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Late-Pleistocene avifaunas from Cape Wanbrow, Otago, South Island, New Zealand

T. H. Worthy[1] and J. A. Grant-Mackie[2]

Abstract Fossil avifaunas from the Hillgrove Formation at Boatmans Harbour, Ruby Gully, and Old Rifle Butts, all on Cape Wanbrow, Oamaru, north-east Otago, are listed. The marine beach sands and gravels at Old Rifle Butts that form the lowest part of the Hillgrove Formation and overlie the palaeo-wave platform were deposited during the last interglacial ~130–110 kyr BP (Oxygen Isotope Stage 5). There are a few small avifaunas (totalling 11 spp.) from these beach sediments (J41/f8710, f8214, f8227). The colluvial, valley-fill deposits in Ruby Gully and at its mouth are the youngest in the sequence. Radiocarbon dating indicates their emplacement between 27 and 34 kyr BP, or the later part of Oxygen Isotope Stage 3. If these ages are representative of the true age of the samples and not the limitations of radiocarbon technology, they indicate that these deposits in Ruby Gully are much younger than the beach deposits. Radiocarbon ages on a pitfall fauna from a small cave 3–4 m above the base of the Hillgrove Formation indicate that the cave fauna has a similar age as that in Ruby Gully. The dune and interdune waterlaid deposits at Old Rifle Butts (>2 m above the wave platform) may date from an unknown time between 100 and 35 kyr BP or be coeval with those in Ruby Gully. Fifty-three species of bird (32 land and freshwater taxa) are represented in the combined avifaunas making this the richest Pleistocene avifauna known from New Zealand. All bird taxa are known from Late Holocene avifaunas in the eastern South Island. Key taxa (*Pachyornis elephantopus*, *Emeus crassus*, *Euryapteryx geranoides*, *Coturnix*, *Chenonetta*, *Cnemiornis*, *Harpagornis*, *Fulica*, *Porphyrio*, *Gallinula*) indicate that the habitat was mainly grassland and shrubland. Tuatara, indeterminate skinks, and seals are also present.

Keywords fossil avifaunas; late Pleistocene; Hillgrove Formation; Cape Wanbrow; New Zealand

INTRODUCTION

A rich fossil avifauna is known from Late Pleistocene and Holocene deposits throughout New Zealand (Fordyce 1991). Faunas from the South Island have been described in detail by Worthy & Holdaway (1993, 1994, 1995, 1996) and Worthy (1997a, 1998a,b). In all areas of the South Island, many of these faunas are from deposits in caves accumulated either as pitfall deposits or by avian predators. In Canterbury, Otago, and Southland there are significant swamp and lacustrine faunas. In Marlborough and Southland, coastal dune faunas are present. Waipara, in North Canterbury, has the only known fluvial deposit of fossil bird bones (Fig. 1).

[1]Palaeofaunal Surveys, 2A Willow Park Drive, Masterton, New Zealand. Email: twmoa@wise.net.nz
[2]Department of Geology, Faculty of Science, University of Auckland, Private Bag 92 019, Auckland, New Zealand.

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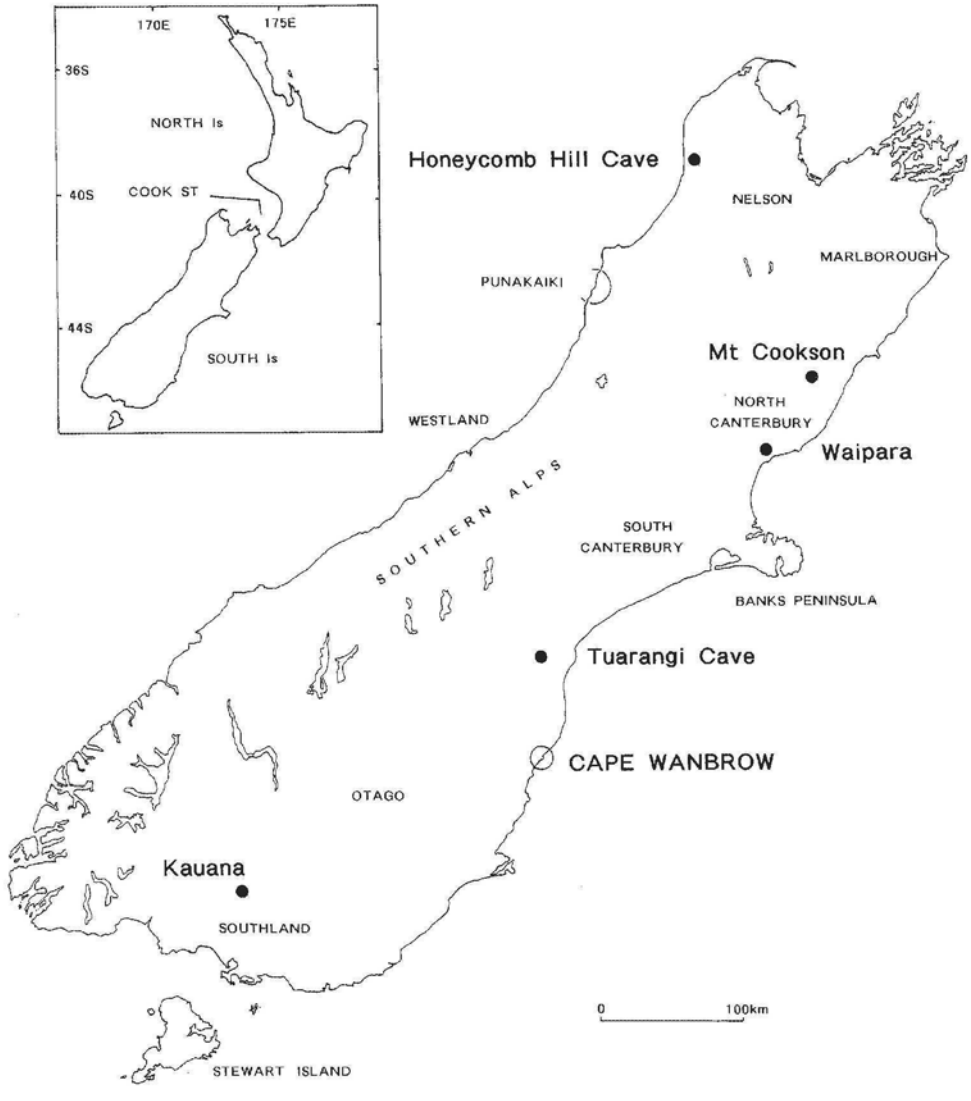


