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Quaternary fossil faunas, overlapping taphonomies, and palaeofaunal reconstruction in North Canterbury, South Island, New Zealand

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This paper describes the late Quaternary fossil fauna from the area within a 10 km radius of Waikari, North Canterbury, New Zealand. Fossils from a pitfall deposit (Waikari Cave), ten predator sites attributed to laughing owls *Sceloglaux albifacies* (notably Ardenest, Gowan Hills Owl site, and P. Lamb's Owl site), five swamp sites (notably Pyramid Valley and Glencrieff), and three archaeological sites, contributed most of the data. A few specimens came from coalluvial deposits in rock shelters. A small fauna is described from alluvial deposits along Home Creek, near Waipara. The age of these faunas includes the Late Pleistocene (Otira Glacial) for the Home Creek fauna, Late Glacial – early Holocene for Glencrieff, and Late Holocene for Pyramid Valley swamp, Waikari Cave, and all predator sites. Some of the predator sites accumulated fauna until late in the nineteenth century.

The total avian fauna for the Waikari region (including Glenmark) comprises 65 indigenous and 4 introduced species of birds. In addition, tuatara *Sphenodon* spp., two species of gecko *Hoplodactylus* spp., including the large *H. duvaucelii*, undetermined skinks and fish, two species of bats *Mystacina* spp., three rodents *Mus musculus*, *Rattus norvegicus* and (most common) *Rattus exulans*, and European rabbits *Oryctolagus cuniculus* were found. All introduced species were in deposits accumulated by laughing owls.

The derivation of faunas from the diverse taphonomic processes of cave-pitfall trapping, swamp-miring / lacustrine accumulation, and predation, has resulted in an unusually broad perception of the composition of the Late Holocene fauna. This fauna differs in relative frequency of species from the much wetter regions of the West Coast and Takaka. It also differs from Mt Cookson in North Canterbury, which is closer to mountains, at higher altitude, and wetter than the Waikari district. The Waikari moa fauna was dominated by *Dinornis giganteus, Emeus crassus, Euryapteryx geranoides*, and *Pachyornis elephantopus.* Among smaller terrestrial birds, kiwis *Apteryx* spp. and wekas *Gallirallus australis* were less common than in wetter regions. Finsch's duck *Euryanas finschi*, paradise shelduck *Tadorna variegata*, extinct coot *Fulica prisca*, extinct gallinule *Gallinula hodgenorum*, laughing owl *Sceloglaux albifacies*, and adzebill *Aptornis defossor* were common in contrast to their absence or near-absence in the west. Snipe *Coenocorypha* cf. *aucklandica* and piopio *Turnagra capensis* were noticeably more common in Waikari faunas than in more western ones.

The Otiran moa fauna comprised the same species as in the Holocene, except that *Pachyornis elephantopus* was more common. Comparisons between the large, well-dated, samples from Glencrieff and Pyramid Valley, show that *P. elephantopus* but not *E. crassus* exhibited post-glacial dwarfing in this region.

The importance of predator sites in palaeofaunal reconstruction is indicated by the fact that 17 bird species and virtually all non-bird taxa were recognised solely from these deposits. These include five procellariiforms, and three river-bed inhabitants

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Charadrius bicinctus, *Thinornis novaeseelandiae*, and *Sterna albostriata*. In these faunas the abundance of two species that live or lived in open shrublands and grasslands, the extinct quail *Coturnix novaezelandiae* and pipit *Anthus novaeseelandiae* is positively correlated with the abundance of kiore *Rattus exulans* in the late Holocene. While quail and pipit dominated the late-Glacial to early Holocene small-bird fauna of Glencrieff indicating the presence of shrubland at that time, these species were virtually absent from the well-represented pre-rat fauna of the latest Holocene in Pyramid Valley, Waikari Cave, and older predator sites. Forest was established, at least in low altitudes, in the Waikari region about 5,000 years ago. The marked increase in abundance of these birds after the arrival of kiore reflects the increased presence of shrublands in the area following human arrival and anthropogenic burning.

Their absence in the extensive late Holocene faunas from around Waikari strongly suggest that pukeko *Porphyrio melanotus*, swamp harrier *Circus approximans*, and shoveler duck *Anas rhynchotis* were not part of the prehuman New Zealand fauna.

Fossil insect faunas were obtained from three laughing owl sites. Nineteen species of weevils and 22 species of other ground beetles were represented. These showed that the former ranges of several now-relict species, most notably *Amychus ?granulatus*, *Mecodema costellum lewisi*, *Anagotus stephenensis*, *A. rugosus*, and *Ectopsis ferrugalis*, were considerably more extensive in the past.

Faunas are listed from two sites near the study area. The fauna from Mimiomoko Pocket, Waipara River, was re-examined and recognised as having been accumulated by laughing owls, and found to include several small passerines. Puffinus Cleft, Nape Nape Scenic Reserve on the adjacent North Canterbury coast, contained abundant bones of *Puffinus griseus*. A specimen list is given for bones retrieved over the years from Glenmark Swamp and still surviving in New Zealand collections.

Keywords: fossil vertebrates, fossil insects, taphonomy, Quaternary palaeofauna, Waikari, North Canterbury, New Zealand.

INTRODUCTION

> *".. yet as the whole area is continuous, and the physical conditions of each district graduate away somewhat insensibly into those of the other, we cannot expect to find any more material differences in their natural productions than such as may be attributed to the modifying influences produced by difference of climate."*
>
> W. T. L. Travers, 1869

This contribution is the fourth in a series describing the Quaternary palaeofaunas of the South Island. In this programme we are describing the palaeofaunas of selected areas, identifying the changes associated with the last glacial cycle within each area, and drawing comparisons between areas (Worthy & Holdaway 1993; 1994a; 1995). Travers (1869) made the above comments with respect to floras, but the flora of an area provides the habitat within which faunas live, and so they ultimately limit the faunal composition. We therefore expect that faunas of adjacent areas will be similar, or were similar in the past, but that by studying geographically separated areas, associated differences in climate and vegetation will have discernible effects on the faunal composition. The palaeofaunas of the regions studied each have individual characteristics which are directly related to climate and hence the flora. To date we have studied the very humid western regions of the West Coast (Worthy 1993b; Worthy & Holdaway 1993), the somewhat drier Takaka region in the northern South Island (Worthy & Holdaway 1994a), and the even drier area of North Canterbury on Mt Cookson (Worthy & Holdaway 1995). However, Mt Cookson is on the fringe of the North Canterbury region where its climate is modified by the close proximity of the Amuri Range at the south end of the Seaward Kaikoura mountains. In this paper we describe the palaeofaunas of the more arid zone of lowland North Canterbury.

North Canterbury lies east of the Southern Alps in the South Island, north of Christchurch.

It is a district of gently rolling hills and alluvial plains, with a western backdrop of the snow-covered Southern Alps. The very dry climate facilitated the forest clearance which has denuded the land of its original vegetation; now intensive pastoral farming practices shape the landscape.

It was the breaking in of the land for farming, and especially the improvement of the drainage, that led to the first palaeofaunal discoveries in this district. The first and most remarkable discovery was at Glenmark, where the Provincial Geologist, Julius Haast, oversaw the excavation and recovery of thousands of moa bones (Haast 1869). These fossils were sufficient in quantity to allow the articulation of numerous moa 'skeletons' that were sent to overseas museums in exchange for specimens to fill the display halls of the new Canterbury Museum (Haast 1948). In addition, the bones of a giant eagle *Harpagornis moorei*, now known as Haast's eagle, were recovered and described (Haast 1872; 1874). Bones of other carinates found were not listed, but some still survive in the Canterbury Museum (listed herein).

No other sites were described last century, although bones in Canterbury Museum show that Hutton obtained some specimens from a swamp near Cheviot. There is little limestone exposed in the district, and most of it is noncavernous, so there are few caves from which fossils could be obtained, in contrast to in many other areas of the South Island (Worthy & Holdaway 1993; 1994a). Large archaeological midden sites, abundant south of Christchurch (e.g. data in Anderson 1989), can contain much faunal material providing evidence of at least the latest palaeofauna, but such sites are absent in North Canterbury. Hence, the palaeofauna of North Canterbury remained virtually unknown until the excavations of the Pyramid Valley moa swamp stimulated by the discovery of moa bones there in 1937 (Duff 1952). However, despite the large collections obtained, only species lists were published (Falla 1941; Scarlett 1955), and no extensive analyses in a national context have ever been made. We have recently completed the study required to fill this gap (Holdaway & Worthy in press).

Other than Pyramid Valley, the best known local palaeofaunas come from the northern end of the North Canterbury region, at Annandale Station on Mt Cookson. The limestone there is cavernous, and the limestone sinkholes contain fossil faunas which we have recently studied (Worthy & Holdaway 1995). These pitfall faunas, in association with predator-derived faunas from deposits in cliff sites, have allowed the description of faunal changes in Canterbury from the mid-Otiran period to the present. The faunal changes over time were in response to shifts in climatic and other environmental parameters, and are similar in scale, though not in detail, to those deduced from West Coast deposits (Worthy & Holdaway 1993) and Takaka deposits (Worthy & Holdaway 1994a).

To continue our survey of the South Island palaeofaunas it was desirable to describe the lowland faunas of an area more typical of North Canterbury, since a fringe area such as Mt Cookson was unlikely to represent drier land at lower altitude. We chose the region centred on Waikari, as a large fauna was already known from Pyramid Valley. While Pyramid Valley is an extremely important site, it is still only a single wetland site, and so has inherent taphonomic biases which impose severe limitations on reconstructing the regional palaeofauna, especially the microvertebrate component. The limited temporal range of this site also prohibits observations of faunal changes over lengthy periods of time in response to climatic and other changes, such as we have observed elsewhere (see above). Atkinson & Millener (1991) attempted a reconstruction of the palaeofauna of the last 5,000 years, based on the then available published data on fossil birds of the area, but since they had no data on relative frequency of species, and little on the microvertebrate component, they detected few differences from other areas in New Zealand.

However, we knew of other sites in the vicinity of Pyramid Valley, including at least one unpublished pitfall fauna from a cave (McCulloch 1975), and numerous limestone cliffs upon which we expected to be able to discover deposits of fossils accumulated by laughing owls. The latter expectation was based on our recent discovery of such sites on the West Coast (Worthy & Holdaway 1994b), and Takaka Hill (Worthy & Holdaway in press). In addition a few small faunas were known from rock-shelters in the area (Scarlett 1969; Trotter 1972), plus another small swamp fauna (Burrows et al. 1984), and a large unexcavated swamp site at Glencrieff. Fossiliferous, fluviatile deposits of Otiran age were known from the nearby Waipara area (Harris 1982).

Each type of fossil site has a particular taphonomy that defines the way in which the fauna it contains can reflect the source fauna (Worthy & Holdaway 1993). Because we had a suite of swamp-miring, lacustrine, archaeological, predator, and pitfall taphonomies, the limitations of any one site-type were redressed in another. Our aim, therefore, was to draw together data from all these sources, which, with the variety of taphonomies and ages, would enable us to build up a relatively complete picture of the evolving fauna of the area through at least the last 20,000 years.

ABBREVIATIONS AND DEFINITIONS

New Zealand institutions: MNZ, Museum of New Zealand Te Papa Tongarewa, Wellington (ex National Museum of New Zealand); CM, Canterbury Museum, Christchurch; OU, Geology Department, Otago University, Dunedin. When listing specimens only the first number in a series from an institution is prefixed with letters denoting the institution and the collection, e.g. CM Av. Succeeding numbers in a series separated by commas can be assumed to have the same prefix.

MNI (minimum number of individuals) was determined for each taxon at each site from the most frequent skeletal element (maximum of left or right side only) in the sample. In species lists, x/y = number of bones/MNI represented by the sample. Sites at different locations in a cave, or in different caves, were treated separately, so MNI for a species from the region is the sum of site MNI's.

When listing material, bones are sometimes identified as left (L) or right (R) elements. If L or R is prefixed by 'p' or 'd', this means 'proximal' or 'distal' part of the element. For example, pR femur means proximal right femur.

Measurements

Measurements were made to 0.01 mm with dial or vernier callipers, and rounded to 0.1 mm.

Identification

Bones were identified by THW by comparison with recent reference material, or previously validated fossil material, in either the Canterbury Museum, or the Museum of New Zealand Te Papa Tongarewa. All museum specimens cited were examined unless otherwise stated.

Nomenclature

We follow the nomenclature including higher taxonomy given in the Checklist of the Birds of New Zealand (Turbott 1990) with the modifications at the specific level as detailed in Worthy & Holdaway (1993). We therefore list *Cnemiornis calcitrans* and *Aptornis defossor* as distinct South Island species, and *Fulica prisca* as distinct from the Chatham Island *Fulica. Anas chlorotis* is recognised as a species, distinct from its flightless relatives on Auckland and Campbell Islands. This follows Oliver (1955), and is supported by a study of the morphology of the Australasian teal group (Livezey 1990), and as recognised in Marchant & Higgins (1990). We do not accept that the extinct New Zealand crow is generically distinct from *Corvus*, and neither do we consider that the extinct New Zealand owlet nightjar is generically distinct from *Aegotheles*, and so we list the New Zealand species in these genera. We follow Trewick (in press) in recognising that the South Island takahe is a distinct species from the North Island takahe, and so takahe are referred to by their original specific names *Porphyrio hochstetteri* (A. B. Meyer, 1883) and *P. mantelli* (Owen, 1848), respectively.

Common names of plants are used when discussing plant species, although genera are described by their scientific names; scientific names are given in Appendix 1. When discussing pollen taxa scientific names are used because fossil taxa are often not directly comparable with living plant species, or can be identified only to genus. When discussing pollen the *Nothofagus fusca* group or type pollen includes red beech *N. fusca*, black beech *N. solandri* var. *solandri*, mountain beech *N. solandri* var. *cliffortioides*, and hard beech *N. truncata*.

Anatomical nomenclature follows that advocated by Baumel et al. (1993), but after the first reference simple English translations are used.

The geological periods discussed are defined as follows: Holocene – the present interglacial period, taken as starting at 10,000 radiocarbon yrs BP; Otira Glaciation – the last glaciation, from about 70,000 to 14,000 yrs BP broadly equivalent to the Wisconsinan – Weichselian; Late Glacial – the period of rapid climatic and vegetational change from 14,000 to 10,000 yrs BP.

Radiocarbon dating

Submitted bone samples were cleaned, the bone ground up and demineralised in 0.5M HCL, then treated with alkaline sodium pyrophosphate and acid again, to remove humic acids and make an impure collagen extract. Finally, a gelatin fraction was extracted by a final hot acid treatment leaving an insoluble residue of mainly humics (Redvers-Newton & Coote 1994), and dated using accelerator mass spectrometry. The gelatin extraction purification process was not used at the Rafter Radiocarbon Laboratory until 1993, so results here are not strictly comparable with those obtained before that date. However, analyses made on subsamples of the same specimen gave very similar results, except that gelatin dates were up to 2% older because more of the young humic contamination was removed by the pretreatment (Redvers-Newton & Coote 1994). This scale of difference is unlikely to affect comparisons we are drawing between Otira Glacial and Holocene time periods.

The results of radiocarbon dating are given in the section on fossil sites. Full details for all samples are given in Appendix 2. Dates are reported as conventional radiocarbon ages, based on Libby $T^{1/2}$ = 5568 yrs, uncorrected for secular variation, in years before present (yrs BP), where present is 1950.

PRESENT ENVIRONMENT

Location and topography

The area of study is found on the NZMS 260 series, 1:50,000 metric maps N33 (Culverden) – Waikari Valley, N34 (Motunau) – Home Creek, M33 (Waikari) – Hawarden/Waikari, and M34 (Amberley) – Fergusons Rd/North Dean.

All sites in this study lie within about a 10 km radius of Waikari (Figs 1, 2). Within this area flat alluvial plains, several kilometres wide, rise from between 220 m at Waikari, to 300 m west of Hawarden. Rolling hills, reaching about 460 m, protrude through the plains about Hawarden, and immediately to the south rise to 800 m as the Doctors Hills. The Waikari Valley drains east between hills rising to 748 m on Mt Alexander to the north, and about 400 m to the south. Home Creek drains off the southern hills to the south, past Glenmark Station where Haast's famed moa site was, and joins the Omihi Stream near Waipara.

We studied fossils from Late Pleistocene fluvial deposits in the Omihi Stream, near Waipara, three swamp sites (Glencrieff, Pyramid Valley, and North Dean), one cave (Waikari Cave), and a number of limestone cliff sites. Glencrieff lies on a terrace at about 300 m, and about 0.5 km from the nearest hills. Pyramid Valley lies within a sheltered depression at about 330 m, nestled against the northern side of the Doctors Hills.

The predator sites were found on the lower slopes of the hills where limestone is exposed, usually at below 300 m altitude (Fig. 2). The cliffs we examined include: a 3 km northwest-facing set of five (mainly on the farm Arden) in Waikari Valley; those in the valley around Timpendean; the northwest-facing bluffs on the east side of the main road at the north end of Weka Pass that extend northeast towards Mt Donald in 0.7 and 1.2 km lengths (P. Lamb's property); a 0.3 km long north-facing cliff north-northeast of Mt Donald; the cliffs lining three southeast-trending valleys (each about 0.5 km long) near Weka Pass itself (E. Murchison's

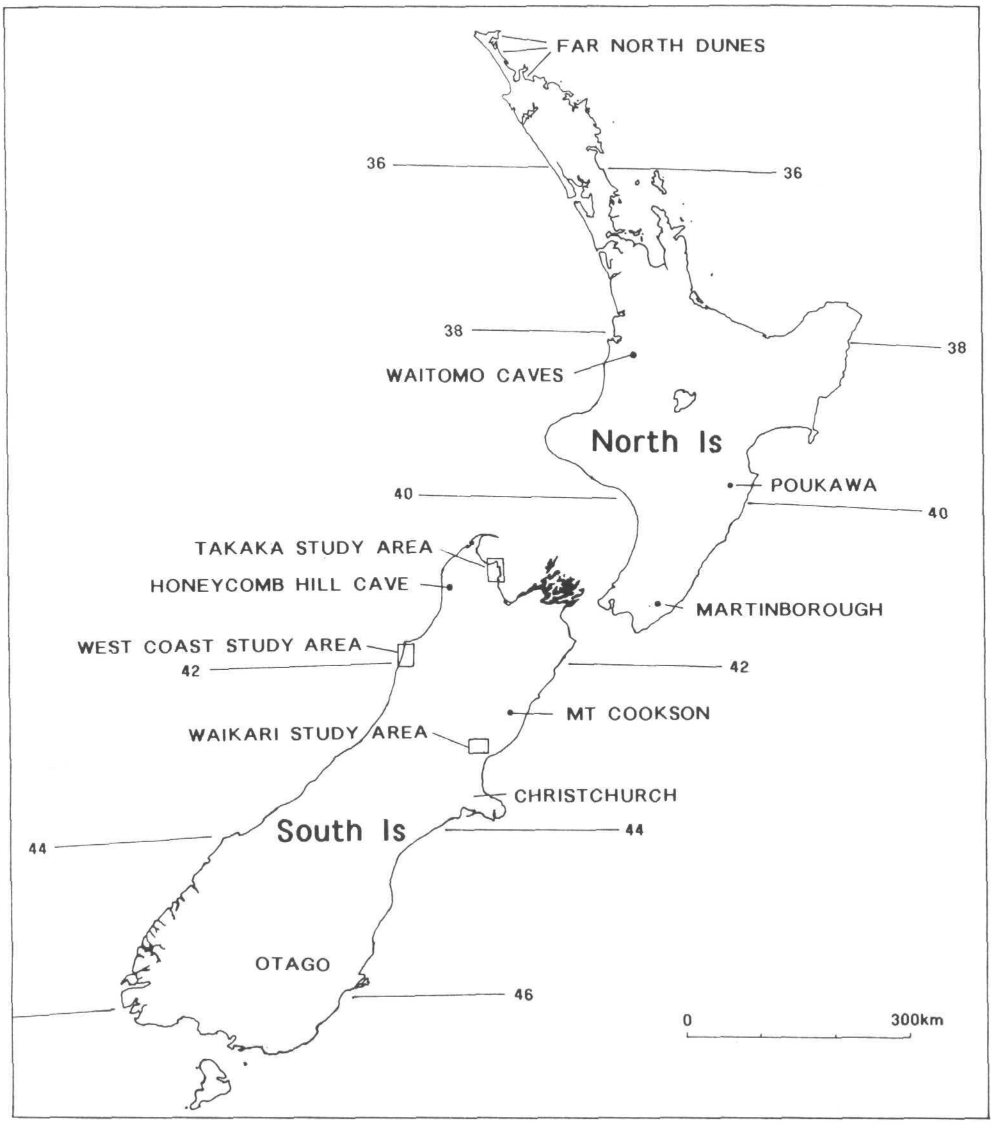


Fig. 1 Map of New Zealand locating the Waikari study area in relation to other significant fossil sites and previous study areas.

property); about 1 km of the northeast facing cliffs up Fergusons Road that are cut through by Weka Creek (Gowan Hills), except the northernmost kilometre of this cliff, which was not examined as it was of low height, composed of soft rock, had no overhangs, and did not appear to have suitable sites in it; and rock outcrops along about a 1.5 km length of the valley at the end of Fergusons Road – Sandhurst Station.

We did not examine the cliffs in the headwaters of Scargill Creek, northeast of Mt Alexander. The south-facing cliffs extending in a broken series from the Old Weka Pass Road eastwards to the present road up Archers Stream were not examined either, as their aspect was considered unsuitable, and they did not appear to have any promising overhangs or crevices. Neither did we examine closely the cliffs immediately west of the main road by

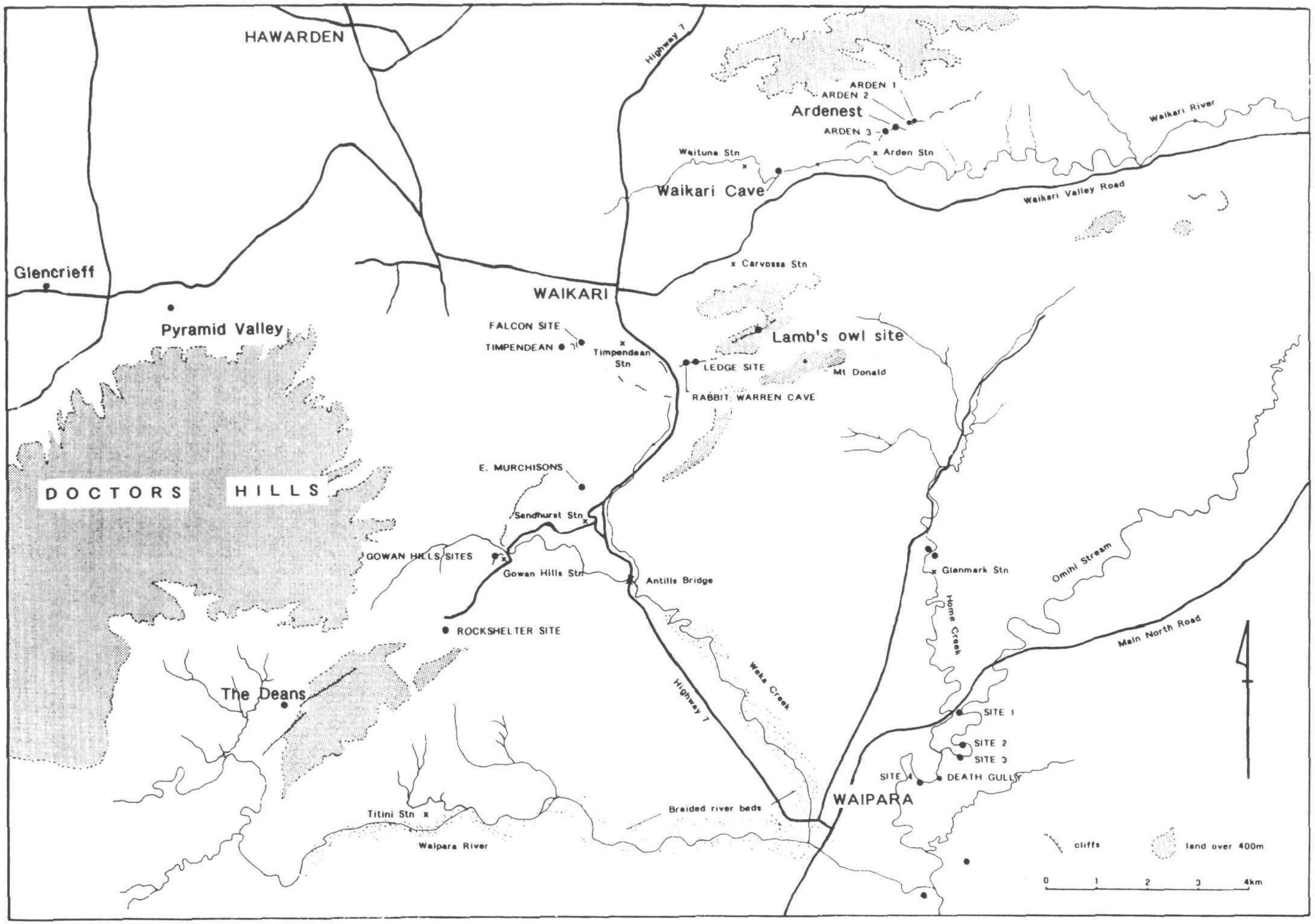


Fig. 2 A map of the Waikari study area locating the fossil sites in relation to the main geographical features of the district.

Timpendean as no suitable sites were obvious from the road. The cliffs west of North Dean were not all examined because their low height and the soft rock showed little promise of predator sites.

Climate

Canterbury is sheltered from the prevailing westerly airflows as it is in the rainshadow of the Southern Alps. As a result, it has a dry climate – generally less than 1500 mm rainfall (de Lisle 1969). Anticyclones can produce hot föhn winds (up to 35–39°C, dry, strong, northwesterly winds) that dry the environment markedly: summer (November – March) drought is normal (de Lisle 1969). Most of Canterbury receives 1,900 to 2,000 hours of sunshine a year. During winter frosts are common, and snow can be expected on the foothills and occasionally reaches down to sealevel.

The closest weather station to Waikari is about 12 km to the north at Balmoral Forest (Latitude 42° 52′S, Longitude 172° 45′E, 198 m), and its climate is very similar. The mean annual rainfall for the period 1921–1980 was 658 mm, with a fairly even monthly distribution. The mean temperature for the period 1928–1980 was 10.8°C; the highest average monthly maxima were 31.2°C and 31°C in January and February, and the lowest monthly minima were –6.5°C and –7.1°C in June and July. Ground frost was recorded on an average of 118.3 days per annum in the period 1927–1980. Relative humidity (1950–1980) has varied from monthly means of 57% in November to 84% in July, with an annual mean of 70%. Snow fell on 3.6 days per year (1929–1973).

History of vegetation

Otiran

The low temperatures of the last glacial period (Otira Glacial) depressed the general treeline by about 800 m, and the pollen record of most of the South Island, particularly eastern areas, is dominated by herbs and grasses (McGlone 1988). Loess mantles the hills surrounding the Waikari – Hawarden basin, indicating that during this period they were covered in grassland or shrubland.

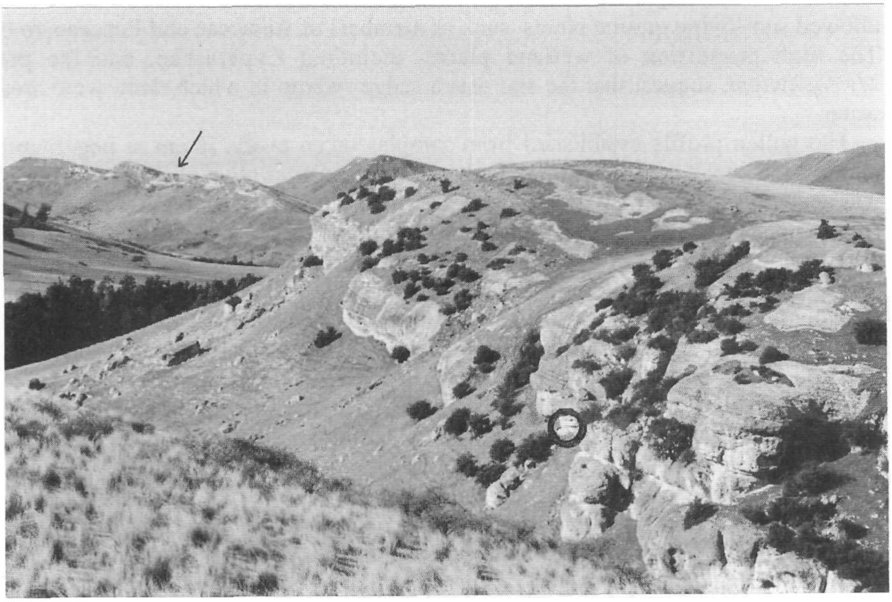
Late Glacial – early Holocene

Between 11,000 and 7,500 years ago, tall shrubland began to replace the Otiran grassland/ shrubland communities in the South Island, at different times in different areas (McGlone 1988). Moar (1971) and McGlone (1988) presented pollen-derived data that showed a *Dacrydium – Phyllocladus* shrubland became widespread in eastern areas at this time.

The Glencrieff site described herein provides the first data for this period for the lowlands of North Canterbury, and confirms the presence of a similar tall shrubland there. The palynology of Glencrieff will be described in detail separately, so only a summary is presented here. We took two spot-samples from 75 cm depth – one in square F0 and the other above the main bone accumulation at the junction of squares A1 and B1. Thirdly, a pollen profile was analysed from adjacent to peg 1. The sample from F0 was analysed by Janet Wilmshurst, Landcare Research (Appendix 6). The A1/B1 sample and the pollen profile were analysed by N. Moar and M. McGlone, Landcare Research, and will be described in detail separately.

The pollen spectrum from the A1/B1 sample, indicates that at the time of deposition grassland/shrubland was the dominant vegetation, in which tussock grasses were dominant, and *Phyllocladus, Coprosma* and Asteraceae were characteristic components. This sample is considered to be older than the sample from F0, albeit from the same depth, which reflects a more closed woodland vegetation (Moar and McGlone pers comm. 3 November, 1995).

The F0 sample indicates that the surrounding vegetation comprised a low forest or tall shrubland dominated by *Phyllocladus*, with some *Libocedrus*, and in which *Coprosma* spp., *Cyathea smithii*, *Myrsine* and *Hoheria* spp. were present. The open canopy would have



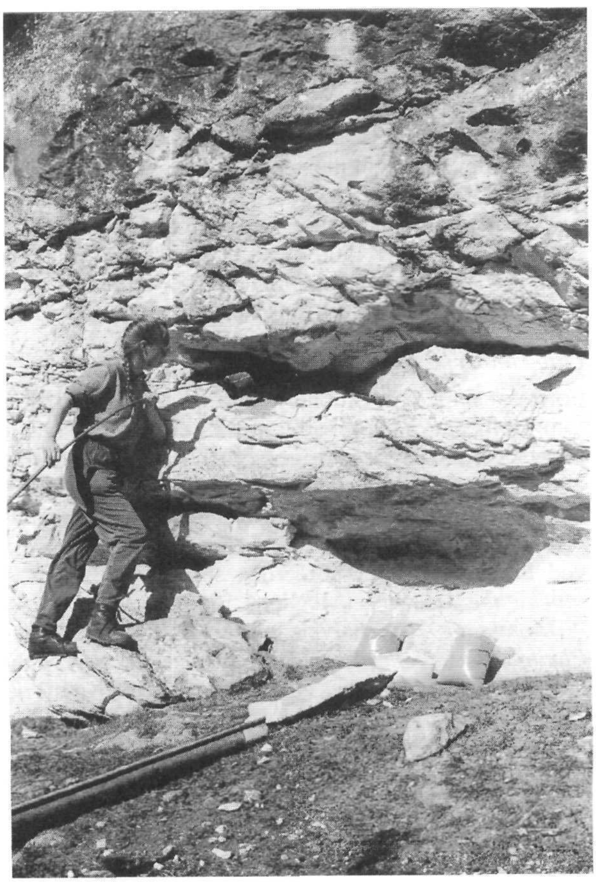


Fig. 3 A general view of the valley below the Timpendean archaeological site looking east to P. Lambs owl site (arrowed) in the distant cliffs. The falcon site is circled in the foreground. The lower photograph shows Anne Melhuish extracting material from the Falcon site.

allowed sun-loving ground plants, such as members of Apiaceae and Poaceae, to be present. The high proportion of wetland plants, including Cyperaceae, and the presence of *Myriophyllum*, suggest that the site was a sedge swamp in which there were areas of open water.

The pollen profile established from samples taken every 10 cm at peg 1 unfortunately reached the peat base at about 85 cm depth, whereas over most of the bone deposit the base was at about 120 cm. In this profile, dates on peat samples from 80 cm were 9,030 yrs BP and from 65 cm, 5,460 yrs BP (McGlone pers comm. October, 1995). *Nothofagus* was initially absent, but above 70 cm became prominent with about 20 % of the count. *Prumnopitys taxifolia* was abundant throughout. The 80 to 70 cm zone recorded a fall in abundance of *Phyllocladus* and *Plagianthus* to very low levels from about 10%. Above 20 cm a sharp drop in *Nothofagus*, *Prumnopitys*, and *Coprosma* pollen, was associated with dramatic rises in Poaceae and *Pteridium*, and a massive rise in charcoal, reflecting deforestation. This profile records the spread of beech (*N. fusca* type) into the area after about 6,000 years ago to form a mosaic of podocarp and hardwood forest. Throughout the rest of the Holocene an open mosaic of forest and shrubland surrounded the site and the area generally, as judged by the presence of *Sophora*, *Cassinia* and *Olearia* type pollen in addition to the forest species.

This record differs substantially from those obtained a few metres further out in the bog at square F0 and A1/B1, and so needs explanation. In the spot sample from 75 cm depth over the richest bone deposit at A1/B1, a grassland flora was indicated suggesting an age greater than 10,000 years BP. The tall shrubland of *Phyllocladus* and *Libocedrus* indicated by the spot sample from 75 cm depth at F0 is only represented by the 9,000 year old sample at 80 cm depth at peg 1, so must have largely been present before this time. We interpret these observations to be the result of the site originally having a peat dome, with very slow, or at times, discontinuous deposition. If so, the peat would have thinned towards the edge (peg 1) and so the older layers could be represented in only the bottom 10 cm, or be altogether absent, and would be thickest in the middle. If the top of the dome has been planed off by pastoral development then equivalent layers to those seen at peg 1 would be shallower in the middle of the site.

As the fossil bones were mostly embedded below 75 cm depth, and had been entrapped in the peat and were 10,500–12,000 radiocarbon years old, we consider the spot pollen sample from A1/B1 to be representative of the vegetation surrounding the site when the bones were deposited. At that time a grassland flora dominated the environment.

Late Holocene (<5,000 yrs BP)

Forest of some type probably grew on most soils below the treeline in Canterbury during the Late Holocene, and probably was absent only from newly formed surfaces such as river beds, rockfaces, and exposed ridges, or the driest parts of the Plains (Knox 1969). McGlone (1989) considered that the vegetation of areas on the Canterbury Plains, within the 600–800 mm isohyet, and on stony, light soils under dry climates would have been dominated by kanuka scrub. Areas with heavier, deeper soils probably had forests dominated by matai, kahikatea and totara, but with numerous shrubby clearings of *Coprosma*, kanuka, manuka, and *Muehlenbeckia* vines (McGlone 1989).

Moar's (1970) analysis of the pollen record at Pyramid Valley showed spikes of *Phyllocladus*, *Hoheria* and Gramineae at the base of the sequence about 5,000 years ago. The tailing off of these spikes correlates with the overall rise in tree and shrub pollen, largely due to the establishment of *Nothofagus* in the area at this time. These data suggest that the late Glacial shrubland persisted until about 5,000 years ago. The dominant podocarp in the *Nothofagus* period was matai, and leaves and branches of this species were common macrofossils at the site.

