accel sand, btm 1/3, No. 2	"	5.12	0.19	0.04	0.12	0.15	0.59	1.09	.	1.09
85	Accel soil, top 1/3, No. 1	20/9/91	6.03	0.24	0.49	0.90	1.63	1.86	.	2.49	27.39
86	Accel soil, top 1/3, No. 2	"	5.94	0.21	0.60	0.91	1.62	1.93	.	2.37	26.07
87	Accel soil, top 1/3, No. 3	"	6.08	0.22	1.17	0.89	1.59	1.94	.	2.26	24.86
88	Accel soil, btm 1/3, No. 1	20/9/91	6.01	0.39	1.53	0.84	1.52	1.42	.	1.96	21.56
89	Accel soil, btm 1/3, No. 2	"	5.96	0.45	1.95	0.89	1.65	1.40	.	2.36	25.96
90	Accel soil, btm 1/3, No. 3	"	5.98	0.44	2.46	0.80	1.62	1.34	.	2.35	25.85

Notes: M.C. = moisture content
O.C. = organic content
$Ca^{2+}(1)$ = initial result of calcium run
$Ca^{2+}(2)$ = results for diluted calcium samples
$Ca^{2+}(3)$ = recalibrated calcium results (see text for full explanation of these)

Table 4.5 Summary of soil chemistry results (means) for the experimental weathering. Notes as for Table 4.4, with (n, std dev) given for each value.

Provenance	pH	M.C.	O.C.		Base Cations (me%)		
		(%)	(%)	K^+	Mg^+	Na^+	Ca^{2+}(3)
68 Nairn St - before experiment	6.99 (10, 0.09)	.	0.33 (5, 0.03)	0.31 (10, 0.05)	0.42 (10, 0.07)	0.75 (10, 0.28)	21.09 (10, 3.03)
68 Nairn St - conclusion of experiment							
above bones	6.82 (4, 0.03)	2.15 (4, 0.11)	0.51 (3, 0.02)	0.37 (4, 0.06)	0.74 (4, 0.12)	0.56 (4, 0.08)	25.47 (4, 9.56)
below bones	6.68 (4, 0.16)	2.09 (4, 0.15)	0.46 (4, 0.03)	0.42 (4, 0.12)	0.70 (4, 0.06)	0.44 (4, 0.09)	20.22 (4, 3.67)
Warrington - before experiment	5.30 (10, 0.09)	.	0.04 (1, -)	0.03 (10, 0.02)	0.16 (10, 0.02)	0.40 (10, 0.14)	0.30 (10, 0.07)
Warrington - conclusion of experiment							
above bones	4.75 (4, 0.25)	0.17 (4, 0.06)	0.20 (4, 0.05)	0.07 (4, 0.01)	0.28 (4, 0.06)	0.25 (4, 0.04)	0.75 (4, 0.15)
below bones	4.54 (4, 0.11)	0.16 (4, 0.03)	0.20 (4, 0.04)	0.03 (4, 0.02)	0.14 (4, 0.01)	0.14 (4, 0.05)	0.34 (4, 0.08)

Table 4.5 (ctd.)

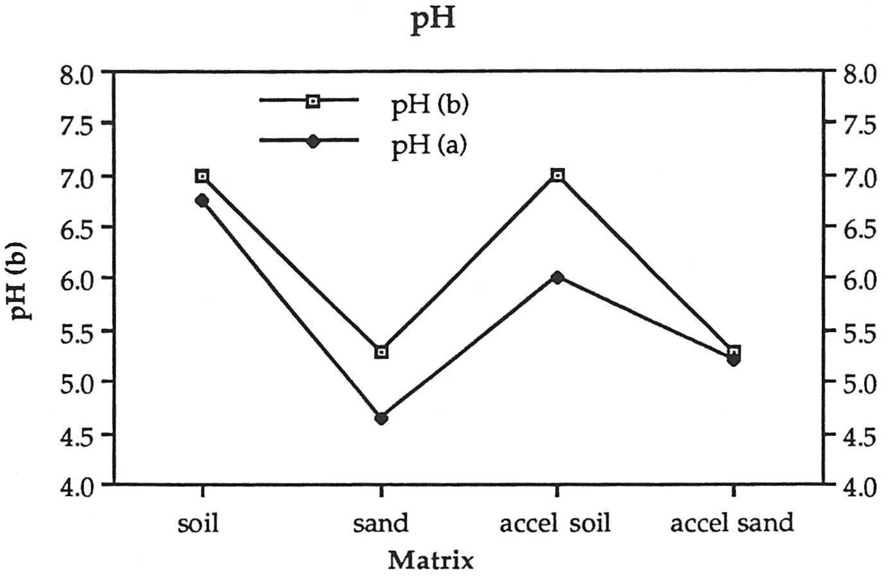
Provenance	pH	M.C.	O.C.	Base Cations (me%)			
		(%)	(%)	K^+	Mg^+	Na^+	Ca^{2+}(3)
Accelerated soil - conclusion							
top 1/3	6.02	0.22	0.75	0.90	1.61	1.91	26.11
	(3, 0.07)	(3, 0.02)	(3, 0.37)	(3, 0.01)	(3, 0.02)	(3, 0.04)	(3, 1.27)
bottom 1/3	5.98	0.43	1.98	0.84	1.60	1.39	24.46
	(3, 0.03)	(3, 0.03)	(3, 0.47)	(3, 0.05)	(3, 0.07)	(3, 0.04)	(3, 2.51)
Accelerated sand - conclusion							
top 1/3	5.16	0.11	0.13	0.24	0.33	1.14	1.22
	(2, 0.10)	(2, 0.04)	(2, 0.07)	(2, 0.01)	(2, 0.06)	(2, 0.09)	(2, 0.21)
bottom 1/3	5.28	0.23	0.06	0.11	0.16	0.49	1.09
	(2, 0.22)	(2, 0.06)	(2, 0.03)	(2, 0.02)	(2, 0.01)	(2, 0.15)	(2, 0.01)

is presumed that for the 'accelerated' sand and soil matrices the pre-experiment levels of the variables are the same as the sand and soil matrices from which they were derived. The pH levels of the soil matrices are interesting, as it was presumed that the sand would be more likely to be neutral, or even alkaline, and the soil matrix acidic. In this case the soil pH is near neutral and the pH of the sand dune is moderately acidic (NZ Soil Bureau 1968:76). The variation away from this could be the result of the soil matrix coming from a vegetable garden, which has probably seen quite a bit of fertilizer applied to the garden over the years which would raise the pH, and the sand dunes having had pine trees growing on them up to, and including, the time that the experiments were conducted. It is well known that to increase the acidity of a garden, for rhododendrons especially, then a liberal spreading of pine needles does the trick.

The moisture content levels were not measured at the beginning of the experiment and only a few of the organic content levels were recorded. The base cation levels are given in me% which is the level of exchangeable potassium, magnesium, sodium and calcium in milliequivalents/100g soil.

The results for the Ca^{2+} are presented in three separate columns — when the AAS was first run 50% of the samples had Ca^{2+} levels which were too high to be accurately measured (column Ca^{2+}(1)). These samples were then diluted 11x, the AAS rerun to give the values in the next column (Ca^{2+}(2)) and recalibrated out to give the overall values in the final column (Ca^{2+}(3)). The very high levels recorded for the Nairn St soil — 24 of the 35 samples with high Ca^{2+} levels — are possibly the result, primarily, of fertilizer application, especially those which contain 'lime' ($CaCO_3$), although this soil type does have quite high base levels of carbonates (see below).

The New Zealand Soil Bureau (1968) provides the base data for the description of the soils in which these two 'burial' sites are located (Figure 4.22). The Warrington site is located within a band of subhygrous to hygrous yellow-brown sands which are characterised by being low in organic matter and have low levels of bases except where shell fragments provide a supply of calcium (op. cit.: 55). The pH ranges from



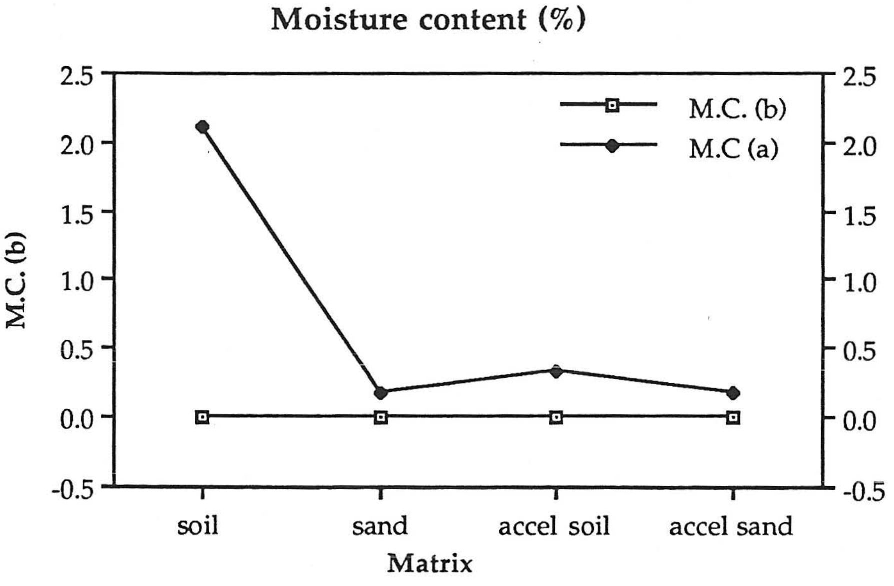
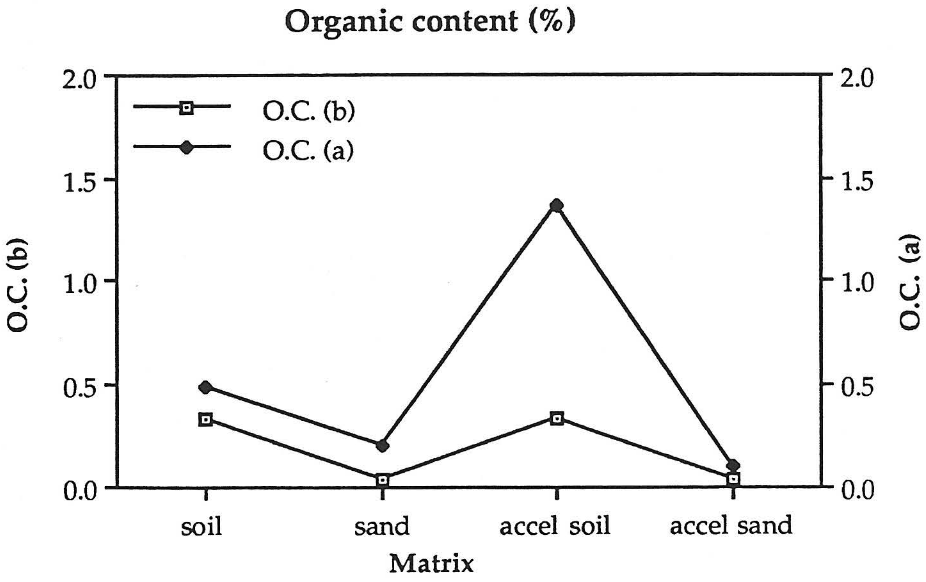


Figure 4.18 Summary graphs of pH (top) and moisture content (bottom) levels in the soil matrices, before '(b)' and after '(a)' the experiments.



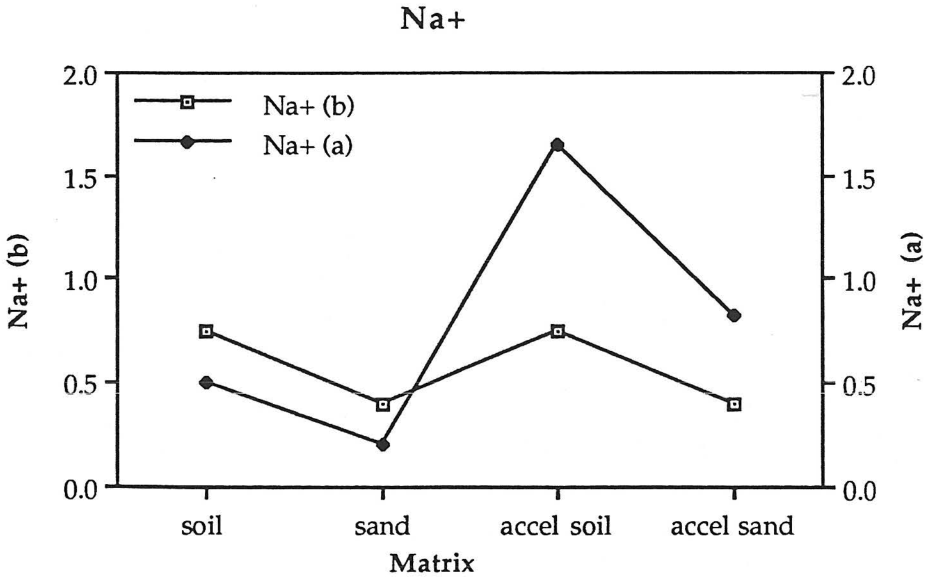
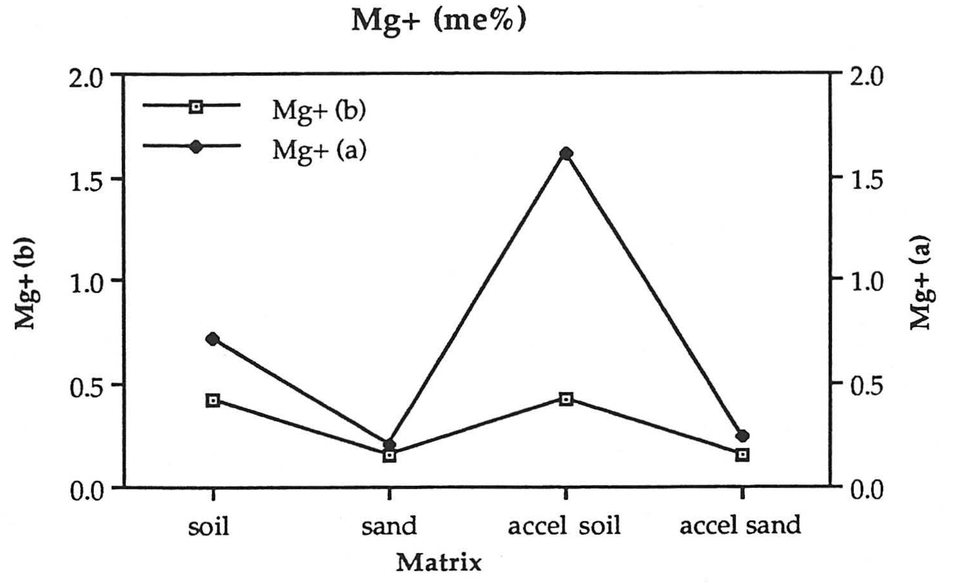


Figure 4.19 Summary graphs of organic content (top) and potassium [K^+] (bottom) levels in the soil matrices, before '(b)' and after '(a)' the experiments.



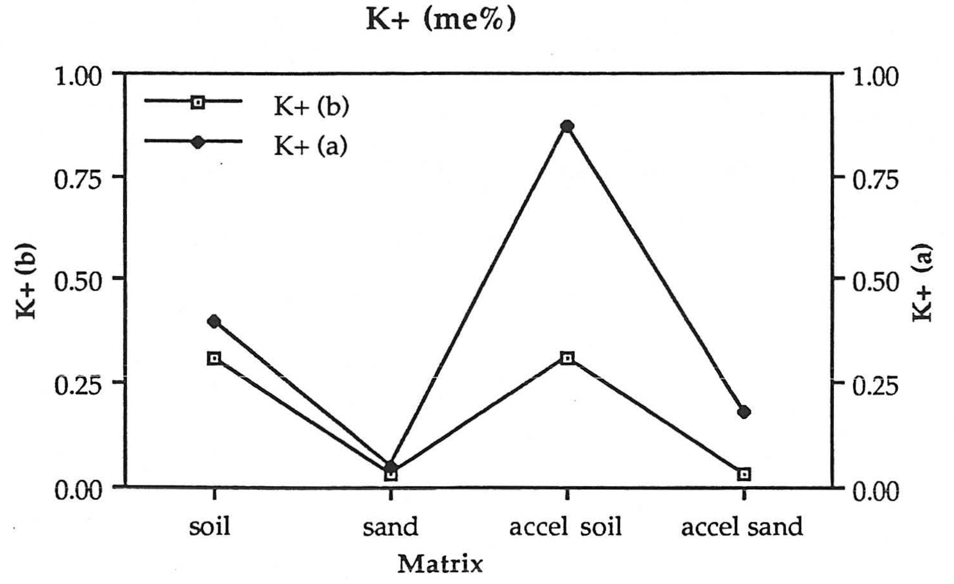


Figure 4.20 Summary graphs of magnesium [Mg^+] (top) and sodium [Na^+] (bottom) levels in the soil matrices, before '(b)' and after '(a)' the experiments.

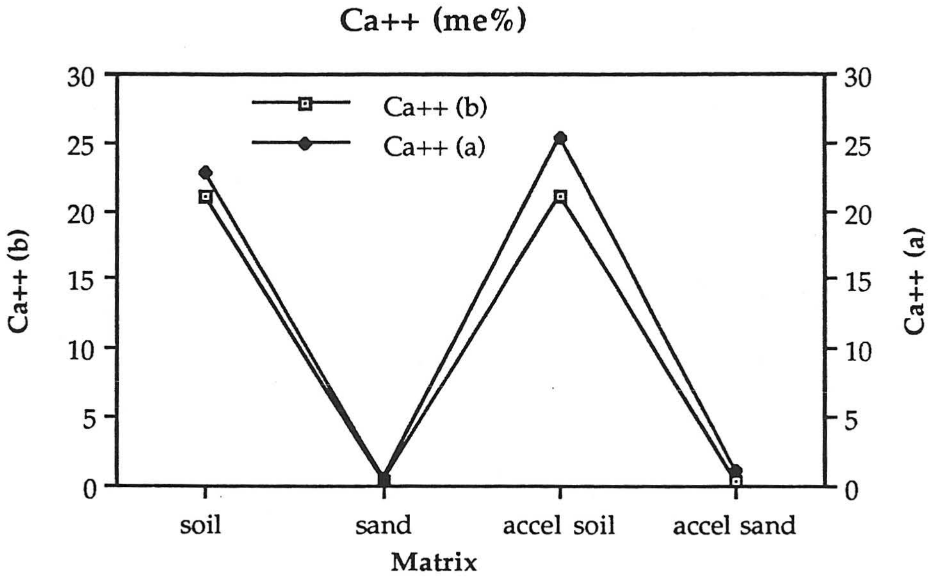


Figure 4.21 Summary graph of calcium [Ca^{++}] levels in the soil matrices, before '(b)' and after '(a)' the experiments.

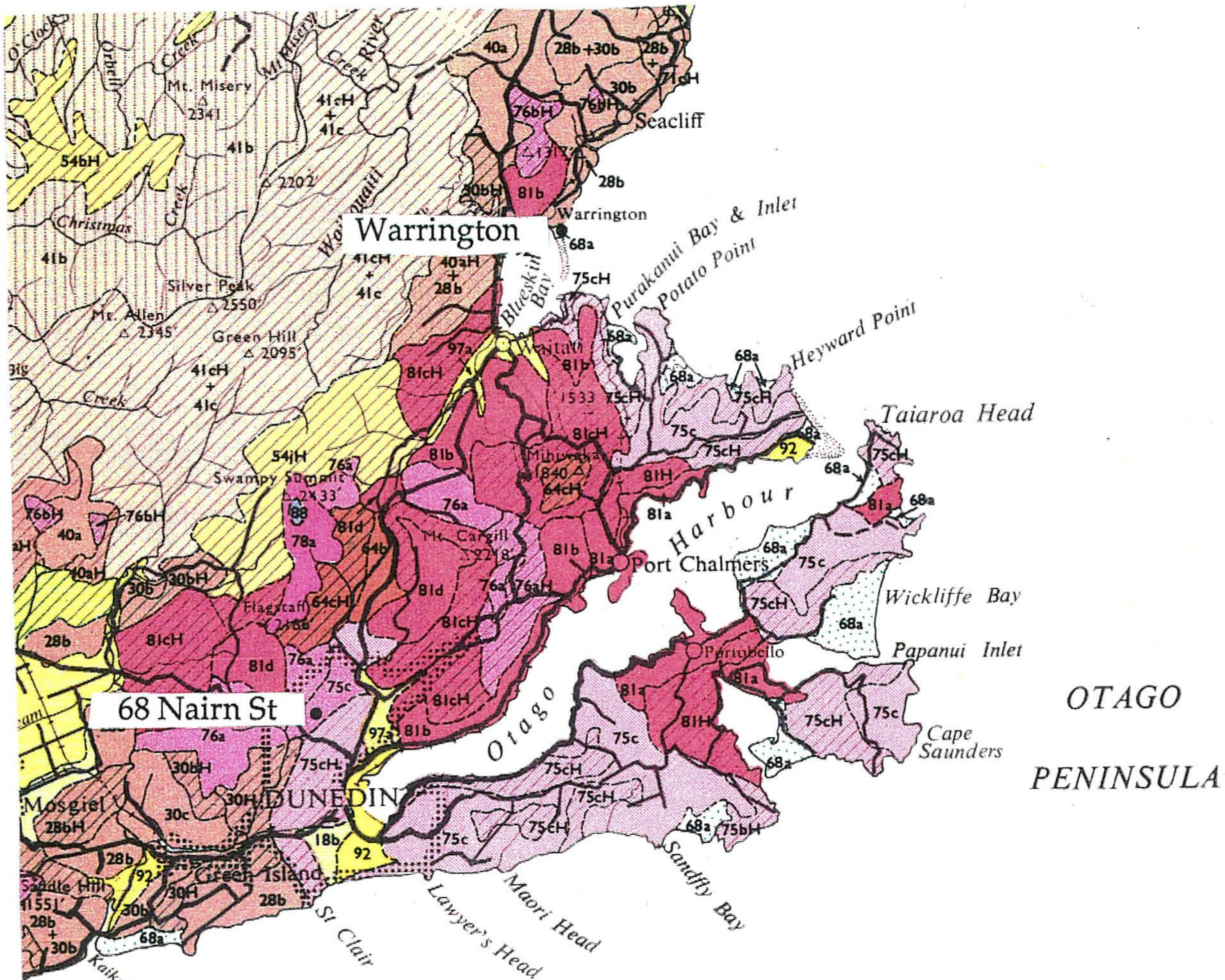


Figure 4.22 Soil map of the Dunedin area showing the approximate locations of the Warrington and Nairn St experimental sites.

4.8 at 0–1.5in. depth to 5.6 at 14–19in. and 5.9 at 21–25in. depth (op. cit.:141). The Nairn St site is within a zone of subhygrous to dry-hygrous brown granular loams and clays, on clays, often with a band of secondary carbonate horizons under the subsoil, and in drier climates are weakly leached with a pH of 7.0 (op. cit.:60). The pH ranges from 6.9 at 6–14in. depth to 6.6 at 22–30in., mean Ca level is 19.82 me%, mean Mg level 6.48 me%, mean K level 0.7 me%, and mean Na level is 0.35 me% (op. cit.:145).

By the conclusion of the experiment some very interesting patterns had emerged in the soil results. For the soil in the Nairn St site; the pH decreased slightly, the organic content, K and Mg levels all increased, the Na level decreased, and there was a split in the Ca results, with the samples taken from immediately above the bones showing an increase, and those immediately below the bones showed a slight decrease.

The Warrington results saw the pH decrease (to become strongly acidic), the organic content, Mg (slightly) and Ca all increase, while the Na level decreased. This activity is possibly due to diagenetic changes within the bone structure, as discussed in Chapter 2, with the divalent Ca being leached from the bone and replaced within the OHA structure by the divalent Mg, and even the monovalent K and Na.

In the two accelerated soil matrices, the change in all results was even more marked. In the case of the soil, there was a decrease in the pH, and large increases in all other measured variables. In the accelerated sand matrix, the pH was lowered and there were increases (albeit not as marked as for the accelerated soil matrix) for all the remaining variables. These results would tend to suggest that perhaps the diagenesis of the bones was increased as a result of their having been placed in an environment where both the temperature and moisture levels were artificially raised above those which would be expected naturally. The chemical results are interesting because the outwardly visible appearance of the bones tended to suggest that the weathering process had been slowed by the burial in these 'accelerated' soil situations (see descriptions of the bones earlier in this chapter). The reasons for this difference are not immediately clear, but may be due to a lack of soil microbes and other organisms in the 'accelerated' matrices to completely breakdown the soft tissue surrounding the bone itself.

FREEZE-THAW EXPERIMENTS

As discussed in Chapter 2, it is envisaged that the extreme ranges of temperature (up to 40°C) experienced between seasons and on a day-to-day basis in some areas of the South Island, especially the Mackenzie Basin and Central Otago and the mountains surrounding them, will be particularly severe on bone survival, through the action of freeze-thaw cycles. A relatively straight-forward experiment was conducted, following the methodology of Miller (1975) to determine the sequence of events through which bones pass as they weather in this manner.

The cattle bones had been obtained fresh from the butcher, having first had all excess soft tissue removed, and were stored in the freezer until required. For the purpose of this experiment two situations were set up — one set of bones was cleaned entirely of all soft tissue by bringing them to the boil in a large pot of water and allowing to simmer for 6–7 hours, while a second set was left in the state in which they had been received from the butcher with tendons, cartilage and fat still present. Both 'sets' of bones comprised a femur, a tibia (which in the case of the set with the soft tissue present had the tarsal still articulated), several vertebrae and ribs.

The experiment was conducted for two months with the bones alternating between three days in the freezer (mean temperature -14.8°C) and three days in the 'Bugroom' in the Anthropology Department (maintained at a temperature of approximately 28°C). They were inspected every 24 hours for evidence of any change.

After the first three days in the 'Bugroom' surficial cracks were starting to appear in the bones. After a further three days, in the freezer, several large longitudinal cracks had appeared along the shaft of the femora and the tibiae. These cracks went through the compact bone to the marrow cavity. Several large cracks likewise had appeared on the surface of the ribs and vertebrae, and were exposing the underlying cancellous bone. Figure 4.23 illustrates the weathering stage that the bones were in before ('(b)') and after ('(a)') the experiment — with set '(1)' being those which retained their periosteum, and set '(2)' being the cleaned set.

During the remainder of the course of this experiment very little further change was

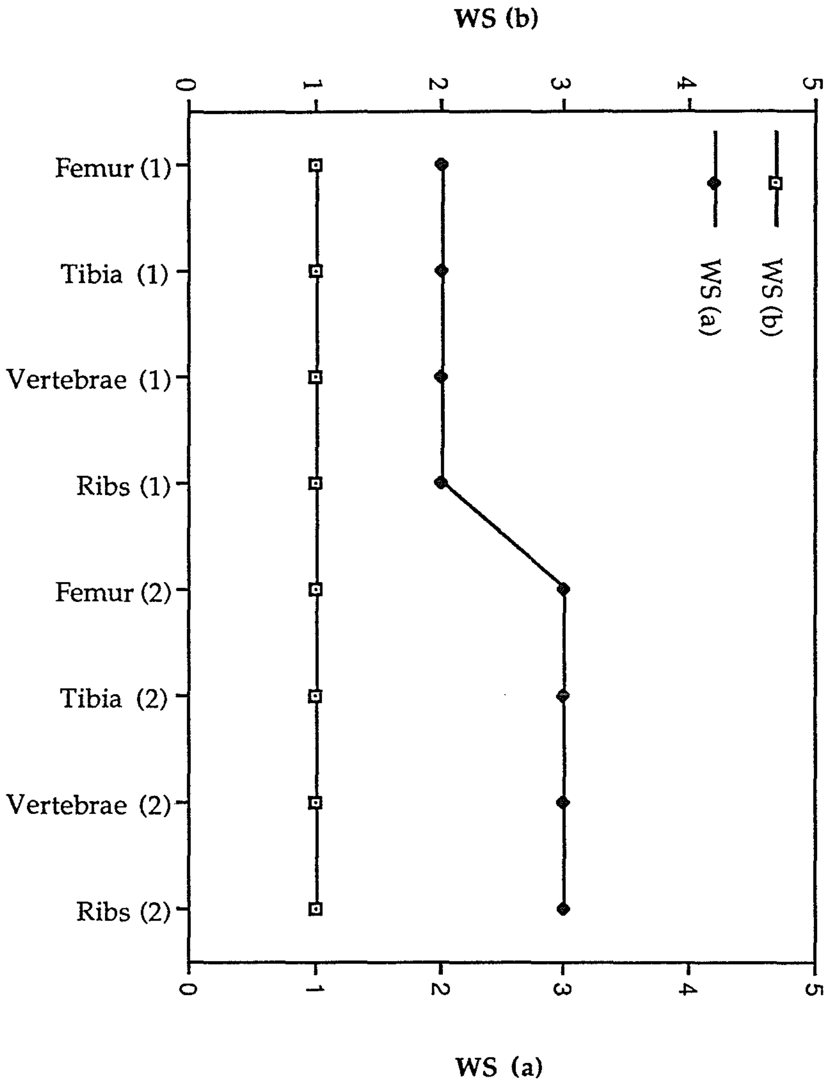


Figure 4.23 Summary graph of weathering stages of the cattle bones, before '(b)' and after '(a)' the freeze-thaw experiments.

recorded. The set of bones which still retained their soft tissue were probably 'protected', to a certain degree, by the presence of this tissue which inhibited any large scale breakdown. The main change noted was the continuing loss of fat from the two long-bones, due to the breakdown of the marrow within the shaft. The bones which had had their soft tissue removed prior to the experiment also appeared to reach a state of equilibrium. In addition to two or three large cracks through into the marrow cavity they had numerous surface cracks covering the remainder of the bones, generally less than 1mm deep and, in places, exposing the cancellous bone below.

In a natural setting the most likely scenario for freeze-thaw weathering would be for the bones to go through the short cycle described above, which appears to occur quite rapidly and involves the initial cracking of the bone's outer structure, after which the effects of wind, rain, and sun would take over. By breaking down some of the exterior cover it allows a greater area of cancellous and inner cortical bone to be affected by climatic variables. This would lead, in turn, to rapid disintegration (in geological terms) of the bones over, possibly, a six or seven year period.

An example of bones which had passed through this weathering sequence was recovered in January 1990 while I was conducting an archaeological site survey of the Ahuriri River valley at the southern end of the Mackenzie Basin. The skeleton of a cattle beast was discovered on the river terrace which the land-owner confirmed was a sick beast he had shot some five years previously (Mike Thomas, Killermont Station, pers.comm.). The bones had become scattered over an area of approximately $15m^2$, with those exposed on the surface being bleached white and in advanced stages of weathering (see Figure 4.24). These bones have many longitudinal cracks, some through to the marrow cavity, and have the outer layers of cortex flaking away. Small patches of lichen are also present. Those elements which are comprised primarily of cancellous bone (ribs and vertebrae) exhibit a distinctive weathering pattern. The weathering is most advanced on the epiphyses and the ventral ends of the ribs with large areas of cancellous bone exposed. The parts in between exhibit large numbers of fine cracks which, in places, have allowed surface bone to flake off. The two femora have both broken in half midway along the diaphysis, with large

Figure 4.24 Remains of cattle bones, Killermont Station, showing their bleached appearance and distribution.

spiral cracks exposing the cancellous bone of the proximal and distal ends. The outer surfaces of the epiphyses are very cracked and flakey with the underlying cancellous bone exposed. Those bones, and parts of bones, still buried in the river silt were relatively unweathered, to the extent that some bones showed marked differences between exposed and buried surfaces (Figure 4.25).

Figure 4.25 A cattle tibia from Killermont Station, showing the difference between exposed (top) and buried (bottom) surfaces of the bone.

The skeletal remains were beside a fence on the edge of the river terrace, approximately 20m from a main highway (SH8), and were unlikely to have been damaged by stock. The most plausible explanation for the damage evident in the skeletal remains is that of weathering and probably, in particular, primarily that of freeze-thaw cycles. If this much damage can be sustained in only approximately five years, what hope is there for moa bones deposited on the ground surface, in this area, 500 years ago ? I would suggest very little, and this is probably why so few moa remains have been found in this part of the South Island, despite the common occurrence of silcrete and porcellanite flake and blade tools which, elsewhere, are a reliable indicator of moahunting sites. Trotter (1969) recorded patches of flakes and other stone debris on terraces along the shores of Lake Pukaki and the upper Waitaki River, but no evidence of any bone was found.

DISCUSSION

These experiments have shown that subsurface weathering is initiated almost immediately the bones are deposited. The time lag between deposition and initiation of the weathering cycle will be dependent upon the amount of soft tissue present. If it is assumed that archaeological remains are similar to the experimental sample, i.e. all the usable soft tissue has been removed (meat, tendons etc), then subsurface weathering will proceed almost immediately.

On the basis of changes observed during the period of this experiment, it is possible to suggest the course that the bone weathering undergoes. The first stage is the breakdown of any remaining soft tissue by micro-organisms in the soil. This leads to disarticulation of the elements and opens the bone surface up to further attack by the micro-organisms and to chemical change from the matrix in which it is buried. The second stage is the physical breakdown of the bone itself — as the outer structure cracks it exposes both the inner surface of the cortical bone, and the cancellous bone of the epiphyses, ribs, vertebrae etc., to further microbial and chemical attack. The chemical composition of the bone itself undergoes change as ions leach along a gradient both into, and out of, the bone from the immediately surrounding soil matrix.

The rate of decay of the bones is governed by three principal factors — moisture levels, temperature, and the pH of the soil matrix. Weathering/diagenesis is likely to be slowest in a matrix which has a relatively neutral pH, is free-draining (and therefore has a low moisture content) and is at a low temperature. The rate of decay is greatest when the converse of these three variables is realised. If long term weather patterns were observed in close conjunction with weathering patterns (at a microscopic level) it is anticipated that the rate of decay would increase and decrease to match the coincidence of higher temperature levels and high moisture content of the soil.

How does all this relate to archaeological samples ? Suffice it to say that sites in which bones were deposited and subsequently covered by sediment in a relatively short period of time (e.g. in sand dunes which experience constant shifting of the sediment or river soils which experience regular inundation), and where the pH is basic or nearly neutral, conditions should be conducive to longterm survival of the bone. If, on the other hand, it is an acidic sediment with a low pH, or one where there is excess soil moisture and a high temperature, then the period of survival would be significantly shortened. Thus we could probably safely assume that sites in which bone was found to survive in relatively good condition, which may date back several hundred years, must have contained optimal conditions for bone survival.

Bones which lie exposed on the ground surface will undergo a faster rate of weathering. Behrensmeyer (1978) demonstrated this for material in East Africa. My experiment showed that within three years from time of deposition the soft tissue was drying and peeling back, and the exposed bone had cracked. This would, in turn, allow the weather through into the internal structure of the bone and would hasten the decay rate. This rate of weathering is similar to that recorded by Behrensmeyer (op. cit.) and suggests a certain degree of universality in the initial stages of bone weathering, at least within the time-frame in which my experiments were run. In areas which experience considerable variation in temperature on a day-to-day and seasonal basis, cracking of the bone surface occurs relatively rapidly, within three to four days, to allow weather to penetrate to the interior of the bone.

While we can predict the process of subsurface weathering it is less easy to quantify it, especially as a percentage change over time. Theoretically the long bones, containing the greatest proportion of strong cortical bone, will weather more slowly and have a better chance of surviving over time than elements which are largely composed of cancellous bone (ribs, vertebrae, pelvis etc). How long they survive is very much dependent on the soil matrix in which they are buried. I was able to observe changes in the external character of the bones, albeit very small, after only three years. Given that archaeologically recovered moa bones have survived many hundreds of years of burial, there must come a time when they reach an equilibrium with their surrounding matrix and the weathering process is halted, or significantly slowed.

If one were to measure the physical characteristics of the soil matrix from which bones have been recovered, and the age of the deposit was known, then one might be able to estimate the rate of change of bone tissue over time. One could also estimate the extent to which the recovered material is representative of the material that which was originally deposited, given that elements of cancellous bone are less likely to stand the rigours of time. A major problem arises, however, when one considers that most of the remains recovered in sites probably came not from whole moa or seals which had been butchered and had their skeletons discarded at the site, but from animals which had been butchered away from the site and select pieces returned for consumption and/or further processing.

To investigate the survival of bones in the archaeological setting, this thesis now develops along two lines. Firstly, it examines the moa remains from a site excavated in the summer of 1988 to look at survival rates and differential element weathering of bones recovered archaeologically. Secondly, the results of this analysis, and the experimental conclusions, are applied to a study of archaeological collections from large big-game hunting sites from around New Zealand, to examine inter-site and inter-district differences in bone weathering and how this might be a factor of local soil morphology and climatic variation.

Chapter 5.

Application to an Archaeological Case – the Shag Mouth Site.

The results of the weathering experiments described in Chapter 4 indicate that it is possible to predict, to a certain degree, what will happen to bones buried in an archaeological site provided one has data available for the soil conditions (pH, moisture levels etc.) and the local geographical and climatic regimes. This chapter investigates a real archaeological case, examines the bones recovered during the excavation, and establishes a means for describing the degree of weathering evident on archaeological bone samples via an ordinate scale. The site chosen on which to test the theoretical model of weathering in New Zealand is the Shag Mouth site. After more than a century of intermittent investigations a large areal excavation was conducted in late 1988 which yielded a vast amount of faunal and artefactual material. The moa bone component was selected as a test case to examine weathering from an archaeological perspective, and as a basis for the comparative study of faunal collections from big-game hunting sites throughout New Zealand.

SHAG RIVER MOUTH — THE EXCAVATION AND THE FAUNAL REMAINS

The location of the site

The site is located on the southern side of the Shag River in North Otago (Figure 5.1) where it is situated over most of the sand spit and also encroaches out onto a swampy flat adjacent to the shallow estuary. The prehistoric inhabitants had immediate access to resources of the sea, river and estuary, from both rocky and sandy seashores, and from the forest which probably once covered the now barren hill surrounds, a legacy of both Maori and European land clearance. This exploitation of a wide range of resources has been revealed through excavations

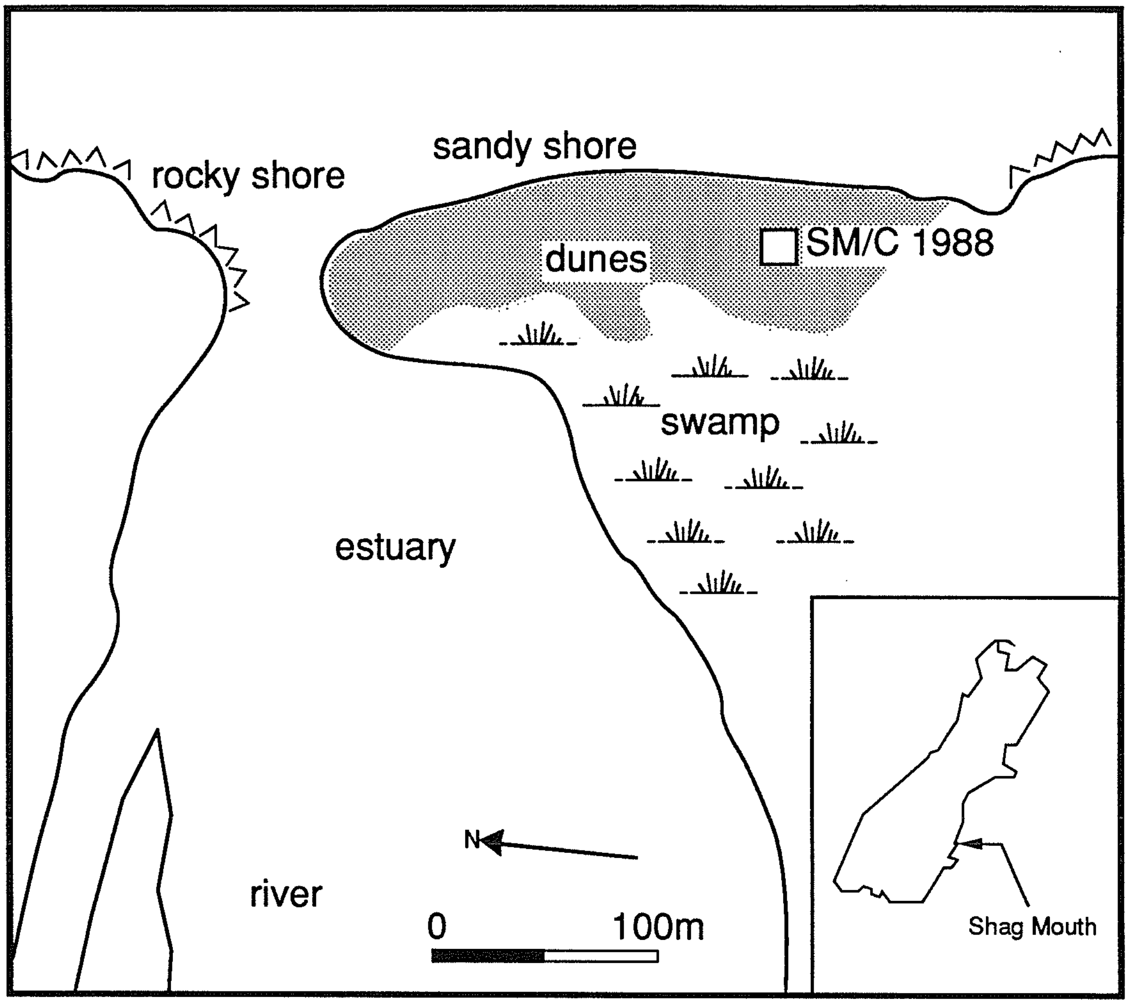


Figure 5.1 The Shag Mouth site in relation to the local environment showing the approximate position of the SM/C excavation.

undertaken over the past 100 years where shellfish and bones of fish, moa, sea mammals and birds have been recovered. The Shag River valley would have allowed access into the hinterland.

Soil chemistry and climate

The site is located in a Recent dune system which overlies a bed comprised of Claremont series dry-hygrous yellow-grey earths (silt loam), reference number 20, and Karitane series hygrous yellow-grey to yellow-brown earth intergrades, reference number 30 (NZ Soil Bureau 1968:194, 218). The background chemical profile is quite complex: in the Claremont series the pH ranges from 5.8 at 0–6" down to 5.2 at 22–30", and the cation levels for Ca range from 8.1me% at 0–6" down to 2.4me% at 22–30" (op cit:101).

The closest climate station to the Shag River Mouth is located at Cherry Farm, and while the site is some 20km south and approximately 1km inland, it is considered to be close enough that there would not be a significant difference in climatic patterns. The figures for the Cherry Farm weather patterns are: average annual rainfall 604mm; temperatures – mean daily maximum 15.4°C, mean daily 9.7°C, mean daily minimum 5.1°C, mean daily grass minimum 2.7°C; and annual average sunshine hours of 1689 hours (NZ Met. Service 1973:65).

History of investigations

The site was first brought to the attention of scientists in 1872 when Julius von Haast, who was staying in Palmerston at the time, was informed of a site with "extensive kitchen middens with moa-bones" (Haast 1874:91) at the mouth of the Shag River. Preliminary investigations revealed moa bones in association with 'chipped flint implements', similar to those he had previously collected from the Rakaia mouth site in Canterbury (ibid). Two years later he returned to undertake more extensive excavations, during which he recovered moa and sea mammal bone, stone and bone tools and large quantities of shell midden. He recognized two occupation phases — the lower (or "moa-hunter") consisted of ovens and moa remains, while the upper (or "shell-fish eaters") was composed chiefly of fish and shellfish midden. Haast believed the middens of the shell-fish eaters to be very old and, therefore, the lower, and distinctly quite separate moa-hunter remains, to be of "considerable antiquity" (op. cit.:98).

The following year, 1875, Hutton (the Curator of the Otago Museum) and his co-worker, B.S. Booth, arrived to examine for himself the middens at Shag Mouth and to address the question regarding the antiquity of the moa-hunter deposits. A trench was cut across the highest point of the dunes, and test pits dug on the lower dunes and flats to ascertain the extent and nature of the deposits. Hutton described the middens as being "seldom more than four feet deep" (Hutton 1875:104) and "moa bones were never found unassociated with beds of shells, and although shell beds did occur without moa bones, these just as often underlaid beds with moa bones as overlaid them" (ibid:105). There was no evidence to suggest two separate occupation phases, widely separated by time, and there was nothing to suggest the moa remains were more than a century old (ibid:107).

Haast immediately replied (Haast 1876) and reiterated his earlier comments that "the undisturbed layers with moa bones ... never contained any shells, and the undisturbed shell-beds did not contain any moa bones" (op. cit.:672). The mixing of shells and moa bones was entirely due to the shifting nature of the sand dune system.

Booth's diary of his excavations at the site, for so long lost until recently rediscovered by Anderson (1989b), reveals that the true picture of the stratigraphy lies between the two extremes painted by Haast and Hutton. "There was, generally speaking, a stratigraphic division between lower layers rich in moa bone (and also seal and dog bone), and overlying shell middens. Moa bone, however, occurred in and on shell beds, and shell and fishbone occurred in the lowest layers" (Anderson 1989b:74). In addition, with the trench being cut across the top of the high dunes, it was not possible for moa bone to be introduced into the upper shell layers as the result of the deposit mixing during episodes of sand dune slumping.

Hamilton excavated a midden in 1890 from which he recovered shell midden, fishbone and moa bone, as well as 50 moa crania each with the associated cervical vertebrae (Hamilton 1890, cited in Anderson 1989a:134). There then followed a hiatus of activity at the site until around 1920 when H.D. Skinner, of the Otago Museum, enlisted the aid of a local man, David Teviotdale, to excavate at Shag Mouth to identify the material culture of the earliest settlers of New Zealand (Skinner 1924; Skinner and Teviotdale 1927; Teviotdale 1924, 1932). Teviotdale had already been working at the site for a number of years, and at Skinner's insistence (Teviotdale 1924:3) he began to keep a diary into which he recorded notes about his excavations, along with "plans and sections, whenever possible, and [a] catalogue [of the] finds".

The combined amounts of faunal remains and artefactual material, in both bone and stone, which were recovered over the years (Anderson 1989a:134–135) is almost without parallel and led Skinner to declare (1924:12) "The Shag River site is probably the richest that has ever been excavated in New Zealand". An indication that settlement here was on a more permanent basis lies in the presence of 36 stone-lined hearths, recorded by Teviotdale and shown on his 1924 plan, which define the position of hut sites.

It was over 40 years before systematic excavations were again undertaken in the area. In 1970 Trotter excavated a site at nearby Shag Point (Trotter 1970) in which moa bones were found but Trotter proposed that they had been collected from the Shag River site, on the south side of the river mouth, as material for making tools (op. cit.:170).

In the late 1980's a new programme of work at the Shag Mouth site was initiated by Atholl Anderson with the central aim being to try to solve the interpretation of the site's stratigraphy and to collect material for dating. In late 1987 six squares measuring 1 x 1m were excavated on the south side of the 'clay knoll' shown on the Teviotdale (1924) plan, near to where he marked the position of a hearth. Moa bones and some artefactual material were recovered. Four months later a 4 x 4m square was opened, closer to the estuary, along with a 1 x 1m square on the bank of the estuary. These revealed undisturbed midden of fish and shellfish remains and suggested unexcavated areas of the site still remained.

In November–December of 1988 a large-scale excavation, the subject of this chapter, was undertaken on an undisturbed section of the high dunes at the southern end of the sand spit. This revealed cultural deposits to a depth of 3m below the ground surface from which a large amount of faunal and artefactual material was recovered. In May of 1989 a final series of smaller excavations was undertaken at points along the estuary bank and near where Teviotdale (1924) marks the recovery of a wooden bowl on his plan. These again revealed dog and moa bone along with artefactual material in bone and stone. In conjunction with this final set of excavations, a series of test pits was dug across the sand spit to trace the movement and geological history of the dune system. All the material from the excavations in these three years is currently being worked on and prepared for publication (Anderson, Allingham and Smith in prep.).

The November–December 1988 excavation

Test excavations earlier in the year had revealed the probability that the high dunes at the southern end of the sand spit had acted to protect intact deposits by virtue of their thick overburden of sand. This layer, at least a metre thick, was removed from one of the high dunes to reveal the surface of a dark cultural layer in which shell and fishbone were visible, along with burnt and broken hangi stones and artefactual stone material, including a large adze head. An area measuring 8 x 10m was mapped out, with squares labelled A to J running west-east and squares 1 to 8 running south-north, i.e. square 'A1' was in the southwest corner of the excavation.

The cultural layer revealed by the removal of the overburden was labelled Layer 2 — this extended across the majority of the site. Beneath this was a thin sterile sand layer of varying depth, below which was found one of the principal cultural layers — Layer 4. While this was identified across most of the excavation area, it was deepest in the northeastern squares (especially G7–8, H7–8, I7–8 and J6–8) where it comprised a shell midden at least a metre thick which appeared to be filling a hollow in the dunes. This shell midden contained numerous lenses of burnt and fragmented shell, ash and fishbone in 'upper layer 4' along with a large number of artefacts, while 'lower layer 4' consisted almost entirely of cockle shells (*Chione stutchburyi*) and few artefacts (Higham 1990). Numerous bulk samples were retained from this shell midden in the northeastern corner, especially some of the individual lenses and from 'lower layer 4'. This material formed the basis of Higham's (1990) study of seasonality at Shag Mouth.

A total of 11 layers were identified, with moa bone being present in nearly all of them. The other principal cultural layers were Layers 5, 6 and 7. Sixteen radiocarbon dates were obtained for this excavation, from collagen, shell, and charcoal, with the most reliable series being the charcoal which suggests a brief occupation about the 14th century (Anderson 1991:791–792).

The excavation followed stratigraphic layers and all material was sieved through 3.175mm (1/8") sieves. All artefactual material was bagged, numbered (see following section for a description of the bag numbering system) and returned to the laboratory, but preliminary sorting of the faunal material was conducted in the field. Shell fragments and non-diagnostic fish bone were discarded, hinges of bivalves and the whorls of gastropods were counted and recorded and then these were discarded, and all other bone fragments returned to the laboratory. Analysis of the bird bone was undertaken by Kirk (1989) and the remaining faunal analysis will appear in Anderson et al. (in prep.).

Computerisation of the Shag Mouth data

The excavation at Shag Mouth provided one of the first opportunities in New Zealand archaeology to develop a computer based data storage and analytical facility. Although computers have long been used for the analysis of material there has been very little development of database storage systems for the, often vast, quantities of raw data which are recovered in an excavation — an operation which is commonplace on excavations anywhere else in the world. Here I will give a brief description of the computerisation of the Shag Mouth material, with full details given in Appendix 1.

During the excavation we recorded the position of all artefacts and bones in 3-dimensional space, allocating them bag numbers in a sequential series. These data were entered onto an NEC portable in the field and down-loaded onto the Otago University VAX/VMS mainframe computer at the end of the excavation. Using software such as SAS GRAPH and 3DGRAPH this has allowed an examination of the relationships of material in both 2- and 3-dimensional space.

During the analytical phase of all the faunal and artefactual material, it became apparent that some means was needed of storing the data generated, for subsequent easy access and analysis. For that purpose a relational database system — named the 'Excavation Database System' (EDS) — was developed on the mainframe which allowed data entry through screens which contained a range of data fields for which the operator supplied information. Unique bag numbers were given to the bags of material prior to the identification of material contained in those bags, and then sub-bag numbers given to bags of identified material from within these bags, and these numbers served to link the two halves of the EDS — the provenance data and the identifications. With use the EDS has subsequently been refined and additional screens added such that the data from any site, whether it be historic or prehistoric, can be entered. Through the release of new software, particularly SAS/ACCESS, we are able to interact directly with the EDS for the analysis of the data stored, particularly for statistical analysis. This has made for far easier post-excavation work, especially when one considers that there are at least 10,000 items recorded in the EDS for the Shag Mouth excavation alone.

The moa remains from the Nov–Dec 1988 excavation

The collection of moa bones from this excavation comprised the majority share of the faunal component from the site. The second largest component was the mammal bone (this group includes both sea mammals and dog bone), followed by small-bird material, fish, and rat. As described above, all shell material was processed and analysed in the field with only the bulk samples being returned to the laboratory. The identification of this material to species, and discussion of MNI (Minimum Number of Individuals), butchery patterns, and the hunting patterns and strategies of the site's inhabitants is contained in Anderson, Worthy and Kooyman (in prep.). Discussion of the moa remains in this chapter is confined primarily to the taphonomy of the collection with only some passing comments on the element representation. Suffice it to say, however, that I analysed all the material independently of Anderson et al. and the figures presented here will not necessarily match theirs.

My analysis of the moa bones involved first sorting all the bone by layer and then removing all the smaller material (phalanges, sesamoids, tracheal rings and eggshell) which was analysed separately. The remaining bones and bone fragments were then analysed. For each bone the following data were recorded — bag number, sub-bag number (a fuller description of these two terms is contained in the preceding section), species (if known), element, portion, side, number of fragments, age, weight (in gm), burning category, weathering category, gnawing (presence/absence), and notes. All the results were entered into the Excavation Database System (EDS), on the Otago University VAX/VMS mainframe system. Table 5.1 presents a summary of the element frequencies for the moa bone in terms of NISP (Number of Identified Specimens), by layer. Nearly all the remains were able to be identified to element — those which were fragments of long bone (either femur or tibiotarsus) but could not be confidently placed in one or other class were grouped in the category 'LEG'. The category 'RESIDUE' includes all material which could not be identified to element or type of element (i.e. it could not even be assigned to the category 'LEG'), and these pieces of bone tended to be small and often very fragmentary. A full table of all the data recorded for the Shag Mouth moa bone collection is contained in Appendix 2.

Two broad patterns emerge from these results. It is apparent that Layers 4 through 7 were the main occupation layers, given the number of fragments recovered in them. Even after removing the high numbers of eggshell fragments and tracheal rings these four layers have greater quantities of bone in them than the others. Moa bone was, however, recorded throughout the sequence, with Layers 1 and 3 containing very little cultural material and being essentially sterile. Layer 0 was ascribed to surface material for the purposes of the EDS when recording the layer from which those bones derived. There is only one fragment

Table 5.1 Summary table of moa remains (NISP) from Shag Mouth.

	Layer												
Element	0	1	2	3	4	5	6	7	8	9	10	11	Total
CR	.	.	2	.	4	6	9	2	.	5	.	1	29
MAND	.	.	10	.	2	3	11	.	.	.	.	.	26
TR	.	.	58	.	54	144	288	300	146	77	34	6	1107
V-CE	.	.	3	.	5	12	29	18	9	1	.	.	77
V-TH	.	.	.	.	4	.	3	.	.	20	.	3	30
V-CA	.	.	8	.	3	4	4	7	2	5	.	3	36
V	.	.	8	.	15	12	24	24	4	3	.	1	91
R	.	.	35	.	69	64	90	104	28	10	4	8	412
R-ST	.	.	4	.	1	19	13	5	1	4	1	2	50
ST	.	.	4	.	6	20	12	7	.	.	.	.	49
PEL	.	.	11	.	30	9	15	6	3	6	.	2	82
FEM	.	3	11	8	5	11	11	6	.	1	1	.	57
TT	1	4	77	3	91	39	90	38	6	6	5	1	361
FIB	.	1	3	.	30	10	14	6	.	.	.	.	64
LEG	.	.	35	.	26	17	18	8	.	3	.	.	107
TMT	.	.	.	.	11	6	20	8	3	4	.	1	53

Table 5.1 (ctd.)

	Layer												
Element	0	1	2	3	4	5	6	7	8	9	10	11	Total
SES	.	.	3	.	6	10	21	13	6	5	2	.	66
PH	.	3	21	.	56	57	128	102	23	18	6	4	418
PHU	.	.	7	.	20	15	52	34	5	5	1	.	139
RESIDUE	.	3	51	.	51	43	47	22	5	10	.	.	232
ES	.	.	31	.	26	126	293	273	84	38	9	49	929
TOTAL	1	14	382	11	515	627	1192	983	325	221	63	81	4415

Key: CR - cranium
ES - eggshell
FEM - femur
FIB - fibular
MAND - mandible
PEL - pelvis
PH - phalanx
PHU - ungual phalanx
R - rib
R-ST - sternal rib
SES - sesamoid
ST - sternum
TMT - tarsometarsus
TT - tibiotarsus
V - vertebrae
V-CA -caudal vertebrae
V-CE - cervical vertebrae
V-TH - thoracic vertebrae

of tibiotarsus from the layer and it can probably be more correctly ascribed to Layer 1.

The second point to note in conjunction with Table 5.1 is that it is a record of element frequency (NISP) and, as such, does not differentiate between large and small fragments of bone — simply the number of fragments present. All elements of the body are represented with only the tibiotarsus ('TT') present in all layers. The high proportion of both 'TT' and 'LEG' fragments, the latter of which probably derive from 'TT' but could not be placed in that category with any degree of certainty, indicates the degree to which bones in this site were broken. There are two primary reasons for the breakage of tibiotarsi — the extraction of marrow and the utilisation of the bone for industrial purposes. Many of the proximal and distal ends of the 'TT' remain whole suggesting they were broken or smashed off to leave the shafts in one major piece which was then further broken down. The presence of bone fishhooks, tabs and discarded cores from fishhook manufacture attests to the use of moa bone for industrial purposes. The best portion of bone for the manufacture of tabs is the flat bone on the distal anterior and proximal posterior surfaces of the shaft and extraction of this bone would lead to the shattering of the remainder of the shaft.

There were no examples of the two uppermost cervical vertebrae — the atlas and axis. Kooyman (1985:351) postulates that this may be due to bones being smashed beyond recognition in the process of separating the head from the neck during butchery.

There is a surprising under-representation of the fibula in the remains — this element attaches tightly to the tibiotarsus and one would expect that it would appear in similar numbers. Kooyman (1985:221) attributes this lower frequency of fibula remains to a problem with identification, and it is quite possible that the high number of fragments identified as 'RIB' in this study includes some that are, in fact, from fibulae.

The high number of phalangeal fragments ('PH' and 'PHU' (ungual phalanx)) present indicates that a large number of 'feet' were discarded in the site during the butchery process. There were fewer fragments of tarso-metatarsi recorded than thigh elements, but the fragments tended to be larger. Given that the tarsometatarsi probably had little meat value, this would suggest that the 'TMT' were not broken up as much as the other leg elements, especially the 'TT', for the extraction of marrow or industrial use either.

TAPHONOMIC PATTERNS IN THE SHAG MOUTH REMAINS

The weathering and burning patterns evident in the Shag Mouth material are presented in summary form in Tables 5.2 and 5.3 where all elements and layers are combined. The full results are given in Appendix 3 — 3a contains a summary of the burning and weathering by element; 3b contains a summary of the burning and weathering by layer; and 3c contains a breakdown of the burning and weathering ordered by layer and by element.

Weathering evidence

The wide range of categories which finally appeared in the weathering analysis, especially all the intermediate stages, is probably a reflection of my unease with the very subjective nature and uncertainty of the weathering scales and, in hindsight, probably resulted in my sorting the bones with too much refinement. Suffice it to say, however, that most of the intermediate stages are represented by less than 1% of the bone fragments and the results of the principal categories, highlighted in bold type in Table 5.2, reveal some interesting patterns.

The weathering class 'N' consisted almost entirely of eggshell and tracheal ring fragments — material which does really fit into the category of bone types that one can apply weathering scales to. These are primarily designed for solid cortical bone fragments with allowances, such as in the Todd et al. (1987) scale, for articular surfaces and cancellous bone. They have been recorded as 'N' to indicate that they have not weathered, and the fact that so much of this finer material has survived in the site is important in itself. Conditions within the burial matrix

Table 5.2 Summary of weathering stages recorded in the Shag Mouth moa remains (all elements and layers combined).

Weathering stage	Number of fragments	Percentage	Amended percentage
1	663	15.0	30.0
1+	266	6.0	12.0
1–1+	4	.	.
1–2	47	1.1	2.1
1–2+	3	.	.
1–3	4	.	.
1/2	93	2.1	4.2
1/3	5	.	.
1/3+	1	.	.
2	479	10.8	21.7
2+	74	1.7	3.3
2–3	3	.	.
2–3+	7	.	.
2–4	5	.	.
2/3	63	1.4	2.9
2/3+	6	.	.
2/4	1	.	.
3	271	6.1	12.3
3+	35	.	1.6
3/4	35	.	1.6
4	78	1.8	3.5
4+	8	.	.
4/5	19	.	.
5	40	.	1.8
N	2205	49.9	-
	4415		

Notes: 1) class 'N' includes 929 fragments of ES, 56 fragments of RESIDUE, and 1106 fragments of TR

2) in the percentage columns, '.' indicates less than 1%

3) see text for a description of the 'Amended percentage' column

must have been very conducive to bone survival for this material to be recovered intact, and this is represented in the distribution of bones across the weathering classes. The percentage representation of the remaining weathering classes in the remains was recalculated with the class 'N' removed, and the results are shown in Table 5.2 in the column headed 'Amended percentage'. The discussion which follows of the weathering evident in the Shag Mouth moa remains utilises the amended percentage figures.

A full 42% of the bones were in an unweathered state when they were recovered and approximately 76% were less than Stage 3. This indicates that either one, but probably both, of the following conditions acted upon the bones. Firstly, the length of time the bones spent exposed on the ground surface must have been relatively short. None of the bones was recorded as being sun-bleached, and the nature of the substrate on which they were deposited, a loose, free-flowing sanddune system, very exposed to the prevailing wind patterns, would have ensured that bones would have been quickly covered by sand. Secondly, the burial matrix was very conducive to bone survival.

The presence of about 6% of the bones in advanced stages of weathering (Stage 4 or higher) does indicate that some material was either exposed for a longer period of time or was affected by conditions within the burial matrix. There is a further possibility, that bones within a sandy matrix are more likely to be frequently exposed and reburied as the dune systems deflate and rebuild during particularly rough periods of weather. The very low frequency of advanced weathering in the bone remains from this site suggests that this was probably not a major factor in bone survival. Figure 5.2 shows some examples of weathering in the moa bone from Shag Mouth.

Looking at the patterns evident in the elements (Appendix 3a), in general all the elements tend to show a similar pattern in their distribution across the weathering categories (Figures 5.3–5.13). The largest numbers of bones appear in Stages 1 and 2 and then decrease markedly across the remaining Stages. The range of values in Stage 1 is from 5% for cervical vertebrae up to 45% for cranial fragments and in Stage 2 from 3% (V-TH) to 45% (ST). In almost all the elements, at least 65% of the fragments can be placed in Stage 1 or 2, with a high of 94% of R-ST and 100% of MAND, except for the following — FEM (58%), PEL (57%), V-CA (53%) and V-TH (23%). The latter four element groups have higher percentages in the more advanced weathering categories, but most of the fragments fall within Stage 3.

There is no difference in weathering observed between bones which are traditionally considered as being the more fragile (CR/MAND/ST/PEL/V) and the heavier leg bones. Individually, the vertebrae are slightly more weathered than other elements with 30% of unspecified fragments (V), 47% of caudal vertebrae and 76% of thoracic vertebrae (V-TH) being in weathering classes higher then Stage 2. Similarly, 42% of pelvic fragments (PEL) are in Stage 3 or higher. While it can be argued that these weathering patterns are probably due to their structure being primarily cancellous bone, which theoretically weathers more rapidly than cortical bone once exposed, the same cannot be said for femoral fragments which have 44% in Stage 3 or above. In fact, 16% of the total femoral fragments recovered in the excavation can be placed in class 5 — showing evidence of advanced weathering. Eight of the nine fragments in Stage 5 are derived from Layer 3 (the ninth from Layer 1) perhaps suggesting a hiatus of several years duration in the site's occupation when bone material was exposed on the ground surface.

The thoracic vertebrae (V-TH), as a group, are at total variance with the weathering patterns evident in the other elements. Only 23% are in the unweathered to slightly weathered Stages (1 or 2) and, of the remainder, 23% are in Stage 3, 3% in Stage 4, and 47% in Stage 5. All the bones in this last group are from Layer 9 and the highly weathered state of these, and indeed much of the thoracic vertebrae remains, may be due to their having been broken during the butchery process to expose the underlying cancellous bone, which was subsequently affected by aerial and subsurface weathering.

In looking at the weathering patterns by layer (Appendix 3b) we find a similar distribution in all the layers with most of the bones occurring in unweathered or slightly weathered states (Stages 1 and 2, and the various intermediate stages)

Figure 5.2 Examples of bone weathering in moa bone from Shag Mouth.

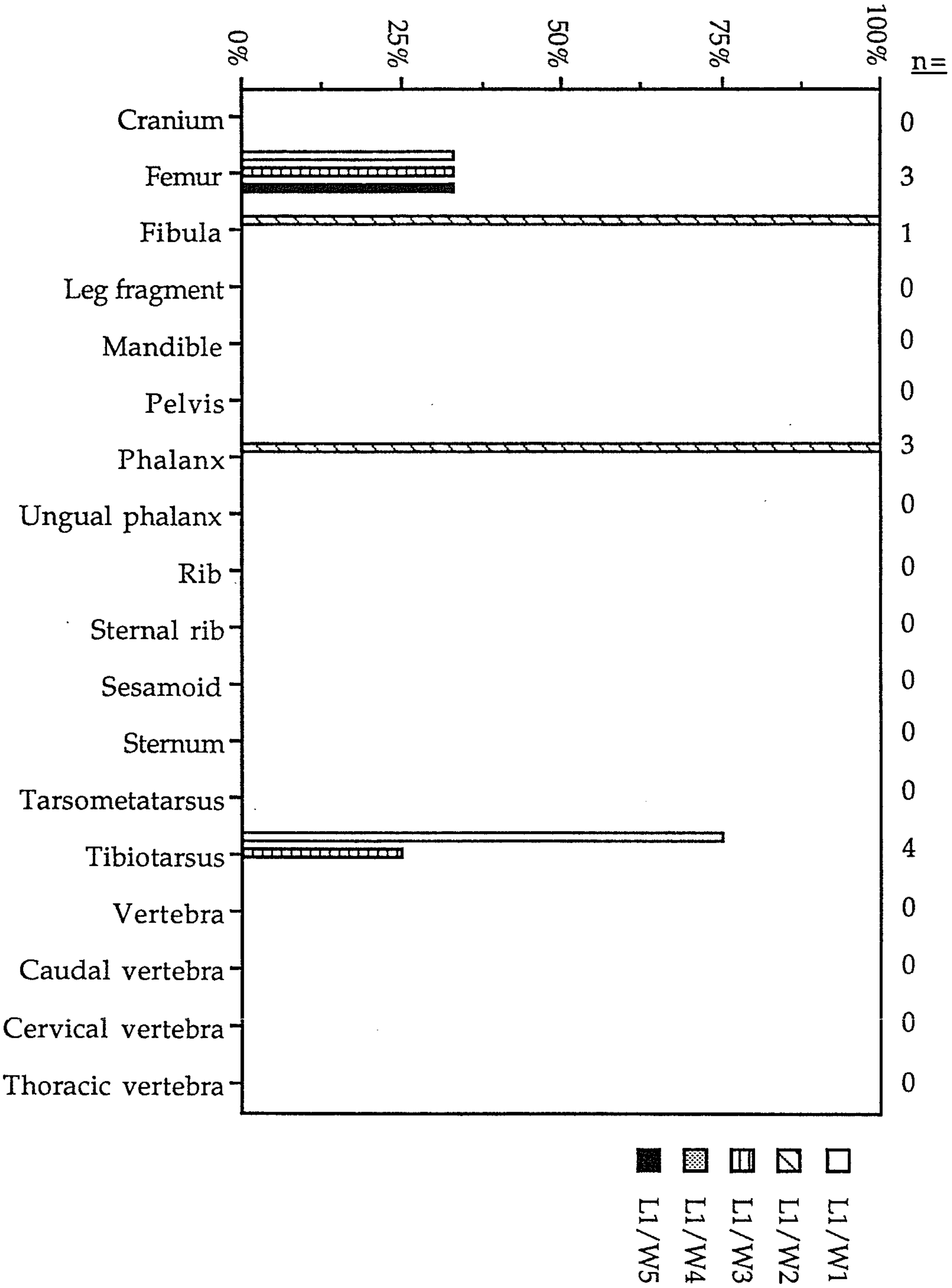


Figure 5.3 A breakdown of the weathering stages recorded for each skeletal element of moa present in Layer 1 of Shag Mouth.

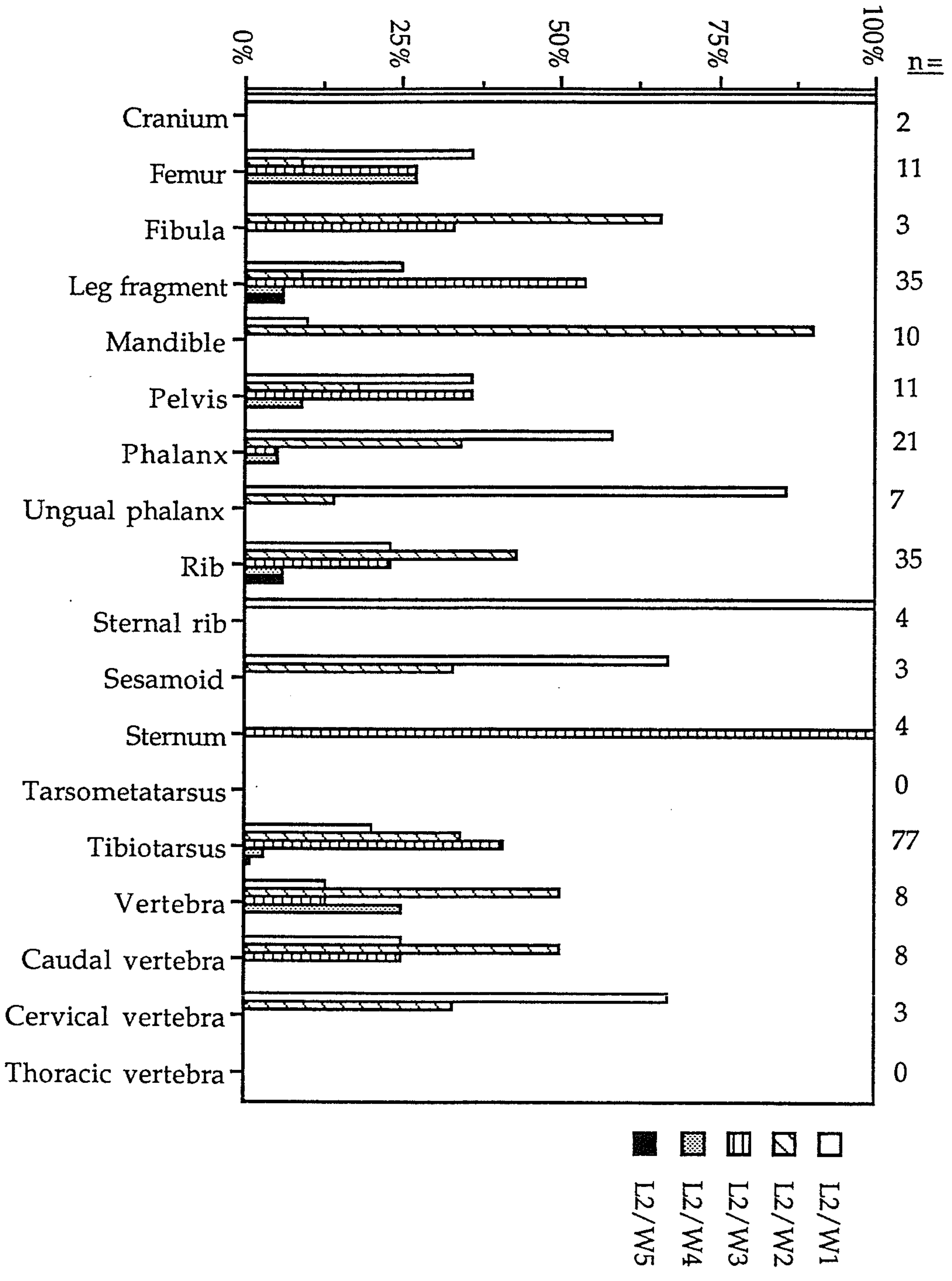


Figure 5.4 A breakdown of the weathering stages recorded for each skeletal element of moa present in Layer 2 of Shag Mouth.

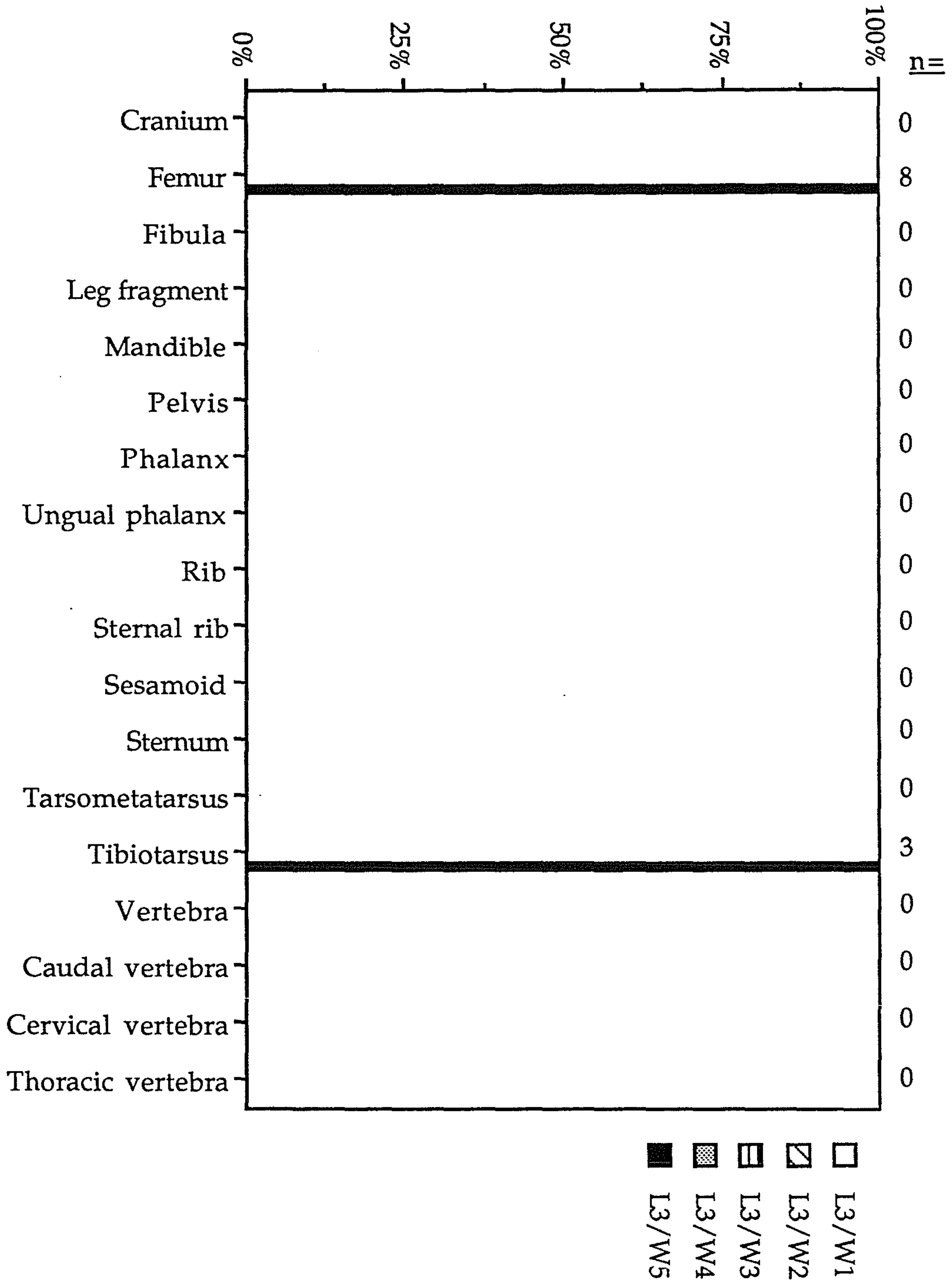


Figure 5.5 A breakdown of the weathering stages recorded for each skeletal element of moa present in Layer 3 of Shag Mouth.

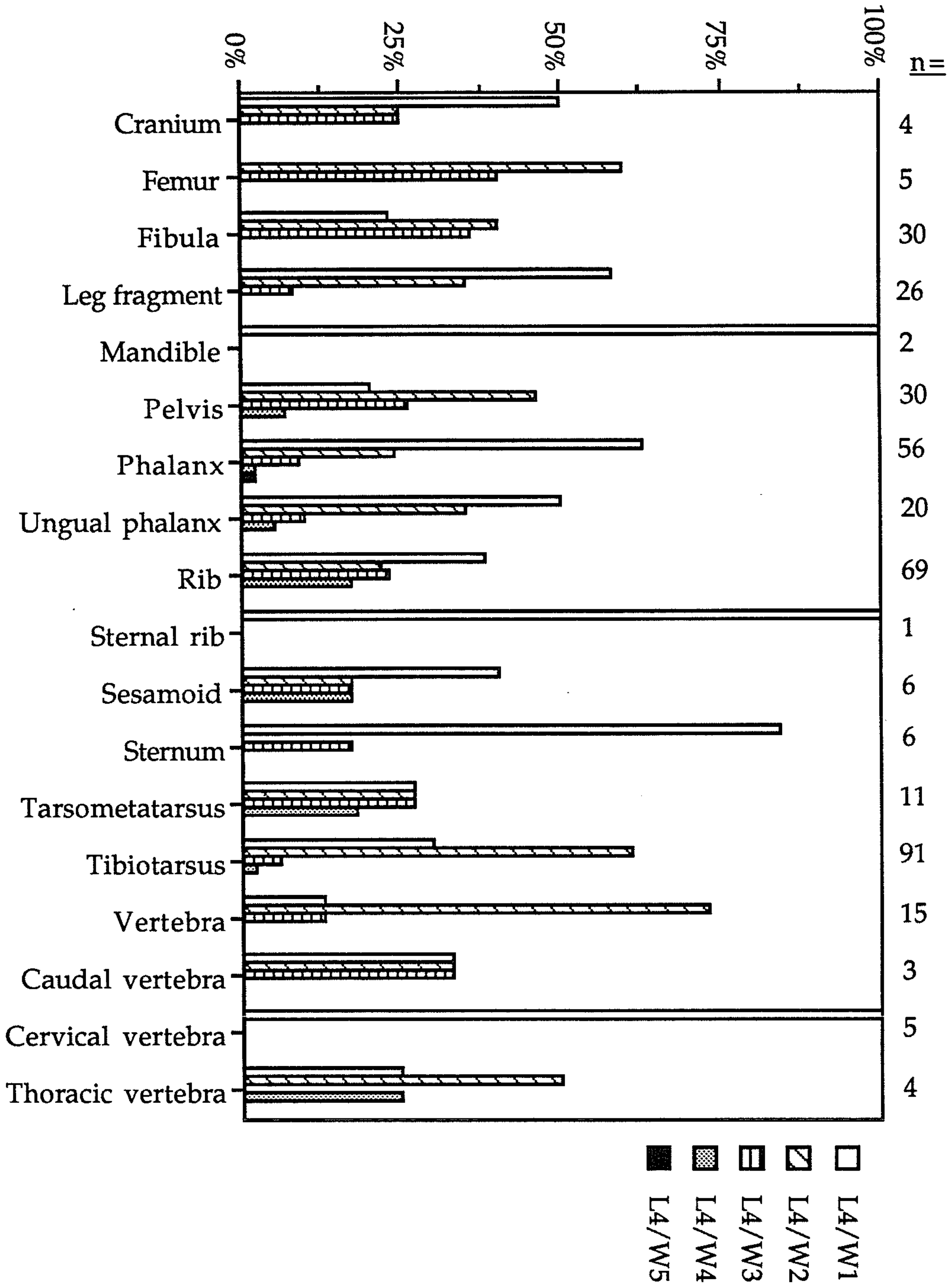


Figure 5.6 A breakdown of the weathering stages recorded for each skeletal element of moa present in Layer 4 of Shag Mouth.