Fig. 1 Location of Cape Wanbrow and main fossil localities mentioned in the text.

Most of these faunas are of Holocene age, but a growing number of those known are of last glacial (Otiran; 70–14 kyr BP; Oxygen Isotope Stages 2 and 3) age. The oldest date pertaining to a fossil avifauna from the West Coast is from the Punakaiki karst and is c. 25 kyr BP (Worthy & Holdaway 1993). In Takaka Hill deposits, the oldest date is about 29 kyr BP (Worthy & Holdaway 1994). However, in both instances these dates relate only to specific moa skeletons and do not date a larger fauna. The large faunas from Honeycomb Hill Cave in north-west Nelson are not known to exceed 20 kyr BP (Worthy 1993a). On Mt Cookson in North Canterbury, a deposit in Merino Cave containing five moa and nine other bird species is at least 38 kyr old (Worthy & Holdaway 1995). Otiran age fossils from North Canterbury are mostly isolated moa bones in loess (Worthy 1993b), although a single fauna from the Omihi Stream Gravels at Waipara contained five species of moa, seven other birds, and

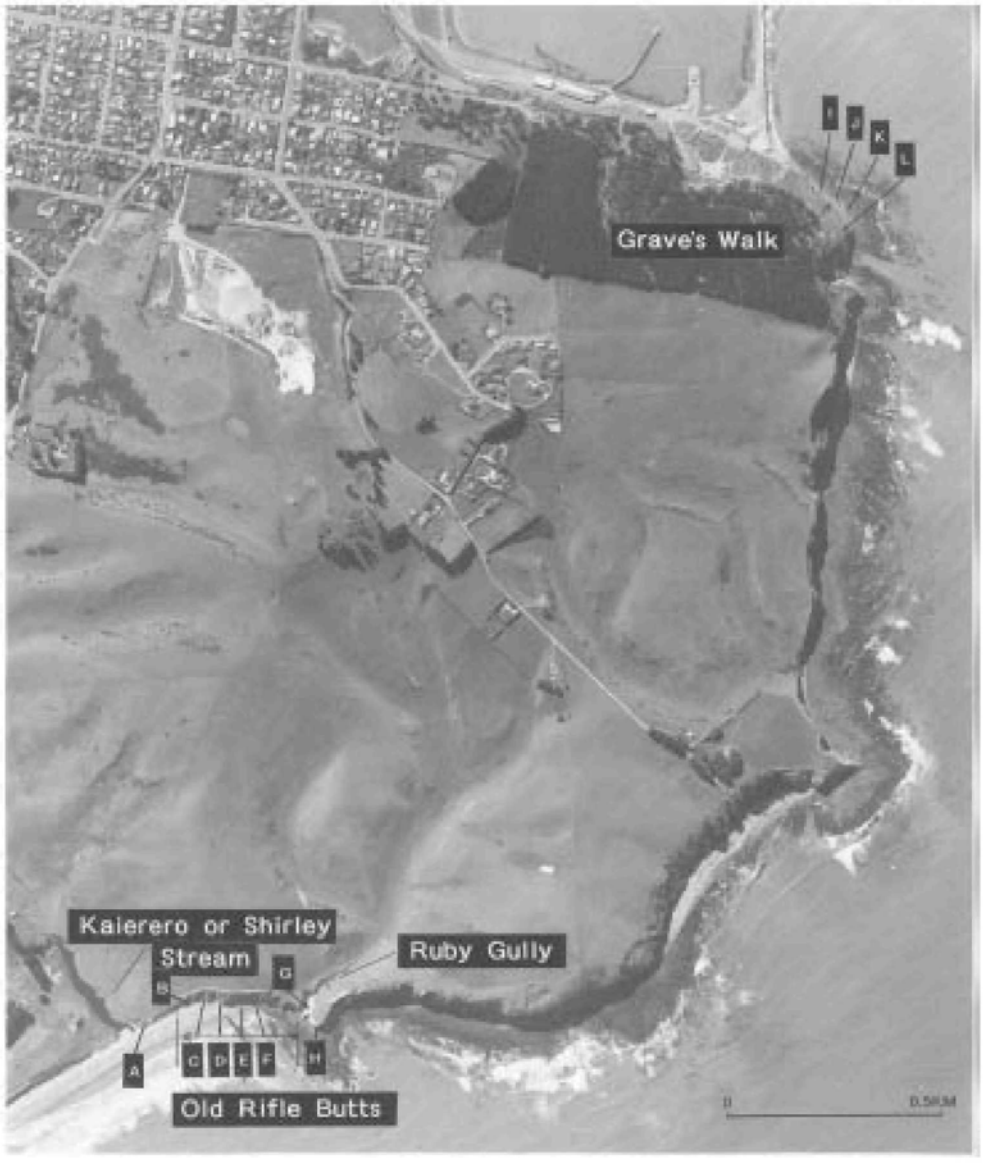


Fig. 2 Aerial view of Cape Wanbrow showing the location of the major exposures of the Hillgrove Formation and some of the fossil localities (A–L) at Grave's Walk and Old Rifle Butts. A, f133, f 134, f213; B, f8214; C, f8212; D, f8210, f8211; E, f8225–8228; F, f8229; G, f8213; H, f131, f8230; I, f9641; J, f9637; K, f9638; L, f9642. Photograph courtesy of Aerial Surveys Limited, Nelson.

immediately predates 22.6 kyr BP (Worthy & Holdaway 1996). In the South Canterbury downlands, cave deposits on Tuarangi Station contain faunas of Otiran age. The most significant was in Tuarangi Cave where a single date of 47.5 kyr BP is applicable to a fauna of four moa species and nine other birds. Nearby, deposits in Tomos 1 and 2 between 21.6 and 31 kyr BP contained two species of moa and six other birds (Worthy 1997a). Otago has no previously reported faunas of proven Otiran age (Worthy 1998b). In Southland, the single identified Otiran fauna from the Kauana swamp site is older than 37 kyr BP (Worthy 1998a)

and is the oldest swamp fauna from New Zealand. It contains six moa species and a single carinate species.

This brief review of South Island Pleistocene avifaunas shows that only five predate the Glacial Maximum and are older than 20 000 years, and the most diverse of these consists of only 13 species of bird. All provide limited samples of birds other than moas.

There are, however, largely undescribed avifaunas from Cape Wanbrow on the southern margins of Oamaru (Fig. 1, 2). These avifaunas are derived from several sites on the north and south side of the peninsula, from either reworked loess, back-beach sand deposits, or possible dune deposits. Grant-Mackie & Scarlett (1973) briefly described the sections on the south side of the Cape from the area known as Old Rifle Butts. There, the avifaunas were derived from what is collectively referred to as the Hillgrove Formation (see below). Grant-Mackie & Scarlett (1973) considered that these deposits were of Oturian interglacial age, which preceded the Otiran Glacial Period, and, thus, are Oxygen Isotope Stage 5, or 75–130 kyr BP (Nelson et al. 1993).