Burrows (1989) used evidence from pollen, macrofossils, and moa gizzard contents to generate the following reconstruction of the vegetation around the lake at Pyramid Valley. In places New Zealand flax *Phormium* spp. and rushes *Baumea* spp. grew at the lake edge.

Manuka, mountain toatoa, weeping matipo, *Olearia virgata*, and *Coprosma* spp. formed a narrow shrub band between the lake and forest. Matai dominated an adjacent tall forest, which probably had a broken canopy over the following understorey species: kaikomako, putaputaweta, lacebarks *Hoheria* spp., ribbonwood *Plagianthus regius*, ngaio, toothed lancewood, pokaka, and cabbage tree. On the limestone slopes above the lake and the matai forest, shrubs including *Corokia cotoneaster*, *Carmichaelia* spp., *Teucridium parvifolium*, and the vines *Muehlenbeckia* spp. and *Rubus squarrosus* grew.

The data from Pyramid Valley are augmented by those from above about 60 cm in the core from Glencrieff. The incidence of beech was high in the pollen assemblage from Pyramid Valley and the upper levels of Glencrieff. We envisage matai-dominated forests in the sheltered valley basins, with beech, probably *Nothofagus solandri*, dominating the forests of favoured localities on the hillslopes above, but also penetrating the lower forests as forest-openings permitted. The presence of abundant *Coprosma*, *Myoporum*, *Sophora*, *Cassinia*, and *Olearia* pollen indicate that the vegetation in the area was an open mosaic of forest and shrubland, very different in structure from the closed canopy podocarp forests of the west.

While there is evidence of natural fire destroying eastern South Island forests at several times during the Holocene, the damage was always limited in area and the forest always recovered (McGlone 1989). However, between 800 and 500 years ago, the vast majority of the eastern forests, including those around Waikari and Hawarden, were permanently destroyed by anthropogenic fire (Molloy et al. 1963; McGlone 1983, 1989).

Present vegetation

The majority of the Waikari area is intensively farmed at present. All flat land and gentle slopes are regularly ploughed and are either in pasture or crops. Most trees are introduced pines or willows. The hills around Waikari are mainly in rough pasture with some unpalatable shrubs, notably matagouri, but also divaricating small-leafed *Coprosma* spp., native brooms *Carmichaelia* spp., and vines *Muehlenbeckia* spp. and *Rubus squarrosus* interspersed among grasses. In sheltered gullies some patches of forest understorey species survive. These include mahoe, broadleaf, fivefinger, and golden akeake. Kowhai and small-leafed kowhai are present in most valleys.

The Nape Nape Scenic Reserve on the coast about 20 km due east of Waikari preserves the best and most extensive sample of the original vegetation growing in coastal North Canterbury. As it is on limestone and relatively close to Waikari, some similarities could be expected. The canopy species include akeake, ngaio, broadleaf, and some kowhai. The main undergrowth species are kawakawa, red matipo, and golden akeake. Black matipo, karamu, koromiko, mahoe, and five-finger are common. The presence of a few young totara trees suggests a former canopy of podocarps.

Historical fauna

There is very little written information describing the fauna of the Waikari area in the nineteenth century. Hope (1927) briefly described the disappearance of birds in North Canterbury. Extracts relating to individual species were quoted by Worthy & Holdaway (1995) in a discussion on Mt Cookson in North Canterbury, so will not be repeated here. Stack (1875) recorded that large lizards (probably tuatara) survived in North Canterbury but were, even then, endangered.

Present fauna

Introduced birds dominate the fauna as the region is now virtually entirely in pasture, and the few trees are usually introduced species. Habitat variety is provided by some scrub above 300 m on the hills, especially in unploughable areas, and in damp, sheltered valleys some forest understorey plants survive. Silvereye *Zosterops lateralis*, spur-wing plover *Vanellus miles novaehollandiae*, goldfinch *Carduelis carduelis*, chaffinch *Fringilla coelebs*, yellowhammer *Emberiza citrinella*, blackbird *Turdus merula*, European thrush *T. philomelos*, white-backed magpie *Gymnorhina tibicen*, California quail *Callipepla californica* are all common. The feral pigeon *Columba livia* nests in abundance on limestone cliffs. The native species present include fantail *Rhipidura fuliginosa*, grey warbler *Gerygone igata*, bellbird *Anthornis melanura*, pipit *Anthus novaeseelandiae*, paradise shelduck *Tadorna variegata*, harrier *Circus approximans*. Around wetlands, for example Pyramid Valley, water birds including pukeko *Porphyrio melanotus*, grey teal *Anas gracilis*, mallards *A. platyrhynchos*, pied stilts *Himantopus h. leucocephalus*, and white-faced herons *Ardea novaehollandiae* are common.

FOSSIL SITES

History of exploration

The history of exploration of Pyramid Valley is described by Allan et al. (1941), Duff (1952), and Holdaway & Worthy (in press).

Euan Murchison's rockshelter was investigated by R. Kennington and R. J. Scarlett (Scarlett 1969). Most of the limestone areas have been surveyed for archaeological rock art sites (McCulloch 1968), and during the course of such work a few isolated moa bones were found. The archaeological excavation of Timpendean dates back to last century, but the available fauna is derived from the Canterbury Museum excavations (Trotter 1972).

The swamp site known as Glenmark was in Home Creek, on Glenmark Station, about 10 km over hills to the southeast of Waikari. There are several poorly documented sites in this valley (Haast 1869). Haast recorded *Pachyornis* and *Harpagornis* bones from below thick gravel deposits, which we assume were of Otiran age, but identifiable fossils from these sites are few. The majority of fossils came from 'turbary deposits' of Holocene age. It seems more likely that these fossils were actually deposited in peat swamps, and so derived from swamp-miring, as there is no evidence of stream transport on any bones THW has examined, and all have the look of peat-derived specimens. McCulloch & Trotter (1979) obtained a single date on a *P. elephantopus* tibiotarsus of 2,730 ± 70 yrs BP (NZ1729), and Anderson (1989) listed a date of 7,110 ± 109 yrs BP (NZ4943), showing that the age of deposits there could have spanned the Holocene.

An exhaustive study of the fauna from this site is difficult at present, as the majority of specimens were dispersed to museums all over the world (Haast 1948), and most do not now survive with adequate data to be certain they are from Glenmark. For this reason we do not include this site in our present study. However, a crude assessment of the fauna can be made. Worthy (1990) converted Haast's (1869) list to modern taxonomy, and concluded that there were 57% *Emeus crassus*, 15% *P. elephantopus*, 12% *Euryapteryx geranoides*, 8% *Dinornis struthoides*, 2% *D. novaezealandiae*, and 5.5% *D. giganteus* in a sample of 144 individuals. In the Canterbury Museum the surviving bones from this site (listed in Appendix 5), include in addition to these species, six bones of two individuals of *Megalapteryx didinus* (CM Av8623, 9089), and five bones of two individuals of *Anomalopteryx didiformis* (CM Av8640, 8813–16). Following our recent study of Pyramid Valley *Dinornis* (Holdaway & Worthy in press) THW now considers that surviving bones from Glenmark in the Canterbury Museum that were referred to *D. novaezealandiae* should be listed as *D. giganteus*, and so it seems likely that *D. novaezealandiae* was absent from the fauna. Carinates known from the site include the adzebill *Aptornis defossor*, Haast's eagle *Harpagornis moorei*, extinct goose *Cnemiornis calcitrans*, kiwis *Apteryx* spp., New Zealand pigeon *Hemiphaga novaeseelandiae*, weka *Gallirallus australis*, and extinct gallinule *Gallinula hodgenorum* (data herein).

Taphonomy of fossil sites

Several taphonomic processes are involved in the accumulation of Holocene fossil assemblages in the Waikari area.

1. Accumulation of fossils in shallow lucustrine and peat swamp deposits following either miring or vagrant death of individuals at Pyramid Valley, North Dean, and Glencrieff Swamp. Pyramid Valley has been treated in detail (Allan et al. 1941; Duff 1952; Gregg

1972; Holdaway & Worthy in press), North Dean was described by Burrows et al. (1984), and Glencrieff below.

2. Pitfall entrapment in caves was responsible for accumulation in only one site, Waikari Cave.
3. Predator accumulation of fossils in crevice deposits in cliffs. The majority of sites were on the floor of 0.2 to 0.5 m wide crevices extending back into cliffs. All were dry, and had entrances with sunny aspects. We used taphonomic evidence as described below to show that these faunas were accumulated by owls rather than falcons. The age of the deposits, which are all predominantly pre-European on faunal grounds, rules out the little owl *Athene noctua* as the predator. This species was first introduced to New Zealand in 1906. Marples (1942) examined the stomach contents of 242 birds from mainly Otago and Southland in 1938–1940 and found that most of the vertebrate prey little owls took were introduced finches, thrushes and blackbirds. The morepork was excluded because it takes predominantly invertebrate prey; if vertebrates are taken they are small; and the sites were not typical of morepork roosts (see discussion in Worthy & Holdaway 1994b). We therefore consider that all the Waikari predator sites were the work of laughing owls. The 'falcon site' at Timpendean was unusual, for it was not a crevice, but rather a small cave whose entrance opened out of a cliff about 1 m off the ground (Figure 3).
4. A taphonomy of minor significance was the death of a vagrant bird on a ledge, or in an overhang under a cliff, leaving a deposit of associated bones of one individual. At Gowan Hills a few bones were found in a coalluvial deposit of loess and limestone clasts that had accumulated at the base of the cliff about 20–30 metres from the owl site. These were probably vagrants, but the bones of smaller species may have been reworked from owl deposits.
5. Some material had an archaeological source, that is, the bones were accumulated by people, but only those from Timpendean contribute significantly to the total fauna. The Gowan Rockshelter deposit contained few bones, and the one from Euan Murchison's Rockshelter is considered herein to mainly have been accumulated by laughing owls.
6. The Late Pleistocene deposits exposed in the banks of the Omihi Stream, near Waipara, are fluvial or lacustrine in derivation (Harris 1982). Fossils were found in sand and gravel layers along with shells of freshwater mussels of the genus *Hyridella*. Near the top of the sequence the c. 22.6 kyr Aokautere Ash is preserved, and all fossils are older than this (Brent Alloway, in litt 21 September 1993). Fossils were found either singly, or as several associated bones of an individual. We disagree with Harris's suggestion that the fossils were derived from swamp-mired birds, similar to those in Pyramid Valley. All fossils we have collected from these sites were lying horizontally in the sediments, and long bones often had some abrasion to their extremities e.g. the distal condyles of S34449 and S34446. The part skeleton of *Pachyornis elephantopus* collected by M. Dickie was found spread out in a 10 cm layer of coarse grit or fine gravel under- and over-lain by a sand layer. Having examined and collected from the sites, we consider that the fossils were derived from water-transported carcasses or bones that settled in channels, or pools, in a streambed.

Detailed description of important swamp sites

Pyramid Valley

The history of excavations and a re-analysis of the fauna is presented in Holdaway & Worthy, in press. Falla (in Allan et al. 1941), and Scarlett (1955) have provided previous species lists from the site. Our species list and MNI data are derived from a complete reidentification of specimens, given in Holdaway & Worthy (in press).

Glencrieff Swamp, Hawarden

Site location

Glencrieff Swamp is located on what was until 1993 the Eaves's farm (called Glencrieff), at Hawarden, now owned by Mark Wilson.

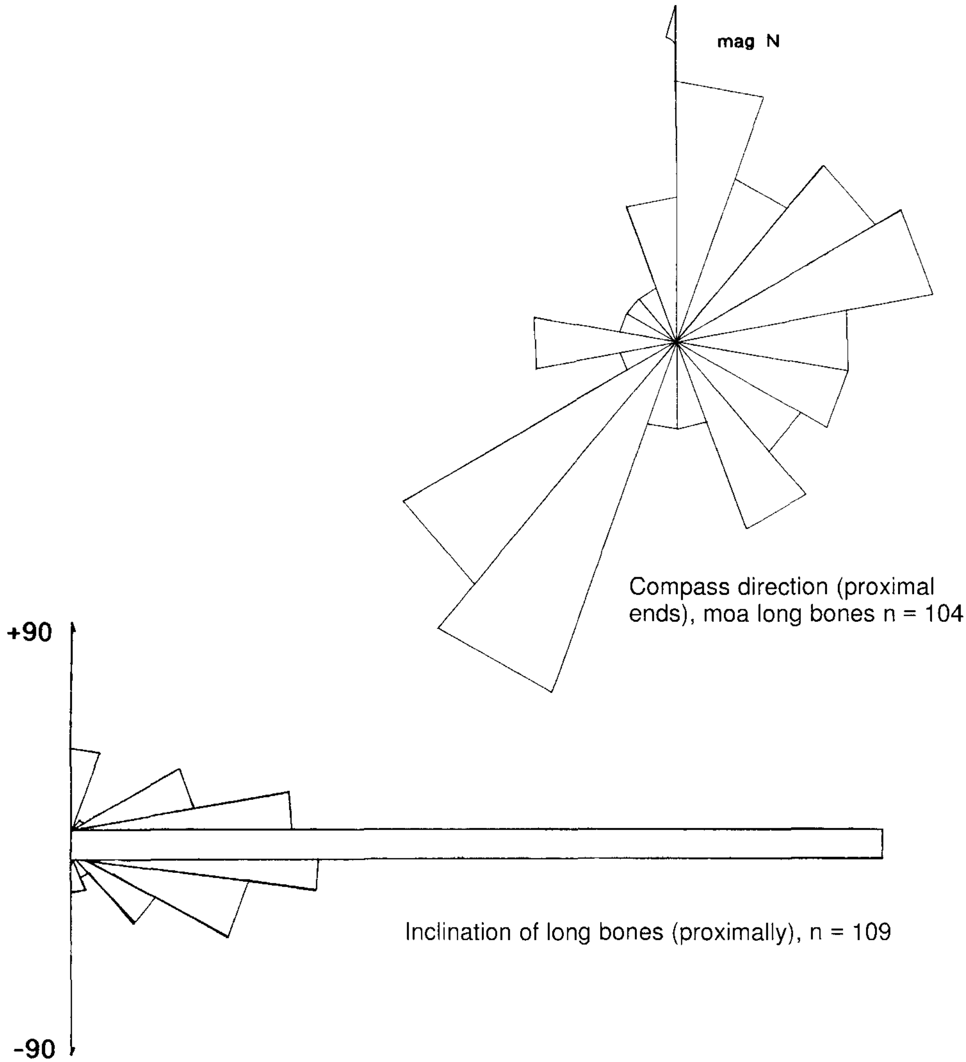


Fig. 4 Rose diagrams of moa longbone orientation (upper) and inclination (lower) in the Glencrieff site.

History of investigation

On 1 April 1971 Don Gregg, R. J. Scarlett, D. Eaves and family excavated 67 bones of a *Dinornis giganteus* skeleton from this site. The exact location is not known, but is presumably not within the area of the E1 – E2–1993/4 excavations, because if it were, disarticulated bones rather than one discrete skeleton would have been encountered.

In February 1991 Kim Eaves, son of D. Eaves, excavated two pits (E1, E2 – Fig. 6) in the site and obtained 356 moa bones. He determined where to excavate by probing. Only two bones were found in E1; the bulk were "in a heap" in E2. THW identified these in March, 1991 and numbered the collection E1 to E216 – some numbers have more than one bone associated with them.

During the period 1–4 March THW and RNH excavated squares A0–A3 and B0–B3, and over 1–4 May 1993 squares C0, E0–G0, E1, about 10 m^2 in total. We mapped the site, and determined the extent of bone by probing. On 24 March, 1994 square H was excavated so that a pollen profile could be obtained by M. McGlone.

Description of the site

The site is an isolated bog in the middle of pasture on a terrace. Grey silts overlie gravels on the terrace. The bog is very wet during winter months, and the turf surface is then very spongy to walk on. The bog is sheltered by poplar trees on two sides and a large weeping willow on another. A typical section through the bog is as follows. Pasture grew on the surface of peat about 1.2 m thick. The peat overlaid a liquid blue-grey clay which ended on a gravel base at about 2.5 m. However, in places the blue clay formed domes under the peat so the apparent peat-base was shallower. This was the case in square H near peg 1 where the base was encountered at –85 cm, and where the pollen profile was examined. If during excavations the base of the peat was ruptured, the excavation quickly filled with liquid clay.

The peat was structurally uniform except for an old surface at between 35 and 40 cm. This surface was marked by a thin white line, that during excavation was revealed as the peat above lifted easily off it. The top 70 cm of peat was relatively oxidised, and the top 50 cm occasionally had desiccation cracks extending from the surface. Below 70 cm the peat when freshly excavated was orange-brown, but oxidised to black in about 30 minutes. In the excavated area we saw only one solid plant macrofossil, a twig about 1 cm in diameter. Some of the peat appeared to consist of moss, and in places compressed sedge leaves were visible.

Taphonomy of the site

During the excavation we recorded the depth, proximal direction, and slope of all long bones. All moa bones were disarticulated except for the tarsometatarsus and phalanges of one foot. As the rose diagram of inclination shows (Fig. 4) most longbones in our excavation were lying horizontally, with their proximal ends aligned mainly northeast – south west. The first bones were encountered at –70 cm, but most were concentrated between 85 and 110 cm (Fig. 5). The site plan shows the deposit formed an arc aligned northeast – southwest, about 10 m long, which extended from the Eaves's excavation to square GO (Fig. 6). Within this arc the width of the main deposit was only about 1.5 m. Figure 7 shows bones as revealed during excavation.

We interpret these observations and the associated pollen data to make the following site reconstruction. The terrace surrounding the present bog was a tussock shrubland with *Phyllocladus* and understorey *Coprosma* spp. The terrace would have been seasonally quite wet underfoot (it is now), and trees and shrubs would have become fewer closer to the bog. Sedges probably surrounded the bog, which would have been moss-covered in its wettest places. A spring in the middle probably had a channel leading from it, with a floating moss mat covering it. The total disarticulation of the skeletons, and the orientation of most bones horizontally in the base of the channel 85–100 cm below the present surface, suggests this channel contained semi-liquid peat under the surface, allowing carcases to decompose and disarticulate. Some bones may have been pressed deeper into the mire by subsequent struggling birds.

We believe that all of the moa bones recovered from this site derive from birds that became trapped in this channel – these heavy birds were predisposed towards being mired. Apart from those of eagle and kea that were probably attracted to the bog by the mired moas, the few bones of the smaller birds found could be accounted for by the random death of individuals on or around the bog, and subsequent incorporation of their bones in the fossil deposit.

Excavations have revealed the remains of 15 adult *Pachyornis elephantopus*, 14 *Emeus crassus*, and four *Dinornis giganteus*. Probing has revealed that we have excavated most of the arc deposit, with unexcavated bones mainly lying next to squares GO, FO, EO, and some between B2–B3–H and the Eaves's excavation.

The fossil specimens from Glencrieff are listed in Table 1, and summarised to determine

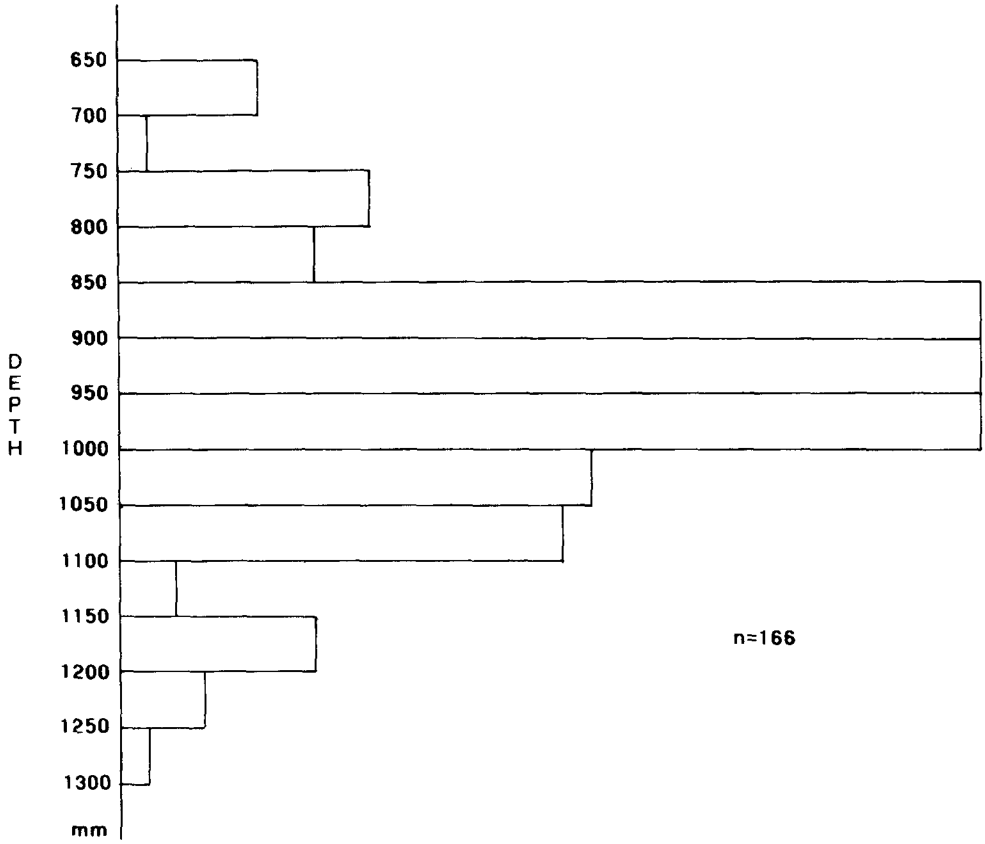
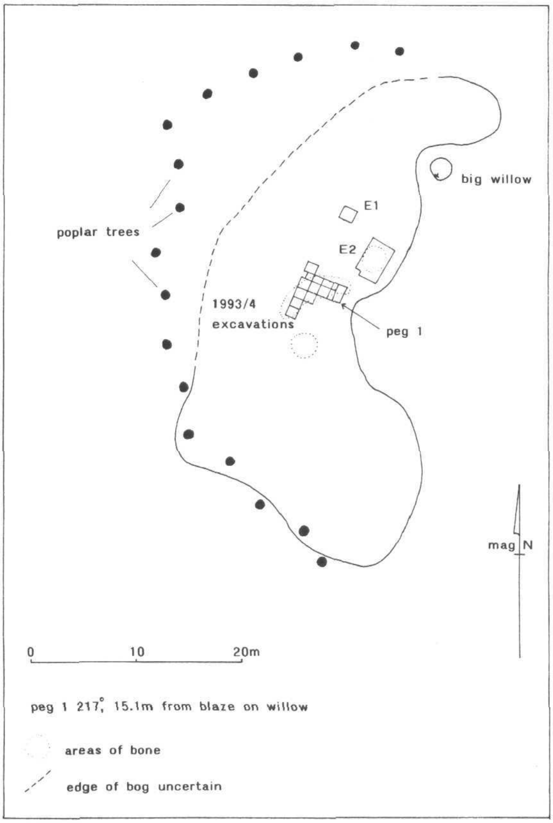


Fig. 5 The distribution of moa bones by depth below the surface in the Glencrieff site.

MNI in Table 2. Numbers of crania, pelves, sterna, femora, tibiotarsi, tarsometatarsi, fibulae, presacral vertebrae, and phalanges were totalled for each species, and expressed as a percentage of the total expected from the known number of individuals (N) present in the bog (Table 3).

The survival of elements is directly related to size. The larger leg bones and pelves are well represented while the phalanges, presacral vertebrae and crania are under-represented. Two factors have contributed to this. On three *Emeus* pelves (Sq A1/A2, A1, E1), one *Pachyornis* pelvis (Sq B2), and one *Dinornis* pelvis (Sq F0) there were puncture and rip marks to the ilia (Figure 8) which we interpret as caused by Haast's eagle killing the already mired moa (see Holdaway & Worthy 1991). A kea bone was also recovered, and as keas are known carrion feeders, it is likely they too were feeding on the moa carcases. Feeding activities by both these species could easily explain the absence of crania and vertebrae from the immediate site. The under-representation of phalanges is harder to explain, but these small bones may have moved further in the pool than the bigger heavier elements, and as a result may be scattered around the periphery of the main deposit, outside the excavated area. We can compare the proportion of larger bones in Eaves's excavation with that in ours. In the Eaves's excavation 280 bones (excluding ribs, and detached pubes and ischia) were collected, with large bones represented as follows: femora 14–5%, tibiotarsi 9–3.2%, tarsometatarsi 12–4.3% pelves 1–0.04% and sterna 4–1.4%. In our excavation 917 bones were collected (excluding ribs etc) and large bones were femora 43–4.7%, tibiotarsi 49–5.3%, tarsometatarsi 37–4.0%, pelves 21–2.3%, sterna 17–1.8%. There is little difference in proportions of femora

Fig. 6 Top – Plan of the Glencrieff site showing the position of the excavations. Right – detail of our excavations with excavated squares labelled in top, left-hand corner. Other annotations, e.g. 5P,4S,28 summarize bone distribution: this example means 5 pelves, 4 sterna, and 28 longbones were present in the square.



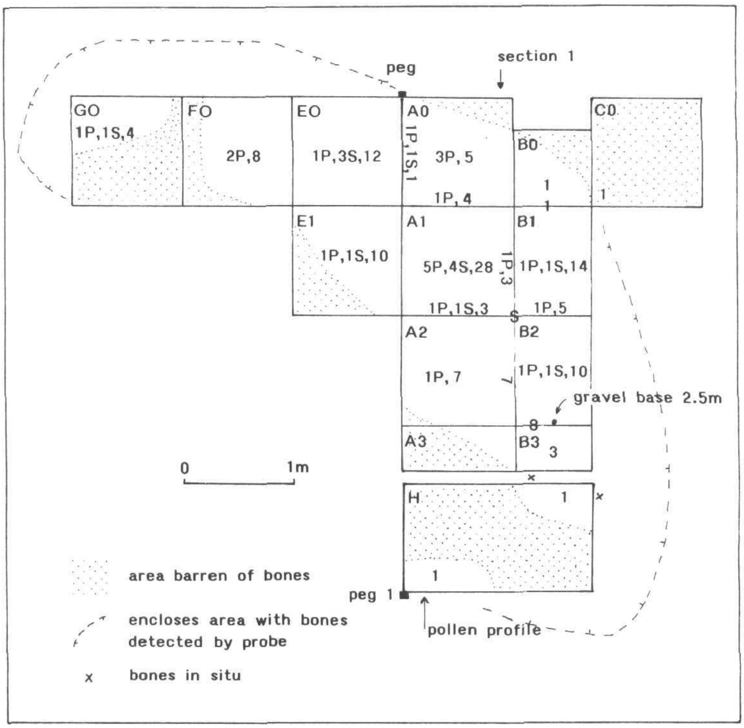


Table 1 List of moa specimens from Glencrieff Swamp. *Pachyornis* is *P. elephantopus*, *Emeus* is *E. crassus*, *Dinornis* is *D. giganteus*. MNZ S numbers refer only to the THW/RNH collections, not Eaves's collection which is tabulated parallel to the former for ease of analysis.

	MNZ S	Elements	THW/RNH	Sub-total	Eaves	Total
Pachyornis	32668	pelves	8	8	2	10
Pachyornis	32669	sterna	9	9	1	10
Pachyornis	32670	femora	11R, 13L, (1LRjuv)	24	2L 4R	30
Pachyornis	32671	tibiotarsi	8R, 12L	20	1L, 2R	23
Pachyornis	32672	tarsometatarsi	9R, 12L	21	2L, 2R	25
Pachyornis	32672.1	phalanges	associated with tmt	11		11
Pachyornis	32673	phalanges	185	185	14	199
Emeus	32674	pelves	11	11	1	12
Pachyornis	32675	fibulae	7R, 10L	17	1L, 1R	19
Pachyornis	32679	juv fem tib	Lfem Ltt	2	1 Rfem	3
Emeus	32680	crania	4	4	1	5
Emeus	32680pt	other crania bones	19	19	0	19
Pachyornis	32681	skull bones	16	16	6	22
Emeus	32682	juv cranial	6	6	0	6
Emeid indet	32683	chick	Rtt	1	8 vert	9
Dinornis	32684	#2	pel, ster, Ltmt, Ltt, vert 24–30, 18	12		12
Dinornis	32685	#1	pel, ster, LR fem, LRtt, LR tmt, LR fib	8		8
Dinornis	Eaves's	#1	LRfem, LRtt, Rtmt, 4 phal, Lfib		10	10
Dinornis	Eaves's	#2	LRtt, Lfib, LRtmt, 2 vert, metatarsal, sesamoid, 8 phal,		17	17
Emeus	32686	sterna	6	6	3	9
Emeus	32687	fibulae	10R, 7L	17	0	17
Emeus	32688	tarsometatarsi	8R, 4L	12	5L, 2R	19
Emeus	32689	tibiotarsi	13R, 12L	25	2L, 1R	28
Emeus	32690	femora	9R, 8L	17	3L, 2R	22
Emeid sp	32691	juvenile	pel, Ltt, 2Rtmt	4		4
Emeus	32696	phalanges	112	112	73	185
Emeus	32697	vertebrae	150	150	65	215
Pachyornis	32698	vertebrae	180	180	44	224
Emeus	32699	ribs, pubes, ischia	235	235	47	282
Pachyornis	32700	" "	155	155	34	189
Pachyornis		Ltmt, R tt, 5 vert, 3 ribs, 1 cranium, 3 phalanges	14 (1994)	14		14
Emeus		4 vert, 2 phal	6 (1994)	6		6
TOTAL				1307	357	1664

1R tt and 1R tmt of *P. elephantopus* from the 1993 excavations were given to Kim Eaves and are included in the totals for his collection.

Table 2 Summary of element distribution by species for Glencrieff moa bones from all collections.

Species	Elements	L	R
P. elephantopus	femora	15 (1 juv)	15 (1 juv)
	tibiotarsi	14	11
	fibulae	11	8
	tarsometatarsi	15	11
	pelves	10	sterna 10
	crania	2	mandibles 7
P. elephantopus juvenile	femora	1	
	tibiotarsi	1	
Emeus crassus	femora	11	11
	tibiotarsi	14	14
	fibulae	7	10
	tarsometatarsi	9	10
	pelves	12	sterna 9
	crania	5	mandibles 4
Dinornis giganteus	femora	2	2
	tibiotarsi	4	3
	fibulae	3	0
	tarsometatarsi	3	3
	pelves	2	sterna 2
	crania	0	mandibles 0

and tarsometatarsi, but we found relatively more tibiotarsi, pelves and sterna (larger elements), which suggests there has been some sorting along the arc.

Detailed description of the important pitfall site Waikari Cave

Description

Waikari Cave is a small phreatic cave (<60 m long) situated in a low limestone hill (Fig. 9). The present entrance to the cave is a 1.5 m vertical drop through a 0.5 m^2 hole between part of the cave roof and large fallen slabs that have collapsed from it. These slabs are extensively calcited together, so the collapse that nearly blocked entry to the cave must be dated to a few thousand years ago, certainly predating the period of deposition resulting in the fossil fauna described below. Inside, the passage development has been guided by joints aligned roughly north-south and east-west. Palaeoflow direction was downdip from the most distant point (labelled 'source of water' on Fig. 10), towards the present entrance of the cave. In times of heavy rain a small stream flows from this source towards site A where it sinks under the wall to reappear in Coot Alley and ultimately to sink in site F. In the recent past this intermittent and very low velocity stream probably flowed between A and C on the present floor, through Coot Alley, carrying fossils along the way.

The sediments in the cave are of three main types. Between the entrance and site E, a layer of subaerially deposited silt, primarily derived from roof weathering, is up to 15 cm deep (where not destroyed by trampling) indicating a considerable period of time since water flowed in this section. Where water still flows during wet periods, such as north of site A and through Coot Alley and site F, grey silts cover the floor. In other areas the floor, beneath the layer of foot-transported clay, was covered in soft calcite interbedded with subaerial weathering products. At site G this combined layer is about 10 cm thick, at I it was about 8 cm, at D about 10 cm. Beneath this subaerially derived layer there are fluvial silt deposits of unknown depth.

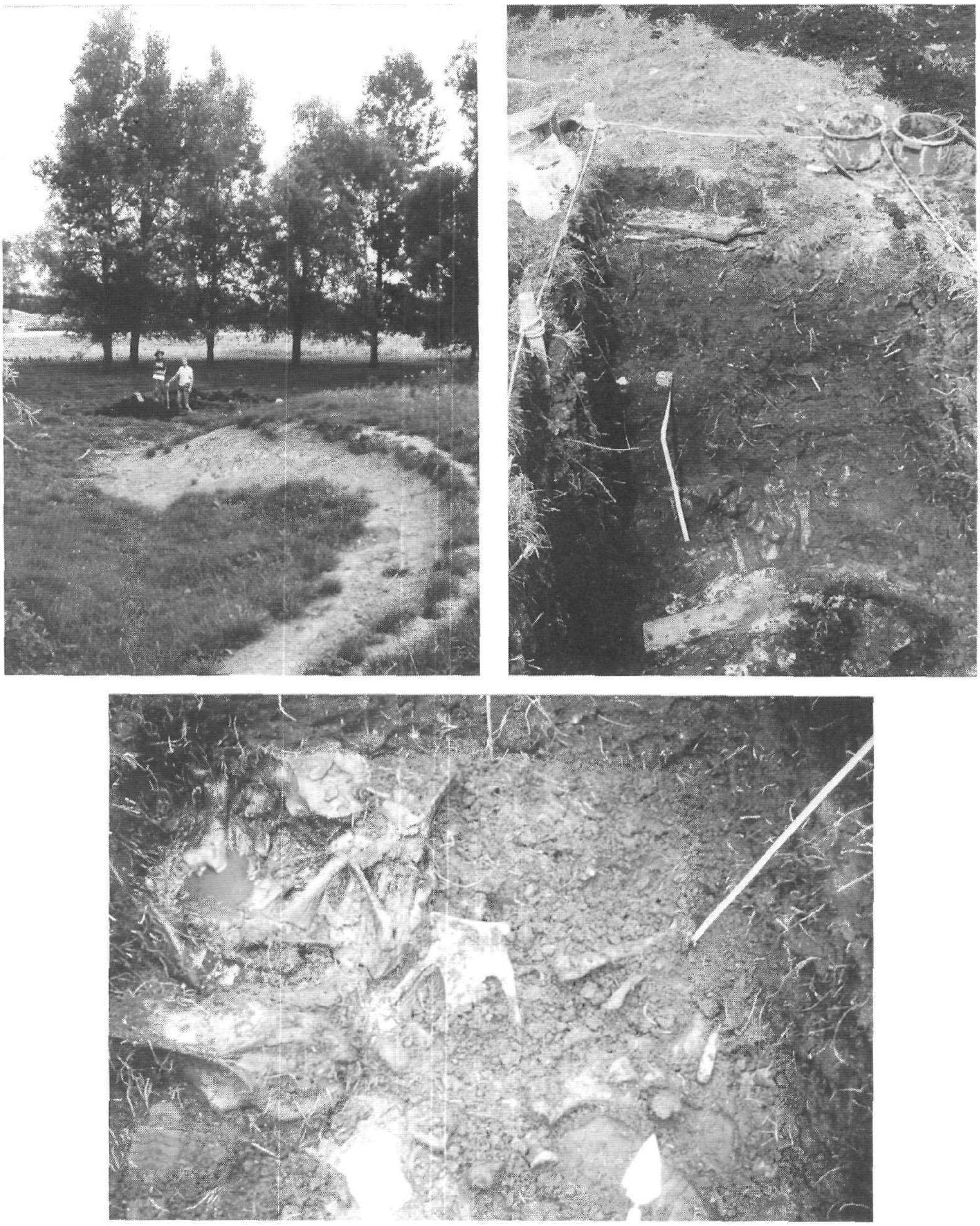


Fig. 7 General view of the Glencrieff site in March 1993 (top left). View of squares A1 towards A2 during the excavation (top right). Note the underlying liquid clay threatening to break through the floor of the excavation. The lower photograph shows *in situ* moa bones in A0. The large pelvis lower left is *Pachyornis elephantopus* and the smaller one at the top *Emeus*. Note the roots from the poplar trees

Fossil deposits

Bruce McCulloch examined the fauna of this cave in an unpublished study (McCulloch 1975). McCulloch's material was relocated only after the present study was completed, and remains uncatalogued in the Canterbury Museum. McCulloch's material listed in the systematic section was examined by THW, but the bulk of the *Euryanas* specimens remain unchecked.