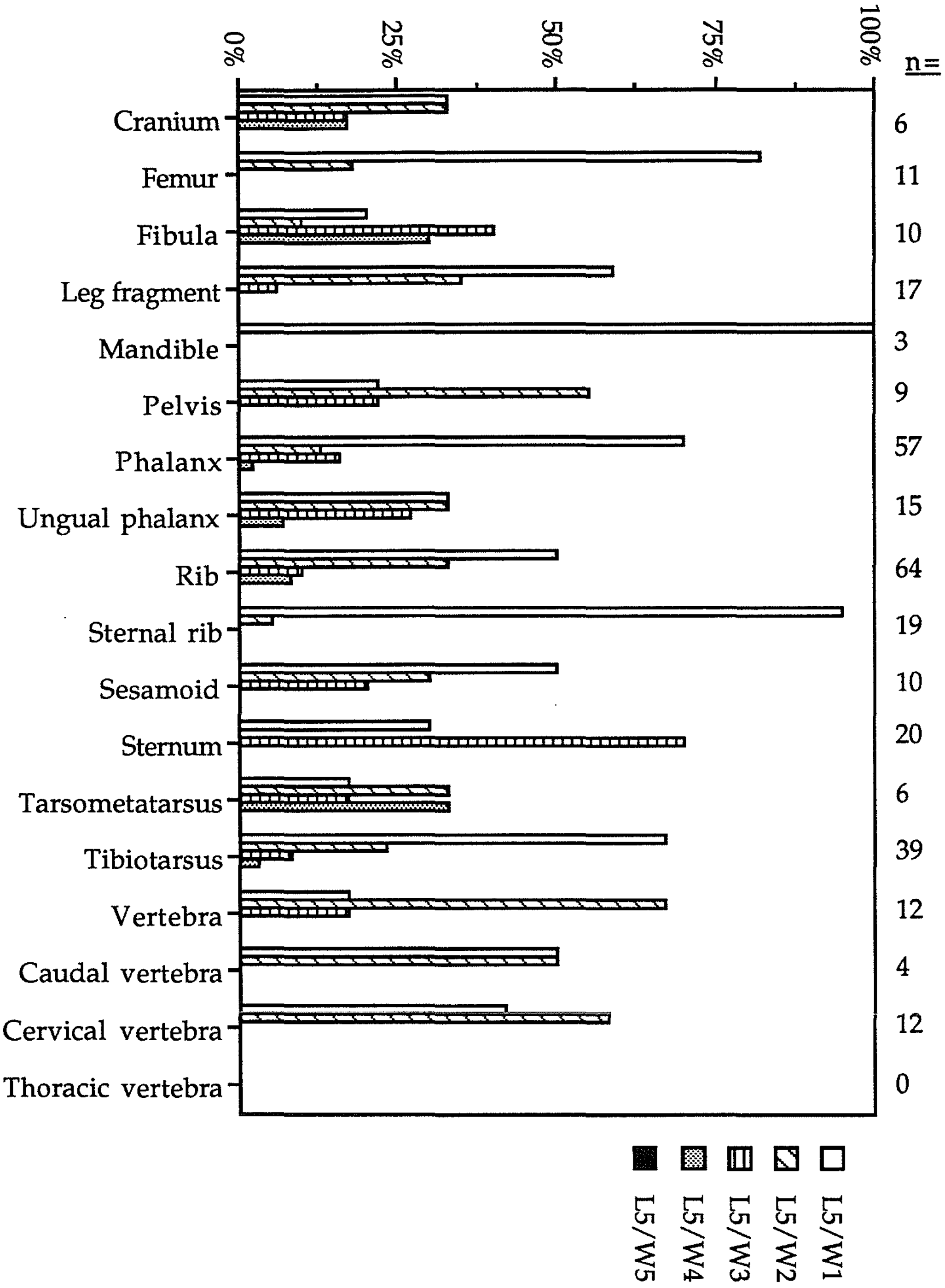


Figure 5.7 A breakdown of the weathering stages recorded for each skeletal element of moa present in Layer 5 of Shag Mouth.

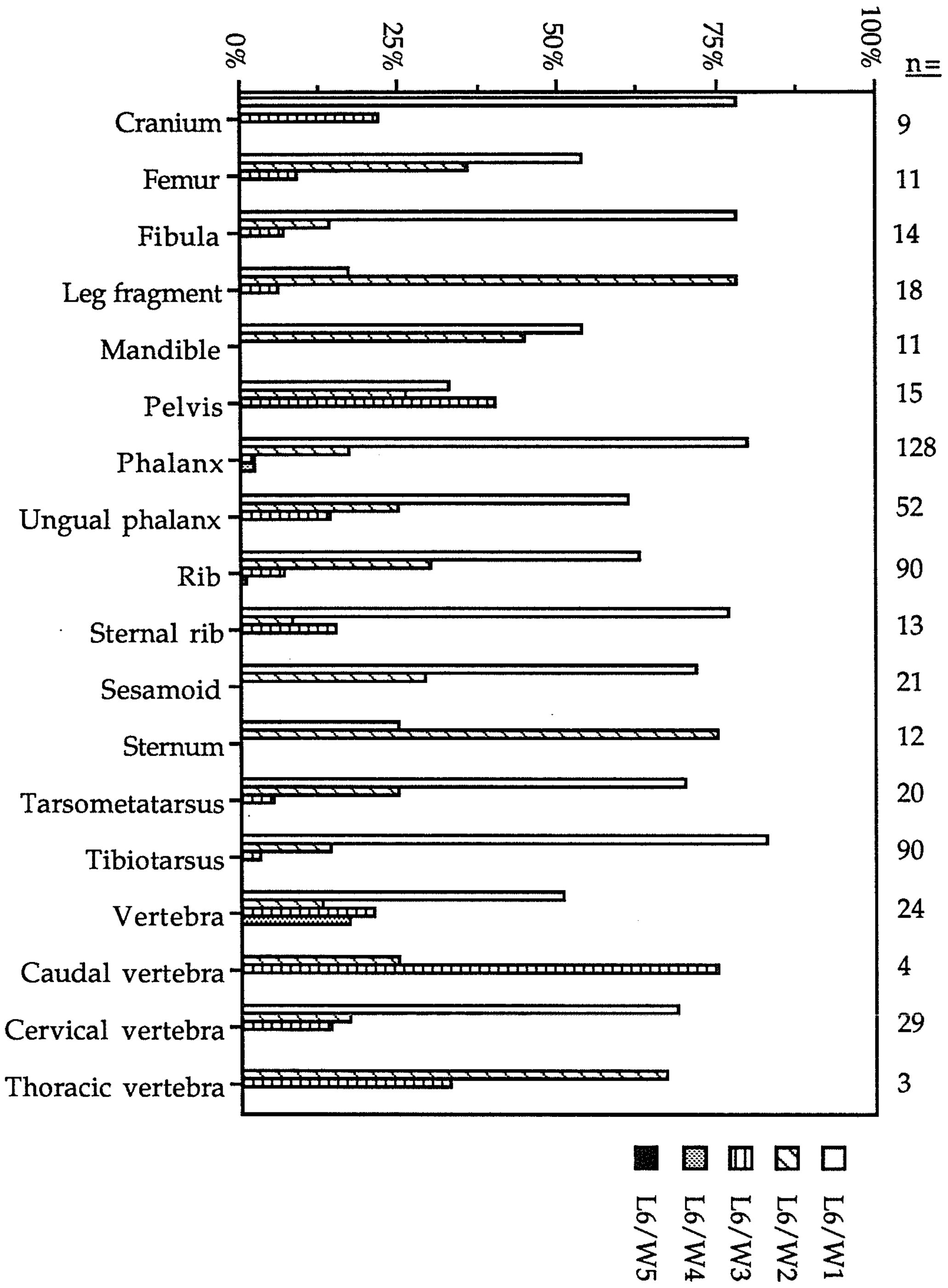


Figure 5.8 A breakdown of the weathering stages recorded for each skeletal element of moa present in Layer 6 of Shag Mouth.

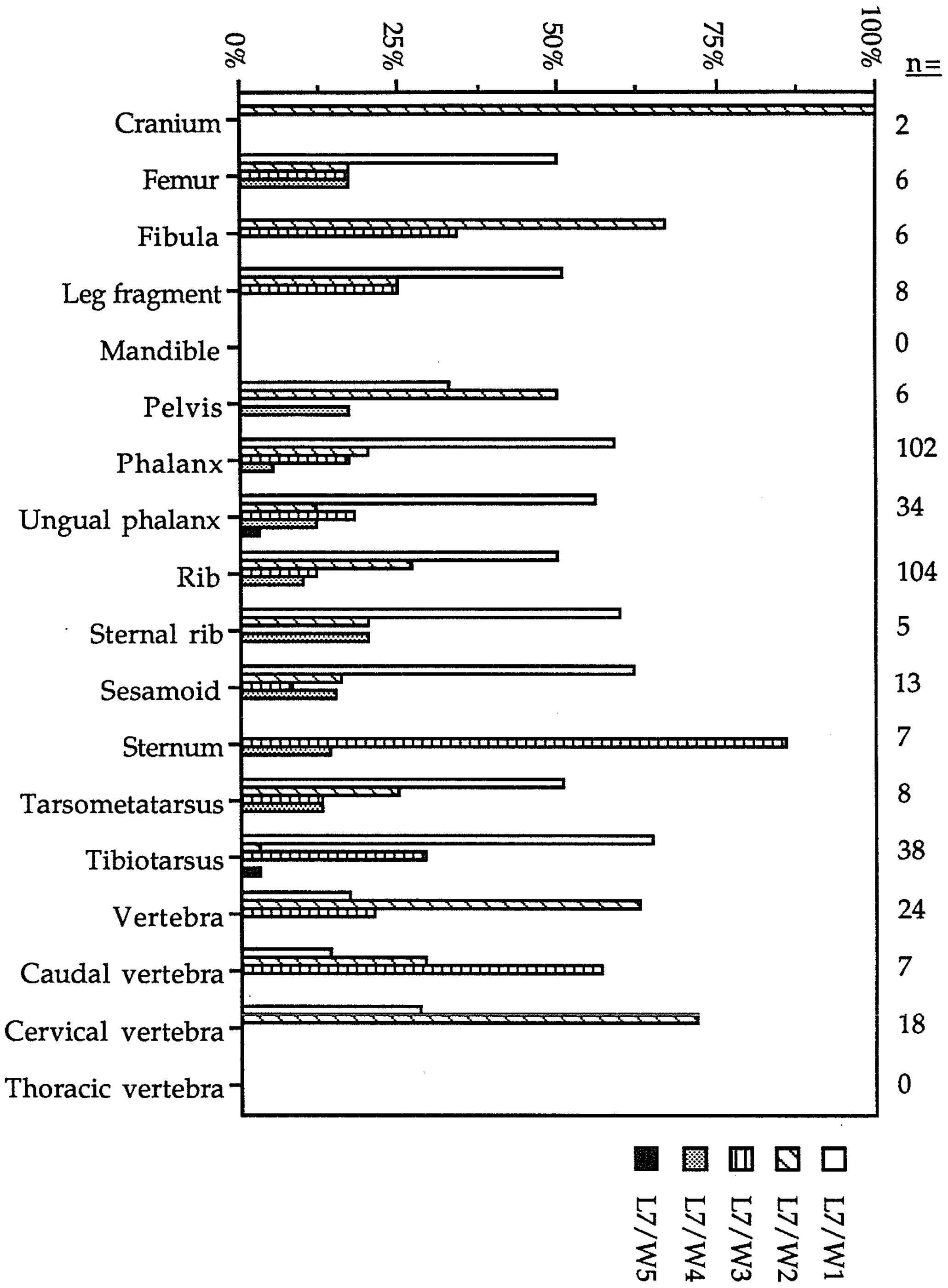


Figure 5.9 A breakdown of the weathering stages recorded for each skeletal element of moa present in Layer 7 of Shag Mouth.

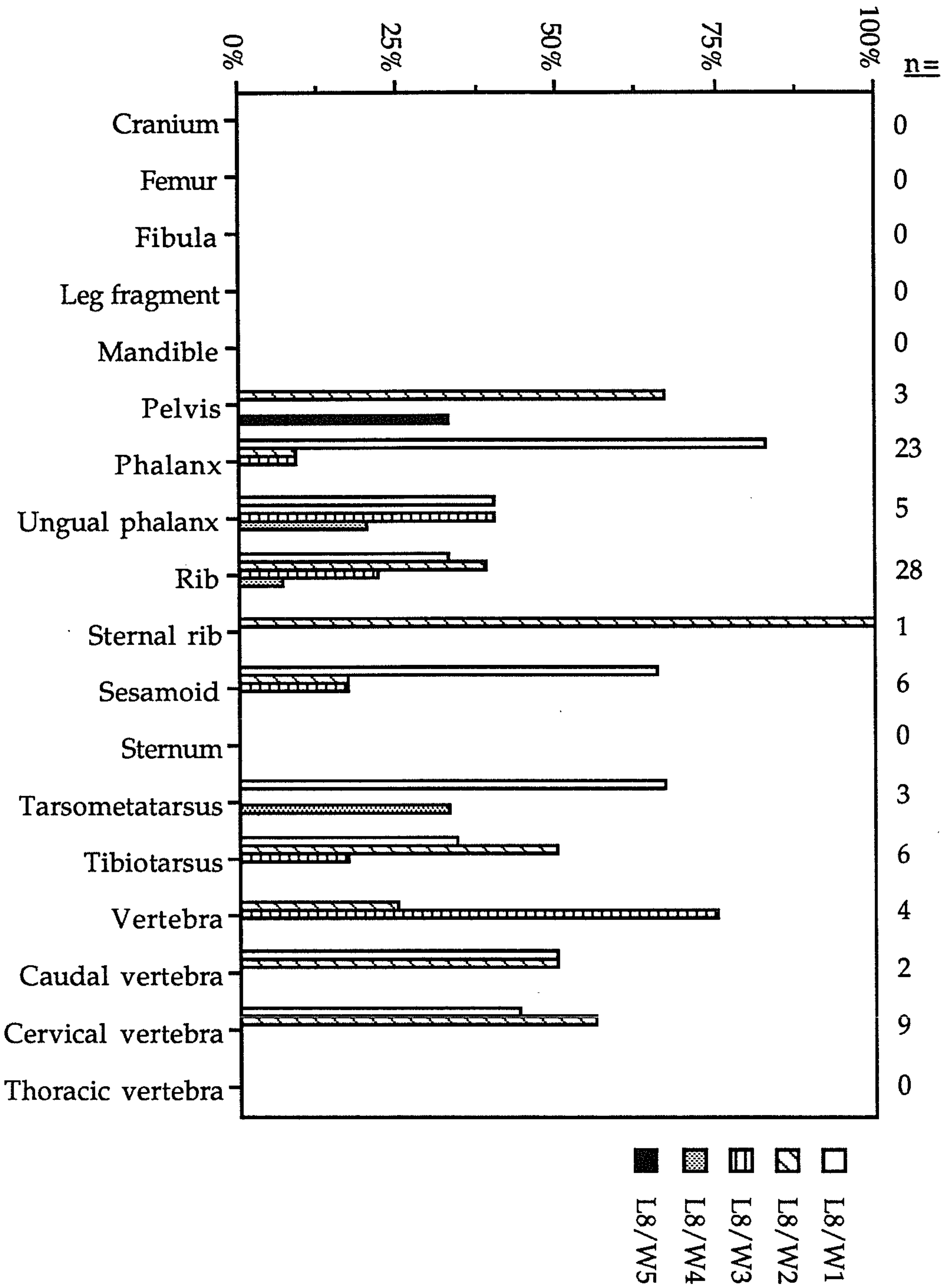


Figure 5.10 A breakdown of the weathering stages recorded for each skeletal element of moa present in Layer 8 of Shag Mouth.

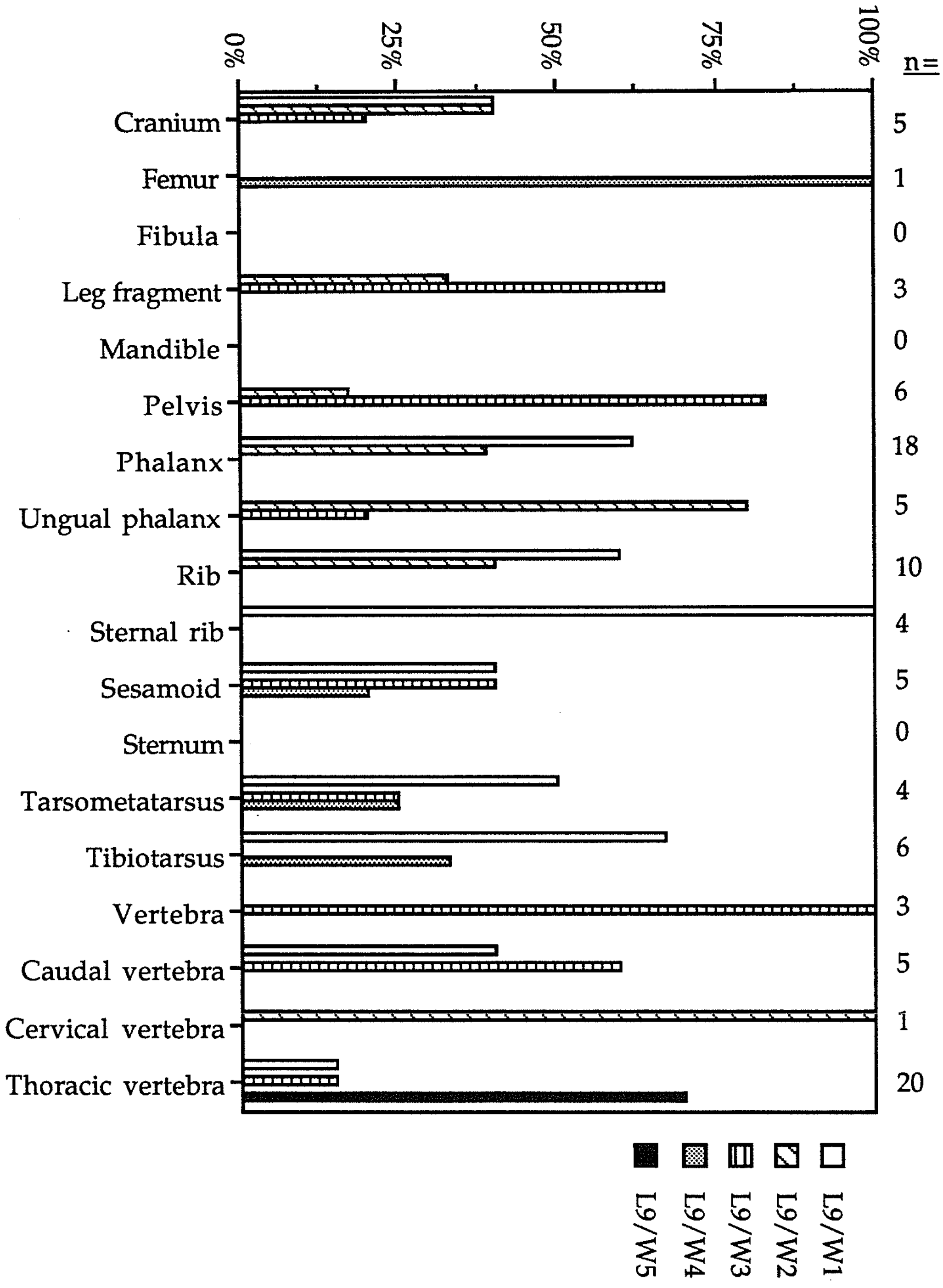


Figure 5.11 A breakdown of the weathering stages recorded for each skeletal element of moa present in Layer 9 of Shag Mouth.

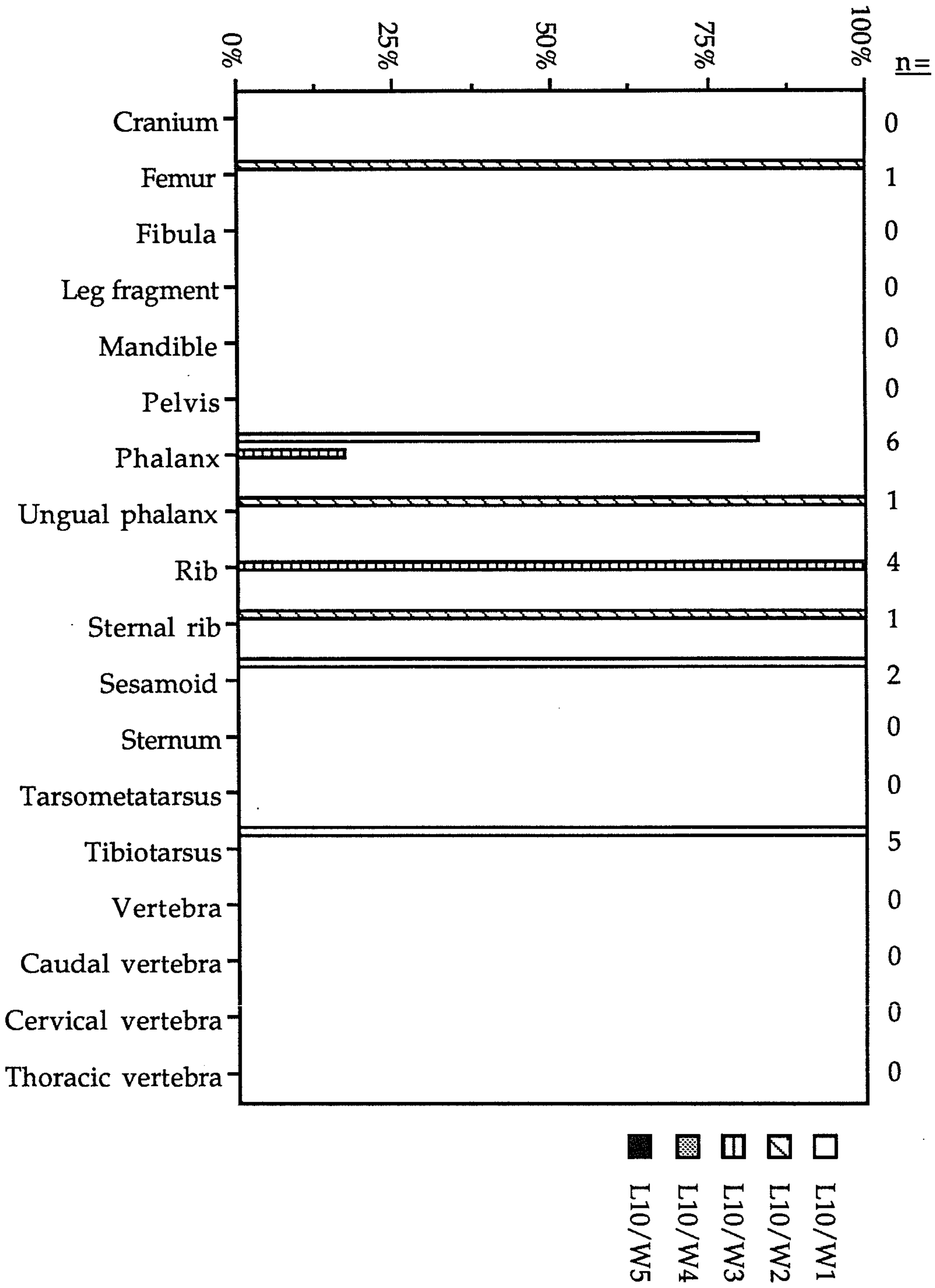


Figure 5.12 A breakdown of the weathering stages recorded for each skeletal element of moa present in Layer 10 of Shag Mouth.

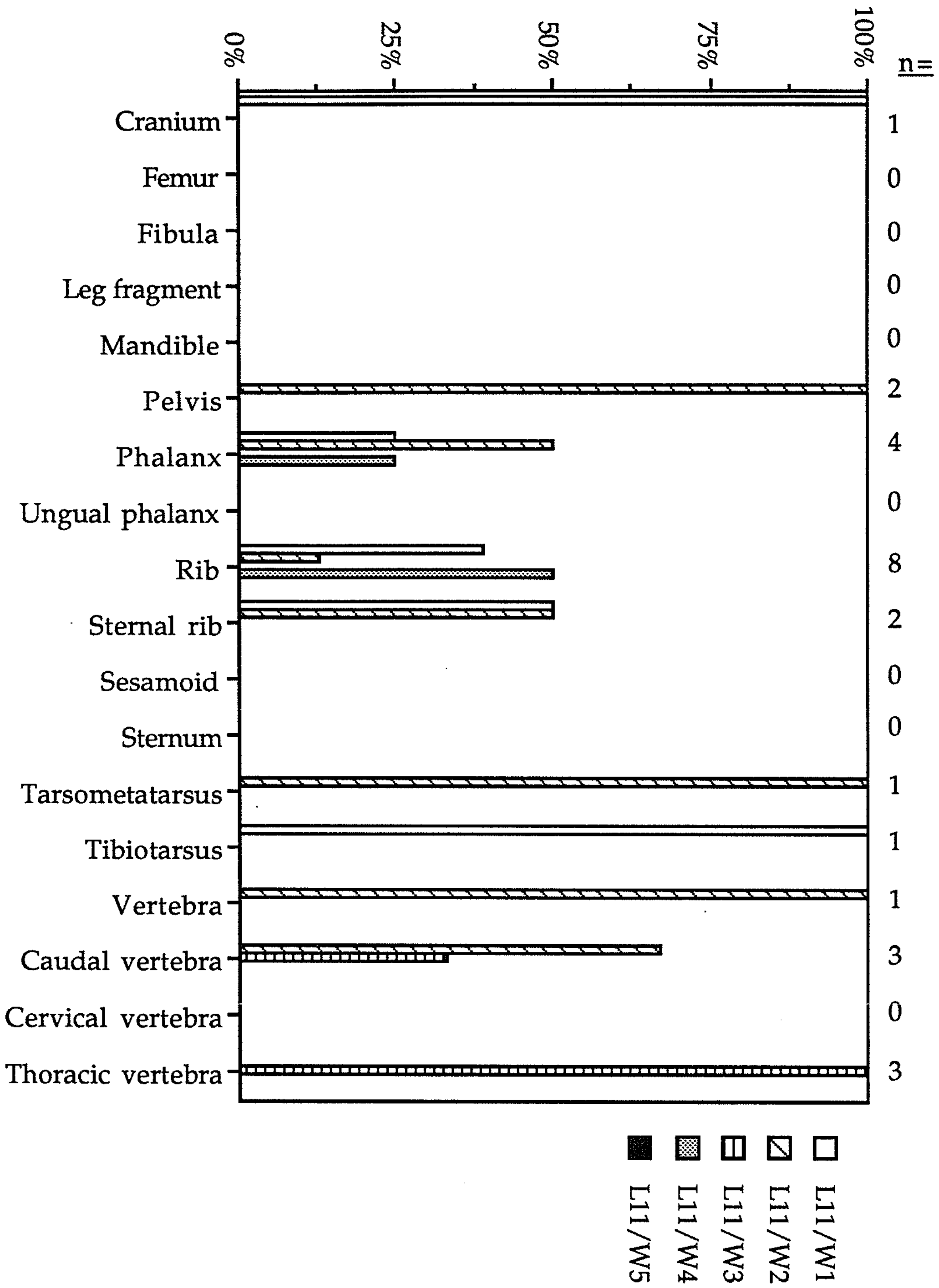


Figure 5.13 A breakdown of the weathering stages recorded for each skeletal element of moa present in Layer 11 of Shag Mouth.

with overall means of 30% in Stage 1, 12% in 1+, and 22% in Stage 2. The amount of material of stage 3 weathering ranges from 7% in Layer 6 up to 25% in Layer 10, with an overall mean of 12%. Only Layers 3, 9 and 11 had sizeable proportions of bones in more advanced weathering stages. Nineteen percent of the bones in Layer 11 were in Stage 4 (compared with an overall mean of 4%), and the material in Stage 5 ranged as high as 17% in Layer 9 and 100% in Layer 3 (discussed above) against an overall mean of 2% for this stage.

Burning evidence

In the analysis of the burning evident in the Shag Mouth moa bones (Table 5.3), I again describe a series of intermediate steps between the main categories as a result of bones which have been in contact with fire exhibiting a range of characteristics within a continuum. Hearths were a common feature in the excavation and these have played a role in the survival of the moa bone in the archaeological record.

As with the weathering stages, there was a large group of material placed in a category 'N' for the burning. This included 929 fragments of eggshell, and while these technically fall within class 1, I recalculated the proportions of material in each of the burning stages in Table 5.3 once this class was removed, and these figures are given in the column headed 'Amended Percentage'.

A total of 59% of the fragments were unburnt, with a further 18% unburnt but blackened from probably being buried within oven rakeout. The remaining 27% of the bone fragments were burnt to varying degrees — with approximately 5% showing evidence of charring (Stage 2), 4% being fully burnt black (Stage 3), and approximately 9% being burnt in either an oxidising or reducing environment so that the bones turn a white/grey colour (Stage 4).

The reasons for burning bone were discussed in Chapter 2, being either bones being in fires during meals, or bones being utilised as 'firewood', or as a means of refuse disposal during periods of tidying the habitation area of the site. The latter

Table 5.3 Summary of burning stages recorded in the Shag Mouth moa remains (all elements and layers combined).

Burning stage	Number of fragments	Percentage	Amended percentage
1	2017	46.7	58.8
1–3	11	.	.
1/2	5	.	.
1/3	2	.	.
1/4	4	.	.
1/5	15	.	.
2	179	4.1	5.2
2–3	3	.	.
2–4	51	1.2	1.5
2/3	5	.	.
2/4	3	.	.
2/5	3	.	.
3	147	3.3	4.3
3–4	16	.	.
3/4	40	.	1.2
4	300	6.8	8.7
5	628	14.2	18.3
N	986	22.3	-
	4415		

Notes: 1) class 'N' includes 929 fragments of ES, and 56 fragments of RESIDUE

2) in the percentage column, '.' indicates less than 1%

3) see text for a description of the 'Amended percentage' column

can involve simply placing bones on cooking fires or gathering bones into discrete heaps when are then set on fire.

When one looks at the burning evident in individual elements (Appendix 3a), some interesting patterns emerge, as summarised in Table 5.4 and Figures 5.14–5.24. It is obvious that some element groups are being discarded in the site as a result of the butchery process while others are being discarded in a different manner. Butchery units which comprise cranium/mandible/cervical vertebrae/ tracheal rings are being discarded away from the cooking areas as very little of this material was recovered with evidence of burning: likewise, butchery units comprising sternum/sternal ribs, and tarsometatarsi/phalanges. On the other hand, the mid-leg elements (tibiotarsus/fibula and undescribed 'LEG' fragments) tend to exhibit burning in 34–44% of the recovered fragments. Whether this is the result of discarding into fire once the meat had been removed, or of disposal/tidying practices is difficult to tell.

Table 5.4 Degree of unburnt (burning categories 1 and 5) versus burnt (burning categories 2, 3 and 4) moa bone for individual elements.

Element	Unburnt (%)	Burnt (%)
CR	97	3
MAND	100	-
TR	94	6
V-CE	100	-
V-TH	53	47
V-CA	75	26
V	59	40
R	62	37
R-ST	98	2
ST	98	2
PEL	51	49
FEM	90	9
TT	66	34
FIB	56	44
LEG	58	42
TMT	86	14
SES	83	18
PH	81	19
PHU	88	12

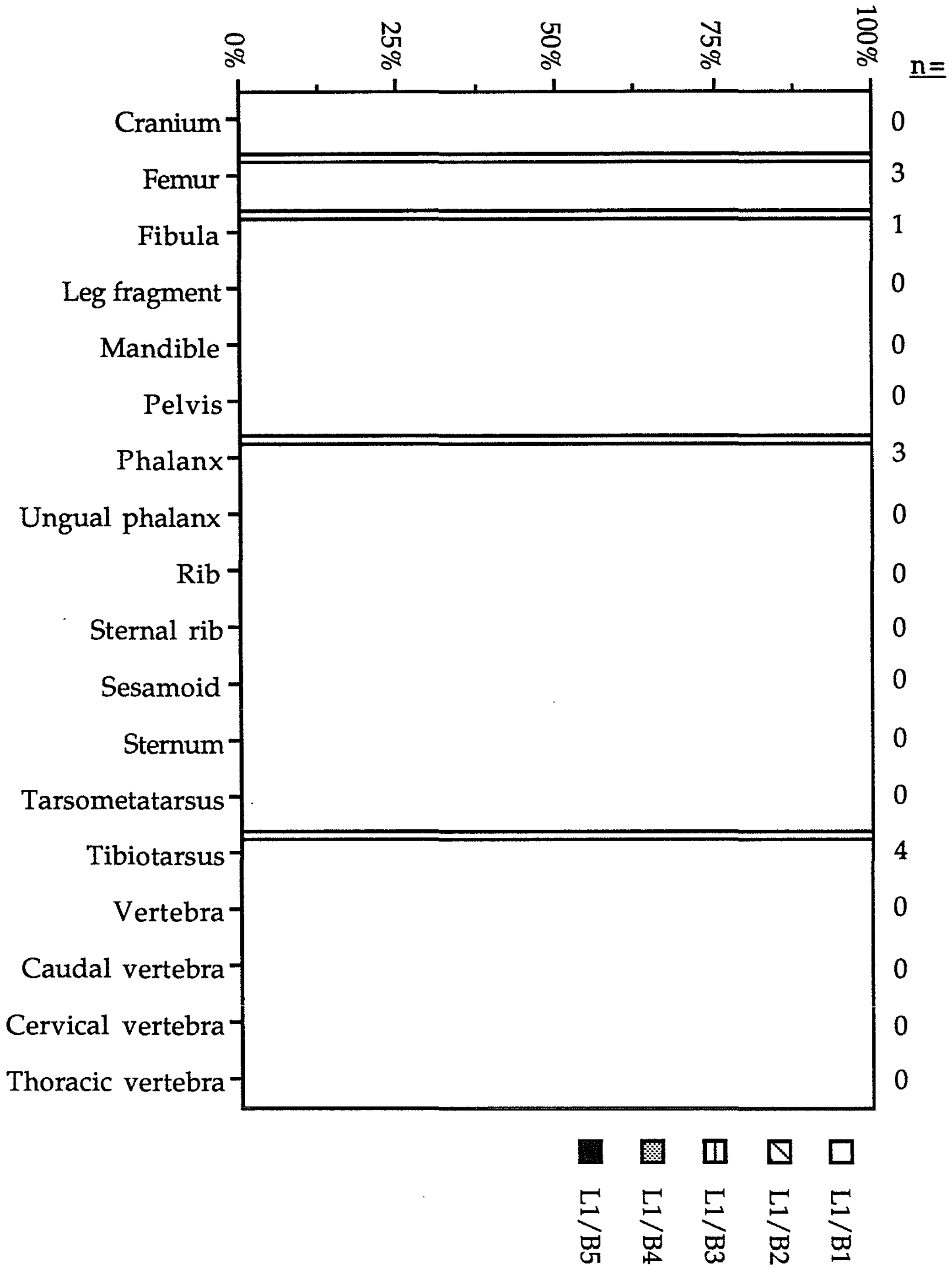


Figure 5.14 A breakdown of the burning stages recorded for each skeletal element of moa present in Layer 1 of Shag Mouth.

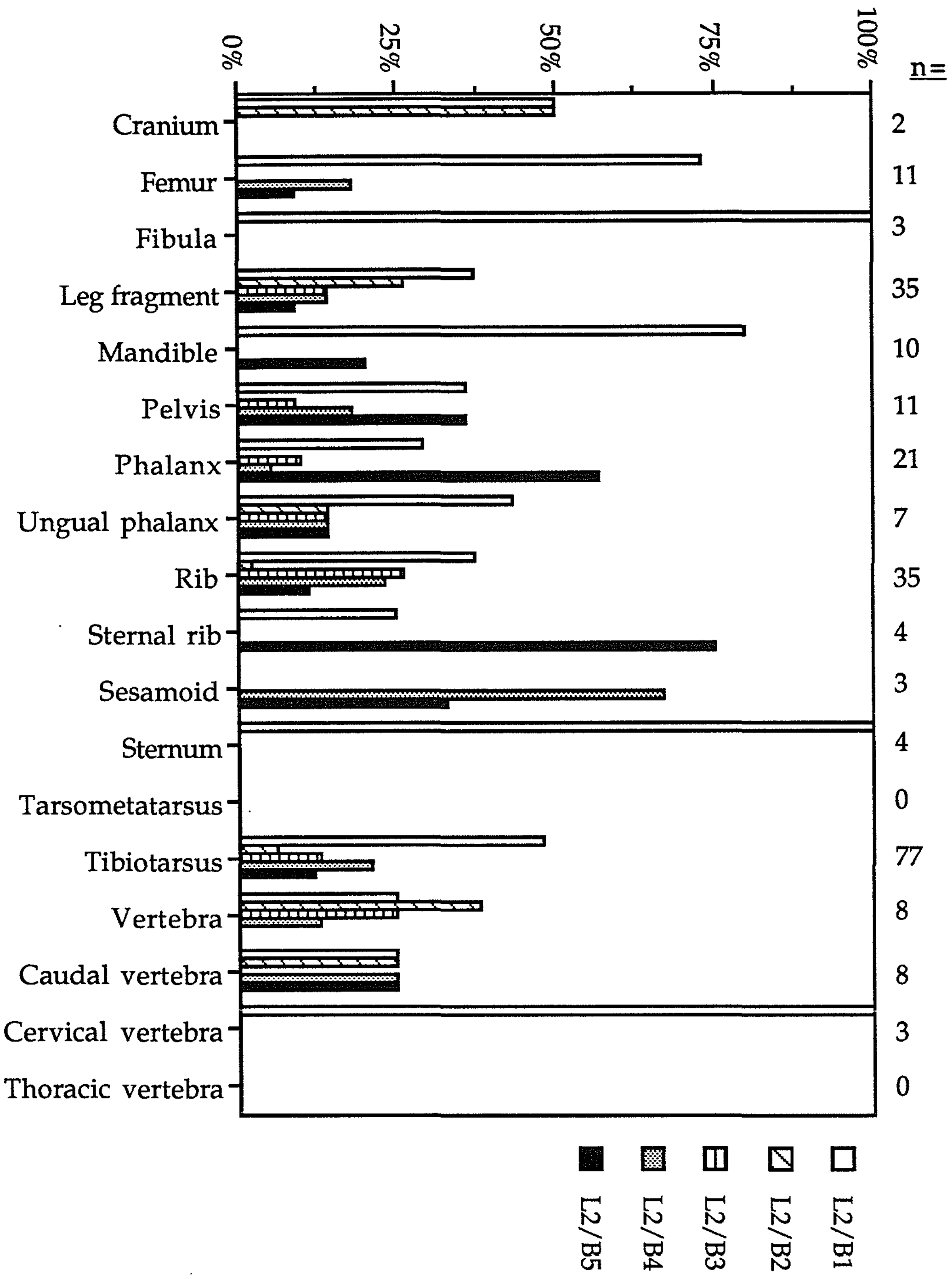


Figure 5.15 A breakdown of the burning stages recorded for each skeletal element of moa present in Layer 2 of Shag Mouth.

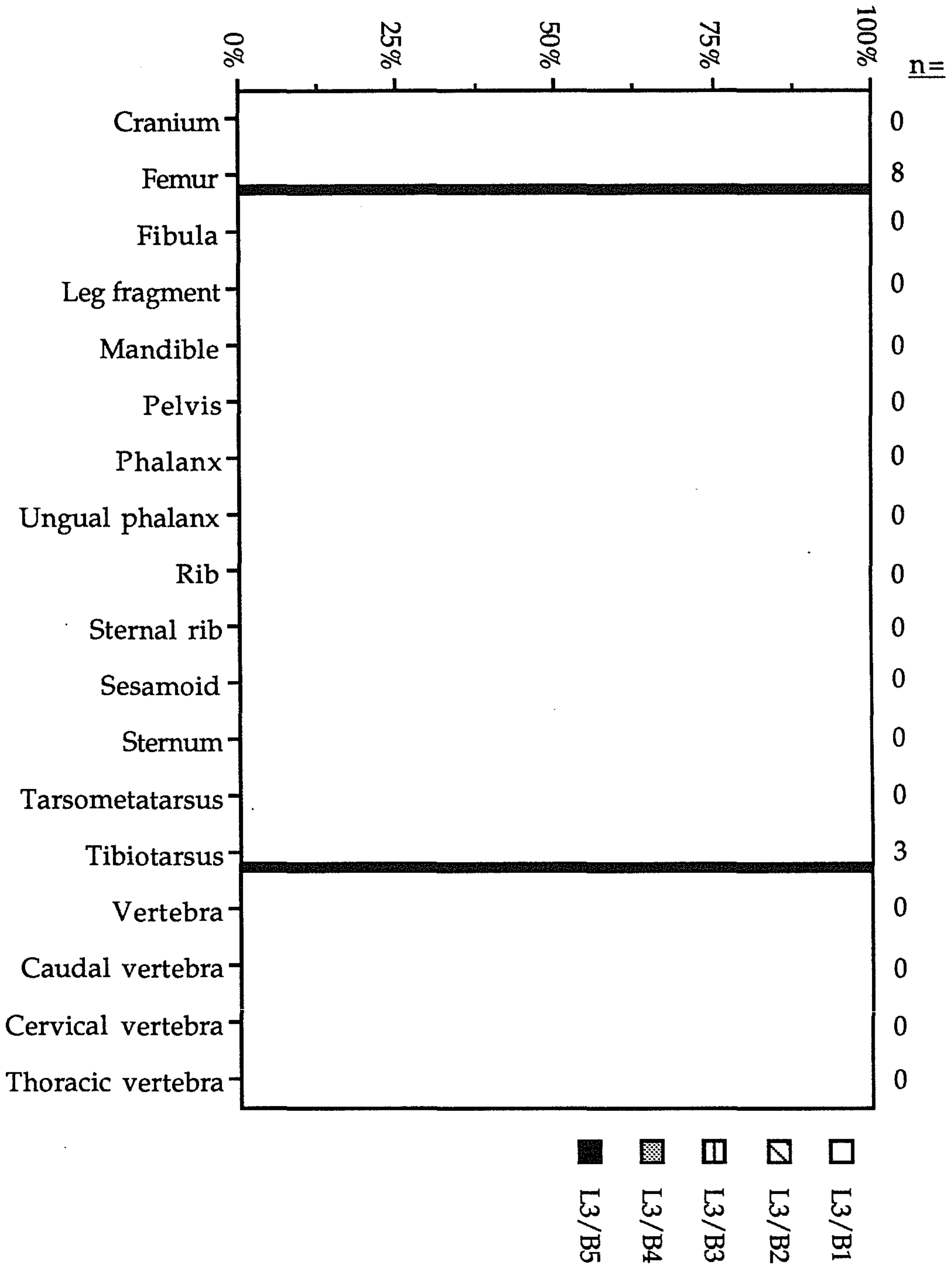


Figure 5.16 A breakdown of the burning stages recorded for each skeletal element of moa present in Layer 3 of Shag Mouth.

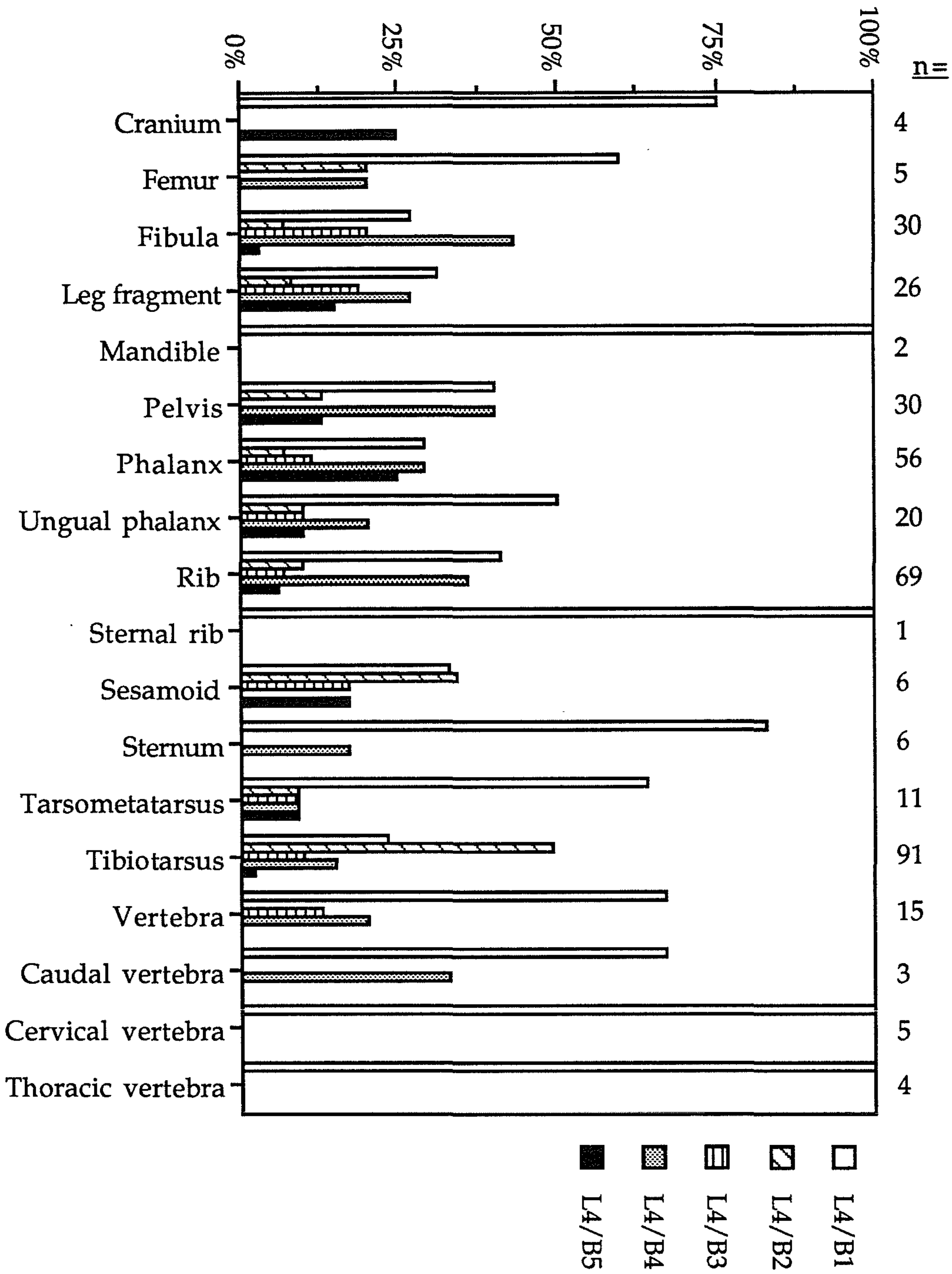


Figure 5.17 A breakdown of the burning stages recorded for each skeletal element of moa present in Layer 4 of Shag Mouth.

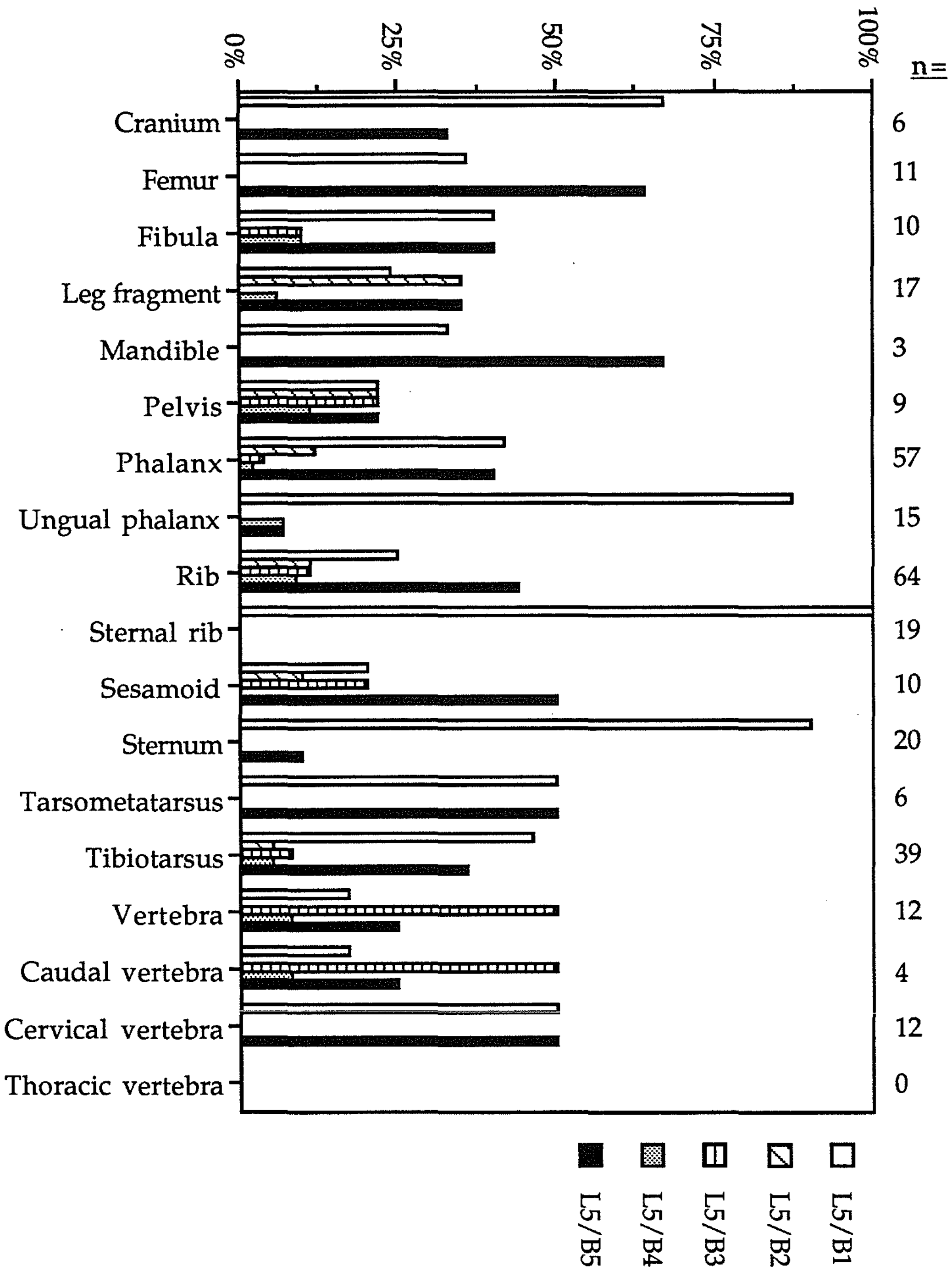


Figure 5.18 A breakdown of the burning stages recorded for each skeletal element of moa present in Layer 5 of Shag Mouth.

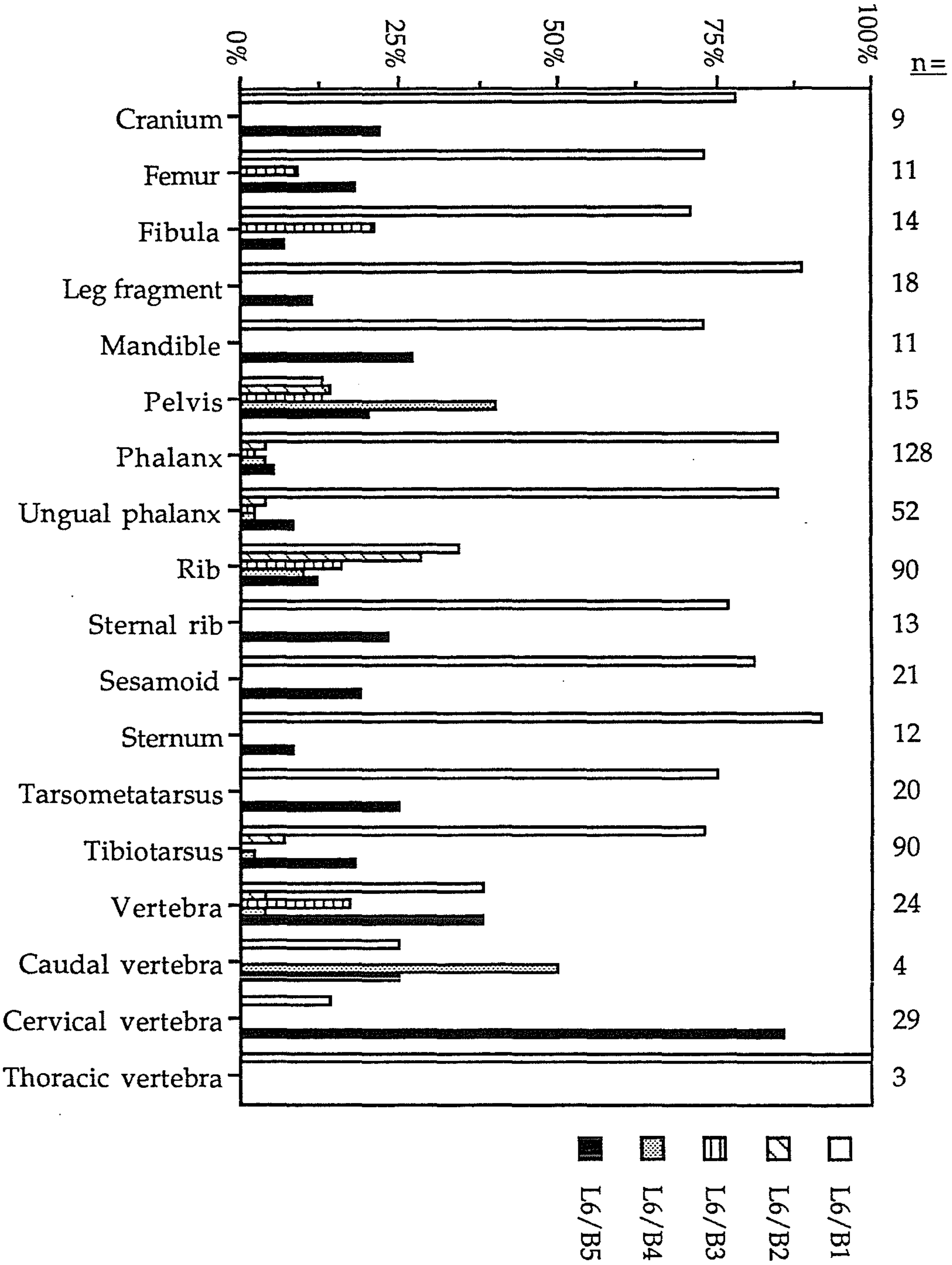


Figure 5.19 A breakdown of the burning stages recorded for each skeletal element of moa present in Layer 6 of Shag Mouth.

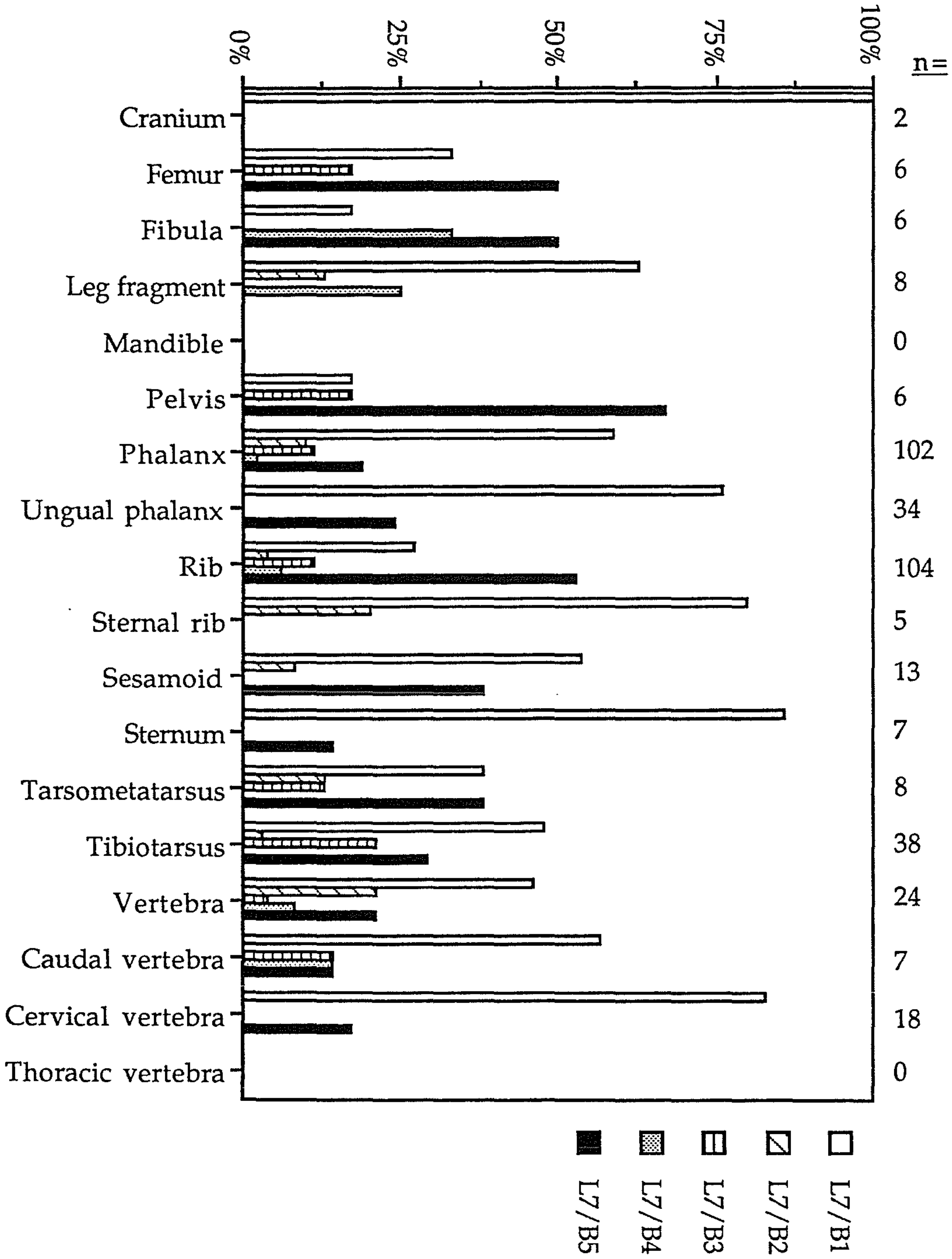


Figure 5.20 A breakdown of the burning stages recorded for each skeletal element of moa present in Layer 7 of Shag Mouth.

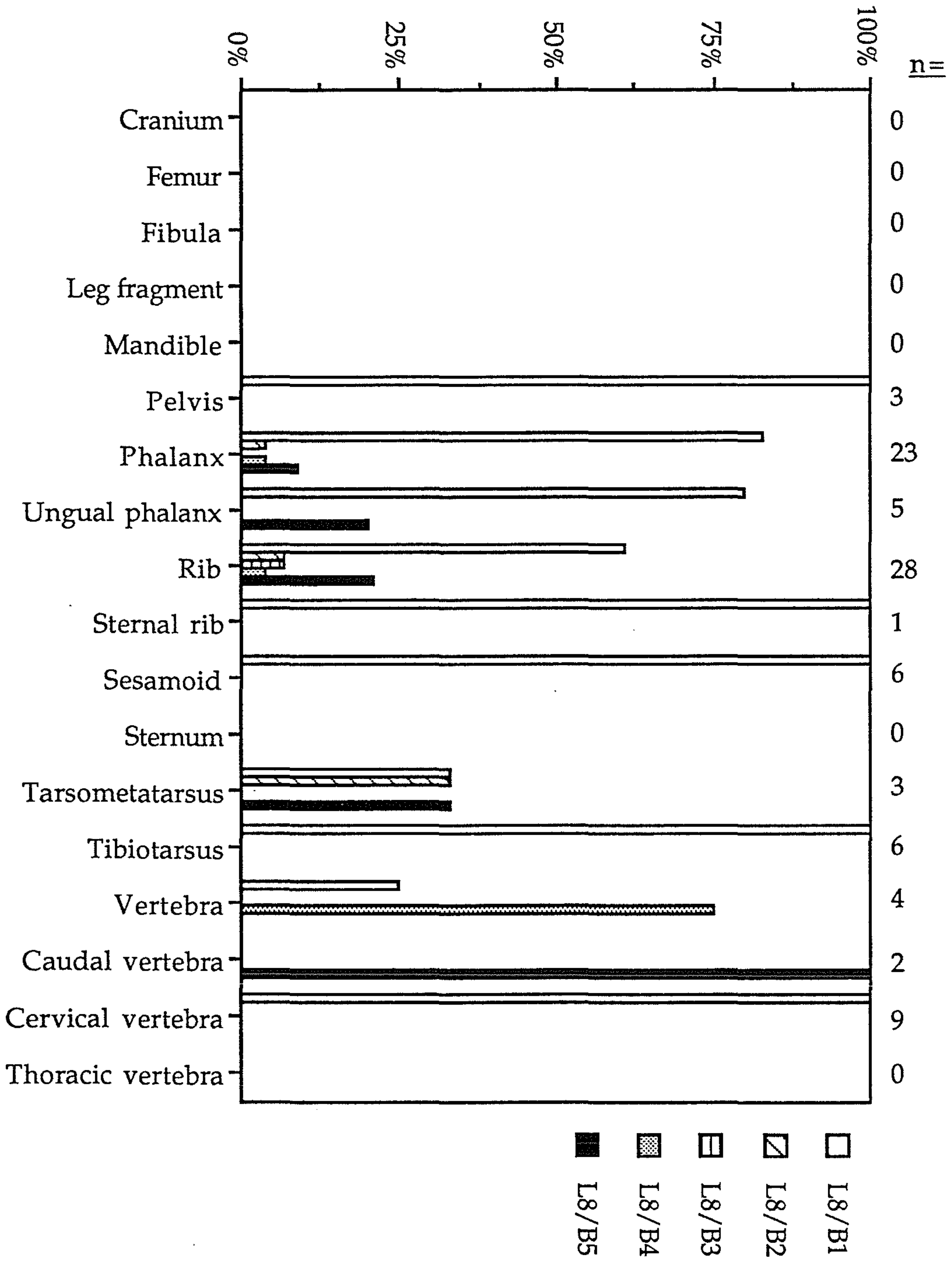


Figure 5.21 A breakdown of the burning stages recorded for each skeletal element of moa present in Layer 8 of Shag Mouth.

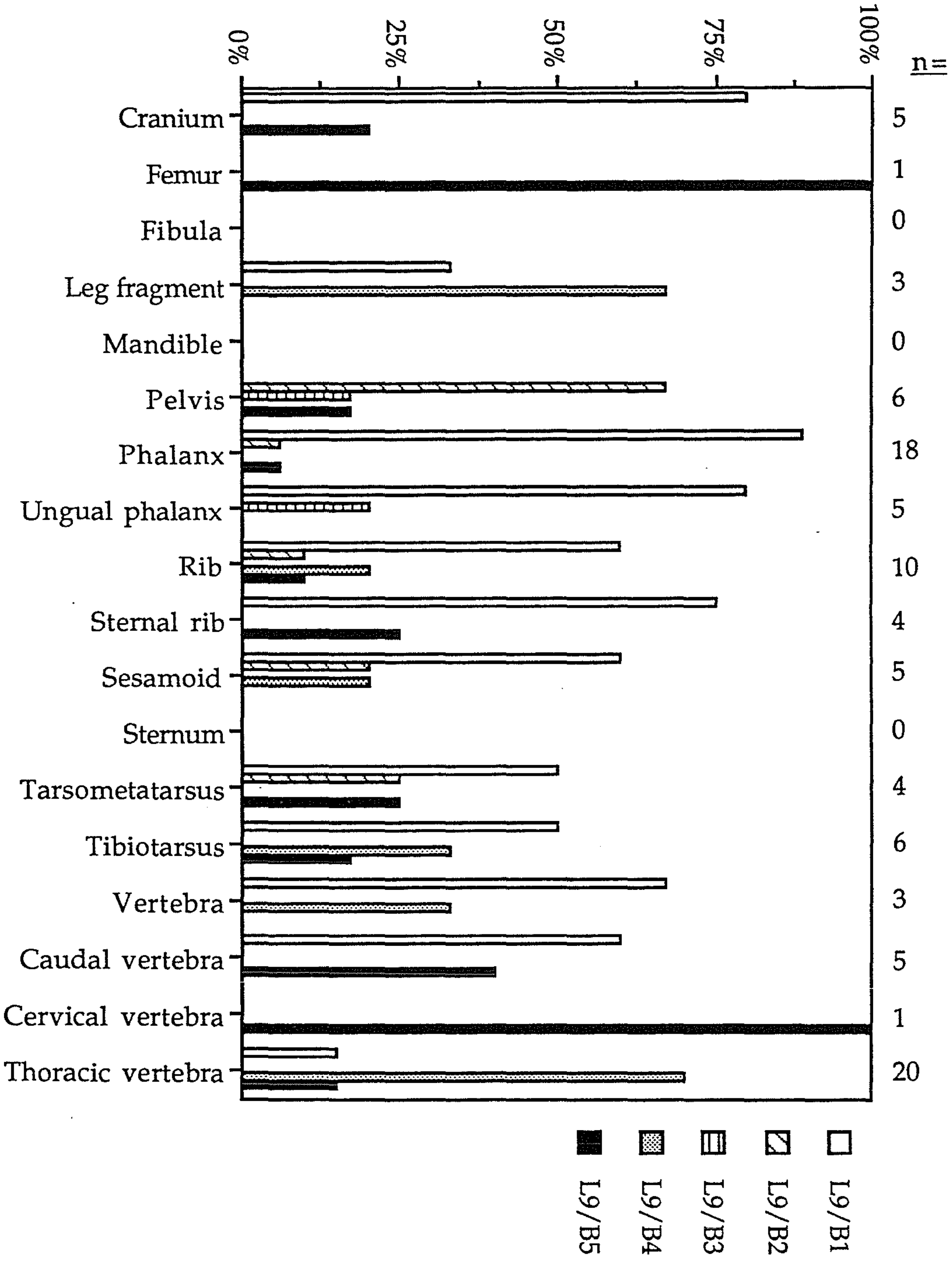


Figure 5.22 A breakdown of the burning stages recorded for each skeletal element of moa present in Layer 9 of Shag Mouth.

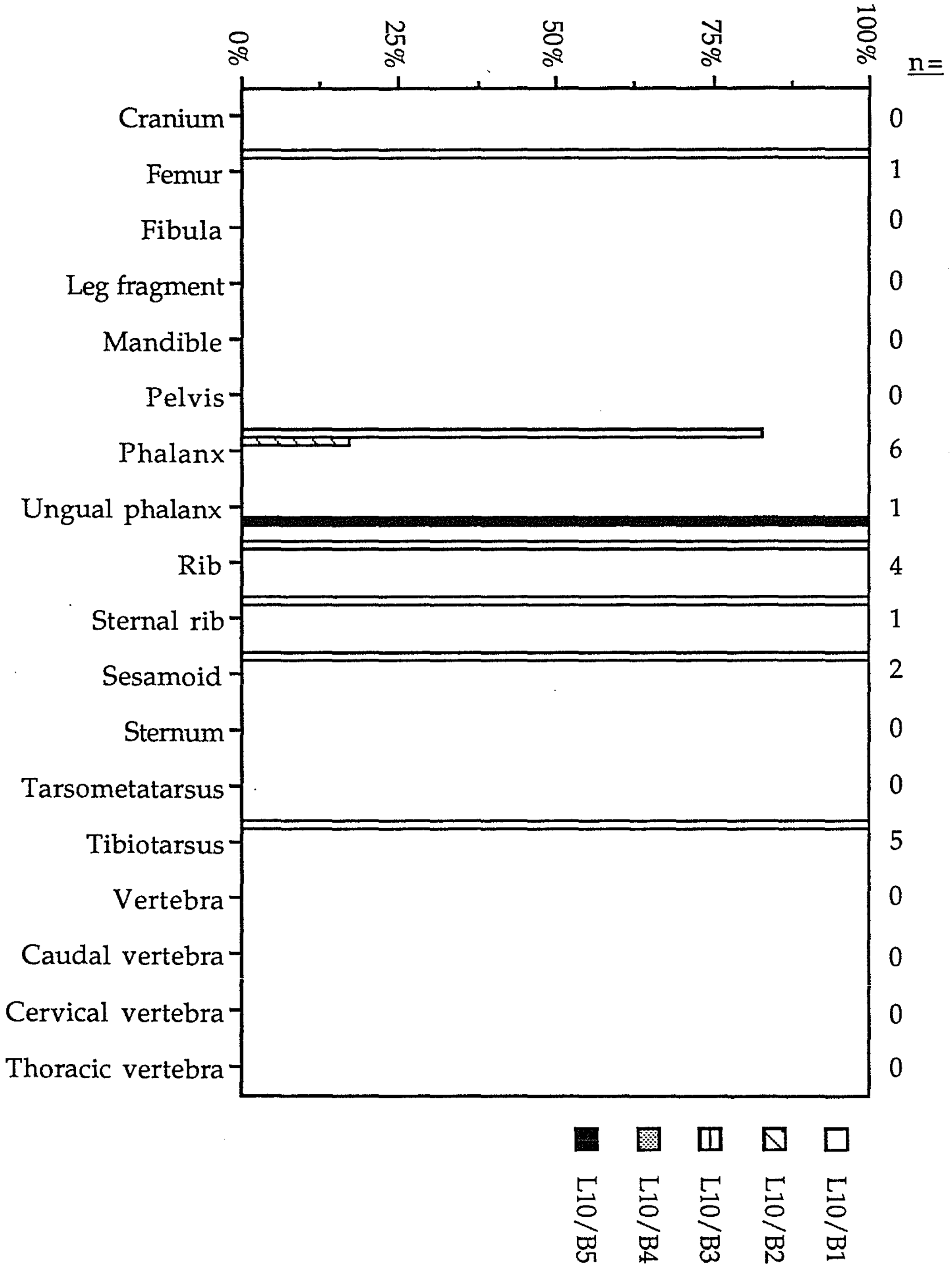


Figure 5.23 A breakdown of the burning stages recorded for each skeletal element of moa present in Layer 10 of Shag Mouth.

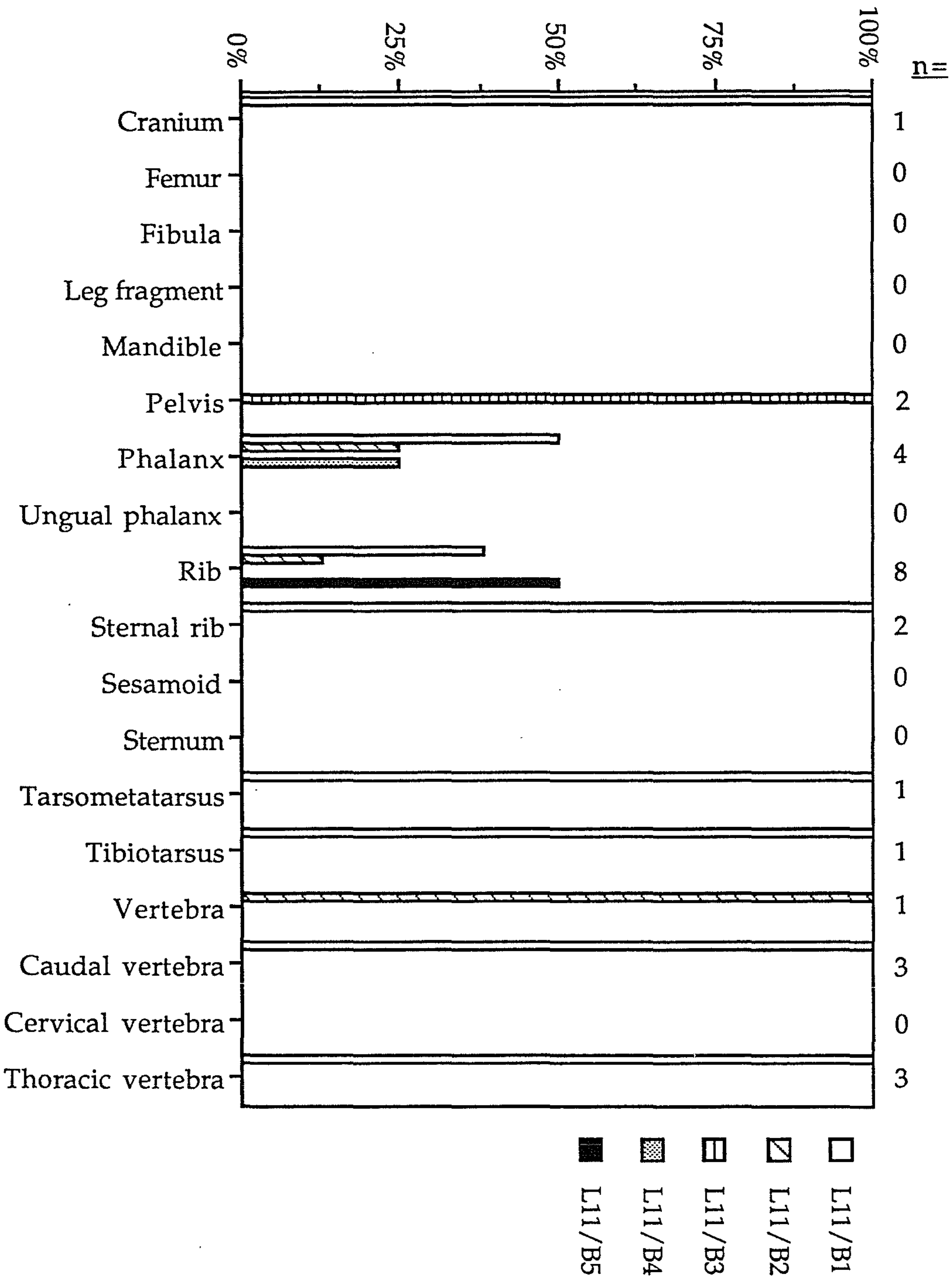


Figure 5.24 A breakdown of the burning stages recorded for each skeletal element of moa present in Layer 11 of Shag Mouth.

A further butchery unit can be proposed for the pelvis and thoracic vertebrae based on the burnt remains. Fifty-three percent of the thoracic vertebrae are unburnt, and this is almost identical to the pelvic fragments where 51% are unburnt. The fact that only 9% of the femoral fragments are burnt suggests that the femur was 'boned out' of the unit before the remainder was discarded on a fire.

In looking at the distribution of burning by layers (Appendix 3b), we find that, while most layers have approximately 80–100% of the bones in unburnt states (Layers 1, 3, 5–8 inclusive, and 10), the remainder show evidence of more concentrated burning. In Layer 2, 8% of the bone is charred (Stage 2), 9% falls into Stage 3, and 20% has been burnt white/grey (Stage 4), with similar patterns existing in Layers 4 and 9. An examination of the distribution of hearths recorded in the excavation shows that a large number were recorded in Layer 4, which may explain the higher percentage of burnt material, but in Layers 2 and 9 there were not nearly as many hearths present so the quantities of burnt material may be related to some other function.

Soil chemistry

A series of eight soil samples were taken from immediately to the north of the 1988 excavation, in order to investigate the possible relationship between the condition of the bones recovered in the excavation, and the soil environment in which they had been interred. Four small test holes ($40cm^2$) were dug, approximately 3m from the northern edge of the excavation, 2.5m apart in an east-west direction, and two soil samples were taken from each test hole — the first from 1m depth, and the second from 50cm depth. The results of the soil analysis are presented in Table 5.5. The pH falls in the range 6.77–8.35, which is near neutral to moderately alkaline (Blakemore et al. 1987:103), the moisture and organic content levels were very low, while the Ca levels were medium to very high. Thus, the soil matrix is very conducive to long-term survival of bones and the probable reason for the high calcium levels is due to the leaching of carbonates out of the bones and shells in the midden.

Table 5.5 Soil chemistry results for Shag Mouth.

Sample No.	Provenance	Date	pH	M.C. (%)	O.C. (%)	Base Cations (me%) Ca^{2+}(3)
91	Shag Mouth, Sample 1	12/10/90	7.21	0.25	0.08	14.05
92	Shag Mouth, Sample 2	"	7.23	0.18	0.09	24.44
93	Shag Mouth, Sample 3	"	6.77	0.22	0	4.01
94	Shag Mouth, Sample 4	"	6.85	0.42	0.12	> 30.00
95	Shag Mouth, Sample 5	"	8.08	0.15	0.11	7.09
96	Shag Mouth, Sample 6	"	8.25	0.23	0	12.31
97	Shag Mouth, Sample 7	"	8.35	0.25	0.08	7.45
98	Shag Mouth, Sample 8	"	8.02	0.22	0.07	10.33

Notes:
M.C. = moisture content
O.C. = organic content
Ca^{2+}(1) = initial result of calcium run
Ca^{2+}(2) = results for diluted calcium samples
Ca^{2+}(3) = recalibrated calcium results (see text for full explanation of these)

DISCUSSION

This chapter has investigated the application of a method for describing taphonomic variables (subsurface weathering and burning) evident in material recovered from an archaeological site. Using weathering scales developed by other workers, in different environments from that experienced in New Zealand, a scale was proposed for examining large faunal remains (moa and sea mammals) in the New Zealand context.

The application of this weathering scale to moa bones recovered from the Shag Mouth site, in North Otago, showed that, despite reservations due to the inherent subjectivity of this means of describing the relative condition of bones in the site, some interesting patterns emerged. The majority of the bone remains are in an unweathered to only slightly weathered condition (weathering stages 1 to 3) and few were in advanced stages of weathering. This would tend to suggest that not only was the material not lying exposed on the ground surface for any lengthy period, but the conditions within the site were very conducive to bone survival, as reflected in the soil chemistry results. In general, there was no difference recorded in the degree of weathering between elements traditionally recorded as being the more fragile, and the more robust elements of the leg. This would indicate that any difference in the proportions of each element recovered are not the result of taphonomic interactions, but reflect cultural practices at the site.

In an examination of the degree of burning evident in the remains, approximately three quarters of the bones were unburnt, with the remainder ranging from bones which were partially charred to those which were burnt white/grey in colour. It was also apparent from the distribution of burning that there was differential treatment of butchery units — with head and neck units, sternal units, and lower legs being discarded away from the main hearth/cooking areas. The pelvic units were evenly distributed between hearths and other areas of the site, while the main leg unit (the 'drumstick') also occurred as burnt fragments in a higher proportion than the average for the site. A more intensive breakdown of the weathering and burning organised by layer for each element is

8	-	-	-	67	50	67	-	-	-	-
	-	-	33	92	100	-	-	-	-	-
	-	-	-	63	42	83	-	-	-	-
	-	-	-	33	93	78	84	-	-	-
	-	-	-	38	63	59	63	36	40	38
	-	-	-	54	47	79	70	80	59	88
	67	50	78	-	57	70	56	63	40	100
1	-	-	29	100	33	39	50	84	33	100
	A									J

8	40	-	-	-	100	71	67	40	-	-
	-	25	43	11	60	72	36	-	100	-
	50	-	-	-	57	80	66	-	-	-
	25	34	50	-	50	100	28	-	67	-
	11	40	-	67	43	80	86	75	25	100
	38	67	34	67	40	36	50	-	40	-
	26	33	10	41	100	51	100	-	100	-
1	-	25	60	57	50	100	-	50	14	-
	A									J

Figure 5.25 Distribution of Stage 1 weathering (percentages) in the Shag Mouth excavation squares — Layer 6 (top) and Layer 7 (bottom). See text for further details.

given in Appendix 3a.