The deposits contain beach gravels, and marine shells are common in the lower part of the formation, implying a beach or subtidal environment. In all sites there are coastal species, for example, penguins, shags, and petrels, which, with fish and seal bones, indicate deposition of the faunas close to and in the sea. However, the presence of landsnails implies that the deposits immediately overlying the gravels are of terrestrial origin, as their fragile shells would not survive in a marine environment. Grant-Mackie & Scarlett (1973) listed 44 taxa of birds including undescribed species of *Eudyptes*, *Anas*, *Harpagornis*, *Fulica*, *Larus*, *Hemiphaga*, *Nestor*, and an owl. The combined faunas therefore contain the most diverse pre-Glacial Maximum Pleistocene avifauna known from New Zealand. The supposed new species listed by Grant-Mackie & Scarlett (1973) have been included in lists of fossil vertebrates subsequently (Fordyce 1982, 1991) and so will be discussed here.

In this paper, we describe the stratigraphic and depositional setting of these Otiran deposits, and describe the avifaunas in detail. The ages of the faunas are determined from stratigraphic considerations and radiocarbon determinations on the bones and peat. The sediments were sampled for optical ages; these data will be published elsewhere. The few deposits of Holocene age, such as at the mouth of Shirley Creek (Gull Site), are included in Appendix 1 but are not considered further. Modern bones, such as those of introduced passerines that have been incorporated in the eroding Pleistocene deposits, are not considered.

ABBREVIATIONS AND DEFINITIONS

New Zealand institutions: AU, Department of Geology, University of Auckland, Auckland; MNZ, Museum of New Zealand Te Papa Tongarewa, Wellington (formerly National Museum of New Zealand and Dominion Museum); CM, Canterbury Museum, Christchurch.

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. In some instances "x" was uncounted and left as "x" while the more important value for "y" was determined. If "x+" is used, it means more than the number given.

Skeletal elements and descriptive terms used (may be singular or plural as appropriate): acet, acetabular part of pelvis; cmc, carpometacarpus; cor, coracoid; cran, cranium; fem, femur; fib, fibula; frag, fragment; fur, furcula; hum, humerus; imm, immature; innom, os innominatum; juv, juvenile; M, manus phalanx; mand, mandible; pel, pelvis; phal, phalanx; pmx, premaxilla; quad, quadrate; rad, radius; sac, synsacrum; scap, scapula; stern, sternum; tmt, tarsometatarsus; tt, tibiotarsus; vert, vertebra. In listed material, bones are sometimes identified as left (L) or right (R) elements. L or R prefixed by "p", "s", or "d" indicates

"proximal", "shaft", or "distal" part of the element, respectively, e.g., pR fem means the proximal part of a right femur.

Measurements

Measurements were made to 0.01 mm with TESA® dial callipers, and rounded to 0.1 mm.

Identification

Bones were identified by THW. When necessary, comparisons were made with recent reference material, or previously validated fossil material, held in AU, MNZ, or THW reference collections.