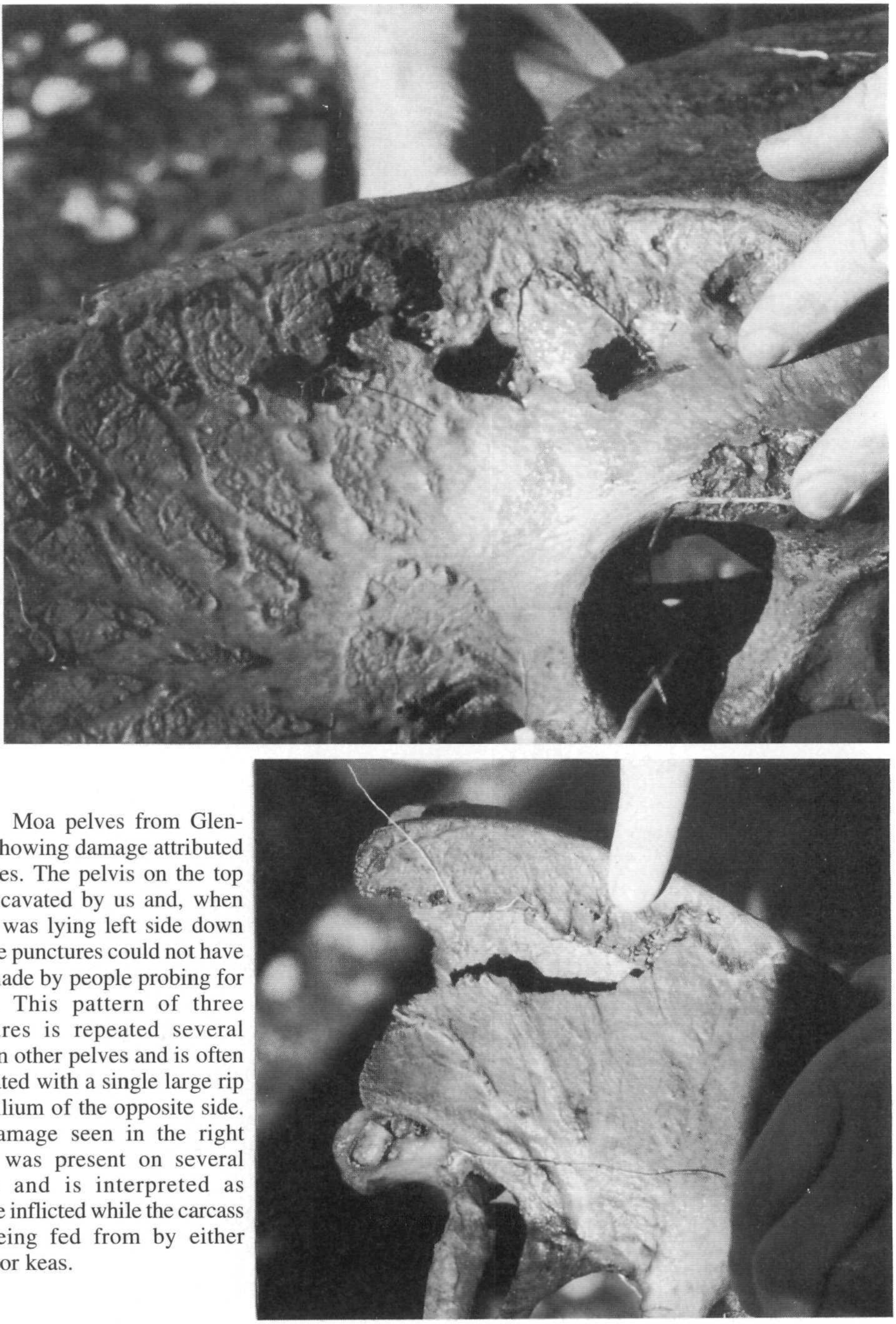
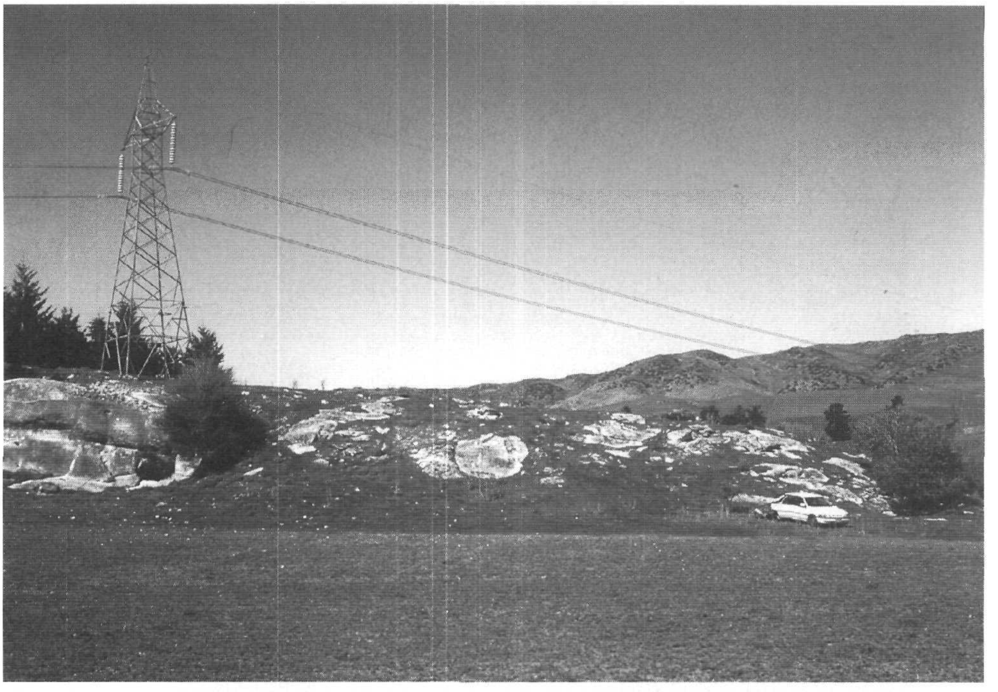


Fig. 8 Moa pelves from Glencrieff showing damage attributed to eagles. The pelvis on the top was excavated by us and, when found, was lying left side down so these punctures could not have been made by people probing for bones. This pattern of three punctures is repeated several times in other pelves and is often associated with a single large rip in the ilium of the opposite side. The damage seen in the right figure was present on several pelves and is interpreted as damage inflicted while the carcass was being fed from by either eagles or keas.

The following descriptions are from our examination of the site/s. The fossils found are listed in Appendix 5, with those recorded by McCulloch for comparison.

In the deep subaerially deposited silts at site J, eggshell was found up to 10 cm below the surface, and assumed by McCulloch to be Finsch's duck *Euryanas finschi* shell. But, as birds would not have nested in a trap site, we consider this identification is probably wrong. The shell is 0.36–0.42 mm thick, too thick for Finsch's duck which is similar in size to grey duck



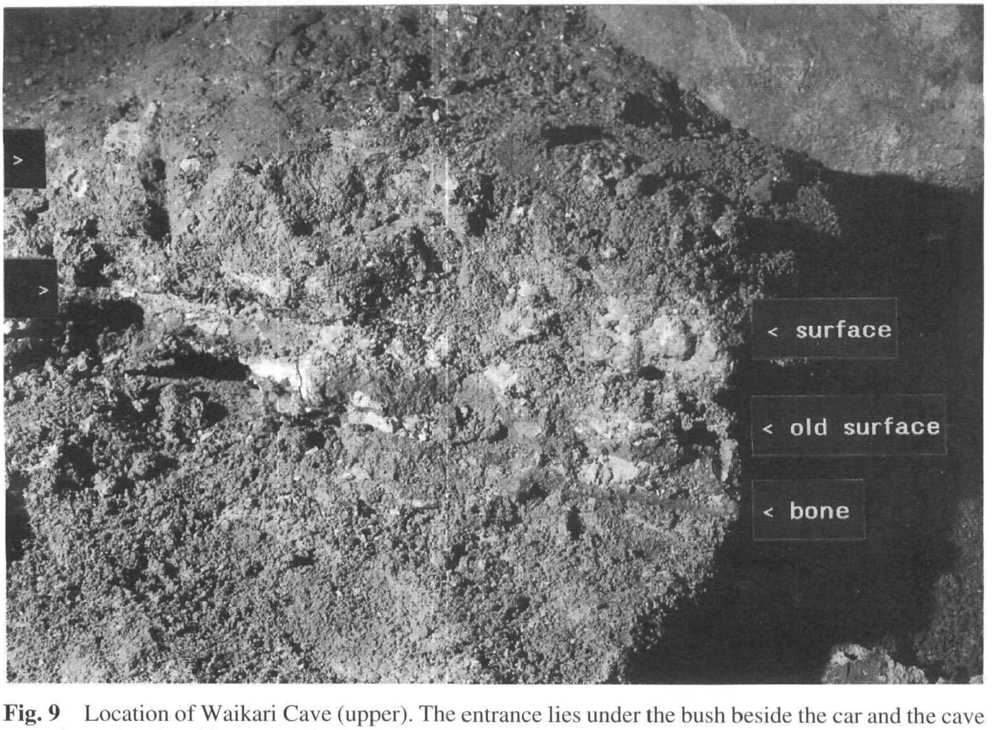


Fig. 9 Location of Waikari Cave (upper). The entrance lies under the bush beside the car and the cave extends under the ridge towards the pylon. The lower figure shows fossil site I. The original 'old surface' (arrowed) was marked by a thin charcoal lens crushed into a thin (1 cm) soft calcite band. The overlying dirt is presumably the result of McCulloch's excavations in an adjacent wall-pocket or the nearby site F. The bone visible in the photograph is a coot humerus and was adjacent to the bone dated from this site.

A. superciliosa, assuming Finsch's ducks had similar sized eggs. Eggshell which is almost certainly of Finsch's duck from Earnscleugh Cave in Central Otago (OM Av6717), ranges in thickness from 0.28–0.32 mm, mean 0.3 mm, N = 15, providing further evidence that this Waikari shell is not Finsch's duck eggshell. Paradise shelduck *Tadorna variegata* has shell this thick, and regularly nests in holes in banks or cliffs today. Its shell has been found at other fossil localities, for example Annandale (Worthy & Holdaway 1995), and in the Waikari area in the Falcon site at Timpendean (including a whole egg), and several others

Table 3 Percentage survival of adult skeletal elements in Glencrieff Swamp from the combined collections of THW/RNH and Eaves. CRAN crania, PEL pelves, TT tibiotarsi, TMT tarsometatarsi, FIB fibulae, VERT presacral vertebrae, PHAL phalanges and metatarsals n = 30 for *Pachyornis* and *Dinornis*, n=28 for *Emeus*, STN sterna. Pael *Pachyornis elephantopus* n= 15, Emcr *Emeus crassus* n= 14, Digi *Dinornis giganteus* n= 4.

	CRAN	PEL	FEM	TT	TMT	FIB	VERT	PHAL	STN
Pael	13.3	66.6	93.3	83.3	86.7	63.3	55.3	46.7	66.6
Emcr	35.7	85.7	78.6	100	67.8	60.7	56.9	46.2	85.7
Digi	0	50.0	50.0	87.5	75.0	37.5	10.0	28.1	50.0

Table 4 Species recorded from Waikari Cave by Bruce McCulloch and J. Yaldwyn (McCulloch 1975), ÷ = species indicated to be present, but bones not listed, and Worthy & Holdaway in 1993 for Coot Alley, Site I, and Site G. THW examined most of McCulloch's collection in December 1995, including all material identified as other than *Euryanas*, to obtain the list headed 'MC colln checked'. THW did not see most of the *Euryanas* bones.

	McCulloch & Yaldwyn	MC colln checked	Coot Alley	Site I	Site G/J
Moa sp. indet	–	1/1	1/1	–	–
Aptornis defossor	38+/1	38+/1	10/1	–	–
Fulica prisca	28/3	25/2	151/7	41/2	1/1 – G
Porphyrio hochstetteri	–	1/1	10/1	–	–
Gallirallus australis	÷	1/1	–	–	–
Gallinula hodgenorum	÷	15/3	44/6	3/1	–
Strigops habroptilus	3/1	1/1	1/1	–	–
Cyanoramphus sp.	–	1/1	–	–	–
Hemiphaga novaeseelandiae	3/1	2/1	–	–	–
Callaeas cinerea	15/3	18/3	–	–	–
Euryanas finschi	1929/63	uncounted	227/14	25/2	32/3 – G
Anas chlorotis	–	2/1	–	–	–
Apteryx owenii	–	–	1/1	–	–
Apteryx sp. juv	÷	2/1	–	–	–
Poliocephalus rufopectus	÷	6/1	–	–	–
Coturnix novaezelandiae	÷	6/2	–	–	–
Coenocorypha cf. *aucklandica*	÷	3/2	–	–	–
Aegotheles novaezealandiae	÷	5/3	1/1	–	–
Philesturnus carunculatus	÷	2/1	–	–	–
Rhipidura fuliginosa	–	1/1	–	–	–
Xenicus sp.	–	1/1	–	–	–
Litoria sp.	÷	2/1	–	–	–
Hoplodactylus sp.	÷	1/1	–	–	1/1 – J
Rattus exulans	÷	5/1	–	–	–
Tadorna variegata	–	–	–	–	shell – J

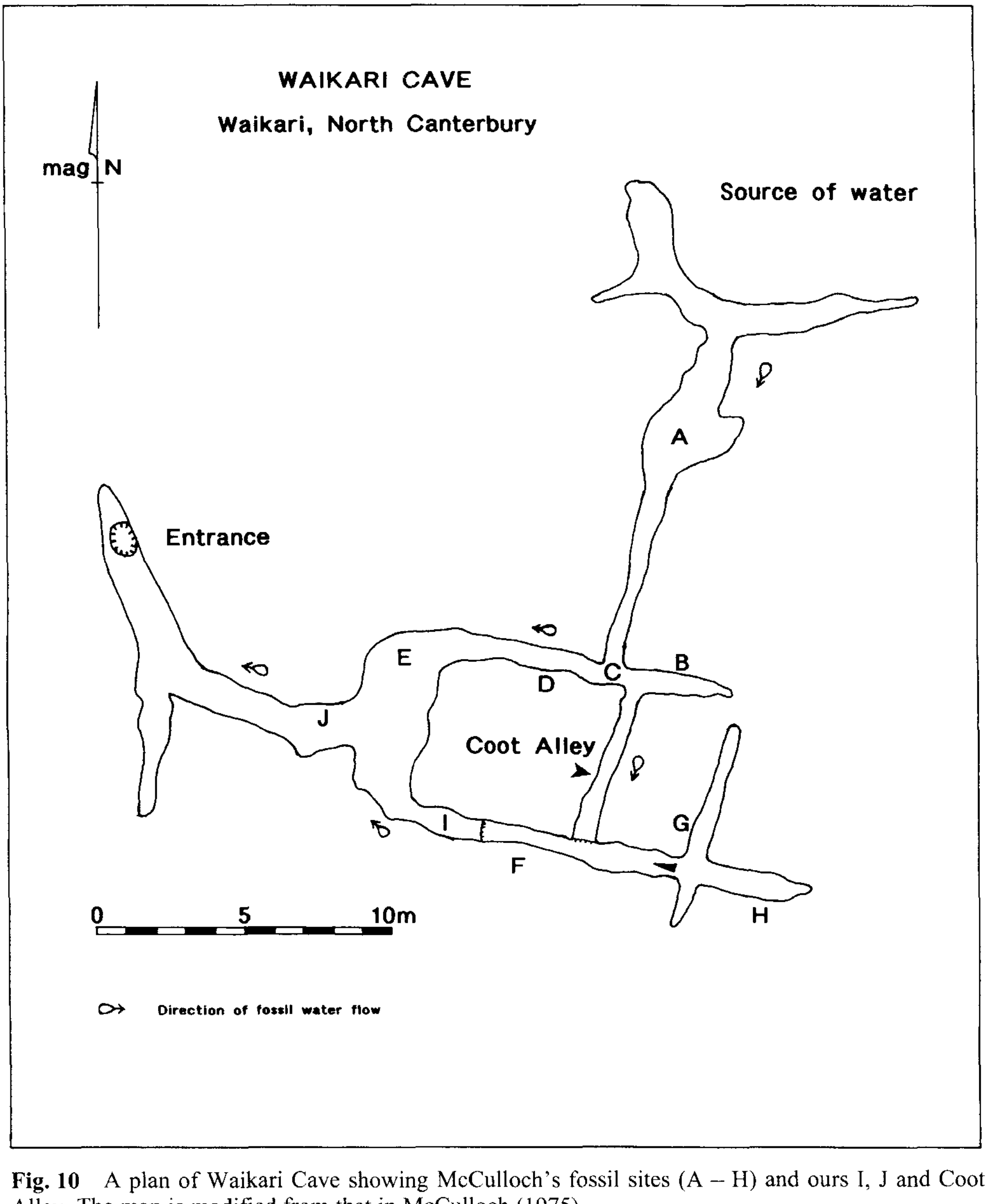


Fig. 10 A plan of Waikari Cave showing McCulloch's fossil sites (A – H) and ours I, J and Coot Alley. The map is modified from that in McCulloch (1975).

(see listing under *Tadorna*). The nature of the present entrance is such that a shelduck could jump and fly in and out, but for flightless ducks this would not have been possible.

At the entrance of the site G passage and at site I, we excavated undisturbed deposits that had fossils only on top of the fluvial silts and incorporated in the subaerial deposits of both silt and calcite (Fig. 9). At sites A, B, C, D the undescribed excavation pits made by McCulloch were visible. They indicate that only 10–15 cm depth was excavated, suggesting that fossils in these sites were also primarily on the surface of the fluvial silts, or reworked

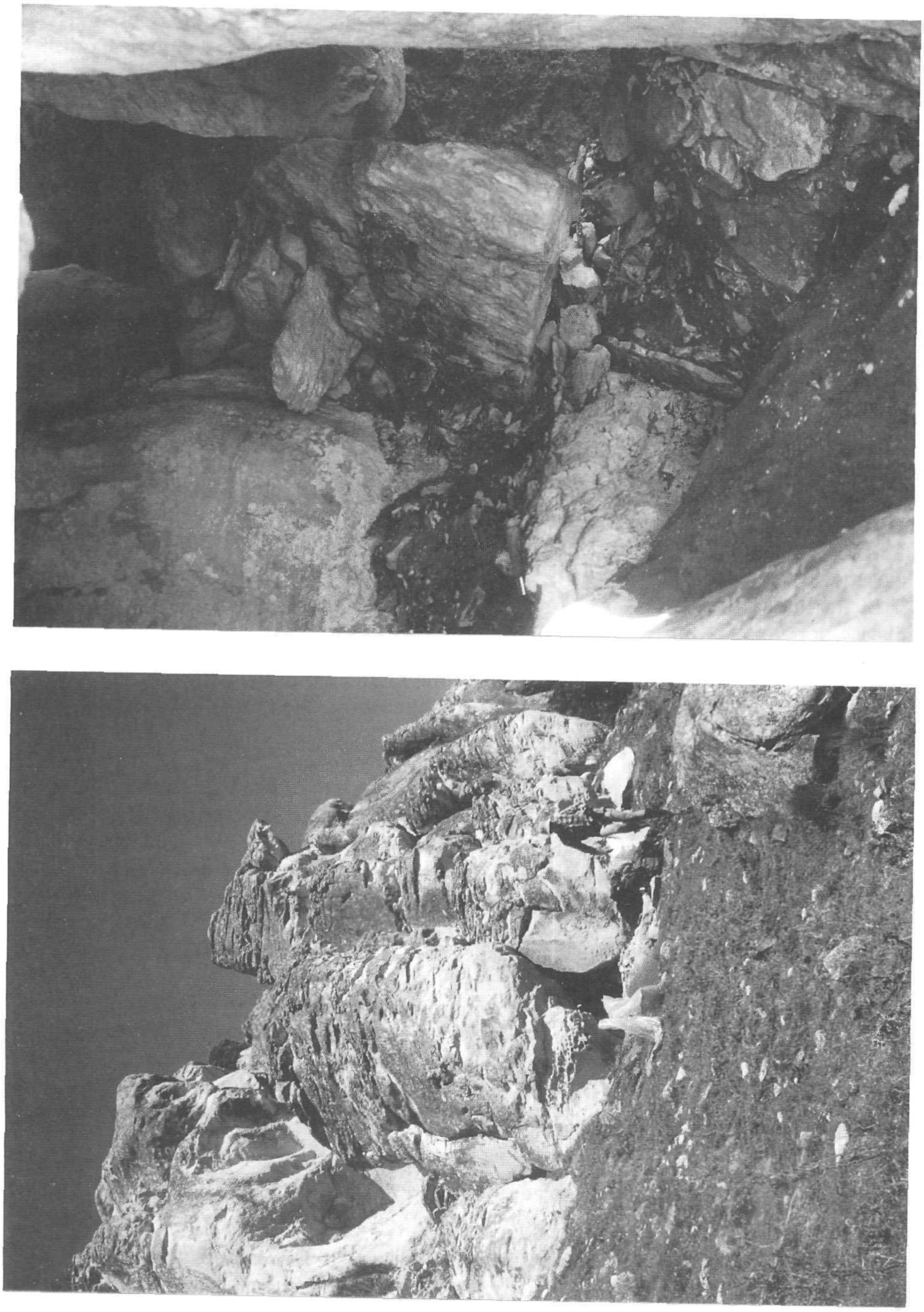


Fig. 11 General view of the Ardenest site. The interior was jumble of rocks around which the fossiliferous sediment had accumulated (right).

into the top few centimetres by the intermittent flow from the source. McCulloch's figs 9, 10 and 11 support this interpretation. At the undisturbed site I, fossils were clearly referrable to just a few individuals. We interpret the deposit as accumulating by the successive deaths of trapped birds which each disturbed the bones of their predecessors, breaking some. This explains why we found fewer vertebrae and other easily crushable elements, and most others were lying against the wall or in alcoves where disturbance was least.

In the extremely productive Coot Alley the top layer was 1–2 cm of powdery calcite. This rested on 15–20 cm of grey friable silt under which was a grey hard compacted layer. The fossils were in the friable grey layer. We excavated this passage to a depth of 30 cm. The silt was deposited by the intermittent stream flowing from the source. Fossils were of birds that died either in Coot Alley or at some point upstream, such as sites B, C, D, or A. Site A was where most, and all larger bones, of the adzebill *Aptornis defossor* McCulloch recorded were found. We found phalanges, vertebrae, the right tarsometatarsus, and a scapula in the sediments of Coot Alley. Bones that were washed right through Coot Alley were eventually deposited in the soak pit where the stream disappeared at site F. The low velocity of the water responsible for this transport is indicated by the fine grained sediments in Coot Alley, and the observation that heavier bones were preferentially left behind, so that a majority of bones in site F were Finsch's duck, while the larger coot and takahe bones remained in the Alley. Bones with greater water flow impedance potential, such as crania and pelves, were under-represented in Coot Alley.

In summary, the fossil deposits are entirely consistent with the hypothesis that the bones accumulated after birds fell into the present entrance and were trapped. No point is more than 30 m from the entrance, so whereabouts they died is not significant. Skeletons were disturbed by subsequent trapped birds, mainly by trampling, and were secondarily transported towards site F by the intermittent stream. The hypothesis of pitfall-trapping as the ultimate source of fossils is supported by the species composition, as the majority of species present were flightless, e.g. Finsch's duck, extinct coot, takahe, Hodgens' rail, kiwi, and adzebill. Kakapo, represented by one individual, could probably climb in and out of the entrance. The owlet-nightjar, represented by three individuals, was a habitual cave user.

Age of the deposits

Two samples, each comprised of several *Euryanas finschi* bones from Bruce McCulloch's excavations, were dated by the gas-counting radiocarbon method (McCulloch & Trotter 1979). The Rafter Laboratory re-calculated the data for us using the most up to date equations, and obtained the following ages for the samples: 1888 ± 93 yrs BP (NZ1723) and 1043 ± 58 yrs BP (NZ4166). These differ only slightly from those published by McCulloch & Trotter (1979). However, as these were composite samples of several bones, these dates are the mean age of all included bones. To obtain further information on the age of the Waikari deposits we dated two more samples.

One takahe *Porphyrio hochstetteri* bone from the base of the fossiliferous layer 2 in Coot Alley at –20 cm was dated as 3,480 ± 100 yrs BP (NZA4612), and a coot *Fulica prisca* bone from the layer immediately below the calcite layer at site I (Fig. 9) was 3,837 ± 71 yrs BP NZA4613). These results suggest that NZ1763 and NZ4166 might under-represent the age of the deposits, but nevertheless suggest a Late Holocene age for most of the material in the cave.

Detailed description of important predator sites

Ardenest

The limestone in Waikari Valley dips to the southeast. It is exposed as a row of low northwest-facing bluffs that have been cut by southeast-flowing streams to form six segments, here referred to as 1 to 6. The three more easterly sections (4–6) were too low and broken to have fossil sites, but sections 2 and 3 (on Arden farm) were up to 10 m high and fissured. Rockshelter #1 was on section 3 in the highest part of the cliff. Rockshelter #2 was under an isolated large limestone rock about 100 m from the section 3 bluff. Rockshelter #3 was in section 2 about 200 m from its western end. A small cave extended about 4 m into the cliff, and a sparse fauna was obtained from dry sediment on its floor.

Ardenest was within the largest outcrop in the section 3 bluff (Fig. 11). A large section of the bluff has split apart, and partially separated from the main outcrop to form a cave within the outcrop. The floor was about 0.5 m wide, and rose up over broken rock for about 4 m. Bones were initially found within the sediment.

About 1 m^3 of material was removed from the floor and processed at the entrance. Limestone rocks were removed before the sediment was sieved through a 6.0 mm sieve. Faunal material retained on the sieve was sorted from the sediment immediately. The material that passed through the sieve was resieved through a 1.5 mm mesh and the retained portion taken home for later sorting. A total of 45 litres of concentrate was collected.

There was no discernible stratification to the site, and the jumbled large rocks around which the sediment had accumulated made excavation by spit impossible. However, we had the impression when excavating in some cracks that kiore bones were more frequent towards the top, and birds more so towards the bottom. Rabbits had warrens within the site, and had no doubt caused much bioturbation of sediment. Sheep used the lower part of the site for shelter, and were effectively eroding material from this part of the site.

In the roof about 6 m above the floor we found a mass of dried vegetable matter within which was more faunal material, obviously of relatively recent origin since the bones lacked signs of weathering and some had ligaments attached. We collected some of the material (MNZ S33620), which we interpret as part of a laughing owl nest, and within it found a few laughing owl feathers (MNZ S33621) and bones of prey species. The nest was primarily made of sedge tillers, as Smith (1884) recorded for sites in South Canterbury. The bones within the nest area were mostly kiore. Not all of the nest material was collected. When THW climbed into the roof and examined the surface of the chamber where the nest had been, no sign of it could be seen, only recent soil and detritus. We did not disturb this chamber.

The Ardenest bone fauna was dominated by kiore, many of which had the characteristic features of predator assemblages, such as greenstick fractures, and digestive erosion features (Andrews 1990; Worthy & Holdaway 1994b). These features are illustrated by bones from the Falcon site (Fig. 12). The above observations suggest the deposit was accumulated by laughing owls.

Falcon site, Timpendean

This site is a small cavity entered via a slot, *c.*0.5 m wide and 0.2 m high, 1.5 m above the base of northwest-facing bluffs in a shallow valley (Fig. 3). One metre in, a chamber 0.5 m high and wide had abundant sediment accumulated on the floor. One complete egg and numerous fragments of *Tadorna* eggshell were present in the sediment, indicating nesting in this site by shelducks. The fossil bone fauna was dominated by those of kiore. Because a falcon bone and worn allochthonous stones considered to be rangle stones (stones ingested by falcons to aid digestion) were present, we first thought the site was a falcon nest site. However, some owls ingest stones in the same manner as falcons – Marples (1942) found stones up to 5 mm diameter in the stomachs of 13 out of 242 little owls *Athene noctua* – so perhaps *Sceloglaux* also ingested stones.

In an attempt to see whether patterns of damage better matched known laughing owl deposits (Worthy & Holdaway in press), or falcon deposits (Worthy & Holdaway 1995), Table 5 compares the survival of different elements. The number of 'selected bones' per individual [(femora + tibia + humeri + ulnae + radii + scapulae + innominates + maxillae + mandibles)/MNI] is higher than that recorded from either a definite falcon site on Annandale, or the owl site on Takaka Hill. Also, the percentage survival of the predicted minimum original number of elements is markedly higher than from in the Annandale sites, and higher than from the owl site on Takaka Hill. For kiore bones the percentage tooth loss from maxillae and mandibles is as high as in the falcon sites on Annandale and the laughing owl

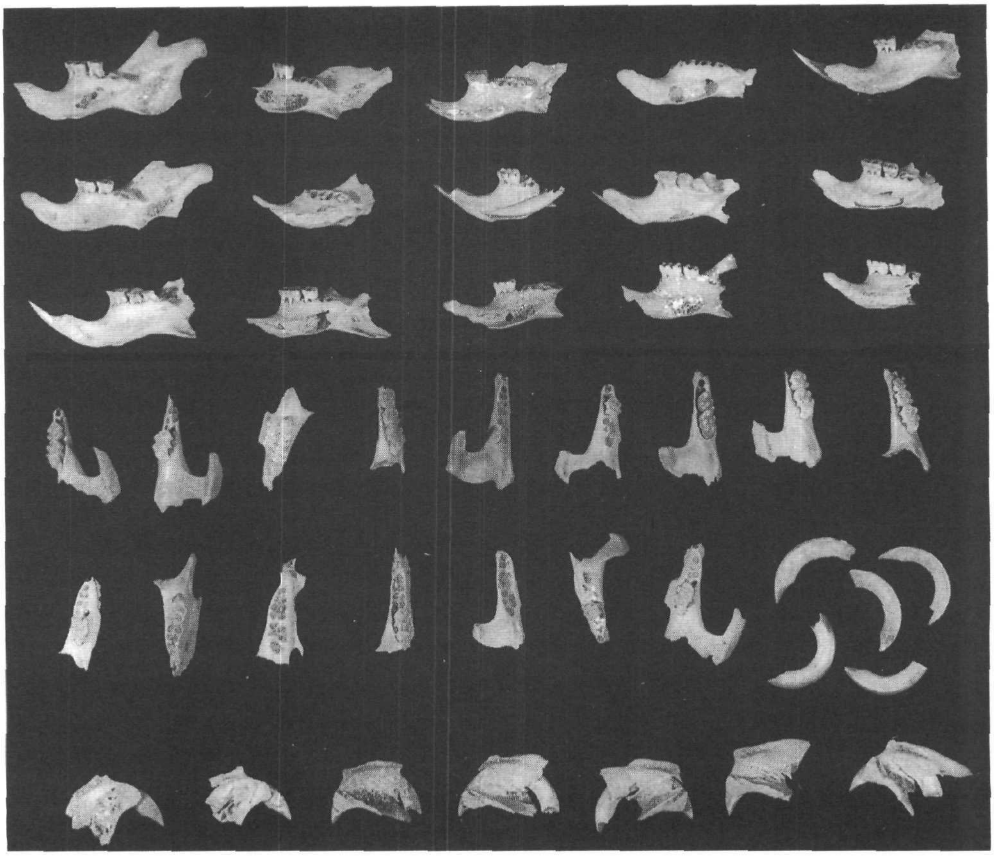


Fig. 12 Examples of kiore bones from the Falcon site showing typical damage found in owl-sites. The upper three rows are right mandibles – note the broken rami and fenestrated central area exposing the incisor. Rows four and five show maxillae and five upper incisors. The lower row shows nasals with upper incisors *in situ*.

site on Takaka Hill, except for mandibular incisors, where there were noticeably fewer losses in the owl site on Takaka. Mandibles and maxillae found in the Timpendean site are shown in Fig. 12 to illustrate the patterns of damage present. Characteristic predator damage to mandibles includes the loss of the ramus, and digestive thinning to expose the incisor. Upper dentition is represented by numerous loose upper incisors, and numerous maxillae that are broken to varying degrees, often with loss of teeth. Nasals with *in situ* incisors are rare.

Falcons tend to nest on ledges or shallow cavities on cliffs or rock-faces that afford good views of the surrounding area. The Timpendean site offers no views, and the nest would have been virtually in the dark. The presence of matai seeds in the deposit also suggests that this gully probably supported matai forest in the last few thousand years, similar to that which existed around Pyramid Valley a few kilometres to the southwest (Moar 1970). Therefore, the above comparison suggests to us that the Timpendean site was primarily accumulated by laughing owls. The single falcon bone's origin is unexplained, and shelducks nesting in the site have probably caused substantial additional breakage to the predator-accumulated bones by trampling.

P. Lamb's property

P. Lamb's owl site was in a crevice running into the base of the large cliff over which the

Table 5 Analysis of Kiore remains at several predator sites. 'Timp' = Falcon site, Timpendean; 'Lambs' is the main predator site at M33 889023 on Lambs property; 'Gowan Hills' is the predator site from that station; A #1 and A #2 are falcon deposits from ledges on Lions Head Bluff, Annandale, Mt Cookson (Worthy & Holdaway 1995). Predator Cave is on Takaka Hill (Worthy & Holdaway 1994a). %MNI = the number of surviving bones divided by the expected number derived from MNI. For example, 133 femora are recorded at Timpendean. A MNI of 206 means a minimum of 412 femora were available, so %MNI = 133/412 *100 = 32.28. In an effort to reduce the effects of collecting bias and weathering, a statistic was made of the "total selected bones" = femora + tibia + humeri + ulnae + radii + scapulae + innominates + maxillae + mandibles. Under trampling o = owl, d = duck, f = falcon, *P* = possu.

Site	Timp.	Lambs	Gowan Hills	A #1	A # 2	Predator Cave
Predator	owl	owl	owl	falcon	falcon	owl
MNI	206	63	227	126	230	55
No bones	3214	1153	3001	1044	1378	505
Total selected bones	1527	631	454	252	862	311
Total No teeth	1548	555	1551	797	1267	515
No bones / ind.	15.6	18.3	13.2	8.3	6.0	9.2
No select bones/ ind	7.4	10.0	8.3	4.9	3.7	5.6
% MNI						
Femora %MNI	32.3	43.6	30.6	33.3	25.4	21.8
Tibia %MNI	61.2	59.5	36.1	31.7	24.8	29.1
Humeri %MNI	55.6	87.3	87.9	52	39.6	48.2
ulnae %MNI	74.1	75.4	69.8	23.8	21.1	32.7
radii %MNI	27.2	23.0	29.5	7.9	6.9	12.1
scapulae %MNI	23.8	37.3	26.9	9.1	8.7	17.3
innominates %MNI	34.7	21.4	31.0	21.4	13.9	11.8
maxillae %MNI	27.7	62.7	42.9	19.4	19.6	44.5
mandibles %MNI	34.2	90.5	59.7	45.6	27.4	66.4
bullae %MNI	13.1	12.7	27.3	9.1	4.8	10.9
crania whole n	0	1	0	2	0	0
nasals n	9	15	38	1	1	0
% No of bones						
metatarsals	19.0	8.9	7.7	11.3	8.7	6.1
talus + calcaneum	7.4	6.1	3.8	5.0	2.6	2.6
presacral vert	8.9	14.1	16.2	13.3	18.1	15.8
caudal vert	15.2	13.3	4.2	8.9	6.4	11.5
loose molars n	541	135	179	190	319	137
loose lower Incisors	221	64	162	88	178	57
loose upper Incisors	402	125	426	246	461	103
n molars in maxillae	118	81	217	60	98	52
n molars in mand.	221	99	445	183	186	121
n Incisors in nasals	9	0	27	5	1	6
n incisors in mand.	36	51	95	25	25	39
% loss molars, maxillae	65.5	66.66	62.9	62.27	63.7	64.62
% loss molars mandibles	47.7	71.05	45.26	46.95	50.8	44.75
% loss incisors mandibles	74.5	55.26	64.94	78.26	80.2	46.57
Site type	small cave	crevice	crevice	ledge	ledge	cave roost
Trampling	yes o,d	yes, o	yes, o	yes, f, d	yes, f	no
substrate	dry	dry	dry	dry	dry	wet [1]
duck nesting	yes	no	no	yes	no	no

Footnote

1. The lower survival of bones in Predator Cave, Takaka Hill, compared with in the Waikari owl sites is almost certainly due to a combination of two factors: 1. the wet substrate would have resulted in more weathering of bones, and this, combined with the wet-screening process used to recover the material, would have destroyed some elements; 2. the uppermost layer in which most of the rat bones were present had been burnt.