An initial intention had been to examine the intra-site spatial distribution of weathering to determine if patterns emerged between squares across the different layers. A close examination of the breakdown of the weathering present indicated, however, that it was essentially random — both the degree of weathering present and its distribution across any individual layer, and from one layer to the next. Figure 5.25 presents the distribution of Stage 1 weathering in both Layers 6 and 7. This weathering stage was chosen for presentation here as it was the most common in these two layers (60% in layer 6 and 43% in Layer 7) and occurred in the greatest number of squares. The causative agents responsible for this apparently random weathering probably include: rapid deflation and covering of the bones in a highly volatile dune system; the weathering scale is inherently wrong; or there are localised differences in chemical action due to the breakdown of organic matter as the soft tissues decomposed after the bones were deposited in the site. From personal experience while working on the excavation at this site, I am all too aware of the manner in which the dunes 'move' during a strong southerly storm and it is quite probable that the bones underwent several phases of exposure and recovering in their taphonomic life. None of the bones was recorded as exhibiting bleaching from long-term exposure to the sun, but periodic exposure on the surface of the dunes would have allowed weathering to continue. While it is unlikely that the weathering scale, *per se*, is wrong, it is quite possible that my relative unfamiliarity with this methodology did contribute somewhat to the creation of a random distribution of weathering stages. It is a very subjective scale, as described in Chapter 3, and this was the first collection I worked on with it, although Behrensmeyer (1978:153) felt that the method was relatively easy for observers to become accustomed to. The third agent, differential chemical action, is quite unlikely given the free-draining nature of the sand, and the fact that the majority of the bones were in Stage 3 or less suggests that there was relatively little post-burial chemical interaction occurring.

An examination of the prevalence of carnivore gnawing on the moa bones in the Shag Mouth site shows that the dogs and rats were not important taphonomic agents in this case. A total of nine bones were recorded with gnawing present, as against 2200 (excluding the eggshell and tracheal fragments) with no evidence present. The bone fragments were: a 'TMT' fragment in Layer 2 (Figure 5.26), two pelvic and three rib fragments in Layer 4, a fragment of 'RESIDUE' in Layer 5, and a 'FIB' and 'TT' fragment in Layer 6. The 'TMT' fragment had dog gnawing on the trochleae, while all the remaining fragments were rat gnawn.

Having shown the applicability of the method to the archaeological material, I now turn to examining large faunal remains from a series of sites around New Zealand, to determine whether taphonomic factors are playing a part in the survival of bone remains in our archaeological sites, and whether this can be measured in any manner. Obviously if the taphonomic variables prove to be important in bone survival in any archaeological site, it is highly likely that this will affect our interpretation of the prehistory of that site.

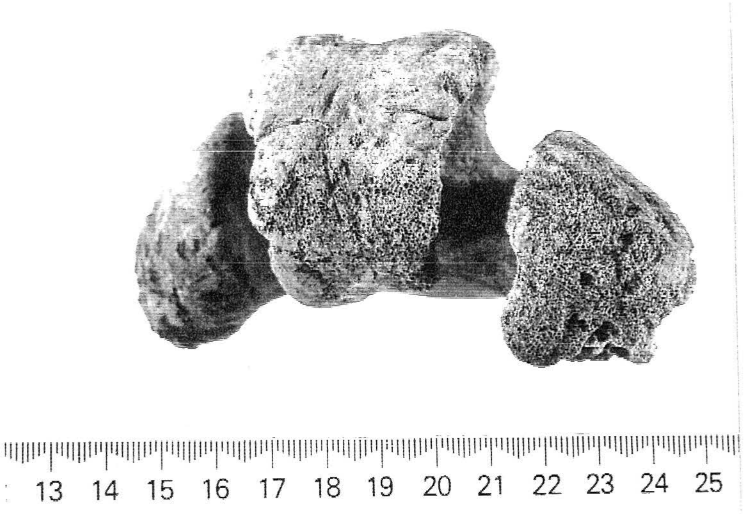


Figure 5.26 Dog gnawing on a moa distal tarsometatarsus, from Shag Mouth.

Chapter 6.

Taphonomy of New Zealand's big-game hunting — the sites.

The previous chapter described the application of the taphonomic analysis, via weathering and burning scales, to the archaeological case. In this and the following chapter I undertake a taphonomic reanalysis of big-game hunting sites from around New Zealand, by examining bone collections recovered during archaeological excavations at the sites from a taphonomic point of view, and comparing the results of this analysis with the geographical and climatic data and the chemistry of the burial matrix to see if there is any correlation. This chapter discusses the sites that were included in the analysis — with details of their history (radiocarbon dates are predominantly taken from Anderson (1991:Table 1), unless stated, and are given as the 95% confidence interval), the excavations and the bone material available, together with a description of the geography and climatic details of the local area (among other variables — Table 6.1) which were gathered during visits to each of the sites from which bone collections were being studied. The climatic data are taken from New Zealand Meteorological Service 30 year summaries (NZ Met. Service 1973) from climate stations around the country and, as much as possible, details are taken from the station closest to the archaeological site. During the visits to the various sites, soil samples were collected from approximately the same layer or depth as those from which the bone material was derived. The following chapter presents the results of the taphonomic and soil analysis for each site, and discusses the currently-held interpretations of the site, based on this analysis, to determine whether the analysis of bone collections from a purely taphonomic point of view alters the way in which we, as archaeologists, interpret New Zealand's prehistory.

The 18 sites, from which archaeological collections of big-game remains were studied, are listed in Table 6.2 and shown in Figure 6.1. A number of questions were asked in the course of the analysis — was there any difference between sites

Table 6.1 The range of physical, chemical and biotic variables which may provide supplementary information to that gained from soil samples.

Topography	Particle size and type	Plant cover and productivity
Parent material	CO_2 and O_2 status	Vegetation history
Moisture status	Temperature: range and variation	Animal presence
Soil pH	Rainfall: amount and distribution	Organic matter inputs and roots present

Table 6.2 Archaeological sites from which bone collections were studied.

Site Name	Site Number[1]	Matrix Type	Situation[2]	Bone Type[3]
Houhora	N6/4	sand	c	m, sm
Port Jackson	N35/88	sand	c	m, sm
Cross Creek	N40/260	sand	c	m, sm
Opito	N40/2	sand	c	m
Tairua	N44/2	sand	c	m, sm
Tokoroa	N75/1	soil	i	m
Whakamoenga	N94/7	soil	i	m
Opua	N118/96	soil	c	m, sm
Kaupokonui	N128/3	sand	c	m, sm
Waingongoro	N129/77	sand	c	m
Te Rangatapu	N129/78	sand	c	m
Tai Rua	S136/1	sand/soil	c	m
Owen's Ferry	S132/4	soil	i	m
Hawksburn	S133/5	soil	i	m
Coal Creek	S152/12	soil	i	m
Pounawea	S184/1	sand	c	m, sm
Papatowai	S184/5	sand	c	m, sm
Tiwai Point	S181/6	sand/soil	c	m, sm

Notes: 1 – site numbers are the for the old 1:63,360 map sheets, site numbers on the new metric maps are not available for the whole country

2 – 'c' = coastal, 'i'= inland

3 – 'm' = moa, 'sm' = sea mammal

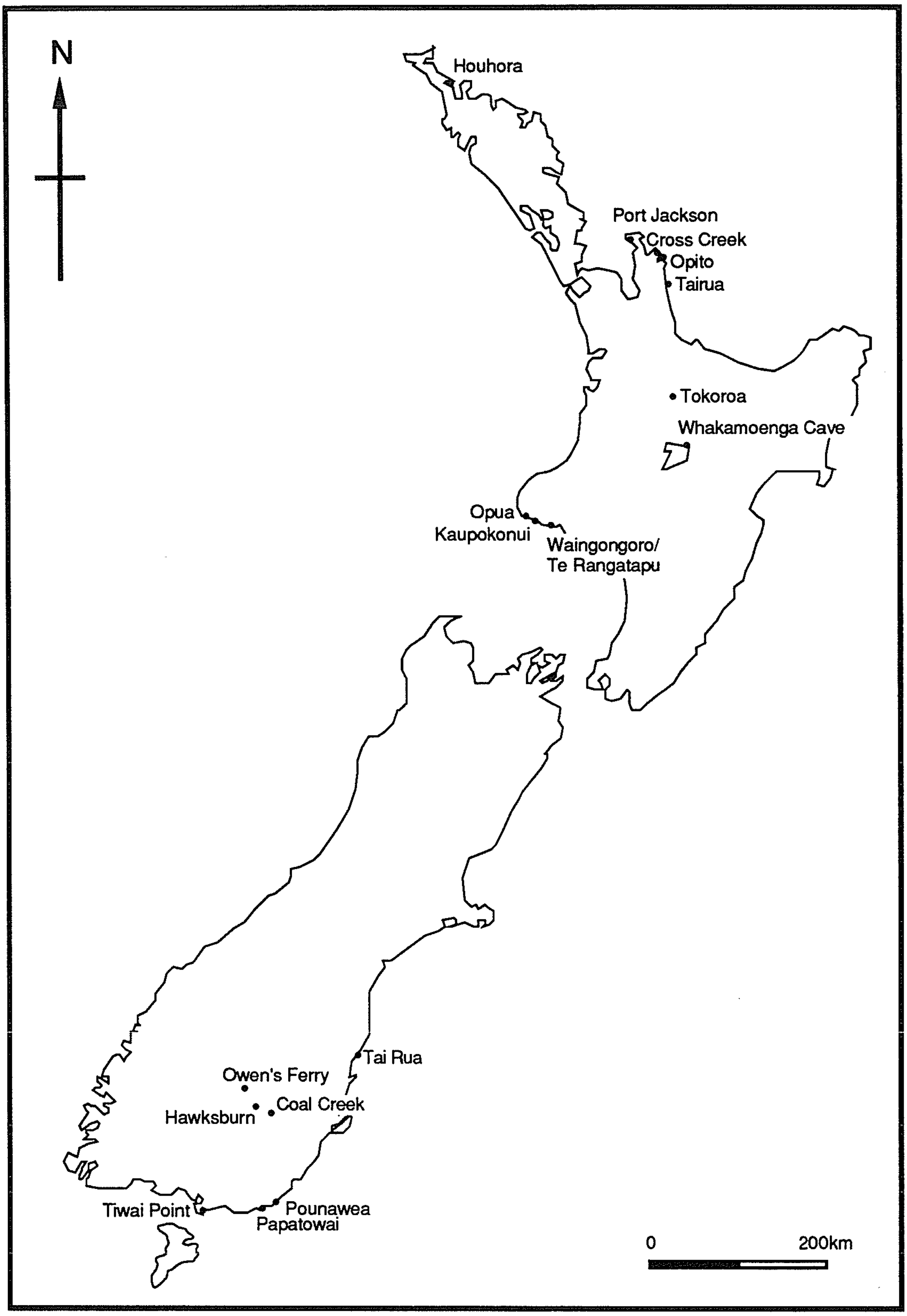


Figure 6.1 Map of New Zealand showing the big-game hunting sites which underwent a taphonomic re-analysis for this study.

on the coast and those inland; was there any difference between bones recovered from a soil matrix compared to those recovered from a sand matrix; and, was there any difference between species whose remains appeared in the bone collections, particularly between moas and sea mammals (especially fur seal which is one of the more common sea mammals recorded in New Zealand archaeological sites — see Smith (1985)) ?

THE ARCHAEOLOGICAL SITES

The following discussion of the archaeological sites whose moa and sea mammal bones form the basis of this analysis are presented in an approximate north-south order. For each site I provide details of when it was recorded; when, and to what extent, excavations were undertaken at the site; the age of the site; a brief overview of what faunal and artefactual material was recovered at the site; local geographical features, including soil type; and, climatic figures for the region. These latter features (local geography and climate) are considered to be important factors in the weathering process, as was shown in Chapter 3. In many cases the figures given in the NZ Met. Service (1973) tables are averages for the periods of 30 or more years, although this is dependent upon the age of the climate station.

Houhora (N6/4)

This site, at the mouth of Houhora Harbour, is the largest moa-hunting site in the northern North Island, at ca. 1.5 ha. It is situated on a low platform, slightly above high water mark, at the foot of Mount Camel. A large portion of the site has been removed by quarrying over the years (Figure 6.2), but in the undisturbed areas that remain a total of 250m^2 was excavated by Shawcross (1972). The occupation layers comprise 12 thin cultural layers separated by sterile sand, indicating intermittent occupations, between which wind blown sand covered exposed cultural material. The site dates to between A.D. 1154–1260 (op. cit.:605), although Anderson (1991:Table 1) gives a date in the range 1161–1450 A.D.

Activities which are represented on the site include: "butchering, particularly apparent on the earliest occupation floor, fish scaling and preparation, cooking, fishhook manufacture and maintenance of fishing gear, and manufacture of bone and ivory ornaments" (ibid). A large amount of faunal material was recovered during the excavation and consists of the bones of fish (snapper (*Chrysophrys auratus*) being the predominant species), seals (especially the NZ fur seal (*Arctocephalus forsteri*)), dolphins, dogs (*Canis familiaris*), rats (*Rattus exulans*) and moa. Shawcross (ibid:607) estimated an MNI of 50±10 moa in the excavated remains and that while there were a few skulls, vertebrae, ribs and pelvi indicating whole carcasses being returned to the site, the high number of upper leg elements suggests that "most of the moa were slaughtered and butchered at some distance from the settlement and ... only the meat covered upper-legs were thought worth bringing back. Virtually no tarso-metatarsi or phalanges have been ..." (ibid). In his re-analysis of the faunal remains from the point of view of meat-weight value to the inhabitants' diet, Smith (1985:290) calculated that only 6% of the total meat weight represented in the excavated faunal remains came from moas, while seals contributed 28% and fish 57%. Nichol's (1990:496) calculation of 8% for the total calorific value of moa meat in the diet, shows that they 'made only a minor contribution to the diet'.

On the landward side of the site, the natural base "is a clay and rock colluvium from Mount Camel, grading seawards into rolled gravels which are the materials being quarried. Above the natural base there is a deposit of dune sand, abutting the foot of the mountain and increasing in thickness seawards" (Shawcross 1972:605). The occupation layers lie within the dune sand and are capped by layers of blackened sand (containing oven-stones), agricultural soil and a modern soil (ibid).

There are no climate stations close to the site, but there is a site at both the north and south ends of the Aupori Peninsula for which details are given. At Te Paki Station, at the northern end of the Aupori Peninsula, the climatic figures are as follows: average annual rainfall 1448mm; temperatures – mean daily maximum 19.1°C, mean daily 15.2°C, mean daily minimum 11.2°C, mean daily grass minimum 9.4°C; and average annual sunshine hours of 2128 hours (NZ Met.

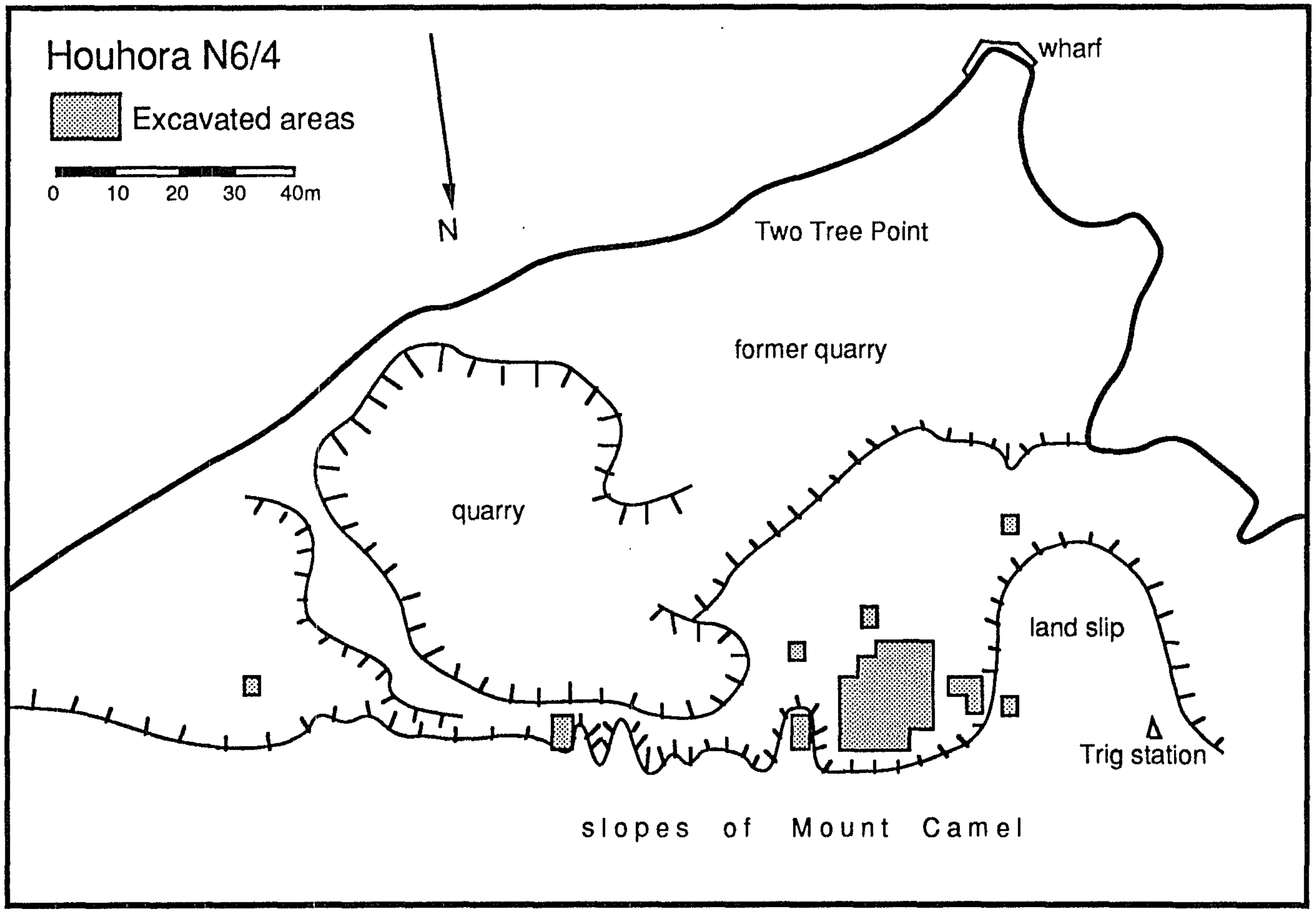


Figure 6.2 The site of Houhora showing the excavation areas (from Roe 1969:5).

Service 1973:5). At Kaitaia Aerodrome, at the southern end of the Aupori Peninsula, the climatic figures are as follows: average annual rainfall 1430mm, temperatures – mean daily maximum 19.4°C, mean daily 15.3°C, mean daily minimum 11.8°C, mean daily grass minimum 9.2°C; and average annual sunshine hours of 2108 hours (NZ Met. Service 1973:6).

The site was not revisited for the purposes of the current study, and there are no details furnished in the Soil Bulletin (1954) regarding the background chemistry of this strip of land. All the faunal remains from the excavations are now housed in the Anthropology Department, University of Auckland, where the current re-analysis was undertaken.

Port Jackson (N35/88)

This large sand-dune site at the northern tip of the Coromandel Peninsula was formerly deeply buried, until cattle grazing on and around the site in the 1970's exposed the midden which has subsequently undergone substantial wind deflation. Large amounts of material has been collected over the years from a number of sources – both surface collections by local residents and archaeologists and excavations, and this work and the later analysis of the remains are reported in a number of sources (Davidson 1979, Foster 1983, Keen and Descantes 1987). Two weeks field work in February 1981 involved the systematic surface collection of faunal and artefactual material from much of the 1ha site, and 47 one metre squares were also excavated. Faunal material recorded from the site includes moa, seal, rat, and bird bone including bones of now extinct species, such as crow (*Palaeocorax moriorum*), North Island takahe (*Porphyrio mantelli*) and huia (*Heteralocha acutirostris*). A number of features/activity areas were identified and included cooking areas, working floor and a 'shell mound' which consisted of a heavily concentrated area of shells with hangis and firescoops. In this mound five layers, separated by clean sand, were identified (Foley 1981). This period of fieldwork formed the basis of Foster's analysis (1983).

The site is found on the south side of a small stream which empties into the northern end of the beach at Port Jackson (Figures 6.3a, b and c). The dunes overlie rolling farmland and to the immediate rear (east) of the site the stream meanders have caused the creation of swampy areas. The main exposure of midden and cultural evidence lies across an exposed dune immediately beside the stream, and further shell midden can be found in exposed areas up to 400m southeast from the main deposit. While the distribution of shell material was quite widespread, most was in the northern part of the site where the mound of *in-situ* shell material was found (Foster 1983:21). The deflated nature of the site means that little contextual information is available for much of the faunal material, apart from that which was recovered during excavations, and the site is undated, although the style of artefacts recovered from the site is similar to that from other early Coromandel sites. In addition, the presence of moa bone from a number of species (Davidson 1979, Kooyman 1985) places it within the early settlement period and a moa bone collagen date for the site places occupation in the range 1288–1426 A.D. (Anderson 1991:Table 1).

The site falls within a band of young podzolic sands formed from eolian sands, reference number 23a, known as Pinaki sands (NZ Soil Bureau 1954:88). The soil immediately to the east of the site back to the foot of the hills is Kairanga alluvium, reference number 2, which is a silt and clay loam of recent origin (Figure 6.4). The pH of the Pinaki sands is 6.5, at 0.5" depth, and the level of exchangeable bases is 3.9me% for Ca and 1.7me% for Mg.

There are no climate stations actually situated on the Coromandel Peninsula — the only two are at the southern end of the peninsula, at Thames (on the west coast) and Tairua Forest (on the east coast). The climate figures for these two stations are given below but it must be cautioned that their immediate relevance to sites further up the Coromandel may be difficult to ascertain. At Thames, on the western side of the peninsula, the climatic figures are as follows: average annual rainfall 1278mm; temperatures – mean daily maximum 19.0°C, mean daily 14.8°C, mean daily minimum 10.6°C, mean daily grass minimum 8.0°C; and average annual sunshine hours of 2218 hours (NZ Met. Service 1973:12). At Tairua Forest, on the eastern side of the peninsula, the climatic figures are as

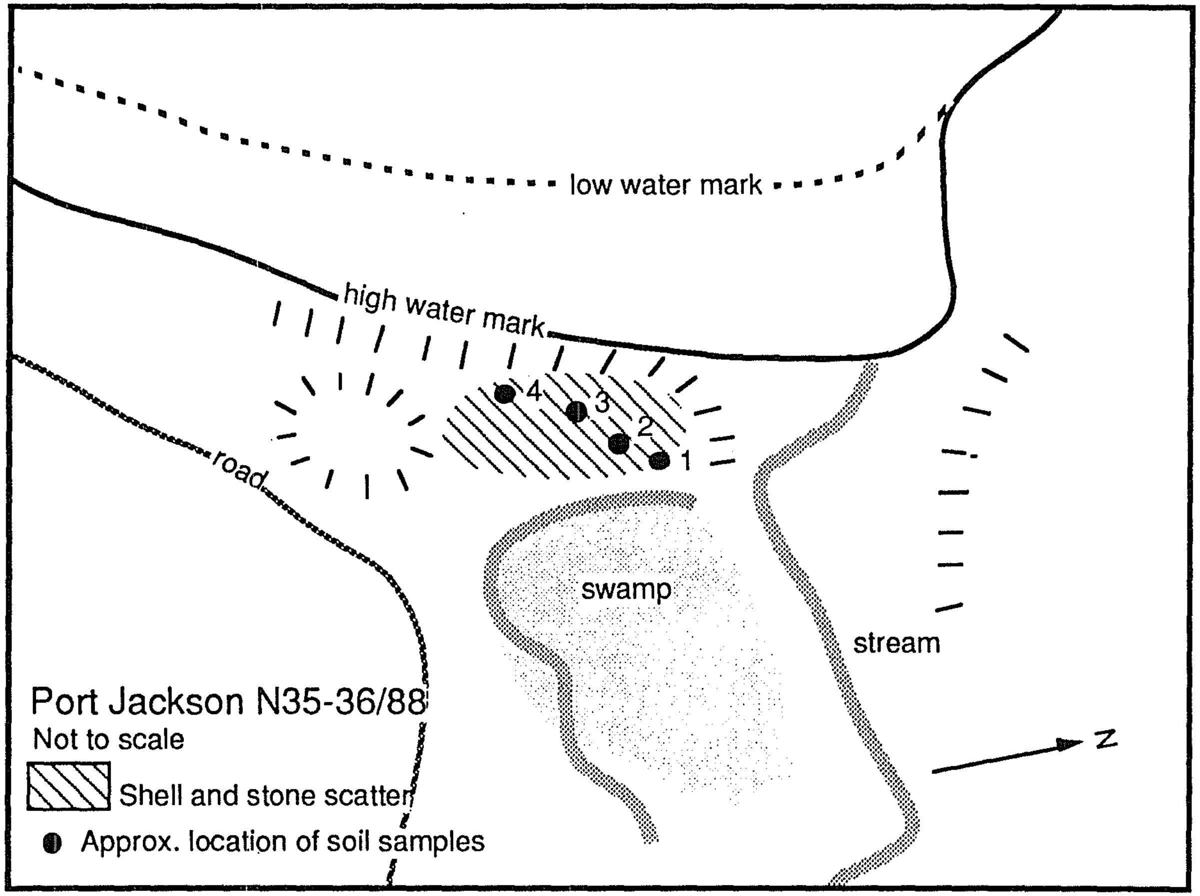


Figure 6.3a Port Jackson showing the position of the soil samples in relation to the archaeological site.

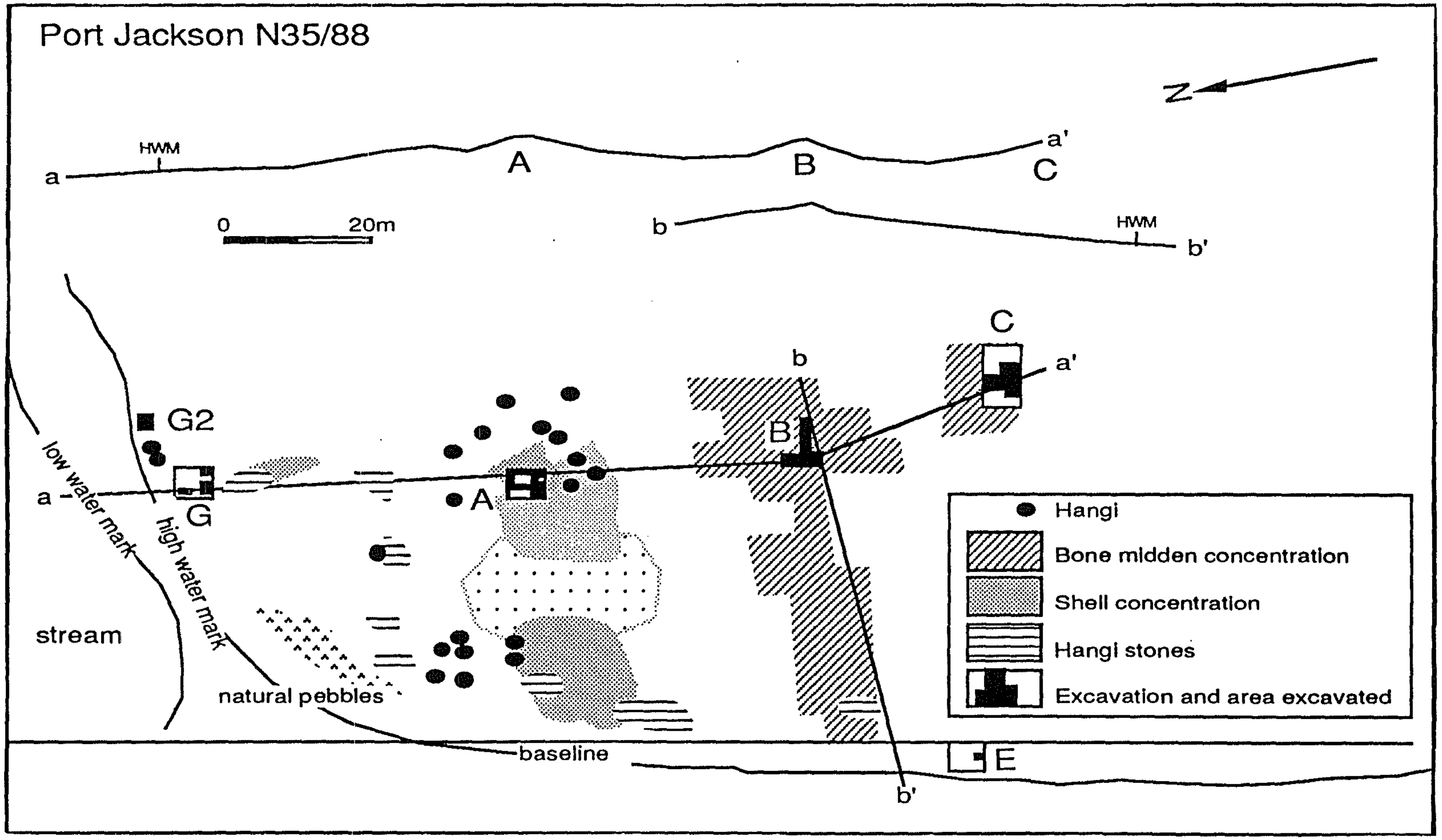


Figure 6.3b A more detailed site plan of Port Jackson (from Foster 1983).

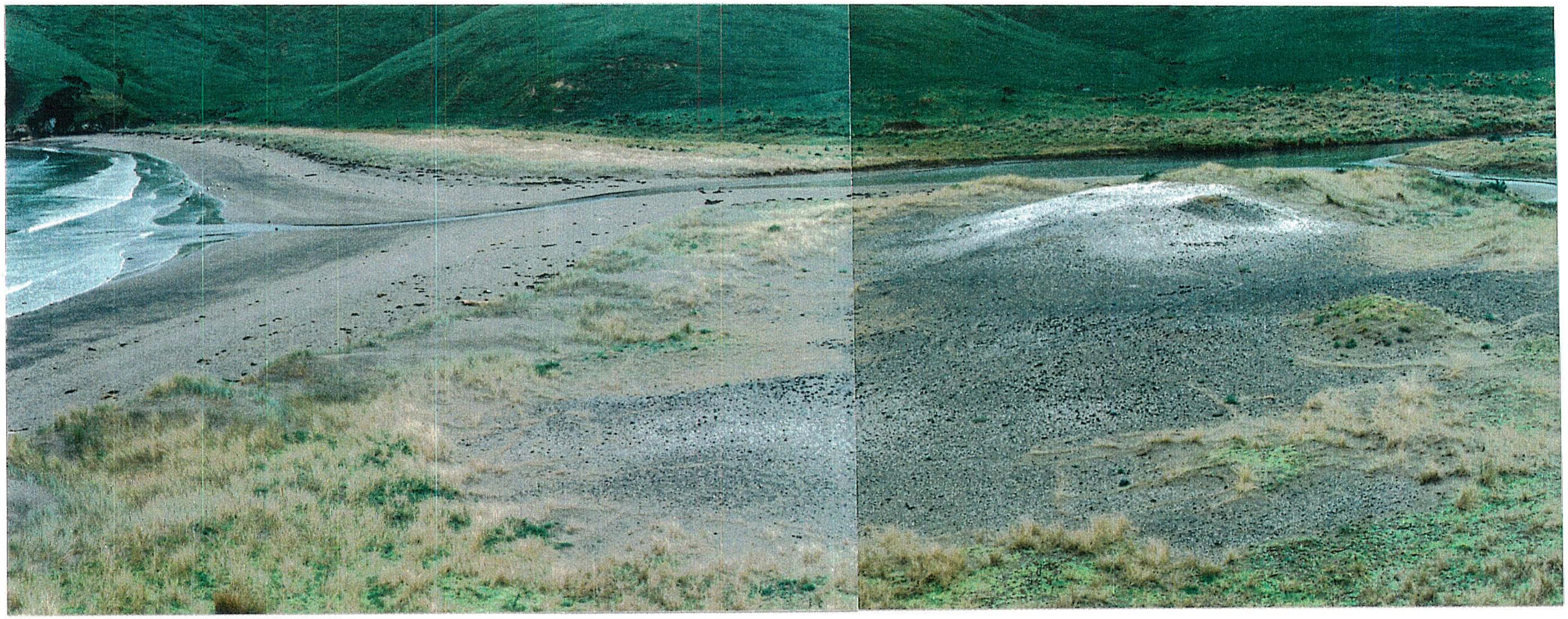


Figure 6.3c The deflated nature of the Port Jackson midden.

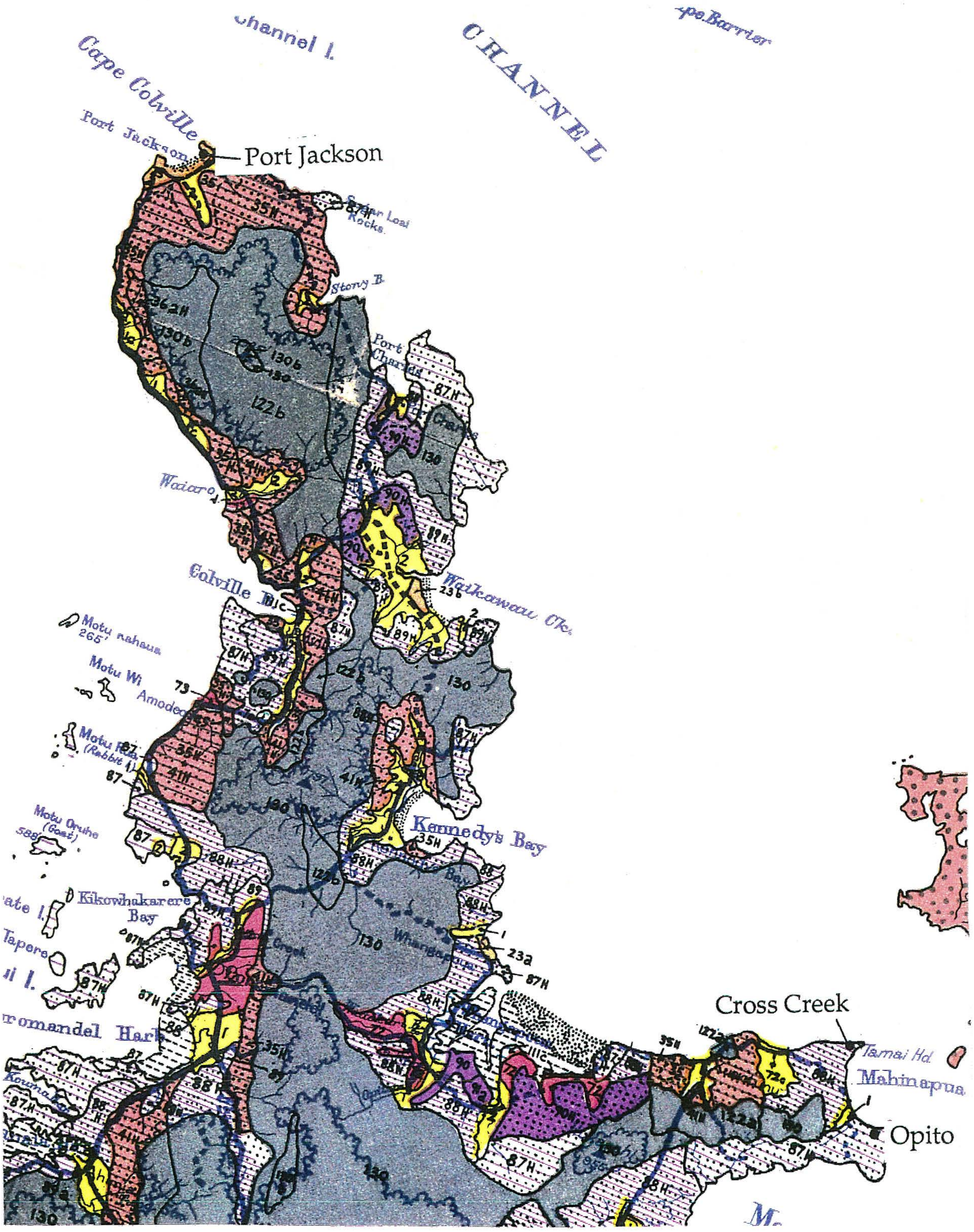


Figure 6.4 Soil map of part of the northern end of the Coromandel Peninsula showing the Port Jackson, Cross Creek and Opito sites in relation to local soil types (from N.Z. Soil Bureau 1954: Map 2).

follows: average annual rainfall 1823mm; temperatures – mean daily maximum 19.1°C, mean daily 14.2°C, mean daily minimum 9.8°C, and mean daily grass minimum 7.1°C (ibid).

The site was revisited for the current study during August 1990, and the following notes were taken. The site is now very wind deflated with very few bones to be found, although those which were seen on the surface of the dune included moa, snapper, bird (tui (*Prosthemadera novaeseelandiae*), kaka (*Nestor m. meridionalis*), blue penguin (*Eudyptula minor*), shag (*Phalacrocorax* sp.), and shearwater (*Puffinus* sp.)), and intrusive European species (cattle (*Bos taurus*) and sheep (*Ovis aries*)). Damage to the site has also occurred from motorbikes being ridden across it and people shifting the larger hangi stones around. The surface of the site now comprises shells, pebbles and hangi stones and very little of the northern extent has been covered by vegetation (marram grass, lupin, or pasture). The exposed bones tend to be bleached white and cracked indicating an unknown period, but probably several years, lying exposed on the surface. Some intact ovens with hangi stones and charcoal have recently been exposed.

A total of four soil samples was taken across the site, as shown on Figure 6.3a, and they are described in the following section. All samples were taken from the surface as this is where all the cultural material currently lies, and the purpose of the current study is to examine the effects of the soil matrix on bone survival. Details of the areas from which the samples derived are:

1) an area of exposed oven stones, and only a small amount of shell and bone.

2) a sample from the north side of the large mound with exposed shells, described by Foster (1983). The sample was taken from beside a small area of ovenstones, charcoal, and moa bones exposed on the side of the mound.

3) a sample from the western end of the same dune where there was a much

thinner scattering of cultural material.

4) the fourth sample was derived from a small deflated area of exposed shell midden, approximately 30m south of sample 3.

Cross Creek (N40/260)

This site was so named because it lies across the creek, to the south, from the famous Sarah's Gully Site (N40/9) excavated by Golson in the late 1950's (Golson 1959a, Green 1963). Excavations at Cross Creek by Brenda Sewell in 1983 revealed a deep site consisting of large concentrations of *Cellana denticulata* and other shell species, along with bones of fish, birds, seals, dogs and moa (Sewell 1984). Also recovered were a large number of bone (including moa bone) and stone (especially Tahanga basalt) artefacts. A number of hearths were recorded, along with storage pits and flaking floors (Figure 6.5) and the site was dated to the 15th century A.D (Sewell 1986). Sewell's north-south datum line pegs were still present so it was possible to trace the position of her excavations with a reasonable degree of confidence. The moa remains all came from a single individual in layer 8, at the bottom of the site, and Sewell (1984:84) suggests that it died on this spot, and its bones were subsequently used for industrial purposes. This is a response typical of many northern archaeologists who ascribe moa remains in sites to a subfossil origin, or suggest that the bones were imported for industrial purposes, rather than assuming they are the result of hunting (Anderson 1989a:111–112). Sewell's (1984) analysis of activity areas revealed that there was a continuity in the location of discrete areas, with similar activities occurring in the same portion of the site throughout the cultural sequence.

The site lies at the mouth of a small stream draining farmland which rises steeply behind the site (Sewell 1984:Figure 2). There is an area of swampy ground lying in the small basin formed by the surrounding terraces, through which the stream passes. The site is ca. 50m inland from the high water mark, spilling from the face of a high dune, the top of which is covered with marram and young pine trees (*Pinus radiata*). The underlying soil formation for this site is a semimature

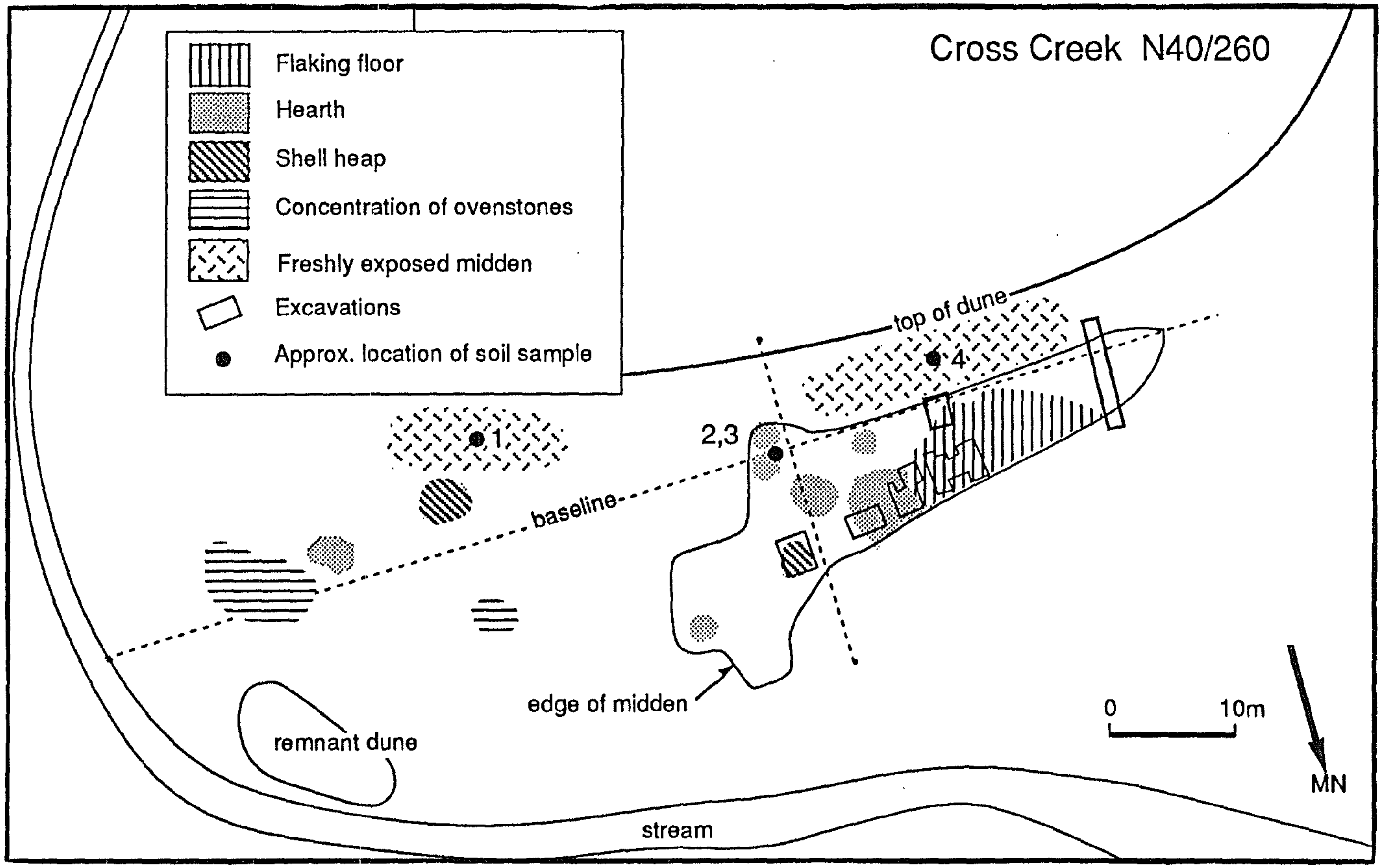


Figure 6.5 Cross Creek showing the position of the soil samples in relation to the archaeological site (based on Sewell 1984:Figures 4 and 5).

brown granular loam/clay of the Waitakere set, reference number 88H (NZ Soil Bureau 1954:156), with a base pH of 3.4 (at a depth of 0–3.5") and levels of exchangeable bases at 10.7me% for Ca and 9.7me% for Mg. Climatic data for the Coromandel Peninsula is discussed above under the Port Jackson site.

The site was revisited in August 1990 at which time there was considerable ongoing damage from cattle which were grazing on the flats around the stream, and had to be chased off before I could get to the site to take soil samples. There were many hoofprints across the site and these, in addition to the wind, had ensured that the face of the dunes had blown back and large areas of midden had been exposed and stirred up, especially a large concentration of *Cellana denticulata* towards the eastern end. Pine trees are growing on the top of the dune and are helping to stabilise much of the dune system. Four soil samples were taken from the site, shown on Figure 6.5, and are as follows:

1) a sample taken from 10cm below the present ground surface in an area where there is a large amount of midden exposed (including fish, dog, bird, paua (*Haliotis iris*), seal, shellfish). The bone material was in an excellent condition suggesting that it had not spent long on the ground surface exposed to the elements, although some had a partially bleached appearance.

2) a sample taken from 50cm below the surface, 1m east of the central datum peg of Sewell's excavation grid.

3) a sample taken from 1m below the surface, 1m east of the central datum peg of Sewell's excavation grid.

4) a sample taken from 10cm below the surface in an area immediately upslope from Sewell's excavation where there is now a large exposed area of shell, hangi stones, and occasional bones.

Opito (N40/2)

Known variously as Parker's Midden and Pohutukawa Flaking Floor Midden, this site saw a series of small excavations over a long period of time (Davidson 1979). The names derive, respectively, from the surface collecting of Parker, and the large areas of stone flaking which were revealed beneath and around a large pohutukawa (Figure 6.6a and b). The early excavations by Jolly and Green on the surface of the dune, 15–20 feet above sea level, revealed cultural material to a depth of 12–14" in a dark brown sand matrix, and containing faunal remains (shell, fish and moa bone) and large quantities of stone material (including basalt and obsidian) (Jolly and Green 1962, Green 1963, Murdock and Jolly 1967, Jolly and Murdock 1973). While most of the excavations were probably carried out to recover artefacts, most also produced moa bone (Jolly and Murdock 1973:71, Scarlett 1974, Davidson 1979:Table 12.1). Smith (1985:257) analysed the meat weight value of the Jolly and Murdock (1973) assemblage and calculated that the moa contributed about 25% of the total meat in the midden. Nichol (1990:499–500) rejects this figure as being far too high, in favour of a figure of 5%, and argues that the fragmentary nature of the moa bone, coupled with the small size of the excavation, means too much reliance is placed on the bone fragments (Nichol calls this the "MNI=1 syndrome" (ibid)) with little recognition of the value of shellfish and fish.

The site is on the eastern side of a small stream which empties into the southern end of Opito Bay, approximately 500m south of the houses. There is a large pohutukawa growing on the site, and there is another on the opposite side of the stream. The dunes are at present 6–7m above high water mark and the distance from the sea would vary with the amount of sand dumped on the flat level beach by the prevailing weather patterns. Approximately 100m west along the beach is an outcrop of dense homogeneous basalt, exposed at the base of the hill, which is being broken up by the action of the sea. The stream drains a swampy area behind the site which is surrounded by farmland. The soil base is an immature brown granular loam of the Awapuku set (reference number 87H) formed from andesitic basalt and andesite (NZ Soil Bureau 1954:156). At a depth of 0–5" it has a pH of 6.9 and exchangeable base levels of 7.5me% for Ca and 5.0

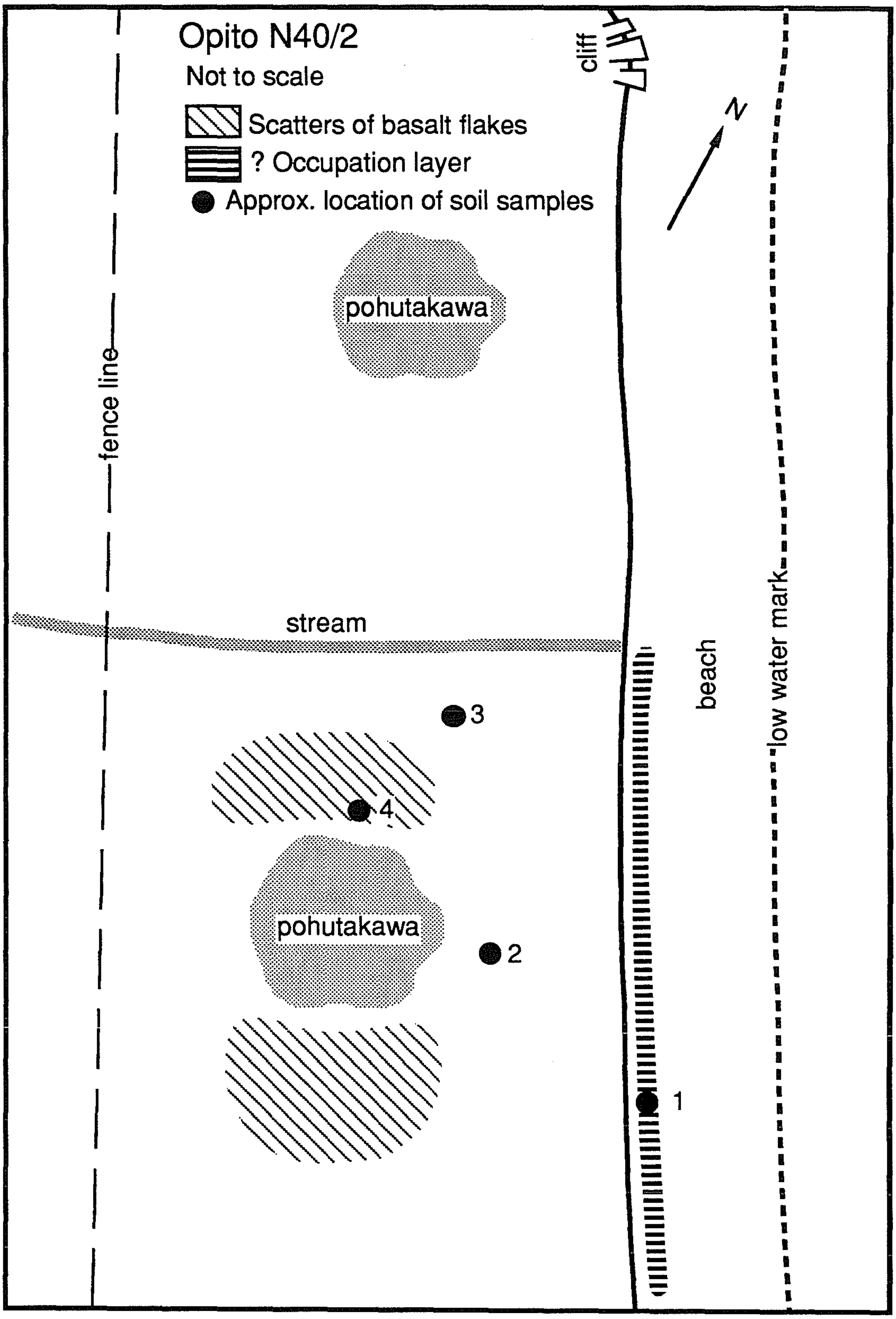


Figure 6.6a The Opito (N40/2) site, showing the approximate position of the soil samples in relation to the archaeological features.

Figure 6.6b The Opito site, showing the pohutukawa on the crest of the dune and the black band of probable cultural material exposed at the base of the dune.

me% for Mg. Climatic data for the Coromandel Peninsula is discussed above under the Port Jackson site.

A report, added to the site record form, by A. Calder in December 1972 records that the site was being extensively damaged through the actions of fossickers and stock and other traffic passing through into the neighbouring paddocks. When I visited the site, in August 1990, most of the high dunes were covered in vegetation (grass and marram) which provided protection from the weather and stabilised the dune system. There did not appear to be much ongoing damage to the site at that time. Along the foot of the dunes, running from the stream for about 200m in a southeast direction, is an exposed thick black band which may represent a living floor. There was no immediate sign of any bone or other cultural material. Behind this the dunes slope back to a maximum height of about 7m above the beach. Along the face of the dune are scatters of shell, hangi stones and basalt flakes, with two intact hangi exposed in section.

Around the pohutukawa tree are exposed areas of basalt flakes, amongst which I found two broken adze preforms. The slope from the pohutukawa down to the stream has midden and flakes eroding from it. Four soil samples were taken for analysis:

1) a sample from the black band which runs along the base of the dunes.

2) a sample taken 1m above sample 1 from an area of brownish sand which had a band of cultural material in the form basalt flakes and large shells running through it.

3) a sample from the brown granular sand beside the stream which has a small amount of shell in it.

4) a sample from the top of the dune, 5m west of the pohutukawa, in an area where there is a large quantity of basalt flakes and some shell midden.

Tairua (N44/2)

This site saw a number of excavations in 1958, 1959 and 1964 (Yaldwyn 1959, Smart and Green 1962, Green 1964) with both the artefacts (Green 1967, Jones 1973) and faunal remains (Scarlett 1974, Rowland 1975, 1977a, 1977b, Smith 1978) being intensively studied. The site consisted of two separate layers — an earlier Archaic layer in which the midden consisted of moa and seal bone, along with birds and shellfish (of a quite different nature to more recent middens in the area (Smart and Green 1962:245)), a later layer of predominantly pipi and cockle shell and, in places, a black, greasy matrix. There were quite distinct activity areas (flaking floor, cooking and midden disposal areas) recorded in the site and large quantities of artefactual remains, including a pearl shell fishing lure. The two dates from the site, one in the 11th–13th centuries and the other in the 15th century, were rejected by Anderson (1991:783) because of their great variation even though they derive from the same stratigraphic position. The collection of moa material from Tairua represents a range of species with taxonomic revisions altering the species list given by Davidson (1979:Table 12.1 – see Nichol 1990:503). Smith's (1985:244) analysis of the meat weight values from the site was based on the presence of nine individuals from four species, although Rowland (1977) recognized 11 individuals, which between them contributed about 24% of the total meat weight value. Again, Nichol (1990:503) argues this figure might be too high given that only one individual was complete, with "almost all the other birds [being] represented by single legs".

The site is located on the northern side of Tairua Harbour on the south-east coast of the Coromandel Peninsula. At the mouth of the harbour is a small rock island, locally known as Paku Island, which is connected to the hill country at the head of the head by a low-lying sand tombolo approximately two kilometres long. The site is on the harbour side of the tombolo about 100m from the base of Paku, and is landmarked by a solitary pohutukawa growing over the site.

At the Tairua Forest the climatic figures are as follows: average annual rainfall 1823mm; temperatures – mean daily maximum 19.1°C, mean daily 14.2°C, mean daily minimum 9.8°C, and mean daily grass minimum 7.1°C (NZ Met. Service

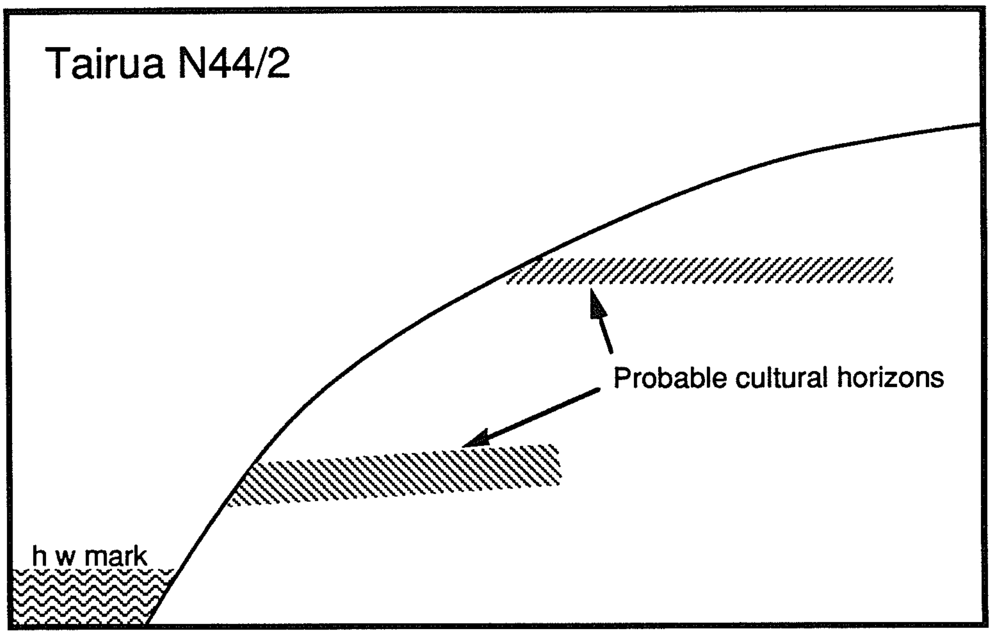


Figure 6.7a The stratigraphy of the remains of the Tairua site (see text for details).

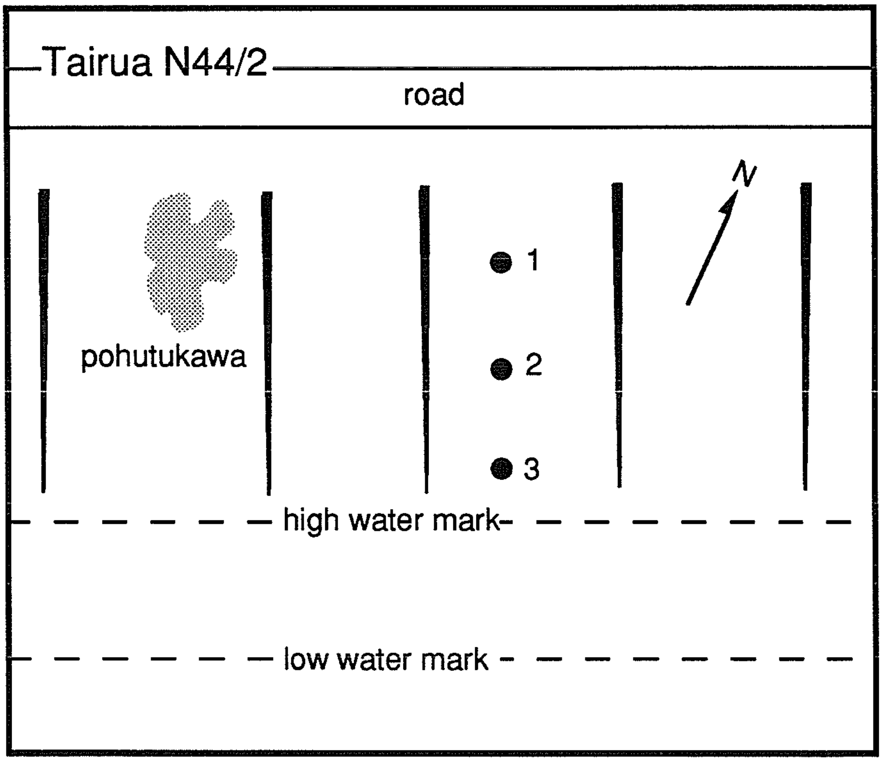


Figure 6.7b The location of the three soil samples in relation to the remaining Tairua midden.

1973:12).

The dune in which the site is situated formerly protruded out into the harbour, but when I visited the site in August 1990 the dune had eroded well back and was running parallel with the road. The pohutukawa was still present at the western end of the site, and shells were cascading down the face of the dune for a distance of about 13m in length and 3.5m height. Some grass is growing in places along the face of the dune acting to stabilise the surface. The only cultural material immediately visible was shells and a few hangi stones, with the shells eroding from two layers (Figure 6.7a) which may correspond with the two cultural horizons identified by Smart and Green (1962:247–248, Figure 4). The upper layer appeared to be the source for most of the eroding shells and hangi stones; the lower layer was 1m above high water mark at the base of the dune.

Three soil samples were taken from various places down the face of the dune (Figure 6.7b) with sample 3 taken from the lower shell layer. In each instance, the outer 10cm of sand and exposed midden was cleared out of the way before the sample was taken.

Tokoroa (N75/1)

The Tokoroa site was excavated in 1961 by Rod Cook and then again in 1962 by a small group under the direction of Roger Green (Cook and Green 1962, Law 1973) and is unique in being one of only two moa-hunting sites in the inland North Island. The rather limited excavations revealed a few shallow ovens, a series of postholes in no apparent pattern, and a shallow drain. The only artefacts recovered in the excavation were 510 flakes of obsidian (Morwood 1974), in addition to the large obsidian core and six adzes which the landowner had found while ploughing the site (Law 1973:156–159). Moa bone, representing several individuals of *Euryapteryx exilis* (Scarlett 1974) was the only faunal material found and although leg bone fragments predominated, the presence of pelvic fragments and phalanges showed that this bone was food refuse and not sub-fossil bone being utilised for industrial purposes (Law 1973:156).

The site was located on the south side of a branch of the Matarawa Stream, in a bend in the stream and just downstream from a 2m high concrete weir, half a mile west of the outskirts of Tokoroa. When the site was recorded in November 1962 it had been ploughed to a depth of 6–8" and a European drain had been cut through the centre of the site to a depth of five feet. Both these activities would have substantially disrupted any intact occupation material. The presence of moa in this site, and other evidence cited by Law (1973:160–162), shows that moa and forest species successfully recolonised the central North Island after the Taupo eruptions of the 2nd century AD.

The site is located within an area of immature primary podzolic soils, classed as Taupo sandy silts, of the Taupo suite (reference number 18) which have developed on top of the Taupo ash showers (NZ Soil Bureau 1954:78). Also present in this regions are pockets of Tokoroa sandy silts (reference number 18c), in the same Taupo suite, which have formed from water-sorted Taupo ash (ibid:80). The chemistry of these two soils is similar, with pH levels of 5.7 and 5.6–6.5 respectively, and base cation levels of 4.4me% for Ca and 1.6me% for Mg for the Taupo silts, and Ca levels of 3.1me% at 0–2" and 1.0me% at 3–6" depth and Mg levels of 0.8me% and 0.4me% at the same depths, for the Tokoroa silts (op. cit.:195–196).

The closest climate station to Tokoroa is situated at Arapuni Power station on the Waikato River, where the climatic figures are as follows: average annual rainfall 1417mm; temperatures – mean daily maximum 18.9°C, mean daily 13.2°C, mean daily minimum 8.0°C, and mean daily grass minimum 5.7°C (NZ Met. Service 1973:25).

When I revisited the site in August of 1990, there had been quite substantial changes to the area. The growth in population of Tokoroa had seen an expansion in housing out to the west and I had quite a lot of difficulty in relocating the site. Davey's farm, on which the site was originally recorded, no longer exists, the area has now been subdivided and the land along the south side of the stream has been turned into a park. In the latter process the land has all been ploughed and smoothed and the ignimbrite outcrop, shown on the drawings included with the

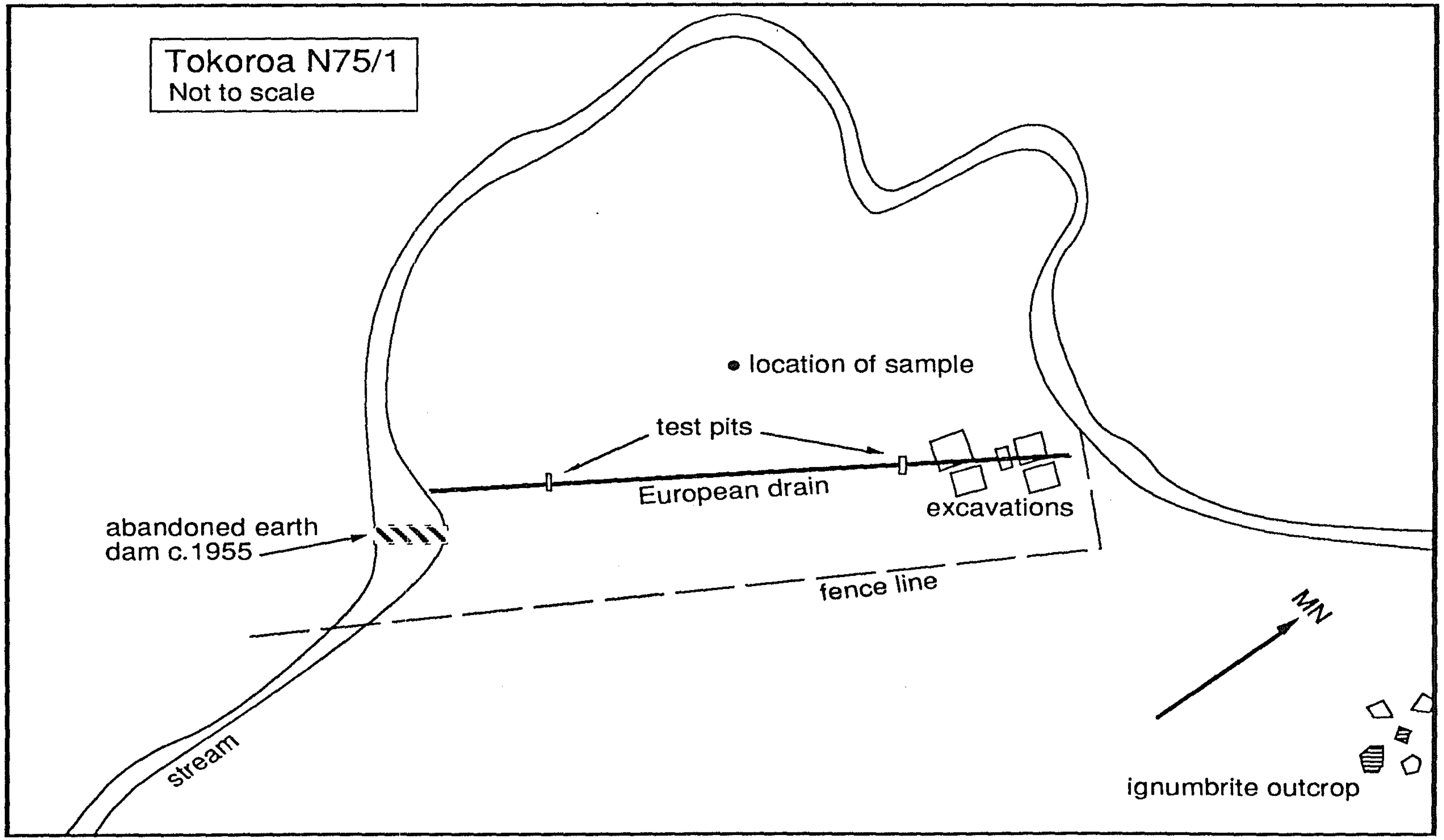


Figure 6.8 The original site drawing of Tokoroa showing the location of the soil sample in relation to the features.

site record form, has been removed. No evidence remains of the European drain and this was possibly filled in when the park area was developed. An old dam/weir still exists which may be the one referred to by Law (1973:150) but the stream downstream from here has altered in the past 30 years making it very difficult to orientate oneself in relation to the original site drawings.

Given the difficulty in relocating the site, I took three samples from the back of the river terrace beside the stream, where it began to slope up to the playing fields, in a position I felt was close to where the original site had been. The ground had been ploughed and the three samples were taken from the same hole at depths of 30cm, 50cm and 1m respectively. While I was taking the samples a passing local informed me that when they formed the park and rugby fields 10 years ago the whole area had been bulldozed and a hummock with large rocks on it had been removed. The latter was quite probably the ignimbrite outcrop described on the site record form and shown on the site drawings.

Whakamoenga Cave (N94/7)

Whakamoenga is the second site on the volcanic plateau in which moa bones have been found in a cultural context. Excavations by Hosking between 1961 and 1963 (Hosking 1962) were reported on by Leahy (1976). Because of the conditions within the cave environment, material has been very well preserved — especially the moa bones, bone artefacts, and botanical material (including flax net fragments, portions of cloaks, and decorated gourd fragments). The moa-hunting and small bird remains of Occupation 1 were sealed by a rock-fall, subsequent to which the site was reoccupied by people whose diet centred on freshwater mussels (*Hyridella* sp.) and imported marine molluscs, along with bracken rhizomes and cultigens (Leahy 1976). Leahy (op. cit.:51) argues for the capture and return to the site of whole birds, three or four individuals, although Nichol (1990:505) reduces the number to three. They were hunted at a time when forest still existed over the landscape but by the end of Occupation 1 "most, if not all, of the bush the bush around the lake had been destroyed and replaced by fern and scrub" (Leahy 1976:68). The contribution these moa made to the diet of the

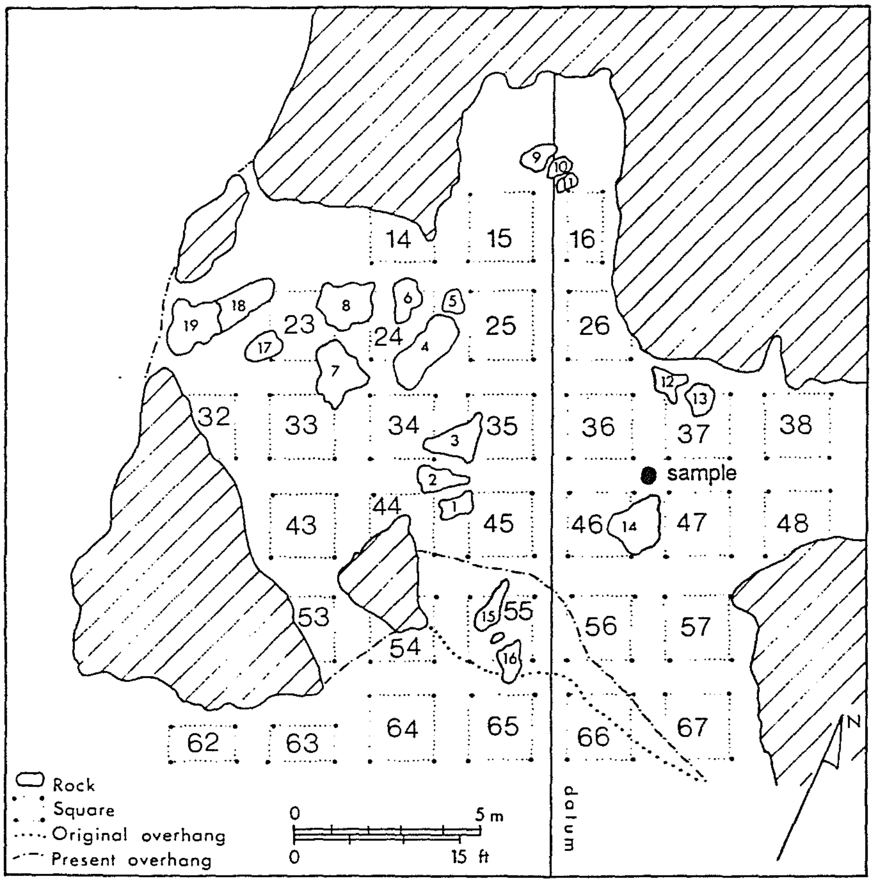


Figure 6.9a Site plan of Whakamoenga Cave showing the position of the soil sample (amended from Leahy 1976:Figure 3).

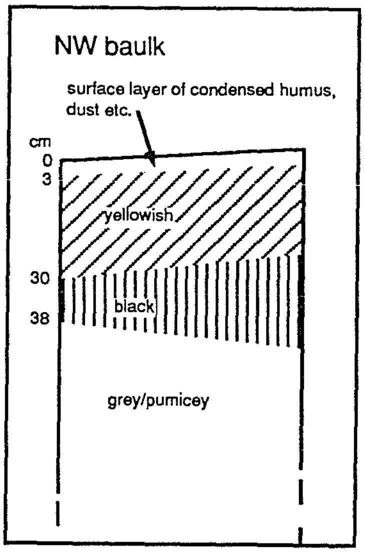


Figure 6.9b Stratigraphy of the column dug for taking soil samples (see text for details).

inhabitants would have been substantial, and Nichol (1990:506) calculates it to be around 60%. The moa-hunter layers date to the late 14th – early 15th centuries AD (Leahy 1976:46, Anderson 1991:Table 1).

The effects of the climate would be marginal on the material within the cave, in terms of affecting the longterm survival, or otherwise, of bone, but Leahy (op. cit.:32) notes that this area has a rainfall of less than 1200mm per annum, with a dry period between September and April. The average maximum January temperature is 23.4°C with an average minimum of 10.8°C, while the July averages range from 10.9°C down to 1.7°C. The Meteorological Service climatic figures for Taupo are as follows: average annual rainfall 1199mm; temperatures – mean daily maximum 17.2°C, mean daily 11.7°C, mean daily minimum 6.6°C, mean daily grass minimum 4.4°C; and average annual sunshine hours of 2037 hours (NZ Met. Service 1973:19).

The site is situated ca. 100m from the lake edge at Whakamoenga Point on the north-eastern shore of Lake Taupo. Hosking (1962:22) gives details of the cave itself, suffice it to say that it is now surrounded by regenerating native forest and is reasonably well protected from view, both from the lake and from people walking around the shore.

When I visited the site in August 1990 there was some evidence of disturbance within the cave, in the form of seats cut into the soft limestone rocks which are visible in the site photos in Leahy's report (1976:Figure 9). The large rock, described as "Rock 14" by Leahy (op. cit.:Figures 3, 4 and 9), is still standing above the surface and it was to the rear of this rock that I took my samples. It would appear from Leahy (op. cit.:Figure 9) that the baulks were not removed, so I dug a small testpit 1m to the rear of the rock to take the three samples (Figures 6.9a and 6.9b):

1) sample 1 was from the grey pumice layer at the base, ca. 45cm deep.

2) sample 2 was from the black soil layer.

3) sample 3 was taken from the yellowish pumice sand just below the surface.

Opua (N118/96)

This is one of the three major moahunting sites in south Taranaki, along with those at Waingongoro [Ohawe] and Kaupokonui. This site was originally recorded in 1896 when wind erosion exposed a large midden. Fossickers collected moa and other bird bones from the site but the whereabouts of this early collection are unknown (Fyfe 1988). In 1907 M.G. Maxwell, the son of the original finder, visited the site and made a second collection of material which was deposited in the Taranaki Museum. This collection comprised moa, small bird, dog, human and sea mammal remains (Prickett 1983:299–300, Table 1; Fyfe 1988; Worthy 1990:241) and is important because it is the only moahunter midden on the west coast of the North Island, north of the Kaupokonui River. The site was test-pitted by Fyfe in 1980–1981 but he found no evidence of any remaining cultural midden, although the site where he excavated was described by Maxwell's son as the place where the moa bones had been retrieved from (R. Fyfe pers.comm. 1/8/90).

The site was located on a spur projecting into the Okawau Stream (Figure 6.10), approximately 100m upstream of the mouth. "The old dunes which covered the site have completely disappeared and only small fore-dunes immediately behind the beach now exist. The stream valley in the vicinity is narrow with difficult access down 20m cliffs" (Fyfe 1988:228). The underlying base of the site is a young secondary podzolic soil derived from eolian sand, of the Patea sand group, reference number 23 (Figure 6.11; NZ Soil Bureau 1954:88), which has a pH ranging from 5.7 (at 0–7") to 6.2 at (10–18"), and base cation levels of Ca of 2.7–3.0me% and 0.6–0.7me% of Mg (op. cit.:197).

The closest climate station for all three of the South Taranaki sites is the Manaia Demonstration Farm, approximately halfway between Kaupokonui and Waingongoro, where the climatic figures are as follows: average annual rainfall 1256mm; temperatures – mean daily maximum 16.6°C, mean daily 12.3°C, mean daily minimum 8.6°C, and mean daily grass minimum 6.3°C (NZ Met. Service

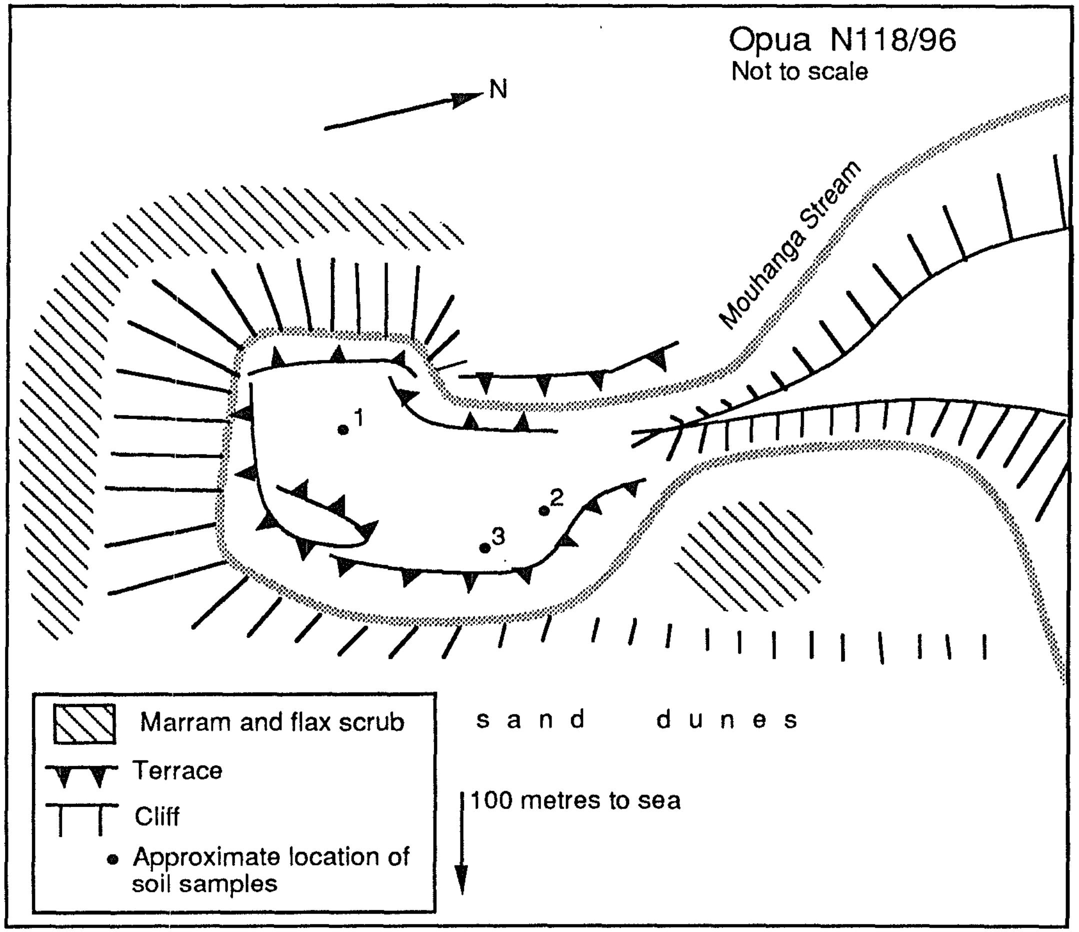


Figure 6.10 Opua showing the location of the soil samples in relation to the modern landscape.

1973:42).