Nomenclature

The nomenclature and higher taxonomy advocated by Turbott (1990) as modified by Holdaway et al. (2001) are followed. Therefore, *Cnemiornis calcitrans* and *Aptornis defossor* are accepted 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 following Marchant & Higgins (1990). The South Island takahe is recognised as a species that is distinct from the North Island takahe following Trewick (1996), and their respective original specific names *Porphyrio hochstetteri* and *P. mantelli* are used. The bones of king shag (*Leucocarbo carunculatus*) do not differ from those of Stewart Island shag (*L. chalconotus*) except in size, and then only in the Stewart Island area (Worthy 1996, 1998c). All North, South, and Stewart Island *Leucocarbo* are considered to be one species, *L. carunculatus*. The small albatrosses or mollymawks are referred to *Thalassarche* following Robertson & Nunn (1997).

Anatomical nomenclature follows Baumel et al. (1993), and English translations are used after the first reference.

The geological periods referred to here are: Last Interglacial, from 130 to 70 kyr BP, or Oxygen Isotope Stage 5; Otira Glaciation, the last glaciation, from ~70 to 14 kyr BP, which is broadly equivalent to the Wisconsinan–Weichselian or Oxygen Isotope Stages 4–2; Late Glacial, the period of rapid climatic and vegetational change from 14 to 10 kyr BP; Holocene, the present interglacial period, taken as starting at radiocarbon 10 kyr BP. These latter two divisions better reflect the major episodes of vegetation history than does use of the term Aranuian, which covers all the time from 14 kyr to the present.

We use Fossil Record Numbers to define faunas from different strata and different sites within the sequence. The database is maintained in the Fossil Record File of the Geological Society of New Zealand. For example, the number J41/f9638 refers to the locality number 9638 on 1:50 000 sheet J41 in the map series NZMS 260.

Radiocarbon dating

The radiocarbon ages discussed here were obtained over several years. All determinations were made by the (now) Institute of Geological and Nuclear Sciences (IGNS), Lower Hutt, New Zealand. Most of the ages were standard gas counting ages (prefixed by NZ) and were obtained from a variety of media as outlined in Appendix 2. Only one accelerator mass spectrometry (AMS) age was obtained (prefixed by NZA). Determinations on bone were based on the purified "collagen" fraction (Redvers-Newton & Coote 1994). IGNS records, searched by D. Chambers and N. Beavan Athfield (pers. comm.), show that NZ3092 and 3093 were washed in 3*M* HCl and the organic fraction dated. For the later measurements, NZ4743 and 4753, the bone samples were ground and the powder treated with 0.6N HCl at room temperature for several hours. The residue or "collagen" was stirred with 0.1N NaOH,

filtered, washed, and dried at 40°C. This purified residue was dated. NZA3609 was cleaned of surface dirt, ground, and washed in HCl till effervescence ceased, and the purified sample dated. The peat samples were washed in boiling water, then in hot H_3PO_4. The remaining solids were then dated. The shell for NZ1587 would probably have been washed and scrubbed, ground up, and dated without further purification.

The recorded pre-treatments show that all the bone samples dated were acid demineralised which means that carbonate contamination was removed, but it is probable that humic acid contamination was not wholly removed from any sample. The presence of humic acids in a dated sample usually creates radiocarbon ages that are artificially young (Stafford et al. 1988). However, the depositional environment in or below deep loess in a dry environment means there is likely to be less humic acid in the environment compared with that under forest or in peat. Cooler environments usually result in better preservation of the organic components of bone (THW pers. obs.), so the preservation conditions for bones at Cape Wanbrow, where the present mean annual temperature is c. 11°C, is favourable. The only data recorded for the early samples pertaining to preservation were for NZ3093; 77 g of organic residue was obtained from 401 g bone (19.2%), which is a high percentage. The later samples (NZ4743, NZ4753) had "collagen" yields of 22.5 and 26%, respectively. In THW's experience, the best preserved moa bones can have up to 30% organic residue or "collagen" after the acid wash, but dates consistent with other data have been obtained where this value is less than 1%. We contend that the reported "collagen" yields indicate that humic contamination was likely to have been minimal.

Ages are reported as conventional radiocarbon ages (CRA) based on the Old (Libby) half-life ($T_{½}$ = 5568 years) as defined by Stuiver & Polach (1977).