Fig. 13 Cliffs beside the state highway at the north end of Weka Pass showing the location of Rabbit Warren Cave (arrowed).

power lines pass. The entrance was sunny and dry, sheltered by a large overhang that was open to the northwest. Sediment from the floor of the first two metres of crevice was sieved at the entrance to remove fine dust (<1.5 mm) and rocks. A 11.5 litre concentrated sediment sample so obtained was later sorted in the laboratory. We interpret this as a laughing owl site for the following reasons: greenstick fractures and digestion features indicate a predator; the degree of damage to bones (as indicated by high proportions of surviving bones, and high values for 'number of selected bones per individual') is much less than in falcon sites (Table 5); a high proportion of the prey are nocturnal; and the site location is characteristic of laughing owls (Worthy & Holdaway 1994b; in press).

Rabbit Warren Cave is in the cliffs adjacent the highway in Weka Pass (Fig. 13). The cave is located about 5 m from the top of the bluffs, and is an old, horizontal stream channel, about 0.5 m wide and initially 1.5 m high. The roof lowers toward the floor inside the entrance, and after about 6 m into the cave, the passage is less than 0.5 m high. The floor of the cave had dry, dusty, loose soil on the surface, which had been extensively burrowed by rabbits beyond 6 m from the entrance. This dry matrix was collected from the 3 to 6 m zone and sieved at the cave entrance. The section of floor following the first corner past the entrance was excavated to 0.5 m deep. Below about 0.3 m the substrate was fluvial in origin (coarser sediment containing rounded mudstone pebbles), and a *Pachyornis* mandible was collected from this zone.

The fossils collected from the loose upper sediment, with the exception of the vagrant blackbird, were considered to be prey-remains of a laughing owl for the reasons outlined above.

Gowan Hills

The Gowan Hills predator site was at 180 m in a dry crevice in a cliff (Fig. 14), facing west. Unstratified sediment was excavated from between the blocks on the floor of the crevice, sieved through a 1.5 mm sieve to remove fine dust with a high organic content (*c.* 80% of bulk), and 15 litres of concentrate was taken for laboratory sorting. Rat bones dominated this sample. On a second visit to the site on 4 September, 1994, a small deposit at the base of the cliff below the crevice was discovered. The sediment was consolidated loess and limestone clasts, from which about 15 l was collected and wet-sieved to give 2 l of concentrate. That the bones were predominantly those of birds, plus only a few rat bones, suggests the lower deposit was older than the sediment within the crevice.

The fauna of the younger, within-crevice deposit, was dominated by kiore bones, many of which had the characteristic features of predator assemblages, such as greenstick fractures and digestive erosion features (Andrews 1990; Worthy & Holdaway 1994b). These features were similar to those shown by bones from the Falcon site Timpendean (Fig. 12), and other sites interpreted here as accumulated by laughing owls. The high 'number of selected bones per individual' (Table 5), high proportion of surviving long bones, and low percentage loss of incisors from mandibles are not typical of kiore bones in the falcon deposits investigated on Mt Cookson (Worthy & Holdaway 1995). These taphonomic considerations plus the faunal composition – most species are/were nocturnal, and the site's location in a crevice low on a cliff – lead us to conclude that the deposit was accumulated by a laughing owl.

Along the cliff from the owl site there are remnant outcrops of a coalluvial deposit of loess and limestone clasts that have accumulated under the cliffs. Molluscs were common (see appendix) and a few bones were found (Appendix 5, Fig. 15).

Euan Murchison's Rockshelter

This rockshelter lies under a large isolated outcrop of limestone (Fig. 16). R. Scarlett and R. Kennington excavated the site in 1961 obtaining the CM fauna listed herein. They considered the site to be archaeological in origin, from the oven stones, charcoal and the freshwater mussel shells found there (Challis 1994; B. McCulloch pers comm to THW 1993).

McCulloch (1994) reported that *Aegotheles novaezealandiae* bones from an archaeological site was evidence that this species survived into the Polynesian period. The evidence was that this species was found in a (unspecified) rockshelter at Weka Pass. She listed associated species, as named by Scarlett (1969), from which we infer that the site was Euan Murchison's Rockshelter. McCulloch (1994) states that she visited this shelter with M. Trotter and found an archaeological deposit on its floor, at a depth of 15–25 cm, and from this inferred that Scarlett's collection was all derived from this layer.

When we visited the site in 1993 we noticed a small cave extending up under the boulder at the uphill end of the shelter (Fig. 16), and in sediment below this we found bones of rats and parakeets. The sediment bank still showed signs that it had been dug into. The sediment does not look to be cultural – it has no charcoal, and the bones had characteristic digestion and breakage patterns of laughing owl damage, similar to that shown in Fig. 12. In addition, we consider the bird fauna to be too diverse, and to contain species unlikely to turn up in an archaeological site. When we examined the bones, we found that many showed fracturing and digestion features typical of owl damage. Only one bone is identified in the catalogue as being specifically from the burnt layer. Therefore, we consider the fauna has a dual origin: much of it is derived from owl pellets, but some from an archaeological site.

Timpendean

This is a well-known archaeological site (Trotter 1972) that dates back to moa-hunter times. Trotter recorded that the moa they excavated had died naturally, as it had a collagen date of 1,525 ± 60 yrs BP (NZ918). The prehistoric archaeological layer was dated as 436 ± 53 yrs BP (NZ892) on sea shells, and 704 ± 41 yrs BP (NZ893) on fresh-water mussels, although the

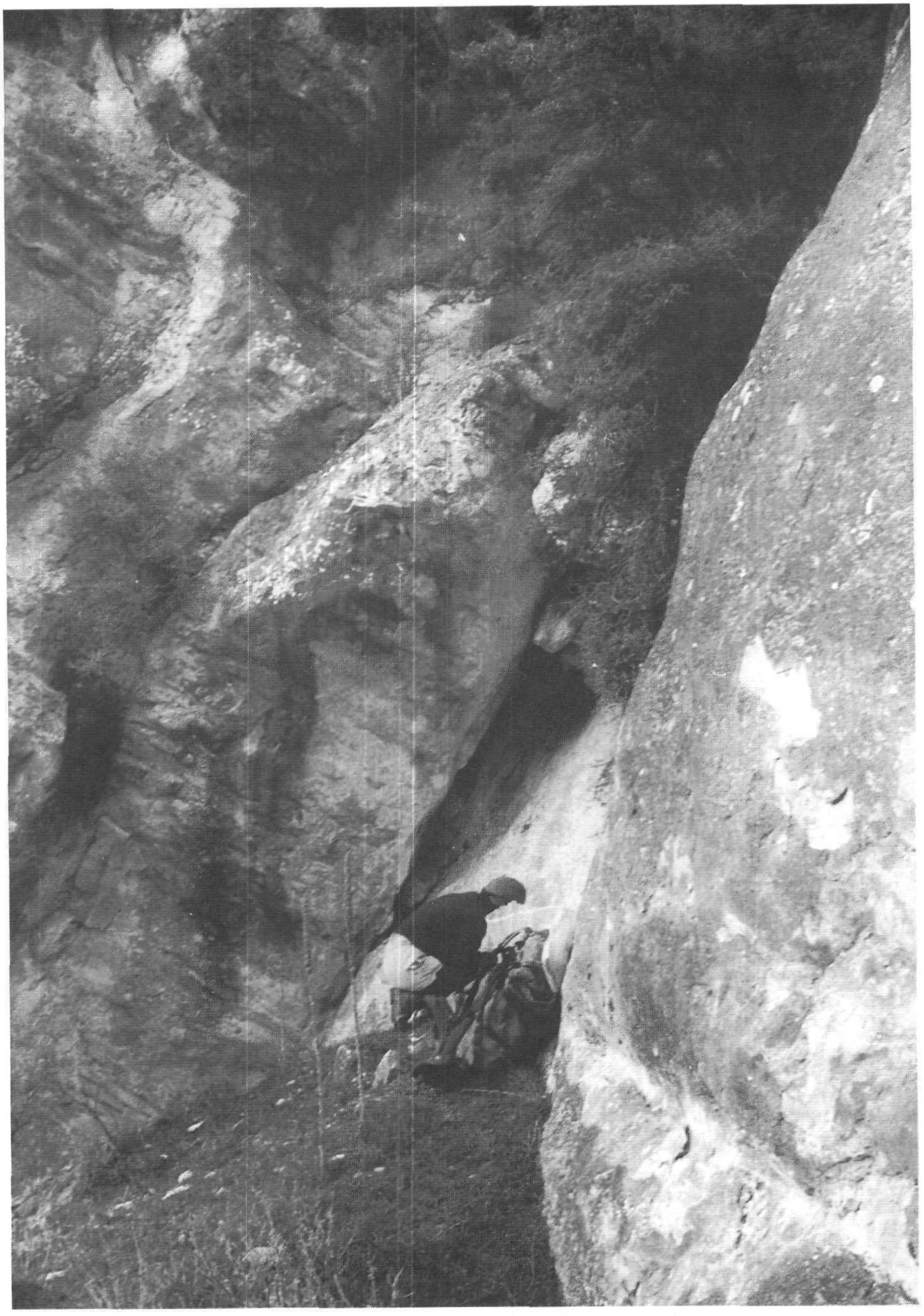


Fig. 14 A general view of the Gowan Hill owl site. The younger rat-rich material was found within the crevice. But in consolidated sediment at the foot of the crevice (at the bottom left) an older fauna was obtained from a small sample collected for wet-sieving.

Fig. 15 A moa bone *in situ* in a remnant bank of coalluvium preserved under the cliffs near the Gowan Hills owl site.

latter date probably has an inbuilt old age (Trotter 1972). The *Diomedea* bone was almost certainly transported to the site by people, but the rest could be of local origin.

The low frequency of common forest prey such as kaka, kakapo, parakeets, kiwis, and the high frequency of open country species, such as quail (which dominates the fauna), suggest this fauna dates from a time when forest clearance was already well advanced. The presence of pukeko also supports the young age for the fauna, as this species is unknown in natural sites older than about 1,000 years in New Zealand. The earliest pukeko fossils are found in Poukawa, where 410 bones were recorded from layer 1, and four from layer 2 (Horn 1983). Layer one was defined as above 7 cm above the Taupo Ash: therefore, probably all pukeko fossils postdate the Taupo Ash (c.1,850 yrs BP, Froggatt & Lowe 1990) at Poukawa. The Timpendean fauna contrasts markedly with that from Euan Murchison's Rockshelter, only a few kilometres distant, supporting our contention that the fauna from the latter site is primarily natural in derivation.

Late Pleistocene sites at Omihi Stream, Waipara

Fossils were documented from fluviatile sediments exposed in the banks of the Omihi Stream by Harris (1982), and others were collected by Brent Alloway (pers comm. 1993). Alloway (in litt, 21 Sept 1993) told THW that the top of the sequence preserves the *c.* 22,600 year old Aokautere Ash, and all fossils are older than this but less than 100 kyr. The sites on the banks of the Omihi Stream are about 10 km southeast of Waikari, and therefore provide the closest Otiran fauna with which to compare the Holocene aged faunas around Waikari.

Below we list the fauna from several sites in collections made by B. Alloway (pers. comm 1993), Mike Dickie, and ourselves. THW identified Alloway's material, which remains in his collection.

Site 1. N34/928958. *Emeus crassus* dR tibiotarsus (Alloway colln.), fluviatile sediments, last glacial maximum.

Site 2. N34/928951 (Big Loop site of Harris, 1982): THW coll. 30/9/93 – MNZ S33734, ?*Dinornis* spp., 1 thoracic vertebrae; MNZ S33728, *Euryapteryx geranoides,* 1R tarsometatarsus; MNZ S33733, *Pachyornis elephantopus,* 2 phalanges; MNZ S33736, *Aythya novaeseelandiae,* distal end plus shaft R humerus; THW coll. 2 February 1994 – MNZ S33735, *Aptornis defossor* pt pelvis; *E. geranoides,* MNZ S33730, pt sternum; MNZ S33729, R femur; MNZ S33732, moa spp. indet pelvis frags; THW coll. 13 July 1995 – MNZ S34446, *Dinornis struthoides* 1R tarsometatarsus, *c.* 2 m below terrace; MNZ S34448, *Pachyornis elephantopus,* 1 phalange, about 5 m below terrace; MNZ S34449, *Euryapteryx geranoides* 1L tibiotarsus, about 3 m below terrace.

Harris (1982) gave the following Fossil Record Numbers to layers within this site – N34/f51, N34/f63, N34/f64. THW collected fossils from several places within the 100 m length of exposures in this site. The *Euryapteryx* bones were found in close association about 3 m below the terrace surface. The *Aythya* humerus and the *Pachyornis* phalanges were within 2 m of the terrace.

Site 3. N34/926948 (site 6 or Moa Bank of Harris, 1982). *Pachyornis elephantopus* pelvis, LR femur, L tibiotarsus, L tarsometatarsus, 4 phalanges. Coll. by Mark Adorian, given to B. Alloway 1992; MNZ S33737 *P. elephantopus* mandible, coll THW 30/9/93; MNZ S33738 *Hemiphaga novaeseelandiae* L coracoid, coll THW 30/9/93; MNZ S33740 *Aptornis defossor* pL tibiotarsus, coll THW 30/9/93; MNZ S33739 *P. elephantopus* R quadrate, coll THW 30/9/93.

Harris (1982) assigned the following Fossil Record Numbers to the site – Upper unit N34/f57, Middle unit N34/f58, Lower unit N34/f59. The fossils THW collected came from the 'upper unit'.

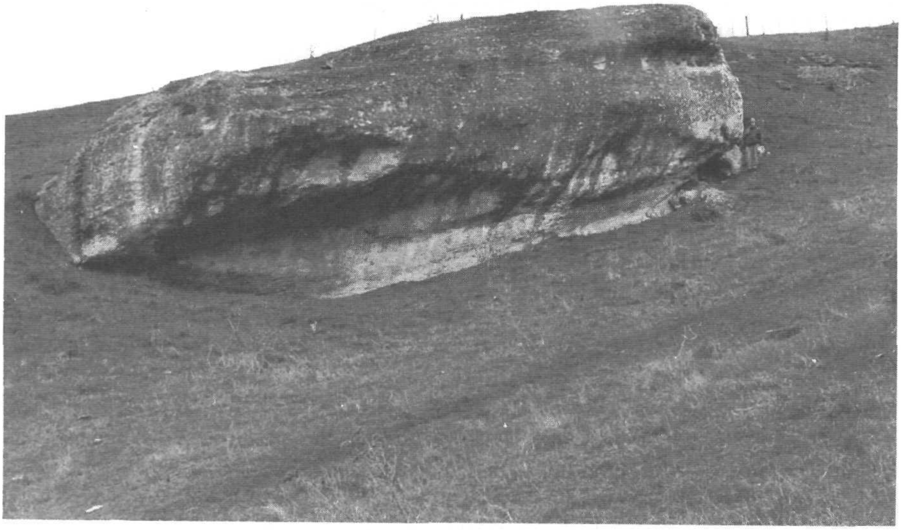
Site 4. N34/920943. *Dinornis ?struthoides* dL tarsometatarsus, 6 phalanges plus L3.1, sesamoid bone (Alloway colln.). Enclosing fluviatile sediments slightly pre-date the Aokautere Ash (c.22.6 kyr) (Alloway in litt., 21 September, 1993).

Site 5. N34/93209575 (to 50 m accuracy). This site is especially interesting as it is located in the neck of a loop of the Omihi Stream that was excavated in the 1960s or 1970s to re-route the stream and dam the loop for irrigation purposes. The section so exposed comprises about 1.5 m of loess on top of about 10 m of fluvial sediments, which are fine sands with an occasional lens of fine gravel. The Aokautere Ash (22.6 kyr BP) is present just below the loess, which therefore was deposited during the last glacial advance 20–18 kyr BP. *Hyridella* shells are found *in situ* at all levels. On 23 December, 1993 a large flood scoured the bank on the true left and revealed the disarticulated bones of a moa skeleton in a 10–15 cm layer of coarse grit or fine gravel that overlay fine sands 0.5 m above the water level. These were found and collected by the farmer Mike Dickie, who has found other isolated bones in the stream bed near this point as listed below. THW visited the site on 14 July 1995 and collected specimens from the top and bottom of the sequence.

Mike Dickie collection: *Pachyornis elephantopus*, 23/12/93, LR tibiotarsi, LR fibulae, LR tarsometatarsi, 15 phalanges, pt pelvis, sternum, 14 vertebrae, about 18 ribs (55/1); *P. elephantopus* isolated bones: LR femora, dR tibiotarsus, L fibula, 1L tarsometatarsus; *P. elephantopus* or *Euryapteryx geranoides* isolated bones: 1dL2dR femora, 1sR femora; *E. geranoides*: 1L tarsometatarsus.

THW collection 14 July, 1995: *P. elephantopus* from 0.5 m above stream (same layer as 55/1 above), MNZ S34445, 1R tibiotarsus; moa sp. indet, MNZ S34447, first pelvic vertebra, in gravels about 1 m below loess.

Unknown site: Bones on display in the Waipara tearooms in 1992 and 1993 were collected by Mark Adorian from the Home Creek area. David Adorian, his father, told THW that the site was either sites 2 or 3 above. Fossils present include: *Pachyornis elephantopus* L tarsometatarsus, R femur, R tibiotarsus; *Euryapteryx geranoides* L femur.



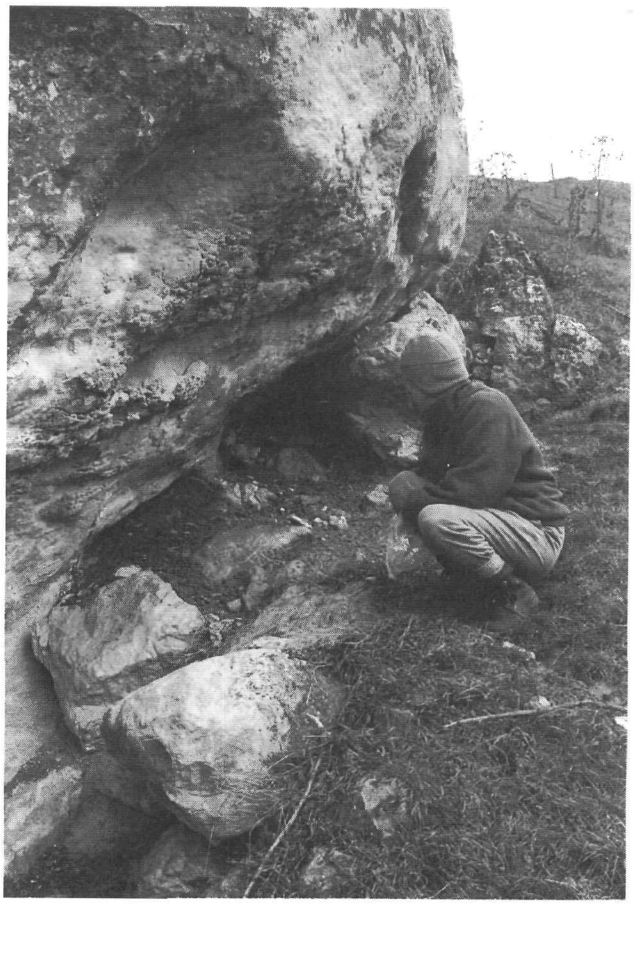


Fig. 16 General view of Euan Murchison's fossil site (top) and closeup of cave at upper end (right). Fossils were found in sediment below the two rocks in the lower photograph.

The following is a list of the fauna from Harris (1982). Harris listed 24 moa bones all from his Moa Bank site. These were examined and reidentified by THW, except OU12037 which could not be found, and so the following list differs from that in Harris (1982):

Moa Bank N34/926948 (= site 3 above). Fossil Record Nos. – Upper unit N34/f57, Middle unit N34/f58, Lower unit N34/f59.

Pachyornis elephantopus OU12024 cranium, OU12025 cranium, OU12026 R tarsometatarsus, OU12037 L tarsometatarsus, OU12038 L tarsometatarsus;

Emeus crassus OU12016 L femur, OU12018 R femur; OU12027 L tarsometatarsus, OU12029 R tarsometatarsus, OU12030 L tarsometatarsus, OU12039 L tarsometatarsus, OU12040 L tarsometatarsus;

Euryapteryx geranoides OU12019 R femur, OU12020 R femur, OU12021 L femur, OU12022 L femur, OU12023 R femur, OU12028 R tarsometatarsus, OU12031 pL tarsometatarsus, OU12032 L tarsometatarsus, OU12033 R tibiotarsus, OU12034 pR tibiotarsus, OU12035 dL femur, OU12036 L tarsometatarsus.

In addition to moa bones Harris recorded and figured the following fossils of carinates. The photographs were sufficient to verify the specific determinations, with the exception of OU12015 which THW re-examined.

Cnemiornis calcitrans OU12002 R tarsometatarsus, OU12003 R coracoid, OU12004 L carpometacarpus.

Cygnus sumnerensis OU12017 R coracoid.

Death Gully (Harris's site 5) N34 924944

Gallinula hodgenorum OU12005 L femur, OU12006 L tibiotarsus, OU12007 R tibiotarsus, OU12008 R tarsometatarsus, several vertebrae (5+/1). Harris (1982) considered the silts in this site to be 'markedly older' than the Canterbury Gravels in which the rest of these Waipara fossils were found.

GR N34 926943

Anas superciliosa OU12009 L scapula .

GR N34 926942

Hemiphaga novaeseelandiae OU12010 L scapula, OU12011 L coracoid, OU12013 distal tibiotarsus, OU12014 pt sternum, OU12012 R coracoid (5/1).

Fulica prisca OU12015 L humerus. This humerus is not *Porphyrio melanotus* as in contrast to that species the shaft is straighter and relatively narrower, the bicipital area is smaller, and the distal end is relatively narrower. In addition, the *processus flexorius* is truncated distally so that in cranial profile there is a notch between the *epicondylus ventralis* and the *processus flexorius* unlike in *Porphyrio* where the *processus flexorius* is not truncated and so there is no notch. In all these respects the fossil is like *Fulica prisca* to which species we refer it.

Harris obtained a radiocarbon date of 10,550 ± 150 yrs BP from associated *Hyridella* shell. This date may be wrong as *Hyridella* has been shown to be an unsatisfactory dating medium, and Alloway (in litt.) reckoned the nearby Moa Bank site as >24 kyr old, because Aokautere Ash (22.6 kyr) lies at the top of the sequence.

Summary of Omihi Stream Otiran fluviatile fauna

Table 6 summarises the frequency of the 12 recorded species from the Otiran sediments exposed in the Omihi Stream. At least four moa species, four waterfowl, 3 gruiforms, and a pigeon are represented.

Additional specimens from loess

Loess deposits are found mantling the hills in the Waipara – Waikari area, and have produced a few fossils which can be added to the Otiran fauna. B. Alloway in 1992 recovered from a site at N34/921921 a distal left tibiotarsus of *Gallirallus australis* MNZ S33726, and a proximal left radius of *Cnemiornis calcitrans* MNZ S33727. A few moa bones have been derived from loess elsewhere near Waikari, for example CM SB14, CM SB18 (both *Pachyornis elephantopus*), and SB2 *Dinornis giganteus*.

SYSTEMATIC PALAEONTOLOGY

Introductory notes for each species can be found in Worthy & Holdaway (1993; 1994a). Species lists for each site are given in Appendix 3 for associated mollusca, Appendix 4 for fossil insects, and Appendix 5 for vertebrate fossils. Specimen catalogue numbers and numbers of bones over MNI are given for all sites, except Pyramid Valley where specimen lists are given in Holdaway & Worthy (in press). All Pyramid Valley material is listed under Canterbury Museum (CM), but some has been given to other institutions. Full details of where each specimen from Pyramid Valley is now located are given in Holdaway & Worthy (in press).

Phylum Mollusca

Land snail faunas from four sites near Weka Pass were sorted and identified by Mr D. Roscoe (Appendix 3), and the specimens lodged in the MNZ.

The mollusc assemblages preserves elements of two separate faunas.

1. A dry scrubby-habitat fauna of limestone cliffs. High numbers of a few species that are obligate calciphiles are present, for example *Therasia* cf. *thaisa*, and the rotadiscids *Climocella maculata*, and the undescribed CALjac. *Allodiscus adriana* also has a preference for limestone habitats. These species can be expected to be observed on the limestone cliffs where the sites were. *Cavellia serpentinula* is a species usually associated with dry, scrubby habitat, and so can also be expected to live near the sites. *Charopa* cf *montivaga* dominated the Mt Cookson snail-faunas which we interpreted as specialist limestone cliff assemblages (Worthy & Holdaway 1995), so its rarity in Waikari may relate to the much drier climate there.
2. A forest fauna. The Ardenest snail fauna is unusual for the area in its high diversity (17 spp), and this plus the presence of *Therasia zelandiae* rather than *T. thaisa*, *Rhytida stephenensis*, and the two punctids, suggest that at least part of the Ardenest assemblage is derived from a time when the surrounding area was more heavily vegetated than it is now. Normal species diversity for litter samples from the scrubby habitats remaining in these eastern areas is 5–7 species, but it is higher in the few forest remnants that have survived burnoffs, e.g. Ironside Creek, Kaikoura (D. Roscoe pers. comm. to THW 25 July

Table 6 Summary of the species present and their abundance in the Omihi Stream Otiran sediments.

Moas	Frequency
Pachyornis elephantopus	common
Euryapteryx geranoides	common
Emeus crassus	common
Dinornis struthoides	1 bone
Dinornis ? struthoides	9 bones, 1 individual
Dinornis sp. larger	1 bone
Carinates	
Cygnus sumnerensis	1 bone
Cnemiornis calcitrans	3 bones, 1 individual
Anas superciliosa	1 bone
Aythya novaeseelandiae	1 bone
Gallinula hodgenorum	5 bones, 1 individual
Fulica prisca	1 bone
Aptornis defossor	2 bones, 2 individuals
Hemiphaga novaeseelandiae	6 bones, 2 individuals

1994). However, the large numbers of *C. serpentinula* in the Ardenest fauna are derived from more recent deposition out of the scrub habitat that covers the site now.

Phylum Insecta

Insect faunas obtained from three Weka Pass predator sites, Gowan Hills, Falcon site – Timpendean, and Ardenest, are listed in Appendix 4. Insect remains were preserved only in dry dusty matrices. Remains, mainly heads, mandibles, thoraces and elytra, were extracted from the sediment by THW and sent to G. Kuschel (Ardenest weevils only) and P. M. Johns for identification. Comments on the known habitats of identified species, made by Johns or Kuschel, are presented below as an aid to palaeoenvironment reconstruction.

Comments on the insect fauna: Gowan Hills

Insect remains were common in the younger Gowan Hills deposit, especially those of *Metaglymma monilifer* Bates with 13 elytra, 6 thoraces and 16 heads, and *Megadromus rectangulus* (Chaudoir) with 2 elytra and 18 heads. The three largest carabids (*Metaglymma monilifer, Megadromus rectangulus,* and *M. antarcticus* (Chaudoir) (5 heads and 2 thoraces)) are 18–28 mm in length and are active early evening surface foragers. Of the medium sized species (12–18 mm) *Mimopeus ?lateralis* (Broun) (2 thoraces, 1 head) is presently common in Canterbury, and *Holcaspis subaenea* (Guèrin) (3 heads) is an active night forager. The incomplete remains make it difficult to be certain of the identity of specimens listed as *Metaglymma monilifer*; some could be of the similar *Mecodema sulcatum* (Sharp), which shares similar habitats.

The observation that *Metaglymma monilifer* and *Megadromus rectangulus* were abundant in Gowan Hills, but absent in Ardenest, suggests that the surroundings at Gowan Hills were damper and supported a more diverse forest.

The *Ectopsis* sp. (1 elytra, 1 thorax) may be *E. ferrugalis* Broun, which was common in Ardenest.

The three largest carabids above, and *Holcaspis subaenea*, *Mimopeus lateralis*, and *Lissotes reticulatus* (Westwood) indicate a relatively dry, closed-canopy forest typical of what can now be seen near Waiau, Hurunui Gorge, and the drier parts of the Canterbury Plains margin from Oxford to Rangiora. The *Otiorhynchus* weevil is a very common introduced species now widespread in Canterbury grasslands. It is probably a vagrant in the deposit, and not part of the fauna killed by laughing owls.

Comments on the insect fauna: Ardenest

One of the most interesting specimens was a single elytra of a giant click beetle *Amychus* sp. cf. *granulatus* (Broun). *A. granulatus* is known only from a few islands in Cook's Strait (Meads 1990), and has never been reported from the mainland before.

Prominent among carabid remains in the Ardenest fauna were those of the large *Mecodema costellum lewisi* Broun, with more than 50 elytra pieces and many heads. The size and microsculpture of several complete elytra and many halves agreed closely (by direct comparison) with specimens from Poulter River, Arthurs Pass National Park. *M. costellum gordonense* Broun (Gordons Knob, Nelson) and *M. howitti* Castelnau (endemic to Banks Peninsula) were clearly different. *M. c. lewisi* is rare but is known from relatively dry *Nothofagus* forest at several sites within the upper Waimakariri catchment, and from one site in the upper Hodder River, Awatere Valley, Marlborough. Ardenest lies almost midway between these regions, but *M. c. lewisi* almost certainly is not extant in the area now.

All specimens of *Mecodema sulcatum* were fresh. It is a burrowing species that wanders on the surface in cool summer nights, and lives in scrub or forest habitats. Beetles of the genus *Oregus* are uncommon in North Canterbury, but in other parts of Canterbury and Otago are associated with dry shrublands. The species of *Oregus* present in Ardenest could not be identified. *Megadromus antarcticus* is abundant in Canterbury in a wide variety of environments from pasture, scrub, and moderately wet forests, and a fossil of it was found in Pyramid Valley (identified by P. M. Johns).

There are three, possibly four, species of *Mimopeus* in the Ardenest fauna. The form of the elytra costae is variable, and they tend to wear so identification from these is difficult. The presence of two of the listed species was determined from the more diagnostic thoraces. *M. granulosus*, endemic to Banks Peninsula, was not present. Several thoraces were referred to *M. lateralis* after direct comparison with recent specimens taken within 30 km of Ardenest. This species is mainly known from North Canterbury where it can be common in dry shrubland dominated by *Leptospermum*, *Discaria* and *Muehlenbeckia*, or very dry *Nothofagus* forest, and even in *Pinus* plantations. *Mimopeus* sp. nov. is known to P. M. Johns from one recent specimen from the middle Waipara Gorge, North Canterbury. More than 10 thoraces from Ardenest are identical to this specimen, in that they have no flattened lateral margin, the posterior margins in front of the corner are distinctly sinuate, and the corner is acute and sharp. *Mimopeus costellum* Broun is a rare North Canterbury species usually found in scrub, and it was represented by a single elytron. It is possible that a few of the larger elytra are of the widespread and common *M. opaculus* (Bates).

Lissotes reticulatus is a common species in many parts of Canterbury in dry *Nothofagus* forest and broadleaf shrublands.

Species in the family Histeridae are common in sites with rotting matter, faeces, etc, and are often found associated with birds' nests (especially penguins). The Ardenest specimen could not be identified to species.

The weevil fauna can be split into a group of forest species and a group of open tussock country species (Appendix 4). We think it certain that the more frequent remains of large forest dwelling species represent prey items, but the rarer remains of smaller litter-dwelling or open-country species are probably from vagrants that either walked into the site or fell between the rocks from the forest floor (or, in later times, scrub) above, and died there.

The large and flightless weevil *Anagotus stephenensis* (Kuschel), now restricted to Stephens Island, was common in the deposit. No host plant is known, but its larvae are expected to be wood-borers. On Stephens Island it is usually found on ngaio (I. Millar pers comm to THW), which is common in the coastal forest at Nape Nape and was detected in the pollen record at Glencrieff.

A good series of fragments of *Anagotus rugosus* (Broun) was obtained. This large species is now restricted to islands from the Poor Knights to Foveaux Strait, except for relict populations on Mt Egmont and near Lake Manapouri. Its larvae bore in trunks and larger limbs of *Coprosma* species.

Numerous fragments of *Ectopsis ferrugalis* Broun were obtained. This large species is very common in the southern half of the North Island and the Chatham Islands. While never before having been found on the South Island mainland, it is known from Maud Island in the Marlborough Sounds, and Secretary Island in Fiordland. It is strictly associated with *Pseudopanax* species.

Tychanus verrucosus Pascoe is host-specific to the vine genus *Rubus*. *Psepholax sulcatus* White lives in a range of dying and freshly dead trees, particularly *Myrsine* and *Weinmannia*. *Strongylopteryus hylobioides* (White) is a widespread wood-borer. *Didymus impexus* (Pascoe) lives in all sorts of trees and shrubs east of the main divide.

The rest of the forest species *Tychanopais fougeri* (Hutton), *Crisius longulus* Broun, *C. ornatus* Broun, *Clypeolus cineraceus* Broun, and *Phrynixus terreus* Pascoe are forest floor or litter dwellers. *Clypeolus* prefers rather dry scrub litter.

The open country suite of species, namely three *Epitimetes* spp., *Sargon suturalis* (Broun) and *Irenimus aequalis* (Broun) could live in the vicinity of Ardenest at present, and except for *E. grisealis* Broun were rare in the deposit and, therefore, probably not part of the fauna assembled by the owls.

Comments on the insect fauna: Falcon site, Timpendean

This fauna was characterised by fewer large fragments, possibly related to the use of the site by Paradise shelducks for nesting, and subsequent trampling of the material. Insect remains were dominated by *Mecodema sulcatum* and *Megadromus antarcticus*. There were few identifiable pieces of other species: one elytron of a *Holcaspis* sp., two thoraces of a small elaterid, parts of an *Odontria* sp., and a large histerid. *Mimopeus* was, surprisingly, rare with only one head and a small portion of a thorax present. A recent origin for this fauna is indicated by the retention of the distinctive green sheen to the *Megadromus* material, and that most mandibles of this species still have a clean, bright ventral row of setae. This supposed recent origin is supported by the presence of a fully articulated forelimb of ?*Mecodema sulcatum*, and five male cerci of the introduced European earwig *Forficula auricularia*.

Phylum Chordata

Subphylum Vertebrata

Class Reptilia, Order Sphenodonta

Family Sphenodontidae

Genus *Sphenodon* Gray

The two extant tuatara presently recognised from New Zealand (Daugherty et al. 1990), *S. punctatus* and *S. guntheri* appear to have similar skeletal morphology (THW unpubl. data), and the fossil elements were not diagnostic of either species.