When I visited it in August 1990 it appeared the same as it had when Fyfe undertook his excavation here 10 years previously (pers.comm. 1/8/90); low fore-dunes and no evidence of the high back dune system so prevalent to the north and south of this site along the coast, and with fresh evidence that the stream had risen and flowed over the area where the site had originally been. Three soil samples were taken from around the areas that Fyfe had test-pitted:

1) this small test bore revealed a thick level of river-borne silt on top of the original soil, evidence that the stream had been washing over the area for a long time. It was decided not to retain a sample from this bore.

2) this also consisted of intermingled soil and silt, but a sample was retained from 20cm depth.

3) a sample taken from a low sand ridge, from 50cm depth, which was dark in colour but not the typical black ironsand of this coast.

Kaupokonui (N128/3)

Excavations at this site were initially undertaken by Buist in the early 1960's (Buist 1963, Robinson 1963) who excavated about 34m^2 to reveal three midden layers separated by sterile sand, containing moa, dog, seal, rat and fish bone along with bone and stone artefacts, predominantly in the two lower layers (4 and 6). Later excavations in 1974 and 1979 of an area of about 45m^2 by Cassels (n.d., Anderson 1989a:116–119), close to Buist's excavations, revealed that the two lower layers "[were] not continuous and they ... combined into single cultural layer (4) of 10–40cm in thickness" (Anderson 1989a:116). This comprised a lower level, from which there was a lot of moa bone recovered of mainly intact skeletons, and an upper level where moa bone was scarcer. Material continued to erode from exposed portions of the midden and surface collections of bones were made by Fyfe, Till and Scarlett in June 1980, and by Lambert and Fyfe in June

1981. Moa bone collagen dates for the site place occupation in the 14th century (Anderson 1991:Table 1).

This site was extraordinarily rich in faunal material, in comparison to many other North Island sites. Over 50 species of small birds were recorded including the extinct swan (*Cygnus sumnerensis*), goshawk (*Circus eylesi*), giant rail (*Aptornis otidiformis*), crow , and species now extinct in the North Island such as the little spotted kiwi (*Apteryx oweni*), takahe, huia and kakapo (*Strigops habroptilus*). Mammal bone present in the site included dogs and sea mammals, while fish and shellfish were very uncommon in the moa-bone layer. The principle component of the midden was the moa bone and the analysis of these bones, in particular, has been undertaken on a number of occasions, with seemingly different results reported each time (Scarlett 1974 [the Buist moa bones], Foley 1980 [both the Buist and Cassels collections], Prickett 1983, Kooyman 1985, Anderson 1989a, Worthy 1990). I will not dwell on these results here, as the MNI present in the site is essentially immaterial to the present study. However, the results from this site serve to show us how subjective the field of faunal identification can be, when the reference collections and taxonomy are built upon species which have been identified from bones only, without the convenience of the animals being seen 'in the flesh'. This is particularly emphasised in the moa where there existed a number of species very similar in size and bone morphology, and where both sexual dimorphism and latitudinal size gradients were present.

The site lies on the western side of the mouth of the Kaupokonui River and was revealed in 1962 when wind erosion, caused by westerly winds funnelling up a small gully next to the river, removed the sand cover and exposed a large area of cultural material (Figure 6.12). Anderson (1989a:117) describes the site as consisting of "a series of activity bands aligned along the course of the river". There was a concentration of ovens in the dune nearest the river and behind them were three different levels of processing areas — a primary area where many of the articulated skulls, necks and other low meat value body parts were recovered, a secondary area of primarily long bones (many of them smashed) and stone tools, and a tertiary area of "discrete patches of stone tools and debitage and

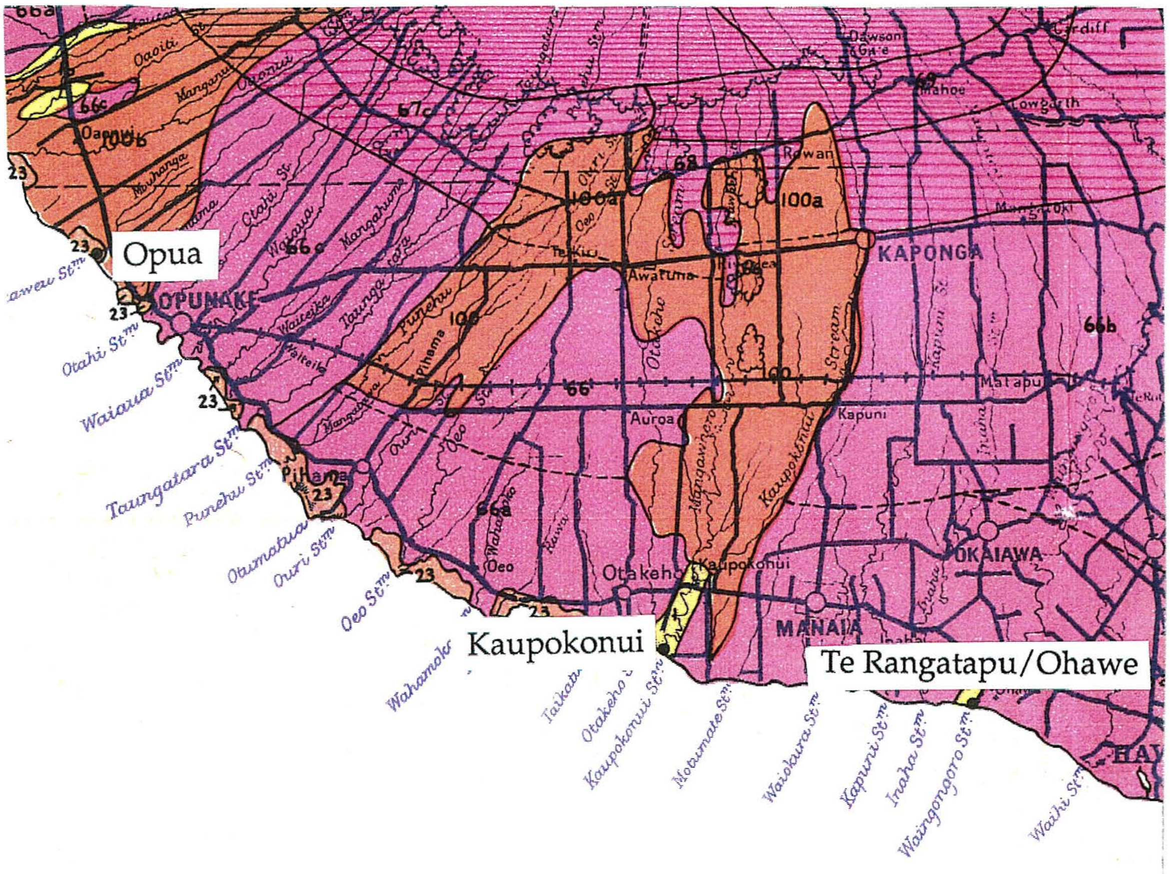


Figure 6.11 Soil map of part of the south Taranaki coast showing the positions of the Opua, Kaupokonui and Ohawe sites in relation to local soil types (from N.Z. Soil Bureau 1954: Map 6).

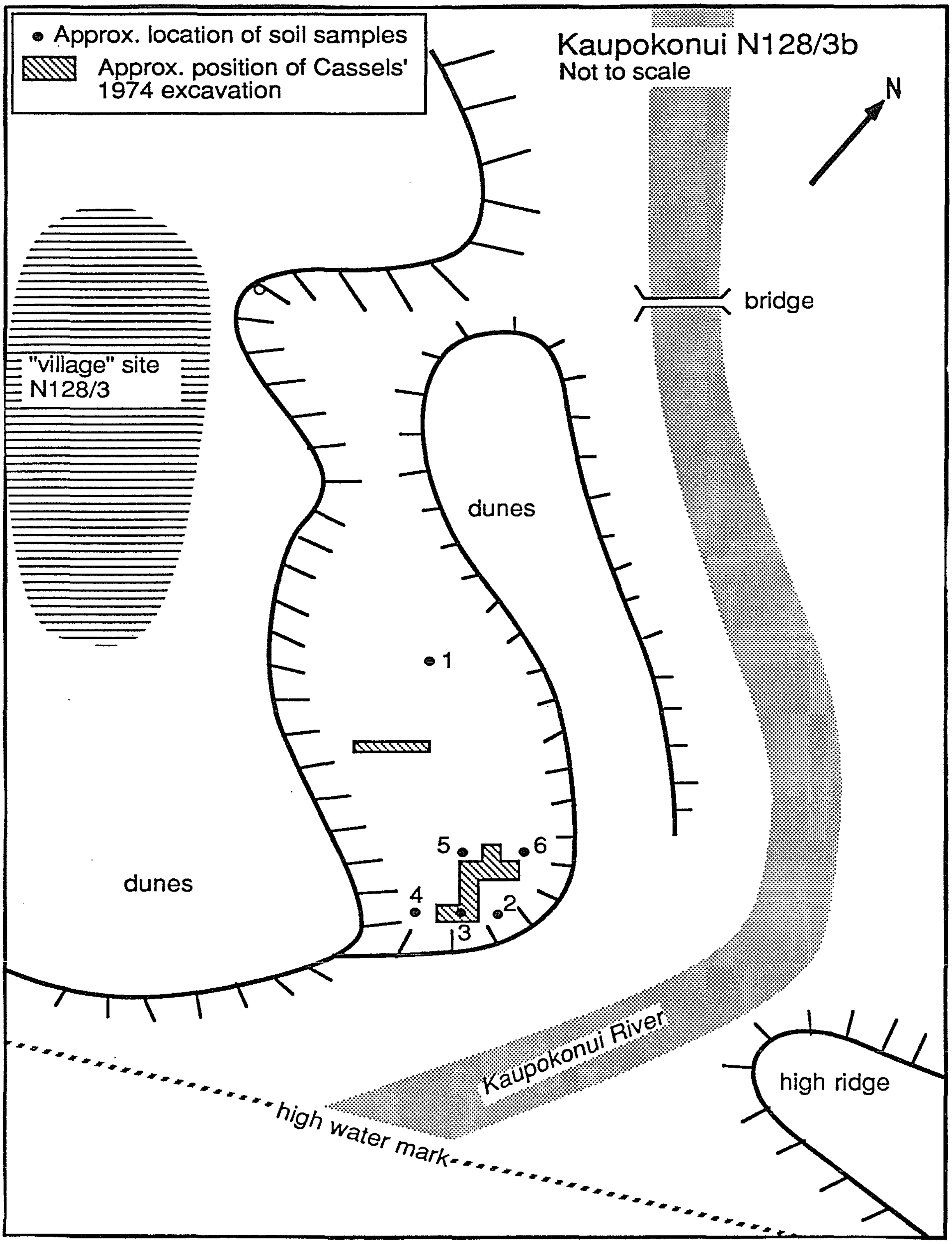


Figure 6.12 The Kaupokonui site showing the approximate positions of the excavation areas and soil samples.

relatively sparse, but highly fragmented, moa bone" (ibid).

The site lies within the band of black ironsands, which comprise most of the coastal dunes of the south Taranaki coast, in a surrounding base soil of recent alluvium of the Manawatu loam, sandy loam, silt loam and clay loam series, reference number 1 (Figure 6.11; NZ Soil Bureau 1954:62). This is a very fertile soil type with a deep layer of loam overlying a slightly heavier base, with the following chemical characteristics: pH of 5.8 (at 0–6" depth) to 6.0 (at 7–13"), and base cation levels of Ca ranging from 6.0–7.8me% and 4.3–4.0me% for Mg for the same depths (op. cit.:192). Climatic figures are given in the discussion of the Opua site above.

When I visited the site in August 1990 the gully where the midden is situated had become stabilised due to the growth of marram grass over it. When Fyfe visited the site in 1987/88 it had been covered by lupins (pers.comm. 1/8/90), which had died off and been replaced by the marram by 1990. The seaward end of the gully had been stabilised by the placement of large tyres across the front edge, which were then covered with sand and planted in marram grass. This has helped to stop the wind from scouring the remaining sand out of the gully and further exposing what remains of the site.

A total of six soil samples was taken from across the site, as shown in Figure 6.12. All samples were taken from immediately above the clay pan, at depths ranging from 10–40cm.

Waingongoro [Ohawe] (N129/77) and Te Rangatapu (N129/78)

At the mouth of the Waingongoro River, two sites containing moa bones were excavated in the 1960. The first was an excavation of about 40m^2 by Buist on the site originally recorded by Taylor and Mantell in the 1840's (Prickett 1983:294). Mantell had obtained a major collection of moa bones from the dunes to the southeast of the river, and Buist excavated an oven which had become exposed on the seaward edge of the sand flat (Buist and Yaldwyn 1960). More important, the articulated leg of a *P. mappini* was uncovered in the oven, lying in the position in which it had been discarded. Further excavations revealed further ovens, and a bone rich midden containing moa bone, as well as smaller species, including the giant rail (Buist 1960, Scarlett 1974). The dates from Waingongoro average around the 13th century A.D., although one (NZ-543) is at least 300 years older than the others (Anderson 1991:Table 1).

On the river bank, some 400m west of the Waingongoro site (which Buist and Yaldwyn renamed Ohawe), Canavan (1960) excavated ovens which had been cut into the compacted conglomerate at the site of Te Rangatapu (N129/78). These, and further excavations at the same site (Canavan 1962), revealed several ovens containing burnt moa and seal bone, along with the remains of dogs, fish and small birds. Artefacts included fragments of bone fishhooks and obsidian. Later analyses of the moa bone were undertaken by both Scarlett (1974) and Worthy (1990). Anderson (1991) rejects the two dates for this site which are at such variance with one another, although they derive from the same cultural horizon.

The situation of these two sites is similar to that of the Kaupokonui site. They lie in the coastal band of black ironsands, and the underlying soil structure is identical to that described above for Kaupokonui (see Figure 6.11). Climatic figures are given in the discussion of the Opua site above.

Both of these sites were visited in August 1990 and notes made about their present condition and soil samples taken (see Figure 6.13). At the Waingongoro [Ohawe] site, there was a gully developing back into the dunes where the westerly winds were deflating the loose sand, and exposing cultural material. In an attempt to stabilise the area, a barrier of tyres and timber had been erected across the front (seaward) side of the gully to prevent continued erosion. The site consists of a series of hard clay/gravel pans over which lies the dune system. In this narrow gulch the back dunes had been blown out and the cultural material was exposed on the surface of the clay pan. There were many fragments of moa bone present (including the symphasis of a mandible), as well as bird, fish and seal bones, a hammerstone and a chert flake. Two soil samples were taken by

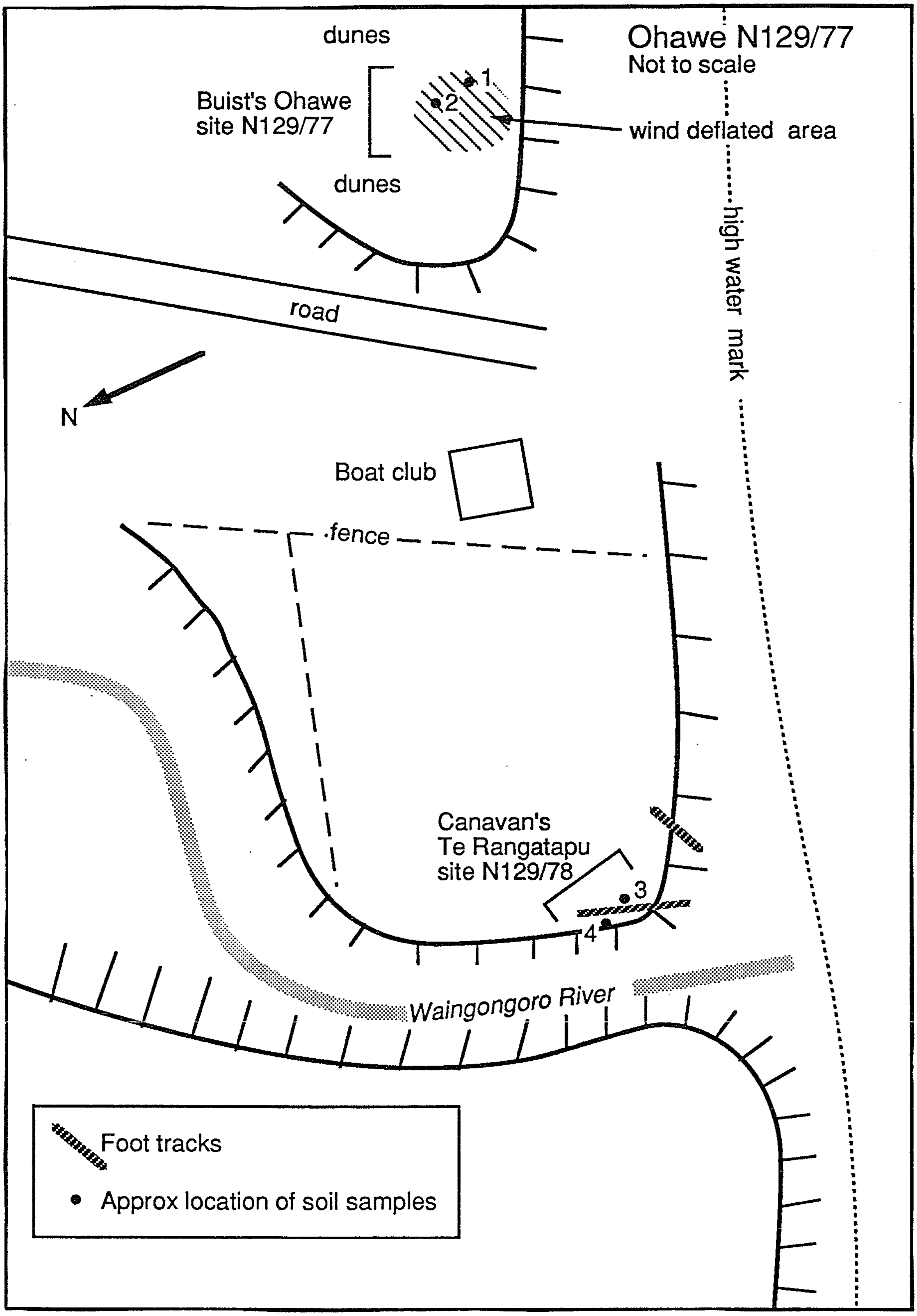


Figure 6.13 The Ohawe and Te Rangatapu sites showing the approximate positions of the soil samples in relation to the archaeological features.

digging a small spade hole down to the hard pan and then collecting the samples from the exposed face.

At the Te Rangatapu site, at the western end of the beach, the action of the wind and sea had stripped all the foredunes back to the hard clay base. There was no evidence of any cultural material and it had probably all been removed. The current track down to the beach cuts through the existing back-dunes on top of the clay pan. Soil samples were taken from just above this level, approximately 1m below the current surface layer.

Tai Rua (S136/1)

The excavations at this site in North Otago, between 1956 and 1962, were initiated as a salvage operation in response to material being exposed during the ploughing of a paddock (Trotter 1959, 1965, 1970, 1979; Otago Anthropological Society 1960; Gathercole 1961). The site stretches from the fossil dunes above high water inland some distance to the margins of a swamp which Trotter (1970:135) surmises was possibly a stream at the time the site was occupied. The midden layer extended into the swamp and material recovered from that part of the site was extremely soft and fragile. There was only one main occupation layer recorded within which there was evidence of spatial variation. On the seaward side of the road was an area (Area D in Trotter 1979) of small fireplaces and postholes consistent with a habitation area, while on the opposite side of the road (Area C) was a series of shell and fishbone middens with very little moa bone. Further inland, within the paddock, is Area E where there was a dense moa bone midden from which were recovered neck units in articulation and heavily fractured leg elements. The moa bones were predominantly from *Euryapteryx* and *Pachyornis* (Scarlett 1974) and there was no evidence of ovens, so this was probably primarily a butchery area. Dates for the occupation lie in the 14th century A.D. (Anderson 1991:Table 1).

The site is located at the northern end of a coastal strip of flat land, behind the present beach, which runs north of the Waianakarua River. "This flat is about

150m wide and its loamy top-soil thins out towards the beach giving way to sand dunes above high tide mark. ... The predominant vegetation at present is pasture grass, and all suitable land in the area is used for mixed farming. In very wet weather a normally dry water course on the coastal flat carries surface water into a swamp which lies between the site and the hill that forms the northern boundary of the flat" (Trotter 1979:205). A modern road cuts across the site preventing the escape of this surface water but probably the water originally flowed into the sea. The soil type is a subhygrous yellow-grey earth (silt loam) of the Timaru type, reference number 15, which developed from a parent material of greywacke loess (NZ Soil Bureau 1968:182). The chemical profile is quite complex; with the pH ranging from 4.9 at 0–4" through to 5.6 at 12–18", and down to 5.0 at 24–36"; the base cation levels for Ca range from 5.0me% at 0–4" down to 1.5me% at 24–36", for Mg 3.4me% to 1.6me% at the same depths, for K they range from 0.60me% down to 0.15me%, and for Na they average around 0.6me% (op. cit.:96).

The only coastal climate station between Christchurch and Dunedin is at Timaru, and while there may be some variation in the climatic patterns between there and south of Oamaru, where Tai Rua is situated, it is not considered that this would be of such magnitude as to warrant discarding the Timaru data. Accordingly, the Timaru climatic figures are as follows: average annual rainfall 601mm; temperatures – mean daily maximum 16.1°C, mean daily 11.1°C, mean daily minimum 6.1°C, mean daily grass minimum 3.4°C; and average annual sunshine hours of 1887 hours (NZ Met. Service 1973:62).

Owen's Ferry (S132/4)

This was one of the largest moa hunting sites in the upper Clutha watershed and was located on the true right bank of the Kawarau River. The site consisted of two main prehistoric cultural horizons in which were a variety of lithic and faunal remains, the latter dominated by moa bones which were found mainly scattered along the river side of the site. Additional occupation evidence in the form of two ovens, eight scoop hearths, and a butchery area and midden (Anderson 1989a:143) indicate that it was a short term camp related to the hunting of moa in the immediate vicinity or upstream of the site (Ritchie and Harrison 1981:97–100) in the late 13th to early 15th centuries A.D. (Anderson 1991:Table 1).

In his analysis of the moa bone, Kooyman (1984) identified nine individuals from seven species, and suggested that this represented the hunting of solitary moa, rather than groups of birds. The differential representation of elements in the remains from the site, which was almost completely excavated, provided evidence that although some whole birds were being returned to the site, in most instances it was the high-value meat bones that were preferentially returned, especially in the Layer 8 material (op. cit.:51). Approximately 48% of the tibiotarsi in Layer 8 had long spiral fractures, which Kooyman (ibid:52–53) attributes to the practice of marrow extraction. Very few cut marks were recorded on the bones with those that were present on the posterior portion of the pelvis being attributed to the stripping of meat from that region (ibid).

The site probably lies within the area of soil type 96, shown on Figure 6.14, which is a recent soil of the Gladbrook set derived from schist alluvium (NZ Soil Bureau 1968:330), which tend to have pH values from 5.7–6.2 and base cation levels of 7.1me% (at 2–8") down to 1.3me% (at 20–25") for Ca, 2.2me% down to 0.3me% for Mg, and 0.6me% down to 0.15me% for K at the same depths (op. cit.:156).

The climatic figures for Queenstown are considered to be the most relevant for this site which lies down the Kawarau valley from Queenstown. The climatic figures are as follows: average annual rainfall 849mm; temperatures – mean daily maximum 15.1°C, mean daily 10.1°C, mean daily minimum 5.0°C, mean daily grass minimum 0.6°C; and average annual sunshine hours of 1933 hours (NZ Met. Service 1973:66).

With the site being located on the banks of the Kawarau River, and having been almost totally excavated, the possibilities of revisiting the site were remote. I did, however, attempt to relocate the site for the purpose of taking soil samples, and feel reasonably confident that I returned to as near as was determinable to the

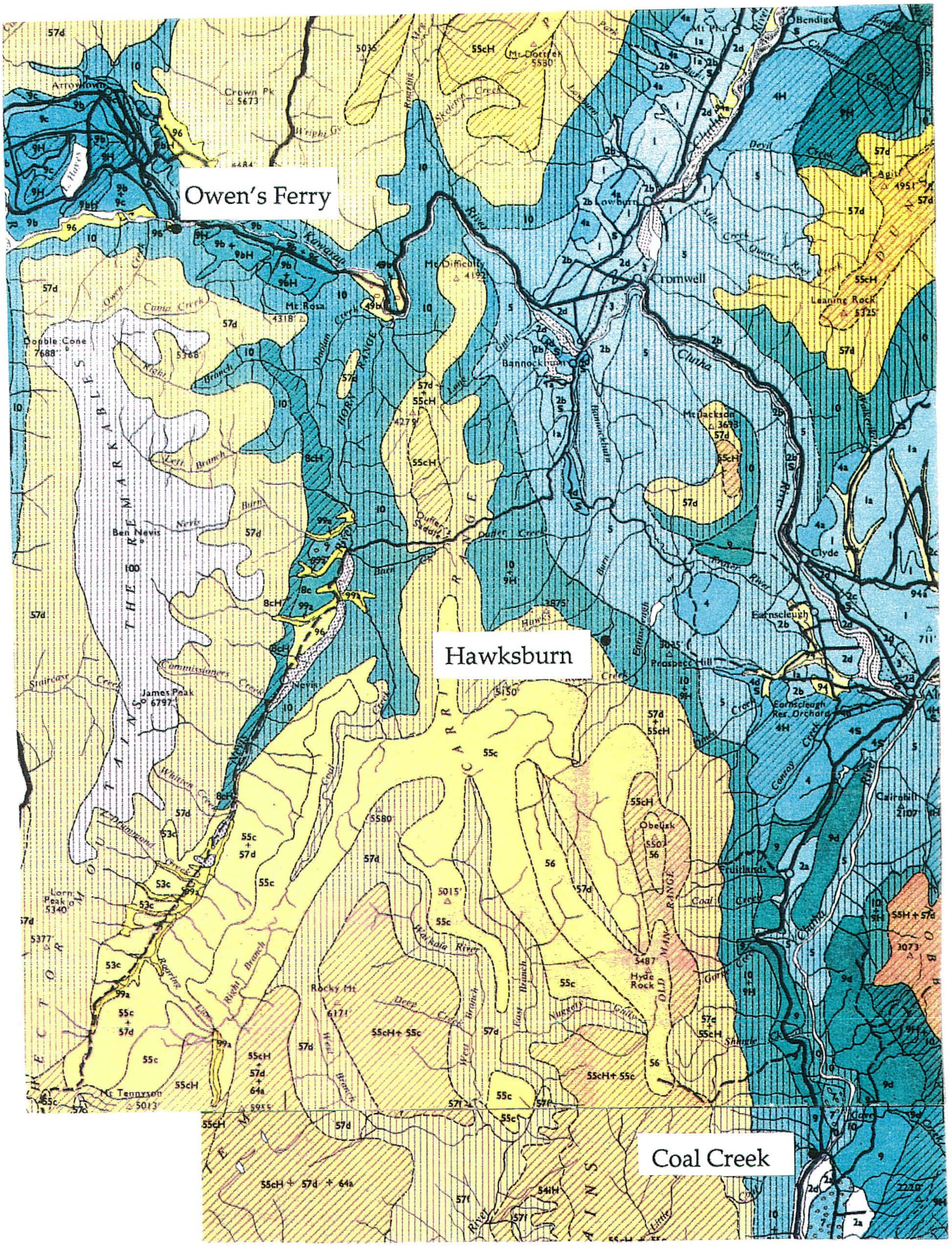


Figure 6.14 Soil map of part of the central South Island showing the positions of Owen's Ferry , Hawksburn and Coal Creek in relation to local soil types (from N.Z. Soil Bureau 1954: Maps 10 and 13).

original point. Ritchie and Harrison (1981:99) record that the site was buried beneath "sterile multi-layered floodwash overburden" and that "Layers 3 to 7 consisted of successive light and dark sterile bands of flood borne silt" (ibid). Given that essentially the site consisted of two occupation layers in the midst of floodwash debris, I took one large sample from approximately 30cm depth at a point I felt was close to where the original site had been.

Hawksburn (S133/5)

This site in the Carrick Mountains of Central Otago is one of the most important, and certainly one of the largest, moa hunting sites in the inland basins of the South Island. It was first excavated by Lockerbie in 1955 (Lockerbie 1955, 1959:85–87) but this remains largely unpublished apart from some isolated analysis (Scarlett 1974, Hamel 1978a). A further excavation was undertaken by Anderson in 1979 and the 223m^2 excavation produced a large amount of both faunal (nearly all moa bone) and artefactual material (Anderson 1979, 1982, 1983, Bain 1979, Carty 1981, Kooyman 1985). A synthesis of information is given by Anderson (1989a:144–147) in which he describes the layout of the site in terms of spatial patterns, evidence for butchery in the moa remains, discusses the MNI for the moa remains, and looks at patterns in the representation of body parts within the remains and the calorific value of different food items.

Briefly, the site area is defined by the spread of lithic material (Figure 6.15), some 2700m^2, and comprises: a band of flakes representing a tool-fabrication area behind a line of hut sites and a double line of ovens stretching back southwest from the stream which lie amongst evidence for extensive moa processing and disposal in the forms of butchery and midden areas. There was a total of 18 ovens excavated, small shallow scoops, some of which showed evidence for reuse. The butchery area tended to have larger bone fragments, stone flakes and blade tools, and only 9% of the bones showed signs of burning, while, on the other hand, the bone fragments in the midden "had been heavily burnt and fragmented to bone 'gravel'" (Anderson 1989a:145) with 98% of the fragments burnt. A fuller discussion of the possible reasons for this degree of burning is given in Kooyman

(1985:295–296) and in Chapter 7 of this thesis during a discussion of the taphonomics of the Hawksburn site. Anderson (ibid:147), by various calculations, estimates an MNI of 400±50 moa are represented by the remains in the site. The greatest problem in attempting to quantify the remains was the 1795kg of highly fragmented and burnt material. Moa were not the only faunal remains recovered in the site — also present were 30 small birds from a range of habitats (McGovern-Wilson 1986:85), dogs, rats, and freshwater mussels. A series of 10 radiocarbon dates suggests occupation at the site occurred between the early 13th to the late 15th centuries A.D. (Anderson 1981b).

The site is situated on the true left bank of the East branch of the Hawksburn at an altitude of 660m. This area now consists of pasture and tussock, but formerly there were extensive stands of trees on some of the higher slopes and scattered scrub in the valley floors (Hamel 1978, Anderson 1982). The site falls on the boundary of two soil types (Figure 6.14) — the dry-subhygrous yellow-grey earths of the Arrow-Blackstone Hill series (reference numbers 10 and 9H respectively) and the brown-grey earths of the Alexandra series (reference number 5) (NZ Soil Bureau 1968:170–179). At a slightly higher altitude the yellow-grey soils grade into the hygrous upland and high country yellow-brown earths of the Dunstan and Carrick series (reference numbers 57d and 55c/55cH respectively). The soil chemistry along this boundary gets a bit confusing; the Arrow series have an average pH of 6.2, and cation levels averaging 7.2me% for Ca, 1.6me% for Mg and 0.08me% for K; the Blackstone hill series have an average pH of 6.0, and cation levels averaging 4.9me% for Ca, 1.3me% for Mg, 0.66me% for K, and 0.1me% for Na; and the Alexandra series have pH values ranging from 6.4 (at 0–3") up to 8.4 (at 16–18"), with a Ca level of 4.9me%, Mg level of 1.3me%, K level of 0.32me% and an Na level of 0.2me% (NZ Soil Bureau 1968:90–94). Both Hamel (1978) and Anderson (1982a) have argued that this boundary of the yellow-grey and yellow-brown soils, where it coincides with the 800mm rainfall isohyet, marks the lower limits of the forested zones, while the boundary between the yellow-grey and brown-grey soils, in coincidence with the 600mm isohyet, marked the transition into a more shrubby landscape. The placement of sites within this transitional landscape is probably to take advantage of a range of moa species feeding in different habitat types.

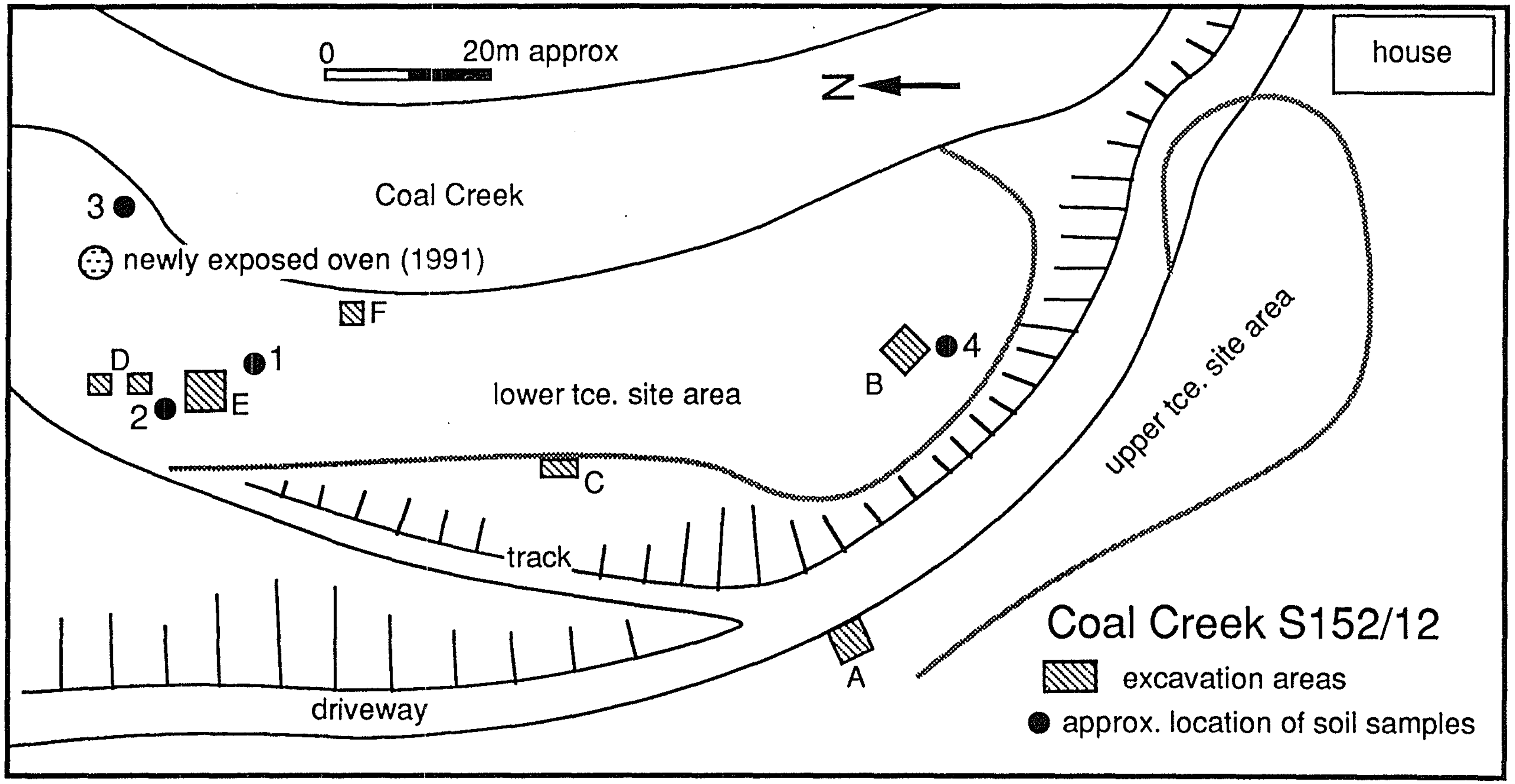


Figure 6.16a Coal Creek showing the position of the soil samples in relation to the archaeological site (based on Anderson and Ritchie 1984:Figure 1).

It is difficult to extract climatic figures relevant to this site from the published Meteorological Service data because the climate stations in this part of Central Otago are located at Earnscleugh and Alexandra, some 500m lower in altitude. This difference will undoubtedly have an effect on temperature ranges and rainfall levels. I will include their figures, however, as they give an idea of the climate in this region. The Earnscleugh climatic figures are as follows: average annual rainfall 361mm; temperatures – mean daily maximum 16.8°C, mean daily 9.8°C, mean daily minimum 3.2°C, and mean daily grass minimum -0.5°C (NZ Met. Service 1973:68), while those for Alexandra are: average annual rainfall 339mm; temperatures – mean daily maximum 16.3°C, mean daily 10.5°C, mean daily minimum 4.6°C, mean daily grass minimum 1.0°C; and average annual sunshine hours of 2073 hours (ibid:69).

I revisited the site in November 1990 for the purpose of taking soil samples. Although this point in the valley is fairly exposed, the site was probably situated here because it is on an area of fine river silt, which is the only area like it for quite some distance. Upstream of the site the ground is too rocky, while downstream it is too swampy, and the silt is the best ground for digging ovens (in terms of ease). When it was excavated, the midden of charcoal and bone gravel formed a low mound approximately 30cm higher than the surrounding ground (A. Anderson pers.comm. 5/11/90). Four soil samples were taken from the site, and are shown on Figure 6.15:

1) and 2) these two samples were taken from within the remains of the midden area.

3) this sample was taken from the band of ovens.

4) the fourth sample was taken from a point northeast of the house revealed in excavation Area D (the northernmost hut site shown on Figure 6.15), in order to measure the background characteristics of the natural silt.

Coal Creek (S152/12)

This small site situated on two terraces on the true right bank of Coal Creek was test excavated by Anderson and Ritchie (1984), after the landowner had unearthed moa bones, oven debris and stone flakes and blades during the preparation of a vegetable garden (Figure 6.16a and b). The upper terrace had been quite heavily disturbed by cultivation, but in an area at the northern end excavations revealed a shallow scoop hearth and numerous flakes of porcellanite, suggesting it was a living area and flaking floor (op. cit.:177). The lower terrace contained a number of ovens and large concentrations of butchered moa bones and stone flakes, predominantly porcellanite derived from the outcrop (S152/3) about 400m from the site. In Area E a pit was recorded in which the bones ranged from partially burnt material on the bottom and periphery, to heavily burnt and fragmented bone and ash at the top. Some of the bones included articulated units — feet (tarsometatarsi and phalanges) and necks (which included crania, cervical vertebrae and tracheal rings). Anderson (1989a:144) suggests that this was "a rubbish heap in which the refuse of both butchery and secondary processing of bone had been dumped" and then set alight. This is described in more detail in Chapter 7 during the discussion of the taphonomics of this bone collection. At the northern end of the lower terrace, excavations (Area D) revealed two cultural layers separated by sterile silt. A sample taken from one of the ovens dated to 1284–1398 A.D. (Anderson 1991:Table 1).

The site lies within the boundary of the dry-subhygrous yellow-grey earths of the Blackstone series (reference number 9, Figure 6.14) (NZ Soil Bureau 1968:174–175). The soil chemistry is somewhat simpler than that for the environs of Hawksburn: the pH ranges from 5.5 at 0–4" to 6.8 at 11–15" depth, while the cation levels for Ca range from 4.9me% at the surface down to 1.5me% at 11–15", 1.5me% for Mg, a range from 0.50me% at the surface down to 0.05me% at 11–15" for K, and 0.13me% for Na (NZ Soil Bureau 1968:93).

The climatic data for this area are taken at the Roxburgh Power Station, less than 1km from the site, and the figures are as follows: average annual rainfall 464mm;

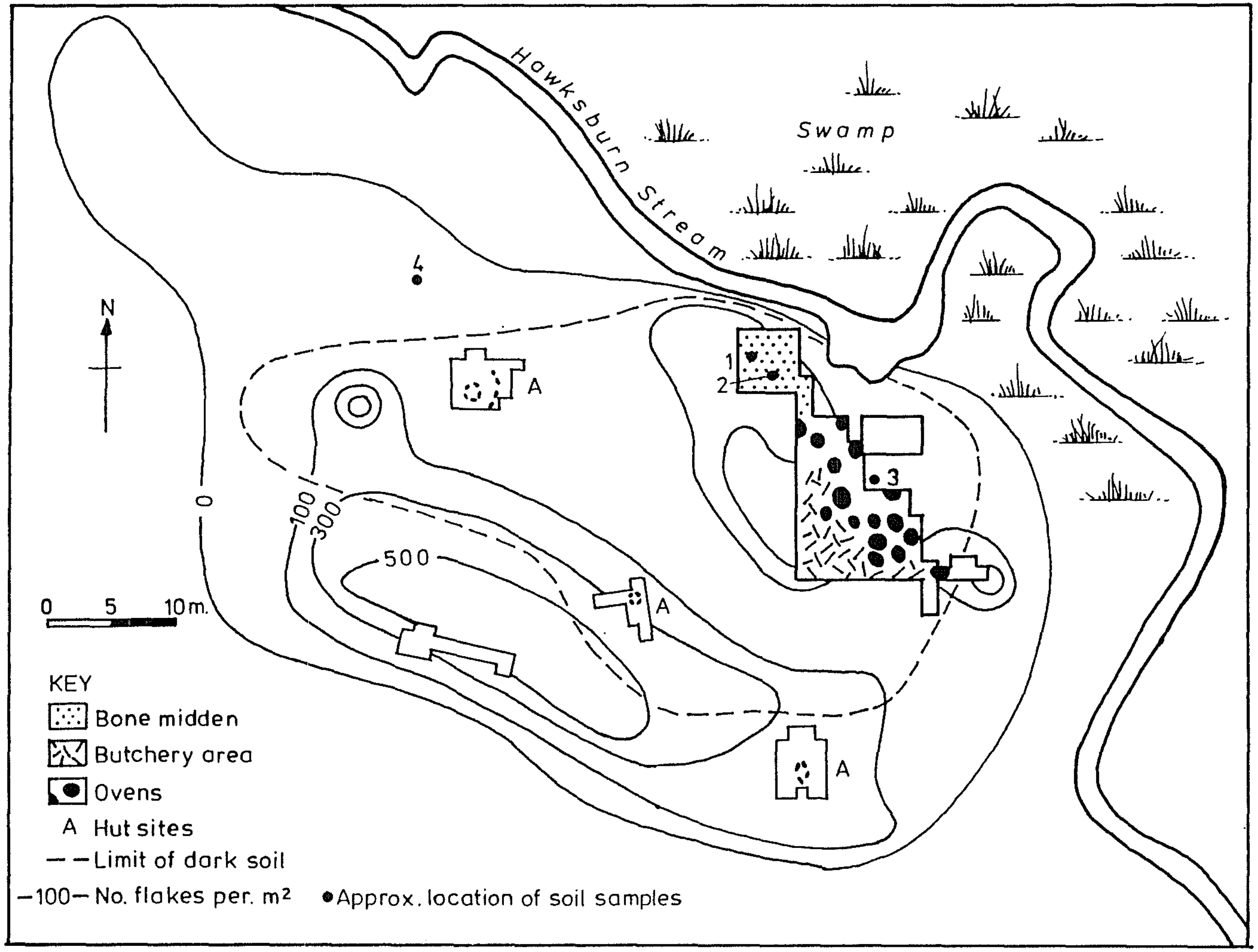


Figure 6.15 Hawksburn showing the position of the soil samples in relation to the archaeological features (amended from Anderson 1989a:Figure 10.3).

Figure 6.16b The lower terrace of the Coal Creek site. Excavation Areas D and E were located in the area of black soil, visible in the centre left of the photo

Figure 6.16c Two views of moa femora collected from Coal Creek at the time of my visit in November 1990.

temperatures — mean daily maximum 16.6°C, mean daily 10.8°C, mean daily minimum 5.2 °C, and mean daily grass minimum 2.5°C (NZ Met. Service 1973:70).

The site was revisited in early November 1990, soon after the landowner had begun developing another section of the lower terrace for garden. During the course of this he exposed a further oven which was plainly visible as a roughly circular area of black 'greasy' soil (ca. 2m in diameter) in the yellow-grey soil of the garden. Four soil samples were taken for analysis (Figure 6.16a):

1) and 2) these samples were taken from the main garden close to where excavations Areas D and E had been dug. The soil throughout this section of the garden was very dark, compared to that in other parts.

3) this sample was taken from the silt in the garden, east of the new section towards the stream, so that I could measure the natural background levels.

4) the fourth sample was taken from the bank near excavation Area B.

All the samples were taken from ca. 30cm below the ground surface, to get below the cultivation zone of the vegetable garden. This were fragments of broken bone visible on the surface near sample 1 which were very soft and wet. Two pieces of femora were recovered from the slope near sample 4; these were bleached and quite weathered (Stage 4) as a result of being exposed on the ground surface for a number of years (Figure 6.16c) after they were extracted from the garden by the land-owner.

Pounawea (S184/1)

Excavations were undertaken by Lockerbie and later by Hamel on this site, which revealed a range of Archaic artefacts in addition to moa and other extinct bird species such as swan, goose (*Cnemiornis calcitrans*), crow (*Palaeocorax moriorum*) and eagle (*Harpagornis moorei*) (Lockerbie 1954:143–144;

1959:82–85, Scarlett 1974, Hamel 1977; 1979; 1980). Moa bones occurred throughout the midden layers, but were in slightly greater abundance in the lower 'greasy black' layer where silcrete blades were also recovered (Lockerbie 1959:82–85, Hamel 1980). Hamel's excavation (1980) was the only one to have the midden component fully analysed and it revealed a relatively broad spectrum faunal base for the inhabitants — 10 individuals of moa from five different genera, 11 dogs, nine fur seals, six sea lions, two elephant seals, fish, small birds (34 different species representing a range of environments (McGovern-Wilson 1985)), and shellfish which were predominantly found in the upper layer. Smith's (1985:174) analysis of the meat weight values of the fauna from Hamel's excavation showed that in Layer 2 sea mammals contributed 58% of the meat weight, as against 25% for moa, while in Layer 1 this had declined to 30% for sea mammals and only 4% for moa.

The dates for this site range from 1279–1460 A.D. for Layer 1 down to 1037–1303 A.D. for Layer 2, and Anderson (1991:787) argues that this Layer 2 date, NZ-5032, is a predominantly manuka (*Leptospermum scoparium*) sample with a low inbuilt age, and if it is "on cultural charcoal (it was taken from the base of the lowest cultural layer), is one of the more convincing early dates" for an early settlement in southern New Zealand.

The site was situated on a narrow tongue of land, Manuka Point, protruding into the Catlins River estuary at the point where the Owaka River meets the Catlins River (Hamel 1980:Figure 4). This point originally consisted of deep deposits of midden and ovens on the sandy spit but erosion from around 1856 onwards caused the point to be substantially reduced. By the time of Hamel's excavation, it had been reduced to the stage of being an island 22m long and 3–4m wide from which the cultural material was recovered. The excavation revealed that some of the material had previously been disturbed and of the $16m^2$ excavated, only $8.63m^2$ was of undisturbed strata (op. cit.:14).

By January 1980 the remainder of the island had all but disappeared, along with all the occupation material (op. cit.:5, Figure 6). For that reason I was unable to revisit the site for the purpose of taking soil samples, and it was assumed that the sandy substrate in which the bones were recovered was similar to that at Papatowai.

There are no climate stations on the southeast coast of the South Island and so accurate climatic figures are not available. At a gross level, however, are the graphs and figures given by Tomlinson (1976) whereby this region has an average annual rainfall of 800–1200mm, an average annual temperature of 7.5–10.0°C, and averages 1600–1800 hours of sunshine per annum. Garnier (1958, cited in Hamel 1980:7) gives figures of 917mm rain in the Owaka–Pounawea district, sunshine values below 1750 hours per annum, and monthly average temperatures below 15.5°C.

Papatowai (S184/5)

There has been a series of series of excavations over the years at this site (Figure 6.17), beginning mainly with Teviotdale in the 1930's (Teviotdale 1937, 1938a, 1938b), continuing with Lockerbie in the 1941 and 1956 (Lockerbie 1953, 1954:142–3, 1959:80–82), Hamel in 1971 (Hamel 1977, 1978b) and finally Anderson and Smith in 1990 (Anderson and Smith 1992) (Figure 6.17). The excavations have revealed a sequence of probably three occupations during which time large dune swales were infilled with midden and other cultural material (Anderson 1989a:138–139). The lowest layer was a "deep, black sand layer containing abundant moa and seal bones together with smaller quantities of dog, bird and fish bone and occasional lenses of shell" (ibid). Overlying this is a relatively sterile layer, with some artefact working areas, and above this "is a thick, dense, shell midden which also contained some moa and seal bones" (ibid). The artefacts recovered during the earlier excavations were used by Golson (1959b) in his characterization of the South Island Archaic phase, along with material from Wairau Bar and Shag Mouth.

Scarlett (1974) has quantified the moa bones from the earlier excavations, but only Hamel's (TT1) and Anderson and Smith's excavations have provided a fully analysed set of faunal material. Hamel (1977) recorded 10 moa and 16 seals, along with bird (mainly penguin), dog, fish and shellfish. Smith's (1975:162)

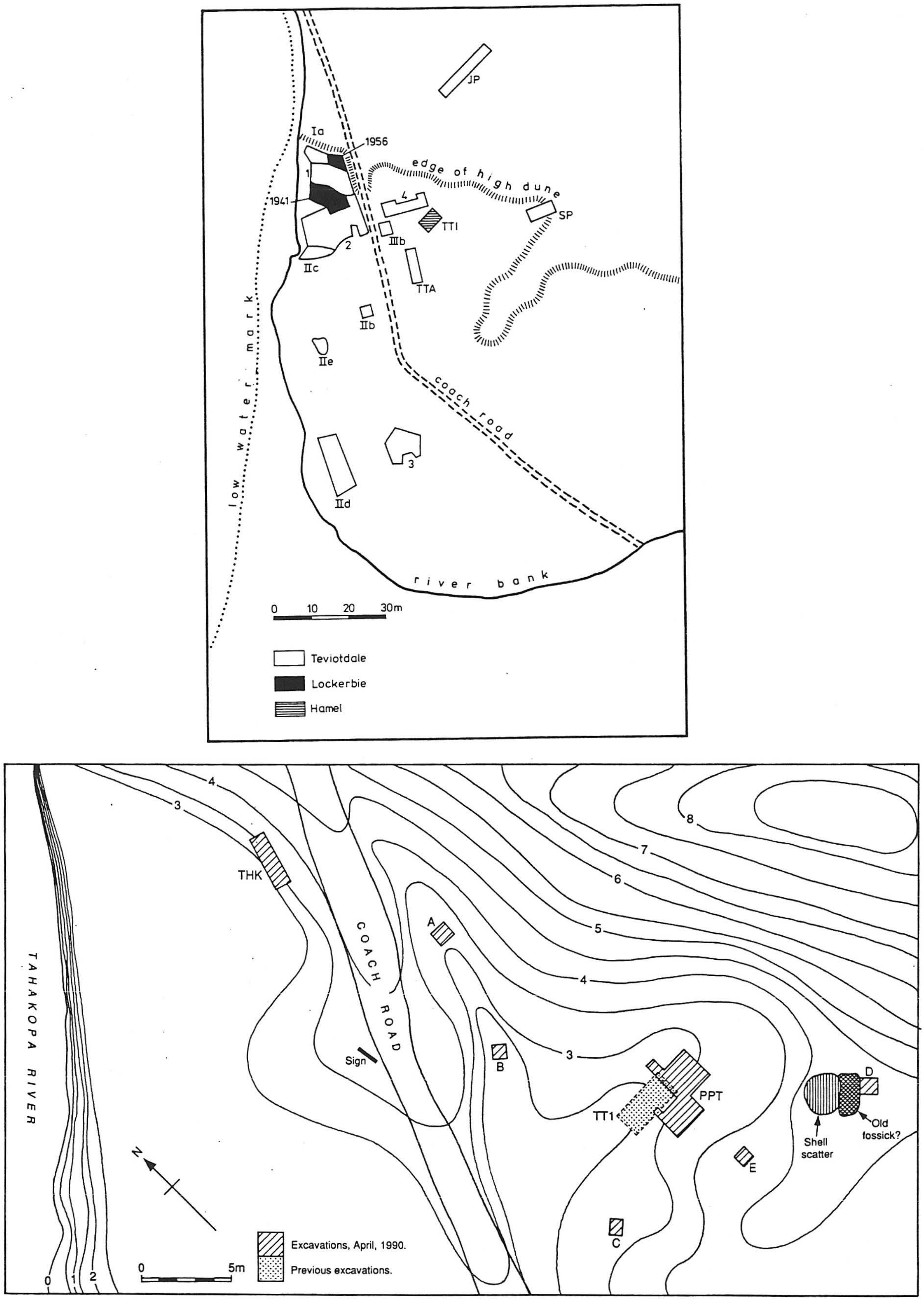


Figure 6.17 Two plans of Papatowai showing the positions of excavations undertaken on the site (Anderson and Smith 1992).

analysis of the meat weight showed that in the lower layer seals contributed 70% of the meat and moas 28%, while in the upper shell layer seals were only 27% to the 45% contribution from moas. In the Anderson and Smith excavations five moas, seven seals and a wide range of birds, fish and shellfish comprised the faunal component (1992:Table 5) in the PPT excavation, while in the THK excavation fish, birds, and a single individual each of moa, seal and dog were represented (op. cit.: Table 3). The meat weight estimates for the PPT layer 3 midden (which corresponds with Hamel's TT1 'Upper Shell' layer) sees moa contributing 34% of the meat, seal 40% and birds and fish both approximately 10% (op. cit.: Table 6).

Anderson (1991:787) rejects most of the earlier dates reported for this site, on the basis that they were from charcoal samples in which the wood contained as much as 50–90% totara (*Podocarpus totara* and *P. hallii*) and thus had a significant inbuilt age. The two dates from the 1990 excavations were on samples containing at least 50% manuka and other shorter lived species so giving only a modest inbuilt age, and a date of 1283–1405 A.D. (op. cit.:Table 1).

The site is located on a terrace of low dunes at the western end of the Tahakopa sand spit, on the northern side of the Tahakopa River mouth, and it lies within a band of hygrous to hydrous lowland podzolized yellow-brown earths and podzols of the Toetoes series, reference number 63b, which are sandy loams and loamy sands in undulating to easy rolling dunes (NZ Soil Bureau 1968:282–3). There is a thin band of this soil type along the north side of the Catlins River mouth within which the Pounawea site was probably located. The soil notes recorded here, therefore, would probably also apply to that site. The soil chemistry for this soil type is not described in detail but it is closely related to the Omaui type (reference 63c) which is described below for the Tiwai Point site. The climatic variation for Papatowai is discussed under the Pounawea site above.

Tiwai Point (S181/16)

Excavations at this site took place during 1968 in response to the plans to build an aluminium smelter on the point. Two areas were excavated: Area B (of about

115m^2) was a stone-working area, while Area X (ca. 150m^2) revealed several discrete working floors with high concentrations of flake debris and appears to have been an adze manufacturing area (Park 1969). Adjacent to Area X was a shallow, but dense, single layer of midden comprised mainly of moa, seal and bird bone, the latter of which included an MNI of 177 sooty shearwaters (*Puffinus griseus*), 138 of them being immature/sub-adult (Sutton and Marshall 1980). There was a total of 11 moa, of 2 species (*Eu. gravis* and *E. crassus*), but it was the marine mammals which made up the largest component of the diet — seals contributed 72% of the meat weight, to 17% for the moas and almost 10% for the birds (Smith 1985:144). The occupation of the site was dated to a short period about the 13th century A.D. (Park 1978), although a problem with samples being dominated by totara means that only NZ-4469, "on a sample dominated by manuka with a minor totara component" (Anderson 1991:787), and giving a date of 1285–1396 A.D. for Area X, is the most acceptable one.

The site was located towards the western end of the long sandy peninsula that stretches along the southern side of Awarua Bay. The peninsula is composed mostly of hygrous yellow-brown sands of the Riverton series (reference number 70a) and the site itself lies close to the boundary of these sands and the area of the western point where there are numerous outcrops of volcanic and metamorphic rock amongst which are "several seams of fine grained black argillite, and a low hill of grey-green, coarser argillite" (Park 1969:143). The soils of this point are hydrous to hygrous lowland podzolized yellow-brown earths and podzols of the Omaui series (reference number 63c) (NZ Soil Bureau 1968:137). In terms of their chemistry, the Riverton sands have a pH of 6.1 and cation levels as follows — Ca: 1.8me% at 0–2" down to 0.1me% at 12–15", Mg: 1.6me% down to 0.2me% at the same depths, K and Na: 0.2me% down to 0.0me%, while the Omaui soils have an average pH of 4.7, Ca levels of 33.3me% at 0–6" down to 6.6me% at 12–18" and 1.0me% at 26–32", Mg levels of 22.1me%, 4.3me% and 1.5me% at the same depths, K levels of 2.70me%, 0.50me% and 0.15me% at the same depths and Na levels of 3.3me%, 1.7me% and 0.5me% (NZ Soil Bureau 1968:137, 141).

Hamel (1969:149) records the weather pattern as being predominantly from the west and south-west, with Bluff Hill sheltering the western half of the peninsula from the prevailing westerlies. Temperatures tend towards the colder end of the spectrum and annual rainfall is about 1020mm. The Meteorological Service has a climate station at the Invercargill airport, as the closest to Tiwai Point, and the figures for that site are as follows: average annual rainfall 1042mm; temperatures – mean daily maximum 15.3°C, mean daily 10.0°C, mean daily minimum 5.0°C, and mean daily grass minimum 2.5°C (NZ Met. Service 1973:73).

I was unable to revisit the site as the Comalco Aluminium Smelter was built on the area where the archaeological site was, and the whole area has been mixed and altered during the construction.

Chapter 7.

Taphonomy of New Zealand's big-game hunting — the soil and the bones.

The previous chapter provided the background data on the archaeology, climatic and environmental data for the big-game hunting sites which form the base for the present study. This chapter now discusses the results of the analysis of the moa bone collections from around the country in relation to the main taphonomic variables which I was studying: namely, burning and weathering. It will begin with a discussion of soil chemistry, and then discusses each site in turn with results of the soil chemistry and bone analysis.

SOIL CHEMISTRY

Soil is defined as "a natural body of mineral and organic constituents that results from the combined action of climate, organisms and man on a mineral or organic material" (Courty et al. 1989:7). There are essentially five factors which play a major role in the development of soils (Bohn et al. 1979:120, Courty et al. 1989:10): parent material (p), climate (cl), organisms (o), relief (r) and time (t), all of which tend to be interdependent and McClaren and Cameron (1990) express the relationship between them as follows:

$$\text{soil (s)} = f\ (p, cl, o, r, t)$$

The two important climatic variables are temperature and moisture (which have a direct control as well as affecting the vegetation which influences fauna within the soil) with the main effect of temperature being to influence the rate of reactions — for every 10°C rise in temperature the speed of a chemical reaction increases 2–3 times (Fitzpatrick 1980:24), as does the average total organic matter and nitrogen present in a soil (Brady 1974:156). The temperature of soil is affected by factors such as: latitude and aspect, altitude, vegetational cover, soil colour, and soil moisture content; while the amount of water entering the soil is determined by factors such as: intensity of rainfall, vegetation cover, permeability and slope, and the original moisture content of the soil (ibid:28). The leaching process by which soluble substances are released from mineral and organic materials continues while the soil matrix is moist and, therefore, tends to be intermittent, occurring after each fall of rain long enough for the moisture to be absorbed (Limbrey 1975).

The pH of the soil, as measured by standard techniques, is really a measure of the pH of the soil solution (Limbrey 1975:57). In mineral soils the range is normally from 3.5 to 10 (Brady 1974:34, Fitzpatrick 1980:112) with occasional values outside these limits — very low levels are often found in soils of drained swamps that contain pyrite or elemental S, while very high values result from the presence of $CaCO_3$, such as might be expected from concentrated shell middens. The two principal controlling factors are organic matter and type and amount of cations. Large amounts of organic matter induce acidity and the acidity of soils is associated with the presence of H^+ and Al^{3+} in exchangeable form (Black 1968:273, McClaren and Cameron 1990:170). Aluminium is released by hydrolysis of the primary minerals or comes into solution from the exchange sites. In soils depleted of basic cations, aluminium becomes increasingly soluble because of the decreasing pH and is absorbed in preference to hydrogen. The pH tends to be related to rainfall — as rainfall increases the pH falls as a result of the depletion of basic cations (Fitzpatrick 1980:113). Acidity in the soil can also be derived from rainfall — the H_2CO_3 can have a significant input to acidity in soils and a significant factor in soil mineral weathering (Bohn et al. 1979:122) — and be produced by plant residues or organic wastes decomposing into organic acids, which is particularly important in forested areas (op. cit.:196). Phosphate is released into the soil from a variety of sources, but predominantly primary minerals, bone and organic combinations, in a variety of valency states, $PO_4{}^{3-}$, $HPO_4{}^{=}$ (predominant in basic soil solutions) and $H_2PO_4{}^{-}$ (predominant in acid soil solutions), which form salts with Ca, Fe and Al (Limbrey 1975:70). In basic soils phosphate is associated with Ca, while in acid soils most solid phase phosphate is associated with Fe and Al (Bohn et al. 1979:289). The preservation of bones and teeth is controlled more by pH than Eh, although these phosphatic derived fossils persist at lower pH than calcareous phytoliths or shells (Retallack 1984:71).

Other sources of soil acidity may be important in certain instances, one such being the acidity produced from oxidation of iron sulphides. "Accumulation of significant quantities of iron sulphide requires a source of more sulphate than is found in poorly drained soils. Thus the principal occurrences of sulphide-bearing soils are along the seacoast where the sulphate in the sea water serves as the source" (Black 1968:308). This could have important consequences for New Zealand archaeological sites given the coastal orientation of such a large percentage of the prehistoric sites, but in particular along the South Taranaki coast where there is such a great predominance of 'ironsands'.

The levels of organic matter in soils are generally in the order of 1–20% and while *a priori* , climate, vegetation, parent material, time and topography might be assumed to determine the organic matter content of soils (Wilson 1987:163), these can vary in importance in different soils and in different locations. Soil organic matter is an accumulation of partially decayed and resynthesized plant and animal residues (Bohn et al. 1979:90). "Temperature affects the rate of photosynthesis and microbiological activity and thereby the quantity of organic matter deposited on a soils and its subsequent rate of transformation. Precipitation affects the types of vegetation present and hence the organic matter present" (Wilson 1987:164). The content and nature of humus in soils is largely a balance of the synthesis and decomposition of humic substances expressed through the activity of soil micro-organisms, which are affected by climate and vegetation (op. cit.:174), and both the humus and nonhumus fractions are important to the soil environment in providing "long-range effects such as maintaining good soil structure and increasing soil cation exchange, pH buffering, and water holding capacities" (Bohn et al. 1979:90).

Most mineral soils in New Zealand have topsoil organic matter levels ranging from 3–20%, with organic soils having much higher levels (McClaren and Cameron 1990:150). "Differences between the two are due mainly to variations in: climate, soil acidity, drainage conditions, human activity and inorganic nutrients and soil parent material" (ibid). At a climate related level, the "lowest levels of organic matter are found in the semi-arid regions of Central Otago and some of the highest levels on the West Coast of the South Island and in the wetter and cooler regions of the North Island. The effects of climate are due mainly to the influence of temperature and moisture on the growth of vegetation, and on the rate of decomposition of organic residues in the soil" (ibid).

Jenkinson (1981) describes a series of factors which influence the decomposition of organic remains in soil, which are: (1) moisture — activity is overall governed by moisture levels and hence the rates of decomposition; activity is minimal under dry conditions; experiments showed a flat optimal water content at which the mineralization of which both N and C was maximal (op. cit.:535); (2) oxygen — most organisms in the soil are aerobes, while under anaerobic conditions biological activity is predominantly bacterial (ibid:537); (3) soil pH — fresh organic material decomposes more slowly in strongly acid soils than in neutral or near-neutral soils (ibid:540); (4) inorganic nutrients; (5) temperature — the rate of evolution of CO_2 by a subtropical soil increases up to a maximum at 37°C, then declines (presumably because most of the soil population is inactivated) and again rises at temperatures of 60°C and above, probably as a result of chemical oxidation (ibid:548); (6) clay — other things being equal, heavy soils contain more organic matter than sandy soils (ibid:550); and (7) accessibility — finely divided organic matter usually decomposes more quickly than does coarse (ibid:552).

The chemical effects of acidity on buried bone are such that "in any aerated soil the organic matter of the bone will be destroyed biologically and in a sufficiently acid one the mineral components will suffer more alteration than they would in alkaline conditions" (Dowman 1970:21). "For full organic breakdown moisture, oxygen, alkaline to only slightly acid conditions (a pH above 5) and warmth are necessary. The lack of even one of these factors will slow down or stop the whole process" (op. cit.:33).

Two major soil divisions are recognized in New Zealand — Zonal soils, in which climate and organic life played a large part in the formation of the soil properties; and Azonal and Intrazonal soils, where the variables of parent material, topography and time were to the fore in soil formation processes (Gibbs 1980:23). The Azonal soils "includes recent soils from volcanic ash, yellow-brown pumice soils, yellow-brown loams, brown granular soils, red loams and brown loams [which] are formed from materials erupted from volcanoes either as tephra or lava" (op. cit.:30), while "in the sedimentary class this group comprises recent soils from alluvium, yellow-brown sands, gley soils, saline soils, lowland organic soils and rendzina soils" (ibid:44). In general these soil types have relatively high organic levels, are free-draining and have a friable top soil, and have pH levels on the acidic side — ranging from 6.0–6.5 in alluvial soils to very acidic levels of 3.0–4.5 in organic soils (Molloy 1988).The yellow-brown loams are very friable, with a high moisture retention level and organic levels resistant to biological breakdown (op. cit.:53), while the organic soils have low soil nutrient levels but a moderately high exchange capacity (op. cit.:68).

By comparison, the Zonal soils are derived from processes dominated by climate and associated native vegetation — "their general correlation with climatic zones is clearly demonstrated by the brown-grey earth, yellow-grey earth, yellow-brown earth, podzol and gley podzol sequence of soil groups with increasing degrees of humidity in the South Island" (Gibbs 1980:53). The zonal soils exhibit a wide range of characteristics — the northern yellow-brown earths are poorly drained, with acidic topsoils and low nutrient levels (Molloy 1988:96). Yellow-grey earths occur in regions where there is a period of moisture deficiency for 1–3 months per annum and, as a result, are poorly drained with low organic content levels (op. cit.:110). A common feature includes "an increase in soil acidity from about pH 6.2 in weakly leached members to about pH 5.2 in strongly leached members of the group" (Gibbs 1980:57). The yellow-brown earths, the largest soil group in New Zealand, in general have friable to firm topsoils, are moderately free-draining, have high organic content levels and, in areas where leaching is high, low levels of nutrients and high acidity (Molloy 1988:137). The other major soil type in this group, the brown-grey earths (or semi-arid soils), formed from schist and greywacke under tussock grassland, annual rainfalls of 350–500mm, and hot, dry summers (Gibbs 1980:53), predominate in drier areas of New

Zealand, such as the basins of Central Otago. They have friable topsoils but firm subsoils, drainage varies with soil age with the older soils developing less permeable layers, they have a low capacity for holding nutrients but exchangeable calcium levels are moderate to high (Molloy 1988:163).

TAPHONOMY OF THE BONE COLLECTIONS

Seventeen collections of faunal material from big-game hunting sites from around New Zealand were studied in the course of this analysis. The eighteenth, from Ohawe, was unable to be relocated, as discussed below. The analysis of these faunal collections followed along similar lines to that undertaken with the material from Shag Mouth — bones were identified to element, portion, side and age, and taphonomic details relating to the degree of burning, weathering and the presence/absence of gnawing were also recorded. A more rigorous application of both the weathering and burning scales ensured that the large number of intermediate categories were all but eliminated, only remaining in instances where large numbers of fragments were bagged together and it proved easier to place them all within a range (e.g weathering scales '1–3') rather than undertaking a separate analysis of each bone. There is not a great occurrence of material of this type. Given that all the collections had undergone previous analysis, in some instances many analyses, details of species identifications were taken at face value.

Full details of all the collections studied are presented in Appendix 4 while summaries of the taphonomics appear in Appendix 5. In Appendix 4, species identifications are included, where known, for the moa remains but in running the analysis for the taphonomics it proved to be too cumbersome and all moa bone was reclassed within the species descriptor "MOA", as can be seen in the tables in both the current chapter and Appendix 5. Opua, for example, had 30 different moa species labels and retaining all these in the analysis confused the results. What I am particularly interested in, is tracing definable patterns in the weathering of moa bones within a site, and comparing these with other species present. All sea mammal identifications are retained in Appendix 5 and in the current chapter for the purpose of the analysis and discussion. Table 7.1 presents a list of the species (mammal) and element abbreviations used in this chapter.

In the discussion which follows, each site is dealt with in turn and two tables are presented for each site: the first describes the degree of burning evident in the bone remains, while the second describes the distribution of weathering classes in the collection. These are discussed at a species level and then the reader is referred to Appendix 5 where more complete tables are presented which will be discussed in the text. These include a breakdown of taphonomics by element, and a cross-tabulation between species and elements. In some of the very large South Island sites where a number of collections and excavations have been undertaken over the years (including Hawksburn, Pounawea and Papatowai) the analysis first discusses the bone collections as a whole before discussing the material from the individual collections.

The results of the soil analysis for each site are presented in Table 7.2 and will be referred to during the discussion of the faunal remains from the individual site collections. During the analysis of the base cations in the soil samples, I also calculated the levels for K, Mg and Na but because they have no direct relevance to the breakdown of bone they are not reported in the current discussion. Descriptions of the relative acidity/alkalinity of the soils were taken from Blakemore et al. (1987) as were descriptive ratings of the levels of the cation exchange properties, both of which are given below in Table 7.3.

The level of the moisture content in a soil is highly variable and depends on factors such as the amount of recent rainfall, the draining nature of the soil matrix and its ability to hold water, and the nature and ability of the bedrock to allow excess moisture to flow away. In all of my cases soil samples were taken after dry periods of at least a week so little moisture would have been retained in the matrix save for that bound to the soil molecules. The high reading for the Tokoroa samples reflects the very moist nature of the soil in that region, while the levels at Coal Creek reflect, to a certain degree, the fact that the samples were collected from a vegetable garden which was being artificially watered. In general the pH is quite alkaline for most of the sites, probably due to the presence of large

Table 7.1 Mammal and element abbreviations used in the tables and text of the current chapter. (They are also used in Appendices 4 and 5).

Mammals. The following mammal abbreviations are used:

cetacean ?sp. (ie some kind of whale)	C
elephant seal	ES
fur seal	FS
fur seal or sea lion	FS/SL
large sea mammal ?sp.	LSM
leopard seal	LS
sea mammal ?sp	SEA MAM
sea lion	SL
sea lion or elephant seal	SL/ES

Element. The following element descriptors are used:

Moa bones:

cranium	CR
mandible	MAND
vertebra	V
vertebra - cervical	V-CE
vertebra - thoracic	V-TH
vertebra - caudal	V-CA
tracheal ring	TR
sternum	ST
rib	R
rib - sternal	R-ST
pelvis	PEL
femur	FEM
tibiotarsus	TT
fibula	FIB
tarsometatarsus	TMT
long bone	LEG
phalange	PH
sesamoid	SES

Table 7.1 (ctd.)

Mammal bones:

carpal	CAR
cranium	CR
femur	FEM
fibula	FIB
humerus	HUM
hyoid	HY
long bone	LB
mandible	MAND
metacarpal	MC (MC1,MC2 etc)
metatarsal	MT (MT1,MT2 etc)
metacarpal or metatarsal	MC/MT
os penis	OSP
pelvis	PEL
phalange	PH
phalange - forelimb	PH-FL
phalange - hindlimb	PH-HL
radius	RAD
rib	RIB
scapula	SCAP
sternum	ST
sternum - manubrium	ST-M
sternum - segment	ST-S
sternum - xiphoid	ST-X
tarsal	TAR
tibia	TIB
tooth	TOOTH
vertebra	V
vertebra - cervical	V-CE (-CE1,-CE2 etc)
vertebra - thoracic	V-TH (-TH1,-TH2 etc)
vertebra - lumbar	V-L (-L1,-L2 etc)
vertebra - sacral	V-S (-S1,-S2 etc)
vertebra - caudal	V-CA

Note: any fragments that were not able to be identified to element were bagged and entered as 'RESIDUE'.

Table 7.2 Soil chemistry results for the archaeological sites.

Sample No.	Provenance	Date	pH	M.C. (%)	O.C. (%)	Base Cations (me%)		
						Ca^{2+}(1)	Ca^{2+}(2)	Ca^{2+}(3)
49	Port Jackson, Sample 1	19/8/90	8.48	0.69	0.20	.	1.89	20.79
50	Port Jackson, Sample 2	"	8.39	0.57	0.16	.	1.58	17.38
51	Port Jackson, Sample 3	"	8.76	0.43	0.15	.	3.19	35.09
52	Port Jackson, Sample 4	"	8.74	0.33	0.27	.	2.11	23.21
57	Cross Creek N40/260, No. 1	20/8/90	8.12	0.30	0.10	13.49	.	13.49
58	Cross Creek N40/260, No. 2	"	8.25	0.39	0.08	.	2.33	25.63
59	Cross Creek N40/260, No. 3	"	8.13	0.43	0.05	.	2.43	26.73
60	Cross Creek N40/260, No. 4	"	8.09	0.19	0.11	.	1.67	18.37
29	Opito N40/2, No. 1	20/8/90	8.52	0.67	0.05	.	5.54	60.94
30	Opito N40/2, No. 2	"	8.45	0.55	0.12	.	8.05	88.55
31	Opito N40/2, No. 3	"	8.46	0.69	0.09	.	3.97	43.67
32	Opito N40/2, No. 4	"	7.92	0.50	0.09	.	2.89	31.79
82	Tairua, Sample 1	21/8/90	8.38	0.61	0.27	.	1.67	18.37
83	Tairua, Sample 2	"	8.13	0.35	0.17	15.74	.	15.74
84	Tairua, Sample 3	"	8.20	0.34	0.18	14.28	.	14.28
33	Tokoroa, No. 1	21/8/90	5.14	3.17	0.73	4.55	.	4.55
34	Tokoroa, No. 2	"	5.10	2.30	0.33	1.75	.	1.75

Table 7.2 (ctd.)

Sample No.	Provenance	Date	pH	M.C. (%)	O.C. (%)	Base Cations (me%) Ca^{2+}(1)	Ca^{2+}(2)	Ca^{2+}(3)
35	Tokoroa, No. 3	"	5.20	2.78	0.43	1.19	.	1.19
79	Whakamoenga, Sample 1	22/8/90	7.98	0.70	0.26	14.44	.	14.44
80	Whakamoenga, Sample 2	"	7.86	0.90	0.37	.	3.99	43.89
81	Whakamoenga, Sample 3	"	6.78	1.04	0.26	3.74	.	3.74
75	Opua, No. 2	1/8/90	6.33	0.73	0.25	5.14	.	5.14
76	Opua, No. 3	"	8.19	0.46	0.12	21.59	.	21.59
65	Kaupokonui, No. 1	1/8/90	6.37	0.22	0.15	0.51	.	0.51
66	Kaupokonui, No. 2	"	6.59	0.26	0.23	1.02	.	1.02
67	Kaupokonui, No. 3	"	7.19	0.66	0.13	3.68	.	3.68
68	Kaupokonui, No. 4	"	7.51	0.36	0.04	3.13	.	3.13
69	Kaupokonui, No. 5	"	6.92	0.32	0.00	1.16	.	1.16
70	Kaupokonui, No. 6	"	7.67	0.32	0.04	1.25	.	1.25
71	Ohawe, No. 1	1/8/90	8.34	0.25	0.09	1.39	.	1.39
72	Ohawe, No. 2	"	7.76	0.30	0.08	1.43	.	1.43
73	Ohawe, No. 3	"	7.80	0.29	0.08	1.51	.	1.51
74	Ohawe, No. 4	"	6.58	0.23	0.15	0.61	.	0.61
36	Owens Ferry	5/11/90	8.60	0.65	0.00	.	1.97	21.67

Table 7.2 (ctd.)

Sample No.	Provenance	Date	pH	M.C. (%)	O.C. (%)	Base Cations (me%) $Ca^{2+}(1)$	$Ca^{2+}(2)$	$Ca^{2+}(3)$
53	Hawksburn, No. 1	5/11/90	6.63	0.79	0.60	.	2.99	32.89
54	Hawksburn, No. 2	"	7.70	0.80	0.34	.	2.44	26.84
55	Hawksburn, No. 3	"	6.67	0.75	0.37	26.29	.	26.29
56	Hawksburn, No. 4	"	5.33	0.55	0.21	4.76	.	4.76
45	Coal Creek, No. 1	5/11/90	5.67	1.72	0.47	.	2.40	26.40
46	Coal Creek, No. 2	"	5.13	1.30	0.45	21.50	.	21.50
47	Coal Creek, No. 3	"	5.55	1.34	0.53	11.75	.	11.75
48	Coal Creek, No. 4	"	4.79	0.37	0.49	7.71	.	7.71

Notes:
M.C. = moisture content
O.C. = organic content
$Ca^{2+}(1)$ = initial result of calcium run
$Ca^{2+}(2)$ = results for diluted calcium samples
$Ca^{2+}(3)$ = recalibrated calcium results (see text for full explanation of these)

Table 7.3 Ratings of chemical properties of soils, as used by the NZ Soil Bureau (from Blakemore et al. 1987:103).

Rating	pH (1:2.5 soil:water)		Cation exchange properties Ca (me%)
	> 9.0	(extremely alkaline)	
Very high	8.4–9.0	(strongly alkaline)	> 20
	7.6–8.3	(moderately alkaline)	
High	7.1–7.5	(slightly alkaline)	10–20
	6.6–7.0	(near neutral)	
Medium	6.0–6.5	(slightly acid)	5–10
	5.3–5.9	(moderately acid)	
Low	4.5–5.2	(strongly acid)	2–5
Very low	< 4.5	(extremely acid)	< 2

amounts of bone and shell midden and, in addition, one generally finds that the higher the acidity the higher the organic content, and vice versa, due to the break-down by-products of the organic material which release H^+ ions into the system (Richard Morgan pers.comm. 7/7/92).

Houhora (N6/4)

The bone recovered in the excavations at Houhora was predominantly unburnt (Table 7.4), ranging from 85% in the moa up to 99% of the sealion (and 100% in the few fragments of unidentified sea mammal). This would have been higher in the moa but for a large bag of broken shaft fragments which exhibited a range of burning (Stages 2–4) and which were lumped together rather than being analysed separately. In both the fur seal and moa remains some burnt material was recorded, but no more than the 2% exhibited by the moa in Stage 3.

Table 7.4 The degrees of burning evident in the Houhora remains.

		SPECIES					
		?SL	FS	LSM	MOA	SL	ALL
BURNT							
1	N	2	190	3	1184	81	1460
	PCTN	100	91	100	85	99	87
1-4	N	.	.	.	130	.	130
	PCTN	.	.	.	9	.	8
2	N	.	6	.	15	1	22
	PCTN	.	3	.	1	1	1
3	N	.	3	.	25	.	28
	PCTN	.	1	.	2	.	2
4	N	.	2	.	11	.	13
	PCTN	.	1	.	1	.	1
5	N	.	8	.	20	.	28
	PCTN	.	4	.	1	.	2
ALL	N	2	209	3	1385	82	1681

This material was some of the first analysed after I had completed the Shag Mouth collection (described in Chapter 5), and the range of weathering stages shown in Table 7.5 clearly indicate I was still not totally satisfied with my abilities to separate bones into distinct groups. The problem was compounded by the presence of a large number of bags of assorted shaft fragments, exhibiting a range of stages within a single bag. This problem was only found with the moa bones, as the bones of the sea mammals were bagged individually, presumably due to their prior analysis by Smith (1985).