STRATIGRAPHIC AND DEPOSITIONAL SETTING

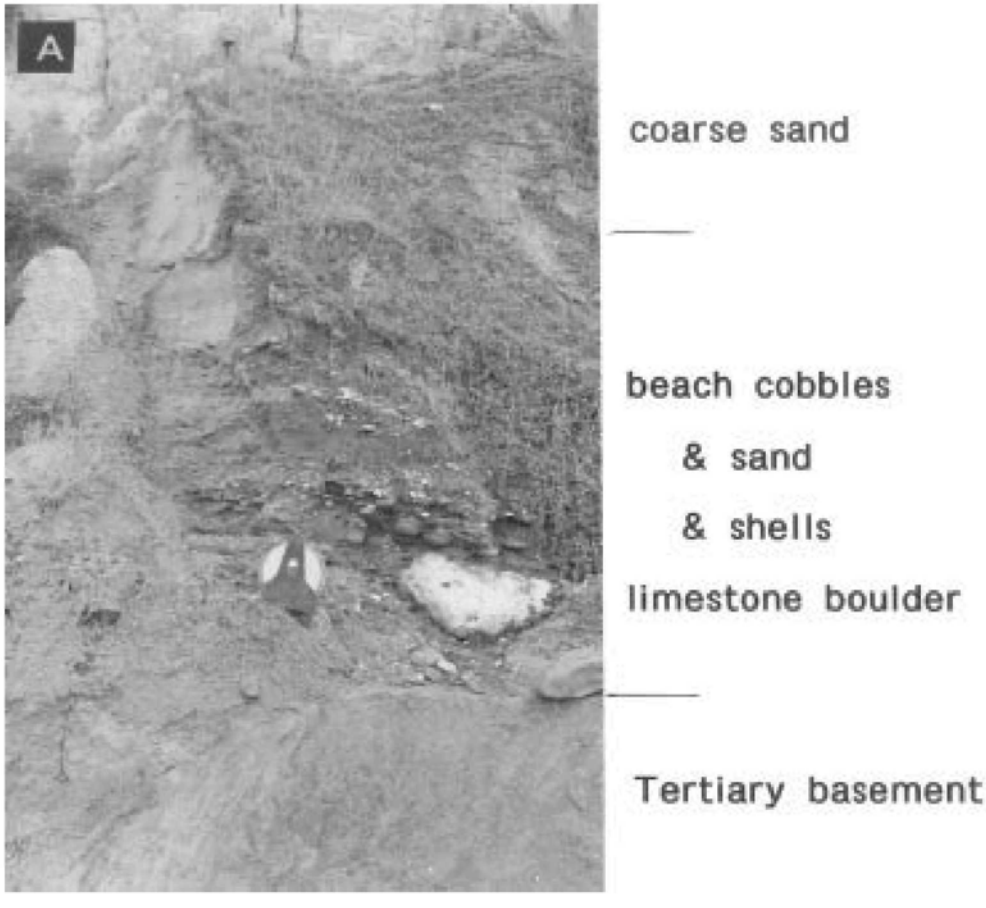
Quaternary climatic fluctuations between glacial and interglacial conditions saw glaciers advance and retreat, and moraines, pediments, and outwash gravels deposited in the uplands and valleys west of Oamaru. Loess was deposited and streams were downcut in the Oamaru district. In the coastal region, there was alternating regression, with exposure of pre-existing seafloor, and transgression, with terrace cutting, cliffing, and accumulation of sediments (see, e.g., Gage 1957; Mutch 1963). Thus, Quaternary sediments in the region include shallow marine conglomerates and sands, beach and dune sands, and lithologically more varied stream, lake, and swamp deposits, with a widespread cover of loess.

Wedges of coastal sediment run discontinuously along the north Otago coast, lying on remnants of wave-cut platforms now above modern beach level and backed by fossil cliffs exposed where the modern cliff has retreated enough, and with both features and the associated deposits completely removed where retreat has been faster (as on Cape Wanbrow itself). The preserved platforms are seen at two levels: a lower more extensive one reaching nearly 4 m above modern High Tide Mark at its inner edge, and a higher one at ~13.5 m; both are said to fall gently seawards, as would be expected from their origin and the apparent absence of subsequent tilt. The lower platform, cut during Oxygen Isotope Stage 5 (Forsyth 2001), shows irregularities in its level because of more resistant beds in the Tertiary rocks on which it is cut, e.g., concretionary horizons in Rifle Butts Formation and Ototara Limestone (Gage 1957), projecting somewhat above the level of softer units.

The sequence overlying the lower terrace and beneath the loess cover has been termed the Hillgrove Formation, with the older Boatmans Formation on the higher surface (Mutch 1963). In addition, younger, probably Last Glacial and Postglacial, deposits occupy low coastal flats and the Waitaki River mouth environs (Morven Formation and others; Mutch 1963).

Fig. 3 Boatmans Harbour showing the erosional contact (across centre) between the Hillgrove Formation above and the Waiareka Volcanics below. The conglomeratic shelly basal Hillgrove passes up into sands with a vegetation cover; the sharp oblique line marking the top of the vegetation is the outer edge of Grave's Walk, with a cutting in loess above. Note the human figure at bottom right for scale. Photographed May 1975 (JAG-M).

Bird bones, especially moa, have been recorded from all these units as well as from the loess. The Boatmans Formation consists of "impersistent remnants of well weathered marine beach sands" (Mutch 1963) "now scarcely recognisable owing to the combined effect of marine erosion and obliteration by yellow silt washed down from loess deposits above" (Gage 1957, p. 64). This unit has not been sampled for the present study. The bulk of the material discussed here comes from the Hillgrove Formation or from the contact between it and the loess on either side of Cape Wanbrow (Fig. 2), at Boatmans Harbour in the north, and in the south from the eastern side of the mouth of Shirley (or Kaierero) Creek, the region well known to geologists as "Old Rifle Butts" because of its early use as a small arms firing range, eastwards to Ruby Gully.



Fieldwork in the area has gone on intermittently by JAG-M with student field parties (May 1969, Nov–Dec 1973), with P. R. Millener and/or R. J. Scarlett (Sep 1970, May–Jun 1975, Jan 1983) or alone (Jan 1983, May 1990, Dec 1996). Collections are housed in the Geology Department, University of Auckland, apart from those made by RJS, which are in the Canterbury Museum. THW visited the area in Dec 1988, Jul 1993, Dec 1994, Sep 1995, Oct 1996, and Jul 1999, and deposited the fossils collected in MNZ.