***Sphenodon* species indeterminate**

Material: Euan Murchison's Rockshelter – CM Rep60, 87, 459 (6/1); Falcon site, Timpendean – MNZ S33409 1/1; Rabbit Warren Cave – MNZ S33617 3/1; The Deans – CM Rep511 1/1; Pyramid Valley – CM 28/6; Arden Rockshelter 3 – MNZ S33669 3/2; Ardenest – MNZ S33706 21/4; Gowan Hills coalluvial deposit – MNZ S33803 1/1; Gowan Hills owl site old deposit – MNZ S33822 6/1 juvenile.

Order Squamata

Family Gekkonidae

Genus *Hoplodactylus* Fitzinger

Gecko bones were identified to genus by the form of the frontal described in Worthy & Holdaway (1995). As in that paper we continue to refer *Hoplodactylus* bones to 'super-species' complexes labelled as *H.* cf. *maculatus* and *H. granulatus*. Large geckonid bones the size and shape of *H. duvaucelii* specimens from Coppermine Island and The Brothers Islands (MNZ unreg) are referred to *H.* cf. *duvaucelii*.

***Hoplodactylus* cf. *maculatus* (Common gecko)**

Material: Falcon site, Timpendean – MNZ S33411pt x/7; Ledge, Weka Pass – MNZ S33437 3/2; Rockshelter, Sandhurst Stn – MNZ S33438 2/1; Rabbit Warren Cave – MNZ S33430 2/1; P. Lamb's owl site – MNZ S33474 79/7; Gowan Hills owl site, young deposit – MNZ S33450 601/132; Gowan Hills owl site old deposit – MNZ S33820 410/66; Pyramid Valley – CM 1/1; Arden Rockshelter 1 – MNZ S33655 1/1; Arden Rockshelter 3 – MNZ S33668 10/2; Ardenest – MNZ S33704 100's bones /151; Waikari Cave – MNZ S33709 1/1; Waikari Cave, McCulloch colln, CM unreg. – 1/1.

***Hoplodactylus* cf. *duvaucelii* (Duvaucel's gecko)**

Material: Rabbit Warren Cave – MNZ S33501 5/1; Gowan Hills owl site, young deposit – MNZ S33451 3/2; Gowan Hills owl site old deposit – MNZ S33821 7/2; Arden Rockshelter 3 – MNZ S33667 8/2; Ardenest – MNZ S33703 409/19; Gowan Hills coalluvial deposit – MNZ S33804 1/1.

Family Scincidae

Genus *Oligosoma* Girard

Oligosoma Girard, 1857 has been reinstated for New Zealand skinks previously listed in the genus *Leiolopisma* (Patterson & Daugherty 1995). New Zealand, therefore, has two endemic skink genera, but only *Oligosoma* is present in the South Island.

A few skink bones were recorded from the predator sites, and were divisible into two size classes. All were referred to *Oligosoma* as *Cyclodina* is a North Island endemic genus. No bones were specifically identified, as cranial elements were lacking. However, femora 6–7.5 mm long and humeri 5–6 mm are probably from small species in the *O. nigriplantare* complex, of which only *O. nigriplantare polychroma* is present in the area of this study (Patterson & Daugherty 1990). Larger femora, 10–11 mm long, and humeri 8–9 mm long, are the size of these elements in *O. lineoocellatum*, which could be expected in the area and whose bones were found in Mt Cookson sites (Worthy & Holdaway 1995).

***Oligosoma* spp. indet.**

Material: Falcon site, Timpendean – MNZ S33411pt x/1; Ledge, Weka Pass – MNZ S33434 5/2; P. Lamb's owl site – MNZ S33473 64/6; Gowan Hills owl site, young deposit – MNZ S33459 3/1; Gowan Hills owl site old deposit – MNZ S33819 2/1; Ardenest – MNZ S33705 7/4.

Fish

Material: Gowan Hills owl site, young deposit – MNZ S33461 3 vertebrae.
These bones are very short, and have distinctive very strong parapophyses. They are probably eel *Anguilla* sp. (R. M. McDowall, 17 April 1996 pers. comm.)

Class Aves, Order Dinornithiformes

Family Emeidae

Genus *Anomalopteryx* Reichenbach

***Anomalopteryx didiformis* (Owen, 1844) (Little Bush Moa)**

Genus *Megalapteryx* Haast

***Megalapteryx didinus* (Owen, 1883) (Upland Moa)**

Rare bones of both these species were found in Glenmark faunas.

Anomalopteryx didiformis* or *Megalapteryx didinus

Material: The Deans – CM Av33877 1/1.

Genus *Pachyornis* Lydekker

***Pachyornis elephantopus* (Owen, 1856) (Heavy-footed moa)**

Material: Rabbit Warren Cave – MNZ S33618 R ramus in Otiran sediments; Swamp between Culverden and Waikari – CM Av30492–4, 14347 (9/3); The Deans – CM Av33253 1/1; Glencrieff Moa Swamp – MNZ S32668–73, 32675, 32679, 32681, 32698, 32700, Eaves's Coll. (623+/15); Rockshelter, North Dean, Weka Pass – CM SB13 3/1; Sandhurst Creek, Weka Pass – CM SB14 1/1; Upper Sandhurst Creek, Weka Pass – 2+/1; Antills Bridge, Weka Pass – CM unreg. 1/1; Pyramid Valley – CM 17 part skeletons; Omihi Stream Otiran sediments Site 2 – MNZ S33733 2/1, S34448 1/1; Omihi Stream Otiran sediments Site 3 – Alloway colln. 9/1, MNZ S33737 1/1, MNZ S33739 1/1; Omihi Stream Otiran sediments site unknown – Waipara tearooms display 3/1; Omihi Stream Otiran sediments site 3 – Harris collection OU 12024–26, 12037–38 (5/2); Omihi Stream Otiran sediments site 5 – Mike Dickie collection 55/1, 5/1, MNZ S34445 1/1; Gowan Hills coalluvial deposit – MNZ S33801 1/1.

The Glencrieff and Pyramid Valley samples give us the chance to assess temporal variation in body size of populations living in essentially the same area. To do this, measurement data for both populations are summarised in Table 7. The Glencrieff *Pachyornis elephantopus* had femora 2.4% longer (not significant), tibiotarsi 4.1% longer (significant, $P < 0.05$), and tarsometatarsi 4.9% longer (significant, $P < 0.01$) than the Pyramid Valley birds. Therefore, the length of the legs became shorter between the late Glacial and the late Holocene. That femora did not shorten to the same extent suggests body size did not reduce in proportion. However, mean changes in width values of leg bones are also shown in Table 7, which show significant reductions in most values. Femora width is a good indicator of body weight, and the highly significant reduction in this value indicates that there was a reduction in body mass from the Late Glacial to the Late Holocene in this population of *P. elephantopus*. This reduction in body mass was associated with a greater reduction of length of distal leg bones.

Genus *Euryapteryx* Haast

Euryapteryx geranoides (Owen, 1848) (Stout-legged Moa)

Material: Rabbit Warren Cave – 2 leg bones not relocated (see Appendix 5); Timpendean Rockshelter – CM Av22373–4 , 36443 3/1; The Deans – CM Av33183, 33186–9, 33192, 33196, 33219–21, 33224, 33252, 33255, 33868, 33885 (156+/7); Pyramid Valley – CM 21 part skeletons; Omihi Stream Otiran sediments site 2 – MNZ S33728–30, 34449 4/1; Omihi

Table 7 Summary statistics for measurements of *P. elephantopus* long bones from Glencrieff Swamp compared with those from Pyramid Valley from Holdaway & Worthy (in prep). Data are given as mean, (N), Std Dev., CV, min – max. Abbreviations as follows: Fem – femora, Tib – tibiotarsi, Tmt – tarsometatarsi, L = length, *P* = proximal, S = shaft, D = distal. The % change column shows the difference between Glencrieff and Pyramid Valley. The T-test data shows the t-statistic, the significance level assuming unequal variances (NS = not significant ($P > 0.05$), * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$), and degrees of freedom.

	Glencrieff	Pyramid Valley	% change	T-test
FemL	312.6 (19), 18.25, 5.84, 265–337	305.2 (11), 9.36, 3.07, 292–320	–2.37	1.46, NS, 28
FemP	118.9 (19), 7.94, 6.68, 103–128	112.1 (11), 7.92, 7.06, 96–127	–5.72,	2.28, *, 21
FemS	53.7 (19), 3.35, 6.24, 47–59	48.36 (11), 2.11, 4.36, 44–52	–9.94	5.33, ***, 28
FemD	145.7 (19), 9.45, 6.48, 116–158	139.6 (11), 6.28, 4.50, 127–146	–4.19	2.12, *, 27
TibL	568.9 (17), 22.32, 3.92, 536–60	546.5 (11), 22.86, 4.18, 506–592	–3.94	2.56, *, 21
TibP	163.0 (15), 8.7, 5.34, 152–180	159.0 (11), 8.72, 5.48, 144–173	–2.45	1.16, NS, 22
TibS	53.5 (18), 4.37, 8.17, 49–69	51.0 (11), 4.34, 8.50, 45–58	–4.67	1.50, NS, 21
TibD	101.2 (18), 5.09, 5.03, 94–110	95.5 (11), 4.3, 4.5, 87–101	–5.63	3.18, **, 24
TmtL	232.3 (21), 8.14, 3.51, 219–246	221.4 (11), 9.24, 4.18, 206–240	–4.69	3.32, **, 18
TmtP	106.3 (21), 7.06, 6.64, 96–120	101.4 (11), 6.56, 6.47, 90–110	–4.61	1.96, NS, 22
TmtS	63.4 (21), 4.41, 6.95, 56–70	57.91 (11), 4.91, 8.48, 52–70	–8.66	3.13, **, 19
TmtD	139.6 (21), 9,52, 6.82, 124–155	132.0 (11), 6.24, 4.73, 125–144	–5.44	2.72, NS, 28

Stream Otiran sediments site unknown – Waipara tearooms colln 1/1; Omihi Stream Otiran sediments site 3 – Harris colln OU12019–23, 12028, 12031–36, (12/3).

Genus *Emeus* Reichenbach

***Emeus crassus* (Owen, 1846) (Eastern moa)**

Material: Swamp between Culverden and Waikari – CM Av30490–1 17/6; The Deans – CM Av33184–5, 33190–1, 33197, 33229, 33278, 34891–2 (19/3); Glencrieff Moa Swamp – MNZ S32674, 32680, 32682, 32686–90, 32696–7, 32699, Eaves's coll. (590+/14); Pyramid Valley – CM 78 part skeletons; Omihi Stream Otiran sediments site 3 – Harris colln OU12016, 12018, 12027, 12029–30, 12039–40 (7/4); Omihi Stream Otiran sediments site 1 Alloway colln 1/1.

Summary statistics of lengths of *Emeus* long bones from Glencrieff and Pyramid Valley, given in Table 8, show that the temporal variation in these two populations, which lived in the same area at different times, was not significant.

Family Dinornithidae

Genus *Dinornis* Owen

Dinornis legbones were identified according to measurements given for each species by Worthy (1994). There is some uncertainty about specific identifications as Worthy (1994) showed that the size ranges of leg bones of *D. novaezealandiae* overlapped *D. struthoides* at the small end, and *D. giganteus* in its upper end, and none of the diagnostic crania was present.

***Dinornis struthoides* Owen, 1844 (Slender Moa)**

Material: Swamp between Culverden and Waikari – CM Av30497–8 2/1; Pyramid Valley – CM 1 part skeleton; Omihi Stream Otiran sediments site 4 – Alloway colln 8/1; Omihi Stream Otiran sediments site 2 – MNZ S34446 1/1.

***Dinornis giganteus* Owen, 1844 (Giant Moa)**

Material: Swamp between Culverden and Waikari – CM Av30495–6 6/2; The Deans – CM Av33225 66/1, 33181 6/1; Glencrieff Moa Swamp – MNZ S32684–5, Eaves's coll. (47/4), CM Av25373 67/1; Titini, Weka Pass – CM SB2 1/1; Antills Bridge, Weka Pass – CM unreg. 2/1; Pyramid Valley – CM 62 part skeletons.

Table 8 Summary statistics for length data of *Emeus crassus* long bones from Glencrieff Swamp compared to those from Pyramid Valley (PV) after Holdaway & Worthy (in prep). Differences in the means were not significant (t-tests, assuming unequal variances, given as t-statistic, significance level, degrees of freedom).

	Femur		Tibiotarsus		Tarsometatarsus	
	Glencrieff	PV	Glencrieff	PV	Glencrieff	PV
mean	273.3	265.4	442.7	454.4	209.7	206.7
N	13	56	22	55	12	57
Std dev	13.98	16.84	37.43	32.14	14.35	12.33
CV	5.12	6.35	8.45	7.07	6.84	5.96
Max	297	296	489	502	227	233
Min	258	224	373	359	173	173
t- tests	–1.75, NS, 21		1.29, NS, 15		0.66, NS, 15	

Moa eggshell

Material: Rabbit Warren Cave – 2 pieces with MNZ S33618; Ardenest – MNZ S33708 3 pieces 0.93 mm thick; Gowan Hills coalluvial deposit – MNZ S33805 1 piece; Gowan Hills owl site old deposit – MNZ S33824 3 pieces.

Order Apterygiformes

Family Apterygidae

Genus *Apteryx* Shaw and Nodder

***Apteryx australis* Shaw & Nodder, 1813 (Brown Kiwi) or *Apteryx haastii* Potts, 1872 (Great spotted Kiwi)**

Material: Timpendean Rockshelter – CM Av22334, 22370, 22375 (4/2); The Deans – CM Av33176, 33882 (2/1); Pyramid Valley – CM (22/3).

***Apteryx owenii* Gould, 1847 (Little Spotted Kiwi)**

Material: The Deans – CM Av33227, 33241 (2/1); Waikari Cave – MNZ S33720 1/1.

***Apteryx* spp. juv (Kiwi species)**

Material: Euan Murchison's Rockshelter – CM Av17331, 17788, 17789 (4/2); Glencrieff Moa Swamp – MNZ S33490 1/1; Pyramid Valley – CM (22/3); Ardenest – MNZ S33671 3/1; Gowan Hills owl site old deposit – MNZ S33808 1/1; Waikari Cave, McCulloch colln, CM unreg. – 2/1.

Order Podicipediformes

Family Podicipedidae

Genus *Poliocephalus* Selby

***Poliocephalus rufopectus* (G. R. Gray, 1843) (New Zealand Dabchick)**

Material: Pyramid Valley – CM 9/2; Waikari Cave, McCulloch colln, CM unreg. – LR tibiotarsus, cranium, synsacrum, LpR humeri (6/1).

Order Procellariiformes

Family Diomedeidae

Genus *Diomedea* Gould

***Diomedea cauta* Gould, 1841 (White-capped (Shy) Mollymawk)**

Material: Timpendean Rockshelter – CM Av22340 1/1.
This specimen may be an artefact (Challis 1994), but if not, it is certainly archaeological in origin, and was brought to the site by humans from elsewhere along with marine fish and shells.

Family Oceanitidae

Genus *Oceanites* Keyserling and Blasius

***Oceanites nereis* (Gould, 1841) (Grey-backed Storm Petrel)**

Material: Ardenest – MNZ S33681 1L 1R humerus, 1dL tibiotarsus, 1L 1dL coracoid, 1L ulna and radius and *os carpi radiale* articulated (8/2).

Family Procellariidae

Genus *Pelecanoides* Lacépède

***Pelecanoides urinatrix* (Gmelin) (Common Diving Petrel)**

Material: P. Lamb's owl site – MNZ S33467 2/1.

Genus *Pterodroma* Bonaparte

Pterodroma inexpectata (Forster, 1844) (Mottled Petrel)

Material: P. Lamb's owl site – MNZ S33465 4/1; Euan Murchison's Rockshelter – CM Av16393, 17790 (9/2).

Pterodroma cookii (Gray, 1843) (Cook's Petrel)

Material: P. Lamb's owl site – MNZ S33468 5/1; Euan Murchison's Rockshelter – CM Av16392 8/1.

Genus *Puffinus* Brisson

Puffinus gavia or *huttoni* (Shearwater)

Material: Euan Murchison's Rockshelter – CM Av17339, 17340 2/1; Gowan rockshelter – CM Av15133 1/1.

Order Ciconiiformes

Family Ardeidae

Genus *Egretta* T. Forster

Egretta alba (Linnaeus, 1758) (Great White Heron)

Material: Pyramid Valley – CM 1/1.

Order Anseriformes

Family Anatidae

Genus *Cnemiornis* Latham

Cnemiornis calcitrans Owen, 1865 (Extinct Goose)

Material: Euan Murchison's Rockshelter – CM Av17792 1/1; Pyramid Valley – CM 25/1; Omihi Stream Otiran loess site- MNZ S33727 1/1; Omihi Stream Otiran sediments site 3, Harris colln OU12002–4 3/1.

Genus Euryanas Oliver

Euryanas finschi (Van Beneden, 1875) (Finsch's Duck)

Material: Euan Murchison's Rockshelter – CM Av17775 9/2; The Deans – CM Av33887 2/1; Pyramid Valley – CM 22/5; Ardenest – MNZ S33672 1/1; Waikari Cave – MNZ S33712 32/3, 33714 25/2, 33721 226/14; Waikari Cave, McCulloch colln, CM unreg. – uncounted.

Genus *Malacorhynchus* Swainson

Malacorhynchus scarletti Olson, 1977 (New Zealand Pink-eared Duck)

Until recently this species was known by only the holotype premaxilla and paratype part mandible. Worthy (1995) has identified and described bones from several sites, but mainly from the type locality Pyramid Valley.
Material: Pyramid Valley – CM 30/7.

Genus *Tadorna* Lorenz von Oken

Tadorna variegata (Gmelin, 1789) (Paradise Shelduck)

Material: Falcon site, Timpendean – MNZ S33422 egg and eggshell; Rabbit Warren Cave – MNZ S33615 eggshell; Gowan Hills owl site, young deposit – MNZ S33451 eggshell; Gowan Hills owl site old deposit – MNZ S33823 eggshell; Timpendean Rockshelter – CM Av22366–7 2/2; Pyramid Valley – CM 33/5; Ardenest – MNZ S33707 eggshell; Waikari Cave – MNZ S33710 eggshell.
The basis of our identification of this eggshell as *Tadorna* was that it was white, and ranged in thickness from 0.35 mm to 0.45 mm. This is thicker than that of most birds known from the area, other than moas, but typical of *Tadorna*, which does nest in holes in cliffs, banks and trees.

Genus *Hymenolaimus* Gray

***Hymenolaimus malacorhynchos* (Gmelin) (Blue Duck)**

Material: Gowan rockshelter – CM Av15134 1/1.

Genus *Cygnus* Bechstein

***Cygnus sumnerensis* (Forbes, 1892) (NZ Black Swan)**

Material: Omihi Stream Otiran sediments site 3 – Harris colln OU 12017 R coracoid.

Genus *Anas* Linnaeus

***Anas superciliosa* Gmelin, 1789 (Grey Duck)**

Material: Pyramid Valley – CM 20/3; Omihi Stream Otiran sediments N34/926943 – Harris colln OU12009 1/1.

***Anas chlorotis* Gray, 1845 (Brown Teal)**

Material: Timpendean Rockshelter – CM Av22339 3/1; The Deans – CM Av33874 1/1; Glencrieff Moa Swamp – MNZ S33487–8 5/1; Pyramid Valley – CM 105/11; Waikari Cave, McCulloch colln, CM unreg. – 2/1.

***Anas gracilis* Buller, 1869 (Grey Teal)**

Material: Pyramid Valley – CM 4/3.

Genus *Aythya* Boie

***Aythya novaeseelandiae* (Gmelin, 1789) (New Zealand Scaup)**

Material: Pyramid Valley – CM 25/5; Omihi Stream Otiran sediments site 2 – MNZ S33736 1/1.

Order Falconiformes

Family Accipitridae

Genus *Circus* Lacépède

***Circus eylesi* Scarlett, 1953 (Eyles's Harrier)**

Material: Euan Murchison's Rockshelter – CM Av17783 1/1; Pyramid Valley – CM 149+/7; Timpendean Rockshelter – CM Av22342 2/1.

Genus *Harpagornis* Haast

***Harpagornis moorei* Haast, 1872 (Haast's Eagle)**

Material: Glencrieff Moa Swamp – MNZ S28377, 28378 (2/2); Pyramid Valley – CM 22/2.

Family Falconidae

Genus *Falco* Linnaeus

***Falco novaeseelandiae* Gmelin, 1788 (New Zealand Falcon)**

Material: Falcon site, Timpendean – MNZ S33421 1/1, 33422 rangle stones; Timpendean Rockshelter – CM Av22378 1/1; rockshelter, Weka Pass – CM Av36942 12/1; Pyramid Valley – CM 6/1.

Order Galliformes

Family Phasianidae

Genus *Coturnix* Bonnaterre

***Coturnix novaezelandiae* Quoy and Gaimard, 1830 (New Zealand Quail)**

Material: Falcon site, Timpendean – MNZ S33420 2/1; Ledge, Weka Pass – MNZ S33432 13/

1; Rabbit Warren Cave – MNZ S33500 2/1; P. Lamb's owl site – MNZ S33462 184/16; Gowan rockshelter – CM Av15116 6/1; Gowan Hills owl site, young deposit – MNZ S33444 7/2; Euan Murchison's Rockshelter – CM Av16385, 17778 (21/5); Timpendean Rockshelter – CM Av22335, 22341 (102/15); The Deans – CM Av33878 1/1; Glencrieff Moa Swamp – MNZ S33476–83 13/2; Pyramid Valley – CM 1/1; Arden Rockshelter 1 – MNZ S33653 1/1; Arden Rockshelter 3 – MNZ S33659 2/1; Ardenest – MNZ S33680 29/6; Waikari Cave, McCulloch colln, CM unreg. – 6/2.

Order Gruiformes

Family Rallidae

Genus *Gallirallus* Lafresnaye

***Gallirallus australis* (Sparrman, 1786) (Weka)**

Material: Rabbit Warren Cave – MNZ S33504 1/1; Euan Murchison's Rockshelter – CM Av16384, 16390, 17329, 17776, 17777 (25/3); Timpendean Rockshelter – CM Av22336, 22368–9 (14/3); The Deans – CM Av33178–80, 33871, 33880, 33888 (6/2); Pyramid Valley – CM 180+/17; Arden Rockshelter 2 – MNZ S33619; Ardenest – MNZ S33674 1/1; Omihi Stream Otiran loess site – MNZ S33726 1/1; Waikari Cave, McCulloch colln, CM unreg. – 1/1.

Genus *Gallinula* Brisson

***Gallinula hodgenorum* (Scarlett, 1955) (Hodgen's Rail)**

Material: Euan Murchison's Rockshelter – CM Av17330, 17773 (5/2); Pyramid Valley – CM 35/9; Arden Rockshelter 3 – MNZ S33658 1/1; Ardenest – MNZ S33673 7/1; Waikari Cave – MNZ S33713 3/1, 33724 44/6; Waikari Cave, McCulloch colln, CM unreg. – 15/3; Omihi Stream Otiran sediments Death Gully – Harris colln OU12005–8 (5/1).

Genus *Porphyrio* Brisson

***Porphyrio hochstetteri* (A. B. Meyer, 1883) (South Island Takahe)**

Material: Ledge, Weka Pass – MNZ S33613 1/1; The Deans – CM Av33240 1/1; Pyramid Valley – CM 10/3; Waikari Cave – MNZ S33717 10/1; Waikari Cave, McCulloch colln, CM unreg. – 1/1.

***Porphyrio melanotus* Temminck, 1820 (Pukeko)**

Material: Timpendean Rockshelter – CM Av22365 2/1.

Genus *Fulica* Linnaeus

***Fulica prisca* Hamilton, 1893 (New Zealand Coot)**

Material: Pyramid Valley – CM 44/8; Waikari Cave – MNZ S33711 1/1, 33715 41/2, 33721 151/7; Waikari Cave, McCulloch colln, CM unreg. – 25/2; Omihi Stream Otiran sediments N34/926942 – Harris colln OU12015 1/1.

Family Aptornithidae

Genus *Aptornis* Owen

***Aptornis defossor* Owen, 1871 (Adzebill)**

Material: The Deans – CM Av33175 13/1, 33226, 33869, 33872 (23/1); Pyramid Valley – CM 517+/10; Waikari Cave – MNZ S33718 10/1; Waikari Cave, McCulloch colln, CM unreg. – 38+/1; Omihi Stream Otiran sediments site 2 – MNZ S33735 1/1; Omihi Stream Otiran sediments site 3 – S33740 1/1.

Order Charadriiformes

Family Recurvirostridae

Genus *Himantopus* Brisson

***Himantopus novaezelandiae* Gould, 1841 (Black Stilt)**

Material: Pyramid Valley – CM 14/2.

Family Charadriidae

Genus *Charadrius* Linnaeus

***Charadrius bicinctus* Jardine and Selby, 1827 Banded Dotterel**

Material: Falcon site, Timpendean – MNZ S33414 1 distal + shaft R humerus, 2 dL humeri, 1 dR femur, 1 head of L coracoid, 1 pR tibiotarsus (6/2); Ardenest – MNZ S33682 1R tarsometatarsus Length = 32.84 mm, 1dR tarsometatarsus, 1L articular of mandible (3/2).

Genus *Thinornis* G.R. Gray

***Thinornis novaeseelandiae* (Gmelin, 1789) (Shore Plover)**

Material: Ardenest – MNZ S33683 LR carpometacarpus, R tibiotarsus – articular length = 38.4 mm (3/1).

No mainland *Thinornis* specimens were available, so these bones were compared to Chatham Island specimens MNZ 24059, MNZ 1403, and CM Av1771. The fossils are clearly charadriiform and smaller than *Charadrius bicinctus*. Tibiotarsi of MNZ 24059 were 39.5 mm (from the proximal articular surface), MNZ 1403 40.8 mm, and CM Av1771 42.64 mm long. *Thinornis* tibiotarsi differed from those of *Charadrius* by being broader anteriorly at and between the base of the *crista cnemialis cranialis* and *crista cnemialis lateralis* adjacent the proximal end of the fibular crest (compressed in *Charadrius*), as well as shorter (e.g. *Charadrius bicinctus* MNZ 24888 length 45.4 mm). Tibiotarsi of *Anarhynchus frontalis* were longer than *Thinornis* (MNZ 22295 42.6 mm, MNZ 1408 43.3 mm, MNZ 22306 44.8 mm), and also differed in shape. The fossil carpometacarpi were not whole so total-length comparisons were not possible. The *processus extensorius* of both fossils are enlarged and thickened anterocaudally compared to those of *Charadrius*, but the *trochlea carpalis* is thinner dorsoventrally than *Charadrius*. In these features the fossils are similar to *Thinornis*. The lengths of the *spatium intermetacarpale* in MNZ 24059 11.85 mm, MNZ 1403 11.68 mm, and CM Av1771 12.38 mm are a little longer than in the fossils (11.9 mm, 10.6 mm), but so were the tibiotarsi. Carpometacarpi of both *Thinornis* and *Anarhynchus* were considerably longer than the fossils.

Family Scolopacidae

Genus *Coenocorypha* G.R. Gray

***Coenocorypha cf. aucklandica* (Gray, 1845) (New Zealand Snipe)**

Material: Falcon site, Timpendean – MNZ S33415 3/2; Rabbit Warren Cave – MNZ S33502 1/1; Gowan Hills owl site, young deposit – MNZ S33446 4/1; Gowan Hills owl site old deposit – MNZ S33806 4/2; Glencrieff Moa Swamp – MNZ S33484–5 2/1; Arden Rockshelter 1 – MNZ S33651 1/1; Arden Rockshelter 3 – MNZ S33657 3/1; Ardenest – MNZ S33679 21/4; Waikari Cave, McCulloch colln, CM unreg. – 3/2.

Family Laridae

Genus *Sterna* Linnaeus

***Sterna albostriata* (G.R. Gray, 1845) Black-fronted Tern**

Material: Rabbit Warren Cave – MNZ S33614, 1L carpometacarpus, 1pR coracoid.

Order Columbiformes

Family Columbidae

Genus *Hemiphaga* Bonaparte

***Hemiphaga novaeseelandiae* (Gmelin, 1789) (New Zealand Pigeon)**

Material: Rabbit Warren Cave – MNZ S33499 1/1; Euan Murchison's Rockshelter – CM Av16395, 17779 (5/1); Timpendean Rockshelter – CM Av22338, 22377 (5/1); The Deans – CM Av33870 1/1; Pyramid Valley – CM 643/69; Ardenest – MNZ S33677 10/2; Omihi Stream Otiran sediments site 3 – MNZ S33738 1/1; Omihi Stream Otiran sediments N34/926942 – Harris colln OU12010–14 (5/1); Gowan Hills coalluvial deposit – MNZ S33802 1/1; Gowan Hills owl site old deposit – MNZ S33811 26/2; Waikari Cave, McCulloch colln, CM unreg. – 2/1.

Genus *Columba* Linnaeus

***Columba livia* Gmelin, 1789 (Rock pigeon)**

Material: Timpendean Rockshelter – CM Av22376 1/1.

Order Psittaciformes

Family Psittacidae

Genus *Strigops* Gray

***Strigops habroptilus* Gray, 1845 (Kakapo)**

Material: The Deans – CM Av33228, 33177, 33876 (3/1); Pyramid Valley – CM 23/5; Ardenest – MNZ S33675 7/2; Waikari Cave – MNZ S33719 1/1; Waikari Cave, McCulloch colln, CM unreg. – 1/1.

Genus *Nestor* Lesson

***Nestor meridionalis* (Gmelin, 1788) (Kaka)**

Material: Euan Murchison's Rockshelter – CM Av17780, 33732 (2/1); Timpendean Rockshelter – CM Av22337, 22343 (13/4); The Deans – CM Av33873, 33881 (4/1); Pyramid Valley – CM 138/12.

***Nestor notabilis* Gould, 1856 (Kea)**

Material: Glencrieff Moa Swamp – MNZ S28376 1/1; Pyramid Valley – CM 89/9.

Nestor spp.

Material: Arden Rockshelter 3 – MNZ S33665 9/1.

Genus *Cyanoramphus* Bonaparte

***Cyanoramphus* spp. indet**

Material: Falcon site, Timpendean – MNZ S33417 6/3; Rockshelter, Sandhurst Stn – MNZ S33436 1/1; Rabbit Warren Cave – MNZ S33427 5/2; P. Lamb's owl site – MNZ S33463 58/5; Gowan rockshelter – CM Av15117 1/1; Gowan Hills owl site, young deposit – MNZ S33443 9/2; Gowan Hills owl site old deposit – MNZ S33809 26/3; Euan Murchison's Rockshelter – CM Av16386, 17332, 17782, 33528, 33540, 36539 (26/5), MNZ S33424 1/1; Glencrieff Moa Swamp – MNZ S33486 1/1; Pyramid Valley – CM 30/7; Arden Rockshelter 1 – MNZ S33652 1/1; Arden Rockshelter 3 – MNZ S33660 6/1; Ardenest – MNZ S33676 65/12; Waikari Cave, McCulloch colln, CM unreg. – 1/1.

Order Strigiformes

Family Strigidae

Genus *Ninox* Hodgson

***Ninox novaeseelandiae* (Gmelin, 1788) (Morepork)**

Material: Rockshelter, Sandhurst Stn – MNZ S33435 2/1; Pyramid Valley – CM 2/1.

Genus *Sceloglaux* Kaup

***Sceloglaux albifacies* (Gray, 1844) (Laughing Owl)**

Material: P. Lamb's owl site – MNZ S33466 8/1; Gowan Hills owl site, young deposit – MNZ S33452 1/1; Glencrieff Moa Swamp – MNZ S33491–2 4/1; Pyramid Valley – CM 19/4.

Order Caprimulgiformes

Family Aegothelidae

Genus *Aegotheles* Vigors and Horsfield

***Aegotheles novaezealandiae* (Scarlett, 1968) (Owlet-nightjar)**

Material: Gowan Hills owl site, young deposit – MNZ S33449 18/3; Gowan Hills owl site old deposit – MNZ S33810 34/4; Euan Murchison's Rockshelter – CM Av17333, 17341, 17774, pt17787, 33531 (16/3); Pyramid Valley – CM 15/5; Arden Rockshelter 1 – MNZ S33650 8/1juv; Ardenest – MNZ S33678 14/1juv. + 33/4; Waikari Cave – MNZ S33723 1/1; Waikari Cave, McCulloch colln, CM unreg. – 5/3.

Order Passeriformes

Family Acanthisittidae

Genus *Acanthisitta* Lafresnaye

***Acanthisitta chloris* (Sparrman, 1787) (Rifleman)**

Material: Arden Rockshelter 3 – MNZ S33664 1/1; Ardenest – MNZ S33696 1/1; Gowan Hills owl site, old deposit – MNZ S33814 1/1.

Genus *Xenicus* G.R. Gray

***Xenicus* species (Bush or Rock Wrens)**

Material: P. Lamb's owl site – MNZ S33470 1/1; Gowan Hills owl site, young deposit – MNZ S33440 1/1; Gowan Hills owl site, old deposit – MNZ S33815 4/1. Pyramid Valley – CM 1/1; Ardenest – MNZ S33695 6/1; Waikari Cave, McCulloch colln, CM unreg. – 1/1.

Genus *Pachyplichas* Millener

***Pachyplichas yaldwyni* Millener, 1988 (South Island Stout-legged Wren)**

Material: P. Lamb's owl site – MNZ S33519 2/2; Ardenest – MNZ S33690 2/1.

Genus *Traversia* Rothschild

***Traversia lyalli* Rothschild, 1894 (Stephens Island Wren)**

Material: Pyramid Valley – CM 1/1.

Family Motacillidae

Genus *Anthus* Bechstein

***Anthus novaeseelandiae* (Gmelin, 1789) (New Zealand Pipit)**

Material: Falcon site, Timpendean – MNZ S33419 1/1; P. Lamb's owl site – MNZ S33471 2/1; Gowan Hills owl site, young deposit – MNZ S33445 7/2; Glencrieff Moa Swamp – MNZ S33489 1/1; Ardenest – MNZ S33691 14/3.

Family Muscicapidae

Genus *Turdus* Linnaeus

***Turdus merula* Linnaeus, 1758 (European Blackbird)**

Material: Rabbit Warren Cave – MNZ S33616 16/1.

Family Sylviidae

Genus *Bowdleria* Rothschild

***Bowdleria punctata* Quoy and Gaimard, 1830 (Fernbird)**

Material: Pyramid Valley – CM 3/2.

Family Pachycephalidae

Genus *Mohoua* Lesson

***Mohoua ochrocephala* (Gmelin, 1789) (Yellowhead)**

Material: Falcon site, Timpendean – MNZ S33416 1/1; Gowan Hills owl site, young deposit – MNZ S33442 2/1; Ardenest – MNZ S33693 4/1.

***Mohoua novaeseelandiae* (Gmelin, 1789) (Brown Creeper)**

Material: Pyramid Valley – CM 3/2.

Family Acanthizidae

Genus *Gerygone* Gould

***Gerygone igata* (Quoy and Gaimard, 1830) (Grey Warbler)**

Material: Ardenest – MNZ S33694 3/1.

Family Monarchidae

Genus *Rhipidura* Vigors and Horsfield

***Rhipidura fuliginosa* (Sparrman, 1787) (New Zealand Fantail)**

Material: Rabbit Warren Cave – MNZ S33428 11/3; P. Lamb's owl site – MNZ S33469 2/1; Ardenest – MNZ S33692 9/2; Gowan Hills owl site old deposit – MNZ S33813 2/1; Waikari Cave, McCulloch colln, CM unreg. – 1/1.

Family Eopsaltridae

Genus *Petroica* Swainson

***Petroica macrocephala* (Gmelin, 1789) (Tomtit)**

Material: P. Lamb's owl site – MNZ S33464 1/1; Gowan Hills owl site, young deposit – MNZ S33447 4/1; Pyramid Valley – CM 1/1; Arden Rockshelter 3 – MNZ S33662 1/1; Ardenest – MNZ S33687 5/1.