In both the fur seal and sea lion bones, weathering has advanced to Stage 3 in the

Table 7.5 The weathering stages evident in the Houhora remains.

		SPECIES					
		?SL	FS	LSM	MOA	SL	ALL
WEATHERED							
1	N	.	35	.	69	9	113
	PCTN	.	17	.	5	11	7
1*	N	.	.	.	1	.	1
	PCTN	.	.	.	0	.	0
1-2	N	.	.	.	3	.	3
	PCTN	.	.	.	0	.	0
1-3	N	.	.	.	35	.	35
	PCTN	.	.	.	3	.	2
1-4	N	.	.	.	166	.	166
	PCTN	.	.	.	12	.	10
1-5	N	.	.	.	7	.	7
	PCTN	.	.	.	1	.	0
2	N	1	67	2	210	21	301
	PCTN	50	32	67	15	26	18
2*	N	.	.	.	3	.	3
	PCTN	.	.	.	0	.	0
2-3	N	.	.	.	206	.	206
	PCTN	.	.	.	15	.	12

majority of cases (46% in fur seal and 51% in sea lion). Only 17% and 11%, respectively, remained in Stage 1. Whether this is a reflection of the bones having lain exposed on the surface for some time, or that it is due to weathering within the burial matrix is unclear. Without knowledge of the background chemistry of the thin coastal strip of land at the foot of Mt Camel it is difficult to determine the burial effects. Given the fact that the area is within a region of high annual rainfall, coupled with relatively high mean daily temperatures, the conditions are very conducive to bone degradation, as discussed in Chapter 3.

The moa bone, on the other hand, is difficult to describe accurately because of the less rigorous approach taken with the material. The majority of the material is in Stage 3 or less, with only 12% in more advanced stages. Approximately 8% of the moa bone falls into Stage 4, similar to the sea lion remains, and 2% has reached Stage 5.

In examining material at an elemental level (Appendix 5.1) we find that similar patterns are described for most of the elements — burning, as was discussed above, affected very few of the bones although it was certainly the leg elements which exhibited the presence of burning where it occurred. An examination of the weathering indicates that it is the compact bone of the leg elements that is occurring at a higher level of breakdown — 18% of the 'FEM' fragments are in Stage 4 or higher, and a full 50% of the 'TMT' fragments are also within these stages. The majority of the 'soft' elements exist in relatively unweathered states, suggesting that differential proportions of bone types present are not the result of natural processes, but probably reflect cultural preferences (as discussed in Chapter 6). Overall, 44% of 'PELV' fragments are in Stage 4 which may be a reflection of the high proportion of cancellous bone present in this element. Figure 7.1 shows some examples of weathering in the Houhora bones.

In discussing the distribution of weathering and burning stages between species it becomes clear that while the fur seal remains are predominantly unburnt (95%), they do show a range of weathering up to Stage 3 (Figures 7.2 and 7.3). The mandibles are weathered to Stage 3 in 74% of cases and to Stage 4 in a further 11%, while 70% of the xiphoid fragments of the sternum are in Stage 3.

Table 7.5 (ctd)

```
|--------------+--------------+------+------+------+------+------+------|
|2-3*          |N             |     .|     .|     .|    10|     .|    10|
|              |--------------+------+------+------+------+------+------|
|              |PCTN          |     .|     .|     .|     1|     .|     1|
|--------------+--------------+------+------+------+------+------+------|
|2-4           |N             |     .|     .|     .|   319|     .|   319|
|              |--------------+------+------+------+------+------+------|
|              |PCTN          |     .|     .|     .|    23|     .|    19|
|--------------+--------------+------+------+------+------+------+------|
|3             |N             |     1|    97|     1|   175|    42|   316|
|              |--------------+------+------+------+------+------+------|
|              |PCTN          |    50|    46|    33|    13|    51|    19|
|--------------+--------------+------+------+------+------+------+------|
|3*            |N             |     .|     .|     .|     9|     2|    11|
|              |--------------+------+------+------+------+------+------|
|              |PCTN          |     .|     .|     .|     1|     2|     1|
|--------------+--------------+------+------+------+------+------+------|
|3-4           |N             |     .|     .|     .|    31|     .|    31|
|              |--------------+------+------+------+------+------+------|
|              |PCTN          |     .|     .|     .|     2|     .|     2|
|--------------+--------------+------+------+------+------+------+------|
|4             |N             |     .|     9|     .|   106|     8|   123|
|              |--------------+------+------+------+------+------+------|
|              |PCTN          |     .|     4|     .|     8|    10|     7|
|--------------+--------------+------+------+------+------+------+------|
|4*            |N             |     .|     .|     .|     1|     .|     1|
|              |--------------+------+------+------+------+------+------|
|              |PCTN          |     .|     .|     .|     0|     .|     0|
|--------------+--------------+------+------+------+------+------+------|
|5             |N             |     .|     1|     .|    34|     .|    35|
|              |--------------+------+------+------+------+------+------|
|              |PCTN          |     .|     0|     .|     2|     .|     2|
|--------------+--------------+------+------+------+------+------+------|
|ALL           |N             |     2|   209|     3|  1385|    82|  1681|
|--------------+--------------+------+------+------+------+------+------|
```

Similarly, of the moa bones 85% are unburnt and most of the material is weathered up to Stage 3 (Figures 7.4 and 7.5). The leg elements are generally more heavily weathered than the vertebrae — 44% of 'FEM' fragments are in Stages 4 and 5, as are 50% of 'TMT', and 56% of 'PELV' fragments.

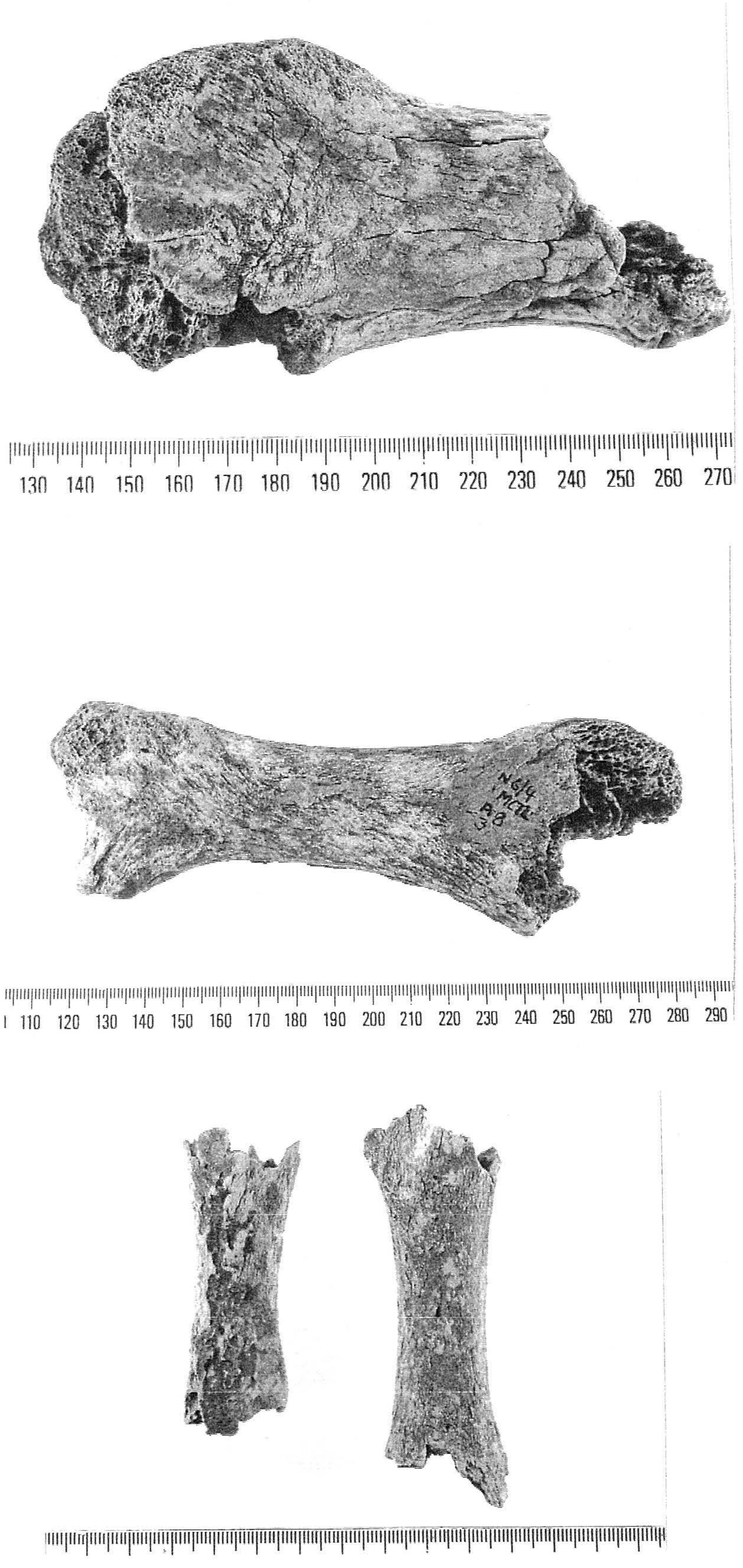


Figure 7.1 Examples of bone weathering in moa bone from Houhora.

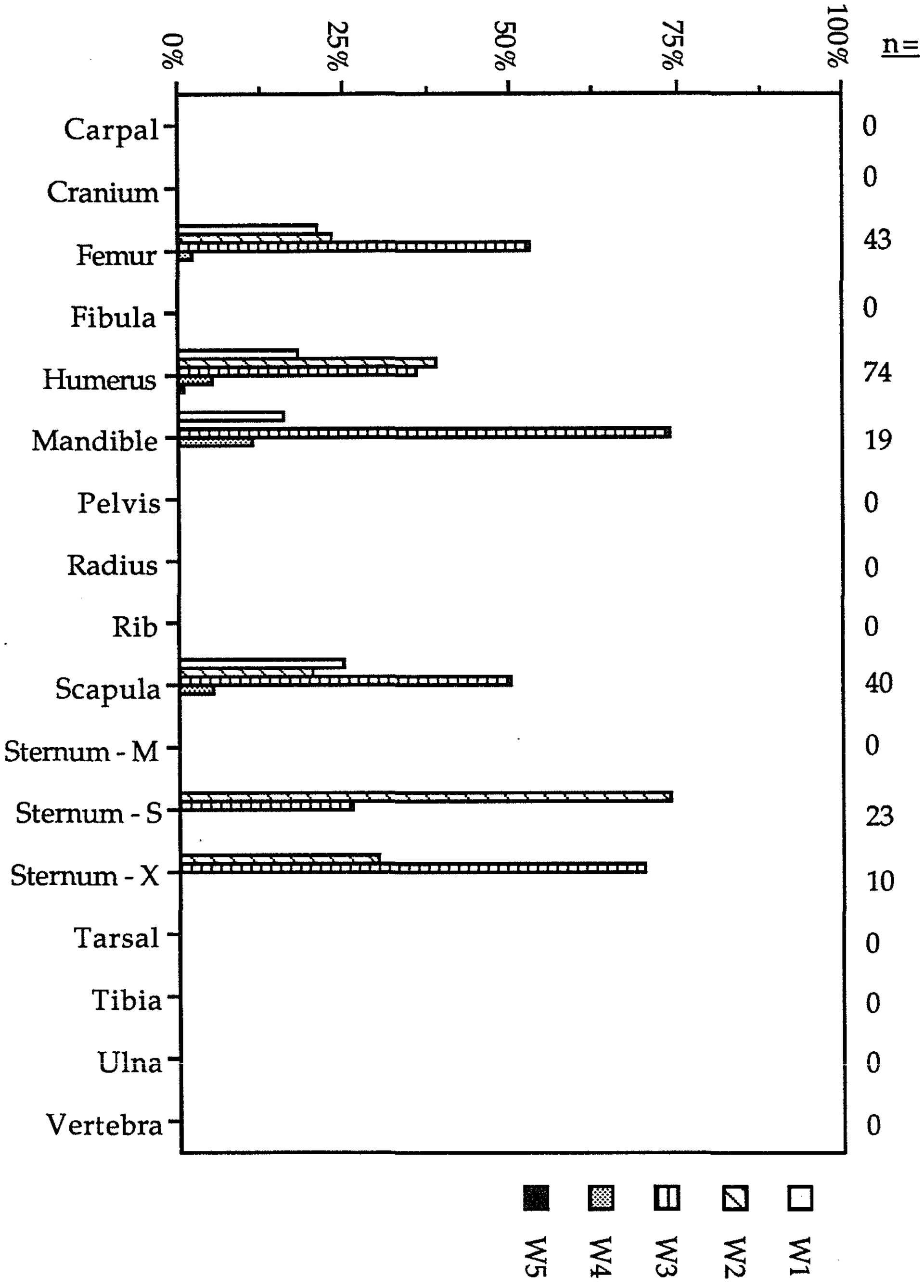


Figure 7.2 A breakdown of the weathering stages recorded for each skeletal element of fur seal present at Houhora.

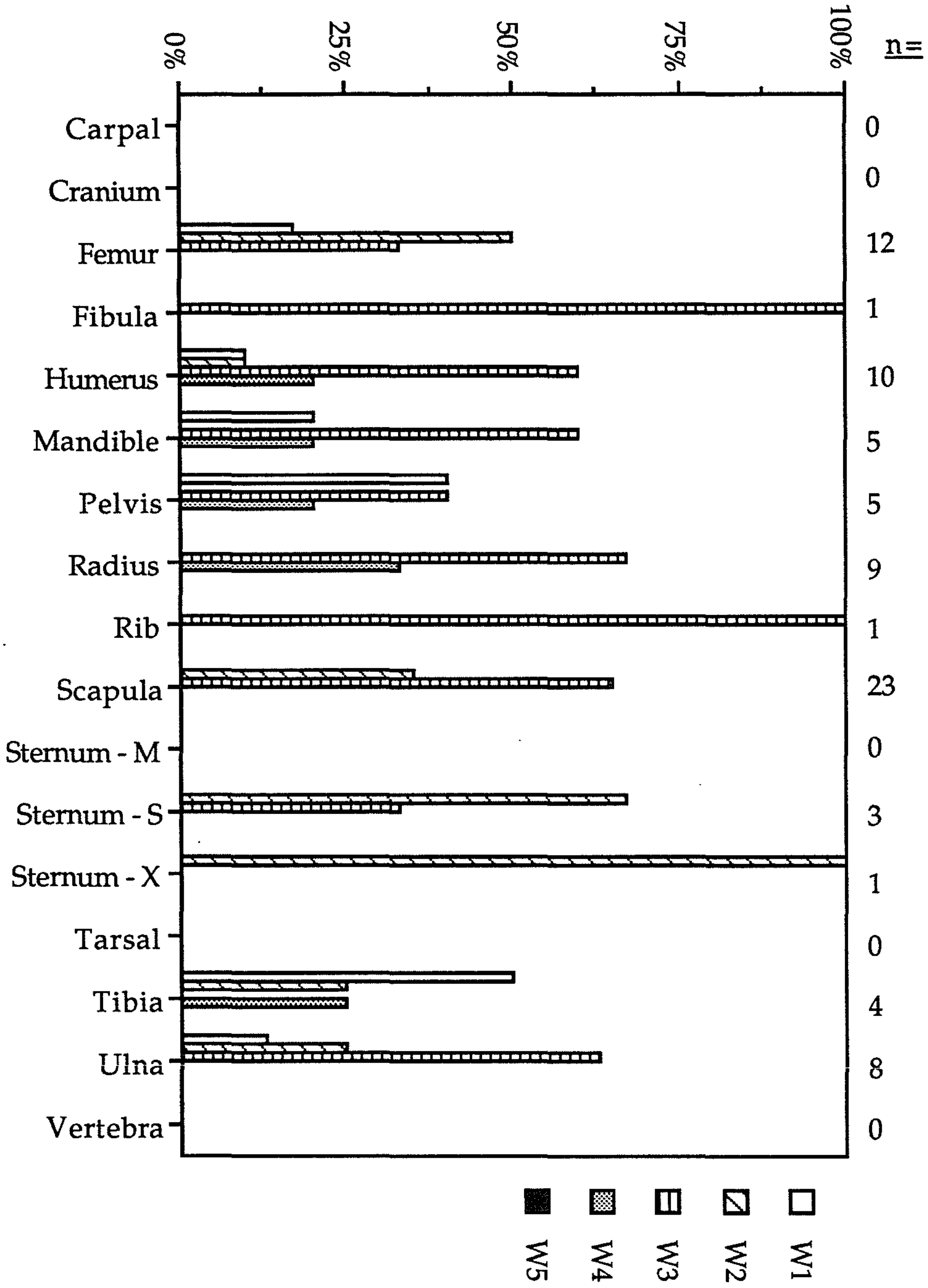


Figure 7.3 A breakdown of the weathering stages recorded for each skeletal element of sea lion present at Houhora.

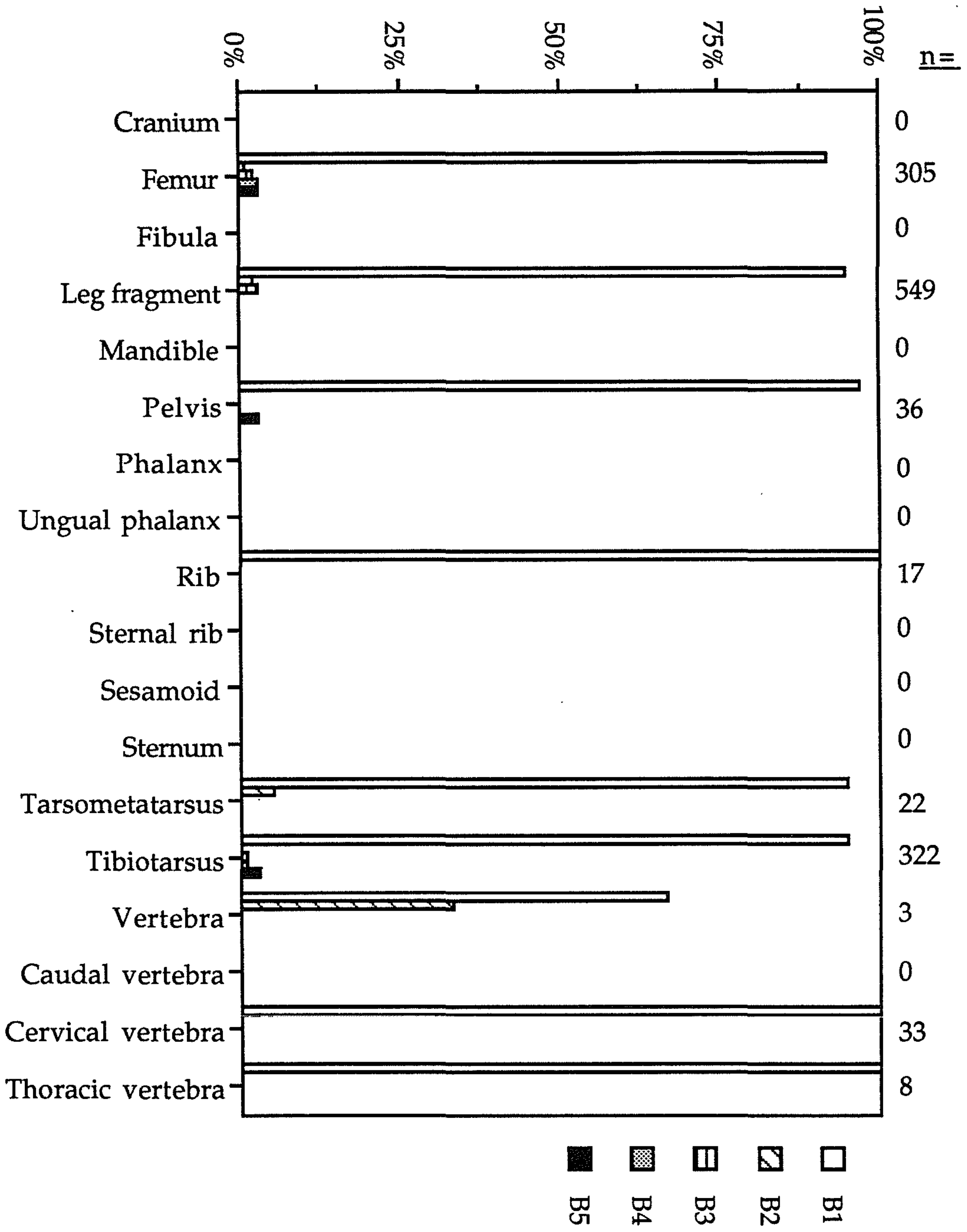


Figure 7.4 A breakdown of the burning stages recorded for each skeletal element of moa present at Houhora.

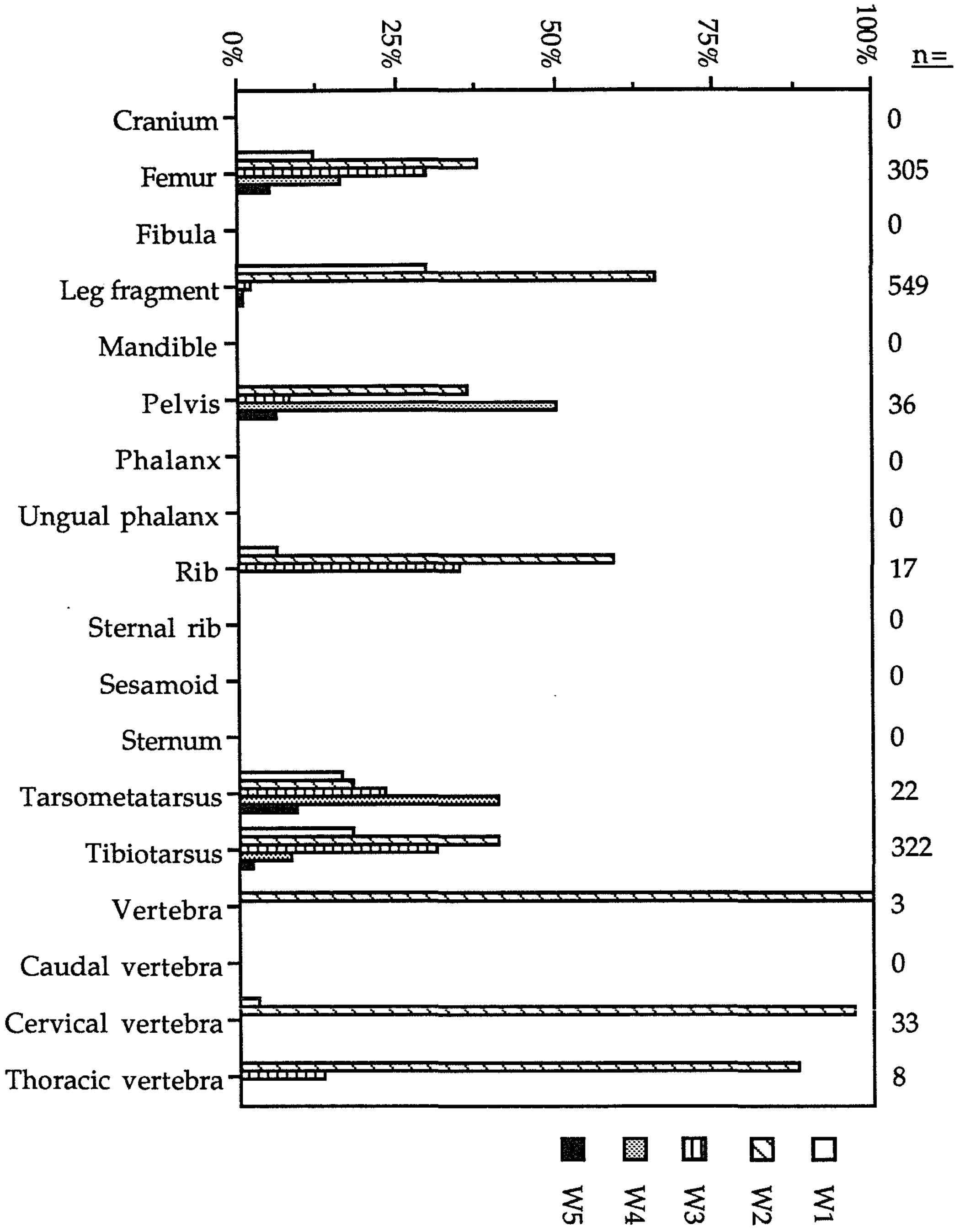


Figure 7.5 A breakdown of the weathering stages recorded for each skeletal element of moa present at Houhora.

Port Jackson (N35/88)

The Port Jackson faunal material bears little evidence of burning (Table 7.6). One bag of moa bone exhibiting a range of stages is the exception to this but the collection does have a high proportion of bone that is bleached (indicated by the '*' categories) from exposure to the sun (Table 7.7, Figures 7.6a and b). The deflated nature of the midden means that a lot of bone material does lie exposed on the surface (Figure 6.3c) and this has affected its survival. What is more, this deflation of the dune system has largely occurred since the 1970s. Approximately 33% of the moa bone is in Stage 3 or higher, most of that being bone which is bleached. Similarly 50% of the sea lion bones are in this group.

Within the moa remains, 3% overall (including 7% of 'LEG' fragments, 13% of 'TMT' and 5% of 'TT') are in burning Stage 4, indicating that they had been burnt to a white/grey colour. The bag containing 115 fragments of residue exhibited a range of burning from unburnt material through to bones in the white/grey phase. Almost 100% of the moa bones (if one includes the residue fragments) are leg elements, and have undergone more advanced weathering than bone from most of the sites I examined — 33% of 'FEM' were in Stage 2 and a further 32% in Stage 3; 80% of 'LEG' fragments were in Stage 3 and a further 13% in Stage 5; 38% of 'TMT' were in Stage 3 and 25% in Stage 4; and, finally, 30% of 'TT' in Stage 3 with 8% in Stage 4 (Appendix 5.2, Figures 7.7 and 7.8).

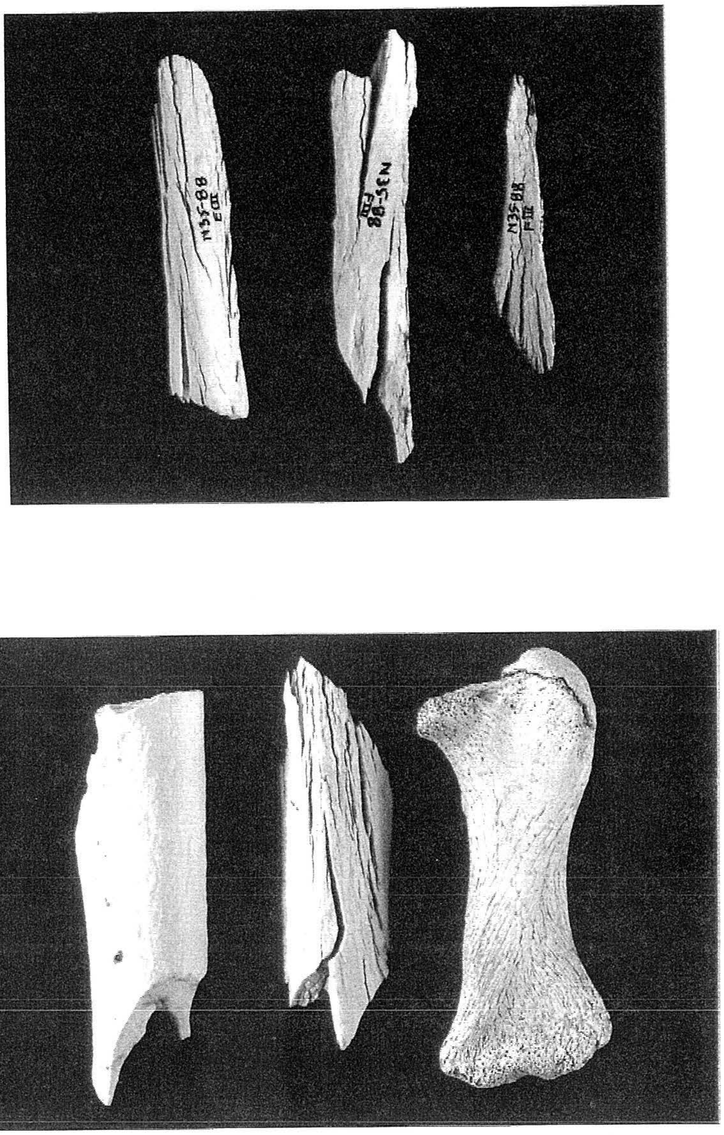
This degree of weathering is evidence of a lengthy period spent exposed on the ground surface. What cannot be determined is whether this occurred when the bones were deposited in the site, or is due to modern damage which has developed since the 1970's when cattle were grazed on the site and exposed the formerly deeply buried material. Certainly this amount of damage is not due to the soil conditions. The dunes are strongly alkaline in their pH (Table 7.2), probably due to the large amounts of shell formerly present in the midden and the very high levels of Ca^{2+} could be the result of leaching into the matrix as the bones cracked and disintegrated while lying exposed on the surface, and from the breakdown of shells within the extensive shell midden due to the percolating moisture from the rain and ocean.

Table 7.6 The degrees of burning evident in the Port Jackson remains.

```
|-----------------------------|---------------------------|------|
|                             |          SPECIES          |      |
|                             |---------------------------|      |
|                             |  ES  |  FS  | MOA  |  SL  | ALL  |
|-----------------------------+------+------+------+------+------|
|BURNT         |              |      |      |      |      |      |
|--------------+--------------|      |      |      |      |      |
|1             |N             |     1|     3|   237|    14|   255|
|              |--------------+------+------+------+------+------|
|              |PCTN          |   100|   100|    64|   100|    66|
|--------------+--------------+------+------+------+------+------|
|1,3,4         |N             |     .|     .|   115|     .|   115|
|              |--------------+------+------+------+------+------|
|              |PCTN          |     .|     .|    31|     .|    30|
|--------------+--------------+------+------+------+------+------|
|2             |N             |     .|     .|     3|     .|     3|
|              |--------------+------+------+------+------+------|
|              |PCTN          |     .|     .|     1|     .|     1|
|--------------+--------------+------+------+------+------+------|
|3             |N             |     .|     .|     2|     .|     2|
|              |--------------+------+------+------+------+------|
|              |PCTN          |     .|     .|     1|     .|     1|
|--------------+--------------+------+------+------+------+------|
|4             |N             |     .|     .|    11|     .|    11|
|              |--------------+------+------+------+------+------|
|              |PCTN          |     .|     .|     3|     .|     3|
|--------------+--------------+------+------+------+------+------|
|5             |N             |     .|     .|     1|     .|     1|
|              |--------------+------+------+------+------+------|
|              |PCTN          |     .|     .|     0|     .|     0|
|--------------+--------------+------+------+------+------+------|
|ALL           |N             |     1|     3|   369|    14|   387|
|--------------+--------------+------+------+------+------+------|
```

Table 7.7 The weathering stages evident in the Port Jackson remains.

		SPECIES				
		ES	FS	MOA	SL	ALL
WEATHERED						
1	N	.	.	10	1	11
	PCTN	.	.	3	7	3
1*	N	1	.	21	2	24
	PCTN	100	.	6	14	6
2	N	.	.	124	1	125
	PCTN	.	.	34	7	32
2*	N	.	.	41	3	44
	PCTN	.	.	11	21	11
2-3*	N	.	.	42	.	42
	PCTN	.	.	11	.	11
2-4*	N	.	.	10	.	10
	PCTN	.	.	3	.	3
3	N	.	1	6	.	7
	PCTN	.	33	2	.	2
3*	N	.	2	88	5	95
	PCTN	.	67	24	36	25
4*	N	.	.	19	1	20
	PCTN	.	.	5	7	5
5*	N	.	.	8	1	9
	PCTN	.	.	2	7	2
ALL	N	1	3	369	14	387



Figures 7.6a (top) Bleached and cracked moa bone fragments from Port Jackson, and 7.6b (bottom) bleached moa bone fragments from Port Jackson (left and centre) and fur seal bone from Cross Creek (right).

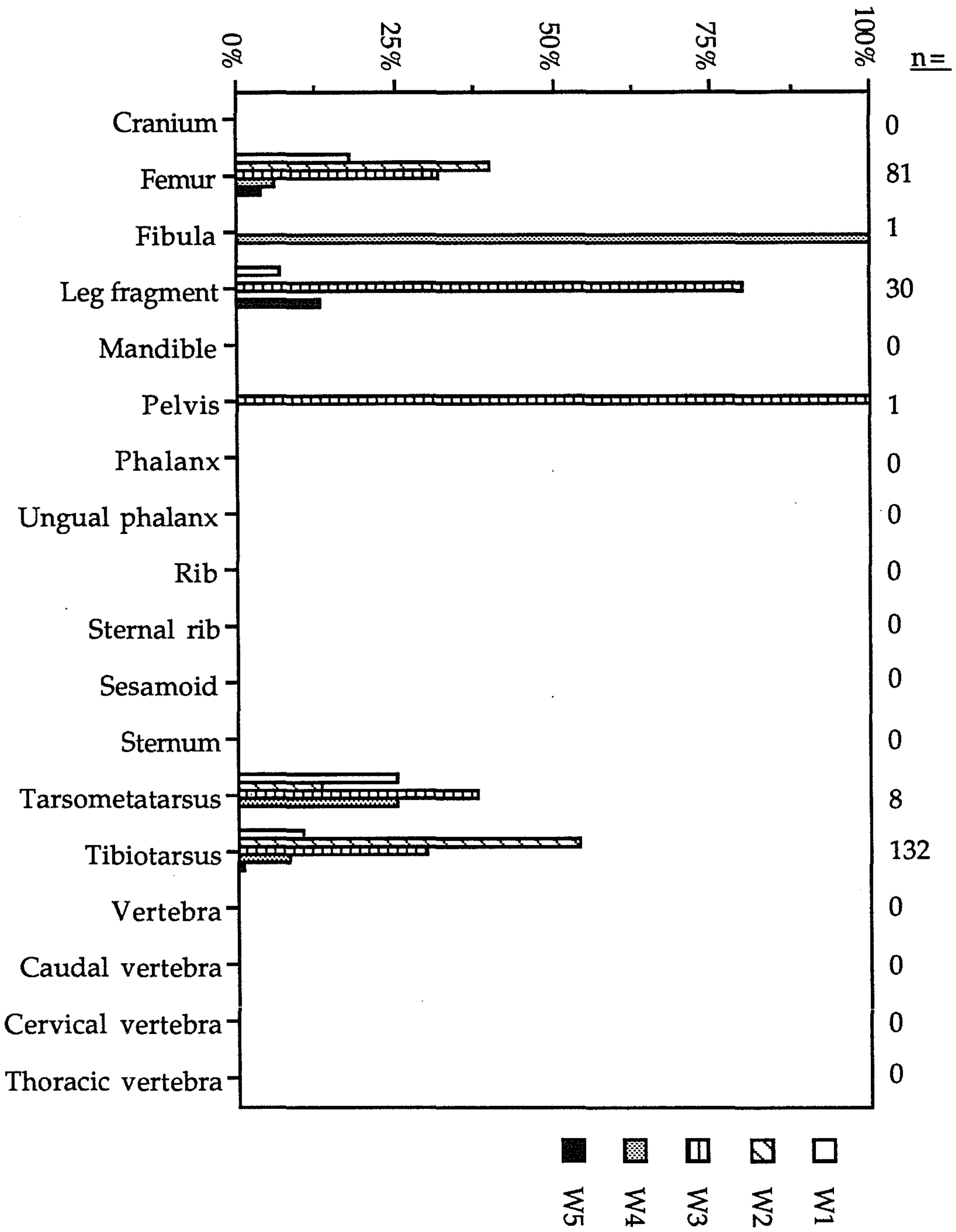


Figure 7.7 A breakdown of the weathering stages recorded for each skeletal element of moa present at Port Jackson.

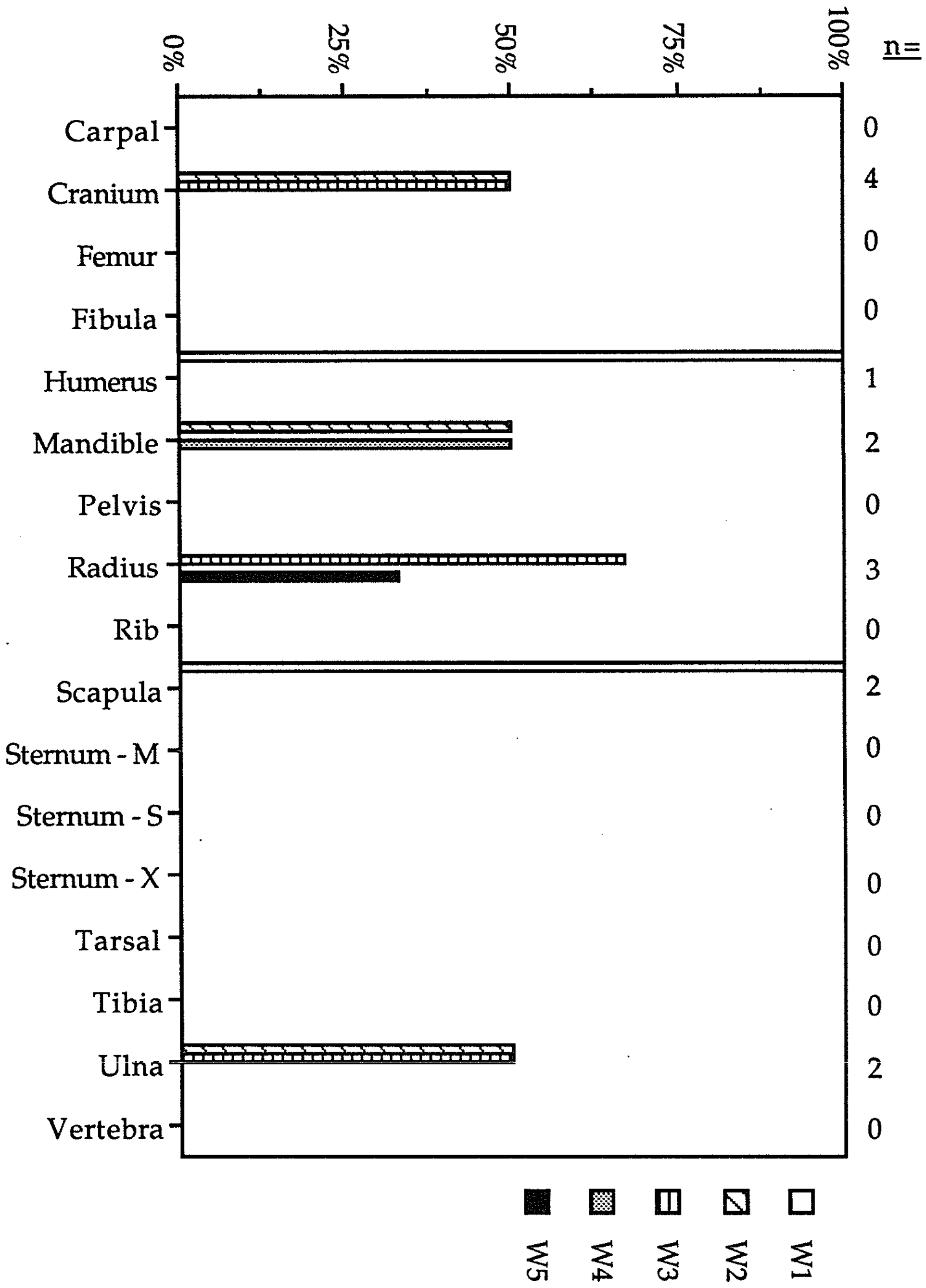


Figure 7.8 A breakdown of the weathering stages recorded for each skeletal element of sea lion present at Port Jackson.

Cross Creek (N40/260)

As with the Port Jackson bone, the material from Cross Creek is essentially unburnt (Table 7.8), apart from one moa bone and one sea lion bone, which is surprising given the number of hearths in and around the midden area (Figure 6.5). The bone is generally in an unweathered to moderately weathered state (Stages 1–3), with a few fragments (predominantly moa) in more advanced stages of weathering (Table 7.9). The high percentage of bleached material is probably a direct result of midden deflation due to the presence of stock on and around the site in recent years.

In examining the bones at a species level (Appendix 5.3) most of the sea mammal bones are unburnt and relatively unweathered (Figure 7.9). Within the moa bones, little comment can be made given that Sewell (1984) argues they all derive from a single individual at the base of the site. There was only one fragment of

Table 7.8 The degrees of burning evident in the Cross Creek remains.

		SPECIES					
		C	FS	FS/SL	MOA	SL	ALL
BURNT							
1	N	1	21	4	46	6	78
	PCTN	100	100	100	98	86	98
2	N	.	.	.	1	.	1
	PCTN	.	.	.	2	.	1
3	N	.	.	.	.	1	1
	PCTN	.	.	.	.	14	1
ALL	N	1	21	4	47	7	80

Table 7.9 The weathering stages evident in the Cross Creek remains.

		SPECIES					
		C	FS	FS/SL	MOA	SL	ALL
WEATHERED							
1	N	1	1	2	22	2	28
	PCTN	100	5	50	47	29	35
1*	N	.	14	.	.	.	14
	PCTN	.	67	.	.	.	18
2	N	.	.	2	3	5	10
	PCTN	.	.	50	6	71	13
2*	N	.	4	.	1	.	5
	PCTN	.	19	.	2	.	6
3	N	.	.	.	17	.	17
	PCTN	.	.	.	36	.	21
3*	N	.	1	.	1	.	2
	PCTN	.	5	.	2	.	3
4	N	.	.	.	2	.	2
	PCTN	.	.	.	4	.	3
4*	N	.	1	.	1	.	2
	PCTN	.	5	.	2	.	3
ALL	N	1	21	4	47	7	80

leg bone recovered, an unidentified piece of longbone shaft, with the remainder possibly utilised in the manufacture of fishhooks and other bone artefacts. The remaining bones are scattered through weathering stages 1–4 (Appendix 5.3, Figure 7.10) with one fragment of 'RIB' and two fragments of 'V-TH' appearing to be the most weathered. The bones present include ribs, sternal fragments, a cranial fragment, 'V-TH' fragments and two phalanges — probably all from one individual, so the distribution of weathering stages is interesting and is possibly due to the shifting nature of the sandy substrate or very localised diagenetic reactions within the site.

Nearly all the unweathered material (Stage 1) was 'TR' fragments indicating that soil conditions probably was of little importance in bone weathering. The four soil samples all had a pH which was moderately alkaline (Table 7.2), with very little organic material incorporated in the dune sand, and with low levels of base cations. The very high values of Ca in Samples 2 and 3, which were both derived from the same core (but at different depths), may be due to their being within the confines of the midden, as determined by Sewell (1984), where Ca was leached during the breakdown of midden material.

When I visited the site in August 1990 I surface collected a number of fur seal bones which had been stirred up by the action of stock walking across the site. Without exception, all had been bleached through exposure to the sun, a process which obviously occurs with some rapidity. While most were still in an unweathered to slightly weathered stage, one fragment of 'FEM' had reached Stage 4 and one fragment of 'RAD' was in Stage 3.

The situation that has occurred at both Port Jackson and Cross Creek serves to illustrate the grave risks which archaeological sites face when the movement of stock across them is not adequately controlled. Material becomes exposed to the elements and, in a relatively short time-span, can be quite affected by subaerial weathering in spite of having been preserved for many hundreds of years in a near pristine condition within the burial matrix. This was also recognised within my experimental bones, and is further discussed above in Chapter 3.

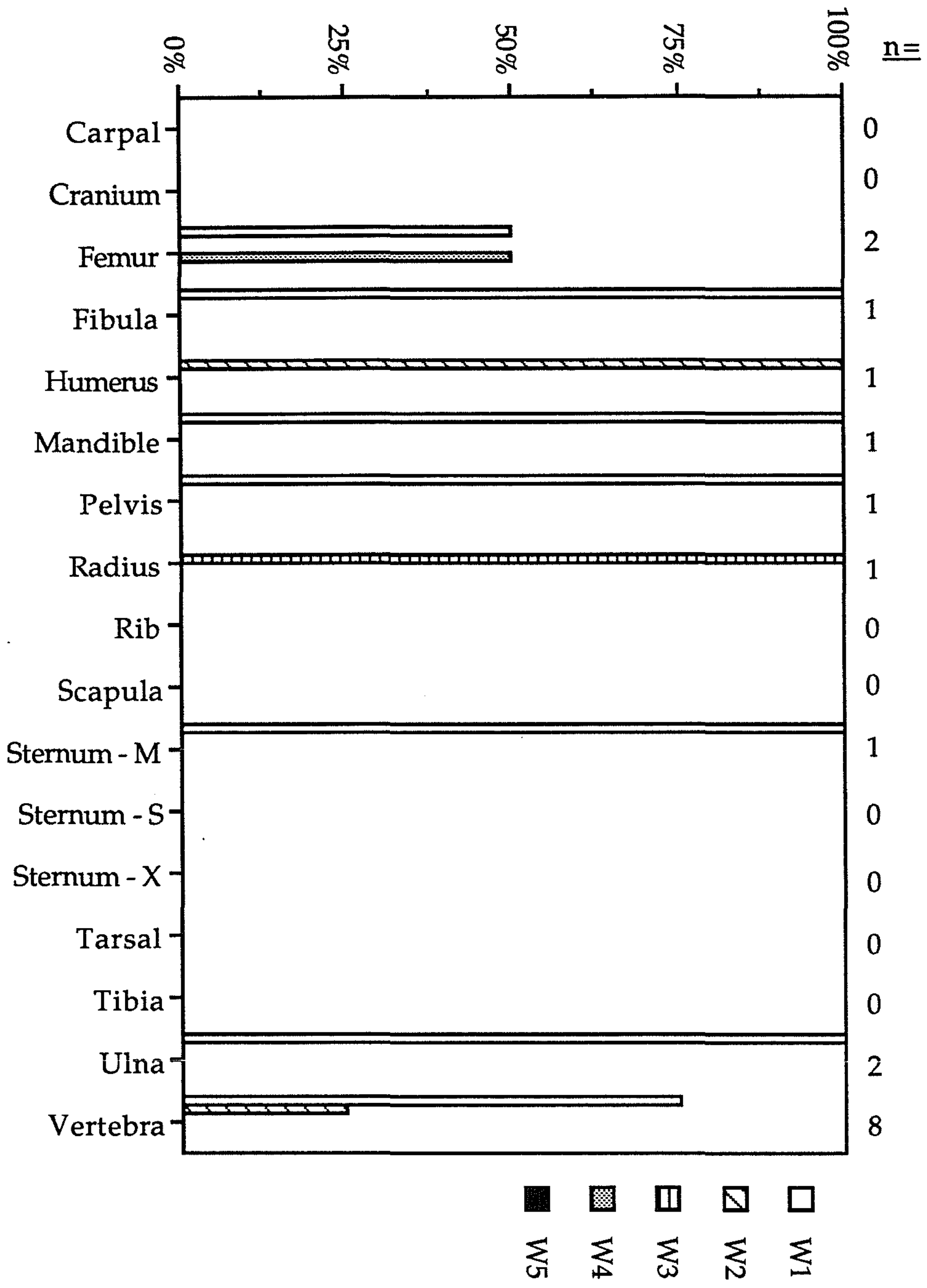


Figure 7.9 A breakdown of the weathering stages recorded for each skeletal element of fur seal present at Cross Creek.

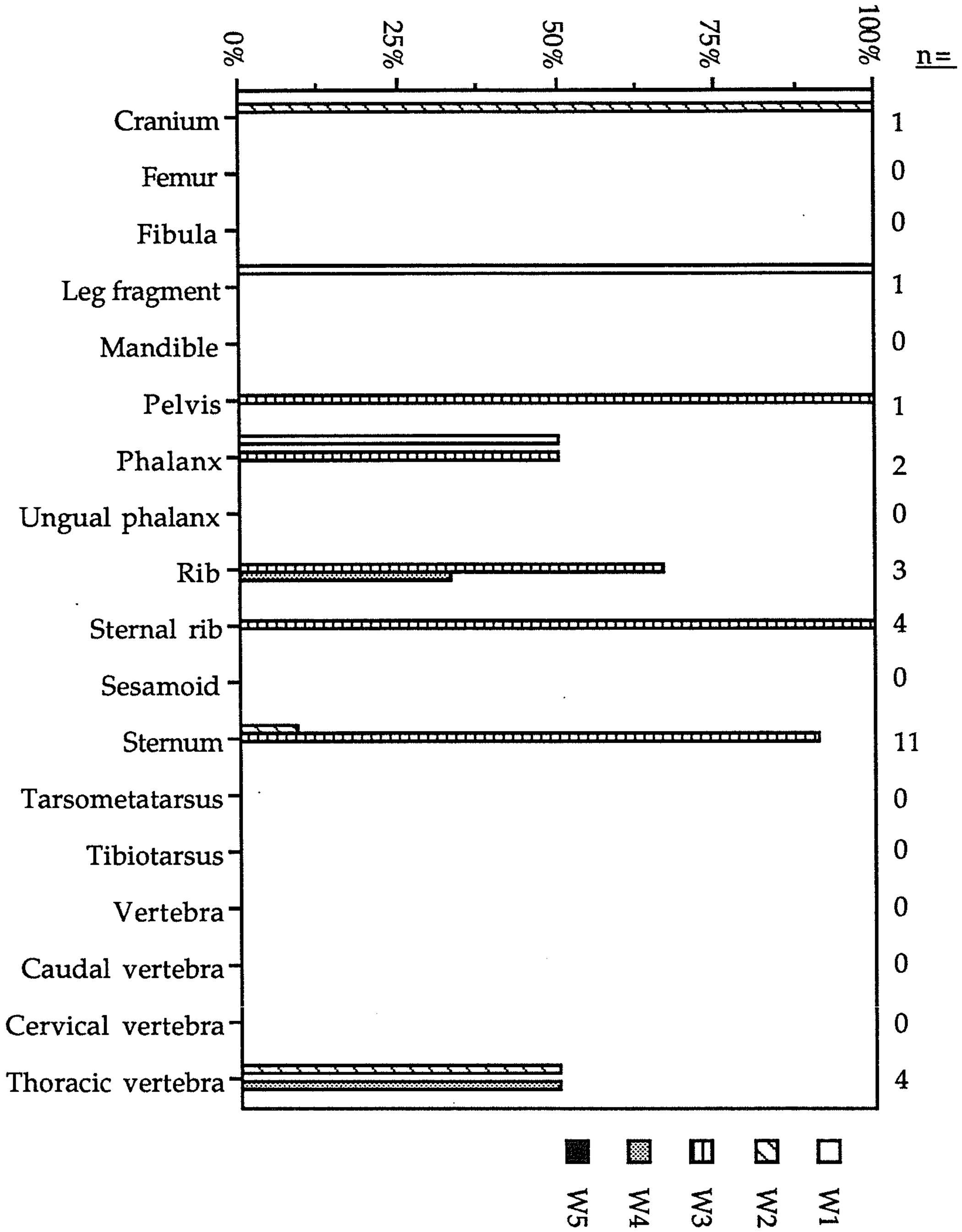


Figure 7.10 A breakdown of the weathering stages recorded for each skeletal element of moa present at Cross Creek.

Opito (N40/2)

The moa bone recovered from Opito was all unburnt material (Table 7.10) but was predominantly all in the higher stages of weathering (Table 7.10) — 33% at Stage 3, 10% at Stage 4, and 19% at Stage 5. The material I examined was from the Jolly and Murdock excavation and is presumably the material Smith (1985) also examined. Apart from single fragments each of 'PELV', 'R' and 'V-TH' (all in weathering Stage 3), the remainder of the bone is from leg elements (Appendix 5.4, Figure 7.11), most of which are 'TT' fragments.

The reason for such advanced weathering in this collection of bones is not immediately clear — only one fragment of 'TT' was sun-bleached, tending to suggest the material was not necessarily exposed on the ground surface for any length of time. The pH for all four soil samples falls within the moderately alkaline range so that is not a source, but the high level of Ca, in comparison to samples from other sites, indicates that some form of chemical action was probably occurring. The Ca value of 88.55 me% for Sample 2 is an exceptionally high value (Richard Morgan pers.comm. 7/7/92) and there are no immediate explanations for the level. Without my having undertaken chemical analyses of the bone fragments themselves, it is difficult to determine whether there is any correlation between the bone conditions and soil cation levels. These levels are significantly greater than Soil Bureau data (quoted in Chapter 6) for Ca.

Table 7.10 The degrees of burning evident in the Opito remains.

```
|-----------------------------|------|
|                             | MOA  |
|-----------------------------+------|
|BURNT         |              |      |
|--------------+--------------|      |
|1             |N             |    21|
|              |--------------+------|
|              |PCTN          |   100|
|--------------+--------------+------|
```

Table 7.11 The weathering stages evident in the Opito remains.

WEATHERED		MOA
1	N	2
	PCTN	10
2	N	6
	PCTN	29
3	N	7
	PCTN	33
4	N	2
	PCTN	10
5	N	3
	PCTN	14
5*	N	1
	PCTN	5
ALL	N	21

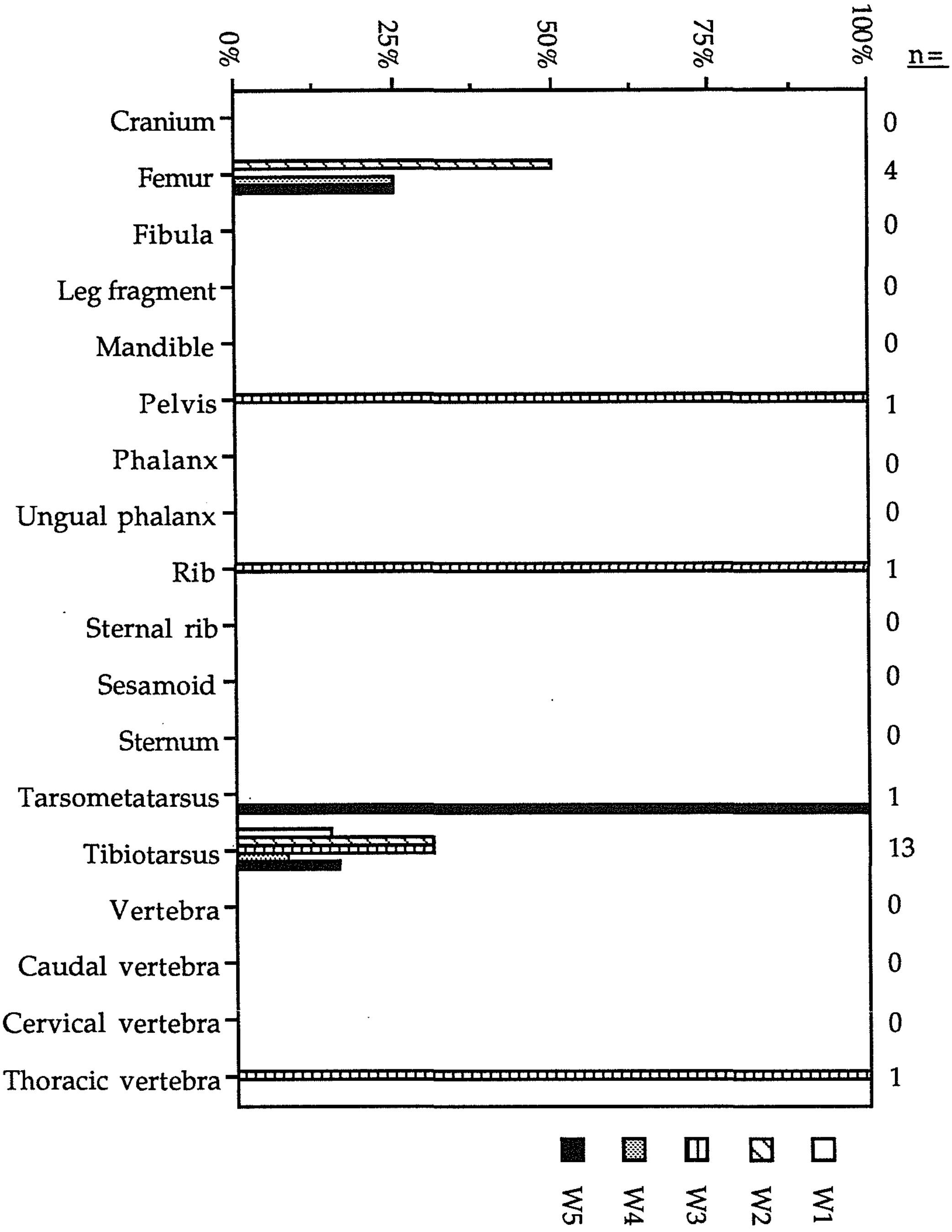


Figure 7.11 A breakdown of the weathering stages recorded for each skeletal element of moa present at Opito.

Tairua (N44/2)

Apart from a few fragments of fur seal and moa bone, nearly 100% of the large game fauna from this site was unburned (Table 7.12). Four fragments (= 3%) of the fur seal bones were stained black (Stage 5) from being in direct contact with oven rakeout or the remains of fires, but only three fragments from the whole collection showed direct evidence of burning.

The two principal components of the big-game fauna, fur seal and moa, show a slightly different distribution in weathering patterns (Table 7.13). In the fur seal 28% are in Stage 1, 40% in Stage 2, and 24% in Stage 3, and there were another 6% of fragments I placed into an intermediate Stage 1–2. The moa bones tend to be more scattered across the weathering scale with 19% in Stage 1, 8% in Stage 2, 25% in Stage 3, with single bones (= 3%) each in Stages 3*, 4 and 5. There was also

Table 7.12 The degrees of burning evident in the Tairua remains.

```
|-------------------------------|----------------------------------|------|
|                               |             SPECIES              |      |
|                               |----------------------------------|      |
|                               | ?SL  |  ES  |  FS  | MOA  |  SL  | ALL  |
|-------------------------------+------+------+------+------+------+------|
|BURNT          |               |      |      |      |      |      |      |
|---------------+---------------|      |      |      |      |      |      |
|1              |N              |     2|    11|   142|    35|     .|   190|
|               |---------------+------+------+------+------+------+------|
|               |PCTN           |   100|   100|    97|    97|     .|    96|
|---------------+---------------+------+------+------+------+------+------|
|2              |N              |     .|     .|     1|     1|     .|     2|
|               |---------------+------+------+------+------+------+------|
|               |PCTN           |     .|     .|     1|     3|     .|     1|
|---------------+---------------+------+------+------+------+------+------|
|4              |N              |     .|     .|     .|     .|     1|     1|
|               |---------------+------+------+------+------+------+------|
|               |PCTN           |     .|     .|     .|     .|   100|     1|
|---------------+---------------+------+------+------+------+------+------|
|5              |N              |     .|     .|     4|     .|     .|     4|
|               |---------------+------+------+------+------+------+------|
|               |PCTN           |     .|     .|     3|     .|     .|     2|
|---------------+---------------+------+------+------+------+------+------|
|ALL            |N              |     2|    11|   147|    36|     1|   197|
|---------------+---------------+------+------+------+------+------+------|
```

a bag of 'TT' shaft fragments which were lumped together as Stage 1–3, equalling 39% of the total.

There was little difference between element classes across the weathering stages (Appendix 5.5, Figures 7.12 and 7.13) as 'softer' elements appear to be as weathered as those one usually expects to be better preserved. The material in Stage 3 weathering includes 'FEM', 'HUM', 'RAD', and 'TT' of the more durable elements, and 'MAND', 'R', 'SCAP' and 'V' of the bones with greater percentages of cancellous rather than cortical bone. The bones at Stage 4 include a sea lion 'UL' fragment and a moa 'TT', while that at Stage 5 is a moa 'FEM' fragment.

The condition of the bone in this collection is probably due almost entirely to surface exposure prior to burial as the soil pH was moderately alkaline (Table 7.2), although the high level of Ca provides evidence that some chemical activity was occurring within the matrix. This is possibly due to the low moisture content of the burial matrix which would generally inhibit much leaching.

The material I studied from Tairua was recovered from Green's second excavation in 1964 (Green 1967). The earlier material, from the Smart and Green excavation in 1959, had been sent to the National Museum in Wellington for examination and is now no longer available for analysis.

Table 7.13 The weathering stages evident in the Tairua remains.

		SPECIES					
		?SL	ES	FS	MOA	SL	ALL
WEATHERED							
1	N	1	.	41	7	.	49
	PCTN	50	.	28	19	.	25
1-2	N	.	.	9	.	.	9
	PCTN	.	.	6	.	.	5
1-3	N	.	.	.	14	.	14
	PCTN	.	.	.	39	.	7
2	N	.	2	59	3	.	64
	PCTN	.	18	40	8	.	32
2-3	N	.	.	3	.	.	3
	PCTN	.	.	2	.	.	2
3	N	.	9	35	9	1	54
	PCTN	.	82	24	25	100	27
3*	N	.	.	.	1	.	1
	PCTN	.	.	.	3	.	1
4	N	1	.	.	1	.	2
	PCTN	50	.	.	3	.	1
5	N	.	.	.	1	.	1
	PCTN	.	.	.	3	.	1
ALL	N	2	11	147	36	1	197

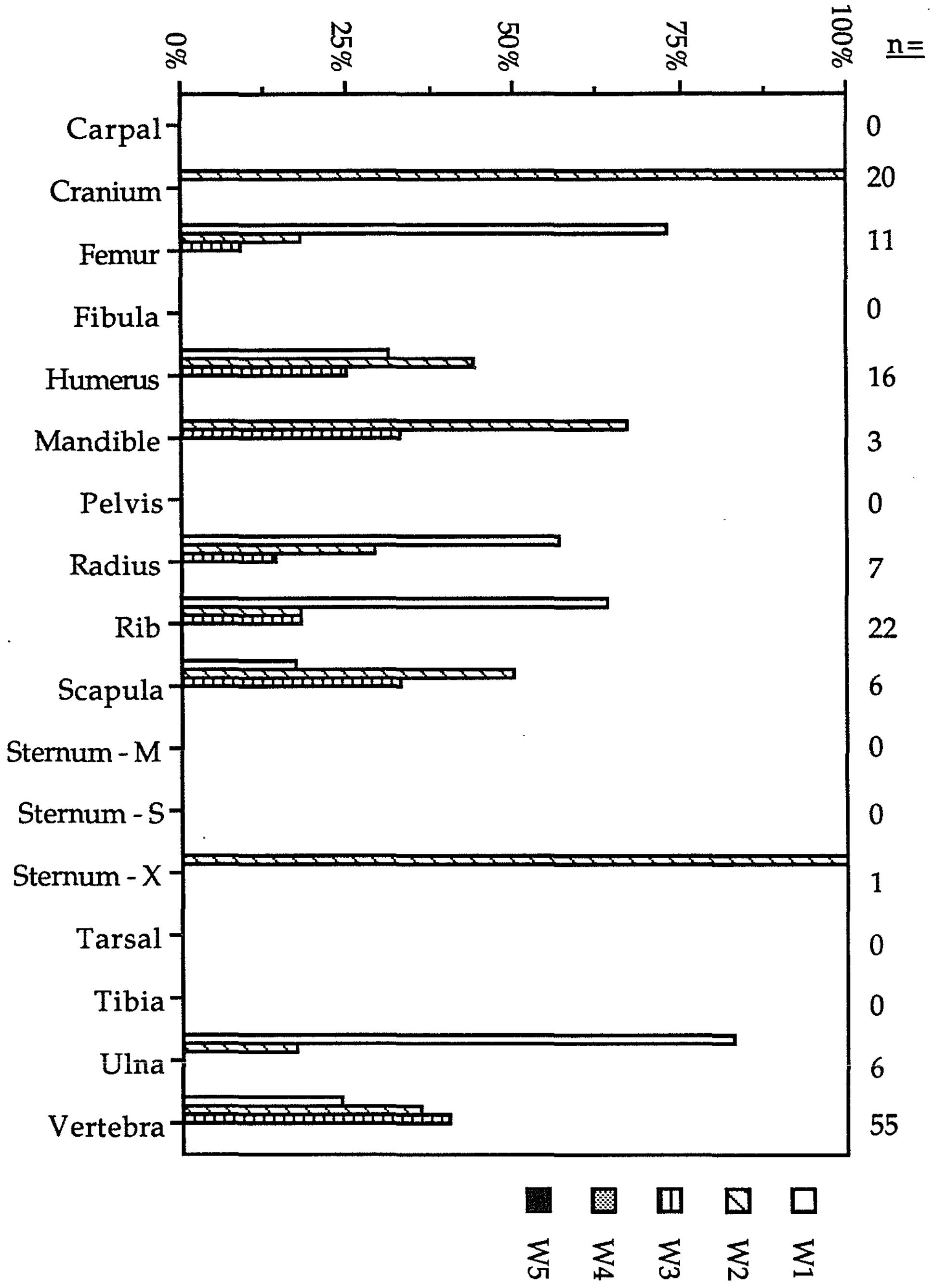


Figure 7.12 A breakdown of the weathering stages recorded for each skeletal element of fur seal present at Tairua.

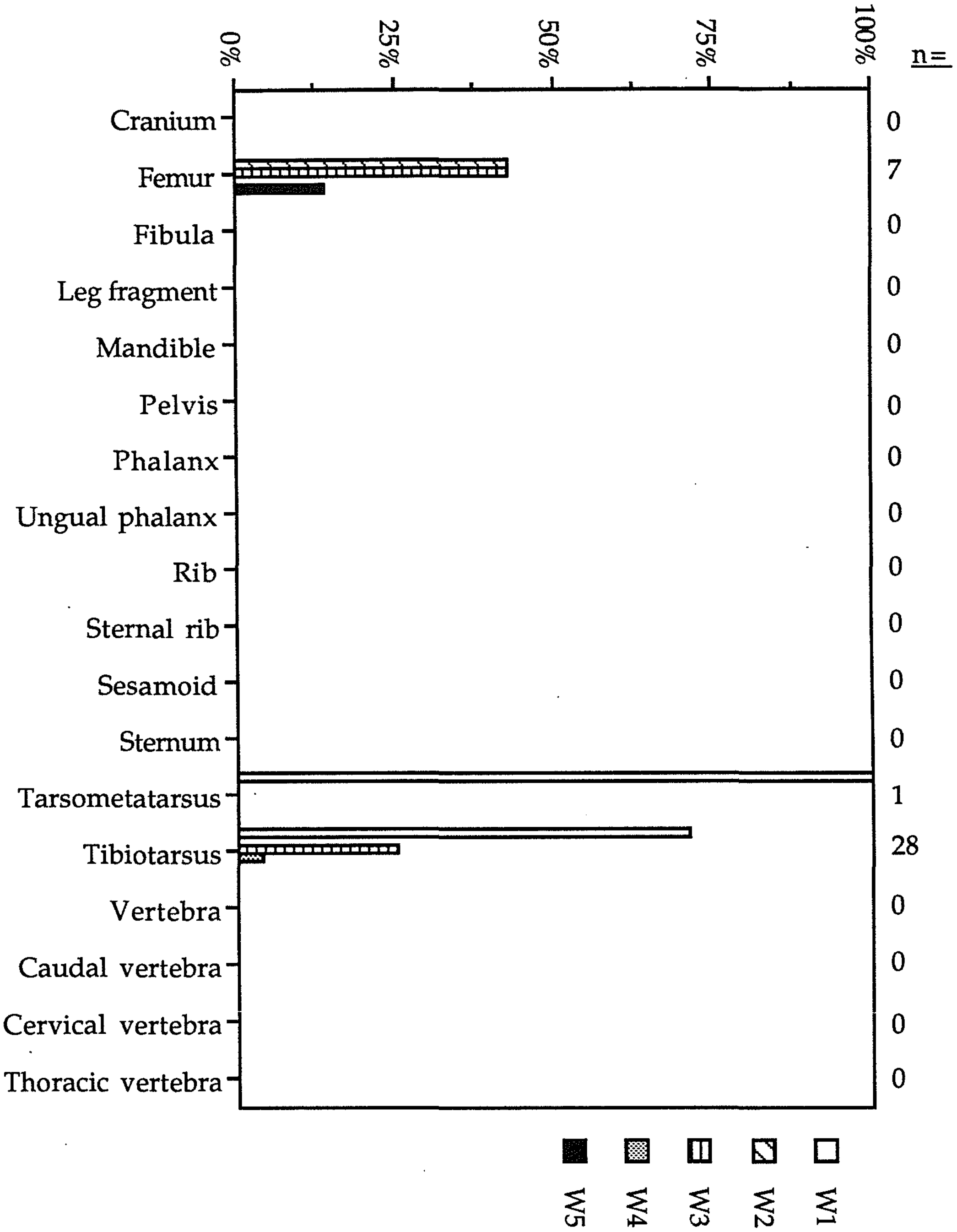


Figure 7.13 A breakdown of the weathering stages recorded for each skeletal element of moa present at Tairua.

Tokoroa (N75/1)

As with the Tairua bone, only part of the collection of material from Tokoroa was available for the current analysis. The site had been testpitted by Rod Cook in 1961, prior to being excavated by Green and Cook in 1962. The testpit material was relocated in the Auckland Museum while it is assumed that the later material was sent to Ron Scarlett at Canterbury Museum for identification and became assimilated into their moa collection.

The bones were all unburned (Table 7.14) and extremely weathered (Table 7.15) with 13% in Stage 4 and 87% in Stage 5. There were only four element groups represented in the remains (Appendix 5.6, Figure 7.14) — 'FEM', 'LEG', 'TMT', and 'TT'. Two fragments of subadult bone, a distal R 'TMT' and a proximal L

Table 7.14 The degrees of burning evident in the Tokoroa remains.

```
|-------------------------------|------|
|                               | MOA  |
|-------------------------------+------|
|BURNT          |               |      |
|---------------+---------------|      |
|1              |N              |    30|
|               |---------------+------|
|               |PCTN           |   100|
|---------------+---------------+------|
```

Table 7.15 The weathering stages evident in the Tokoroa remains.

```
|---------------+---------------+------|
|WEATHERED      |               |      |
|---------------+---------------|      |
|4              |N              |     4|
|               |---------------+------|
|               |PCTN           |    13|
|---------------+---------------+------|
|5              |N              |    26|
|               |---------------+------|
|               |PCTN           |    87|
|---------------+---------------+------|
|ALL            |N              |    30|
|---------------+---------------+------|
```

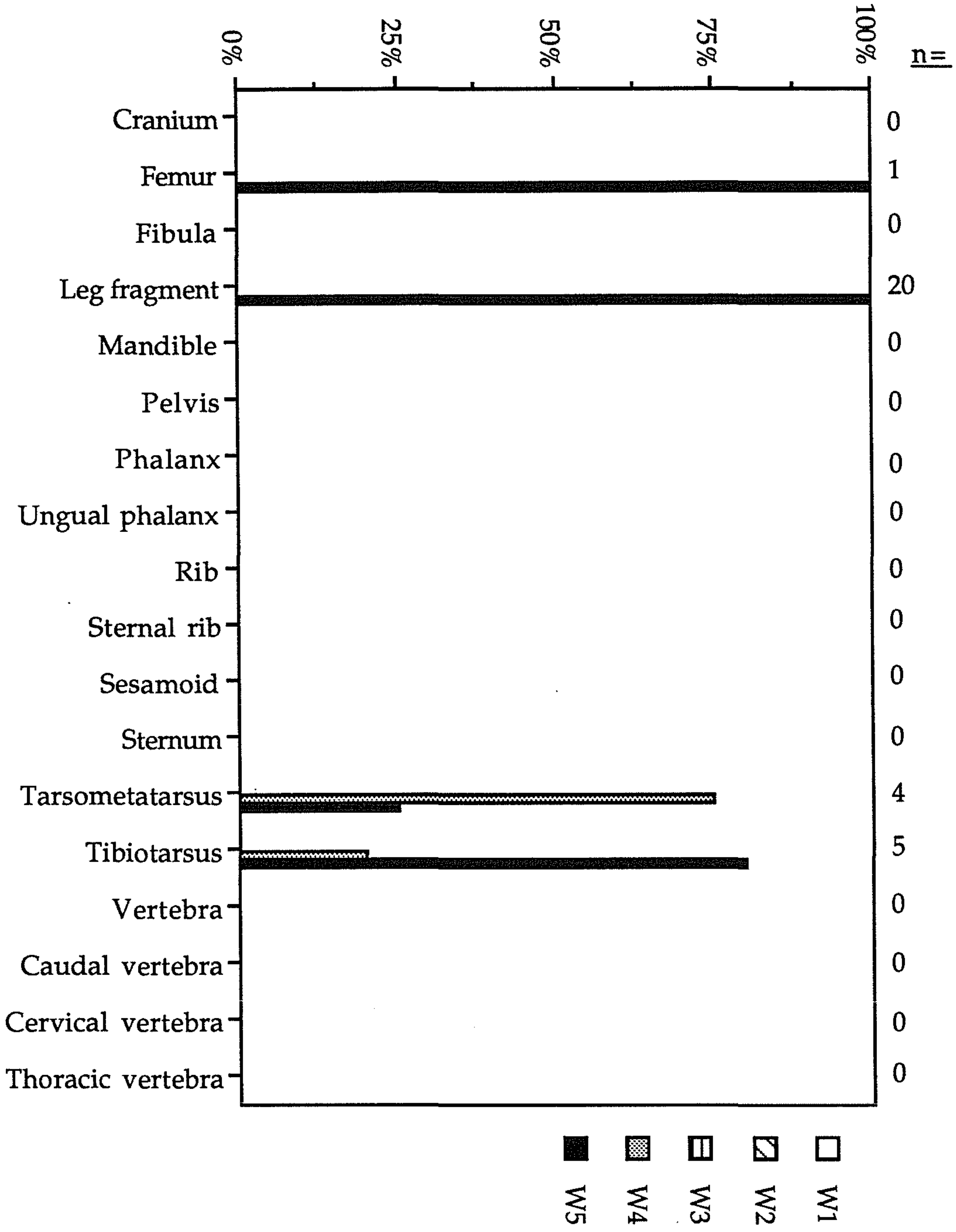


Figure 7.14 A breakdown of the weathering stages recorded for each skeletal element of moa present at Tokoroa.

'TMT' showed no difference in weathering from the remainder of the collection — the former bone was in Stage 5 and the latter in Stage 4.

An examination of the soil chemistry from the site (Table 7.2) provides the most likely explanation for the observed state of the bone as recovered in the excavation. The average pH for the three samples of 5.15 is in the strongly acid part of the range and this, coupled with the high moisture content, ca. 2.8%, would have led to a severe attack on the bone structure. The high moisture content would have actively encouraged leaching and preferential retention of the H^+ ions by the soil matrix (Richard Morgan pers.comm. 7/7/92). The samples also exhibited a higher organic content, in comparison with the levels for the rest of the soil series. Going hand-in-hand with this increased acidity is a drop in Ca and base cation levels. The levels I recorded are similar to the Soil Bureau figures given in Chapter 6.

While there are only leg elements represented in the recovered material, the possibility exists that elements containing higher percentages of cancellous bone were also discarded, but were not able to survive the effects of the soil conditions. During the analysis it was noted how fragmentary the bone was to the touch, indicating how the inorganic matrix was breaking down and was no longer able to hold the bone structure together.

Whakamoenga Cave (N94/7)

The Whakamoenga Cave material was only in a moderate condition when recovered in the excavation. Approximately half of it was unburned (Table 7.16) with the burnt material ranging from charred (7%) through to bones of a black to white/grey colour (35%) showing they had been subjected to greater degree of burning — perhaps through discard in a hearth.

The bones were moderately weathered — 16% were in Stage 1, 56% in Stages 2–3, and 28% in more advanced stages (Table 7.17). It is very interesting that this

Table 7.16 The degrees of burning evident in the Whakamoenga Cave remains.

```
|-----------------------------|------|
|                             | MOA  |
|-----------------------------+------|
|BURNT         |              |      |
|--------------+--------------|      |
|1             |N             |    20|
|              |--------------+------|
|              |PCTN          |    47|
|--------------+--------------+------|
|2             |N             |     3|
|              |--------------+------|
|              |PCTN          |     7|
|--------------+--------------+------|
|3             |N             |     5|
|              |--------------+------|
|              |PCTN          |    12|
|--------------+--------------+------|
|3-4           |N             |    15|
|              |--------------+------|
|              |PCTN          |    35|
|--------------+--------------+------|
|ALL           |N             |    43|
|--------------+--------------+------|
```

should occur even within a cave, and likely reasons for this are discussed below. Over 50% of the bones recorded from the site were classified as 'RESIDUE' — smaller fragments which were not able to be identified with any certainty with a particular element. In examining the distribution of weathering by element (Appendix 5.7, Figure 7.15); the 'FEM' fragments exist in Stage 1 and 3, the 'PELV' fragments are all in Stage 4, the 'RESIDUE' is predominantly in Stage 3, while the 'TT' material is recorded from all weathering stages. There is not sufficient material from cancellous dominant elements to determine whether the elemental representation in the site is due to cultural or weathering phenomena, but I would tend to suggest the former.

The deposition of this material within the cave means that the condition of the bone is due entirely to the burial matrix as the bones could not have been subjected to the usual subaerial weathering factors, such as sunshine, rainfall, dessicating effects of wind flow and so on. The soil results for this site place the pH in the neutral to slightly alkaline phase, while the elevated Ca results for Samples 1 and 2 are probably due to the limestone naturally occurring within the

Table 7.17 The weathering stages evident in the Whakamoenga Cave remains.

WEATHERED		MOA
1	N	7
	PCTN	16
2	N	2
	PCTN	5
2-3	N	15
	PCTN	35
3	N	7
	PCTN	16
4	N	9
	PCTN	21
5	N	3
	PCTN	7
ALL	N	43

cave leaching into the soil. The three samples were taken from a column and show a gradient increasing from 14.44 me% at the base (ca. 45cm depth), to 43.89 me% midway up the column, and then sharply decreasing to 3.74 me% at the surface. The middle layer was a black 'soil' layer (Figure 6.9b), while the other two layers were pumice derived. I can offer no immediate explanation, but the relatively higher moisture, in comparison with the other sites in this study, leads me to suspect that it may be due to some form of chemical action within the pumice substrate.