Boatmans Harbour

Just outside Oamaru's north-south oriented harbour groyne a slightly irregular erosion surface has been cut on the Oligocene Deborah Volcanics (Fig. 3) at 3.5–4 m above beach level. On this has accumulated up to 2 m of crudely bedded pebbly shelly gravel and sand, very coarse at the base, with rounded and tabular clasts up to a metre in greatest length, passing up into pebbly sand. This unit is the Hillgrove Formation and, from consideration of its better exposure at Old Rifle Butts, it probably extends higher up the section. It can not be seen, however, because of a thick veneer of silty loess being washed down the cliff-face. Marine mollusc shells in this veneer suggest that deposits of marine origin may continue upwards beneath the slope wash, or may have been derived from overlying beach or dune sands (see later discussion) or from the higher-level Boatmans Formation.

Fig. 4 (*includes previous page*) Exposures of the Hillgrove Formation at the western end of Old Rifle Butts, Cape Wanbrow. **A**, Detail of the base of the Hillgrove Formation at the Kakanui Beach end of Old Rifle Butts. The interglacial wave platform cut in the Tertiary basement is clearly visible at the base. The beach conglomerates are 1.1 m thick. The limestone boulder eroded from the Ototara Limestone farther east has modern equivalents on the beach now. **B**, An overview of Old Rifle Butts showing the location of A. The interglacial wave platform cut in Miocene mudstones is here ~2–2.5 m above the present beach. The dune sands extend above the beach gravels to about the top of the photograph. For scale, the measuring tape in A is 15 cm diam. Photographed 29 July 1999 (THW).

From the base of the harbour groyne a foot track, Grave's Walk, climbs gently to ~30 m a.s.l. before dropping down onto a small beach 200–300 m further east. It begins at the level of the marine strata but is cut in loess for almost its whole length.

The basal marine unit has yielded a low diversity molluscan fauna together with teleost, seal, and a few bird bones (Fossil Record Number J41/f9638). A rich bird fauna and rarer land snails were collected from massive silty sand with scattered pebbles 1 m above the top of the exposed marine beds (J41/f9637), probably originating from dune sands of the Hillgrove Formation, as occur at Old Rifle Butts. A collection of bird bones and rare weathered marine bivalves was made beside Grave's Walk, ~65 m from the memorial plaque at the beginning of the track and ~4 m above the horizon of the last (J43/f9641). Higher levels of the loess along and above Grave's Walk yield only land snail faunas.

Moa bones were also collected from a cutting in the loess cover on the south side of the railway track running eastwards towards the start of Grave's Walk on the south side of Boatman's Harbour (J41/f50, f128, f129). The fauna is listed but not further discussed here.

Old Rifle Butts

Discussed under this heading are sites in the cliff section on the south side of Cape Wanbrow (Fig. 2). Here the 3–4 m wave-cut platform overlies west- to south-west-dipping Eocene to Miocene rocks mostly of low resistance to erosion but with the Ototara Limestone more cemented and resistant. In the earlier years of this study the platform and its cover beds were

more extensive along the cliff than they are now. In 1995, a 50-m-long section of the cliff collapsed along a cliff-parallel joint plane in the Ototara Limestone, carrying away a significant length of Hillgrove Formation containing the sites of some important fossil collections. Fortunately, extensive collecting had already been undertaken.

The Hillgrove sequence here has already been described (Grant-Mackie & Scarlett 1973) but further observations enable that work to be updated. On the fossil intertidal platform lie many boulders, up to 1 m long but generally less than 0.5 m, of algal and detrital McDonald Limestone (Fig. 4), Waiareka Volcanics, and concretions from the Rifle Butts Formation in a matrix of smaller pebbles, contemporaneous and derived shells, and sand. This very coarse basal part is essentially one boulder thick, up to ~0.5 m; the boulders are seldom in contact and may be well separated (Gage 1957, fig. 21). This grades into a shelly sandy conglomerate with pebbles up to 15 cm diam. and passes up into a well-bedded shelly sand, the whole marine sequence totalling 1.1 m in thickness. There is much lateral variation in this sequence with lenses of fine sand extending only a few metres within a cobble layer. Elsewhere, uniformly large 10–15 cm cobbles may form a prominent lens, or bivalves may dominate a lens (Fig. 4), and total thickness varies up to 1.5 m. In places, a coarse yellow well-graded sand interpreted as dune sand overlies the beach sand cobble layer and is at least another 1 m thick.

In the cliff east of Shirley Creek and eastwards to the Ototara Limestone (now mostly destroyed) the ~4.5 m thick sequence overlying the conglomeratic shelly unit is of massive, well-sorted grey sand containing scattered bones and land snails, rare marine bivalves, and small (30 mm max. diam.) quartz and greywacke pebbles. This is interpreted as mainly of dune origin despite the lack of bedding evidence because of its conformable passage from unequivocal marine beds, its uniform grain-size, and its biota, especially land molluscs and avifaunas. The occasional bivalves present are generally medium-sized *Paphies donacina*, but also *Aulacomya atra maoriana* and *Spisula* (*Crassula*) *aequilatera*. Their presence could have resulted from attempts by gulls (e.g., *Larus scopulinus*, *L. dominicanus*) to break shells for feeding by dropping them from the air, a tactic that can be successful even on sand dunes (Teichert & Serventy 1947; Leopold et al. 1985). This behaviour is commonly seen on New Zealand beaches (JAG-M and THW pers. obs.) performed by gulls of the above species and by oystercatchers.

The top of the shelly sequence and/or the base of the massive unit are believed to include deposits of beach origin because there is no distinct unconformity separating the two.