***Petroica australis* (Sparrman, 1788) (New Zealand Robin)**

Material: Rabbit Warren Cave – MNZ S33503 3/1; Gowan Hills owl site, young deposit – MNZ S33441 5/2; Gowan Hills owl site, old deposit – MNZ S33816 2/1; Euan Murchison's Rockshelter – CM Av33533, 36538 (2/2); Pyramid Valley – CM 8/3; Arden Rockshelter 3 – MNZ S33661 1/1; Ardenest – MNZ S33686 12/2.

Family Meliphagidae

Genus *Anthornis* Gray

***Anthornis melanura* (Sparrman, 1786) (New Zealand Bellbird)**

Material: Gowan Hills owl site, young deposit – MNZ S33448 7/2; Gowan Hills owl site old deposit – MNZ S33812 1/1; Euan Murchison's Rockshelter – CM Av17785, 33543 (3/1); Pyramid Valley – CM 3/2; Ardenest – MNZ S33688 18/2.

Genus *Prosthemadera* Gray

***Prosthemadera novaeseelandiae* (Gmelin, 1788) (Tui)**

Material: Gowan Hills owl site, young deposit – MNZ S33453 1/1; Gowan Hills owl site old deposit – MNZ S33817 1/1; Euan Murchison's Rockshelter – CM Av16388, 17335, 17784 (9/4); Timpendean Rockshelter – CM Av22371 3/3; Pyramid Valley – CM 49/11; Ardenest – MNZ S33689 8/1.

Family Fringillidae

Genus *Carduelis* Brisson

***Carduelis carduelis* (Linnaeus, 1758) (Goldfinch)**

Material: Falcon site, Timpendean – MNZ S33418 2/1; Arden Rockshelter 1 – MNZ S33656 1/1.

Family Sturnidae

Genus *Sturnus* Linnaeus

***Sturnus vulgaris* Linnaeus, 1758**

Material: Ardenest – MNZ S33698 4/1.

Family Callaeidae

Genus *Callaeas* J.R. Forster

***Callaeas cinerea* (Gmelin, 1789) (South Island Kokako)**

Material: Euan Murchison's Rockshelter – CM Av16387, 17781, 33529–30, 36533 (6/1); Pyramid Valley – CM 49/8; Ardenest – MNZ S33697 14/2; Waikari Cave, McCulloch colln, CM unreg. – 18/3.

Genus *Philesturnus* Geoffroy St.-Hilaire

***Philesturnus carunculatus* (Gmelin, 1789) (Saddleback)**

Material: Gowan Hills owl site, young deposit – MNZ S33454 2/1; Euan Murchison's Rockshelter – CM Av17786, 17791, 33729 (4/1); Pyramid Valley – CM 9/2; Ardenest – MNZ S33684 18/3; Waikari Cave, McCulloch colln, CM unreg. – 2/1.

Family Paradisaeidae

Genus *Turnagra* Lesson

***Turnagra capensis* (Sparrman, 1787) (South Island Piopio)**

Material: Euan Murchison's Rockshelter – CM Av16389, 17787, 36535, 36541, 36542 (8/1); Pyramid Valley – CM 11/2; Arden Rockshelter 3 – MNZ S33663 5/1; Ardenest – MNZ S33685 39/5; Gowan Hills owl site, old deposit – MNZ S33807 4/1.

Family Corvidae

Genus *Corvus* Linnaeus

***Corvus moriorum* Forbes, 1892 (Extinct New Zealand Raven)**

Material: Euan Murchison's Rockshelter – CM Av33730, 33731 (2 ungual phalanges, 2/1); Pyramid Valley – CM 5/1.
We consider that the Euan Murchison's specimens should be referred only tentatively to this species, and no certain record at this site should be allowed before confirmation by additional material.

Class Mammalia

Order Chiroptera

Family Mystacinidae

Genus *Mystacina* Gray

***Mystacina robusta* Dwyer, 1962 (Greater Short-tailed Bat)**

Material: Rabbit Warren Cave – MNZ S33429 4/1; Gowan Hills owl site, young deposit – MNZ S33458 2/1; Gowan Hills owl site, old deposit – MNZ S33818 8/2; Pyramid Valley – CM 6/2; Arden Rockshelter 3 – MNZ S33666 3/1; Ardenest – MNZ S33699 42/6.

***Mystacina tuberculata* Gray, 1843 (Lesser Short-tailed Bat)**

Material: Ardenest – MNZ S33700 11/4.

Order Lagomorpha

Family Leporidae

Genus *Oryctolagus*

***Oryctolagus cuniculus* (Linnaeus, 1758) (European Rabbit)**

Bones of mainly juvenile rabbits were found in several of the predator sites, but whether or not they were prey is in doubt as rabbits could have or did burrow in the sediment in these sites.

Material: Falcon site, Timpendean – MNZ S33412 ×/1; Rabbit Warren Cave – MNZ S33426 c. 90/8; Gowan Hills owl site, young deposit – MNZ S33456 6/1.

Order Rodentia

Family Muridae

Genus *Rattus* Linnaeus

***Rattus exulans* (Peale, 1848) (Kiore)**

Material: Falcon site, Timpendean – MNZ S33413 ×/203; Ledge, Weka Pass – MNZ S33431 50/3; Rockshelter, Sandhurst Stn – MNZ S33437 34/4; Rabbit Warren Cave – MNZ S33425 154/14; P. Lamb's owl site – MNZ S33472 1095/63; Gowan rockshelter – CM NZMa 63–64 9/4; Gowan Hills owl site, young deposit – MNZ S33439 3001/227; Gowan Hills owl site, old deposit – MNZ S33825 18/1; Euan Murchison's Rockshelter – CM NZMa176 ×/18, MNZ S33423 45/5; Timpendean Rockshelter – CM NZMa 644 ×/40, 646 ×/48; Arden Rockshelter 1 – MNZ S33654 4/1; Arden Rockshelter 3 – MNZ S33670 9/1; Ardenest – MNZ S33701 7088 bones + 2937 teeth of 441 individuals; Waikari Cave, McCulloch colln, CM unreg. – 5/1.

***Rattus norvegicus* (Linnaeus, 1758) (Norway Rat)**

Material: Gowan Hills owl site, young deposit – MNZ S33460 10/3.

Genus *Mus* Linnaeus

***Mus musculus* Linnaeus, 1758 (House Mouse)**

Material: Falcon site, Timpendean – MNZ S33410 ×/3; P. Lamb's owl site – MNZ S33475 1/1; Gowan Hills owl site, young deposit – MNZ S33455 23/6; Ardenest – MNZ S33702 11/3.

DISCUSSION

Conclusions drawn from the fossil insect faunas

In previously-recognised laughing owl sites, the deposits were too damp to preserve insect cuticle (Worthy & Holdaway 1994b; in press), but three of the nine Waikari owl sites were dry enough. Ardenest was exceptionally good, and a diverse fauna of ground beetles and weevils was obtained from it (Appendix 4). In the Gowan Hills and Ardenest insect faunas the main species taken by predators, *Mecodema costellum lewisi, Mimopeus* spp., *Megadromus antarcticus*, *Holcaspis* sp. and *Anagotus* spp. are large insects that are active in the early evening or at night in forests, thereby supporting our inference that these deposits were accumulated by laughing owls. These same large species plus *Lissotes reticulatus* and *Oregus* sp. indicate that the surrounding habitats included a dry forest. The forest species of weevil have host-specificities that suggest the plants ngaio, *Coprosma* spp, *Pseudopanax* spp, and *Myrsine* spp. were present in these forests.

Five of the represented species now have relict distributions: *Amychus* sp. cf. *granulatus, Mecodema costellum lewisi, Anagotus stephenensis, A. rugosus, Ectopsis ferrugalis.* Their presence in these North Canterbury sites provides important new data on their former distributions. The fact that *Amychus* sp. cf. *granulatus* and *Anagotus stephenensis* ranged considerably farther south in the immediate past has important conservation implications. For example, habitat restoration on the rodent-free Motunau Island may make this a suitable site to establish new populations.

Large *Mecodema* spp. seem to have particularly fragmented distributions, and the largest, body length *c.* 45 mm, is an undescribed species known from cave deposits in western areas of the northern South Island (Townsend 1990). Worthy (1983) described a fossil insect fauna from a cave at Waitomo that provided evidence for major range contractions in both carabids and weevils. Large weevils have been prone to extinction in the latest Holocene. An undescribed *Hydramphus* sp. was recorded from the West Coast (Worthy & Holdaway 1993). *Tymbopiptus valeas* was described from late Holocene central North Island deposits (<2,000 yrs) by Kuschel (1987), and reference made to associated specimens of an undescribed species in each of the genera *Anagotus* and *Tychanopais*. As the Gowan Hills and Ardenest deposits are at most only one or two thousand years old, the presence of *Anagotus stephenensis, A. rugosus*, and *Ectopsis ferrugalis* indicates that their range contracted only in the latest Holocene. It confirms what had been surmised from the relict distribution patterns of many species (e.g. by Watt 1979), that such species were once widespread on the mainland.

Insects in the diet of Laughing owls

These insect remains confirm historical records (Buller 1888; Smith 1884) that insects were a significant component of the diet of laughing owls. Robust exoskeletons have a better chance of being preserved, and so most of the identified insects were large ground-dwelling, or trunk-crawling, ground-beetles and weevils. We cannot know to what extent soft-bodied species such as worms and moths were eaten, but the high frequency of some of the large beetles, e.g. *Mecodema* spp. indicate these were preferred prey. Despite the seemingly robust nature of weta *Deinacrida* spp. mandibles and legs, no remains of these large insects were detected. The principal prey species were active in early evening or at night, coinciding with the owl's activity period as deduced from the species composition of vertebrate prey. The presence of a diverse range of insects being part of laughing owl prey is entirely consistent with our portrayal of this bird as an opportunistic predator, active in the evenings and at night, preying on any species of manageable size that it located either on the ground, or, in the case of diurnal birds, on their roosts. The extremely diverse range of both vertebrate and invertebrate prey found in laughing owl sites gives them unparalleled significance in palaeofaunal reconstruction in New Zealand.

Age of the faunas

The deposits known from the Waikari area cover several distinct periods. The fluvial sediments of the Omihi Stream provide a limited fauna from the Otiran glaciation before about 22,600 yrs BP; Glencrieff swamp dates from the Late Glacial and earliest Holocene 12,000 to 10,000 yrs BP; the large Pyramid Valley fauna dates between 4,000 and 2,000 yrs BP, and North Dean 2,000 to 1,000 yrs BP. The Waikari Cave fauna also represents the late Holocene from about 4,000 yrs BP to the present. The archaeological and predator sites sample the Holocene faunas of the last 1,000 years. However, accumulation of the predator faunas could have begun 2,000 to 3,000 yrs BP, as is almost certainly the case for the Gowan Hills old fauna and Ardenest. These sites, therefore, provide sufficient information from the Otiran to the present from which to assess changes in the composition of the vertebrate faunas in the area.

Palaeofaunal reconstruction

Otira Glacial period

The Otiran fauna, from the Omihi Stream gravels and loess, contains open shrubland and wetland species. The shrubland component consists of the moas *Euryapteryx geranoides*, *Emeus crassus*, *Pachyornis elephantopus*, *Dinornis struthoides* and *Dinornis giganteus*, the extinct goose *Cnemiornis calcitrans*, and the rails *Gallinula hodgenorum*, *Fulica prisca*, and *Aptornis defossor*, while the wetland component includes *Cygnus sumnerensis*, *Anas superciliosa*, and *Aythya novaeseelandiae*. In addition, the rails and the goose are often associated with wetland sites such as spring-holes (e.g. Glenmark – data herein; Hamilton – Booth 1875), or lake deposits (Pyramid Valley). The presence of *Aythya* suggests lacustrine-like habitat. Pigeons use shrublands and forest habitats, but in the fossil record are generally more abundant from drier eastern areas (Worthy & Holdaway 1993). This fauna therefore suggests that in the Otiran the Omihi Valley contained a stream/lake system surrounded in open shrublands.

Between 10,000 and 12,000 years ago the terrace around Glencrieff was still an open grass and shrubland, and the moas *Pachyornis elephantopus* and *Emeus crassus* dominated the moa fauna, although *Dinornis giganteus* was also present.

The absence of *Euryapteryx* from Glencrieff is intriguing, as it is present in the Omihi Stream fluvial deposits and in Canterbury Otiran loess faunas, albeit in low numbers (Worthy 1993a; Worthy & Holdaway 1995). Their absence may be related to topography and to the microhabitat of Glencrieff, located on a terrace which even now has wet puggy soils in winter. Worthy (1990) showed that *Euryapteryx* preferred hill country, and was replaced by *Emeus* at lower altitude. *Euryapteryx* was common in the Pyramid Valley deposits, which although sampling a geologically more recent period, is also in a small valley on the flanks of high hills, so is surrounded by well drained soils. *Euryapteryx* may have required conditions favoured by the well-drained slopes about Pyramid Valley, and which were absent on the flat at Glencrieff. For whatever reason *Euryapteryx* was absent at Glencrieff, its presence in other Otiran sites shows this species was part of the regional Otiran fauna.

Quail *Coturnix novaezelandiae* and pipit *Anthus novaeseelandiae* – birds of open habitats – dominated the Glencrieff small bird fauna. Other birds present were kea *Nestor notabilis*, Haast's eagle *Harpagornis moorei*, brown teal *Anas chlorotis*, kiwi *Apteryx* spp., snipe *Coenocorypha* cf. *aucklandica*, parakeets *Cyanoramphus* spp., and laughing owl *Sceloglaux albifacies*.

Holocene

The prominence of *Phyllocladus* and *Libocedrus* pollen in basal layers at Pyramid Valley (Moar 1970), and at Glencrieff suggests that the mountain toatoa – mountain cedar shrubland prevailed in the area from the early Holocene until a major change in the vegetation about 5,000–6,000 years ago. Then there was a rise to dominance of beech in the regional vegetation, and around Pyramid Valley a podocarp forest dominated by matai became established. We believe that the matai forest would have been restricted to valley bottoms and terraces, whereas that land now in rough pasture on slopes rising above *c.* 300 m supported beech forest. The ridge tops, exposed to climatic extremes, had only shrubland throughout the Holocene. Shrubland was probably replaced by patches of fellfield and tussock grasses at the highest or most exposed points.

The Holocene palaeofauna of the Waikari area of North Canterbury can be reconstructed from the fossil faunas preserved in the fossil sites of this period listed in Appendix 5, and whose taphonomies are described above. The taphonomies represented in these Holocene sites include pitfall-trapping in caves, swamp-miring, avian predator sites, and vagrant deaths with subsequent preservation in rockshelters.

Different taphonomic processes cause different biases in the resulting fossil fauna. Ground-frequenting, usually flightless species, can be expected to predominate in pitfall traps. Larger, heavier species, and/or species attracted to water, dominate the fauna in swamps. Animals in the preferred prey size range, and those exposed behaviourally and ecologically to the predators concerned, will dominate predator-accumulated faunas (Andrews 1990). As the predator responsible for the fossil deposits in the sites discussed above was the laughing owl, nocturnal, ground-frequenting species could be expected to, and did, predominate (Worthy & Holdaway 1994b; in press). To demonstrate these biases we have summarised the faunas into major taphonomic categories in Table 9.

It seems that all the Holocene faunas date from the late Holocene, from 5000 yrs BP to the present, and so were accumulated when podocarp forests occupied the valleys and terraces, while beech forests, and/or shrublands, occupied the higher slopes. However, after the arrival of Polynesians in New Zealand about 800–1000 years ago (Anderson 1991), most eastern areas were deforested rapidly (Molloy et al. 1963; McGlone 1983), so that a tussock – shrubland mosaic had become established by 500 years ago. As all fossil sites are at low

Table 9 Comparison of the total faunas (MNI) from various taphonomies for the Waikari area. Pitfall faunas include Waikari Cave (THW/RNH collection only), and the fluvial component of Rabbit Warren Cave. Swamp faunas include Pyramid Valley, Glencrieff, The Deans, and the swamp between Culverden and Waikari. Predator faunas include Euan Murchison's Rockshelter, Ardenest, Arden 1, 2, and 3, Timpendean Falcon site, Ledge Weka Pass, Sandhurst rockshelter, Rabbit Warren Cave, Lamb's site, and Gowan Hills young and old faunas. Archaeological sites include Timpendean and Gowans. The *Cnemiornis* and *Porphyrio* bones listed in the predator site assemblage are probably older fissure deposit specimens that have been secondarily incorporated in the owl deposit.

	Pitfall fauna	%	Swamp fauna	%	Predator fauna	%	Archaeol fauna	%
?Megalapteryx didinus	0	0.00	1	0.19	0	0.00	0	0.00
Emeus crassus	0	0.00	103	19.51	0	0.00	0	0.00
Pachyornis elephantopus	1	2.38	36	6.82	0	0.00	0	0.00
Euryapteryx geranoides	0	0.00	28	5.30	0	0.00	1	2.44
Dinornis struthoides	0	0.00	2	0.38	0	0.00	0	0.00
D. giganteus	1	2.38	71	13.45	0	0.00	0	0.00
Apteryx australis	0	0.00	4	0.76	0	0.00	2	4.88
Apteryx owenii	1	2.38	4	0.76	0	0.00	0	0.00
Apteryx sp.	0	0.00	4	0.76	4	1.81	0	0.00
Anas chlorotis	0	0.00	13	2.46	0	0.00	1	2.44
Anas gracilis	0	0.00	3	0.57	0	0.00	0	0.00
Anas superciliosa	0	0.00	3	0.57	0	0.00	0	0.00
Aythya novaeseelandiae	0	0.00	5	0.95	0	0.00	0	0.00
Euryanas finschi	19	45.24	6	1.14	3	1.36	0	0.00
Malacorhynchus scarletti	0	0.00	7	1.33	0	0.00	0	0.00
Hymenolaimus malacorhynchus	0	0.00	0	0.00	0	0.00	1	2.44
Tadorna variegata	0	0.00	5	0.95	0	0.00	2	4.88
Cnemiornis calcitrans	0	0.00	1	0.19	1	0.45	0	0.00
Strigops habroptilus	1	2.38	9	1.70	2	0.90	0	0.00
Nestor sp.	0	0.00	0	0.00	1	0.45	0	0.00
Nestor meridionalis	0	0.00	13	2.46	1	0.45	4	9.76

Table 9 Contd

	Pitfall fauna	%	Swamp fauna	%	Predator fauna	%	Archaeol fauna	%
Nestor notabilis	0	0.00	10	1.89	0	0.00	0	0.00
Cyanoramphus spp.	0	0.00	8	1.52	36	16.29	1	2.44
Ninox novaeseelandiae	0	0.00	1	0.19	1	0.45	0	0.00
Sceloglaux albifacies	0	0.00	5	0.95	2	0.90	0	0.00
Aegotheles novaezealandiae	1	2.38	5	0.95	15	6.79	0	0.00
Hemiphaga novaeseelandiae	0	0.00	70	13.26	6	2.71	1	2.44
Columba livia	0	0.00	0	0.00	0	0.00	1	2.44
Falco novaeseelandiae	0	0.00	1	0.19	1	0.45	1	2.44
Circus eylesi	0	0.00	7	1.33	1	0.45	1	2.44
Harpagornis moorei	0	0.00	4	0.76	0	0.00	0	0.00
Gallinula hodgenorum	7	16.67	9	1.70	3	1.36	0	0.00
Gallirallus australis	0	0.00	19	3.60	6	2.71	3	7.32
Porphyrio melanotus	0	0.00	0	0.00	0	0.00	1	2.44
Porphyrio hochstetteri	1	2.38	4	0.76	1	0.45	0	0.00
Fulica prisca	10	23.81	8	1.52	0	0.00	0	0.00
Aptornis defossor	1	2.38	12	2.27	0	0.00	0	0.00
Coenocorypha aucklandica	0	0.00	1	0.19	12	5.43	0	0.00
Charadrius bicinctus	0	0.00	0	0.00	4	1.81	0	0.00
Thinornis novaeseelandiae	0	0.00	0	0.00	1	0.45	0	0.00
Sterna albostriata	0	0.00	0	0.00	1	0.45	0	0.00
Himantopus novaezelandiae	0	0.00	2	0.38	0	0.00	0	0.00
Egretta alba	0	0.00	1	0.19	0	0.00	0	0.00
Coturnix novaezelandiae	0	0.00	4	0.76	34	15.38	16	39.02
Poliocephalus rufopectus	0	0.00	2	0.38	0	0.00	0	0.00
Diomedea cauta	0	0.00	0	0.00	0	0.00	1	2.44
Pterodroma inexpectata	0	0.00	0	0.00	3	1.36	0	0.00
Pterodroma cookii	0	0.00	0	0.00	2	0.90	0	0.00
Puffinus sp.	0	0.00	0	0.00	1	0.45	1	2.44
Pelecanoides urinatrix	0	0.00	0	0.00	1	0.45	0	0.00
Oceanites nereis	0	0.00	0	0.00	2	0.90	0	0.00
Acanthisitta chloris	0	0.00	0	0.00	3	1.36	0	0.00
Xenicus sp.	0	0.00	1	0.19	4	1.81	0	0.00
Traversia lyalli	0	0.00	1	0.19	0	0.00	0	0.00
Pachyplichas yaldwyni	0	0.00	0	0.00	3	1.36	0	0.00
Bowdleria punctata	0	0.00	2	0.38	0	0.00	0	0.00
Prosthemadera novaeseelandiae	0	0.00	11	2.08	7	3.17	3	7.32
Anthornis melanura	0	0.00	2	0.38	6	2.71	0	0.00
Petroica australis	0	0.00	3	0.57	9	4.07	0	0.00
Petroica macrocephala	0	0.00	1	0.19	4	1.81	0	0.00
Mohoua ochrocephala	0	0.00	0	0.00	3	1.36	0	0.00
Mohoua novaeseelandiae	0	0.00	2	0.38	0	0.00	0	0.00
Gerygone igata	0	0.00	0	0.00	1	0.45	0	0.00
Corvus moriorum	0	0.00	1	0.19	1	0.45	0	0.00
Rhipidura fuliginosa	0	0.00	0	0.00	7	3.17	0	0.00
Anthus novaeseelandiae	0	0.00	1	0.19	7	3.17	0	0.00
Callaeas cinerea	0	0.00	8	1.52	4	1.81	0	0.00
Philesturnus carunculatus	0	0.00	2	0.38	5	2.26	0	0.00
Turnagra capensis	0	0.00	2	0.38	8	3.62	0	0.00
Carduelis carduelis	0	0.00	0	0.00	2	0.90	0	0.00
Turdus merula	0	0.00	0	0.00	1	0.45	0	0.00
Sturnus vulgaris	0	0.00	0	0.00	1	0.45	0	0.00
Total	42	100	528	100	221	100	41	100

altitude, below that which would have supported natural shrubland before 1,000 years ago, we can discuss them together. It is necessary, however, to segregate sites dating from the period before deforestation from those that sample the fauna in the man-modified environment.

5000–1,000 years BP

Pyramid Valley provides the single most diverse fauna known from a South Island fossil site, with about 50 species of vertebrates (Holdaway & Worthy in press). As well as a large sample of moas, the wetland fauna is tolerably complete. However, small species are under-represented because they were difficult to detect and extract from the swamp, and because of an inherent bias in wetlands towards sampling bigger, more easily mired, species. The fauna was deposited in the period between establishment of podocarp forest in the lake environs about 5,000 years ago, and about 2,000 years ago.

The moa fauna is dominated by *Emeus crassus* (78 individuals, nearly half of all moas). *Euryapteryx geranoides* and *Pachyornis elephantopus* were present in roughly equal numbers, but together only totalled half that of *E. crassus*. The 63 dinornithids comprised 62 *Dinornis giganteus* and only one *D. struthoides*. This was a substantially different mix of taxa from that at the Late Glacial – early Holocene sample from Glencrieff, only 2.5 km away, where there were no *E. geranoides* among the 30 moas, and *E. crassus* and *P. elephantopus* were codominant. *D. giganteus*, represented by five individuals (c. 17%), was relatively rare. Superficially, therefore, *P. elephantopus* declined in abundance with the transition from a landscape dominated by shrubland to one where tall forest occupied at least the lower slopes, whereas *E. geranoides* appeared for the first time, and the frequency of *D. giganteus* apparently rose.

P. elephantopus dominated Otiran loess faunas in Canterbury (Worthy 1993a), and on Mt Cookson in North Canterbury (Worthy & Holdaway 1995). The decline in frequency of this species with increasing vegetation cover in the Waikari area supports the hypothesis that it favoured areas of open vegetation, and especially the short shrublands – grasslands where loess was being deposited (Worthy 1993a).

The mean size of the late Glacial *P. elephantopus* from Glencrieff was larger than those from the late Holocene in Pyramid Valley. Since both populations were living in essentially the same area, this variation must be related not to geographic features, but to their different ages. Differing climate, and consequent temperature and associated vegetation differences, are the main temporally variable factors that could affect birds. On Mt Cookson *P. elephantopus* increased in mean size from the mid-Otiran to the coldest time of the Late-Otiran glacial period (Worthy & Holdaway 1995). Therefore, *P. elephantopus* conformed to Bergman's Rule; as temperature declined, their body mass increased with an associated decrease in relative surface area. Other moas showed post-glacial dwarfing, in particular *Megalapteryx didinus* (Worthy 1988; Worthy & Holdaway 1993), and *Euryapteryx curtus* and *Pachyornis mappini* (Worthy 1987b). These are all species that were characteristic of shrubland or grassland environments (Worthy 1990), and as such, would have been less protected from lower temperatures and more exposed to wind-chill than those that lived inside forests.

Apart from a reduced size in the post-glacial period, the population of *P. elephantopus* in the Waikari area also showed a change in leg geometry. While femur length was not significantly reduced, tibiotarsus length was ($P < 0.05$), and tarsometatarsus length was ($P < 0.01$) – that is, the more distal the element the greater the reduction in length. Femur sagittal diameter was significantly reduced ($P < 0.001$), showing that there was a decrease in weight associated with the size reductions seen in other elements. Therefore, with decreased body mass *P. elephantopus* developed proportionately shorter lower legs. By this line of reasoning, we infer that as environmental temperature declined, body size was increased without significant increase in femur length, hence more of the tibiotarsus was incorporated in the body mass. It is significant to note that the bigger body would require a longer tibiotarsus and tarsometatarsus to keep it off the ground. The tarsometatarsus broadened significantly to accommodate the extra load. As the increased body mass would mostly be accommodated in the trunk, not the neck and head, femur length would not be expected to alter in proportion to tibiotarsus length, since to do so would alter the weight distribution over the feet. There are also advantages in heat retention to be gained from increased body mass and the subsequent reduction in surface area to mass ratio. These changes should incur positive benefits for survival in exposed areas of low temperature.

The above suggestion, that *Euryapteryx geranoides* could have been restricted to drier soils and hence excluded from Glencrieff, is supported by its presence in Pyramid Valley, which is surrounded by hills. This hypothesis is also supported by the observation that *E. geranoides* was the dominant moa in the hillside earth-flow site of The Deans which lies a few kilometres to the south of, and where deposition was contemporary with, Pyramid Valley. The only moa of known Holocene age from a cave or rockshelter in the area was the *E. geranoides* specimen in the Timpendean site, which lies in a shallow valley within hill country.

Megalapteryx didinus was present at Glenmark, and probably in The Deans fauna, both deposited within hill country. Shrublands on the adjacent ridges probably provided the habitat of these moas, which in western areas were once characteristic birds of the subalpine shrublands (Worthy 1988), and glacial landscapes (Worthy 1993b). The species was absent from both Glencrieff and Pyramid Valley.

Dinornis giganteus was uncommonly well-represented in Pyramid Valley, where it achieved a higher rate of representation than in any other site in New Zealand (see data in Worthy 1990). This probably does not reflect a habitat preference, but rather the special entrapment conditions of the swamp. Many of the *Dinornis* had gizzard contents in which abundant summer fruits such as *Coprosma* spp. and matai were preserved (Burrows et al. 1981), which suggests most were trapped in summer. As the site was a shallow lake during the main period of moa deposition (Burrows 1989), water levels would probably have been high in the wet season, but low during the summer drought (January – March). When the lake was low a bird would have to walk a considerable distance across the exposed lake bed to drink. The long-legged *D. giganteus* could walk out further through the soft gyttja lake sediments (which thickened from 1 m near the shore to 3 m in the lake centre), but its great weight placed it at considerable risk of becoming mired. Most birds were trapped during the lake phase, since Gregg (1972) observed that the horizontal stratification of the gyttja passed uninterrupted over the skeletons, and Burrows (1989) noted that most skeletons were wholly within the gyttja. However, some moas were trapped after the lake phase, as the excavation plans in Duff (1952) show some moas partially within the peat. Summer miring of the large *D. giganteus* therefore biased the frequency of representation of this species at Pyramid Valley.

The single pitfall fauna available, that from Waikari Cave, dates from the Late Holocene. The cave is about 10 m above, and within 100 m of, the Waikari Stream. The trap was an entrance shaft 2 m deep and < 1 m in diameter. Unusually for pitfall traps, only one moa (a juvenile) was present. Waikari Cave therefore provides no information on the moa species composition in the area.

The Glenmark moa fauna (Haast 1869) was probably deposited mainly during the Holocene. As bones from different subsites were not recorded separately, we cannot know whether different faunas were represented. However, Worthy's (1990) interpretation of the species assemblage is supported by the frequency of bones surviving in the Canterbury Museum (see above, and Appendix 5). The emeid fauna was remarkably similar to that in Pyramid Valley, with *Emeus crassus* predominating, and fewer equally abundant *Pachyornis elephantopus* and *Euryapteryx geranoides*. The Glenmark fauna differed, however, in having a greater frequency of *Dinornis struthoides*. There is less room for confusion in interpreting the names Haast applied to dinornithids compared with emeids, and since in both his list and among surviving Canterbury Museum bones, the small *Dinornis* is coabundant with *D. giganteus*, we accept that this species was relatively common in the fauna. The lower proportion of *D. giganteus* is more consistent with other spring sites, and so the site/s probably did not have the same biases that Pyramid Valley had. Glenmark also differs from Pyramid Valley in having more *Cnemiornis*.

Waikari Cave and Pyramid Valley together provide important data on the rail fauna of the area. In Waikari Cave, weka *Gallirallus australis* was rare, whereas the extinct coot *Fulica prisca* and Hodgens' rail *Gallinula hodgenorum* were both relatively common, which is unusual as elsewhere these species are rare (Worthy & Holdaway 1993). For example, Millener (1981) recorded coot from only 21 sites in the South Island, six of which were middens. Coots account for about 24% of the Waikari Cave fauna, and Hodgens' rail 16%. These high proportions may reflect a preference by these species for stream margins as suggested by Holdaway (1989). Both taxa are represented in the lake fauna in Pyramid Valley, together comprising 3–4 % of non-moa MNI (Holdaway & Worthy, in press). A preference for wetlands is supported by the observation that *Gallinula hodgenorum* bones were in a 250–year old midden located beside a wetland near the Rangitikei River (Cassels et al. 1988), indicating late survival of this species in a lowland, wetland, habitat. The Pyramid Valley fauna shows that weka were present in the area, and indeed were more common around the lake than coots and gallinules. This may indicate niche partitioning, with coots and gallinules favouring the riparian margins of streams and wekas the inland habitats.

Of the other rails, takahe *Porphyrio hochstetteri* was present in both Waikari Cave and Pyramid Valley, but it was relatively rare. The large gruiform, the adzebill *Aptornis defossor* was in both Waikari Cave and Pyramid Valley. Its comparative abundance in Pyramid Valley may relate to its larger size and consequent increased propensity for miring. On the other hand, the similar-sized goose was very rare there, which suggests that the abundance of adzebills may truly reflect their greater abundance in the living fauna. By contrast, bones of smaller species almost certainly record the chance death of individuals in or near the lake, and the subsequent preservation of their bones in the lake sediments. If larger size significantly increased miring propensity, then adzebills were less common than weka, coots and gallinules around Pyramid Valley.

The Waikari pitfall fauna shows that kakapo *Strigops habroptilus* and little-spotted kiwi *Apteryx owenii* were present, but rare. Weka, kiwis and kakapo dominated the faunas in pitfall traps on Takaka Hill (Worthy & Holdaway 1994a), as they did at Waitomo and on the West Coast (Worthy & Holdaway 1993). In Pyramid Valley no little spotted kiwi were present, only a larger species about the size of *A. australis*. Although kakapo and kiwi were present in Pyramid Valley, and in The Deans faunas, they were rare or uncommon around Waikari during the Late Holocene, in comparison with their abundance in areas with wetter climates.

Species characteristic of more open country (shrublands and grasslands) include the NZ quail *Coturnix novaezelandiae* and pipit *Anthus novaeseelandiae*. Only one individual quail was present in the lake and two individuals in the cave faunas; neither fauna had *Anthus*. This suggests that the vicinity of the lake and the cave was forested during the relevant periods of deposition in the late Holocene. The rarity or absence of these open country species contrasts with evidence from Glencrieff, where the quail was common and pipits present in a shrubland environment several thousand years before the accumulation of Pyramid Valley deposits.

Waterfowl were abundant in the Pyramid Valley fauna, as expected in a lacustrine habitat. Piscivores, such as shags and bitterns were, however, conspicuously absent, and there was only one white heron *Egretta alba* (Holdaway & Worthy in press).

Of the ducks, only brown teal *Anas chlorotis* was noticeably more abundant than others. Where it frequents waterways now, it prefers shaded overhanging banks (Marchant & Higgins 1990). In fossil faunas from wetter, more western areas, this species is often recorded from more terrestrial habitats under closed canopy forests (see discussion in Worthy & Holdaway 1994a), so its rarity in the Waikari Cave fauna requires an explanation; perhaps it was something to do with the abundance of Finsch's duck *Euryanas finschi* in that fauna.

Finsch's duck dominated the Waikari Cave fauna, as it did in other eastern pitfall sites of Holocene age, such as Martinborough Caves (Yaldwyn 1956), Kings Cave in South Canterbury

(Chapman 1986; THW unpubl. data), Earnscleugh Cave in Otago (unpubl. data), and Castle Rocks in Southland (Hamilton 1893). Finsch's duck was fairly common in the Pyramid Valley deposits, but less so than other waterfowl that use/d wetlands. Finsch's duck has most often been found in fossil faunas deposited within terrestrial environments (Worthy & Holdaway 1993; 1994a), and we consider that, rather than having been an aquatic insectivore (Atkinson & Millener 1991), it depended little on wetlands. A species characteristic of areas inferred to have been covered in shrubland / forest mosaics (Worthy & Holdaway 1993; 1994a), we consider Finsch's duck to have been an ecological equivalent of the Australian wood duck *Chenonetta jubata*, the only terrestrial grazing duck of Australia (Marchant & Higgins 1990). In wet, closed canopy forests, Finsch's ducks were absent, but brown teal were present (Worthy & Holdaway 1993; 1994a). We suggest that in the drier eastern areas Finsch's duck excluded brown teal from terrestrial habitats, and so brown teal were restricted to wetlands. Both species were present in the wet earth-flow deposit of The Deans, but this site provides no meaningful relative frequency data.

Grey teal *Anas gracilis* were present in Pyramid Valley, but in small numbers, along with grey duck *A. superciliosa*, scaup *Aythya novaeseelandiae*, and shelducks *Tadorna variegata*. Except scaup, all these species breed on the lake at Pyramid Valley today (pers. observ. 1993), and the presence of juvenile bones shows that they were doing the same in the late Holocene. The pink-eared duck *Malacorhynchus scarletti* was relatively common. It was a specialist dabbler with a bill adapted to sieving the micro-crustaceans such as ostracods, or insect larvae, from the water (Worthy 1995; Holdaway & Worthy in prep). That pink-eared ducks were present, and shovelers *Anas rhynchotis* were not, is pertinent to the question of when shovelers became established in New Zealand. Shovelers now occupy the same ecological niche that pink-eared ducks used to do. As shovelers were not present at Pyramid Valley, they probably were not part of the New Zealand fauna at that time, or were excluded ecologically by *Malacorhynchus*.