While analysing the bones, it was noticed that material from Layers 10 and 11 was clean and white, similar to the condition of fresh bone, while material from

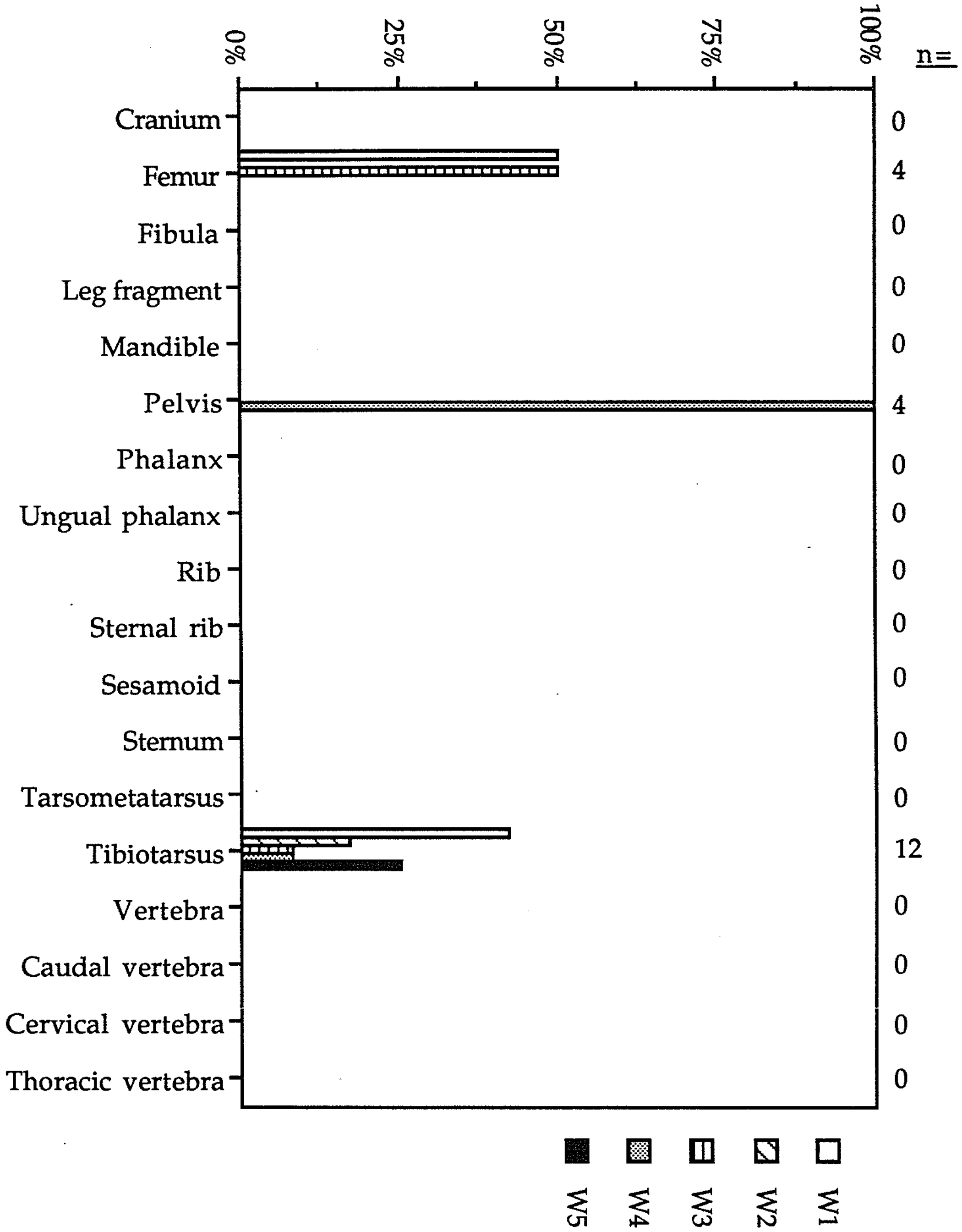


Figure 7.15 A breakdown of the weathering stages recorded for each skeletal element of moa present at Whakamoenga.

further up the site tended to be darker in coloration and slightly more weathered. This may be a difference due to the nature of the burial matrix with bones recovered from the pumicey layers existing in better condition. A note attached to one bone (a 'TT' shaft fragment) by Ron Scarlett claims that it has been fossilized. This latter fragment was one of the three pieces I recorded in Stage 5 weathering.

Opua (N118/96)

Almost without exception, the only two anomalies being fragments of fur seal and moa, the bone recovered from Opua was unburnt (Table 7.18), but it exhibited a range of weathering stages (Table 7.19). A total of 8% of the bone had been bleached by the sun through lying exposed on the ground surface, but in general the bone was slightly to moderately weathered: 25% of that recovered was in Stage 1, 33% in Stage 2, and 25% in Stage 3. A further 5% were in Stage 4 and 3% in Stage 5.

At the species level, the fur seal and moa were again the most common of the big-game fauna represented, with a smaller fraction of sea lion. The fur seal and sea lion bone was only slightly weathered — 47% of fur seal and 40% of sea lion were in Stage 1, and 38% and 47%, respectively, were in Stage 2. The moa bone, however, exhibited a greater variation in weathering with 20% in Stage 1, 37% in Stage 2, 34% in Stage 3, and 9% in Stages 4 and 5. This difference may be due, in part, to the differing nature of the bone structure, or the elements represented within each species.

In general, the fur seal material is from more compact bone (Appendix 5.8, Figures 7.16–7.18) and the fragments of 'CR', 'V', and 'V-L' present are either in weathering Stage 1 or 2. There is a wide spectrum of elements present in the moa bone and there is only a small degree of variation, in the distribution across weathering stages, between cancellous and cortical bone. Elements such as 'PELV', 'SAC', 'ST', and the classes of vertebrae tend to cluster around weathering

Table 7.18 The degrees of burning evident in the Opua remains.

		SPECIES								
		?FS	?FS/SL	?SL	ES	FS	FS/SL	MOA	SL	ALL
BURNT										
1	N	1	1	1	1	31	1	161	15	212
	PCTN	100	100	100	100	97	100	99	100	99
4	N	.	.	.	.	1	.	1	.	2
	PCTN	.	.	.	.	3	.	1	.	1
ALL	N	1	1	1	1	32	1	162	15	214

Table 7.19 The weathering stages evident in the Opua remains.

		SPECIES								
		?FS	?FS/SL	?SL	ES	FS	FS/SL	MOA	SL	ALL
WEATHERED										
1	N	.	1	.	.	15	1	31	6	54
	PCTN	.	100	.	.	47	100	19	40	25
1*	N	.	.	.	.	.	.	2	.	2
	PCTN	.	.	.	.	.	.	1	.	1
2	N	.	.	1	1	12	.	50	7	71
	PCTN	.	.	100	100	38	.	31	47	33
2*	N	.	.	.	.	.	.	9	.	9
	PCTN	.	.	.	.	.	.	6	.	4

Table 7.19 (ctd).

		SPECIES								
		?FS	?FS/SL	?SL	ES	FS	FS/SL	MOA	SL	ALL
3	N	.	.	.	.	4	.	49	.	53
	PCTN	.	.	.	.	13	.	30	.	25
3*	N	.	.	.	.	.	.	7	.	7
	PCTN	.	.	.	.	.	.	4	.	3
4	N	.	.	.	.	.	.	10	1	11
	PCTN	.	.	.	.	.	.	6	7	5
4*	N	.	.	.	.	.	.	1	.	1
	PCTN	.	.	.	.	.	.	1	.	0
5	N	1	.	.	.	1	.	3	1	6
	PCTN	100	.	.	.	3	.	2	7	3
ALL	N	1	1	1	1	32	1	162	15	214

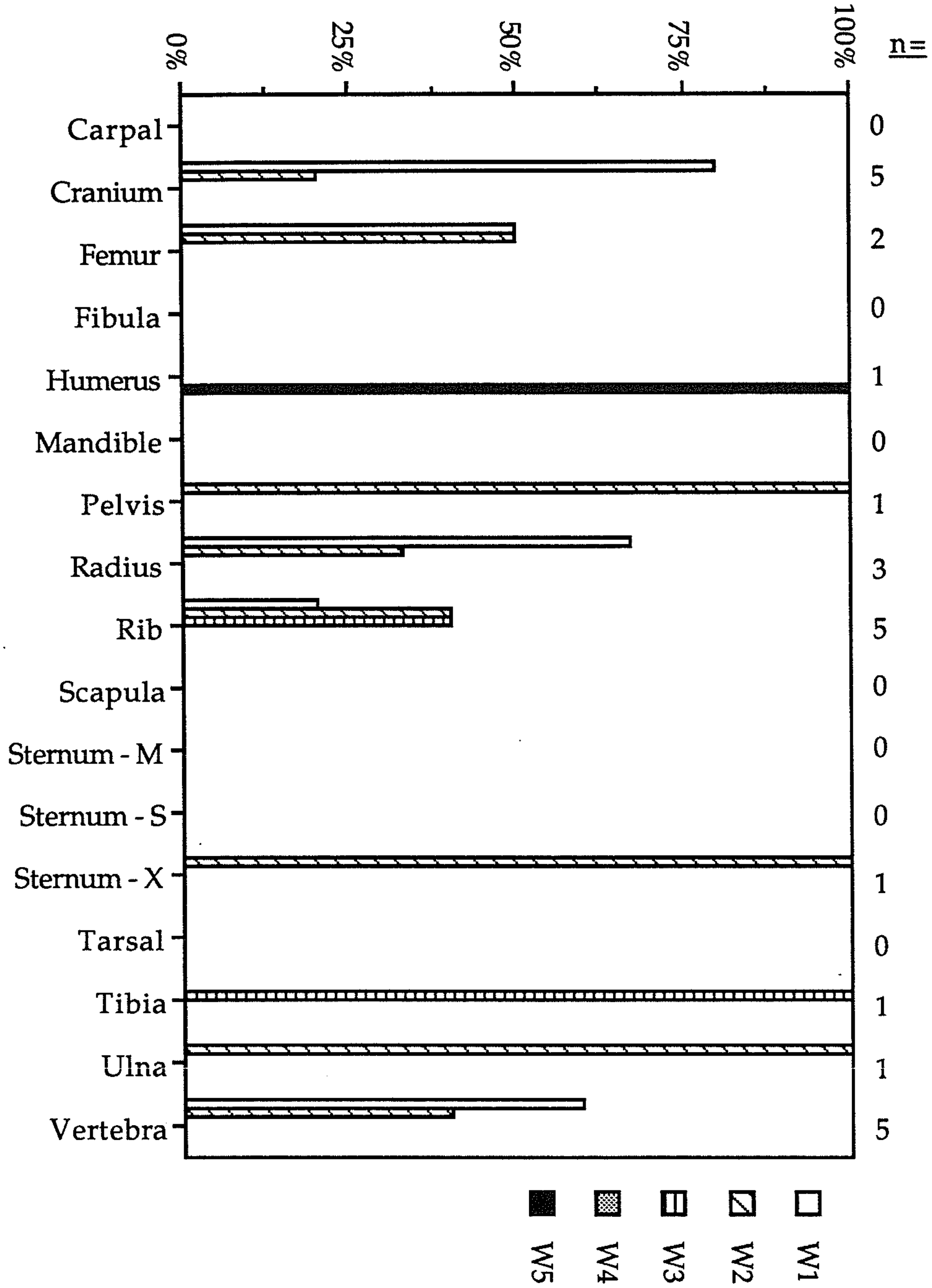


Figure 7.16 A breakdown of the weathering stages recorded for each skeletal element of fur seal present at Opua.

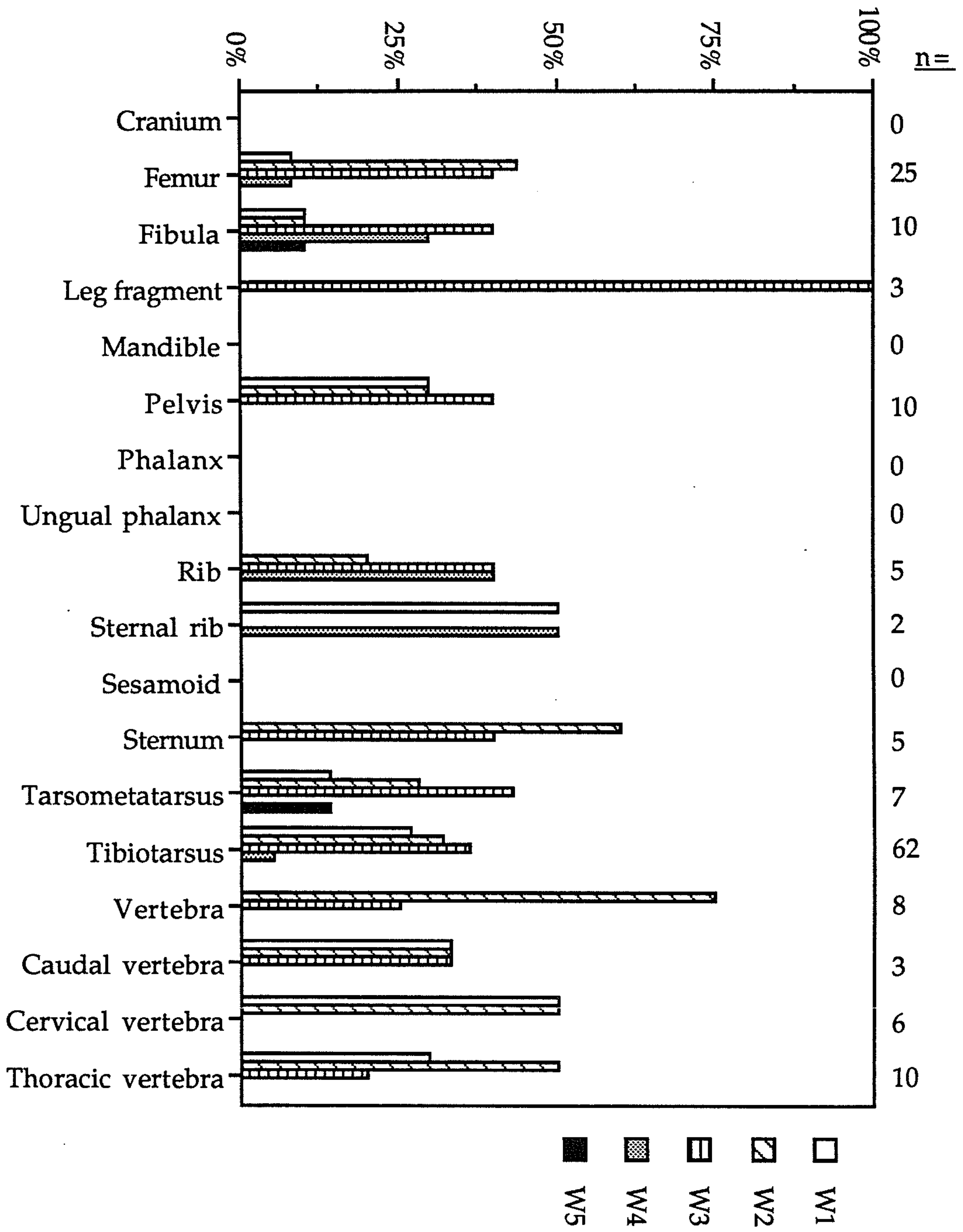


Figure 7.17 A breakdown of the weathering stages recorded for each skeletal element of moa present at Opua.

Figure 7.18 A breakdown of the weathering stages recorded for each skeletal element of sea lion present at Opua.

Stages 2 and 3, while the cortical elements are more widely distributed. Of the material recorded in Stages 4 and 5, three are rib fragments, and the remainder are long-bone fragments. Given that there does not appear to be any significant difference between cortical and cancellous bones in the site, the representation of elements is probably due to cultural reasons.

The two soil samples retained from this site (Table 7.2) exhibit slightly different characteristics. Sample 2, from a mixed soil and silt layer, is more acid and with higher moisture and organic levels than in Sample 3 which has an elevated Ca^{2+} level. The values recorded for all the soil variables are at variance with the Soil Bureau result recorded in Chapter 6, but this could be due to factors linked with the periodic inundation of the site by the Mouhanga Stream.

On the whole, the bones from this site had undergone a medium amount of weathering. The most prevalent type was wearing of the proximal and distal ends, followed by longitudinal splitting and some flaking of material. There were practically no cases of extreme weathering. In quite a few cases there was pitting of the bone surface rather than flaking. A number of the bones and fragments were bleached by the sun, suggesting they had lain on the surface for some time before being covered in sand, or had been repeatedly covered and uncovered. There was no more weathering on these in proportion to the unbleached material, although there were more cases of Stage 3 splitting. There was almost no evidence of burning amongst this material.

Kaupokonui (N128/3)

The analysis of the Kaupokonui bones included material from five different collections: Cassel's 1974 excavation (KPA); a small collection from May 1976 (KPB); Diane Foley's 1979 collection (KPC); a surface collection by Roger Fyfe, Mike Till and Ron Scarlett in June 1980 (KPD); and a surface collection by Ron Lambert and Roger Fyfe in June 1981 (KPE). The material from Alastair Buist's excavations was unable to be relocated and it is assumed that it was sent to the

Table 7.20 The degrees of burning evident in the Kaupokonui remains.

BURNT		SPECIES			
		ES	MOA	SL	ALL
1	N	2	513	33	548
	PCTN	100	59	87	60
2	N	.	6	.	6
	PCTN	.	1	.	1
3	N	.	2	.	2
	PCTN	.	0	.	0
3,4	N	.	100	.	100
	PCTN	.	11	.	11
4	N	.	226	4	230
	PCTN	.	26	11	25
5	N	.	29	1	30
	PCTN	.	3	3	3
ALL	N	2	876	38	916

Canterbury Museum for analysis and subsequently assimilated into their moa collection. This discussion will focus first on all the material as a single collection from the site, before describing characteristics of the individual collections.

Overall, 63% of the bone from the site is unburnt with the remainder grading from charring to heavily burnt to a white/grey colour (Table 7.20). Within the individual species, the moas shows the most variation with 59% in Stage 1, 11% in Stage 3 or 4 (derived from a bag of burnt fragments), and 26% in Stage 4. In the sea lion remains 87% are in Stage 1, 11% in Stage 4, and 3% in Stage 5.

The weathering results likewise show a spread from Stages 1–5 (Table 7.21), with

Table 7.21 The weathering stages evident in the Kaupokonui remains.

```
|-----------------------------|--------------------|------|
|                             |      SPECIES       |      |
|                             |--------------------|      |
|                             |  ES  | MOA  |  SL  | ALL  |
|-----------------------------+------+------+------+------|
|WEATHERED     |              |      |      |      |      |
|--------------+--------------|      |      |      |      |
|1             |N             |     .|   114|     9|   123|
|              |--------------+------+------+------+------|
|              |PCTN          |     .|    13|    24|    13|
|--------------+--------------+------+------+------+------|
|1*            |N             |     .|     7|     .|     7|
|              |--------------+------+------+------+------|
|              |PCTN          |     .|     1|     .|     1|
|--------------+--------------+------+------+------+------|
|2             |N             |     2|   268|    17|   287|
|              |--------------+------+------+------+------|
|              |PCTN          |   100|    31|    45|    31|
|--------------+--------------+------+------+------+------|
|2*            |N             |     .|    24|     2|    26|
|              |--------------+------+------+------+------|
|              |PCTN          |     .|     3|     5|     3|
|--------------+--------------+------+------+------+------|
|2-4           |N             |     .|   100|     .|   100|
|              |--------------+------+------+------+------|
|              |PCTN          |     .|    11|     .|    11|
|--------------+--------------+------+------+------+------|
|3             |N             |     .|   184|     7|   191|
|              |--------------+------+------+------+------|
|              |PCTN          |     .|    21|    18|    21|
|--------------+--------------+------+------+------+------|
|3*            |N             |     .|    20|     2|    22|
|              |--------------+------+------+------+------|
|              |PCTN          |     .|     2|     5|     2|
|--------------+--------------+------+------+------+------|
|4             |N             |     .|   134|     1|   135|
|              |--------------+------+------+------+------|
|              |PCTN          |     .|    15|     3|    15|
|--------------+--------------+------+------+------+------|
|4*            |N             |     .|    14|     .|    14|
|              |--------------+------+------+------+------|
|              |PCTN          |     .|     2|     .|     2|
|--------------+--------------+------+------+------+------|
|5             |N             |     .|    10|     .|    10|
|              |--------------+------+------+------+------|
|              |PCTN          |     .|     1|     .|     1|
|--------------+--------------+------+------+------+------|
|5*            |N             |     .|     1|     .|     1|
|              |--------------+------+------+------+------|
|              |PCTN          |     .|     0|     .|     0|
|--------------+--------------+------+------+------+------|
|ALL           |N             |     2|   876|    38|   916|
|--------------+--------------+------+------+------+------|
```

a small amount of sun-bleached material. There is 14% in Stage 1, 34% in Stage 2, 11% in Stages 2–4 (the same bag of fragments described above), 23% in Stage 3, 17% in Stage 4, and just 1% in Stage 5. The moa bone is the more weathered with 41% in Stage 3 or above, while the sea lion bones have 74% in Stages 1 and 2, and only a further 23% in Stage 3.

In examining the distribution by element (Appendix 5.9), both the moa and sea lion collections are dominated by leg elements which are generally more highly weathered, suggesting that their greater representation in the site is due to cultural actions rather than the loss of cancellous elements. In the sea lion remains (Figures 7.19 and 7.20), all the 'MAND' fragments were in Stages 1 and 2, as were the 'TIB' and nearly all of the 'FEM', 'RAD' and 'UL' material. The 'HUM' fragments were evenly spread between Stages 1–2 and 3–4.

The moa remains similarly showed a normal distribution across the weathering stages for the elements 'FEM', 'TMT' and 'TT' (Figure 7.21 and 7.22). The 'LEG' fragments were 47% in Stage 3 and 53% in Stage 4. Sixty four percent of the 'PELV' fragments were in Stage 2 and a further 29% in Stage 3, while all the 'ST' fragments were in Stage 3. While there is little of these latter elements ('PELV' and 'ST') recorded in the "lower" weathering stages, neither do they appear in the "high" stages, lending further weight to the proposition that their under-representation is due to cultural processes rather than natural.

Turning to an examination of the separate collections: KPA is by far the largest, comprising 733 of the total 916 bones examined from this site. The pattern of weathering in this collection is similar to that discussed above for the overall collection, so will not be expanded upon here. The second group, KPB, comprises just eight moa bones, all unburnt leg elements or fragments thereof, with two in Stage 1 weathering, five in Stage 2 and one in Stage 3. KPC is a further collection of longbone fragments (11 'FEM', 16 'TT' and one each of 'FIB' and 'TMT'), 93% of which are unburnt, and which are distributed across the weathering stages. Approximately 55% of the KPC bones have been bleached including all the Stage 4 and 5 bones, as well as the 14% of the total collection which is in Stage 3, suggesting a lengthy period exposed on the surface. Collection KPD comprises 34

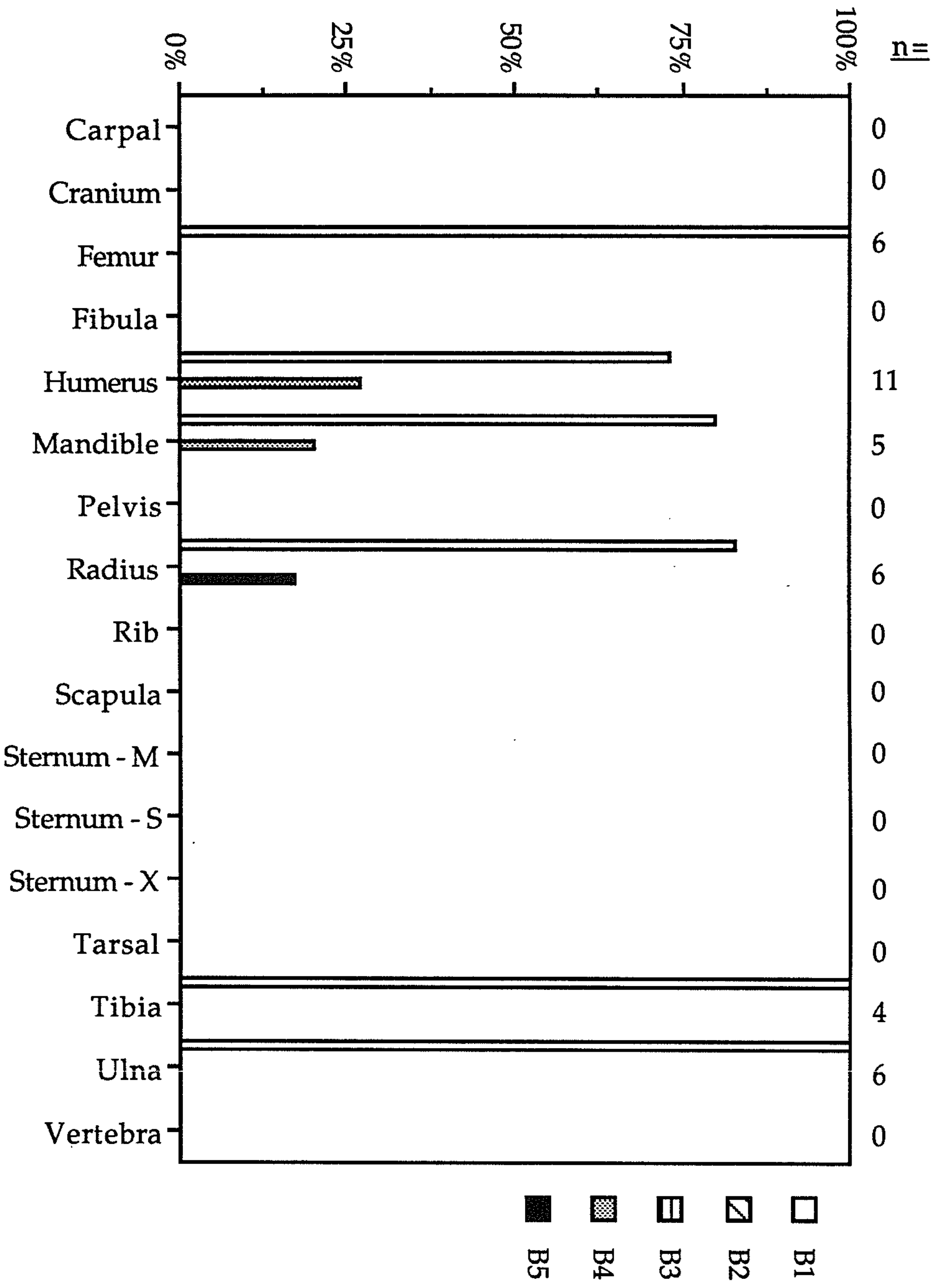


Figure 7.19 A breakdown of the burning stages recorded for each skeletal element of sea lion present at Kaupokonui.

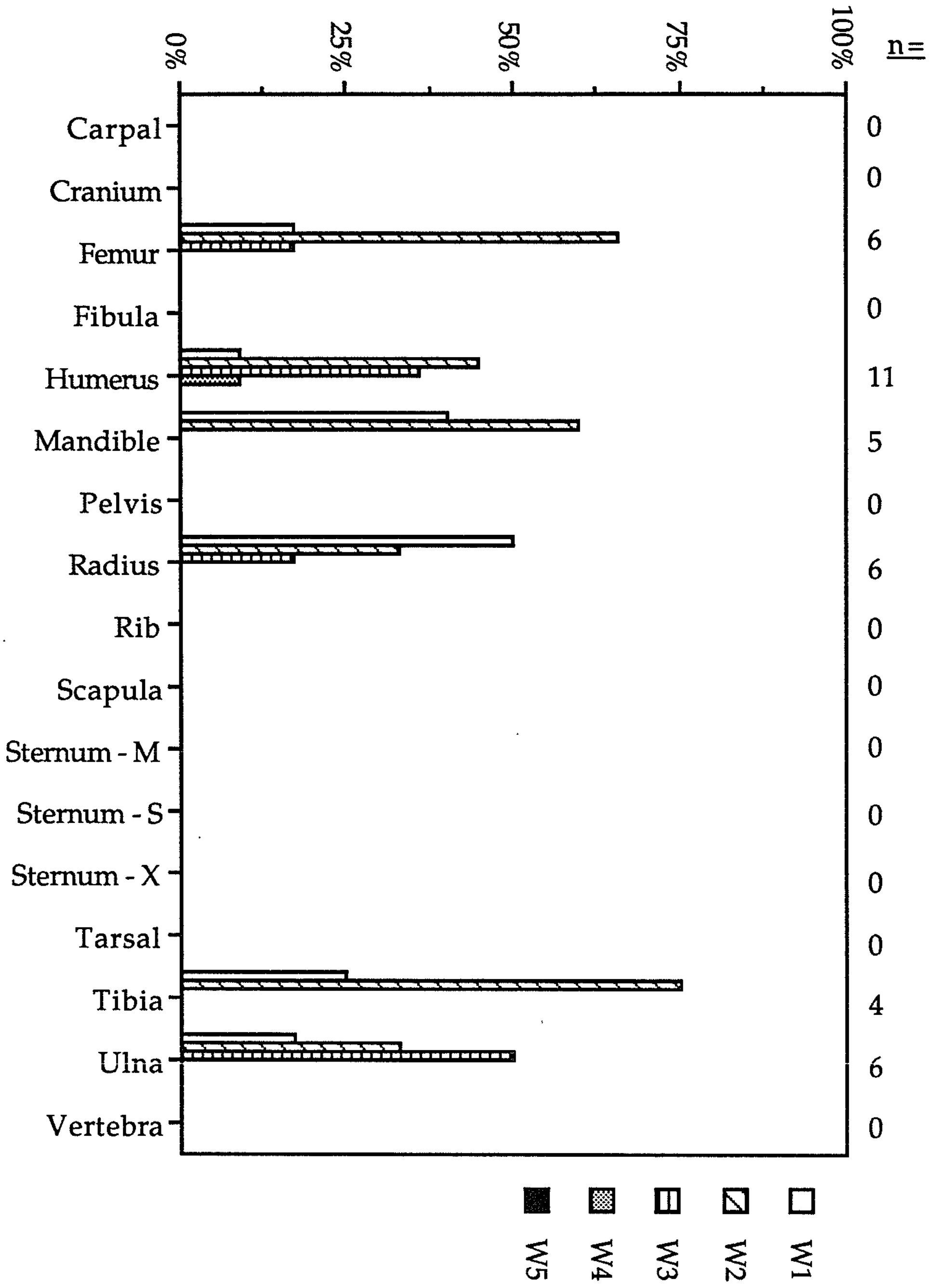


Figure 7.20 A breakdown of the weathering stages recorded for each skeletal element of sea lion present at Kaupokonui.

moa bones (seven 'FEM', one 'PELV', six 'TMT', and 20 'TT') of which 39% are in Stages 1 and 2, 24% in Stage 3, 33% in Stage 4 and 6% in Stage 5. Only 36% of the collection has been sunbleached, suggesting a shorter exposure period than for KPC, but this is, of course, dependent upon the shifting nature of the coastal dune system in which the site is located. The final collection, KPE, comprises 12 longbone fragments and a bag of 100 burnt fragments (not identifiable to element). The longbones were slightly to moderately weathered, 33% in Stage 2 and 58% in Stage 3, while the bag of burnt fragments exhibited a range from Stages 2–4.

The soil samples from this site (Table 7.2) show a surprising uniformity, with the pH of the six samples ranging from 6.37 (slightly acid) to 7.67 (moderately alkaline). The relatively low moisture content is indicative of a free-draining system while the low organic content may be due, in part, to the nature of the ironsands which predominate along the South Taranaki coast. All the base cation levels are in the low to very low end of the scale. These results tend to support the notion of cultural patterning in the faunal remains, as the soil chemistry recorded for the six samples would be conducive to bone survival through time.

This material has been studied quite often (Foley 1980, Kooyman 1985 and Worthy 1990 have all studied the moa bone at some time) and has probably sustained some damage through continued handling. Much of the bone is in very good condition with only slight wear on the articulating surfaces, probably due to trampling across the site. A lot of the bone has been bleached white from lying on the surface and this often advances the state of weathering. Some bone is in a very advanced state of wear — pitting is very common and this is possibly due to chemical wear. The material surface collected by Lambert and Fyfe (KPE) is very bleached and fragmentary, perhaps indicative of a long period exposed on the ground surface. Some of the burnt material has become very broken up.

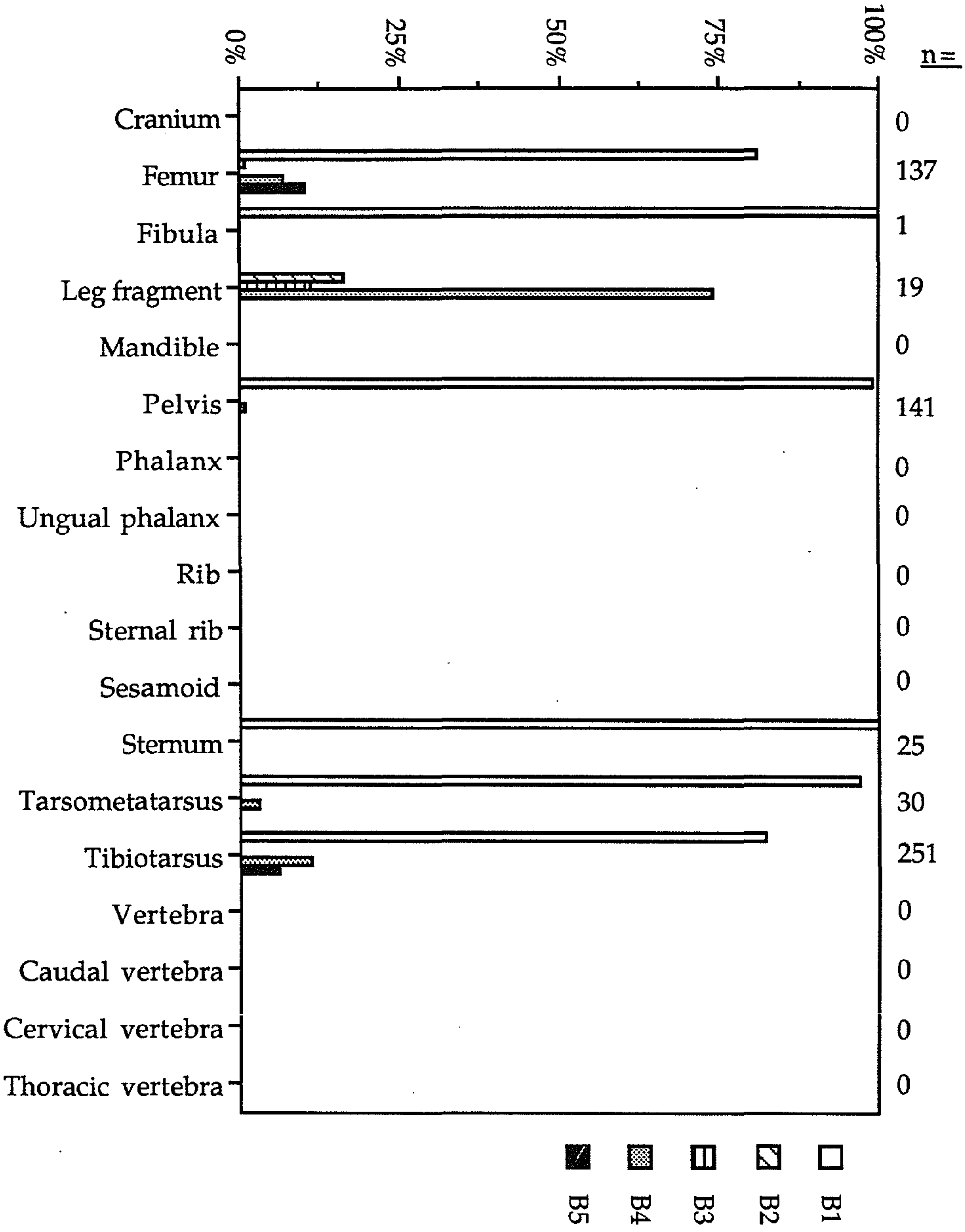


Figure 7.21 A breakdown of the burning stages recorded for each skeletal element of moa present at Kaupokonui.

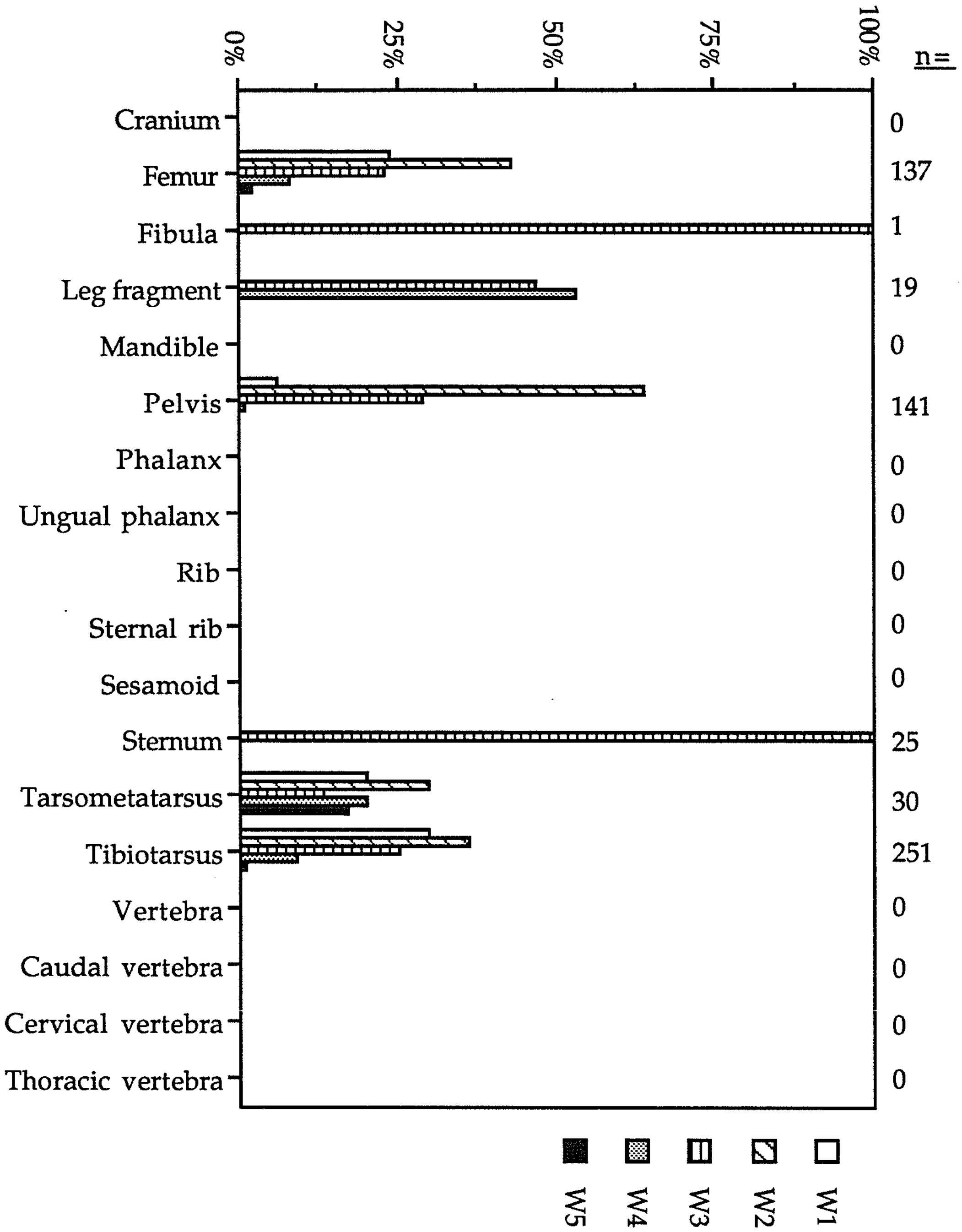


Figure 7.22 A breakdown of the weathering stages recorded for each skeletal element of moa present at Kaupokonui.

Waingongoro [Ohawe] (N129/77) and Te Rangatapu (N129/78)

It was originally intended that the analysis for these sites would include both material excavated by Alastair Buist (Waingongoro [N129/77]), and that from Tess Canavan's excavation (Te Rangatapu [N129/78]). The material housed in the Taranaki Museum is from Canavan's excavation — most of the Buist material was sent to the Canterbury Museum and one box to the National Museum (Alastair Buist pers.comm. August 1990), and in both instances the material was not able to be relocated. There was, however, a small collection of bones which Ron Lambert surface collected in January 1990 from the landward end of Buist's Waingongoro site, which will be discussed separately here from the Canavan material. In Appendix 5.10 the Canavan collection is labelled 'OHA' and the Lambert collection 'OHB'.

Approximately 95% of the Te Rangatapu bones were unburnt (Table 7.22) and exhibited an interesting distribution across the weathering stages: 14% in Stage 1, 22% in Stage 2, 29% in Stage 3, 28% in Stage 4, and 7% in Stage 5 (Table 7.23) — a collection of moderately to severely weathered bones (Figure 7.23). The ovens at this site had been cut into the compacted conglomerate, suggesting that this was possibly close to the dune surface so when the bones were discarded they may have lain exposed on the surface for some time before being covered by sand or floodwash from the Waingongoro River, although there is almost no bleached bone present as there was in the Kaupokonui collection.

Practically all the Canavan bones are leg elements ('FEM', 'TMT' and 'TT') with one fragment each of 'MAND' and 'PELV' which were in Stage 2 weathering. The weathering stage distributions of the individual elements mirrored, more or less, the general distribution of the whole collection. Given that the only two fragments of cancellous bone present in the site are less weathered than the stronger cortical bones, it would be a reasonable assumption to make that again it is cultural practices that have governed element representation in this site.

The 'OHB' collection is essentially unweathered — 45% are in Stage 1 and 55% in

Table 7.22 The degrees of burning evident in the Te Rangatapu remains.

```
|----------------------------------------------|------|
|                              |    SPECIES    |      |
|                              |---------------|      |
|                              | FS | MOA | SL | ALL |
|------------------------------+------+------+------+------|
|BURNT          |              |      |      |      |      |
|---------------+--------------|      |      |      |      |
|1              |N             |     1|   118|     2|   121|
|               |--------------+------+------+------+------|
|               |PCTN          |   100|    94|   100|    94|
|---------------+--------------+------+------+------+------|
|2              |N             |     .|     5|     .|     5|
|               |--------------+------+------+------+------|
|               |PCTN          |     .|     4|     .|     4|
|---------------+--------------+------+------+------+------|
|5              |N             |     .|     3|     .|     3|
|               |--------------+------+------+------+------|
|               |PCTN          |     .|     2|     .|     2|
|---------------+--------------+------+------+------+------|
|ALL            |N             |     1|   126|     2|   129|
|---------------+--------------+------+------+------+------|
```

Stage 2 (Appendix 5.10). An interesting point to note in relation to this material is that 13 of the 16 fragments in Stage 2 are vertebrae classes (either 'V-CE' or 'V-TH') and the 'LEG' fragments comprised nearly all of the bone in Stage 1.

The soil samples (Table 7.2) are all very similar given that the two pairs (Samples 1 and 2 and Samples 3 and 4) are derived from opposite ends of the beach, and points to the general homogeneity of the ironsands matrix. The pH ranges from 6.58 (near neutral) in Sample 4 up to 8.34 (moderately alkaline) in Sample 1; there are very low levels of moisture and organic material, as was also recorded at Kaupokonui, and similarly very low levels of all the base cations. The general lack of chemical activity within the soil tends to suggest that the matrix conditions probably did not play a very great role in determining the element representation of this faunal collection.

As this material has not formerly been studied in full, much is still in small boxes/bags — with very poor provenance labelling. The important feature of this collection of material is that much of the moa bone is in quite an advanced state of weathering. The ends of the bones are worn, and in many cases the surface of

Table 7.23 The weathering stages evident in the Te Rangatapu remains.

```
|----------------------------------------------------------|------|
|                               |       SPECIES      |      |
|                               |--------------------|      |
|                               |  FS  | MOA  |  SL  | ALL  |
|-------------------------------+------+------+------+------|
|WEATHERED      |               |      |      |      |      |
|---------------+---------------|      |      |      |      |
|1              |N              |     1|    27|     .|    28|
|               |---------------+------+------+------+------|
|               |PCTN           |   100|    21|     .|    22|
|---------------+---------------+------+------+------+------|
|2              |N              |     .|    37|     2|    39|
|               |---------------+------+------+------+------|
|               |PCTN           |     .|    29|   100|    30|
|---------------+---------------+------+------+------+------|
|3              |N              |     .|    28|     .|    28|
|               |---------------+------+------+------+------|
|               |PCTN           |     .|    22|     .|    22|
|---------------+---------------+------+------+------+------|
|4              |N              |     .|    27|     .|    27|
|               |---------------+------+------+------+------|
|               |PCTN           |     .|    21|     .|    21|
|---------------+---------------+------+------+------+------|
|5              |N              |     .|     7|     .|     7|
|               |---------------+------+------+------+------|
|               |PCTN           |     .|     6|     .|     5|
|---------------+---------------+------+------+------+------|
|ALL            |N              |     1|   126|     2|   129|
|---------------+---------------+------+------+------+------|
```

the cortex has gone and it exposes the granular bone underneath. Not much of this material has been bleached, probably indicating that it was buried very quickly after deposition on the site. The weathering is more along the lines of pitting rather than splitting/flaking which suggests it is more probably due to chemical action, rather than physical weathering which tends to produce longitudinal splitting and flaking.

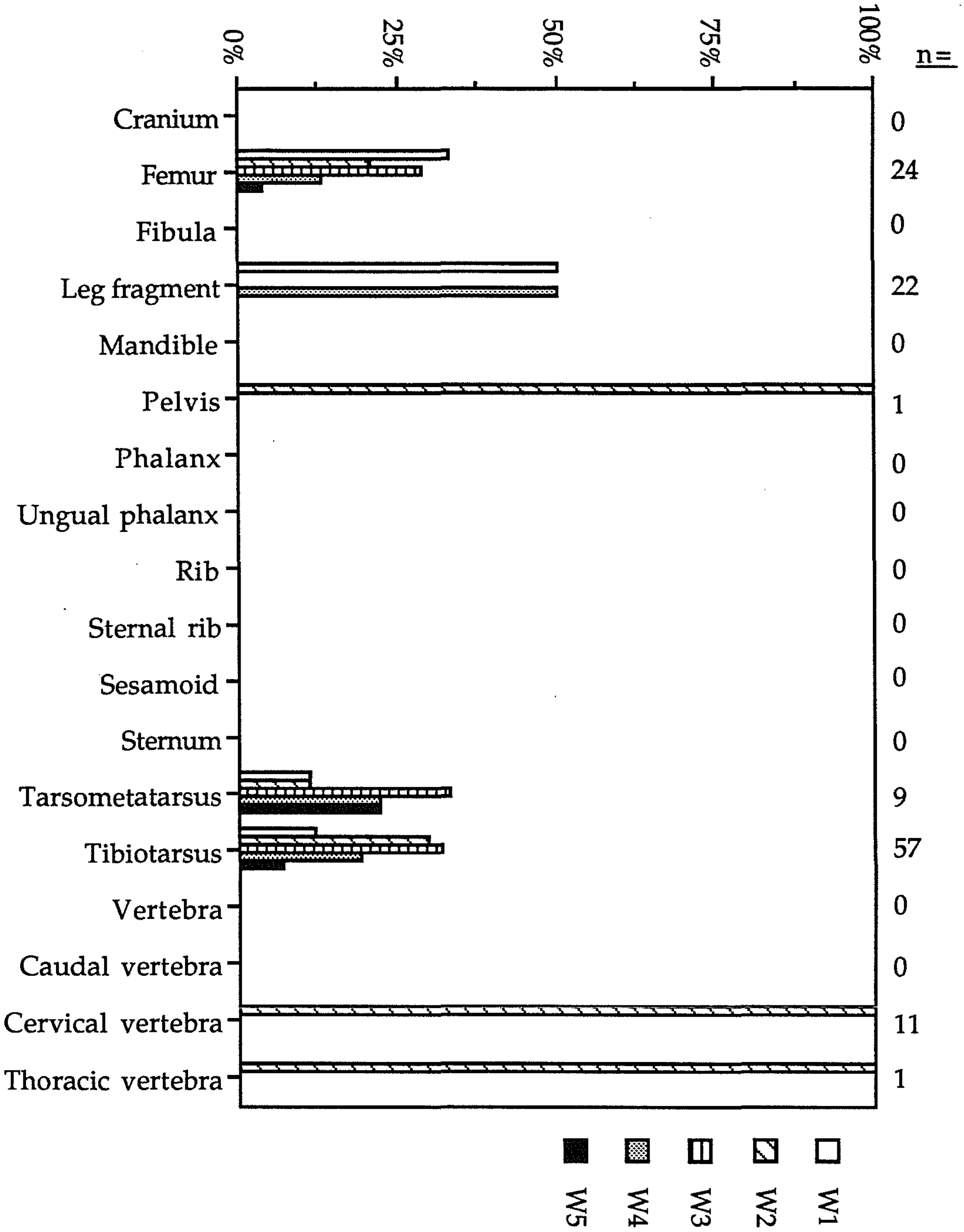


Figure 7.23 A breakdown of the weathering stages recorded for each skeletal element of moa present at Te Rangatapu.

Tai Rua (S136/1)

Within this collection of moa bones, a total of 92% were unburnt with the remainder occurring as charred and burnt fragments (Table 7.24). It is fragments of leg elements ('FEM', 'LEG', and 'TT') which have the greatest degree of burning exhibited (Figure 7.24), suggesting that these bones may have been discarded into fires as a means of disposal. The collection is moderately weathered — 15% in Stage 1, 24% in Stage 2, 54% in Stage 3 and 6% in Stage 4 (Table 7.25, Figure 7.25) and most of this again is leg elements ('FEM', 'LEG', 'TMT', and 'TT') although cancellous elements ('PELV', 'R', and 'V-TH') are also represented (Figure 7.26).

Table 7.24 The degrees of burning evident in the Tai Rua remains.

```
|-------------------------------|------|
|                               | MOA  |
|-------------------------------+------|
|BURNT          |               |      |
|---------------+---------------|      |
|1              |N              |   406|
|               |---------------+------|
|               |PCTN           |    87|
|---------------+---------------+------|
|2              |N              |    14|
|               |---------------+------|
|               |PCTN           |     3|
|---------------+---------------+------|
|2-4            |N              |     1|
|               |---------------+------|
|               |PCTN           |     0|
|---------------+---------------+------|
|3              |N              |     8|
|               |---------------+------|
|               |PCTN           |     2|
|---------------+---------------+------|
|4              |N              |    16|
|               |---------------+------|
|               |PCTN           |     3|
|---------------+---------------+------|
|5              |N              |    22|
|               |---------------+------|
|               |PCTN           |     5|
|---------------+---------------+------|
|ALL            |N              |   467|
|---------------+---------------+------|
```

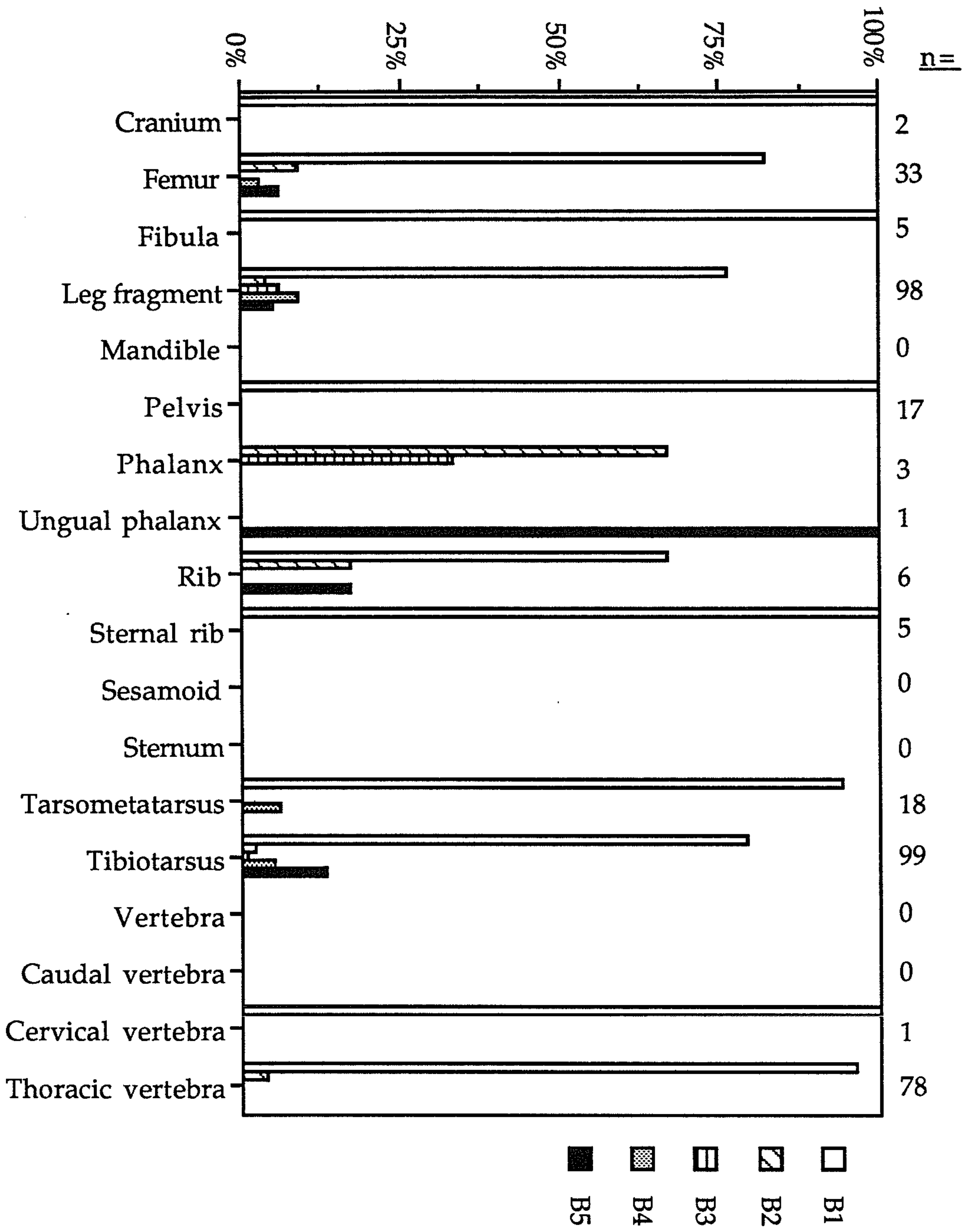


Figure 7.24 A breakdown of the burning stages recorded for each skeletal element of moa present at Tai Rua.

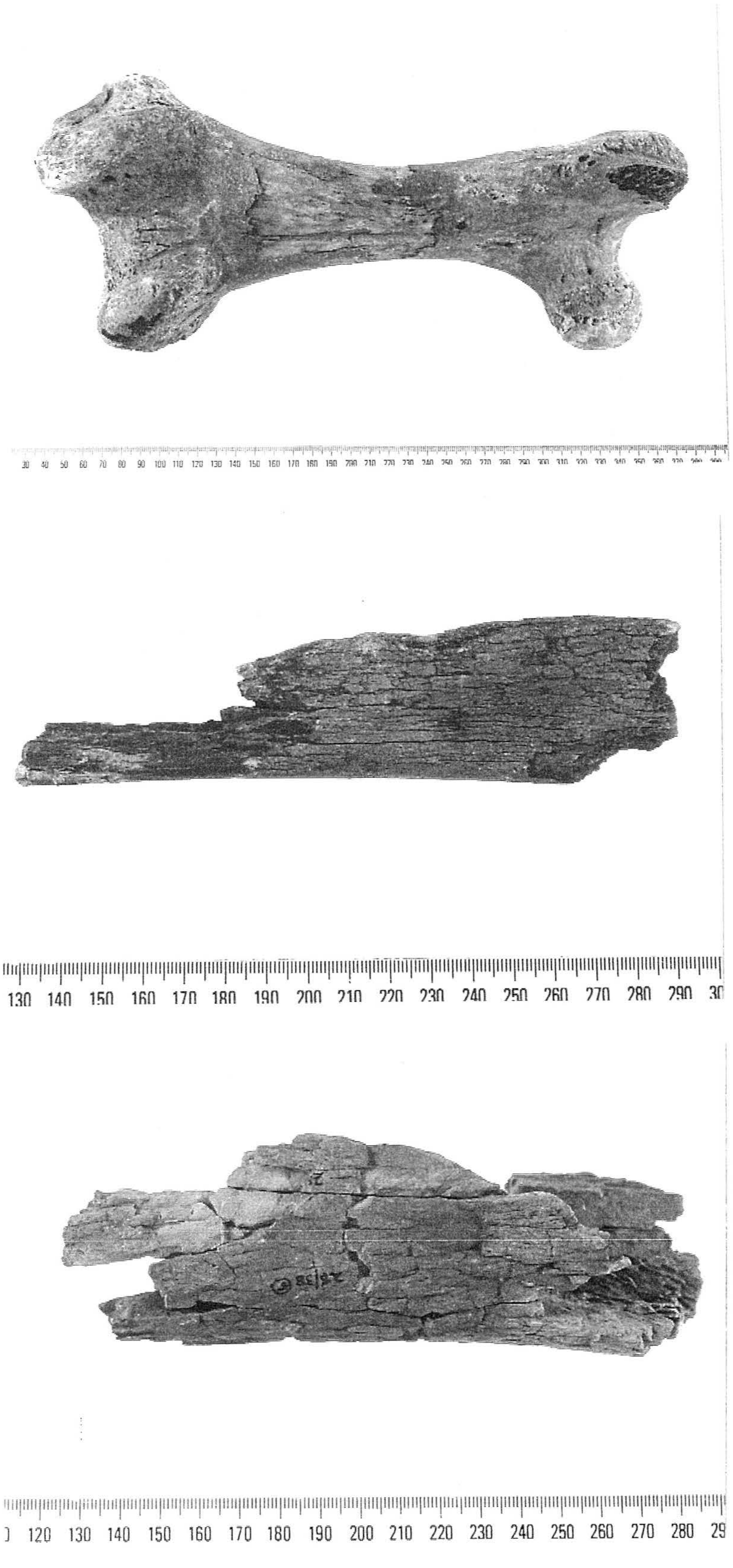


Figure 7.25 Examples of bone weathering in moa bone from Tai Rua.

Table 7.25 The weathering stages evident in the Tai Rua remains.

```
|-------------------------------|------|
|                               | MOA  |
|-------------------------------+------|
|WEATHERED      |               |      |
|---------------+---------------|      |
|1              |N              |    71|
|               |---------------+------|
|               |PCTN           |    15|
|---------------+---------------+------|
|2              |N              |   111|
|               |---------------+------|
|               |PCTN           |    24|
|---------------+---------------+------|
|2-3            |N              |     7|
|               |---------------+------|
|               |PCTN           |     1|
|---------------+---------------+------|
|3              |N              |   251|
|               |---------------+------|
|               |PCTN           |    54|
|---------------+---------------+------|
|4              |N              |    26|
|               |---------------+------|
|               |PCTN           |     6|
|---------------+---------------+------|
|5              |N              |     1|
|               |---------------+------|
|               |PCTN           |     0|
|---------------+---------------+------|
|ALL            |N              |   467|
|---------------+---------------+------|
```

An examination of the distribution of weathering by element (Appendix 5.11) reveals that there is no difference in the degree of weathering between most of the larger sets of bone remains in this site, which would support discussion of cultural practices to explain the element representation. The larger proportion of leg fragments present is indicative of butchery occurring prior to the bones being returned to the site, but the presence of 'CR', 'PELV', 'R', 'R-ST', and 'V-TH' fragments means that some whole carcasses were being returned for processing. There is no difference in the weathering stage recorded for the various element types.

Two fragments of bone had burning gradients across them (Figure 7.27) — from

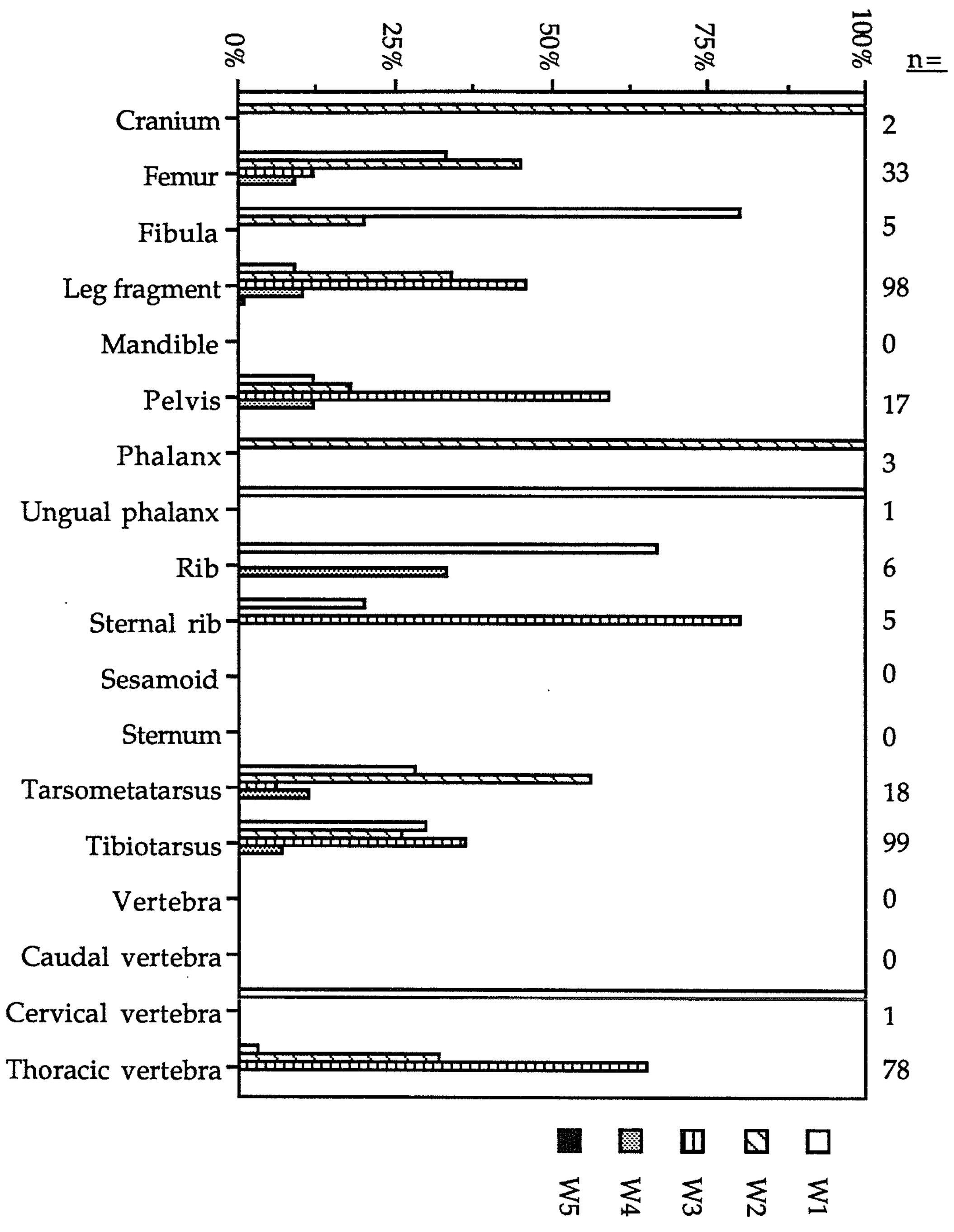


Figure 7.26 A breakdown of the weathering stages recorded for each skeletal element of moa present at Tai Rua.

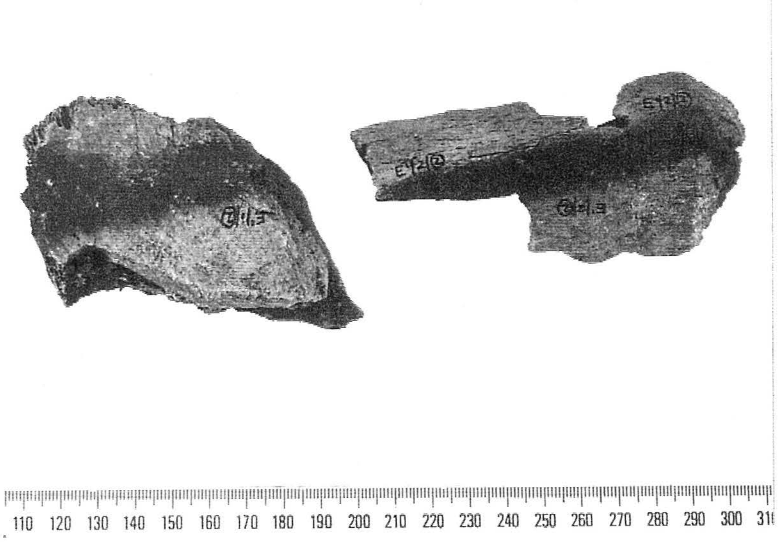


Figure 7.27 Two fragments of moa bone from Tai Rua with burning gradients across them (see text for details).

Stage 1 to Stage 4, suggesting that they lay on the periphery of a hearth or oven when they were discarded. A number of bones had a "chalky" feel and appearance to them, the cause of which is unknown, but is probably linked to the loss of collagen since the bone's deposition within the site.

Owen's Ferry (S132/4)

The recovery of a large proportion of burnt bone from Owen's Ferry (63% — Table 7.26) is consistent with the recording of ovens and scoop hearths during the excavation and possibly suggests bone fragments were being disposed of in the fires. The predominant burnt fragments are 'LEG' (85% burnt), 'PELV' (40%), 'TT' (57%) and 'V' (26%) with a further large group consisting of 'RESIDUE' (90%

Table 7.26 The degrees of burning evident in the Owen's Ferry remains.

```
|------------------------------|------|
|                              | MOA  |
|------------------------------+------|
|BURNT         |               |      |
|--------------+---------------|      |
|1             |N              |   559|
|              |---------------+------|
|              |PCTN           |    37|
|--------------+---------------+------|
|2             |N              |   136|
|              |---------------+------|
|              |PCTN           |     9|
|--------------+---------------+------|
|3             |N              |   452|
|              |---------------+------|
|              |PCTN           |    30|
|--------------+---------------+------|
|4             |N              |   367|
|              |---------------+------|
|              |PCTN           |    24|
|--------------+---------------+------|
|5             |N              |     6|
|              |---------------+------|
|              |PCTN           |     0|
|--------------+---------------+------|
|ALL           |N              |  1520|
|--------------+---------------+------|
```

burnt) (Appendix 5.12, Figure 7.28). In almost all the remaining elements the majority of the bone is in an unburnt state.

The collection was only slightly weathered (Table 7.27) — with 8% in Stage 1, 71% in Stage 2, 16% in Stage 3, and 5% in more advanced stages. There is almost no difference between elements in the degree of weathering as nearly all show a spread across weathering Stages 1–4 (Appendix 5.12, Figure 7.29). Those which were heavily weathered (Stage 5) include 'FEM', 'MAND', 'PELV', 'R', 'ST', 'TMT' and 'TT' indicating that the cancellous bone was no more susceptible to weathering than the cortical bone. During the analysis it was noted that several of the more complete longbones had large longitudinal splits which may be the result of the drying process, either in the field, (by dessication through the freeze-thaw process especially, or in the laboratory, as much as the weathering.

Table 7.27 The weathering stages evident in the Owen's Ferry remains.

```
|-------------------------------|------|
|                               | MOA  |
|-------------------------------+------|
|WEATHERED      |               |      |
|---------------+---------------|      |
|1              |N              |   119|
|               |---------------+------|
|               |PCTN           |     8|
|---------------+---------------+------|
|2              |N              |  1076|
|               |---------------+------|
|               |PCTN           |    71|
|---------------+---------------+------|
|3              |N              |   248|
|               |---------------+------|
|               |PCTN           |    16|
|---------------+---------------+------|
|4              |N              |    62|
|               |---------------+------|
|               |PCTN           |     4|
|---------------+---------------+------|
|5              |N              |    14|
|               |---------------+------|
|               |PCTN           |     1|
|---------------+---------------+------|
|ALL            |N              |  1520|
|---------------+---------------+------|
```

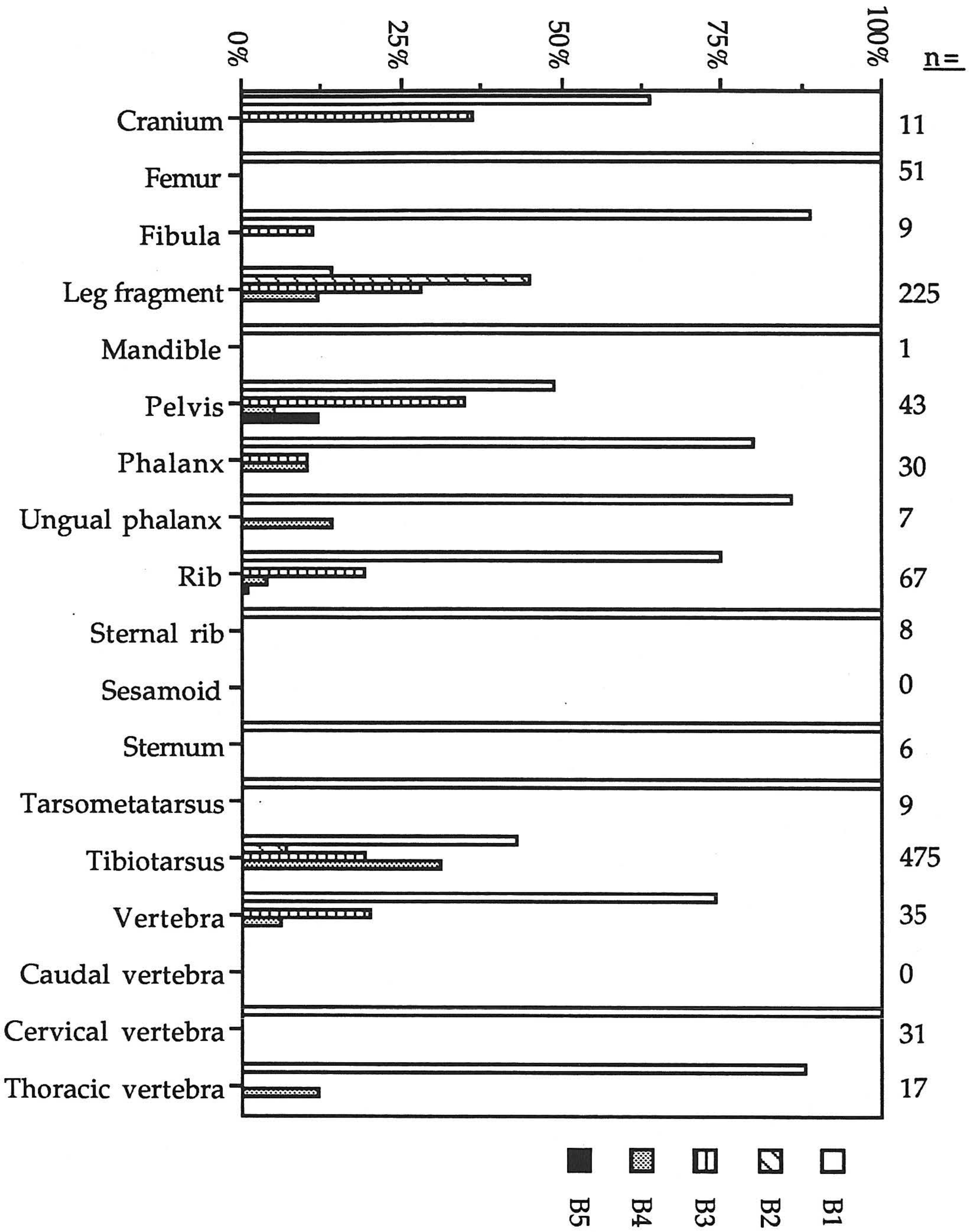


Figure 7.28 A breakdown of the burning stages recorded for each skeletal element of moa present at Owen's Ferry.

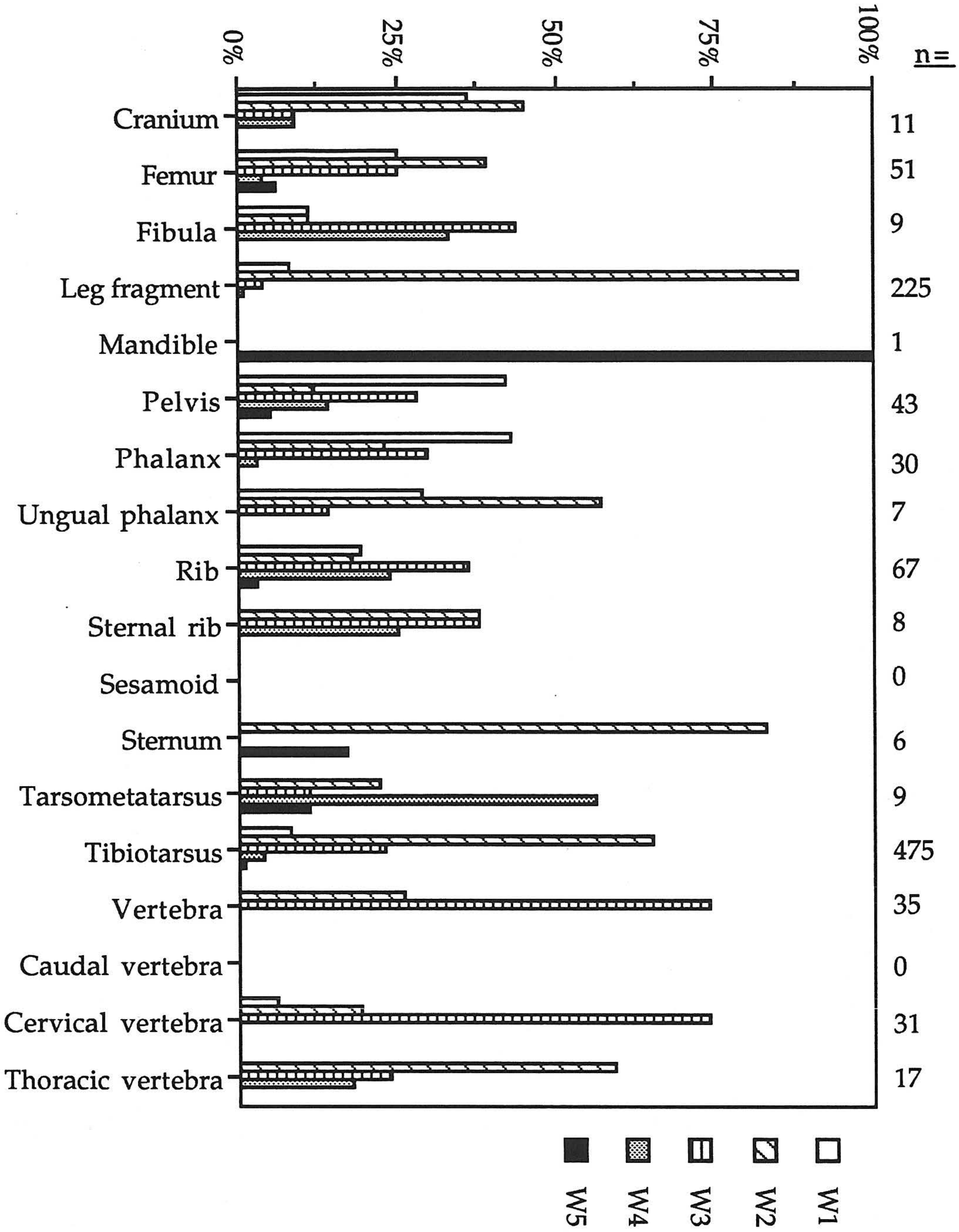


Figure 7.29 A breakdown of the weathering stages recorded for each skeletal element of moa present at Owen's Ferry.

The soil sample (Table 7.2) is strongly alkaline which may be a factor of the flood-wash silt on the banks along this stretch of the Kawarau River. The cation levels are very high for Ca^{2+}, the reason for which is unclear because there is no shell midden to raise the level, as often occurs in the coastal dune systems, and may be due to the schist derived silt which covered the site in several layers. Molloy (1988:163) describes the brown-grey earths of Central Otago as having moderate to high (5–20me% — Table 7.3) Ca levels, and this is the most probable reason. The description of the stratigraphy for this site, in Chapter 6, suggests that the bones probably did not lie exposed on the surface for any great length of time but were quickly inundated by river silt. The site is one of the more alkaline recorded in this study (at pH 8.6) and this would have worked to preserve the bones although periodic inundation from floods would have provided moisture for the decomposition process.

Hawksburn (S133/5)

Two separate collections of material exist from Hawksburn — in the Otago Museum is the Lockerbie material from the 1955 excavation (designated HBA in Appendix 5.13), and in the Anthropology Department, Otago University, is the material from Anderson's 1979 excavation (HBB in Appendix 5.13). This initial discussion considers all the bones as an entity, as all were derived from the same site, and subsequently the material from each collection is discussed separately.

Much of the Hawksburn bone is burnt — 6% in Stage 3, and 48% in Stage 4 — and a further 24% is stained black from contact with oven rakeout but is not in itself burnt (Table 7.28). An examination of the distribution of burning by element (Appendix 5.13, Figure 7.30) indicates that there is no significant difference between element types as all are spread across the burning stages, although the cortical elements ('FEM', 'LEG', 'TMT' and 'TT') along with some of the 'softer' cancellous and compact elements ('PH', 'PHU', and 'V-CE') exhibit a slightly higher percentage as being unweathered. This may be due to the remaining material having been discarded into fires for disposal or as fuel, given that they derive from low meat yield elements.

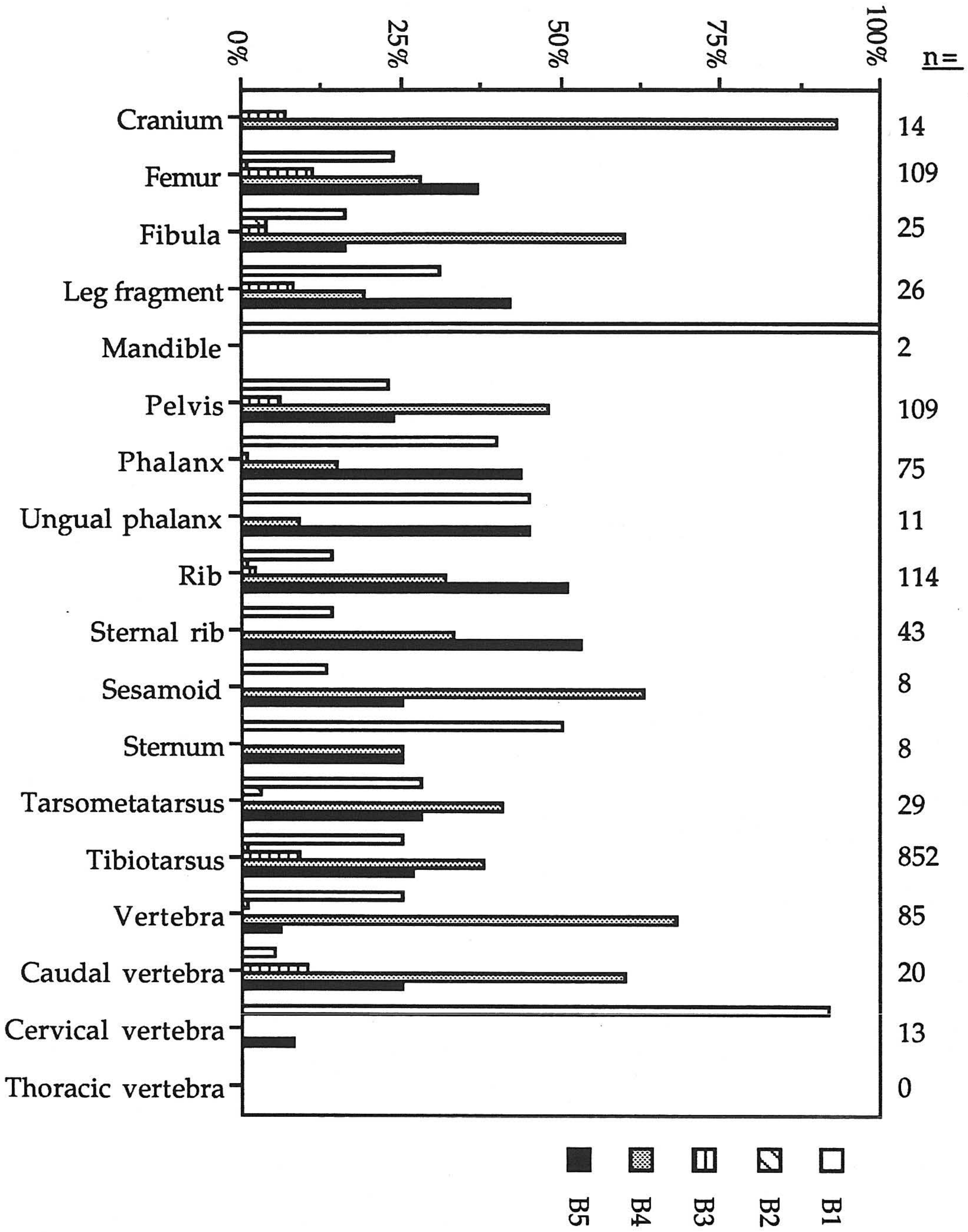


Figure 7.30 A breakdown of the burning stages recorded for each skeletal element of moa present at Hawksburn.