The lower more conglomeratic 0.8–1.0 m of the beach deposits have provided a rich molluscan fauna with rare marine and land vertebrates (J41/f8710) while the upper 0.3–0.5 m of well-bedded shelly sand (0.8–1.3 m above base of the Hillgrove) has seals and a rich bird fauna (J41/f8214). The overlying 4.5 m (1.3–5.8 m) of almost structureless medium brown sand has a few land snails and a varied bird fauna scattered throughout (J41/f8210), some of the latter being articulated partial skeletons. Within this sand, with its base 4.3 m above the base of the Hillgrove Formation, occurred a lens of dark grey pebbly sand 0.45 m thick and 2 m long with a rich bird fauna and rare tuatara, marine bivalves, and landsnails (J41/f8212). This well-bedded deposit is water-lain and probably of ephemeral interdune lake or pond origin.

Overlying this sequence are thin lenses of bone- and shell-bearing carbonaceous silt and sand ~0.1 m thick and up to 3 m long (J41/f8211), also aquatic and also possibly of lacustrine origin. These lie immediately beneath the loess cover from which in this region no bones have been recovered.

About 120 m east of Old Rifle Butts the more resistant Ototara Limestone forms a prominence, which angles obliquely up the cliff. At beach level modern marine erosion has

Fig. 5 Old Rifle Butts in the area of the Ototara Limestone which dips obliquely from upper right and centre down to lower left overlying bedded tuffs of the Waiareka Volcanics. At beach-level a cave has been excavated (behind boulders and log) along the contact between these units. A smaller cave, of comparable origin and position, in which can be seen bedded Hillgrove sands and conglomerate, occurs above the modern one, with similar sediments scattered to the right (east) above the indistinct erosion plane. Further marine Hillgrove Formation lies to the left (west) on a more obvious narrow wave-cut platform and banked against the low undercut buried cliff of Ototara Limestone. Younger non-marine Hillgrove sediments, including fissure filling, occur right of centre along with fractured somewhat displaced limestone (better shown in Fig. 6; see Fig. 6 for scale). Photographed January 1983 (JAG-M).

excavated a triangular cave in the 3-m-thick laminated siltstone beneath the limestone; a corresponding feature occurs above at the level of the Hillgrove Formation (Fig. 5, 6). The erosion platform at the base of the Formation is notched under the overhanging limestone and the profile of the original cliff is clearly visible. Immediately east of the slanting limestone rib the cliff face, before the 1995 collapse, showed a jumble of broken angular limestone fragments resulting from earlier spalling and collapse within the jointed mass. Many interstices appeared open but others were filled with calcareous sand and silt or, at higher levels, with loess. Fossils occurred in some of these fissure fillings, and in the lower beds of the Hillgrove Formation.

The basal shelly conglomerate, nearly 2 m thick here, is well bedded and consists of very rounded "greywacke" pebbles, with occasional locally derived limestone and volcanics, set in a matrix of grey-brown medium to fine sand containing plentiful Mollusca, mostly *Paphies* but including derived Miocene shells, and seal bone (J41/f8228). This unit is overlain by ~1 m of well-bedded fine breccia of siltstone and sandstone fragments derived from strata immediately beneath the limestone, with some very well rounded "greywacke" pebbles, all in a sand matrix. Breccia clasts are poorly sorted, from small flakes to 20 cm in longest dimension. Very poorly preserved decalcified marine molluscs occur in the lower part and a moa bone was collected from the upper part (J41/f8227). Both of these units are of beach deposit origin and equate with f8710 and f8214 to the west.

Above the beach deposits lie the tumbled blocks and fissure deposits. Beneath the *in situ* limestone, occupying an irregularly shaped small cave or large fissure (Fig. 5, 6, 7) was a deposit ~1 m thick of bone-bearing calcareous sand (J41/f8226), the sand including bryozoan fragments derived from disintegrated Ototara Limestone and angular fragments of the limestone apparently broken from the roof and adjacent fissures. The lower half of the cave fill, lying conformably on the water-laid beds, included leached and poorly preserved bones in some of the area, better preserved elsewhere. Bones were in an excellent state of preservation in the

Fig. 6 Central and right portion of the area shown in Fig. 5 with the fissured limestone partly excavated. The box shows the location of the cave site (J41/f8226, see Fig. 7). Ladder is 2 m long. Photographed March 1990 (JAG-M).

rest of the deposit and remains included eggshell at 0.7 m and, in the back of the cave, two incomplete eggs (Fig. 8). The bones were extremely abundant, intricately intermingled, and many were broken, characteristics of the breakage indicating that the fractures occurred well after death and after the bones had significantly weathered, including, perhaps, during collection. Most of the bones belong to either *Eudyptula minor* or *Pelecanoides urinatrix*, and the two eggs are readily ascribed to the former species. The presence of all skeletal elements and at least 11 other taxa strongly suggests that this site was a pitfall trap for most of the period of deposition.

This very rich deposit, which also contained a few land snails, was capped by 350 mm of fine light grey laminated silt over a restricted area of 150 × 750 mm between fallen limestone blocks and with a low void at the roof of the cave still empty. This silt was devoid of macrofossils and proved to be barren of microflora or carbonaceous material of any sort (D. Mildenhall pers. comm. 19 July 1974); it is likely to be loess which has infiltrated from above after the cave had been sealed, presumably by rockfalls.