The extinct goose *Cnemiornis calcitrans* was apparently rare in the district during the late Holocene, with only one individual present in Pyramid Valley, and at least four in Glenmark. It was present in the loess faunas of Canterbury (Worthy 1993a), and in the Otiran fluvial sequence at Omihi Stream. This species was common in the Otiran shrubland forest mosaics of the West Coast (Worthy & Holdaway 1993), and present in similar habitats in Takaka Valley (Worthy & Holdaway 1994a). In sites of Holocene age it is present only in eastern sites, where shrublands were at least likely to have been present, e.g. Enfield swamp (Forbes 1892). It therefore seems likely that this large goose preferred open grassland – shrubland type habitat.

Pigeons *Hemiphaga novaeseelandiae* were very common in the Pyramid Valley deposit. They were probably attracted there by a favourite food, the fruit of matai trees. Their fossil abundance there need not represent their frequency in the original avifauna. Both kaka *Nestor meridionalis* and kea *N. notabilis* were present and relatively common. Kea, now considered an upland species, was present on the Canterbury downlands in the early and late Holocene. It may have been attracted to these sites by carrion, as it certainly is in upland environments today (R. Morris pers comm., and as depicted in 'Kea Mountain Parrot', a Television New Zealand documentary filmed in 1993). Parakeets *Cyanoramphus* spp. were present, but we could not determine which species was represented, for the reasons outlined in Worthy & Holdaway (1994a).

The diurnal predator assemblage of the Late Holocene in the Waikari area included Haast's eagle *Harpagornis moorei*, extinct Eyles's harrier *Circus eylesi*, and falcon *Falco novaeseelandiae*. This contrasts with western areas where eagles and harriers were present during the Otiran, but absent in the Holocene (Worthy 1993b; Worthy & Holdaway 1993; 1994a), suggesting that they required regions where the forest canopy was discontinuous, or that their prey species did. In the Waikari area the lake at Pyramid Valley would have provided a forest margin, and it also would have attracted prey species. Forest would not have been continuous over nearby hills and riverbeds.

Laughing owls *Sceloglaux albifacies* and moreporks *Ninox novaeseelandiae* were both present in the Waikari region in the late Holocene. Laughing owls were not the large arboreal insectivores described by Atkinson & Millener (1991), but generalist predators on reptiles, birds and mammals, preferring to take their food at night and off the ground (Worthy & Holdaway 1994b; in press; Holdaway & Worthy in press). On the other hand they did also prey on insects. We found only remains of large flightless beetles, particularly carabids and weevils, probably because of the robust nature of the exoskeleton of these groups. We attribute several faunal assemblages to laughing owls. As on Takaka Hill, the Waikari deposits show that laughing owls preyed on a diverse range of species, including moreporks. Owlet nightjars *Aegotheles novaezealandiae* were probably fairly common in the area: despite their small size, five individuals were detected in Pyramid Valley, and their bones were also present in Waikari Cave and several owl sites.

In addition to shoveler, two other species were noticeably absent from the Pyramid Valley fauna – pukeko *Porphyrio melanotus* and swamp harrier *Circus approximans* (Holdaway & Worthy in prep). Had they been part of the New Zealand fauna 4,000 to 2,000 years ago, they would almost certainly have been present in the deposits, so we conclude that they were not. Their respective congeners, takahe *P. hochstetteri* and Eyles's harrier *C. eylesi* were present. However, in the 4–500 year old Timpendean fauna pukeko was present. It seems that pukeko and harrier, along with the shoveler duck, were able to establish in New Zealand only following the gross habitat disturbances of the last 1,000 years.

Because the taphonomies of Pyramid Valley and Waikari Cave did not favour the preservation of very small birds, or the subsequent recovery of their fossils, we have few direct data on the composition of the passerine fauna of the period 5,000 to 1,000 years ago. Although the larger kokako *Callaeas cinerea* and tui *Prosthemadera novaeseelandiae* were common in the Pyramid Valley deposits, these and other species are best discussed in conjunction with the owl-accumulated faunas, where all are better represented. Furthermore, the owl-accumulated faunas located were deposited mostly during the last thousand years, as shown by the numerical dominance of kiore, and the contained native birds – with two main exceptions – represent surviving remnants of the undisturbed ecosystem.

The column for predators in Table 9 clearly shows their importance in representing small species: 34% of the birds in the assemblage were passerines. This assemblage can be directly compared with that obtained from Predator Cave on Takaka Hill, which was also accumulated by laughing owls (Worthy & Holdaway 1994a; in press; Holdaway & Worthy in press). There are significant differences between the Takaka and combined North Canterbury faunas.

Acanthisittid wrens made up a significant proportion of avian prey MNI on Takaka Hill (>25%: Worthy & Holdaway in press). By contrast, near Waikari *Xenicus* spp., *Pachyplichas yaldwyni*, *Acanthisitta chloris*, and *Traversia lyalli* were present, but were much less abundant than on Takaka Hill (only 4% of avian MNI). Tui *Prosthemadera novaeseelandiae* were noticeably less common prey than bellbirds *Anthornis melanura* on Takaka Hill, but in Waikari sites both were equally represented. The greater numbers of tui in Pyramid Valley swamp is probably due to their relatively large bones, and the bias against finding small elements in this swamp/lake site. Robins *Petroica australis* and tomtits *P. macrocephala* were present as prey in Waikari sites and, as on Takaka Hill, totalled less than 10% of prey items. Yellowhead *Mohoua ochrocephala* and brown creeper *M. novaeseelandiae* were both present around Waikari, but were not common in the fossil faunas. Grey warbler *Gerygone igata* was represented by a few bones. It is usually rare in fossil sites, probably because its bones are among the smallest for New Zealand birds. Fantail *Rhipidura fuliginosa* are only a little larger than grey warblers, but their bones are much more numerous in the Waikari owl faunas. They were more common than in Takaka Hill owl faunas, which suggests that fantails may have been more common around Waikari.

Another passerine that was more numerous in Waikari fossil faunas than in others studied in the South Island (Worthy & Holdaway 1993; 1994a; 1995) was the piopio *Turnagra* *capensis*. This species was apparently vulnerable to laughing owls, as it is present in most sites: Hermits Cave (Worthy & Holdaway 1994b), Predator and Hawkes caves, Takaka Hill (Worthy & Holdaway 1994a; in press), and others elsewhere (unpublished data). Piopio were a rare prey item in western areas, but around Waikari they were nearly the most abundant passerines, ranking equally with robins and pipits. We therefore conclude that piopio preferred the drier eastern forest – shrublands to the wetter, closed canopy, forests of western areas.

Saddleback *Philesturnus carunculatus* and kokako *Callaeas cinerea* were present in lake, pitfall, and predator faunas at Waikari. In the richest owl site – Ardenest – and in Euan Murchison's rockshelter, they were equally abundant, but kokako were more common in the Pyramid Valley collection, where their large bones were easy to find. They were no doubt equally numerous in the living fauna. Kokako were killed by owls at Hermits Cave in the West Coast lowlands (Worthy & Holdaway 1994b), but were absent from the large owl assemblages from Takaka Hill, and rare in pitfall deposits (Worthy & Holdaway 1994a).

At Takaka, larger species, such as kakapo, kiwi and pigeon, were, like kokako, not taken by owls even though they were present in the area (their bones were in contemporary pitfall traps). Laughing owls could and did take these species, and left their remains at Hermits Cave and the Waikari sites, so their absence in Takaka owl sites requires explanation. Maybe laughing owls were less dependent on a common staple at Waikari, as on Takaka Hill over 30% of the avian MNI were parakeets compared to 16% at Waikari, and in the whole diet, bats *Mystacina* spp. provided a third of the prey items for Takaka owls. If kiore are excluded as absent from the prehuman fauna, the Waikari owls showed no obvious preference for any one prey species. This suggests that no one prey species was superabundant, as parakeets and bats apparently were on Takaka Hill.

The owl deposits show that a range of petrel species nested in the area. Laughing owls at Hermits Cave on the West Coast favoured petrels (Worthy & Holdaway 1994b). The Waikari owl sites contained mottled petrels *Pterodroma inexpectata*, Cook's petrel *P. cookii*, a shearwater *Puffinus* sp., diving petrel *Pelecanoides urinatrix* and a storm petrel *Oceanites (Garrodia) nereis*. We recorded the first four of these in Holocene deposits on Mt Cookson in North Canterbury (Worthy & Holdaway 1995). Diving petrels dominated a small fauna in the 'Mimiomoko pocket' near the mouth of the Waipara River, southeast of Waikari (Rich et al. 1979; Appendix 5), which is almost certainly a predator assemblage although it was not recognised as such when it was described.

Records of mottled, Cook's, and diving petrels came from the Lamb's owl site under a substantial cliff on one of the highest hills in the region (480 m). Extant petrel colonies are often near cliff tops, because they facilitate takeoff when the birds leave the colony. Several petrel bones were also recorded from Euan Murchison's rockshelter. We argued above that much of the material in the shelter could have been owl-derived, but even if the petrel bones are archaeological in origin, the birds could have been collected from the ridge above the Lamb's owl site, and so are still 'local'.

In the coastal site of Puffinus Cleft at Nape Nape Scenic Reserve (see Appendix 5) the sooty shearwater *Puffinus griseus* dominated the fauna, providing evidence of a former colony of these shearwaters there. No other petrels were present in this site. Sooty shearwaters breed on many islands and a few headlands throughout New Zealand; the nearest colonies are on Motunau Island, where about 100 pairs breed (McEwen 1987), and islands in Cook Strait and on Banks Peninsula (Oliver 1955; Marchant & Higgins 1990).

The owl deposits also confirm the presence of some species such as banded dotterel *Charadrius bicinctus*, New Zealand shore plover *Thinornis novaeseelandiae*, and black-fronted tern *Sterna albostriata* as expected from braided riverbed habitats. The shore plover is recorded from an inland site for the first time, either living or as a fossil. It became extinct on the mainland in the mid–1800s (Oliver 1955), but the other two species live in the region's riverbeds today. Black stilts *Himantopus novaezelandiae* were breeding around the lake at Pyramid Valley in the late Holocene, but they are now replaced by pied stilts *H. himantopus*.

Prehuman mammal and reptile fauna

The prehuman mammal fauna of the Waikari area included two short-tailed bats *Mystacina tuberculata*, recorded from one site, and *M. robusta* from several sites. Except for a few bones in Pyramid Valley, all fossil bats came from owl sites. On Takaka Hill both bats were laughing owl prey, and the lesser short-tailed bat was more numerous. In contrast, around Waikari lesser short-tailed bats were much rarer than greater short-tailed bats. Long-tailed bats *Chalinolobus tuberculatus* are unlikely to be detected in owl deposits, even if they had been present in the area, because they are aerial feeders and so probably not exposed to owl predation (Holdaway & Worthy in press).

The prehuman reptile fauna included, in addition to those present today, a tuatara species and Duvaucel's gecko. Tuatara were found in eight sites (two swamps), represented by seventeen individuals. These records substantiate the oral reports, made to the Reverend J. W. Stack by North Canterbury Maori in the nineteenth century, of the former presence there of large lizards (Stack 1875). Allowing for somewhat embellished estimates of size, their description and the reported habit of living in burrows suggests that these lizards were tuatara. Duvaucel's gecko is the largest gecko (32 cm) known with certainty to have been present in New Zealand: only circumstantial evidence links *H. delcourti*, for which there are no provenanced specimens, to New Zealand. *H. duvaucelii*, or a closely related species, was recorded from Mt Cookson at 500 m in North Canterbury (Worthy & Holdaway 1995), along with tuatara. The only other South Island records of Duvaucel's gecko are from Takaka (Worthy & Holdaway 1994a), and it is now restricted to islands; the closest living population is on North Brother Island in Cook Strait. All South Island mainland records are from owl sites. Near Waikari, 27 individuals are represented in five sites, 19 in Ardenest alone.

Other than large reptiles, the owl sites also contained a small gecko (the size of *Hoplodactylus maculatus*), and two skinks, one the size of *Oligosoma nigriplantare*, and the other the size of *O. lineoocellatum*. No bones of green geckoes *Naultinus* spp. were identified, but these are primarily diurnal and were probably not generally exposed to laughing owl predation.

Summary of the Late Holocene fauna older than 1,000 yrs BP

Waikari is the driest area for which regional faunas have been studied to date. The moa fauna was very different from those studied in the progressively wetter climates of Mt Cookson (Worthy & Holdaway 1995), Takaka (Worthy & Holdaway 1994a) and the West Coast (Worthy & Holdaway 1993; Worthy 1993). Around Waikari the dinornithids *Dinornis giganteus* and *D. struthoides* were present and *D. novaezealandiae* absent, in contrast to the wetter areas where *D. novaezealandiae* dominated. Of the emeids, *Anomalopteryx didiformis* was very rare around Waikari, in marked contrast to the wetter areas of the West Coast and Takaka. Even in the late Holocene forests of Mt Cookson *Anomalopteryx didiformis* and *D. novaezealandiae* were the dominant moas. *Megalapteryx didinus* was rare in Waikari faunas; its presence was probably related to areas of shrublands on the hill country. *Emeus crassus* dominated the emeid fauna, and *Pachyornis elephantopus* and *Euryapteryx geranoides* were common.

Paralleling these differences in the moa faunas, the composition of the rest of the bird fauna near Waikari also differed markedly from those of Holocene faunas in wetter areas. The differences are not so much in species composition, for as Atkinson & Millener (1991) noted, this is much the same everywhere, but in the relative frequency of species.

Many taxa were less common. Although all wrens except *Dendroscansor decurvirostris* were present in Waikari faunas, they were relatively uncommon, in comparison with their abundance at Takaka and areas further west. Other large ground-birds such as weka, kakapo, and kiwi, although present, appear to have been substantially less common than in wetter western areas. Parakeets and bellbirds were less abundant in Waikari owl faunas than in the beech forest faunas of Takaka Hill or Mt Cookson. Two species of short-tailed bats were living around Waikari, but the lesser short-tailed bats were less common than greater short-tailed bats, in contrast to the Takaka Hill faunas (the only area with comparable data), where lesser short-tailed bats were much more numerous.

Other species were much more abundant than in wetter western areas. Of the passerines, the most notable difference is the abundance of piopio in the Waikari faunas: in all other faunas studied it has been rare. Fantails also appear to have been more common in eastern areas. Substantial differences are obvious between the rail faunas: extinct coots and the extinct gallinule were more abundant in Waikari faunas than anywhere else in New Zealand so far studied. Finsch's duck was present and probably very common, and adzebill, extinct goose and shelduck were present in the Waikari faunas, in contrast to their absence in Holocene faunas in wetter areas. Snipe were more common in the Waikari faunas than at Takaka or West Coast faunas.

The Waikari faunas are the first of *Holocene* age we have studied in the South Island in which Haast's eagle was present. Farther west it was present only during the Otiran Glaciation. Overlooked in the Waikari fauna by Atkinson & Millener (1991), the laughing owl was nevertheless common, and a major predator of vertebrates there. Although this owl was present on Takaka Hill, it was absent farther west during the Holocene, so it too apparently favoured drier climates. Other nocturnal predators of the Waikari faunas included moreporks and owlet nightjars.

The differences in faunal composition from wetter western areas probably relate to the vegetation of the Waikari region at the time. Above we have traced how a shrubland – grassland fauna of the Otiran glacial period evolved to one where forest was present in the Late Holocene. However, unlike wetter western areas, the forest almost certainly did not have a continuous canopy over wide areas; patches in valleys would have been interspersed with shrubland on hills. There would have been a much greater area of forest margin habitat, because of the shrublands, and wider, prograding, ever-shifting rivers. In the drier climate, the dominant forest species (e.g. matai in the canopy) differed from those of western areas (rimu). The forest floor would have been correspondingly dry, with a leaf-litter cover with few ferns and no moss. The Waikari late Holocene faunas are representative of a relatively dry climate where mosaics of forest, shrubland, and grassland dominated the landscape.

1,000 years BP to the present

Major environmental disturbances in the eastern region of the South Island followed the arrival of humans about 800–1000 years ago (Anderson 1991). The Waikari area was largely deforested by repeated burning, so that hardly any forest remained by 500 years ago (McGlone 1983; 1988). Some valley-bottom stands remained when Europeans arrived (Monro 1869). Large areas of grassland and shrubland became established, especially on the drier hill slopes and ridges. Surviving forest was probably restricted to valley floors where summer drought and winter snows would have least effect. It is in these areas that some forest species survive today. The insect faunas of both the Gowan Hill and Ardenest owl sites (both in valley situations) are significant because the common large weevils and ground beetles are associated with forest habitats (see section on insects above), supporting the palaeobotanical and palaeovertebrate data that indicate a dry forest was present. However, the two dominant carabids in Gowan Hills suggests that a somewhat damper more diverse forest was present there than around Ardenest.

Polynesians brought the Pacific rat, kiore (*Rattus exulans*), to New Zealand. Once ashore, it is safe to assume kiore would have responded to unlimited supplies of invertebrates and small vertebrates by staging a population explosion across the length and breadth of New Zealand. Even during European times, kiore was observed to respond to the short-term unlimited food supplied during beech-mast years (e.g. Meeson 1885). *Rattus rattus* showed the potential population growth of which generalist rodents are capable, when it was accidentally released onto Big South Cape Is in the early 1960s (Morris & Smith 1988: 118–122). Until their arrival Big South Cape Island had an unmodified natural fauna, rich in large invertebrates and flightless birds. Faced with essentially unlimited food, the rats increased their population phenomenally, and devastated the fauna and flora (Morris & Smith 1988;

Watt 1979). The last populations of some species, e.g. the South Island bush wren *Xenicus longipes* and the greater short-tailed bat *Mystacina robusta*, were totally eliminated, along with local populations of snipe and giant weevils. Within the last 150 years, mice have replaced kiore on the mainland, and reach plague proportions in response to beech-mast years (King 1990).

On Takaka Hill we showed that, as other species were exterminated or reduced in abundance, kiore replaced them in the diet of laughing owls (Worthy & Holdaway in press; Holdaway & Worthy in press). Therefore, although predation by kiore may have reduced the prey diversity available to laughing owls, kiore did not threaten the owls' survival, so laughing owls survived into European times.

Kiore remains numerically dominated nearly all Waikari owl sites, and mouse bones were also present in most, showing that these sites mainly accumulated faunas during the Polynesian period, but continued into the earlier part of the historic period. There were no stratified sites, and only one pre-rat fauna – the Gowan Hills old deposit – by which we might directly assess differences between pre- and post-rat faunas. Undoubtedly some of the remains in other deposits will have been derived from earlier periods e.g. Ardenest, as in Falcon #2 on Mt Cookson (Worthy & Holdaway 1995), but the Gowan Hills sites give us our best comparative data.

The 'old' Gowan Hills fauna lacks mice, rabbits, and Norway rats, and has only a few kiore bones which are probably contaminants from the material in the recent deposit directly above. It has a richer fauna of native birds with kiwi, pigeon, piopio, fantail, and rifleman in addition to those in the 'young' deposit. But it lacks the open country indicator species – pipits and quail – both present in the 'young' deposit. It also has more greater short-tailed bat and Duvaucel's gecko bones, and, unlike the 'young' deposit, has tuatara bones. The older fauna was, therefore, sampled from a more diverse native fauna.

The recent appearance of quail and pipit in the Gowan Hill faunas suggests that most of the predator assemblages are young. In Table 9, the totalled data for all owl sites show that quail account for nearly 17% of the MNI of birds, and pipits were significantly abundant. The archaeological Timpendean avifauna is also dominated by quail. This tardy appearance of quail and pipit only in Late Holocene faunas was also observed on Mt Cookson (Worthy & Holdaway 1995). There, pipits and quail apparently were absent from late Holocene deposits up to c. 2,000 years old, but entered the fauna as significant faunal components at the same time as kiore did. In the Mt Cookson and Waikari areas, it seems reasonable to relate the increased abundance of open-country birds to an increase in the amount of shrubland habitat resulting from forest clearance. A comparison of the avifauna of two owl sites in the Waikari area, at different distances from presumed shrublands, accentuates the point (Table 10). Lamb's site is on a ridge at 440 m, whereas the Gowan site is at 180 m, in a valley, that still supports broadleaf, mahoe, and fivefinger trees. Lamb's site had a high proportion of quail; despite the smaller sample the Gowan Hills young deposit had forest species (tui, bellbird, robin, yellowhead, and saddleback) absent from the Lamb's site fauna. The different prey proportions show that owls at the Lamb's site were hunting over shrubland to a much greater extent than those at the Gowan site, which were probably hunting within a forest.

The main component of the Waikari owl faunas was kiore; the collections include thousands of bones representing hundreds of individuals. Very few European rat bones were present – Norway rat *Rattus norvegicus* bones were found in only one site, and only a few mouse *Mus musculus* bones were found. European species were available to laughing owls for a few tens of years, as against several hundred for kiore. Mice were introduced to the South Island in the 1850s, but by the 1890s the owls were in serious decline after the introduction and spread of ship rats *Rattus rattus* and stoats *Mustela erminea* (Smith 1884; Atkinson 1973; King 1990; Holdaway & Worthy in press).

The few introduced passerines in the faunas were, along with the rats and mice, among the last prey taken. The blackbird, listed as part of the predator fauna, was a vagrant juvenile, but the starling *Sturnus vulgaris* bones from Ardenest and goldfinch *Carduelis carduelis* bones from an Arden rockshelter and Timpendean were from birds killed by owls. Starlings and goldfinches were both introduced to New Zealand in 1862 (Oliver 1955). Thus, despite there being no historical records of laughing owls in the Waikari region (Williams & Harrison 1972), we are confident that they survived there until after 1860.

Summary

The fossil fauna from a range of sites in a 10 km radius of Waikari in North Canterbury, New Zealand, document the prior existence of 65 indigenous birds, tuatara *Sphenodon* sp., two species of gecko *Hoplodactylus* spp., including the large *H. duvaucelii*, undetermined skinks and fish, and two species of bats *Mystacina* spp.. In addition, four introduced birds, three rodents *Mus musculus*, *Rattus norvegicus*, and (most common) *Rattus exulans*, and European rabbits *Oryctolagus cuniculus* were in deposits accumulated by laughing owls, and are proof that laughing owls survived around Waikari until after 1860. Six sites at which faunas were accumulated by laughing owls have unparalleled significance in palaeofaunal reconstruction due to the wide diversity of vertebrate and invertebrate prey represented, especially as most were of a size range not well represented in other taphonomies. Three of the sites provide proof that laughing owls ate a broad range of mainly ground-frequenting or trunk-crawling beetles. Swamp-miring, cave pitfall trapping, and vagrant deaths in rockshelters are the other main taphonomies represented in the sites.

The diverse taphonomies represented in the sites have allowed unusually complete palaeofaunal reconstructions. The age range of sites (Otiran through to the present) allow us to describe changes in faunal composition over the last 20,000 years. There was no replacement of one main suite of species with another, from the Otiran to the Holocene, as in wetter, more western regions. There were, however, shifts in the relative abundance of species with, for example, *Pachyornis elephantopus* becoming less abundant into the Holocene. This species also exhibited post-glacial dwarfing, as it had elsewhere. The Holocene faunal record

Table 10 Comparison of the avifauna (MNI) of two owl sites showing how they reflect local site characteristics. In Lamb's, which is on a ridge, there are high numbers of quail and few forest birds, in contrast to fewer quail and a higher proportion of forest species in the Gowan site in a valley.

	Lamb's	%	Gowan	%
Cyanoramphus spp.	5	16.1	2	10
Sceloglaux albifacies	1	3.2		
Aegotheles novaezealandiae			3	15
Strigid spp.			1	5
Pterodroma cookii	1	3.2		
Pterodroma inexpectata	1	3.2		
Pelecanoides urinatrix	1	3.2		
Coturnix novaezelandiae	16	51.6	2	10
Coenocorypha aucklandica			1	5
Pachyplichas yaldwyni	2	6.4		
Xenicus spp.	1	3.2	1	5
Prosthemadera novaeseelandiae			1	5
Anthornis melanura			2	10
Petroica australis			2	10
P. macrocephala	1	3.2	1	5
Mohoua ochrocephala			1	5
Rhipidura fuliginosa	1	3.2		
Anthus novaeseelandiae	1	3.2	2	10
Philesturnus carunculatus			1	5
Total	31		20	

corroborates the palaeobotanical history of a shrubland being replaced by a dry forest at lower altitudes about 5000 years ago, and then the subsequent destruction of these forests 1,000 to 800 years ago. Significant indicator species are the New Zealand quail *Coturnix novaezelandiae* and pipit *Anthus novaeseelandiae*, which show that shrublands and grasslands were widespread mainly before 5,000 and after 1,000 years ago. The presence of kiore *Rattus exulans* indicates accumulation during the Polynesian period, and is thus especially useful in indicating the age of owl sites. The unmodified late Holocene fauna of the Waikari area was the most diverse so far described in the South Island, and reflects the diversity of prehuman habitats, with forests, shrublands, grasslands, rivers and lakes all present.

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APPENDIX 1. LIST OF SCIENTIFIC NAMES OF PLANTS MENTIONED IN THE TEXT

akeake	*Dodonaea viscosa*
black beech	*Nothofagus solandri* var. *solandri*
black matipo	*Pittosporum tenuifolium*
broadleaf	*Griselinia littoralis*
cabbage tree	*Cordyline australis*
fivefinger	*Neopanax arboreum*
golden akeake	*Olearia paniculata*
kahikatea	*Dacrycarpus dacrydioides*
kaikomako	*Pennantia corymbosa*
kanuka	*Kunzea ericoides*
karamu	*Coprosma robusta*
kawakawa	*Macropiper excelsum*
koromiko	*Hebe salicifolia*
kowhai	*Sophora tetraptera*
kowhai, small-leafed	*Sophora microphylla*
mahoe	*Melicytis ramiflorus*
manuka	*Leptospermum scoparium*
marbleleaf	*Lophomyrtus bullata*
matai	*Prumnopitys taxifolia*
matagouri	*Discaria toumatou*
miro	*Prumnopitys ferruginea*
mountain beech	*Nothofagus solandri* var. *cliffortioides*
mountain cedar	*Libocedrus bidwilli*
mountain toatoa	*Phyllocladus alpinus*
ngaio	*Myoporum laetum*
pokaka	*Elaeocarpus hookerianus*
putaputaweta	*Carpodetus serratus*
red beech	*Nothofagus fusca*
red matipo	*Myrsine australis*
rimu	*Dacrydium cupressinum*
silver beech	*Nothofagus menziesii*
toothed lancewood	*Pseudopanax ferox*
totara	*Podocarpus totara*
weeping matipo	*Myrsine divaricata*

APPENDIX 2. LIST OF RADIOCARBON DATES

Radiocarbon dates on bones from natural sites in the Waikari and Weka Pass area are listed here, excluding those from Pyramid Valley which are detailed elsewhere (e.g. Anderson 1989). NZ1723 and NZ4166 differ from published results e.g. McCulloch and Trotter (1979), since the original data were recalculated by the Rafter Laboratory in 1994 using the current methods. The Timpendean date is from Trotter (1972), and The Deans date from Burrows et al. (1984).

Site	Site	Species	Lab. No	^{14}C age	$d^{13}C$
Glencrieff	Peg 1, –85 cm	*Pachyornis elephantopus*	NZA4162	11,898 ± 82	–21.48
Glencrieff	Sq A1, –105 cm	*Emeus crassus*	NZA4079	10,470 ± 130	–24.72
Glencrieff	Sq. A1, –70 cm	*Emeus crassus*	NZA4018	10,480 ± 120	–23.5
The Deans	–60 cm	*Euryapteryx geranoides*	NZ4900	1,445 ± 50	?
Waikari Cave	Site A	*Euryanas finschi* (mixed)	NZ1723	1,888 ± 93	–25.1
Waikari Cave	Site F	*Euryanas finschi* (mixed)	NZ4166	1,043 ± 58	–26.4
Waikari Cave	Site I	*Fulica prisca*	NZA4613	3,837 ± 71	–24.03
Waikari Cave	Base Coot Alley	*Porphyrio hochstetteri*	NZA4612	3,480 ± 100	–21.93
Timpendean		*Euryapteryx geranoides*	NZ918	1,525 ± 60	?

APPENDIX 3. MOLLUSC REMAINS FOUND IN THE FOSSIL SITES

Bulk sediment samples taken from the predator sites were sorted by Dave Roscoe, Nelson, for land molluscs, and the specimens lodged in MNZ. Some taxa are undescribed so are referred to here by parataxon names.

Species	**Ardenest**	**Falcon site**	**Lamb'sGowan Hills, young**	
Rhytida stephenensis	11	–	–	10
Therasia cf. *thaisa*	–	4	2	244
Therasia igniflua	15	–	–	15
Therasia zelandiae flat	447	–	–	–
Therasia zelandiae tall	191	–	–	–
Potamopyrgus antipodum	5	–	–	–
Omphalorissa purchasi	1	–	–	1
Climocella var. *maculata*	154	–	204	605
Mocella eta	1	–	–	1
Rotodiscid n.sp. (CAljac)	–	6	–	220
Micromocella rakiura	33	–	–	–
Cavellia subinfecta	–	1	–	–
Cavellia mutabilis	5	–	2	–
Cavellia buccinella	398	–	4	1
Cavellia serpentinula	462	–	5	1
Allodiscus adriana	147	–	5	83
Phenocohelix pilula	–	–	1	–
Fectola trilamellata	47	–	1	1
Charopa montivaga	–	–	–	6
Sinployea n.sp. (SINexq)	–	–	1	–
Sinployea pilsbryi	7	–	–	–
Phenacharopa pseudanguicula	–	–	2	–
Flammulina n.sp. (FLAvir)	1	–	–	–
punctid 1988:92 (PALmor)	174	–	–	–
punctid 1988:151 (CALwai)	28	–	–	–
punctid 1988:136 (PRYros)	–	–	1	–
Sample volume	45 litres	c.5 litres	11.5 litres	15 litres
TOTAL NUMBER SNAILS	2127	11	228	1188
TOTAL NUMBER OF SPECIES	17	3	11	12

The collection preserves elements of two separate faunas.

1. A dry scrubby-habitat fauna of limestone cliffs. High numbers of a few species that are obligate calciphiles are included, for example *Therasia* cf. *thaisa*, and the undescribed rotadiscids n. gen. (*Mocella*) *maculata* and CALjac. These species are probably extant on the limestone cliffs where the sites were. *Cavellia serpentinula* is a species usually associated with dry, scrubby habitat, and so can also be expected to live near the sites. *Charopa montivaga* dominated the Mt Cookson snail-faunas interpreted as specialist limestone cliff assemblages (Worthy & Holdaway 1995), so it is surprising that only a few kilometres south this species is present in only one of the four sites, and then was rare.
2. A forest fauna. The Ardenest fauna is unusual for the area in being so diverse (17 spp), and this diversity plus the presence of *Therasia zelandiae* rather than *T. thaisa*, *Rhytida stephenensis* and the two punctids, suggest at least part of the Ardenest assemblage is derived from a time when the surrounding area was more heavily vegetated and wetter than it is now. However, the presence of large numbers of *C. serpentinula* suggests continued recent deposition out of the scrub habitat that covers the site now.

APPENDIX 4A. INSECT REMAINS FROM WEKA PASS PREDATOR SITES

Remains were preserved only in the driest of sites. Identification of material was by: Gowan Hills, Falcon site Timpendean, and Ardenest (except weevils) – P. M. Johns; Ardenest weevils – G. Kuschel. Material identified by P. M. Johns remains in the collections of the Zoology Department, University of Canterbury. The material identified by G. Kuschel was deposited with the systematics Section, Landcare Research, Mt Albert Centre, Auckland. ✓✓✓many fragments; ✓✓ several fragments; ✓ few or one fragment.

Species	Gowan Hills	Falcon site, Timpendean	Ardenest
Carabidae			
Metaglymma monilifer	✓✓✓	–	–
Megadromus rectangulus	✓✓✓	–	–
Megadromus antarcticus	✓✓	✓✓✓	✓✓
Holcaspis subaenea	✓	–	–
Holcaspis sp. indet.	–	✓	✓✓✓
? small *H. subaenea*	✓	✓	–
Oregus sp. indet.	–	–	✓✓
Mecodema sulcatum	–	✓✓✓	✓ (recent)
Mecodema costellum lewisi	–	–	✓✓✓
sp. indet.	✓	–	–
Lucanidae			
Lissotes reticulatus	✓	–	✓✓
Elateridae			
Amychus sp. cf. *granulatus*	–	–	✓
sp. indet.	✓	✓	–
Tenebrionidae			
Mimopeus ?lateralis	✓		✓✓
Mimopeus costellus	–	–	✓
?Mimopeus opaculus	–	–	✓
Mimopeus sp. nov.	–	–	✓✓
Mimopeus sp. indet.	–	✓	–
Scarabaeidae			
Odontria sp. *cf. striata*	–	✓	✓
Costelytra zelandica	–	–	✓ (recent)
Pyronota sp.	–	–	✓ (recent)
Histeridae			
sp. indet.	–	✓	✓
Cerambycidae			
Somatidia sp.	–	–	✓
Dermaptera: Forficulidae			
Forficula auricularia (Earwig)	–	✓	–
Curculionidae			
Ectopsis sp.	✓	–	–
Ectopsis ferrugalis	–	–	✓✓✓
Anagotus stephenensis	–	–	✓✓✓
Anagotus rugosus	–	–	✓✓✓
Tychanus verrucosus	–	–	✓✓
Psepholax sulcatus	–	–	✓✓
Strongylopterus hylobioides	–	–	✓✓
Tychanopais fougeri	–	–	✓✓
Crisius longulus	–	–	✓✓
Crisius ornatus	–	–	✓
Didymus impexus	–	–	✓
Clypeolus cineraceus	–	–	✓
Phrynixus terreus	–	–	✓✓
Epitimetes grisealis	–	–	✓✓✓
Epitimetes lutosus	–	–	✓✓

Species	Gowan Hills	Falcon site, Timpendean	Ardenest
Epitimetes cuprealis	–	–	✓
Sargon suturalis	–	–	✓✓
Irenimus aequalis	–	–	✓
Curculionidae sp.	✓	–	–
Introduced spp.			
Otiorhynchus ovatus	✓	–	–
Listroderes difficilis	–	–	✓

APPENDIX 4B. INSECT REMAINS FROM TWO FALCON SITES, ANNANDALE STN, MT COOKSON

The results reported here were not available when Worthy & Holdaway (1995) reported on the vertebrate faunas of this area. Falcon sites # 1 and #2 were ledge sites on cliffs and were accumulated by falcons *Falco novaeseelandiae* rather than laughing owls *Sceloglaux albifacies*. The abundant insect remains in these sites show that insects are important in the diet of falcons. P. M. Johns identified the material and made the following comments.

Falcon Site #1.

The material was much more fragmented than the above described owl sites, with approximately 80% much broken. This site was a nesting site of falcons so remains were interpreted as derived from remains of food brought for chicks, and from ejected pellets from adults (Worthy & Holdaway 1995). Identifiable material included:

Species	Elements
Mecodema sp. near *fulgidum*	ca 20 elytra/hemi-elytra
Mecodema sp. near *sulcatum*	ca 10 elytra/hemi-elytra
Megadromus antarcticus or *rectalis*	ca 10 elytra
Megadromus rectangulus	1 elytron
Holcaspis sp.	3 eytra
Agonum sp.	1 elytron
Mimopeus thoracicus	ca 20 elytra/hemi-elytra
Mimopeus sp. near *lateralis*	1 almost whole (?recent) specimen

Falcon site #2

The material from this site was even more broken than in the preceding site, as were the vertebrate prey remains; all material was interpreted as derived from ejected pellets at a resting site (Worthy & Holdaway 1995). No clearly identifiably different species were present.