Table 7.28 The degrees of burning evident in the Hawksburn remains.

BURNT		MOA
1	N	459
	PCTN	21
2	N	17
	PCTN	1
3	N	129
	PCTN	6
4	N	1060
	PCTN	48
5	N	528
	PCTN	24
ALL	N	2193

In terms of the weathering of bones from this site, it can only be described as slight — 32% are in Stage 1 and 50% are in Stage 2, with a further 14% in Stage 3 (Table 7.29). At an elemental level (Appendix 5.13, Figure 7.31) there are a number of interesting patterns. 'CR' fragments are only slightly weathered (64% in Stage 2), as are 'ST' (75% in Stage 1), 'V-CA' (70% in Stage 2), and 'V-CE' (77% in Stage 1), but the other 'softer' and compact elements ('PELV', 'PH', 'PHU', 'R', 'R-ST' and 'V') occur right through to Stage 5, in varying degrees. This is similar to the leg bone fragments ('FEM', 'LEG', 'TMT' and 'TT'), although the majority of these elements occur in Stages 1 and 2. Figure 7.32 presents an interesting example of differential weathering in a metatarsus whereby the anterior surface is in Stage 2, while the posterior surface is in advanced Stage 4.

Table 7.29 The weathering stages evident in the Hawksburn remains.

```
|-------------------------------|------|
|                               | MOA  |
|-------------------------------+------|
|WEATHERED      |               |      |
|---------------+---------------|      |
|1              |N              |   701|
|               |---------------+------|
|               |PCTN           |    32|
|---------------+---------------+------|
|1*             |N              |     1|
|               |---------------+------|
|               |PCTN           |     0|
|---------------+---------------+------|
|2              |N              |  1088|
|               |---------------+------|
|               |PCTN           |    50|
|---------------+---------------+------|
|2*             |N              |     2|
|               |---------------+------|
|               |PCTN           |     0|
|---------------+---------------+------|
|3              |N              |   303|
|               |---------------+------|
|               |PCTN           |    14|
|---------------+---------------+------|
|4              |N              |    79|
|               |---------------+------|
|               |PCTN           |     4|
|---------------+---------------+------|
|5              |N              |    19|
|               |---------------+------|
|               |PCTN           |     1|
|---------------+---------------+------|
|ALL            |N              |  2193|
|---------------+---------------+------|
```

At a collection level (Appendix 5.13), the HBA bone is all unburnt and only slightly weathered (42% in Stage 1, 48% in Stage 2, and 10% in Stage 3). It is the cancellous elements which generally occur in Stages 2 and 3; for example, only 50% of 'FEM', and 38% of 'TT' are weathered to this extent, while 76% of 'PELV', 83% of 'R', 75% of 'R-ST', and 100% of 'V-CA' occur in Stages 2 and 3.

Shedding the 93 HBA bones from the analysis of the HBB collection makes little difference to the overall distribution figures for burning and weathering. At a more basic elemental level, again there is very little change from the figures, and

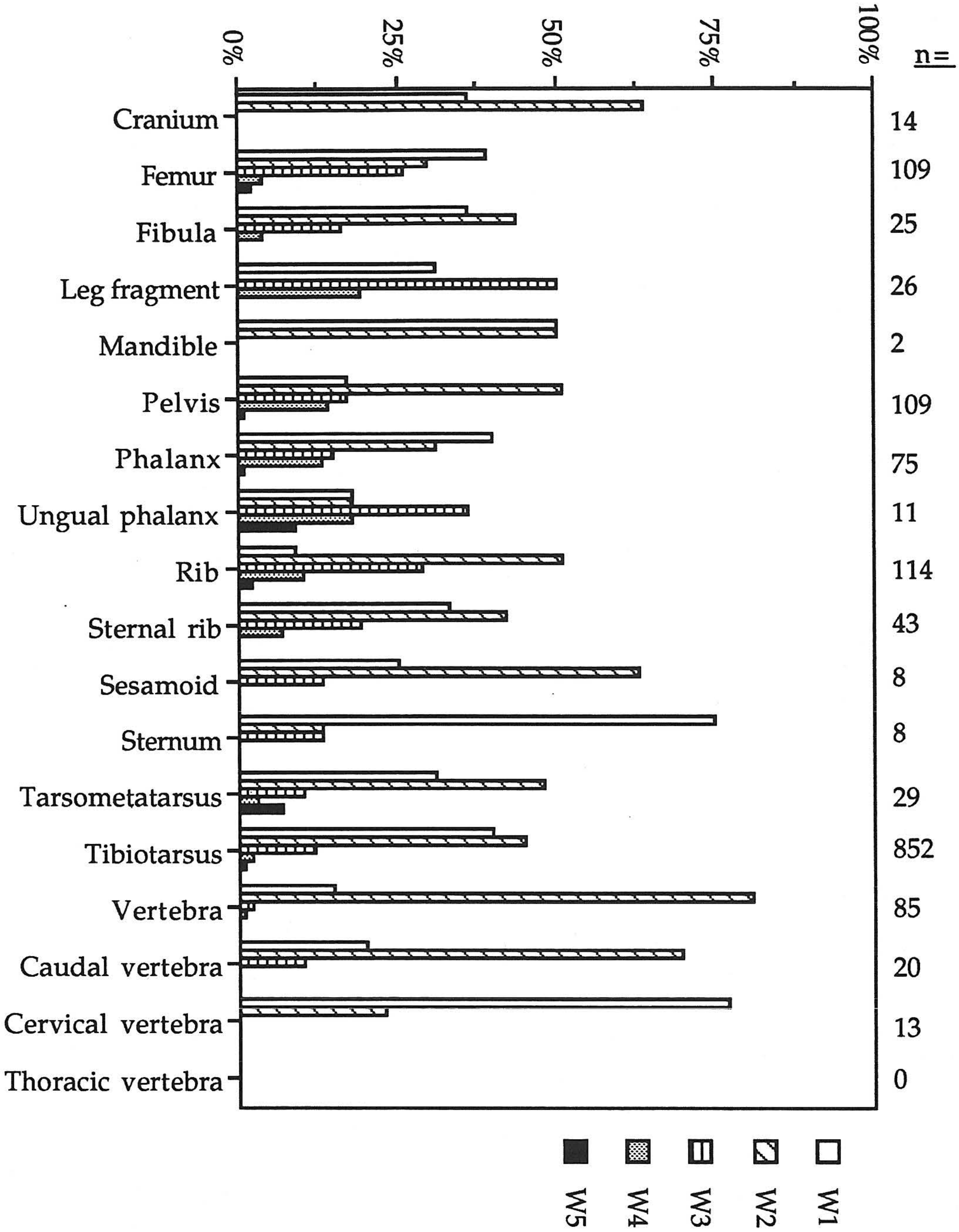


Figure 7.31 A breakdown of the weathering stages recorded for each skeletal element of moa present at Hawksburn.

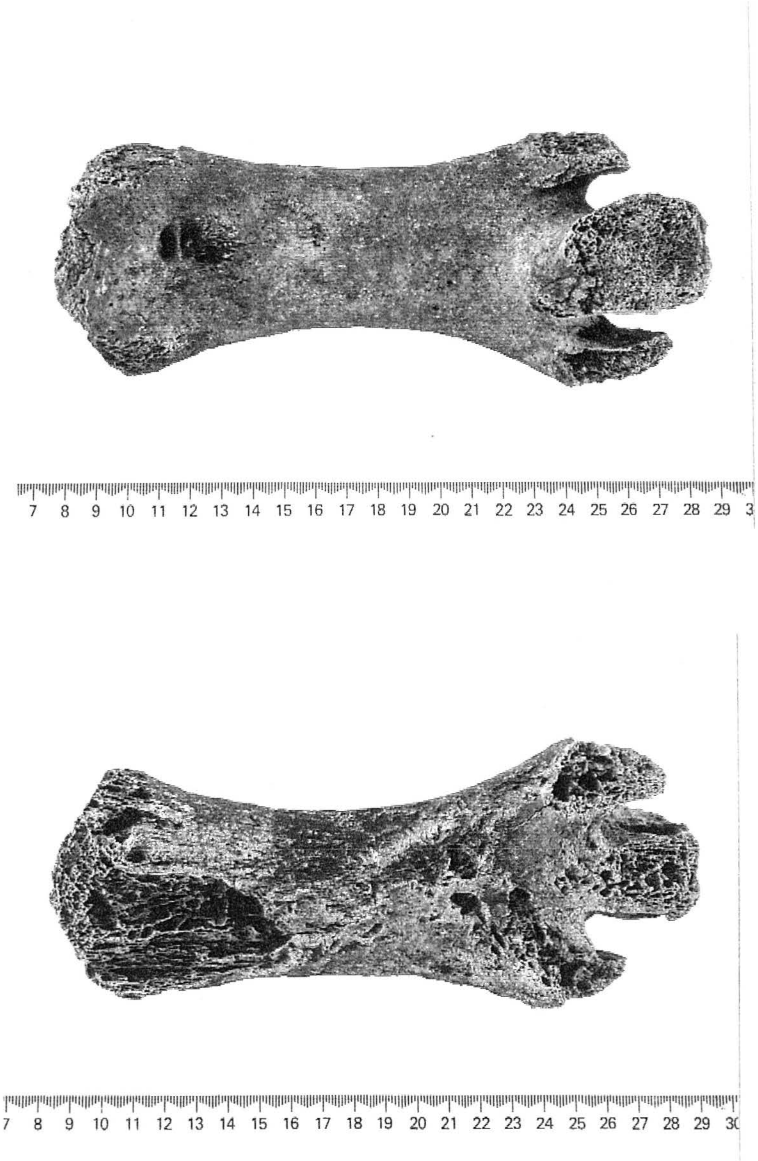


Figure 7.32 Anterior (top) and posterior (bottom) views of a left moa tarsometatarsus from Hawksburn, showing differential weathering.

therefore the discussion, of the total collection. A number of bones were described as being "chalky" in appearance and to the touch during the analysis and were predominantly derived from Areas C, H and L, as well as Areas FA and M to a lesser degree.

In his analysis of the Hawksburn bone, Kooyman (1985:294–296) reported that over 85% of the bone he analysed was burned. It is difficult to explain the variance with my figures but it may be due to the level to which the analysis was taken. I tended to restrict my analysis to material that could be more-or-less identified to element and so bags of bone "gravel" (Anderson 1989a: 145) were by-passed. Kooyman (op. cit.) argues that the quantities of burned bone in this site indicate deliberate attempts to burn bone. He rules out burning *in situ* because there was unburned bone mixed with burned bone, the burned portion of the midden lay directly on the unburned portion. He continues:

> "The area is very close to a series of ovens and additional unexcavated areas adjacent to it could also conceivably have ovens, hence bone burning for fuel is possible. The problem in this regard is that there are obvious rakeout areas around the ovens that contain charcoal and oven stones but little moa bone, and the area of burned bone contains little ovenstone remains [Anderson 1979:55]. It makes no sense to accumulate a pile of refuse, then burn it, and then move it again, hence the burned moa bone is certainly not the result of refuse disposal. It is also unlikely that a refuse pile would be accumulated in the immediate vicinity of a cooking area or any other heavily used area, nor would burned refuse be specifically moved to such a location. Anderson (pers.comm.) has suggested that the clean silt area the ovens are situated on may have been particularly chosen because of its suitability for ovens. As more ovens were built and the silt area was taken up, midden such as the burned moa bone may have been shifted to provide access to the suitable ground it covered. Anderson speculated that the bone might have been burned to extract the grease, but such a procedure would burn the grease rather than extract it (grease might be extracted from bone if the bone was simply heated, not

> burned, so that the grease would not catch fire. It might be possible to do this by applying hot rocks directly onto the bones. Hot rocks were used in NZ for a variety of heating purposes. The only real possibility is that the bone was burned as fuel; the proximity of the bones to the ovens makes this quite probable. Anderson suggested that the bone deposition represented a different episode from the charcoal and ovenstone deposition. This seems reasonable, each representing a different rakeout period, with the bone material perhaps representing the earlier event that was removed further from the ovens because it was known that the ovens would be used again. Oven stones are absent from the bone area either because they were removed for reuse or because they were purposely left behind during the rakeout procedure because of their weight" (Kooyman 1985:295–296).

Given the slow rate of soil deposition in the inland basins it was surprising more material was not recorded as being sun-bleached because most would have lain exposed on the surface for some time. The soil chemistry results (Table 7.2) do not fully explain the degree of weathering evident. The pH ranged from moderately acid (5.33 in No. 4) to moderately alkaline (7.7 in No. 2) with the remaining two being near neutral. Three of the four Ca results are very high and fall outside the ranges reported in Chapter 6 for the soil types in this region — the Arrow, Blackstone and Alexandra series. With the first three samples being derived from the midden and oven areas, the elevated Ca levels may be due to leaching of Ca from the bone fragments, and with the low rainfall in this area of Central Otago there would be less leaching of any anthropogenic Ca away from the surface into the lower soil levels (Richard Morgan pers.comm. 7/7/92). The remote possibility also exists that these three high readings may be due to the application of fertiliser during oversowing of the tussock basin in the past. The very low Ca result for No. 4, which is similar to NZ Soil Bureau figures quoted in Chapter 6, counters this argument and it probably represents the natural background level, as the sample was collected some distance from the archaeological remains. The possibility does exist, however, that it could be a laboratory error which has produced such a low reading, although the values for the other variables in sample No. 4 do not differ significantly from the other three samples.

Coal Creek (S152/12)

The moa bones from Coal Creek exhibited a range of burning stages (Table 7.30) — 30% were unburnt and 59% were stained from the thick, black, greasy matrix, and the remaining 11% exhibited burning ranging from charring (Stage 2) through to complete reduction (Stage 4). The material in the three burnt stages (Stages 2–4) is nearly all from leg elements: 'FEM', 'FIB' (29% in Stage 4), 'RESIDUE' (small fragments probably of broken/shattered longbones), 'TMT', and 'TT'. Also present in Stage 4 were two 'PELV' fragments (Appendix 5.14, Figure 7.33). Not included in my analysis were 13 bags of fine bone "gravel", which are presumably all in Stage 4 burning.

Kooyman also discussed the burnt bone from Coal Creek which, like the bone from Hawksburn, he considered was deliberately burned:

Table 7.30 The degrees of burning evident in the Coal Creek remains.

BURNT		MOA
1	N	286
	PCTN	30
2	N	25
	PCTN	3
3	N	36
	PCTN	4
4	N	48
	PCTN	5
5	N	560
	PCTN	59
ALL	N	955

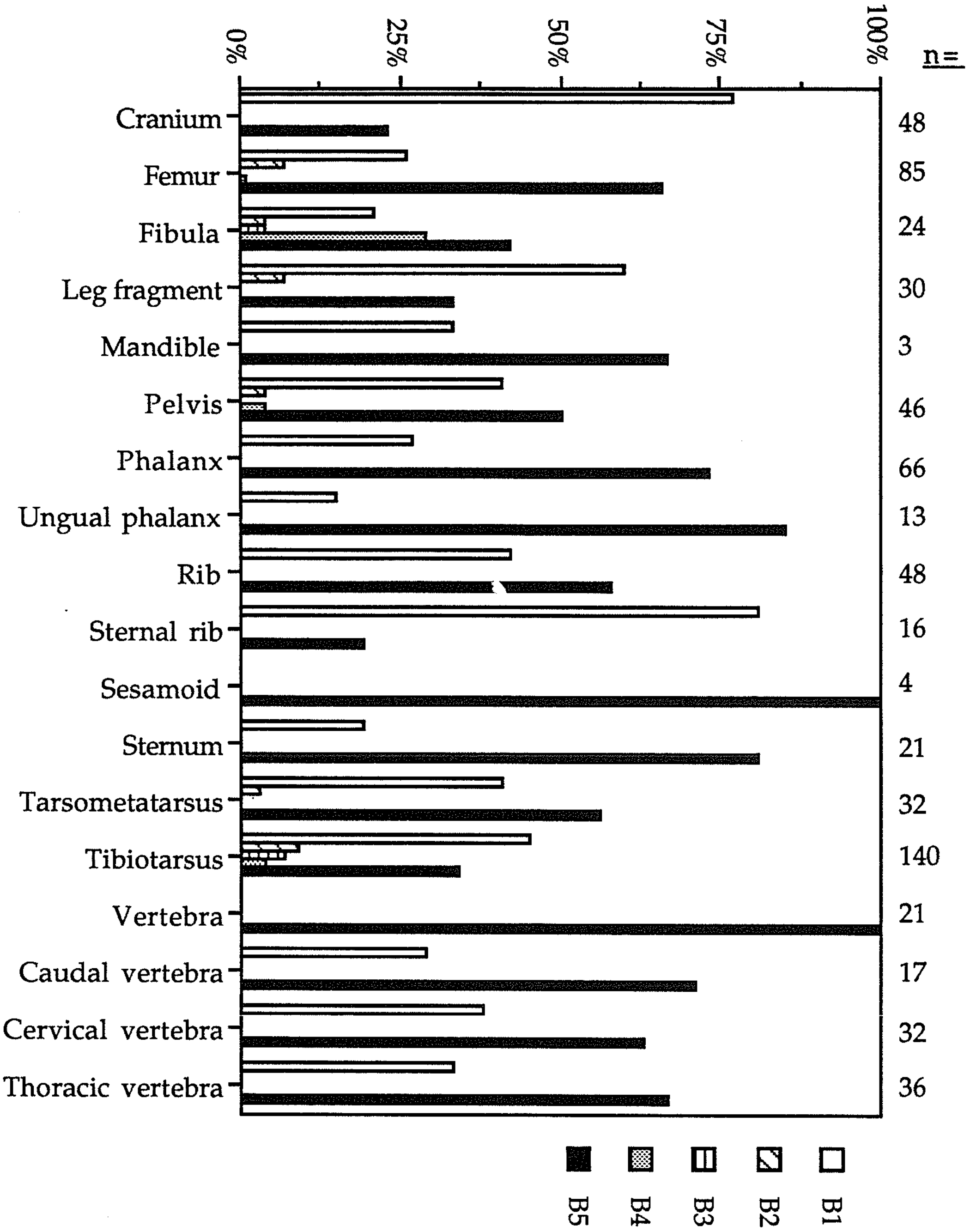


Figure 7.33 A breakdown of the burning stages recorded for each skeletal element of moa present at Coal Creek.

> "Most of the Coal Creek material came from a single pile of bone in Area E. The upper portion of this pile was burned white and was extremely fragmented, to the point where the bone was little more than pea-sized gravel. Lower in the pile the bone was burned black and although much fragmented by burning, the pieces were considerably larger than in the upper portion. At the base of this portion were a number of bone fragments that were burned on the upper surface and unburned on the lower. This clearly was a pile of bone that was burned in situ by lighting the pile from above and can almost certainly be taken as an example of refuse burning. Coal Creek was certainly occupied for some time if refuse burning was required, but since much of the bone (about 75%) was unburned this cannot be confidently ascribed to permanent occupation. Only a small portion of Area E was excavated, however, hence the true extent of burning in not known" (Kooyman 1985:294).

The bones from Coal Creek can be best described as moderately weathered (Table 7.31) — 21% are in Stage 1, 53% in Stage 2, 19% in Stage 3, 5% in Stage 4 and a final 1% in Stage 5. The elements all exhibit a similar distribution across the weathering stages (Appendix 5.14) with Stages 1 and 2 being the most common, and tailing off into Stages 3 and 4 (Figure 7.34). It is generally the more robust elements which are in Stages 4 and 5 (Figures 7.35 and 7.36) — 'FEM' (11% Stage 4 and 6% Stage 5), 'LEG' (23% and 7% respectively), 'TMT' (9% and 3% respectively), and 'TT' (6% and 1% respectively). In addition, however, there are instances of compact and cancellous elements weathered to Stage 4 — 'PELV' (7%), 'PH' (5%), 'PHU' (8%), 'R' (13%) and 'ST' (48%). This would tend to suggest that the bones were all experiencing similar effects from the burial matrix. Given that there is no evidence of bleached material, I can assume that the bones were covered in floodwash silt from Coal Creek within a short time of being deposited. From notes I recorded while undertaking the analysis, I had noted that the bones from Area B were very fragmented and appeared to be more weathered than those from Area E. On many bones the surface of the cortical diaphyseal bone is very pitted, something I tentatively suggest is due to chemical action within the burial matrix.

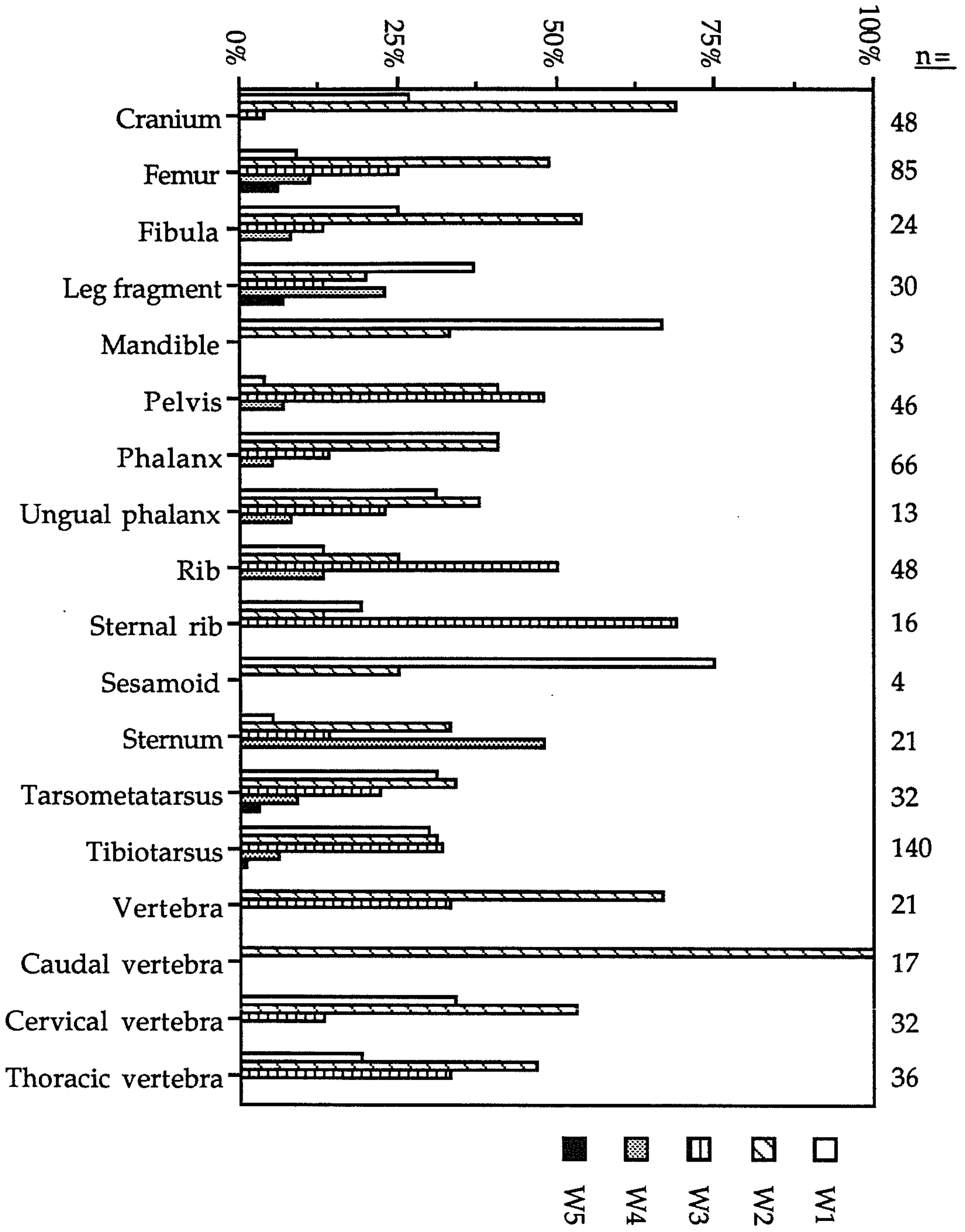


Figure 7.34 A breakdown of the weathering stages recorded for each skeletal element of moa present at Coal Creek.

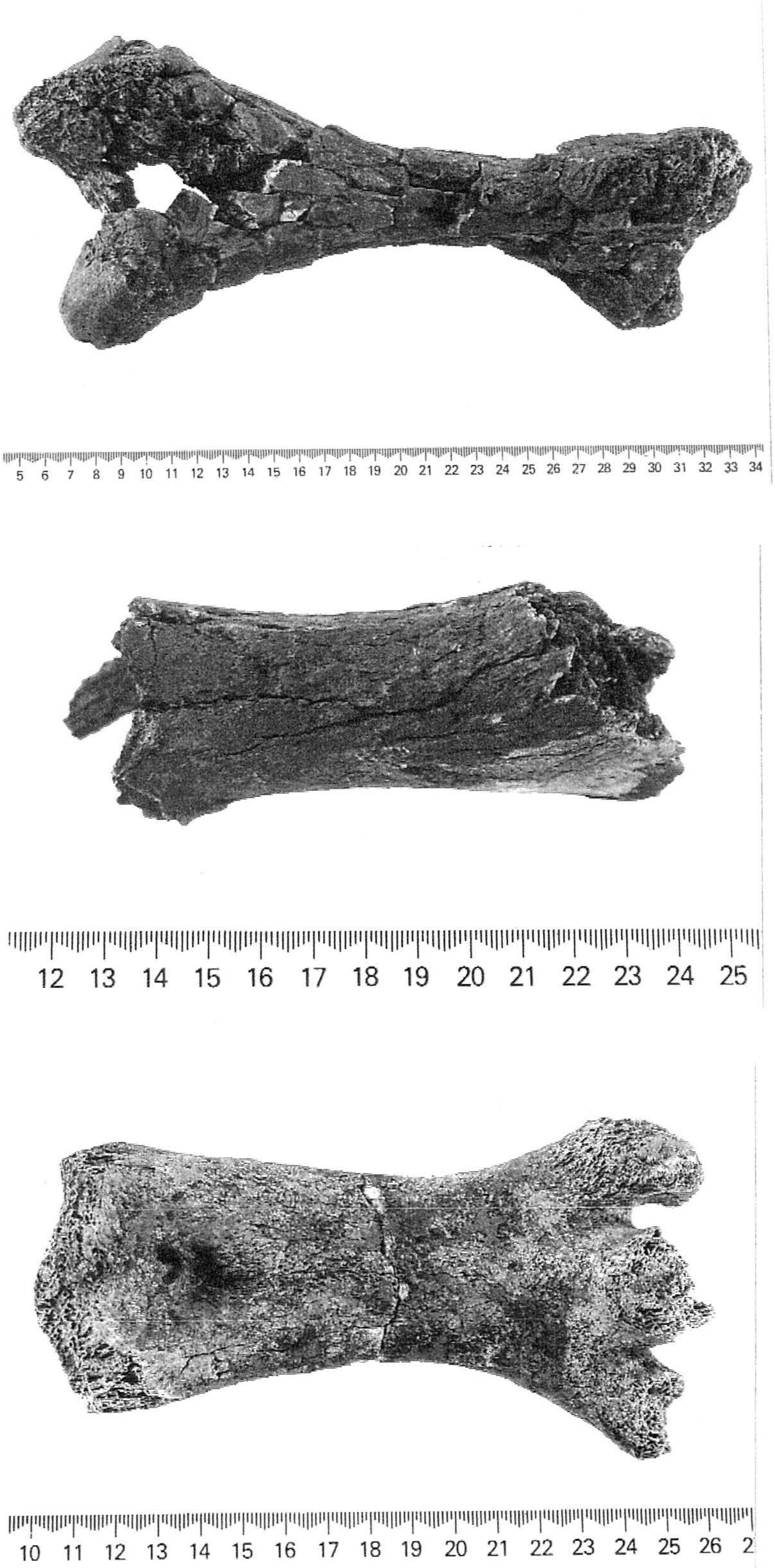


Figure 7.35 Examples of bone weathering in moa bone from Coal Creek.

Figure 7.36 Further examples of bone weathering in moa bone from Coal Creek.

Table 7.31 The weathering stages evident in the Coal Creek remains.

```
|-----------------------------|------|
|                             | MOA  |
|-----------------------------+------|
|WEATHERED     |              |      |
|--------------+--------------|      |
|1             |N             |   205|
|              |--------------+------|
|              |PCTN          |    21|
|--------------+--------------+------|
|2             |N             |   510|
|              |--------------+------|
|              |PCTN          |    53|
|--------------+--------------+------|
|3             |N             |   179|
|              |--------------+------|
|              |PCTN          |    19|
|--------------+--------------+------|
|4             |N             |    52|
|              |--------------+------|
|              |PCTN          |     5|
|--------------+--------------+------|
|5             |N             |     9|
|              |--------------+------|
|              |PCTN          |     1|
|--------------+--------------+------|
|ALL           |N             |   955|
|--------------+--------------+------|
```

The soil results from this site are very interesting (Table 7.2). All have a moderate to strongly acid pH and coupled with a relatively high moisture content would see leaching of the bone occurring (Richard Morgan pers.comm. 7/7/92). Hand in hand with high acidity one often records a high organic content, which is evident here in comparison to the low levels in the remainder of the soil series, apart from Tokoroa which has similar levels to Coal Creek. Samples 1–3 have high to very high Ca levels while Sample No. 4 is significantly lower, and is closer to the NZ Soil Bureau figures quoted in Chapter 6. Samples 1 and 2 show many similarities and were derived from an area in the garden where the soil was very dark. The high Ca levels may possibly be explained as being due to the application of 'lime' (Ca_2CO_3) to the vegetable garden. A further reason for low levels in sample No. 4 may be due to its having come from the bank below the upper terrace, such that fertiliser and moisture were not applied to this area.

Pounawea (S184/1)

Pounawea is another site for which multiple collections are available — PWA was assigned to the Lockerbie material (collected from a series of excavations in the 1940's and 50's), and PWB was assigned to Hamel's 1980 excavation.

Treating all the bones as a single assemblage first, 95% of the bones were unburned (Table 7.32), with a handful of fur seal and moa bone displaying a small degree of burning (8% of moa was in Stage 4). This latter material is composed almost entirely of 'LEG' fragments which have 16% burnt to Stage 4, although fragments of 'RESIDUE' (40% in Stage 4), 'RIB', 'TT' (one of), and 'V' were also recorded (Figures 7.37–7.40).

Table 7.32 The degrees of burning evident in the Pounawea remains.

```
|------------------------------|-----------------------------------------|------|
|                              |                 SPECIES                 |      |
|                              |-----------------------------------------|      |
|                              |      |      |      |      | SEA  |      |      |
|                              |ES/LS |  FS  |FS/SL | MOA  | MAM  |  SL  | ALL  |
|------------------------------+------+------+------+------+------+------+------|
|BURNT         |               |      |      |      |      |      |      |      |
|--------------+---------------|      |      |      |      |      |      |      |
|1             |N              |     1|   164|    37|   311|   119|    48|   680|
|              |---------------+------+------+------+------+------+------+------|
|              |PCTN           |   100|    58|   100|    61|    76|    60|    64|
|--------------+---------------+------+------+------+------+------+------+------|
|2             |N              |     .|     1|     .|     4|     .|     .|     5|
|              |---------------+------+------+------+------+------+------+------|
|              |PCTN           |     .|     0|     .|     1|     .|     .|     0|
|--------------+---------------+------+------+------+------+------+------+------|
|3             |N              |     .|     2|     .|    10|     .|     .|    12|
|              |---------------+------+------+------+------+------+------+------|
|              |PCTN           |     .|     1|     .|     2|     .|     .|     1|
|--------------+---------------+------+------+------+------+------+------+------|
|4             |N              |     .|     4|     .|    39|     .|     .|    43|
|              |---------------+------+------+------+------+------+------+------|
|              |PCTN           |     .|     1|     .|     8|     .|     .|     4|
|--------------+---------------+------+------+------+------+------+------+------|
|5             |N              |     .|   112|     .|   143|    38|    32|   325|
|              |---------------+------+------+------+------+------+------+------|
|              |PCTN           |     .|    40|     .|    28|    24|    40|    31|
|--------------+---------------+------+------+------+------+------+------+------|
|ALL           |N              |     1|   283|    37|   507|   157|    80|  1065|
|--------------+---------------+------+------+------+------+------+------+------|
```

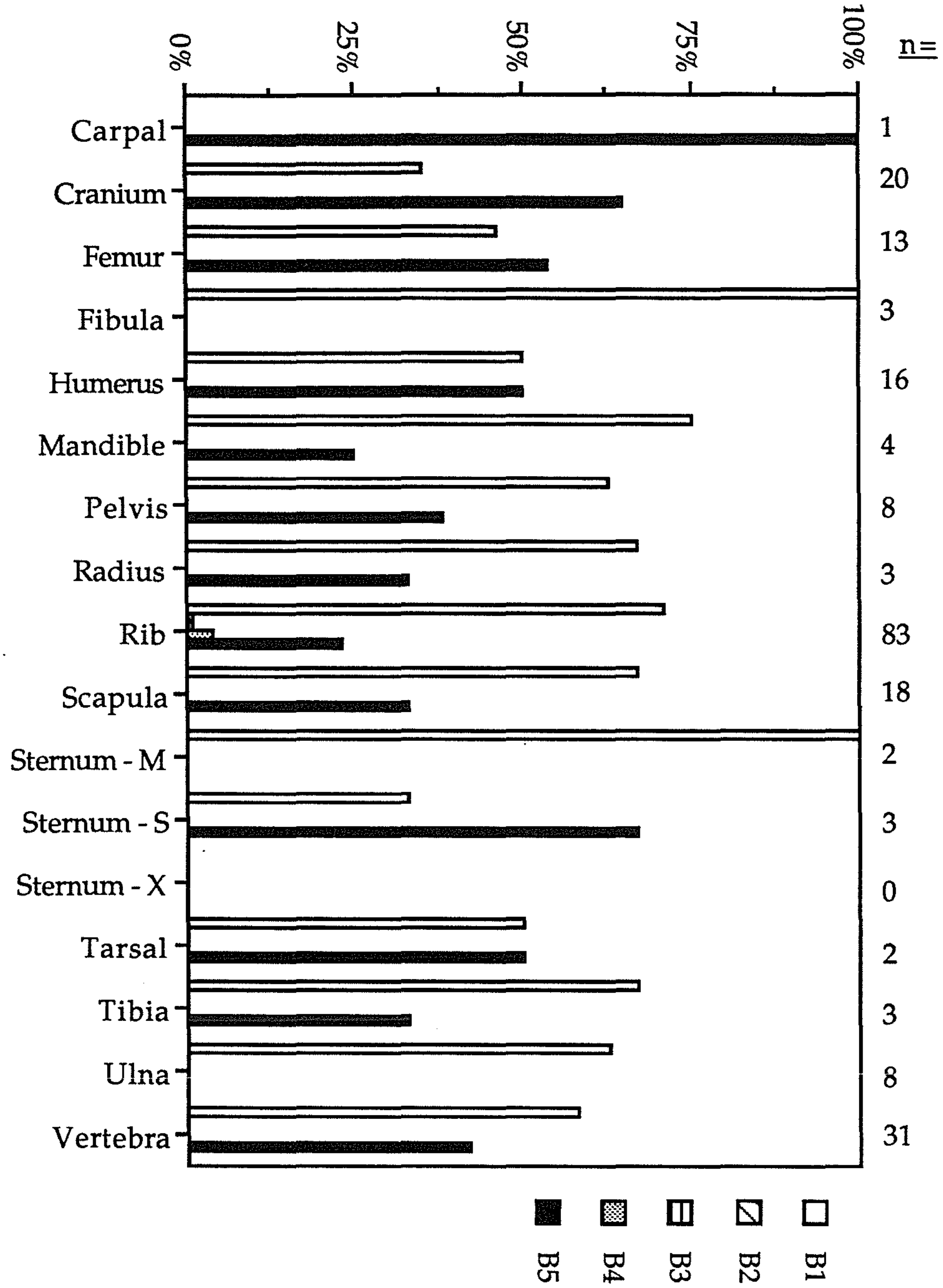


Figure 7.37 A breakdown of the burning stages recorded for each skeletal element of fur seal present at Pounawea.

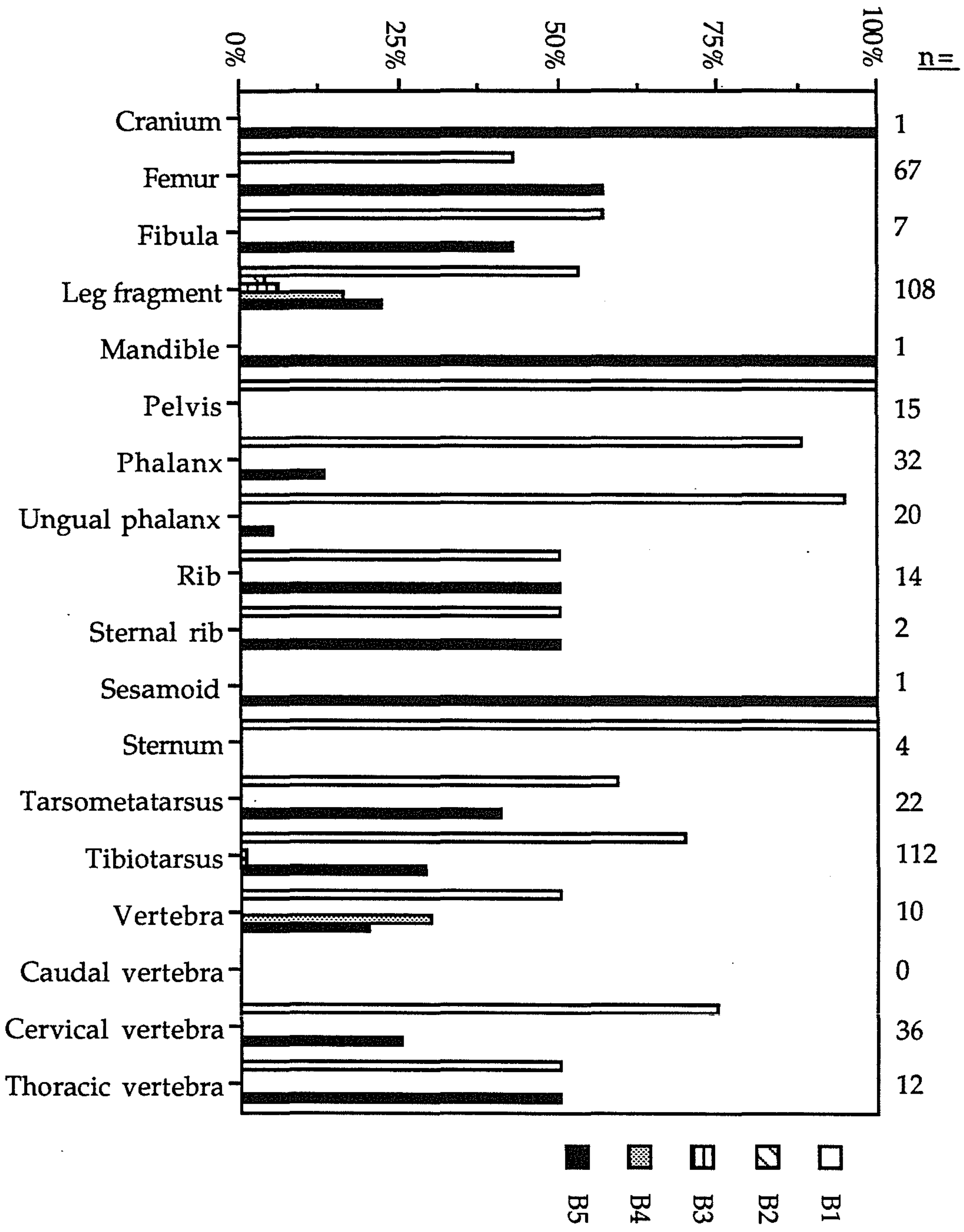


Figure 7.38 A breakdown of the burning stages recorded for each skeletal element of moa present at Pounawea.

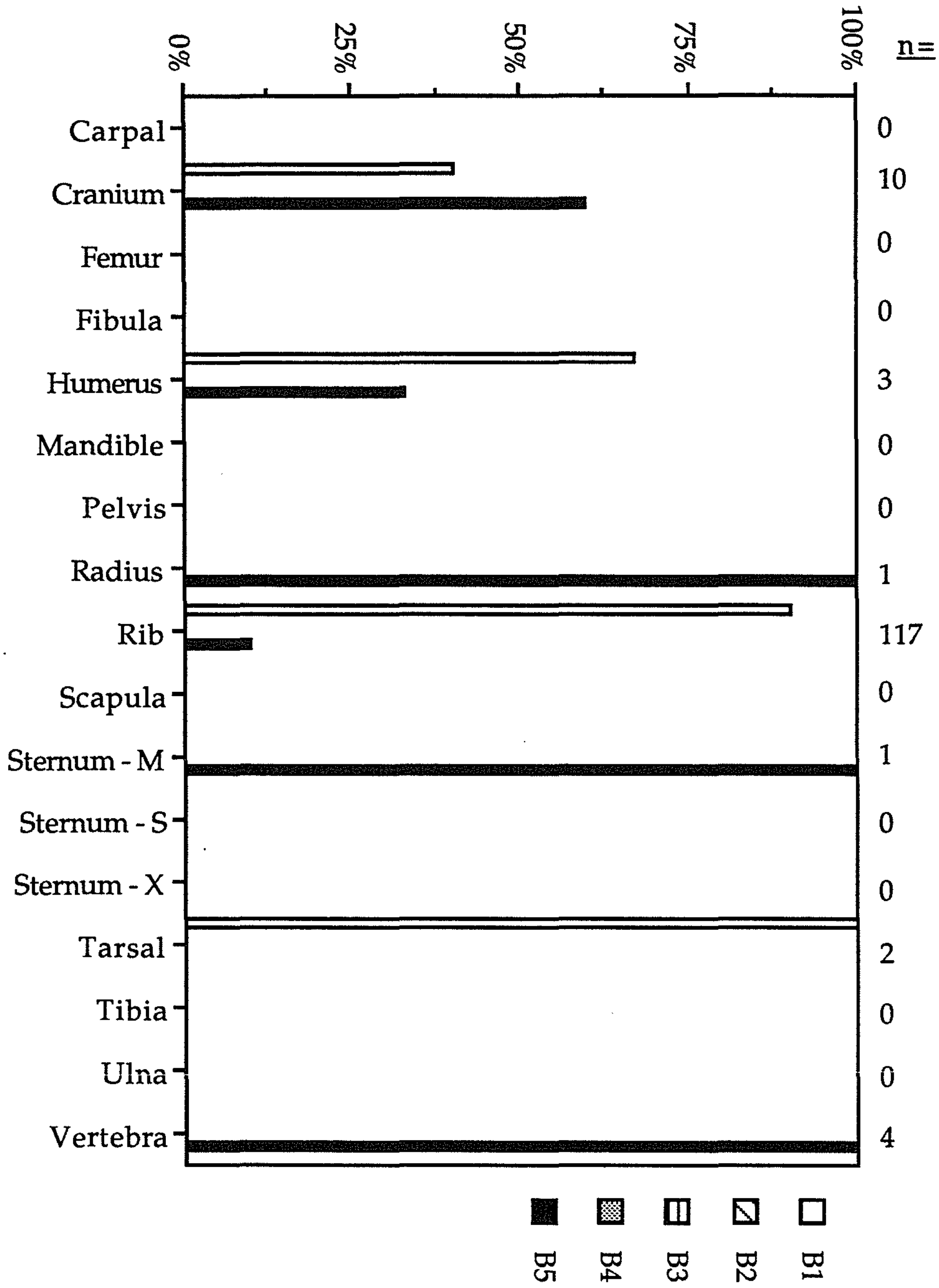


Figure 7.39 A breakdown of the burning stages recorded for each skeletal element of 'SEA MAM' present at Pounawea.

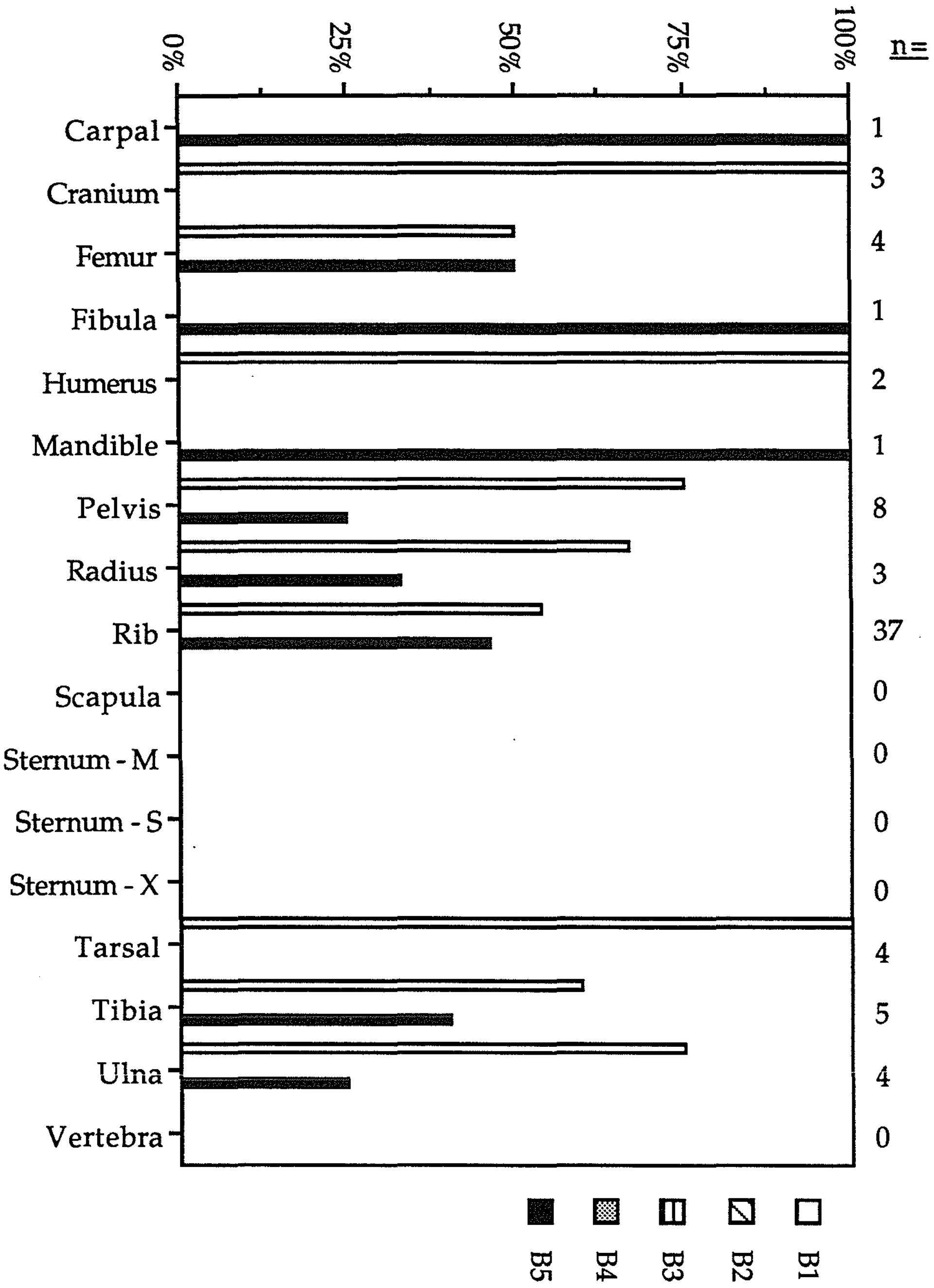


Figure 7.40 A breakdown of the burning stages recorded for each skeletal element of sea lion present at Pounawea.

The bones were slightly weathered (Table 7.33) — 68% in Stage 1 (71% of fur seal, 65% of moa, 62% of sea mammal, and 73% of sea lion), 24% in Stage 2 (25% of fur seal, 26% of moa, 22% of sea mammal, and 20% of sea lion) and 7% in Stage 3 (4% of fur seal, 8% of moa, 10% of sea mammal, and 6% of sea lion). Eighteen fragments of bone were recorded in Stages 4–5 (equalling less than 1% of the total collection). There is little extra to add regarding individual element weathering (Appendix 5.15). The vast majority of material is in Stages 1 and 2 with a few fragments in higher stages which tend to be from less robust elements — 'PELV' (16% in Stage 3), 'PH', 'RAD', 'RIB', 'V', 'V-CE', and 'V-TH' (Figures 7.41–7.44).

Table 7.33 The weathering stages evident in the Pounawea remains.

		SPECIES						
		ES/LS	FS	FS/SL	MOA	SEA MAM	SL	ALL
WEATHERED								
1	N	1	200	37	328	97	58	721
	PCTN	100	71	100	65	62	73	68
2	N	.	70	.	134	34	16	254
	PCTN	.	25	.	26	22	20	24
3	N	.	11	.	39	16	5	71
	PCTN	.	4	.	8	10	6	7
3*	N	.	.	.	1	.	.	1
	PCTN	.	.	.	0	.	.	0
4	N	.	2	.	2	10	1	15
	PCTN	.	1	.	0	6	1	1
5	N	.	.	.	3	.	.	3
	PCTN	.	.	.	1	.	.	0
ALL	N	1	283	37	507	157	80	1065

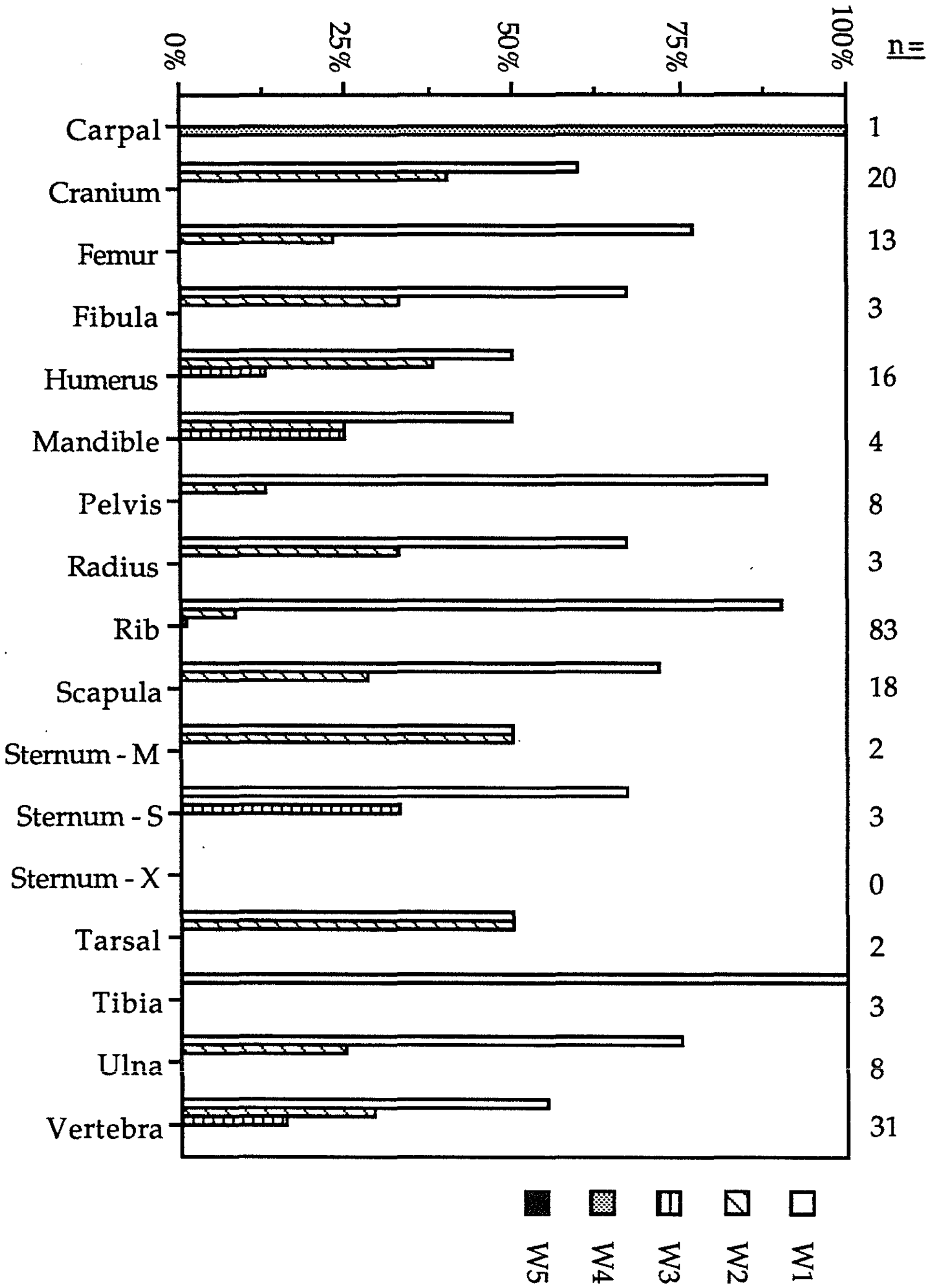


Figure 7.41 A breakdown of the weathering stages recorded for each skeletal element of fur seal present at Pounawea.

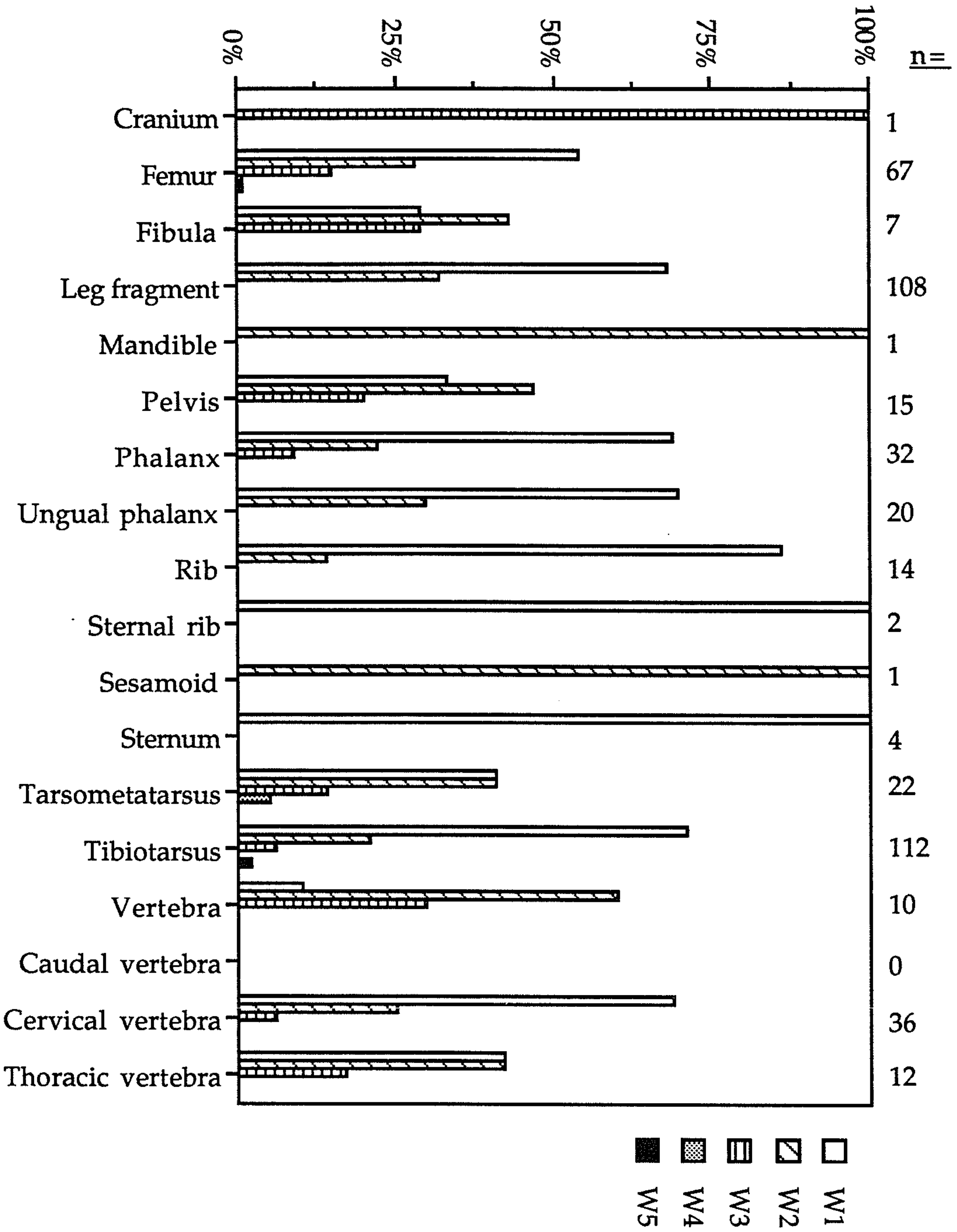


Figure 7.42 A breakdown of the weathering stages recorded for each skeletal element of moa present at Pounawea.

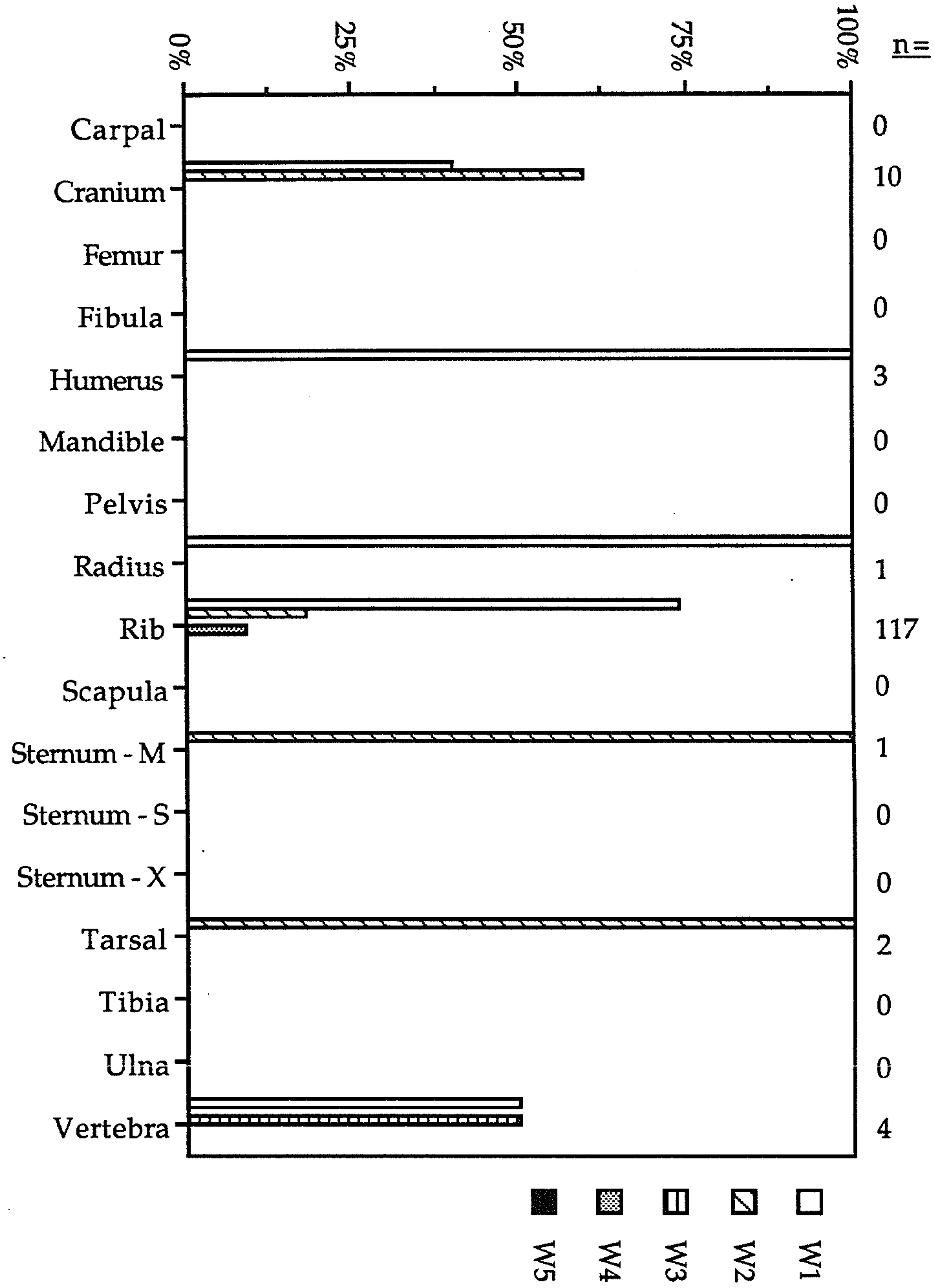


Figure 7.43 A breakdown of the weathering stages recorded for each skeletal element of 'SEA MAM' present at Pounawea.

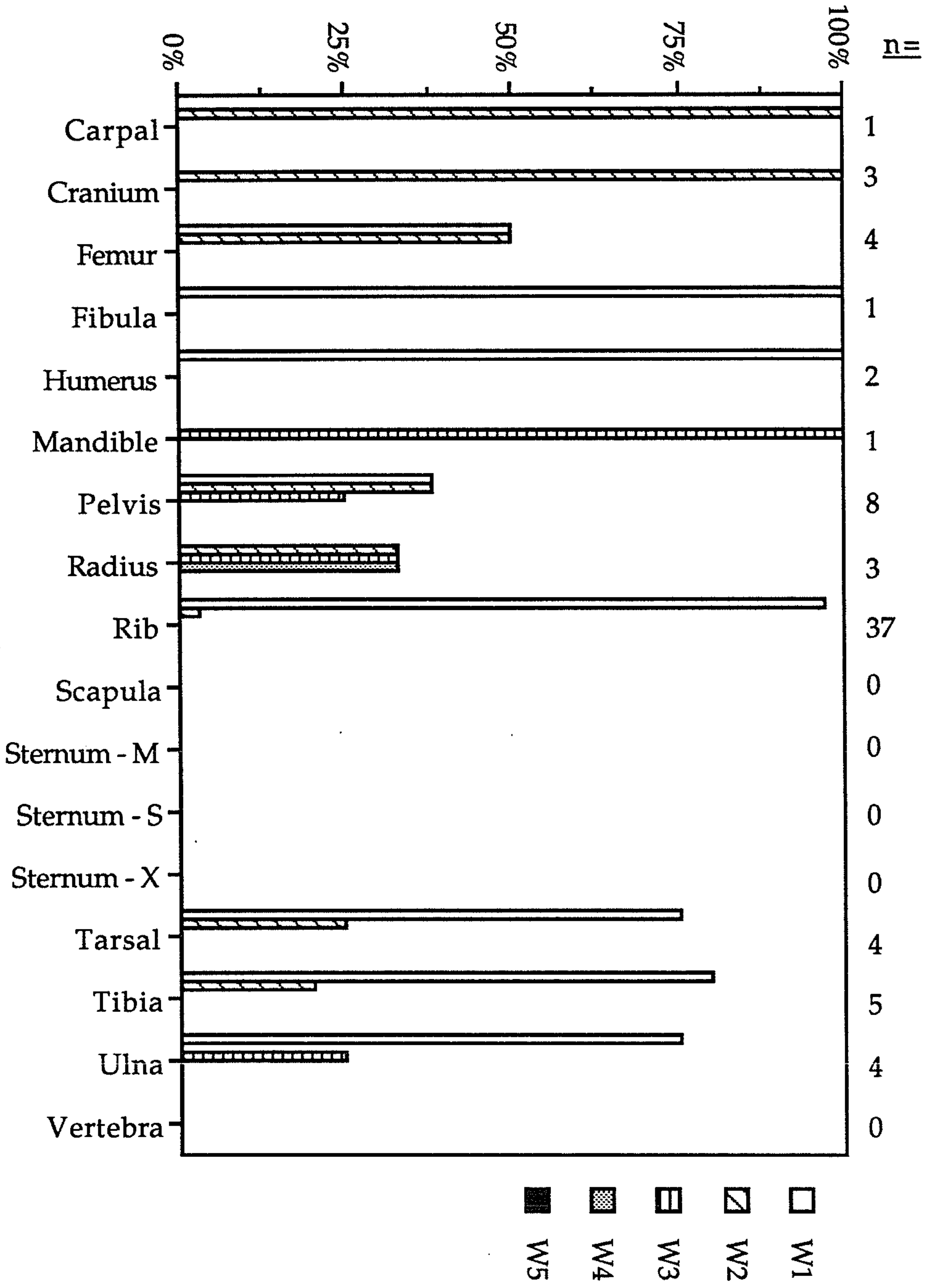


Figure 7.44 A breakdown of the weathering stages recorded for each skeletal element of sea lion present at Pounawea.

All the bones from PWA are moa, unburned, and exhibiting the full range of weathering stages — 44% in Stage 1, 40% in Stage 2, 11% in Stage 3, 2% in Stage 4, and 3% in Stage 5. The collection chiefly consists of 'FEM' and 'TT' which, along with 'TMT', are represented in almost all the weathering stages.

The second collection, PWB, displays similar burning and weathering characteristics to that of the overall results. There are practically no elements weathered beyond Stage 3, save for a fragment of 'RAD', 10 fragments of 'RIB' and two 'V-L' (all weathered to Stage 4). Within the various species from PWB the ES/LS bone is in Stage 1, two fragments of 'V-L' are the only fur seal bone above Stage 3. The sea mammal is mainly in Stages 1 and 2 (62% and 22% respectively) although 9% of the 'RIB' fragments are in Stage 4, and the sea lion is 73% in Stage 1, 20% in Stage 2, and 6% in Stage 3 with only one 'RAD' fragment weathered to Stage 4.

As only one bone in all the material analysed was bleached I assume the bones were covered with sand soon after their deposition. This collection was notable for the number of bones which had been gnawed by dogs, generally on the softer epiphyses of both moa and sea mammal bone. It was more common in the PWA material and on the trochleae of tarsometatarsi. A further factor recorded in the analysis was the large number of bones which had the cancellous bone exposed on the proximal and distal ends of the bones. This was possibly due to pedestrian traffic across the site which acted to cause the flaking off of the thin cortical layers especially from the edges of the proximal and distal articulating surfaces.

Papatowai (S184/5)

A large collection of material exists from all the excavations at Papatowai and in the current analysis it was broken down into four components — PPA was designated for all the Teviotdale and Lockerbie material housed in the Otago Museum, PPB are the bones from Hamel's excavation, PPC are a number of surface collections from the beach and river edge which Hamel undertook, and PPD is the moa bone from the Anderson/Smith 1990 excavation.

In an overall analysis, 99% of the bones are either in Stage 1 or Stage 5 of the burning scale (Table 7.34, Figures 7.45–7.47), the latter being due to the heavy, greasy black layer often recorded at this site. In the weathering analysis there are interesting results between the different species (Table 7.35) with the collection best described as being slightly weathered. Thirty five percent of the material is in Stage 1 (77% of fur seal, 29% of FS/SL, 31% of moa, and 58% of sea lion); 40% is in Stage 2 (18%, 24%, 41%, and 38% respectively); 16% in Stage 3 (5%, 35%, 16%, and 2% respectively); 6% is in Stage 4 (6% of FS/SL and 7% of moa); and 2% is in Stage 5 (6% of FS/SL, 2% of moa, and 2% of sea lion). The tables of element results (Appendix 5.16, Figures 7.48–7.50) indicate that weathering is generally more advanced in the leg elements ('F', 'LEG', 'TMT', and 'TT') although fragments of 'PELV', 'PH', 'R' and 'V' were all recorded as being just as weathered.

Table 7.34 The degrees of burning evident in the Papatowai remains.

```
|-------------------------------|-----------------------------------------|------|
|                               |                 SPECIES                 |      |
|                               |-----------------------------------------|      |
|                               |  ES  |  FS  |FS/SL |  LS  | MOA  |  SL  | ALL  |
|-------------------------------+------+------+------+------+------+------+------|
|BURNT          |               |      |      |      |      |      |      |      |
|---------------+---------------|      |      |      |      |      |      |      |
|1              |N              |     1|    32|     4|     2|   768|    24|   831|
|               |---------------+------+------+------+------+------+------+------|
|               |PCTN           |   100|    57|    24|    50|    76|    50|    73|
|---------------+---------------+------+------+------+------+------+------+------|
|2              |N              |     .|     1|     .|     .|     .|     .|     1|
|               |---------------+------+------+------+------+------+------+------|
|               |PCTN           |     .|     2|     .|     .|     .|     .|     0|
|---------------+---------------+------+------+------+------+------+------+------|
|4              |N              |     .|     .|     .|     .|     2|     .|     2|
|               |---------------+------+------+------+------+------+------+------|
|               |PCTN           |     .|     .|     .|     .|     0|     .|     0|
|---------------+---------------+------+------+------+------+------+------+------|
|5              |N              |     .|    23|    13|     2|   238|    24|   300|
|               |---------------+------+------+------+------+------+------+------|
|               |PCTN           |     .|    41|    76|    50|    24|    50|    26|
|---------------+---------------+------+------+------+------+------+------+------|
|ALL            |N              |     1|    56|    17|     4|  1008|    48|  1134|
|---------------+---------------+------+------+------+------+------+------+------|
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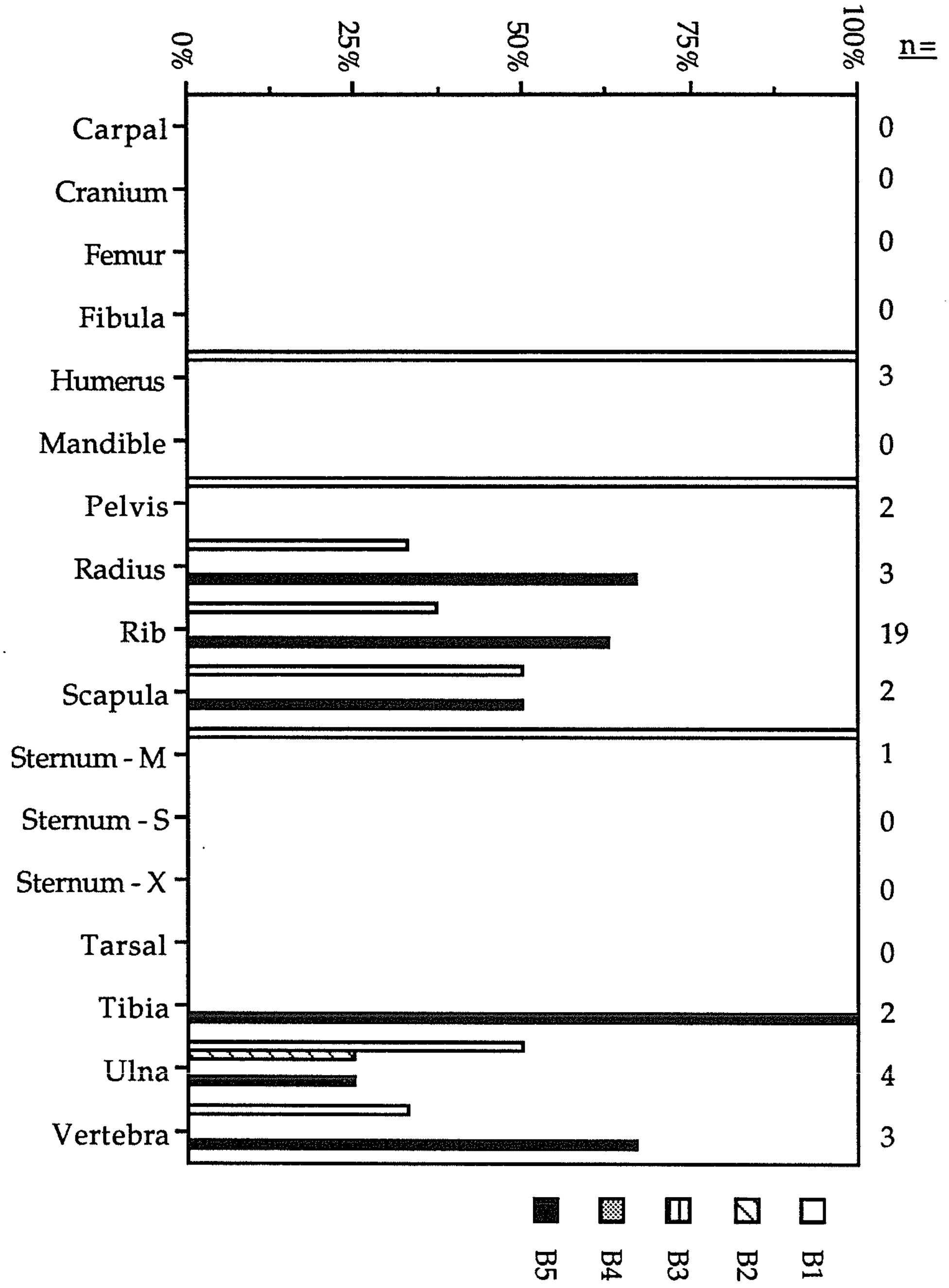

Figure 7.45 A breakdown of the burning stages recorded for each skeletal element of fur seal present at Papatowai.

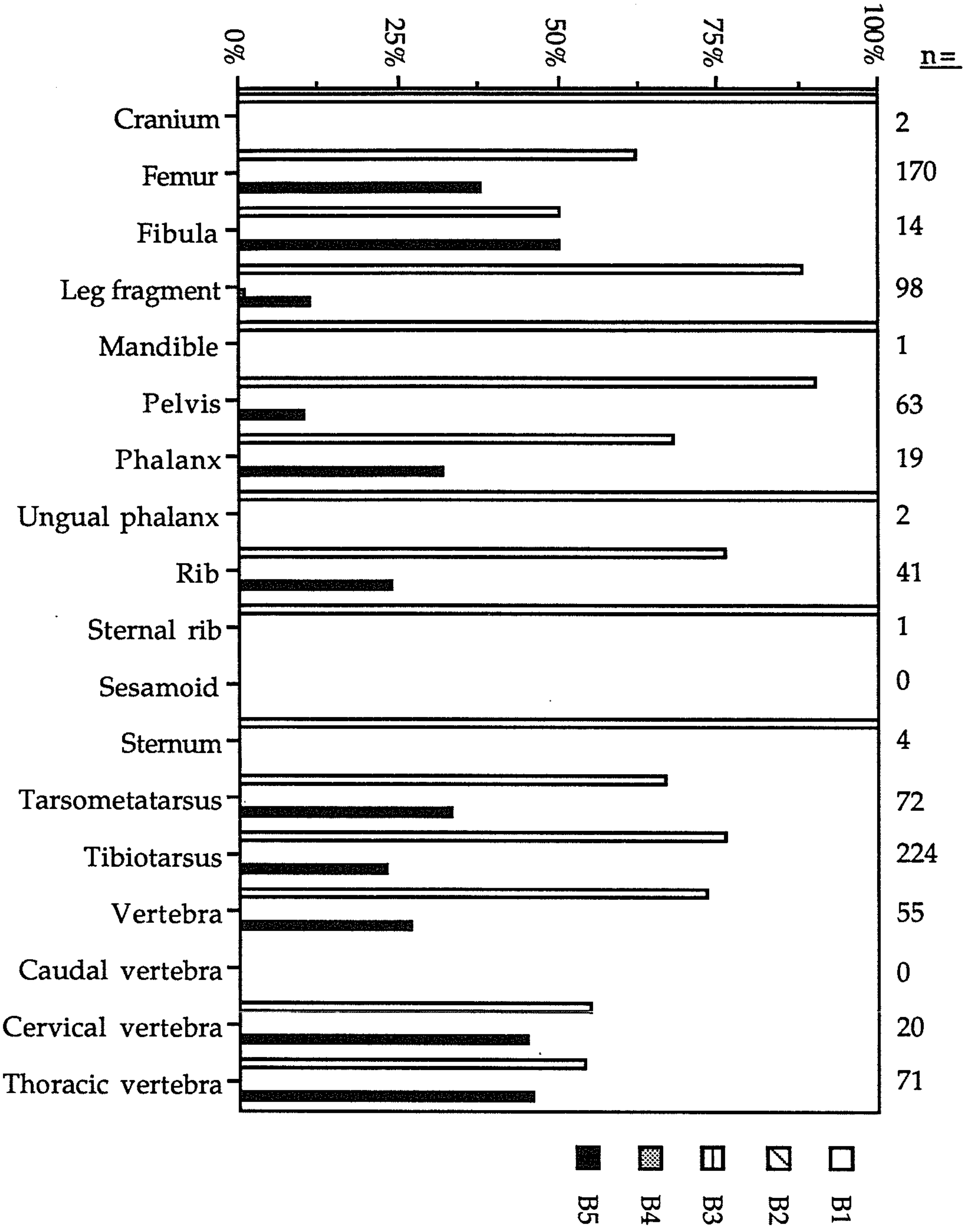

Figure 7.46 A breakdown of the burning stages recorded for each skeletal element of moa present at Papatowai.

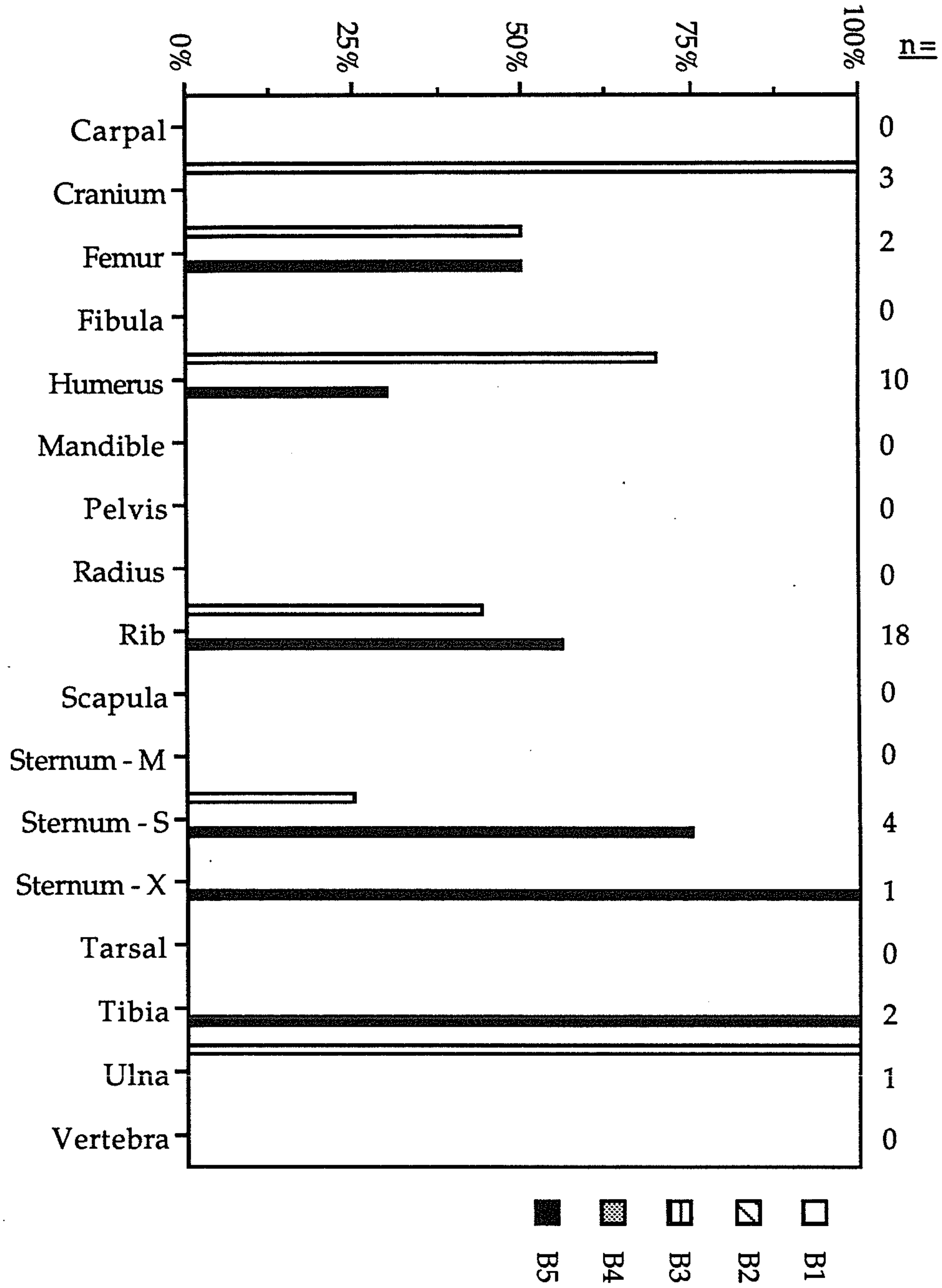

Figure 7.47 A breakdown of the burning stages recorded for each skeletal element of sea lion present at Papatowai.

At a species level, the fur seal remains have only weathered as far as Stage 3 with there being single fragments of 'RAD', 'RIB', and 'UL' at this stage. The FS/SL bones are more scattered with a fragment each of 'V' and 'V-CE' being the most weathered. The moa bones exhibit the greatest degree of variation but apart from 'PELV', 'PH' and 'R' it is the leg bones which have weathered the most.

Table 7.35 The weathering stages in the Papatowai remains.

		SPECIES						
		ES	FS	FS/SL	LS	MOA	SL	ALL
WEATHERED								
1	N	1	43	5	2	313	28	392
	PCTN	100	77	29	50	31	58	35
1*	N	.	.	.	.	3	.	3
	PCTN	.	.	.	.	0	.	0
2	N	.	10	4	2	415	18	449
	PCTN	.	18	24	50	41	38	40
2*	N	.	.	.	.	13	.	13
	PCTN	.	.	.	.	1	.	1
3	N	.	3	6	.	166	1	176
	PCTN	.	5	35	.	16	2	16
3*	N	.	.	.	.	2	.	2
	PCTN	.	.	.	.	0	.	0
4	N	.	.	1	.	72	.	73
	PCTN	.	.	6	.	7	.	6
5	N	.	.	1	.	24	1	26
	PCTN	.	.	6	.	2	2	2
ALL	N	1	56	17	4	1008	48	1134

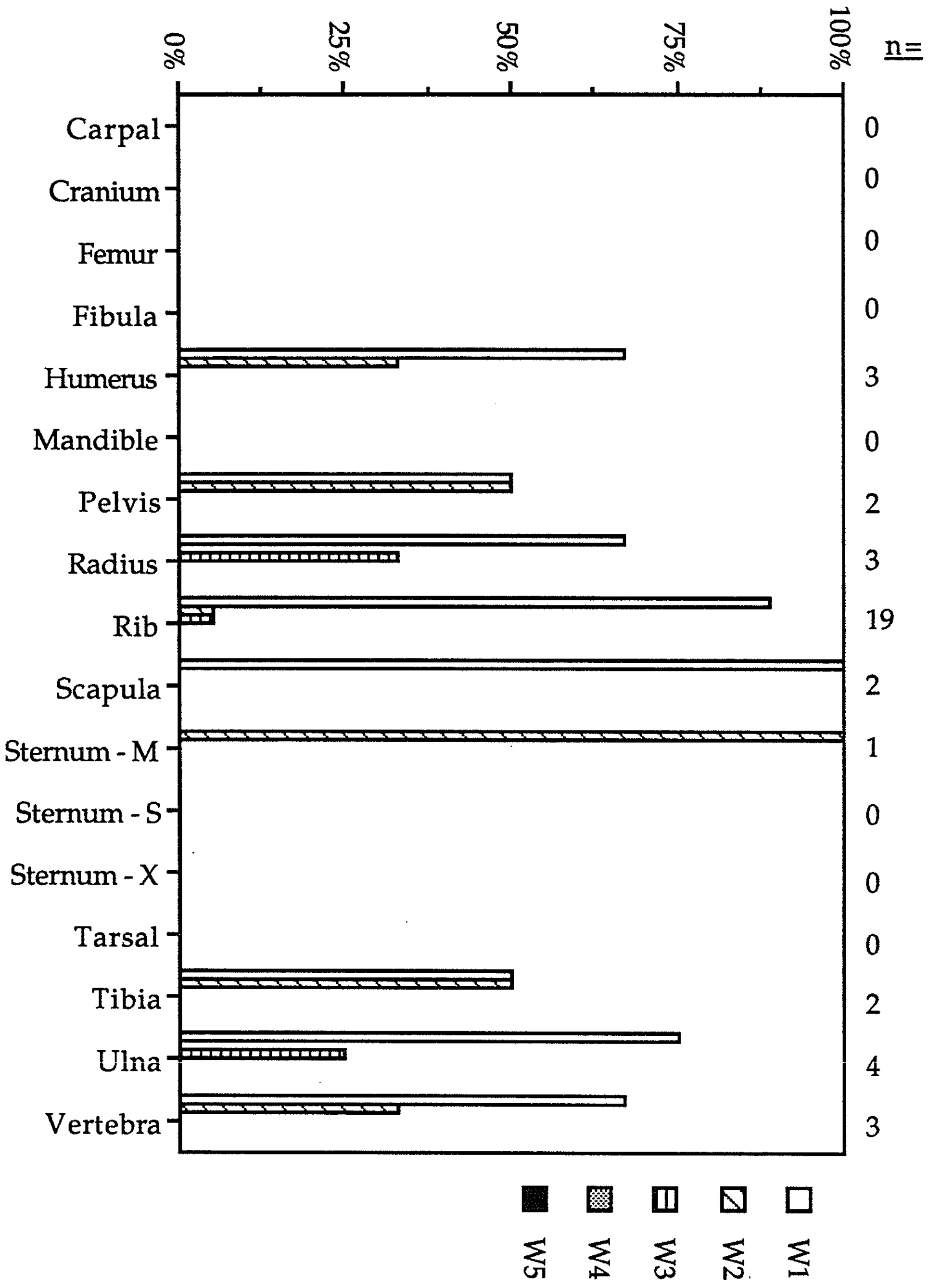

Figure 7.48 A breakdown of the weathering stages recorded for each skeletal element of fur seal present at Papatowai.

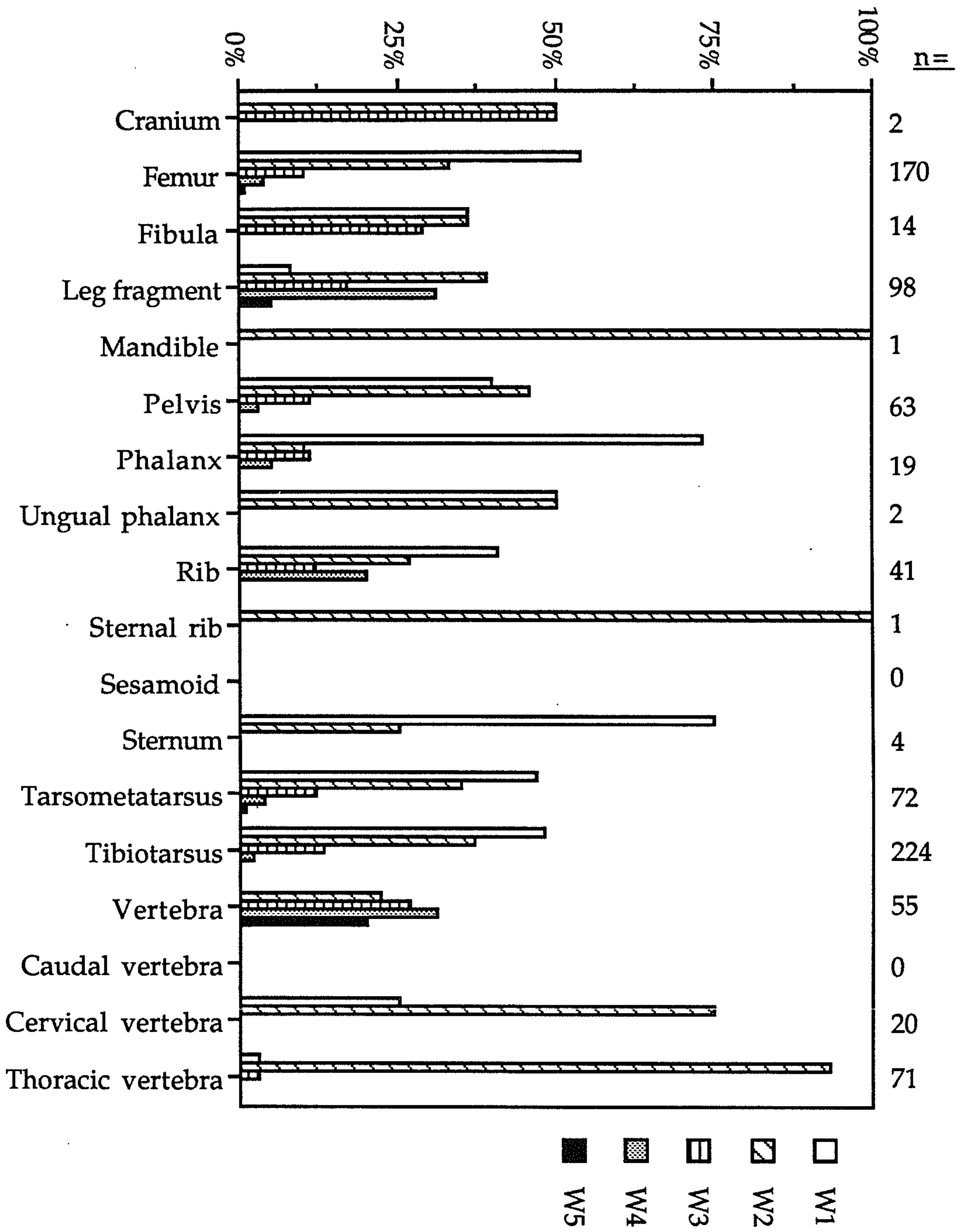

Figure 7.49 A breakdown of the weathering stages recorded for each skeletal element of moa present at Papatowai.

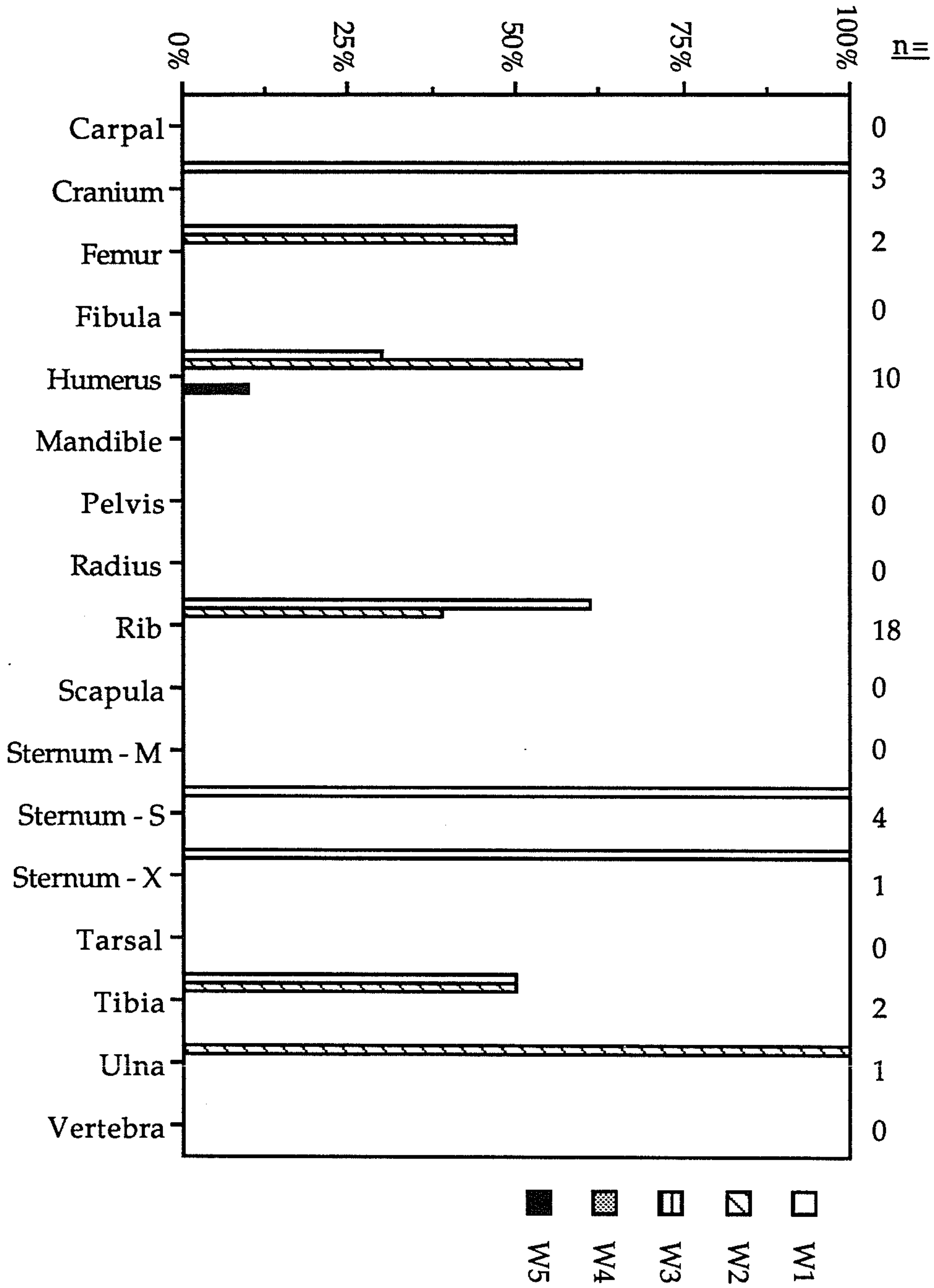

Figure 7.50 A breakdown of the weathering stages recorded for each skeletal element of sea lion present at Papatowai.

The biggest variation to this is the 'V' fragments — 22% in Stage 2, 27% in Stage 3, 31% in Stage 4, and 20% in Stage 5. While this can be explained as a simple difference in rates of weathering experienced by cancellous bone elements versus cortical bone, the fact that the 'CR', 'PELV', 'R' and 'ST' fragments are not as weathered makes it difficult to sustain.

The PPA collection is comprised of 96% moa bone along with a few pieces of fur seal and sea lion bone. The bone is all unburned and exhibits a similar weathering distribution to the whole collection — 52% in Stage 1, 37% in Stage 2, 8% in Stage 3, and 2% in Stage 4. This compares with the PPB material, which contains a greater proportion of sea mammal bone, where there is 31% in Stage 1, 32% in Stage 2, 10% in Stage 3, 18% in Stage 4, and 8% in Stage 5.

The PPC collection of surface collected material, contains some bleached bones, but in general the weathering pattern is very similar to that described for the two previous collections: 30% in Stage 1, 45% in Stage 2, 22% in Stage 3, 2% in Stage 4, and only 1% in Stage 5. The PPD bones show a shift to moderately weathered bones — 4% in Stage 1, 50% in Stage 2, 38% in Stage 3, and 2% in Stage 4. The exact reason for this shift in weathering is not immediately clear.

An interesting feature of the long-bones from the PPA collection is that most exhibit wear on the edges of either, or both, the proximal or distal ends whereby the thin cover of cortical bone has flaked off to reveal the underlying cancellous bone. A lot of the moa fragments from the PPB collection have a very grainy surface which is not a Stage 5 weathering in itself, but possibly shows that something is perhaps happening in the soil matrix. A second note regarding the PPB material is that there was a lot of very small and fragmentary material, especially from TT1/A4 which was not analysed for this study. One proximal R femur exhibited a burning gradient across the ventral lateral surface, running in a band on an angle from the lateral surface to the ventral face of the ball joint, which passes through burning stages 1–3.

In the PPC bones are a number which must have lain exposed on the ground surface for a period of time.They have not been bleached by the elements, rather they have grown a mossy cover which often obscures what is happening to the bone, although most of this material had not passed from weathering Stage 4.

Tiwai Point (S181/16)

An interesting factor of the large fauna collection from Tiwai Point is that although it is practically all unburnt (Table 7.36), 45% of the collection is in Stage 5 where it is stained black through contact with the black, greasy soil matrix. In the fur seal bones 31% are in Stage 1, 11% are burnt white/grey (Stage 4) and 57% are in Stage 5. The moa bone is 91% unburnt or stained, 2% is charred (Stage 2), and 6% is heavily burnt to Stage 4. The sea lion bone is 78% unburnt or stained and 22% burnt white/grey. Given that 45% of the collection is in Stage 1, and 45% in Stage 2, with most of the remainder in Stage 4, a study of burning patterns (Appendix 5.17, Figures 7.51–7.53) shows a similar distribution, irrespective of element type. Thus, disposal of all elements was of a similar nature.

The collection is moderately weathered (Table 7.37) — 19% in Stage 1 (32% of fur seal, 14% of moa, 9% of sea lion); 45% in Stage 2 (40%, 48% and 34% respectively); and 7% in Stage 4 (9%, 6% and 6% respectively). As with the burning, there is no difference between elements as to how weathered they have become — all are represented to Stage 3, and most to Stage 4 (Appendix 5.17). Although there are no 'CR' fragments present, 'PELV', 'ST', and the various classes of vertebrae are all weathered to the same extent as the leg elements 'FEM', 'HUM', 'TIB', 'TMT', and 'TT' (Figures 7.54–7.57).

Table 7.36 The degrees of burning evident in the Tiwai Point remains.

		SPECIES				
		ES	FS	MOA	SL	ALL
BURNT						
1	N	.	73	321	7	401
	PCTN	.	31	51	22	45
1-2	N	.	2	.	.	2
	PCTN	.	1	.	.	0
2	N	.	1	15	.	16
	PCTN	.	0	2	.	2
3	N	.	2	1	.	3
	PCTN	.	1	0	.	0
4	N	.	25	38	7	70
	PCTN	.	11	6	22	8
5	N	1	135	255	18	409
	PCTN	100	57	40	56	45
ALL	N	1	238	630	32	901

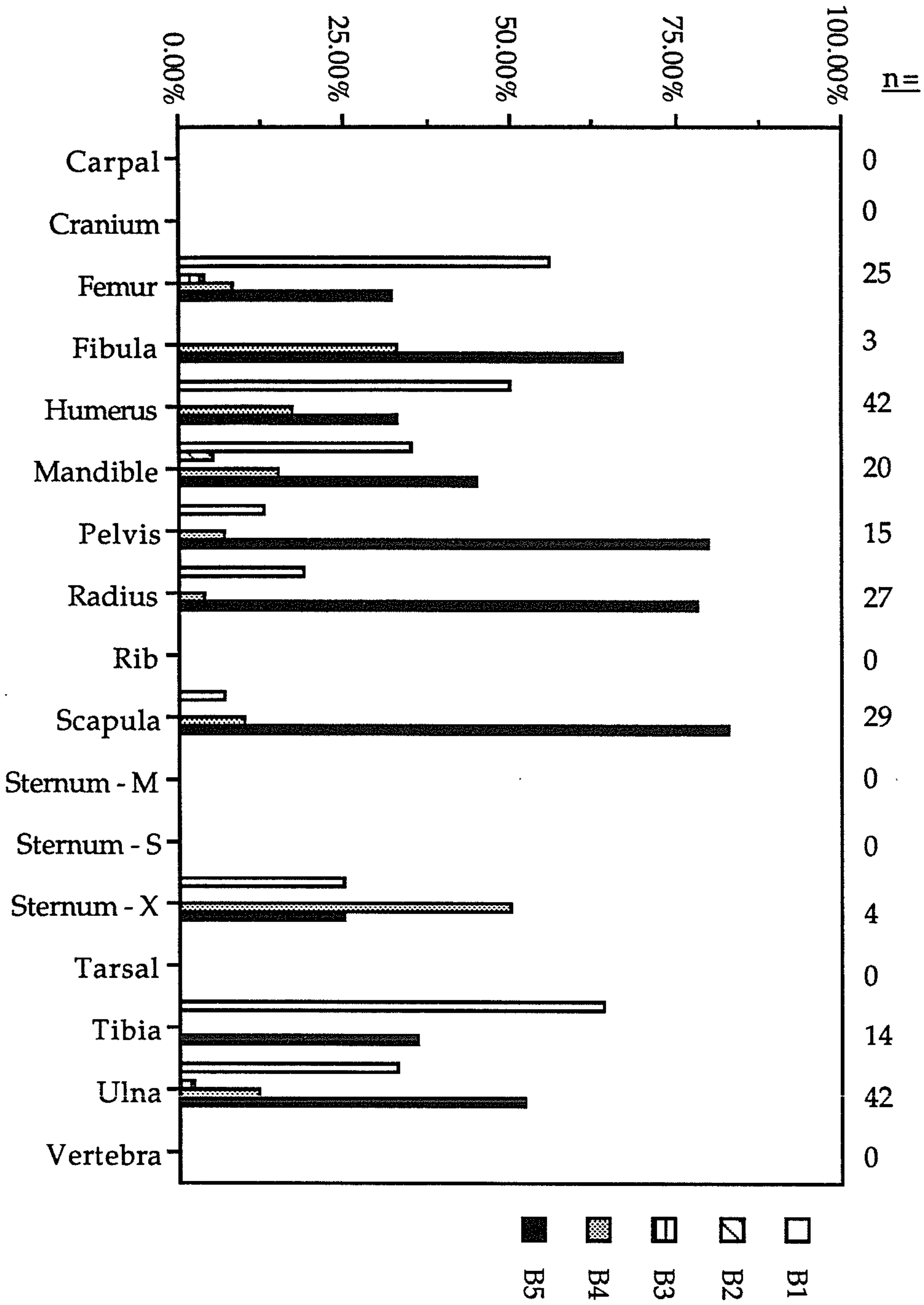

Figure 7.51 A breakdown of the burning stages recorded for each skeletal element of fur seal present at Tiwai Point.

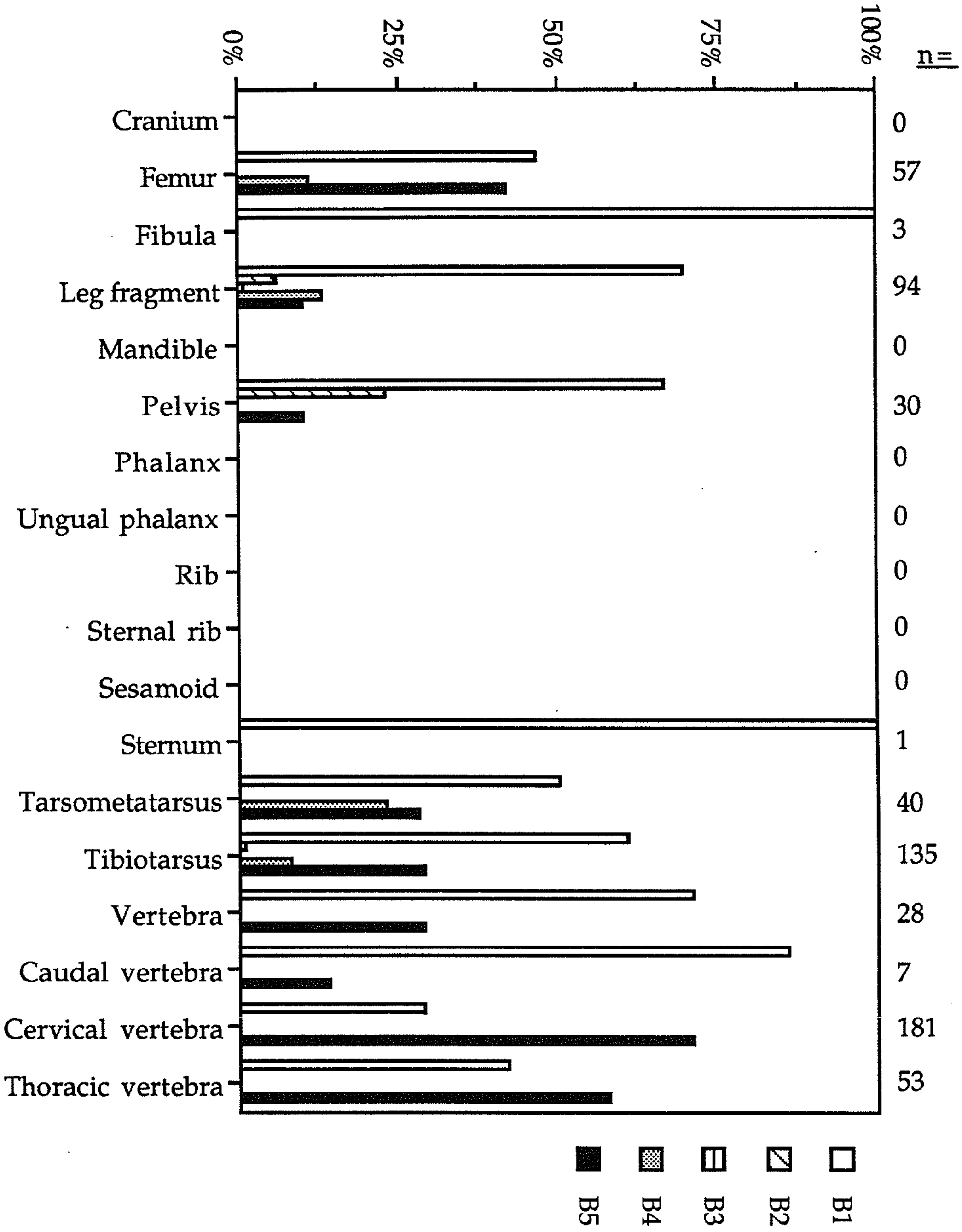

Figure 7.52 A breakdown of the burning stages recorded for each skeletal element of moa present at Tiwai Point.

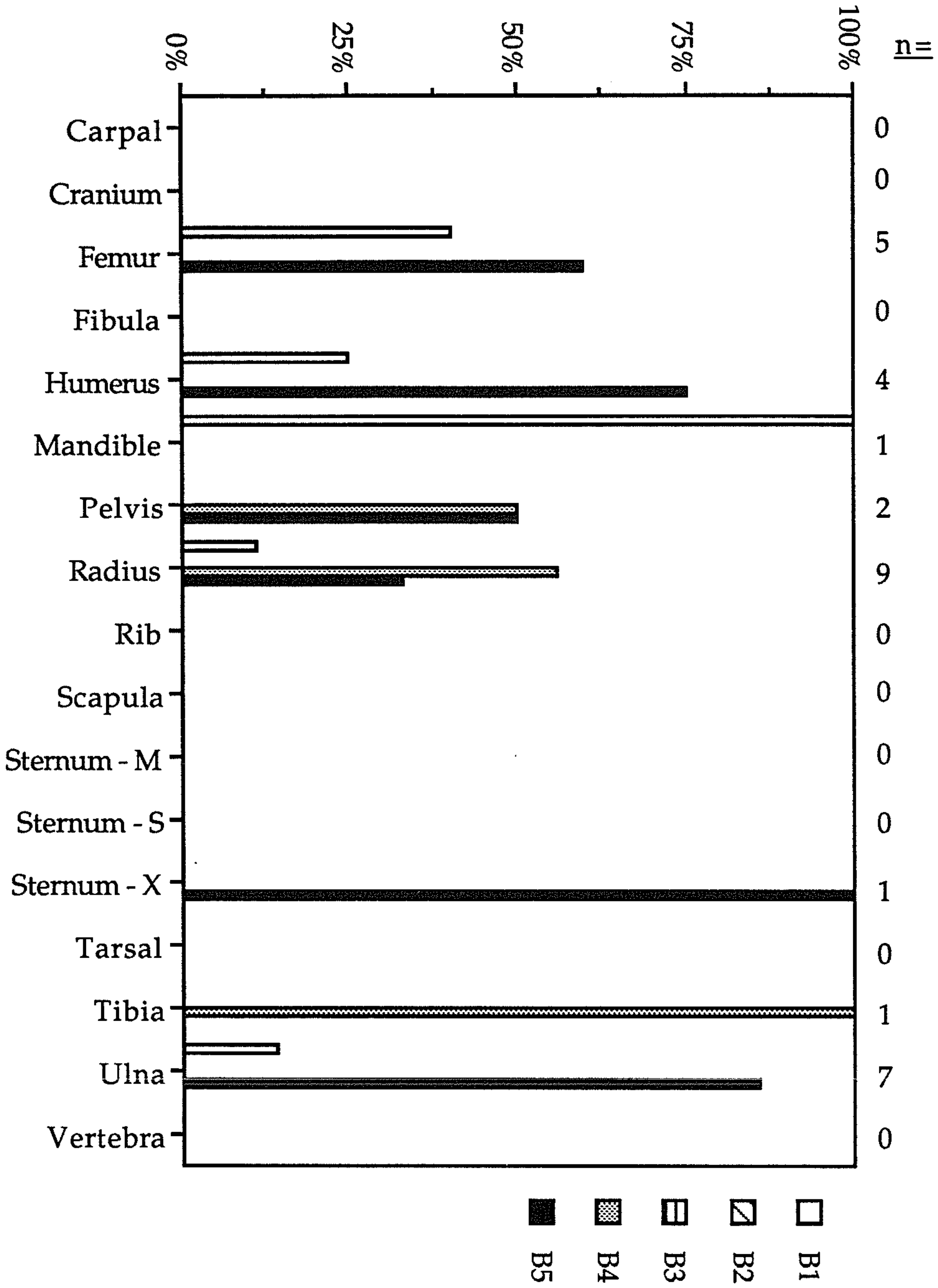

Figure 7.53 A breakdown of the burning stages recorded for each skeletal element of sea lion present at Tiwai Point.

Table 7.37 The weathering stages evident in the Tiwai Point remains.

		SPECIES				
		ES	FS	MOA	SL	ALL
WEATHERED						
1	N	.	76	90	3	169
	PCTN	.	32	14	9	19
2	N	.	95	301	11	407
	PCTN	.	40	48	34	45
2-3	N	.	.	25	.	25
	PCTN	.	.	4	.	3
3	N	1	44	178	15	238
	PCTN	100	18	28	47	26
4	N	.	22	35	2	59
	PCTN	.	9	6	6	7
5	N	.	1	1	1	3
	PCTN	.	0	0	3	0
ALL	N	1	238	630	32	901

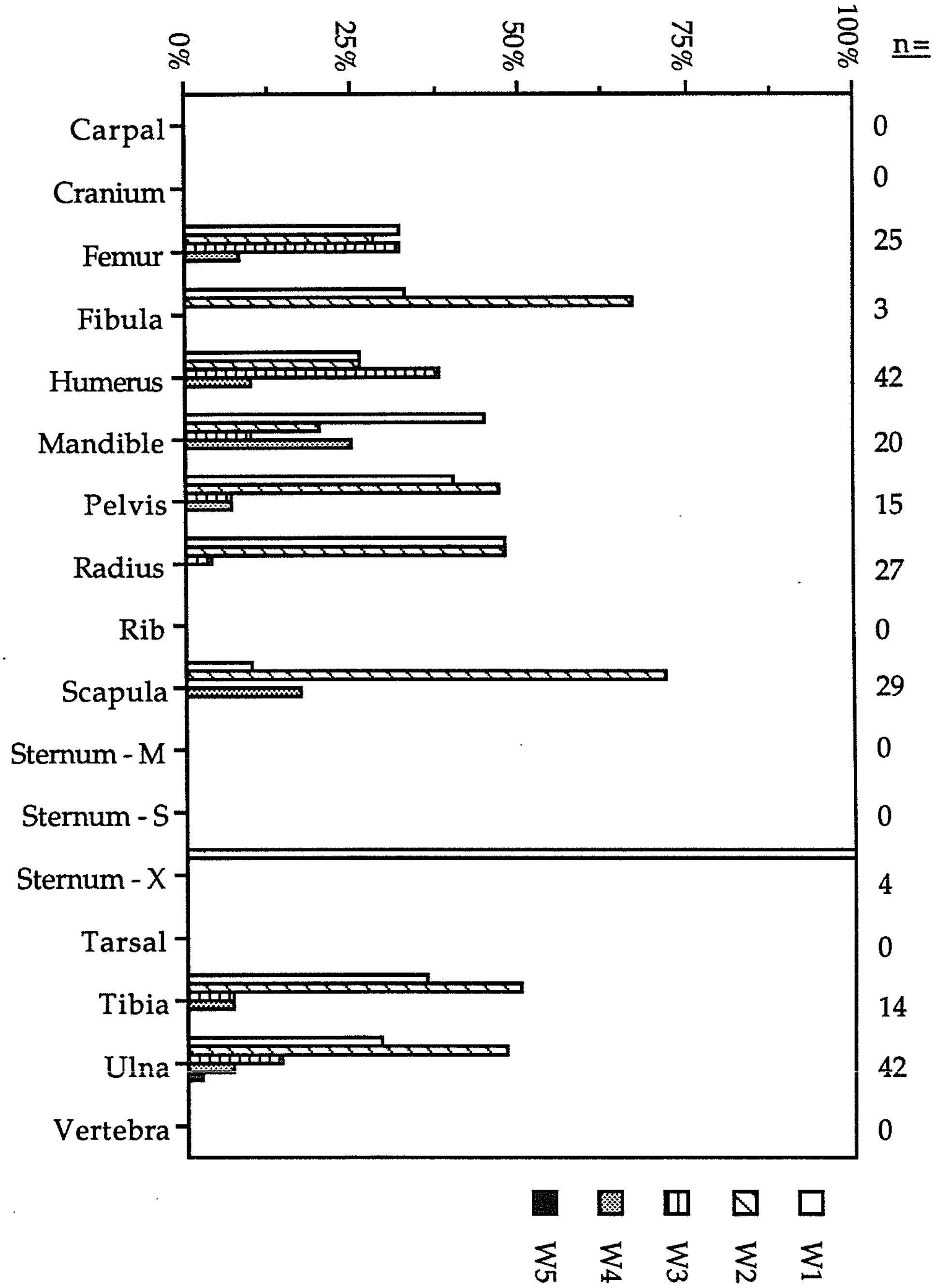

Figure 7.54 A breakdown of the weathering stages recorded for each skeletal element of fur seal present at Tiwai Point.

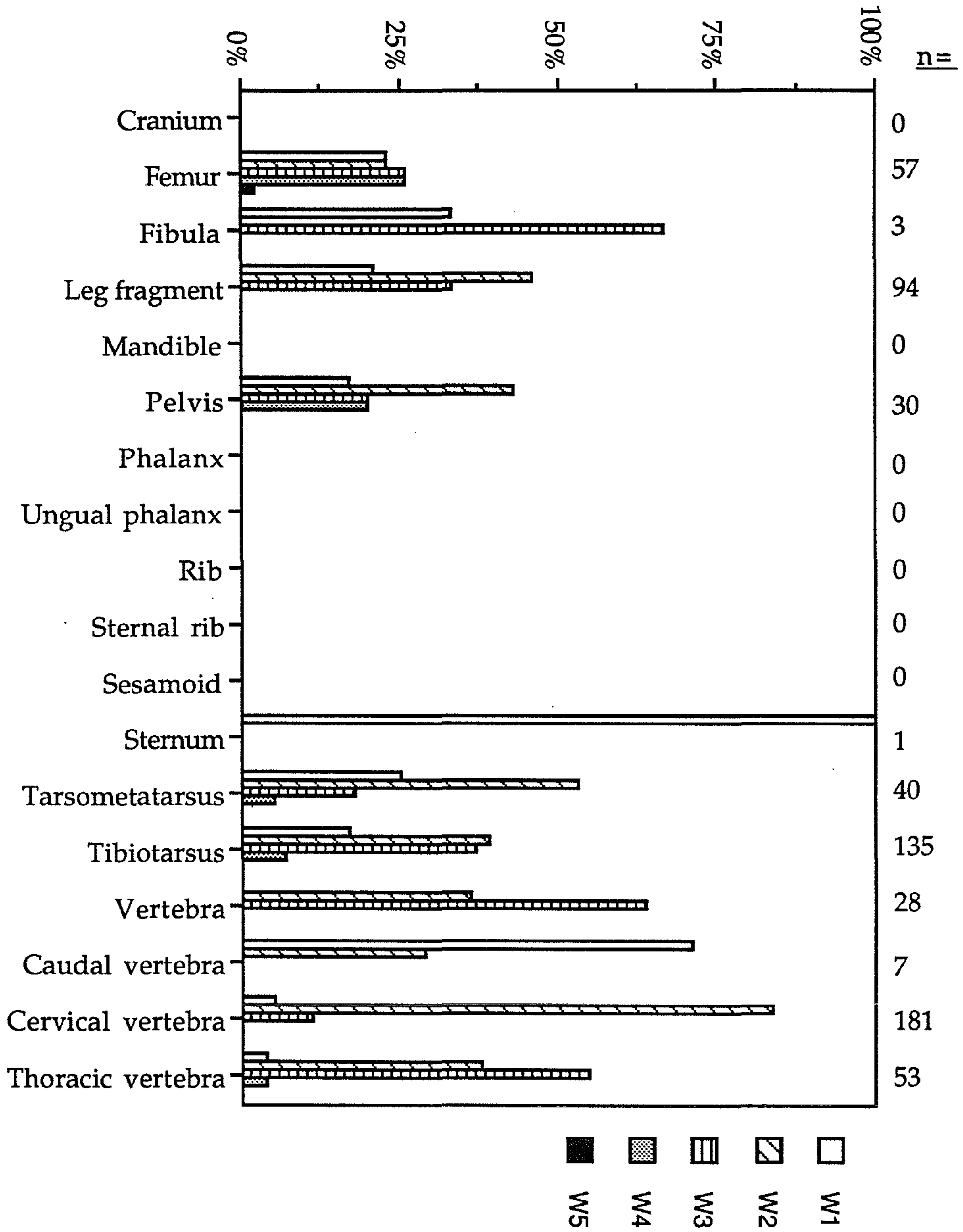

Figure 7.55 A breakdown of the weathering stages recorded for each skeletal element of moa present at Tiwai Point.

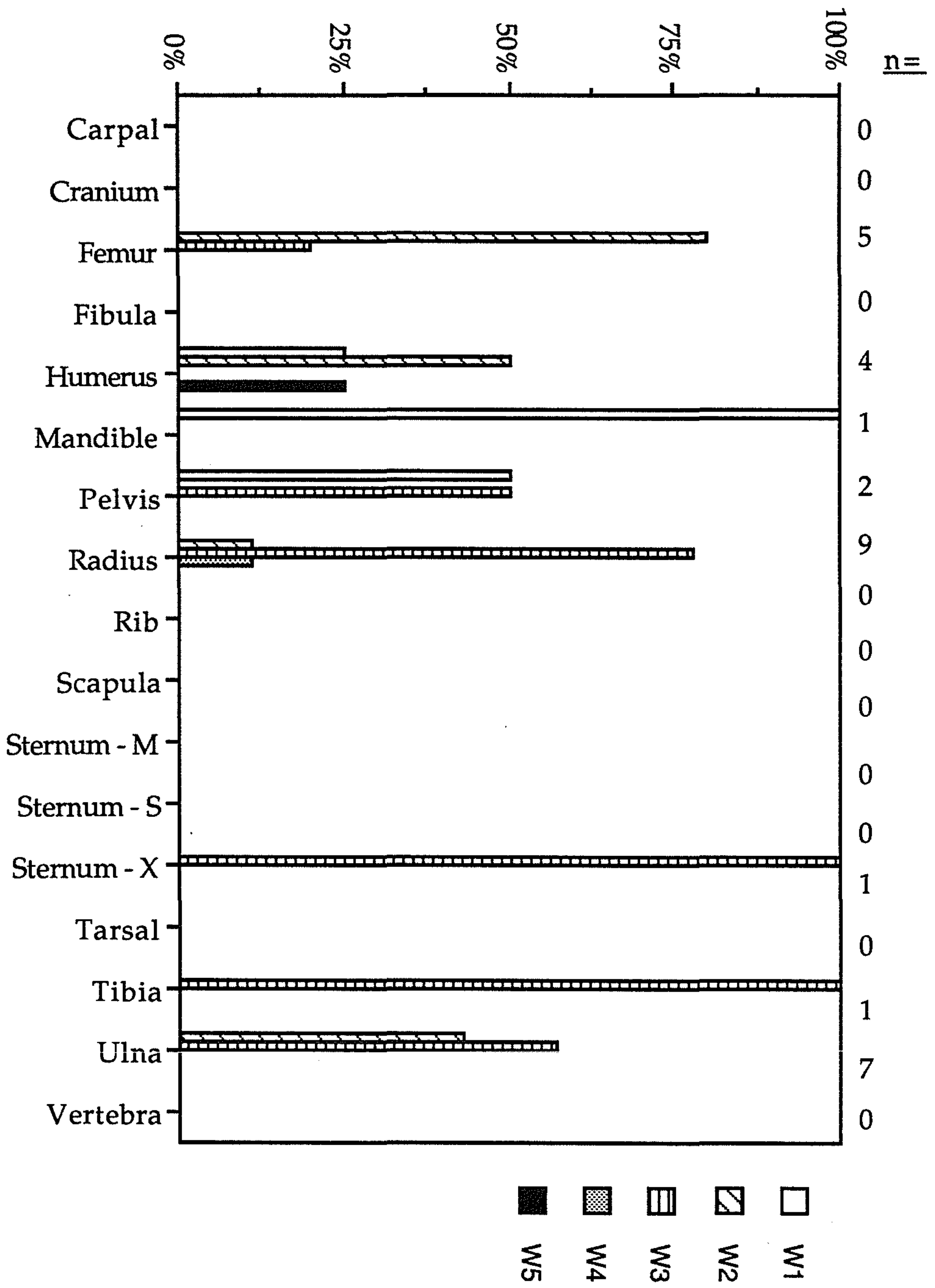

Figure 7.56 A breakdown of the weathering stages recorded for each skeletal element of sea lion present at Tiwai Point.

Figure 7.57 Examples of bone weathering in fur seal bone from Tiwai Point.

DISCUSSION

This analysis of the bone remains from a series of big-game hunting sites in New Zealand, from a taphonomic viewpoint, has reduced them all to a common denominator (the burning and weathering status of the bone remains) so allowing a closer inter- and intra-site comparison of the remains and their relationship to the archaeological landscape. In general, the bones were in a slight to moderate weathering stage (Stages 2–3) and unburnt (Stage 1) with some individual variation. The meaning of these results and a discussion of their taphonomic significance in relation to big-game hunting in New Zealand will be covered in Chapter 8 when I will attempt to answer the questions posed in Chapter 1, in particular whether the taphonomic re-analysis of these collections of big-game fauna has altered the original interpretation of the prehistory of the sites and our interpretation of big-game hunting in New Zealand.

Chapter 8.

Taphonomy of New Zealand's big-game hunting — conclusions.

TAPHONOMY — A NEGLECTED SCIENCE IN NEW ZEALAND'S ARCHAEOLOGY

This thesis set out to examine patterns of bone remains in New Zealand archaeological sites, and the origins of those patterns, from a taphonomic viewpoint. Taphonomy, as a subdiscipline within archaeology, focuses on the events that impact upon bone remains, in the time between an animal's death and the point of analysis, and the effects of these events on the retrieval of information about the past. In spite of the importance of taphonomy to a fuller understanding of bone deposition, and the variables that affect that deposition, there has been relatively little undertaken in this field in New Zealand, to date.

The differential representation of bone elements in archaeological assemblages can be attributed to one, or more, of three factors — cultural practices, natural modification, or carnivore attrition. The range of cultural modifications are the most significant alterations that bone in archaeological assemblages has experienced. These reflect human interactions with the animals and determine what is returned to the site. Thus hunting strategies, butchery practices, the use of animal remains for industrial purposes and site processes all combine to have a significant impact on bone representation in sites. Natural processes have in the past been the least studied, in New Zealand archaeology, and certainly the most under-rated factors, but the importance of subsurface weathering, trampling and geological action may well have played an important role in bone survival and, consequently, element representation within the assemblages. While the effect of dog attrition on New Zealand fauna has never been fully investigated, there have been few examples of bones exhibiting dog gnawing recorded in archaeological sites, and studies of canine dental morphology suggest the possibility that dogs, especially in the South Island, may have had a diet containing resistant material such as the bones of large fauna.

This is not to say that taphonomy has been totally ignored in New Zealand. Sewell (1984) and Nichol (1990) undertook taphonomic analyses as a smaller function within large-scale projects, while Taylor's (1984) analysis of the mammalian fauna from Twilight Beach was the first significant project to adopt a taphonomic perspective in studying an archaeological assemblage. While he did study the effect of weathering (in passing), his primary focus was upon body part representation, age-profiles exhibited by the remains, and animal attrition. Taylor's lead in tackling the taphonomy of big-game hunting sites was not followed, however, until this project began.

There were two taxa of big-game in New Zealand when Polynesians arrived which were quickly adapted to their traditional hunting strategies — the moas and various classes of sea mammal. To date, the major analyses undertaken on the role of New Zealand's big-game fauna within Maori economics (e.g Smith's (1985) work on the sea mammals and Kooyman's (1985) and Anderson's (1982, 1984, 1989a) studies of moa-hunting) have concentrated on the cultural aspects, assuming *a priori* that the representation of these remains within archaeological sites was probably the result of cultural practices.

Anderson (1989a:112) highlighted one of the outstanding short-comings of such analyses of big-game hunting in New Zealand when he stated "we hardly know anything about the range of appearance or any other qualities to be expected in moa bone subjected to a variety of exposure lengths in the highly diverse weathering conditions presented by New Zealand's soils and climates". The appearance of long-bone fragments in an archaeological context is not necessarily due to cultural selection, because these are the very bones that are least vulnerable to likely taphonomic effects such as weathering, gnawing, trampling and so on.

It was felt that these factors represented the source of greatest potential for understanding the archaeology of New Zealand's big-game hunting and until such time as we fully understood the natural processes which impact upon faunal remains in New Zealand sites, we could not confidently state that these remains solely represented the practices of the Maori in big-game hunting and processing.

This thesis, therefore, has examined the effect of subsurface weathering on bone survival in archaeological sites and, in particular, questioned whether differential element representation was the result of natural or cultural processes. The null hypothesis for this research (H_O) can be stated as — There are no significant differences in the weathering of bone in archaeological sites in New Zealand; while the alternative hypothesis (H_A) would be that — There are differences in the weathering of bone from archaeological sites and these are due to agents such as climatic variation, freeze-thaw cycles, and soil chemistry.

WEATHERING AND BONE SURVIVAL IN NEW ZEALAND ARCHAEOLOGICAL SITES

Previous analyses of bone weathering have been undertaken in regions of the world (e.g. equatorial Africa, the central plains of North America, and Greenland) whose environmental conditions are very different from the high latitude temperate zone in which New Zealand is situated. These analyses have shown that bone fragments, exposed on the ground surface, weather at rates dependent upon climatic and environmental factors such as: the amount of sunshine, temperature variations, rainfall levels, and the degree of shade available. Although initially developed as a means of determining the elapsed time since the death of an animal (Behrensmeyer 1978), the method of describing weathering has also been adopted as a means of describing the length of time bones lay exposed on the ground surface prior to burial within a soil matrix (e.g. Todd et al. 1987, Kooyman 1990). These last two studies stopped short of applying a weathering analysis to describe the condition of bones recovered in excavations which is what I have done in this thesis, where I consider exposure on the ground surface and burial within a soil matrix as simply two points on a continuum within the 'accumulation history' (Lyman and Fox 1989).

To overcome the environmental differences, and to establish a baseline for understanding subsurface bone weathering in New Zealand archaeological sites, I conducted a series of experiments to examine the effects of the New Zealand environment on bone survival. Five different soil matrices were established in which cattle bones (a modern analogy to the extinct moa) were buried for a period of three years to allow for the initiation of weathering and to give possible indications of the direction it takes. Climatic records for the Dunedin area were kept during the course of the experiment so that trends in weather patterns, in particular the temperature and amount of rainfall, could be closely followed. Soil samples were taken for analysis at the beginning of the experiment so as to characterise the chemistry of the matrices in which the bones were buried.

At the end of the three year period the bones were exhumed and carefully examined for evidence of weathering. A series of soil samples was collected for comparison with the chemistry prior to the introduction of the bones into the matrices. The experiments showed that subsurface weathering is initiated almost immediately the bones are deposited and the time lag between deposition and initiation of the weathering cycle will be dependent upon the amount of soft tissue present. If it is assumed that archaeological remains are similar to the experimental sample, i.e. all the usable soft tissue has been removed (meat, tendons etc.), then subsurface weathering will proceed almost immediately.

On the basis of changes observed during the period of this experiment, it is possible to suggest the course that the bone weathering undergoes. The first stage is the breakdown of any remaining soft tissue by micro-organisms in the soil which leads to disarticulation of the elements and opens the bone surface up to further attack by the micro-organisms and to chemical change from the matrix in which it is buried. The second stage is the physical breakdown of the bone itself — as the outer structure cracks it exposes both the inner surface of the cortical bone, and the cancellous bone of the epiphyses, ribs, vertebrae etc., to further microbial and chemical attack. The chemical composition of the bone undergoes change as ions leach along a gradient both into, and out of, the bone from the immediately surrounding soil matrix.

The rate of decay of the bones is governed by three principal factors — moisture levels, temperature, and pH of the soil matrix. Subsurface weathering is likely to be slowest in a matrix which has a relatively neutral pH, is free-draining (and therefore has a low moisture content) and is at a low temperature. The rate of decay is greatest when the converse of these three variables is realised. If long term weather patterns were observed in close conjunction with weathering patterns (at a microscopic level) it is anticipated that the rate of decay would increase and decrease to match the coincidence of higher temperature levels and high moisture content of the soil.

Bones which lie exposed on the ground surface will undergo a faster rate of weathering, as Behrensmeyer (1978) demonstrated for material in East Africa. My experiment showed that within three years from the time of deposition the soft tissue was drying and peeling back, and the exposed bone had cracked. This, in turn, allowed the weather into the internal structure of the bone and hastened the decay rate. These results are very similar to the rate of weathering recorded in the Amboseli Basin for the first few years after a bone is discarded, in spite of the environmental and climatic differences experienced between study areas at 2° and 46° S respectively. In the longer term, comparisons are not available because of the nature of the time constraints of the experiments I ran. I envisage, however, a divergence over time in the rates of weathering, for the Amboseli and New Zealand bone samples, with the Amboseli material continuing to weather faster because of the primary effect of an increased temperature. An increase in temperature of 10°C leads to a doubling of the decay rate (Henderson 1987).

The decay rate for the bones in my experiments is also similar to that recorded by Miller (1975) in southern California, and it strongly suggests a universality in the rate of bone weathering in the initial 3–5 years of a bone's 'depositional history' (Lyman and Fox 1989) with bones from many different environmental regimes exhibiting a very similar pattern of breakdown in that initial phase. After this time there would probably be a divergence of these rates of decay as local soil and climatic variables played a greater role in determining the long-term survival of bones.

Experiments into the effects of freeze-thaw cycles on bone survival showed that within the space of 72 hours cracks were appearing in the diaphyseal bone, and within a further 72 hour period large longitudinal cracks had appeared which went through the compact cortical bone to the marrow cavity. In areas which experience considerable variation in temperature on a day-to-day and seasonal basis, cracking of the bone surface occurs relatively rapidly, within three to four days, to allow weather to penetrate to the interior of the bone.

This has important implications for bones deposited in sites located within high frost areas, such as the inland South Island basins of Central Otago and the Mackenzie Basin. Once the outer structure of the bone has cracked it allows the weathering process to proceed at a faster rate. The long term survival of the bone is subsequently greatly diminished and the likelihood of the bone surviving for hundreds of years, as bones buried within soil matrices will, becomes very remote. In the two areas mentioned above, deposition of soil occurs at an extremely slow rate and unless the bones have been discarded near a stream or river course which experiences periodic flooding, which in turn inundates surrounding low-lying land and deposits silt on the land surface, there is little possibility of their being covered in soil by any other natural process. Thus the bones would lie exposed on the ground surface until they had completely broken down and disappeared. A very good example of this type of weathering was revealed at the Glenaray site, in the upper Waikaia River, where Anderson (1989a:147-148) recorded 34 discrete patches of moa gizzard stone and very little evidence of bone material (three small middens of heavily burnt and fragmented moa bone). His contention is that in this site the bone broke down very quickly after discard on the surface of the site, until it was weathered away, or it broke down and then fragmented into dozens of small pieces of 'gravel' consistency. By comparison, the sites of Coal Creek, Hawksburn and Owen's Ferry were situated immediately beside water courses and deposits of river silt were periodically spread across the archaeological remains, through natural flood action, and these served to protect the assemblages over time.

This whole process is important to the archaeologist because it involves the complete removal of an important data set from the archaeological landscape. A common site type for many big-game hunting societies is the isolated kill site where only one or a small number of animals is killed and butchered for removal back to a larger base camp (O'Connell et al. 1992). What remains in these sites for archaeologists to recover later usually consists of a few bones, perhaps a hearth where some parts of the animal were cooked, and maybe some discarded tools. If the bones are totally disintegrating due to natural processes, such as freeze-thaw cycles, then the probability of the site being rediscovered 400 or more years later is quite remote. The probable hunting strategy employed by the Maori in moa hunting, as proposed by Kooyman (1985) and Anderson (1982b, 1983, 1989), involves mobile hunting groups ranging over a territory within the immediate vicinity of the habitation site. This type of hunting pattern, almost identical to that recorded ethnographically for the Hadza (O'Connell et al. 1992), results in a series of temporary kill sites where the preliminary butchery of moa was performed. Many of these sites will never be found by archaeologists, not only because of their small size and scattered distribution, but also because one of the more visible signs, the bone remains, do not survive to act as markers.

The results of my experimental work were applied subsequently to an archaeological case study — the Shag Mouth site. This large coastal 'village' site, occupied between 670±47 and 537±44 BP (Anderson 1991), is a typical example of a coastal South Island big-game hunting site. It is situated at the mouth of a large river, allowing access into the hinterland, and has extensive middens containing abundant remains of the big-game species — moas and seals. In studying the faunal remains from this site, and for the later re-analysis of big-game hunting sites throughout New Zealand, I was primarily interested in the following taphonomic agents: weathering (subsurface), burning, dog gnawing and the effects of soil chemistry. These were considered to be the most important agents acting upon faunal remains which would have a bearing on the long-term survival of bones in an archaeological context. A means of describing the degree of subsurface weathering evident on the archaeological faunal remains, via an ordinal scale, was established and applied to the moa bone recovered during excavations at the site in November–December 1988.

The application of this weathering scale showed that, despite initial reservations due to the inherent subjectivity of this means of describing the relative condition of bones in the site, some interesting patterns emerged. The majority of the bone remains were in an unweathered to an only slightly weathered condition (approximately 75% in weathering stages 1 and 2) and few were in advanced stages of weathering (6% in stages 4 and 5). This would tend to suggest that not only was the material not lying exposed on the ground surface for any lengthy periods of time, but the conditions within the site were very conducive for bone survival. In general, there was no difference recorded in the degree of weathering between elements traditionally recorded as being the more fragile, and the more robust elements of the leg. This would indicate that any difference in the proportions of each element recovered is not the result of taphonomic interactions, but reflect cultural practices at the site.

In an examination of the degree of burning evident in the remains, approximately three quarters of the bones were unburnt, with the remainder ranging from bones which were partially charred to those which were burnt white/grey in colour. It was also apparent from the distribution of burning that there was differential treatment of butchery units — with head and neck units, sternal units, and lower legs being discarded away from the main hearth/cooking areas. The pelvic units were evenly distributed between hearths and other areas of the site, while the main leg unit (the 'drumstick') also occurred as burnt fragments in a higher proportion than the average for the site.

There was only a single bone with evidence of dog gnawing — a distal 'TMT' of *Euryapteryx gravis* from Layer 2, along with eight fragments with rat gnawing. The 'TMT' had been chewed on the distal end of the trochleae, the softest part of the bone with a high percentage of cancellous bone.

Having established the ability of this methodology to describe the degree of weathering evident in faunal remains, it was then applied to 17 previously excavated collections of big-game fauna from around the country. The majority of the sites were visited to allow for the collection of data relevant to an understanding of the environment in which the bones had been interred — this included local geography and geology, climatic records, and soil samples for characterising the soil chemistry of the matrix.

The results of the weathering analysis of some 17,000 bone fragments from these archaeological collections exhibit some interesting patterns. Table 8.1 summarises the percentage of bones within each weathering stage for the collections, grouping all the bones together, irrespective of species and including both moas and seals, as I found that there was no significant difference between the taxa in terms of the conditions of the bones. In all cases, except for Tairua and Pounawea, moa formed the bulk of the faunal material present and trends in the distribution of weathering for individual species tended to mirror the overall trends present.

In general, the faunal material from these sites was in a slightly to moderately weathered state (Stages 2 and 3), with some exceptions. The bone collections from Cross Creek and Pounawea had a higher proportion in an unweathered state (Stage 1), 53% and 68% respectively; the sites of Opito, Whakamoenga Cave, Kaupokonui and Te Rangatapu showed a greater distribution of material across the whole range of weathering stages; and the bones from Tokoroa exhibited heavy weathering (87% of the bones were in Stage 5).

In all cases there was no difference in the degree of weathering exhibited by fragments derived from cancellous bone (e.g. cranial, pelvic and sternal fragments, ribs, and vertebrae), in comparison with the more sturdy cortical bone of the leg elements. In some instances the cancellous bone was less weathered than the bones derived from 'FEM', 'TT' and 'TMT' but it was also just as likely to be in the same weathering stage. In some sites it was found that there was a difference in weathering between the species, as discussed in Chapter 7, although in the majority of sites there was no evidence for this. This may be due, in part, to the different structure of sea mammal bone compared with that of moas. Moas have a thick cortical ring surrounding the marrow cavity of the diaphysis, while the sea mammal bone has a greater proportion of cancellous bone and a thinner outer layer of cortex.

Table 8.1 Distribution of weathering stages evident in the archaeological sites (all species grouped together).

Site	N	Weathering Stage [1]					Bleached
		1	2	3	4	5	bone [2]
Houhora [3]	1681	7	30	52	9	2	2
Port Jackson	387	9	43	41	5	2	63
Cross Creek	80	53	19	24	6	0	30
Opito	21	10	29	33	10	19	5
Tairua	197	25	44	30	1	1	1
Tokoroa	30	0	0	0	13	87	0
Whakamoenga	43	16	5	51	21	7	0
Opua	214	26	37	28	5	3	8
Kaupokonui	916	14	36	35	17	1	8
Te Rangatapu	129	22	30	22	21	5	0
Tai Rua	467	15	24	55	6	0	0
Owen's Ferry	1520	8	71	16	4	1	0
Hawksburn	2193	32	50	14	4	1	0
Coal Creek	955	21	53	19	5	1	0
Pounawea	1065	68	24	7	1	0	0
Papatowai	1134	35	41	16	6	2	2
Tiwai Point	901	19	45	29	7	0	0

Notes:
[1] Percentage of bones in each weathering stage.
[2] Expressed as a percentage of the total assemblage from the site.
[3] The multiple weathering classes identified during the analysis have been compressed for the purposes of this table.

In nearly all the sites, the bones were recovered in an unburnt state (Stage 1), with the principle exceptions being the three Central Otago sites: Coal Creek (11% burnt and 59% stained from direct contact with oven rakeout), Hawksburn (55% burnt and a further 24% stained from oven debris), and Owen's Ferry (with 63% burnt). Anderson (1982b) argued that the higher incidence of burning in interior sites, as opposed to those on the coast, was due to the 'extraction of fat from moa bone for flesh preservation' (op. cit.:56), a situation also recorded at the coastal sites of Waitaki Mouth and Rakaia Mouth, although there was less need "in coastal sites generally where fat from other sources was more readily available and where moa bone had an alternative value as raw material for fish hooks" (ibid). Kooyman (1985) argued more strongly in favour of the use of bone as a fuel for fires and ovens, and as a means of refuse disposal on sites which were being occupied for more than a few days at a time, in the inland sites.

The presence of sun-bleached bones in a collection was taken as evidence that the material had lain exposed on the surface of the site for some period of time. In only two sites — Port Jackson and Coal Creek — was there a significant amount of bones in this condition (63% and 30% respectively). In these two cases I suggest that the level of bleached bone is not due to the length of time the bone spent lying on the archaeological surface from the time the bones were discarded to the the time when they were buried within the soil matrix of the site; rather it is probably a result of the large-scale deflation of these sites due to the presence of stock movement across their surfaces. In the case of the two South Taranaki sites of Opua and Kaupokonui, with 8% of their collections in a bleached condition, their situation on a coast exposed to, at times, very strong westerly wind streams probably indicates that they were buried within a very mobile matrix material which often shifted to expose bones on the surface. This occurred at regular intervals at Kaupokonui during the 1970's and early 1980's until a dune stabilisation programme was instituted (Roger Fyfe pers.comm. 1990).

There was very little evidence of dog gnawing in the collections I examined (Table 8.2). Five sites had dog gnawed material in them, and it was only at Pounawea and Papatowai that it occurred in any numbers, although not a significant portion of the assemblage. In almost all cases the gnawing was on the soft cancellous bone of the epiphyses — at Whakamoenga it was a single moa bone; at Kaupokonui a fragment of sea lion; the collection from Pounawea comprised five fur seal, 10 moa, 14 'SEA MAM', and one sea lion bone; at Papatowai 13 moa, five fur seal and one sea lion; while, finally, at Tiwai Point, were three fur seal bones. The prevalence of seal bones in this list of gnawed material may be due to the fact that most moa bone is from adult individuals whereas the seals tend to be juvenile or subadult, where the epiphyses have yet to fuse and the soft cancellous tissue is easier to chew.

Table 8.2 The degree of dog gnawing in the faunal collections.

Site[1]	Number[2]	% of total NISP
Whakamoenga Cave	1/43	2.0
Kaupokonui	1/916	0.11
Pounawea	30/1067	3.0
Papatowai	20/1137	2.0
Tiwai Point	3/901	0.33

Notes: [1] In the remaining sites there was no evidence of dog gnawing present in the faunal collections.

[2] Number expressed as the number of gnawed fragments out of the total collection for that site.

The effect that soil conditions have on archaeological remains has never been fully examined in the New Zealand situation. A consideration of the soil analyses for the sites in this study, indicates that the long-term effects of New Zealand soils on bone survival may not be as serious as was first thought. Nearly all the sites in this study have a pH that is near neutral to moderately alkaline, and relatively low moisture and organic levels, so providing a conducive environment for bone survival. Even the quite acidic conditions of the Coal Creek matrix have not significantly shifted the weathering to higher stages.

The only exception in all this discussion is the material from Tokoroa. This site has a soil pH in the strongly acidic range, accompanied by high levels of soil moisture and organic content (in comparison with the other soil samples), and I suggest that there is a strong correlation between the soil chemistry and the fact that 87% of bone fragments recovered in the site exhibit Stage 5 weathering. The bone remains were very fragmentary to the touch during the analysis and the total lack of any cancellous bone fragments in the archaeological collection (all the fragments were from leg elements) suggests one of two possible scenarios for the element representation: (1) moa were being killed and butchered elsewhere, and only the legs returned to the site; and (2) the cancellous bones were also returned to the site, and discarded, but have not survived the ravages of time in such a hostile burial matrix. I prefer the latter explanation.

We know from the presence of moa bone at Tokoroa and Whakamoenga Cave that moa had reinhabited this area of the North Island, subsequent to the Taupo eruption, and were being hunted by the Maori. The reason so few archaeological sites have been recorded in this area, however, is not because people were not inhabiting the region, but rather that the bones have not survived to the modern day.

At the start of Chapter 6, it was proposed to investigate the variations in weathering that may exist between groups of sites — such as North Island versus South Island, inland versus coastal, and those in a sand matrix versus those in a soil matrix. The sites conveniently fall into four main geographically distributed groups — northern North Island (Houhora, Port Jackson, Cross Creek, Opito, and Tairua), south Taranaki (Opua, Kaupokonui, and Ohawe/Te Rangatapu), the south east coast of the South Island (Tai Rua, Pounawea, Papatowai, and Tiwai Point), and inland Otago (Coal Creek, Hawksburn, and Owen's Ferry) — but there is such variation in the results from all the sites it becomes very difficult to make any valid intra-group, or even inter-group, comparisons. For example, in the northern North Island group, Houhora and Port Jackson show close similarities in their weathering patterns, apart from the large amount of bleached bone present in the latter site. Cross Creek has a large proportion of unweathered (but also bleached) material, while the Tairua collection falls somewhat between

Cross Creek and Port Jackson, and the Opito material is distributed across all the weathering stages with 19% in an advanced state. The reason for this amount of material in Stage 5 at Opito is not immediately clear, and is certainly not due to the soil matrix, but it is possibly due to the bones having lain exposed on the ground surface for several years prior to burial, although the possibility of this occurring in the highly mobile sand-dune environment is not great.

The three sites in the south Taranaki group are much closer in similarity, although there is less bone in Stage 4 at Opua than there is in the other two sites (Kaupokonui and Ohawe/Te Rangatapu). The remaining two groups of sites (south east coastal South Island and inland Otago) show a surprising degree of variability, although Hawksburn and Coal Creek show similar trends in the slightly weathered state.

Further comparisons along the lines of coastal sites versus inland sites, or material recovered from a soil matrix versus those recovered from sand, or between species of big-game also fail to show any difference in the condition of the faunal collections which can be attributed to subsurface weathering and soil conditions. However, my research suggests a broad division can be drawn between areas where the effects of weathering are of little significance, and those which probably experience high levels of weathering from either freeze-thaw or chemical weathering (Figure 8.1). From my knowledge of the process of weathering, I speculate that the west coast of the South Island will be a region similar to the Volcanic Plateau where weathering will be very advanced, due to the high rainfall levels and the acidic podzol substrate.

Behrensmeyer (1978) showed that a correlation between weathering and time does exist in the short-term, taking into account the arguments of Lyman and Fox (1989), but is there any such correlation over archaeological time spans of several hundred years? Using the radiocarbon dates given in Chapter 6, I examined two groups of sites to determine whether any difference existed over time. The group of younger sites (Port Jackson, Tairua, Kaupokonui, Tai Rua) all exhibit a similar distribution of weathering (Table 8.1) but are no less weathered than the older sites (Houhora, Hawksburn, Pounawea, and Papatowai). In fact,

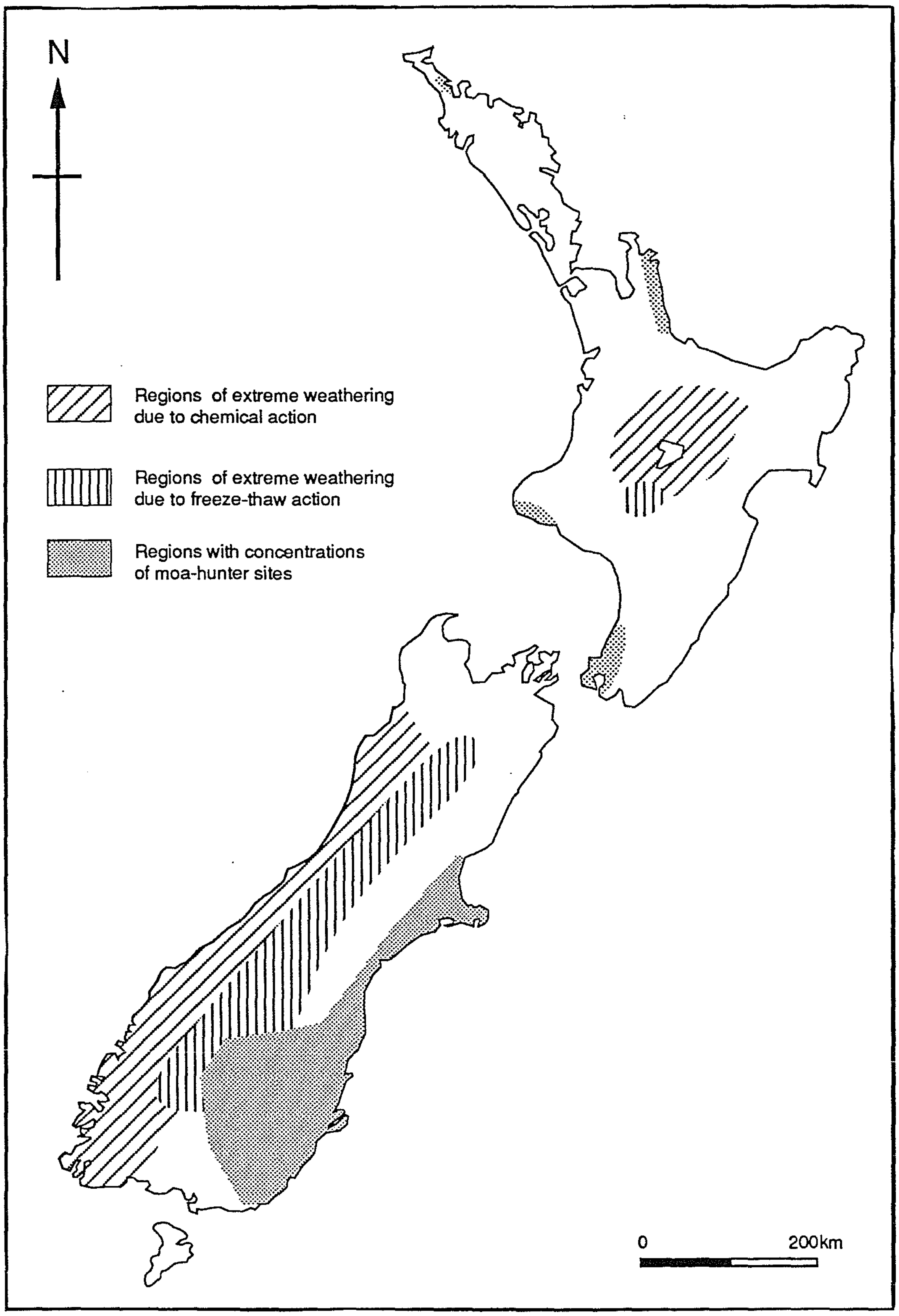

Figure 8.1 Distribution of moa-hunting sites in New Zealand compared to hypothesized regions of extreme weathering conditions due to freeze-thaw or chemical weathering.

the site which is one of the oldest in this study, Pounawea, has the highest percentage of relatively unweathered bones (92% in Stages 1 and 2). Thus, there appears to be no correlation between age and degree of weathering in the material I studied.

DIRECTIONS FOR FUTURE RESEARCH

This research has provided evidence that the faunal remains excavated from archaeological sites in most areas of New Zealand are most probably present in sites because of cultural reasons (such as hunting practices, butchery practices, and refuse disposal patterns), and that taphonomic agents may have played little part in determining the long-term survival of archaeological bone. There do appear, however, to be two exceptions to this statement, as discussed above. The result of my three year weathering experiments showed that the breakdown of the soft tissue, and the initiation of subsurface bone weathering began almost immediately. While it was found that these processes showed similarities to that recorded in other studies (e.g. Miller (1975) and Behrensmeyer (1978)), we do not know what the long-term pattern of subaerial bone weathering is in the temperate New Zealand environment.

Having established that weathering of bones begins almost immediately they are deposited on the ground surface, or buried within a soil matrix, there is now a need to study the long-term effects of bone weathering in the New Zealand situation. I suggest that this should consist of a longitudinal study of at least 20 years duration following the same methodology as my original weathering experiments: using three of the matrix situations (a soil matrix, a sand matrix, and the flat roof of a building removed from the effects of soil conditions) and with the addition of a fourth situation where a set of bones will be left exposed on the ground surface of a plot in Central Otago where they could undergo the full range of climatic extremes, including the natural freeze-thaw cycle. To the first three matrix situations I suggest the addition of sets of seal bones, the other important component of big-game hunting in New Zealand, so that the effects of weathering on those bones could also be examined. Given the difference in structure and density of seal bone, in comparison to moa bone, the results of the experiments in bone weathering, undertaken as part of the research outlined in Chapter 4, cannot be directly extrapolated to explain the long-term weathering and survival of seal bones. Thus any longitudinal study should consider this as an important aspect.

The sets of bones, as described above, should be exhumed/collected and examined every 12 months so that the rate of weathering can be monitored. It is anticipated that this time-span (20 years) will allow for some bones to completely break down due to the effects of weathering (especially those on the roof of the building, and those on the ground surface in Central Otago), while in the remaining two situations the bones will probably reach an equilibrium state with the surrounding matrix and subsurface weathering would be either inhibited or significantly reduced. Thus they should then be able to survive for several hundred years (or longer), given the right matrix conditions, just as bones recovered from archaeological sites have survived.

Further experimentation is required to investigate the correlation with the degree of burning that bones may have undergone, and the degree of weathering that is recorded for those bones when there are recovered. It is my contention that the greater degree of burning of bones prior to their burial within a soil matrix, will result in the bones attaining a higher weathering stage. This was illustrated, to a certain degree, in the Central Otago sites of Owen's Ferry, Hawksburn, and Coal Creek.

Further experimentation is required on bone survival in the humid acidic soils of New Zealand, especially the ash soils of the North Island volcanic zone and South Island podzols, in particular the soils of the west coast. There is also a need to search for and excavate moa-hunting sites, if they can be found, in these two regions. At present, knowledge about big-game hunting and settlement patterns in these regions is limited by the apparent lack of sites — a lack which may be the result of taphonomic agents as discussed in this thesis.

Given the apparent similarity in early weathering patterns between bones in

Africa and those in New Zealand, the possibility exists that there is a universal pattern in these early years of a bone's 'death history', irrespective of prevailing conditions. There is a need, therefore, for the closer examination of bone weathering from a whole range of soil and climatic environments. An interesting comparison would be one involving bones from a series of high latitude sites in southern Africa, Tasmania, southern South America, and the Labrador coast of Newfoundland, Canada. These are all regions in which big-game hunting was prevalent and they exhibit markedly different environmental types. This will allow for testing of the notion of universality in the application of the Behrensmeyer (1978) model to bone weathering studies.

CONCLUSIONS

This study of the effects of subsurface weathering on bone survival of big-game fauna, in New Zealand archaeological sites, was conducted in light of a perceived fear that taphonomic agents played a significant role in determining bone survival in archaeological sites and that this would have a flow-on effect into our interpretation of the prehistory of individual sites, and of big-game hunting as a whole. There were no data available to explain the range of appearances exhibited by large faunal remains subjected to a variety of exposure lengths in the highly diverse conditions of archaeological sites around the country.

The short answer is that taphonomic agents probably played an insignificant part, except for two areas described below, in determining the fate of bones of big-game species in the New Zealand sites that I studied. The taphonomic re-analysis of 17 collections from around the country has not altered the original interpretation of the prehistory of those sites, and has not altered the interpretation of big-game hunting in New Zealand. The weathering of bone could not be correlated either with geographic region or with chronological age. Soil conditions tend to be conducive for the continued survival of bones interred within them, although the short time-span of New Zealand's prehistory may mask the longer term effects.

Arguments about the effects of taphonomic agents in New Zealand are tempered by limits to our current knowledge. The effects of chemical weathering and freeze-thaw cycles may have played a significant role in the long-term survival of sites in the central North Island, the inland basins and the west coast of the South Island, and the loss of data from these areas about big-game hunting is important in understanding the full picture of prehistoric hunting in New Zealand.

We can now say that the differential representation of elements in bone collections from those New Zealand archaeological sites, in the current study, in areas where moa-hunting and sealing appears to have been most common, is culturally derived and that the soil environment has little effect on bone survival. The burning of bone, in general, is not an important factor in site formation processes and dog attrition, likewise, played little part as a taphonomic agent. While it appears that taphonomic agents may not have had a significant role in the big-game sites which I studied, that does not mean to say that the study of taphonomics is not important and these factors should not be considered as a contributing factor which one is studying faunal remains from New Zealand archaeological sites.

There are two important implications that arise from this research. The first affects the field of taphonomy, in that I found it was not possible to state with any degree of certainty what causes bones to be in the condition in which they are recovered by archaeologists. Taphonomy describes conditions but does not provide evidence of which was the most effective of the causative agents. Lyman and Fox (1989) highlight the same fact.

The second and more positive implication is that if there is little or no action on bones from taphonomic agents, as I have shown for the sites under analysis in this study, then archaeologists have a direct connection back to the hunter with no intervening processes. What we recover in archaeological sites mirrors cultural actions and beliefs — in hunting practices, in butchery practices and in population dynamics. New Zealand is, therefore, very well-placed to simply study prehistoric Maori hunting without the concerns that a substantial portion of the remains is missing.

So where does taphonomy in New Zealand go from here? Having shown there is little or no effect on the big-game species, there is now a need to study the taphonomics of smaller game. Nichol's (1990:171–172) analysis of fishbone from Kohika, suggested that differential attrition of the bone by weathering agents played an important role in removing classes of data from the original remains. There is also a need to study the effect of taphonomy on small-bird remains — this was the other important faunal component in the diet, and a similar study to this present one could be undertaken, looking for possible differences between sites of different types or in different locations.

THE END

Appendices.

The appendices for this thesis are contained on a computer disk in a pocket in the rear cover. This disk is formatted for a Macintosh computer — the appendices were constructed using WriteNow® V3.0, and have been compacted using CompactPro®. To extract, and read the appendices, will require the following steps:

1) ensuring a minimum of 3Mb is available on a hard disk for the opened files;
2) by double-clicking the icon, the programme will automatically decompress the files and place them on the hard disk. It may ask first for a destination folder to which the files are to placed, in which case you will need to open a new folder for the decompressed files.
3) the files can be read if WriteNow® V3.0 is installed on the system.

The appendices to this thesis consist of —

Bibliography.

Abbreviations used:

J.A.S. = Journal of Archaeological Science
J.P.S. = Journal of the Polynesian Society
N.Z.A.A.N. = New Zealand Archaeological Association Newsletter
N.Z.J.A. = New Zealand Journal of Archaeology

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