These species assemblages suggest a dry open hillside or terrace scrub of *Leptospermum, Griselinia,* and *Nothofagus*, although the inclusion of *M. rectangulus* indicates that there could be flat damp sites nearby (P. M. Johns pers comm). These listed plants presently dominate the surroundings of the Falcon sites and the area is seasonally very dry. However, there is a flat damp valley below the sites.

APPENDIX 5. VERTEBRATE FOSSILS FROM WEKA PASS SITES

Predator sites – Weka Pass area

SITE NAME	**Arden, Rockshelter 1**	
GRID REFERENCE	N33 919074	
REPOSITORY OF MATERIAL	MNZ	
COLLECTOR	THW, RNH, 27/9/93	
TAPHONOMY	Predator – owl, vagrant	
FOSSIL RECORD NUMBER	N33/f65	
Species	**Catalogue no. MNZ S**	**x/y**
Aegotheles novaezealandiae	33650	8/1 juv
Coenocorypha cf. *aucklandica*	33651	1/1
Cyanoramphus spp.	33652	1/1
Coturnix novaezelandiae	33653	1/1
Rattus exulans	33654	4/1

Hoplodactylus cf. *maculatus*	33655	1/1
Carduelis carduelis	33656	1/1 modern

SITE NAME	**Arden Rockshelter 2**
GRID REFERENCE	N33 918074
REPOSITORY OF MATERIAL	MNZ
COLLECTOR	THW, RNH, 27/9/93
TAPHONOMY	vagrant
FOSSIL RECORD NUMBER	N33/f64

Species	**Catalogue no. MNZ S**	**x/y**
Gallirallus australis	33619	3/1

SITE NAME	**Arden Rockshelter 3**
GRID REFERENCE	N33 914072
REPOSITORY OF MATERIAL	MNZ
COLLECTOR	THW, RNH, 27/9/93
TAPHONOMY	Predator, owl
FOSSIL RECORD NUMBER	N33/f63

Species	**Catalogue no. MNZ S**	**x/y**
Coenocorypha cf. *aucklandica*	33657	3/1
Gallinula hodgenorum	33658	1/1
Coturnix novaezelandiae	33659	2/1
Cyanoramphus spp.	33660	6/1
Petroica australis	33661	1/1
Petroica macrocephala	33662	1/1
Turnagra capensis	33663	5/1
Acanthisitta chloris	33664	1/1
Nestor sp. juv.	33665	9/1
Mystacina robusta	33666	3/1
Hoplodactylus cf. *duvaucelii*	33667	8/2
Hoplodactylus cf. *maculatus*	33668	10/2
Sphenodon sp.	33669	3/2
Rattus exulans	33670	9/1

SITE NAME	**Ardenest, Arden Stn**
GRID REFERENCE	N33 916073
REPOSITORY OF MATERIAL	MNZ
COLLECTOR	THW, RNH, 28/9/93
TAPHONOMY	Laughing owl
FOSSIL RECORD NUMBER	N33/f62

Species	**Catalogue no. MNZ S**	**x/y**
Apteryx sp. juv.	33671	3/1
Euryanas finschi	33672	1/1
Gallinula hodgenorum	33673	7/1
Gallirallus australis	33674	1/1
Strigops habroptilus	33675	7/2
Cyanoramphus spp.	33676	65/12
Hemiphaga novaeseelandiae	33677	10/2
Aegotheles novaezealandiae	33678	14/1subad, 33/4 (2 juv)
Coenocorypha cf. *aucklandica*	33679	21/4
Coturnix novaezelandiae	33680	29/6
Oceanites (Garrodia) nereis	33681	8/2
Charadrius bicinctus	33682	3/2
Thinornis novaeseelandiae	33683	3/1
Philesturnus carunculatus	33684	18/3
Turnagra capensis	33685	39/5

Petroica australis	33686	12/2
Petroica macrocephala	33687	5/1
Anthornis melanura	33688	18/2
Prosthemadera novaeseelandiae	33689	8/1
Pachyplichas yaldwyni	33690	2/1
Anthus novaeseelandiae	33691	14/3
Rhipidura fuliginosa	33692	9/2
Mohoua ochrocephala	33693	4/1
Gerygone igata	33694	3/1
Xenicus sp.	33695	6/1
Acanthisitta chloris	33696	1/1
Callaeas cinerea	33697	14/2
Sturnus vulgaris	33698	4/1
Tadorna variegata	33707	eggshell
moa species indet.	33708	eggshell
Mystacina robusta	33699	42/6
Mystacina tuberculata	33700	11/4
Rattus exulans	33701	7088 bones, 2937 teeth/441
Mus musculus	33702	11/3
Hoplodactylus cf. *duvaucelii*	33703	409/19
Hoplodactylus cf. *maculatus*	33704	x/151
Oligosoma sp.	33705	7/4
Sphenodon sp.	33706	21/4
Sceloglaux albifacies	33620	partial nest
Sceloglaux albifacies	33621	feathers
Bird	33622	eggshell

SITE NAME	**Falcon site, Timpendean**
GRID REFERENCE	M33 853030
REPOSITORY OF MATERIAL	MNZ
COLLECTOR	THW, A. Melhuish, 5 Aug, 1992
TAPHONOMY	falcon
FOSSIL RECORD NUMBER	M33/f26

Species	**Catalogue no. MNZ S**	**x/y**
Falco novaeseelandiae	33421	1/1
Mohoua ochrocephala	33416	1/1
Anthus novaeseelandiae	33419	1/1
Cyanoramphus spp.	33417	6/3
Coturnix novaezelandiae	33420	2/1
Charadrius bicinctus	33414	6/2
Coenocorypha aucklandica	33415	3/2
Carduelis carduelis	33418	2/1
Tadorna variegata	33612	egg, eggshell
rangle stones	33422	several stones
Sphenodon sp.	33409	1/1
Hoplodactylus cf. *maculatus*	33411pt	x/7
Oligosoma sp. indet.	33411pt	x/1
Mus musculus	33410	3
Rattus exulans	33413	203
Oryctolagus cuniculus	33412	1

Tadorna nested in the site. The rangle stones are identified as such as they are of allochthonous origin. Similar stones were not seen in the laughing owl sites. Matai seeds were common in the deposit.

SITE NAME	**Gowan Hills coalluvial deposit**
GRID REFERENCE	M34 836988
REPOSITORY OF MATERIAL	MNZ
COLLECTOR	THW, RNH, S. Read 4 Sept, 1994

TAPHONOMY	Vagrant
FOSSIL RECORD NUMBER	M34/f311

Species	Catalogue no. MNZ S	x/y
Pachyornis elephantopus	33801	1/1
Hemiphaga novaeseelandiae	33802	1/1
moa eggshell	33805	1 piece
Sphenodon sp.	33803	1/1
Hoplodactylus duvaucelii	33804	1/1

SITE NAME	**Gowan Hills owl site**
GRID REFERENCE	M34 836988
REPOSITORY OF MATERIAL	MNZ
COLLECTOR	THW, RNH, A. Melhuish, 7/10/92
	THW, RNH, S. Read 4 Sept, 1994
TAPHONOMY	Laughing owl
FOSSIL RECORD NUMBER	M34/f310

	MNZ S	x/y	MNZ S	x/y
Species	**Young**	**deposit**	**Old**	**deposit**
Apteryx sp. juv			33808	1/1
Juvenile owl ?*Sceloglaux*	33452	1/1		
Cyanoramphus spp.	33443	9/2	33809	26/3
Aegotheles novaezealandiae	33449	18/3	33810	34/4
Coenocorypha aucklandica	33446	4/1	33806	4/2
Coturnix novaezelandiae	33444	7/2		
Hemiphaga novaeseelandiae			33811	26/2
Prosthemadera novaeseelandiae	33453	1/1	33817	1/1
Anthornis melanura	33448	7/2	33812	1/1
Philesturnus carunculatus	33454	2/1		
Turnagra capensis			33807	4/1
Mohoua ochrocephala	33442	2/1		
Petroica macrocephala	33447	4/1		
Petroica australis	33441	5/2	33816	2/1
Rhipidura fuliginosa			33813	2/1
Acanthisitta chloris			33814	1/1
Xenicus sp.	33440	1/1	33815	4/1
Anthus novaeseelandiae	33445	7/2		
Tadorna variegata eggshell	33451	eggshell	33823	eggshell
moa sp. indet			33824	eggshell
Mystacina robusta	33458	2/1	33818	8/2
Oryctolagus cuniculus	33456	6/1		
Mus musculus	33455	23/6		
Rattus exulans	33439	3001^{+}/227	33825	18/1
Rattus norvegicus	33460	10/3		
Hoplodactylus cf. *maculatus*	33450	601/132	33820	410/66
Hoplodactylus duvaucelii	33451	3/2	33821	7/2
skink sp.	33459	3/1	33819	2/1
Sphenodon sp. juv.			33822	6/1
Fish sp. cf. *Anguilla* sp..	33461	3 vert.		

SITE NAME	**Ledge, Carvossa Stn, Weka Pass**
GRID REFERENCE	M33 876026
REPOSITORY OF MATERIAL	MNZ
COLLECTOR	THW, A. Melhuish, 5/10/92
TAPHONOMY	?owl
FOSSIL RECORD NUMBER	M33/f29

Species	Catalogue no. MNZ S	x/y
Coturnix novaezelandiae	33432	13/1

Porphyrio hochstetteri	33613	1/1
Rattus exulans	33431	50/3
skink sp.	33434	5/2
Hoplodactylus sp.	33437	3/2

SITE NAME	**Mimiomoko Pocket, Waipara River**
GRID REFERENCE	N34 917887
REPOSITORY OF MATERIAL	CM
COLLECTOR	R.E. Fordyce, P. Gatehouse 1972–1974
TAPHONOMY	Predator
FOSSIL RECORD NUMBERS	S68/f1258, S68/f1258A, S68/f1258B

This fauna is considered to be a Holocene inclusion within Miocene sediments (Rich et al.. 1979). In 1994 THW re-examined the avian bones in this fauna and was able to identify the small passerines. The site characteristics as described by Rich et al.. (1979), the species composition, and preservation of the bones (greenstick fractured and erosion consistent with digestion) show that this fauna was accumulated by laughing owls. The reptile material was not re-examined. The bones listed here as *Pterodroma cookii*, referred only to Procellariidae previously, are a good match for this species, and are conformable in size with those in a single individual. The diving petrel bones are referred here to *P. urinatrix* as it is not parsimonious to suggest two species were present, lengths were within the range of *P. urinatrix*, and sometimes (ulnae, carpometacarpi, tarsometatarsi) outside the range of *P. georgicus*, and *P. urinatrix* presently breeds in widespread localities in New Zealand, in contrast to *P. georgicus* that breeds only on Codfish Island in New Zealand. The bones identified here as *Gallirallus australis* are from a single small individual. The passerine bones are good matches for their respective species, although the *Rhipidura* bone has had one condyle broken and repaired wrongly. The bone identified as *Hemiphaga* is too incomplete to be certain of this identification, but the surviving portion is identical to these parts of a pigeon femur. It may be that the phalanx Av28667 is referrable to *Hemiphaga* as well.

Species	Catalogue no. CM	x/y
?*Apteryx* sp.	Av28667	1 phalanx L3.1
Pterodroma cookii	Av 28662–3, 28665, 28671	4/1
Pelecanoides ?urinatrix	Av28644–28654, 28657–9, 28661, 28664, 28687	17/3
Gallirallus australis	Av28655–6, 28660, 28672	4/1
Mohoua novaeseelandiae	Av28670	1dR tib
Gerygone igata	Av28666	1dL ulna
Rhipidura fuliginosa	Av28668	1dL tib
Xenicus sp.	Av28669	1dR tib
? *Hemiphaga novaeseelandiae*	Av28694	1pL femur
Lizard sp. indet	Rep 432–438, 442	8/2
gecko sp. indet cf *H. duvaucelii*	Rep 439–441	4/1
Sphenodon sp.	Rep 401–431	31/3

SITE NAME	**P. Lamb's Owl site, Carvossa Stn**
GRID REFERENCE	M33 889033
REPOSITORY OF MATERIAL	MNZ
COLLECTOR	THW, A. Melhuish, 5/10/92
TAPHONOMY	Laughing owl
FOSSIL RECORD NUMBER	M33/f27

Species	Catalogue no. MNZ S	x/y
Coturnix novaezelandiae	33462	184/16
Cyanoramphus spp.	33463	58/5
Pterodroma cookii	33468	5/1
Pterodroma inexpectata	33465	4/1
Sceloglaux albifacies juv.	33466	8/1
Anthus novaeseelandiae	33471	2/1
Rhipidura fuliginosa	33469	2/1
Petroica macrocephala	33464	1/1

Xenicus sp.	33470	1/1
Pachyplichas yaldwyni	33519	2/2
Pelecanoides urinatrix	33467	2/1
Rattus exulans	33472	1095+/63
Mus musculus	33475	1/1
Leiolopisma sp.	33473	64/6
Hoplodactylus cf. *maculatus*	33474	79/7

SITE NAME	**Rabbit Warren Cave, Carvossa Stn., Weka Pass**
GRID REFERENCE	M33 874026
REPOSITORY OF MATERIAL	MNZ
COLLECTOR	THW, A. Melhuish 4/10/92; THW, RNH 29/9/93
TAPHONOMY	owl, vagrant, stream
FOSSIL RECORD NUMBER	M33/f28

This is a small cave about 5 m below the top of the cliff, and c.30 m above present stream level. The passage is about 0.5 m wide and initially about 1.5 m high, and dry and dusty. After about 10 m it is choked. Rabbits have burrowed in the top layers extensively disturbing the original stratigraphy. However, loose dry dusty sediments overlay compacted stream sediments which are at least late Pleistocene in age, if not older. Most bones, and all owl material was from the top layer. The moa material is quite mineralised, and is from the stream sediments.

Species	**MNZ S**	**Taphonomy**	**x/y**
Cyanoramphus spp.	33427	owl	5/2
Rhipidura fuliginosa	33428	owl	11/3
Coenocorypha cf. *aucklandica*	33502	owl	1/1
Coturnix novaezelandiae	33500	owl	2/1
Hemiphaga novaeseelandiae	33499	owl	1/1
Petroica australis	33503	owl	3/1
Gallirallus australis	33504	owl	1/1
Sterna albostriata	33614	owl	Lcmc, pRcor
cf. *Tadorna variegata*	33615	nesting duck	eggshell
Turdus merula	33616	vagrant	16/1juv
Sphenodon sp.	33617	owl	3/1
Hoplodactylus sp. cf. *maculatus*	33430	owl	2/1
Hoplodactylus cf. *duvaucelii*	33501	owl	5/1
Mystacina robusta	33429	owl	4/1
Rattus exulans	33425	owl	154+/14
Oryctolagus cuniculus juv.	33426	vagrant	c.90/8
Pachyornis sp.	33618	pitfall	pt R mandible
moa sp.		"	eggshell (1.3 mm)
Euryapteryx geranoides	NZS Bull 4: 245, 252	?	2 bones

SITE NAME	**Rockshelter, Sandhurst Station**
GRID REFERENCE	M34 826974
REPOSITORY OF MATERIAL	MNZ
COLLECTOR	THW, RNH, 8/10/92
TAPHONOMY	predator
FOSSIL RECORD NUMBER	M34/f309

Species	**Catalogue no. MNZ S**	**x/y**
Ninox novaeseelandiae	33435	2/1
Cyanoramphus spp.	33436	1/1
Rattus exulans	33437	34/4
gecko sp.	33438	2/1

Archaeological Sites

SITE NAME	**Euan Murchison's Rockshelter, Weka Pass**
GRID REFERENCE	M33 853001
REPOSITORY OF MATERIAL	CM, MNZ

COLLECTOR	R. Scarlett, R. Kennington 25/4/59, 23/9/61; THW, RNH
TAPHONOMY	Archaeological, laughing owl
ARCHAEOLOGICAL SITE NUMBER	M33/6; S61/32

NB The only specimen identified in the catalogue as from the burnt layer was Av17340 (*Puffinus*).

Species	Catalogue no. CM Av; MNZ S	x/y
Rattus exulans	S33423	45/5
Cyanoramphus spp.	S33424	1/1
Aegotheles novaezealandiae	Av17333, 17341, 17774, 17784, pt17787, 33531	17/3
Anthornis melanura	Av17785	2/1
Apteryx sp. juv.	Av17331, 17788, 17789	4/2
Callaeas cinerea	Av16387, 17781, 33529–30, 36533	6/1
Circus eylesi	Av17783 (1 phalanx)	1/1
Cnemiornis calcitrans	Av17792 (1 phalanx)	1/1
Corvus moriorum ?	Av33730, 33731 (2 ungual phalanges)	2/1
Coturnix novaezelandiae	Av16385, 17778	21/5
Cyanoramphus spp.	Av16386, 17332, 17782, 33528, 33540, 33729, 36539	28/5
Euryanas finschi	Av17775, 17329	9/2
Gallinula hodgenorum	Av17330, 17773, 16290	6/2
Gallirallus australis	Av16384, 16390, 17776, 17777	24/3
Hemiphaga novaeseelandiae	Av16395, 17779	5/1
Nestor meridionalis	Av17780, 33732	2/1
Petroica australis	Av33533, 36538, 33534	3/2
Philesturnus carunculatus	Av17786, 17791	3/1
Prosthemadera novaeseelandiae	Av16388, 17335	8/4
Pterodroma cookii	Av16392	8/1
Pterodroma inexpectata	Av16393, 17790	9/2
Puffinus sp.	Av17339, 17340	2/1
Turnagra capensis	Av16389, 17787, 36541, 36542	7/1
cf *Passer domesticus*	Av33539 L ulna	1/1
Moa sp. eggshell	Av16391, 17334, 17793	
unidentified (not located by authors)	Av16394, 17336–7 eggshell, 17338 R tmt, 17787 femur, 17794 eggshell small bird, 33527 L tmt, 33532 L tt, 36536 R cmc	
not identifiable (seen by THW)	36534 furcular pt, 36537 dL tt, 36540 sLtt. 36535.	
Sphenodon sp.	CM Rep 60, 87, 459	7/1
Gecko	CM Rep 88	x/4
Rattus exulans	CM NZMa176	x/18

SITE NAME	**Gowan Rockshelter**
GRID REFERENCE	M34 837988
REPOSITORY OF MATERIAL	CM
COLLECTOR	R. J. Scarlett, O. Wilkes 24/3/57; W. L. A. Field 3/3/57
TAPHONOMY	Archaeological
ARCHAEOLOGICAL SITE NUMBER	M34/4

This site is at the south end of the cliff where the natural sites listed above are located. Oven stones are present on the floor of the shelter. The fauna was collected from the floor at '4" depth'.

Species	Catalogue no. CM	x/y
Hymenolaimus malacorhynchos	Av15134	1/1
Coturnix novaezelandiae	Av15116	6/1
Cyanoramphus spp.	Av15117	1/1
Puffinus cf. *gavia*	Av15133	1/1
Rattus exulans	NZMa 63, 64	9/4

SITE NAME	**Timpendean Rockshelter**
GRID REFERENCE	M33 849029
REPOSITORY OF MATERIAL	CM

COLLECTOR	M.M. Trotter Feb, 1968	
TAPHONOMY	Archaeological, vagrant, natural	
ARCHAEOLOGICAL SITE NUMBER	S61/4; M33/11	
Species	**Catalogue no. CM**	**x/y**
Euryapteryx geranoides	Av22373–4, 36443	3/1
Apteryx haastii/australis	Av22334, 22370, 22375	4/2
Columbia livia	Av22376	1/1
Hemiphaga novaeseelandiae	Av22338, 22377	5/1
Falco novaeseelandiae	Av22378	1/1
Porphyrio melanotus	Av22365	2/1
Tadorna variegata	Av22366–7	2/2
Gallirallus australis	Av22336, 22368–9	14/3
Prosthemadera novaeseelandiae	Av22371	3/3
Coturnix novaezelandiae	Av22335, 22341	102/15
Nestor meridionalis	Av22337, 22343	13/4
Anas chlorotis	Av22339	3/1
Diomedea cauta	Av22340	1/1
Circus eylesi	Av22342	2/1
Rattus exulans	NZMa644, 646	x/40, x/48
Canis familiaris	NZMa647, 648	x/1

Cave sites – Pitfall and Vagrant faunas

CAVE NAME	**Puffinus cleft, Nape Nape Scenic Reserve**	
GRID REFERENCE	N33 297068	
REPOSITORY OF MATERIAL	MNZ	
COLLECTOR	THW, RNH, S. Read, 3 September, 1994	
TAPHONOMY	pitfall	
FOSSIL RECORD NUMBER	N33/f49	
Species	**Catalogue no. MNZ S**	**x/y**
Puffinus griseus	33830	765/15
Cyanoramphus spp.	33829	3/2
Prosthemadera novaeseelandiae	33828	1/1
Apteryx sp. juv.	33827	2/2
Rattus rattus juv.	33826	3/1

SITE NAME	**Waikari Cave, Waituna Stn**
GRID REFERENCE	M33 89450635
REPOSITORY OF MATERIAL	McCulloch's collection ?CM, rest MNZ
COLLECTOR	B. McCulloch 1971, 1975; THW, RNH 1993
TAPHONOMY	Pitfall
FOSSIL RECORD NUMBER	S61/f654; f657

We list the material in three lists. That listed under 'McCulloch & Yaldwyn' was identified by Bruce McCulloch with reference to Scarlett (1972), and J. Yaldwyn (÷). It was not catalogued into a museum collection, and was only located in December 1995. THW checked all the material identified by McCulloch and Yaldwyn as species other than *Euryanas*, and this is listed in the column headed 'MC colln checked'. That listed under MNZ S was from our 1993 collection.

Species	McCulloch & Yaldwyn	MC colln checked	Catalogue no. MNZ – x/y
Aptornis defossor	38+/1	38+/1	S33718–10/1
Strigops habroptilus	3/1	1/1	S33719–1/1
moa sp. juv.	–	1/1	S33716–1/1
Porphyrio hochstetteri	–	1/1	S33717–10/1
Fulica prisca	28/3	25/2	S33721–151/7, S33715–41/2, S33711–1/1
Hemiphaga novaeseelandiae	3/1	2/1	–
Callaeas cinerea	15/3	18/3	–
Euryanas finschi	1929/63	uncounted	S33725–227/14, S33714–25/2, S33712–32/3

Anas chlorotis	–	2/1	–
Apteryx owenii	–	–	S33720–1/1
Apteryx sp. juv.	÷	2/1	–
Poliocephalus rufopectus	÷	6/1	–
Coturnix novaezelandiae	÷	6/2	–
Gallirallus australis	÷	1/1	–
Gallinula hodgenorum	÷	15/3	S33724–44/6, S33713–3/1
Coenocorypha cf. *aucklandica*	÷	3/2	–
Aegotheles novaezealandiae	÷	5/3	S33723–1/1
Cyanoramphus sp.	–	1/1	–
Rhipidura fuliginosa	–	1/1	–
Xenicus sp.	–	1/1	–
Philesturnus carunculatus	÷	2/1	–
Litoria sp.	÷	2/1	–
Hoplodactylus sp.	÷	1/1	S33709–1/1
Rattus exulans [1]	÷	5/3	–
?*Tadorna variegata*	–		S33710, 33624 – eggshell

1. McCulloch (1975) listed 'bat' which is here presumed to be a typing error for 'rat' as identified by Yaldwyn.

Site Name **Species**	**Colln.**	**Locality**	**Various** **Specimens**
Pachyornis elephantopus	CM SB13	Rockshelter, North Dean, Weka Pass, 1967, B. McCulloch	RL tmt, Ltt
Pachyornis elephantopus	CM SB14	Sandhurst Ck, Weka Pass 1967, B. McCulloch, below site M34/8	R tibiotarsus
Pachyornis elephantopus	CM SB18	Upper Sandhurst Ck, Weka Pass, B. McCulloch 1971, loess	LR tibiotarsus, 14 frags, gizzard stones
Dinornis giganteus	CM SB2	Weka Pass, Titini, B. McCulloch 1967	tmt frags
Pachyornis elephantopus	CM unreg	Antills Bridge, Weka Pass	thor vert 24
Dinornis giganteus	CM unreg	Antills Bridge, Weka Pass	pRfem, phal2.2
Falco novaeseelandiae	CM Av36942	Weka Pass area, 14/11/69	12/1

Swamp sites

SITE NAME	**Glencrieff Moa swamp**
GRID REFERENCE	M33 747042
REPOSITORY OF MATERIAL	CM, MNZ, K. Eaves numbered E1 – E216.
COLLECTOR	R.Scarlett – 1/4/71, K. Eaves – 1992; THW, RNH – Feb/March 1993, 24 March, 1994.
TAPHONOMY	swamp trapping
FOSSIL RECORD NUMBER	M33/f25

Species	**Catalogue no.**	**x/y**
Dinornis giganteus	CM Av25373	67/1
Dinornis giganteus	Eaves's colln; MNZ S32684–5	47/4
Pachyornis elephantopus	Eaves's colln; MNZ S32668–73, 32675, 32679, 32681, 32698, 32700.	623/15 (2 juv)
Emeus crassus	Eaves's colln; MNZ S32674, 32680, 32682, 32686–90, 32696–7, 32699.	590/14 (1 juv, 4 subad)
emeid juv. moa chick	Eaves's colln, MNZ S32683, 32691	13/3
Apteryx sp.	S33490	1/1
Coturnix novaezelandiae	S33476–483	13/2
Cyanoramphus spp.	S33486	1/1
Coenocorypha aucklandica	S33484–5	2/1
Sceloglaux albifacies	S33491–2	4/1

Anthus novaeseelandiae	S33489	1/1
Harpagornis moorei	S28377, 28378	2/2
Anas chlorotis	S33487–8	5/1
Nestor notabilis	S28376	1/1

Site Name **Glenmark Swamp – bones in the Canterbury Museum**

Aptornis defossor. CM Av6026, 7/1.
Apteryx australis CM Av5096, 1/1
Apteryx owenii CM Av5097, 1/1
Hemiphaga novaezealandiae CM Av5109, 1/1
Gallirallus australis CM Av5315, 1/1
Gallinula hodgenorum CM Av 5316 paratype, 1/1
Harpagornis moorei CM Av5102 (12/1), 5104 (16/1), 5327 isolated vert, 26534 isolated pedal phalanx.
Cnemiornis calcitrans CM Av5409 R hum, 6249 dL tib, 6250 dR tmt, 6251 L tib, 6252 dL tib, 6257 dL tib, 6259 dL tmt – 7/4. Location uncertain, Glenmark possibly. Av 6254 dR tib, 6255 pR tib, 6258 pR tmt, 6260 dL tmt, 6261 RL ulnae, 6262 pR ulna, 6263 pR fem, 6264 d fem, 8293 dL hum. (Total 17/4).
Emeus crassus CM Av8413, 8426, 8600, 8602, 8603, 8608, 8609, 8614, 8615, 8647, 8726, 8907, 8908, 8962, 9070, 9071, 9081, 9092, 9095, 9096, 9098, 9099, 9157, 9159, 9192, 9222, 9227, 9252, 9418, 9533, 9544, 9545, 9641, 14355, 17282, 17288 (MNI = 11 individuals).
emeid sp CM Av9374, 9375, 9376, 9377.
Euryapteryx geranoides CM Av8398, 8605, 8606, 8607, 8782, 8929, 8954, 9054, 9058, 9068, 9115, 9412, 9537, (MNI = 3 individuals).
Pachyornis elephantopus CM Av8391, 8401, 8440, 8443, 8728, 8831, 8959, 8960, 9066, 9114, 9124, 9221, 9226, 9241, 9257, 9359, 9360, 9362, 9367, 9530, 9534, 9536, 9557 (MNI = 7 individuals).
Anomalopteryx didiformis CM Av8640, 8813, 8814, 8815, 8816, 9249, (MNI = 2 individuals).
Megalapteryx didinus CM Av8623, 9089. (MNI = 2 individuals).
Dinornis struthoides CM Av8692, 8759, 8767, 8773, 8787, 8811, 8818, 8821, 8872, 8976, 8987, 8988, 8997, 9019, 9082, 9083, 9237, 9238, 9239, 9242, 9244, 9413, 9414, 9535, 9543, (MNI = 8 individuals).
Dinornis giganteus CM Av8448, 8693, 8788, 8975, 8977, 8979, 8984, 8991, 9001, 9016, 9511, 9529, 9531, 9532 (MNI = 6 individuals).

SITE NAME	**Pyramid Valley**
GRID REFERENCE	M33 772038
REPOSITORY OF MATERIAL	CM, MNZ, AIM, others see below
COLLECTOR	Canterbury Museum Expeditions
TAPHONOMY	Swamp miring, vagrants
FOSSIL RECORD NUMBERS	M33/f11–17; S61 f642–651, f655, f656

Pyramid Valley exemplifies the inadequacies of the fossil record number system which was designed to give sites, or strata within sites, unique identifiers. At Pyramid Valley no number was given for the site as a whole, but one has been allocated for each sample dated, and others for microfossil collections – a total of 19 numbers.

The data in the following list are after Holdaway & Worthy (in prep) wherein a complete listing of all material is given. While all material was collected by the Canturbury Museum, many specimens have been given to other institutions around the world. The current whereabouts of all specimens is given in Holdaway & Worthy (in prep).

Species	**Number of bones**	**MNI**
Emeus crassus	Part skeletons	78
Euryapteryx geranoides	Part skeletons	21
Pachyornis elephantopus	Part skeletons	17
Dinornis giganteus	Part skeletons	62
Dinornis struthoides	Part skeleton	1
Dinornis sp. chick		1
Apteryx australis/haastii	22	4
Apteryx spp. juv.	15	2
Anas chlorotis	109	11

Anas gracilis	4	3
Anas superciliosa	20	3
Aythya novaeseelandiae	25	5
Euryanas finschi	22	5
Malacorhynchus scarletti	30	7
Tadorna variegata	33	5
Cnemiornis calcitrans	27	1
Poliocephalus rufopectus	9	2
Egretta alba	1	1
Himantopus novaezelandiae	14	2
Aegotheles novaezealandiae	15	5
Ninox novaeseelandiae	2	1
Sceloglaux albifacies	19	4
Coturnix novaezelandiae	1	1
Aptornis defossor	517+	10
Fulica prisca	44	8
Gallinula hodgenorum	35	9
Gallirallus australis	180+	17
Porphyrio hochstetteri	10	3
Circus eylesi	149+	7
Falco novaeseelandiae	6	1
Harpagornis moorei	22	2
Cyanoramphus spp.	30	7
Nestor meridionalis	138	12
Nestor notabilis	89	9
Strigops habroptilus	23	5
Hemiphaga novaeseelandiae	643	69
Xenicus sp.	1	1
Traversia lyalli	1	1
Bowdleria punctata	3	2
Prosthemadera novaeseelandiae	49	11
Anthornis melanura	3	2
Callaeas cinerea	49	8
Corvus moriorum	5	1
Mohoua novaeseelandiae	3	2
Petroica australis	8	3
Petroica macrocephala	1	1
Philesturnus carunculatus	9	2
Turnagra capensis	11	2
	TOTAL MNI	439
Bats		
Mystacina robusta	6	2
Lizards		
Sphenodon sp.	28	6
Hoplodactylus sp.	1	1

SITE NAME	**Swamp between Culverden and Waikari**	
GRID REFERENCE	?	
REPOSITORY OF MATERIAL	CM	
COLLECTOR	? 1948	
TAPHONOMY	swamp trapping	
Species	**Catalogue no. CM**	**x/y**
Emeus crassus	Av30490–1	17/6
Pachyornis elephantopus	Av30492–4, 14374	9/3
Dinornis giganteus	Av30495–6	6/2
Dinornis struthoides	Av30497–8	2/1

SITE NAME **The Deans, upper Waipara River**

GRID REFERENCE	M34 794958	
REPOSITORY OF MATERIAL	CM	
COLLECTOR	R. Scarlett 19/4/79; R. J. Scarlett & Mrs Turnbull	
TAPHONOMY	swamp trapping	
FOSSIL RECORD NUMBER	M34/f35	
Species	**Catalogue no. CM**	**x/y**
Euryapteryx geranoides	Av33183, 33186–9, 33192, 33196, 33219–21, 33224, 33252, 33255, 33868, 33885	156+/7
eggshell ?*E. geranoides*	Av33875	eggshell
Pachyornis elephantopus	Av33253	1/1
Emeus crassus	Av33184–5, 33190–1, 33197, 33229, 33278, 34891–2	19/3
Anomalopteryx didiformis or *Megalapteryx didinus*	Av33877	1/1
emeid sp. juv	Av33232, 33256, 33886	4/1, 2/1, 1/1
Dinornis giganteus	Av33225, 33181	66/1, 6/1
Dinornis chick	Av33230,	1/1
gizzard stones	Av33182, 33193, 33222, 33231, 33277, 33879	
Aptornis defossor	Av33175, 33226+33869+33872	13/1, 23/1
Apteryx owenii	Av33227, 33241	2/1
Apteryx australis/haastii	Av33176, 33882	2/1
Strigops habroptilus	Av33228, 33177, 33876	3/1
Porphyrio hochstetteri	Av33240	1/1
Gallirallus australis	Av33178–80, 33871, 33880, 33888	6/2
Hemiphaga novaeseelandiae	Av33870	1/1
Nestor meridionalis	Av33873, 33881	4/1
Anas chlorotis	Av33874	1/1
Coturnix novaezelandiae	Av33878	1/1
Euryanas finschi	Av33887	2/1
Sphenodon sp.	CM Rep511	1/1

APPENDIX 6

Pollen representation in a sample from –75 cm in square F0 (analysis by Janet Wilmshurst, May 1993), and A1/B1 (analysis by N. Moar, October, 1995) at Glencrieff, expressed as % pollen of dryland species (F0 = 210, A1/B1 = 279). Taxa represented by grains less than 1% are shown by *; taxa picked up after the formal count by a scan are shown by +; – not present in sample

	Species	**F0**	**A1/B1**
Trees	*Libocedrus*	2.4	*
	Halocarpus bidwilli	*	*
	Phyllocladus	22.9	14
	Plagianthus	–	1
	Podocarpus undifferentiated	1.9	4
	Podocarpus totara	2.9	*
	Prumnopitys ferruginea	1.4	–
	Prumnopitys taxifolia	*	1
	Weinmannia	–	*
Shrubs	Asteraceae undifferentiated	16.2	15
	Coprosma	15.7	7
	Discaria	–	*
	Hoheria	2.9	–
	Olearia type	–	2
	Leptospermum type	0.5	–
	Muehlenbeckia	2.4	*
	Myrsine	9.5	*
	Rubus	1.4	–
	Schefflera	1.0	–

	Hebe	–	+
Grasses & herbs	Apiaceae (probably *Aciphylla*)	3.3	*
	Centipeda type	–	2
	Celmisia	–	1
	Cruciferae undifferentiated	4.3	–
	Epilobium	Trace	+
	Chenopodiaceae	–	+
	Lobeliaceae	0.5	+
	Oreomyrrhis	–	*
	Myosotis	–	*
	Kirkianella	–	+
	Plantago novaezealandiae	1.4	–
	Poaceae	9.5	45
	Rumex	–	*
	Tillaea (*Crassula* now)	–	*
Wetland herbs	Restionaceae	0.5	–
	Brassicaceae	–	3
	Apiaceae	–	*
	Cyperaceae	89.0	30
	Gentiana	–	1
	Gonocarpus	–	+
	Hydrocotyle	–	*
	Lilaeopsis	–	*
	Oreobolus type	–	7
	Schizeilema	–	*
	Sebaea	–	*
	Myriophyllum	1.4	–
Ferns	*Cyathea smithii*	1.0	*
	Dicksonia squarrosa	–	*
	Pteridium	–	+
	Ferns undiff.	2.0	–
	Lycopodium fastigiatum	1.4	–
	Phymatosorus type	0.5	–
	Monolete fern spores	1.0	–
	Trilete fern spores	1.4	–