East of the Ototara Limestone promontory, the Hillgrove sequence appears comparable to that west of the limestone, but apart from the basal shelly conglomerate it has not been sampled, being either vegetated or inaccessible. J41/f8229, yielding a very rich molluscan fauna and the bone of a large seal, came from 25 m east of the limestone. The deposit

Fig. 7 The partially excavated cave site (J41/f8226), located in box in upper right of Fig. 6, showing the crudely bedded sands, which yielded penguin eggs and numerous bones, overlain by a thin unfossiliferous layer of very fine dry unconsolidated laminated clay (presumably infiltrated loess). Above the top of this deposit (at level of hammer handle) the fissure was empty. Hammer 325 mm long. Photographed January 1983 (JAG-M).

examined is 1.5 m thick, with a basal layer of boulders mostly of Ototara Limestone and Waiareka Volcanics up to 1 × 1 × 0.5 m in size overlain by pebbles of "greywacke", some quartz-veined, in a matrix of medium-coarse sand and quartz granules. Above this, and laterally equivalent to the cave and fissure deposits, is c. 2 m of gravelly sand with rare shells of *Perna*, *Tiostrea*, and *Paphies*.

Ruby Gully

About 80 m east of the Ototara Limestone the sub-Hillgrove erosion surface is cut onto Waiareka Volcanics, also at c. 4 m above beach level. Here a small gully reaches the coast, with its present floor 1.9 m above the modern shore platform and c. 1.3 m above high tide mark. The base of the Hillgrove Formation lies 2.9 m above the floor of the valley at its mouth. The gully is termed Ruby Gully locally on account of the volcanic crystals derived

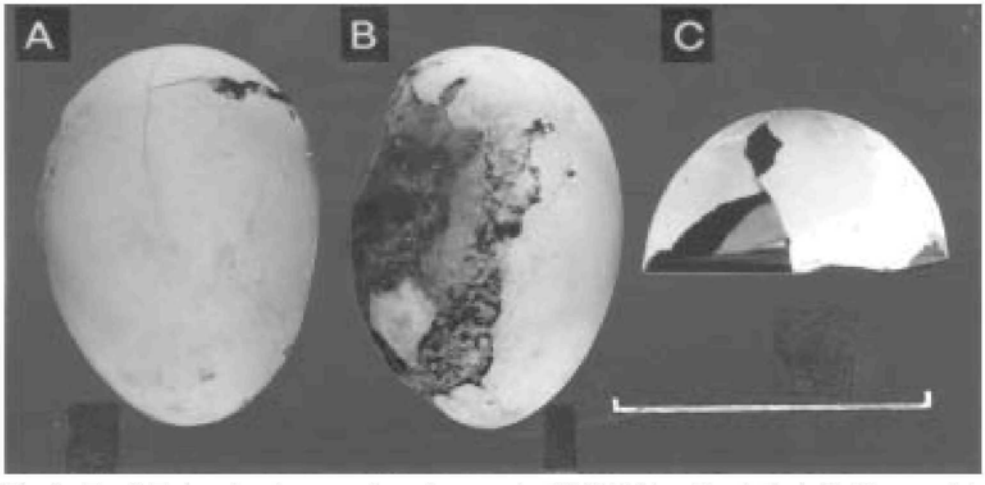


Fig. 8 Fossil *Eudyptula minor* eggs from the cave site J41/f8226 (see Fig. 6, 7). **A**, **B**, Views at right angles to each other of the more complete specimen, with infilling matrix of calcareous sand; **C**, the smaller specimen, with no adhering matrix. Scale bar is 50 mm.

from the Waiareka rocks present in the Hillgrove. The erosion surface rises very gently up the gully for 28.5 m where it is backed by a 2-m-high cliff, behind which it again rises gently until it becomes covered by vegetation some 15 m further inland.

At the mouth of the gully a basal conglomerate is 1.2 m thick and composed of very well rounded and poorly sorted pebbles of Torlesse sandstone and rare Waiareka Volcanics in a matrix of medium to coarse sand, quartz granules, and shell fragments. A layer one or two cobbles thick forms the base and top of this unit (Fig. 9). This distinctive unit is traceable for 10–12 m inland. From c. 20 m up the gully, the basement slopes uphill and is overlain by a single coarse conglomerate up to 0.5 m thick, dominated by angular, very poorly sorted Waiareka cobbles and pebbles, with much rarer rounded Torlesse sandstones and quartz granules, and includes lenses of sand. The conglomerate near the gully mouth is interpreted as an extension of the marine beach unit seen either side of the gully immediately on top of the Tertiary basement. The upstream conglomerate is interpreted as of fluvial origin from farther up the gully.

At the mouth of the gully, a 1-m-thick layer of well-sorted unconsolidated yellow sand with rare bones, labelled "coarse beach sand" in Fig. 9, overlies the beach conglomerates. This sand layer thins inland and is not traceable farther than about 15 m up the gully. Generally an irregular cover of loess washed down from the upper part of the valley walls obscures its presence.

Overlying both the upstream fluvial conglomerate and the coastal beach sand wedge is an "unlayered colluvial silt" (Fig. 9) c. 4 m thick. Near the gully mouth, the sequence above the yellow sand begins with 1.05 m of massive silty sand with a greenish tinge in fresh section, and black root traces. The overlying 3 m has irregular layers of silt and thin lenses of small greywacke pebbles indicating fluvial deposition. In the upstream parts of the section, the upper 2 m of this unit contains thicker lenses (~0.5 m) of pebbles up to 2 cm diam. This unit is interpreted as a valley fill deposit where periodic streams have deposited eroded loess and occasionally coarser material. Fossils in this unit are numerous but difficult to extract (J41/f8213). They include isolated bones of moa, kiwi, and many smaller birds. Moa bone fragments are common in the upper more well-layered section of the unit. Goose bones were

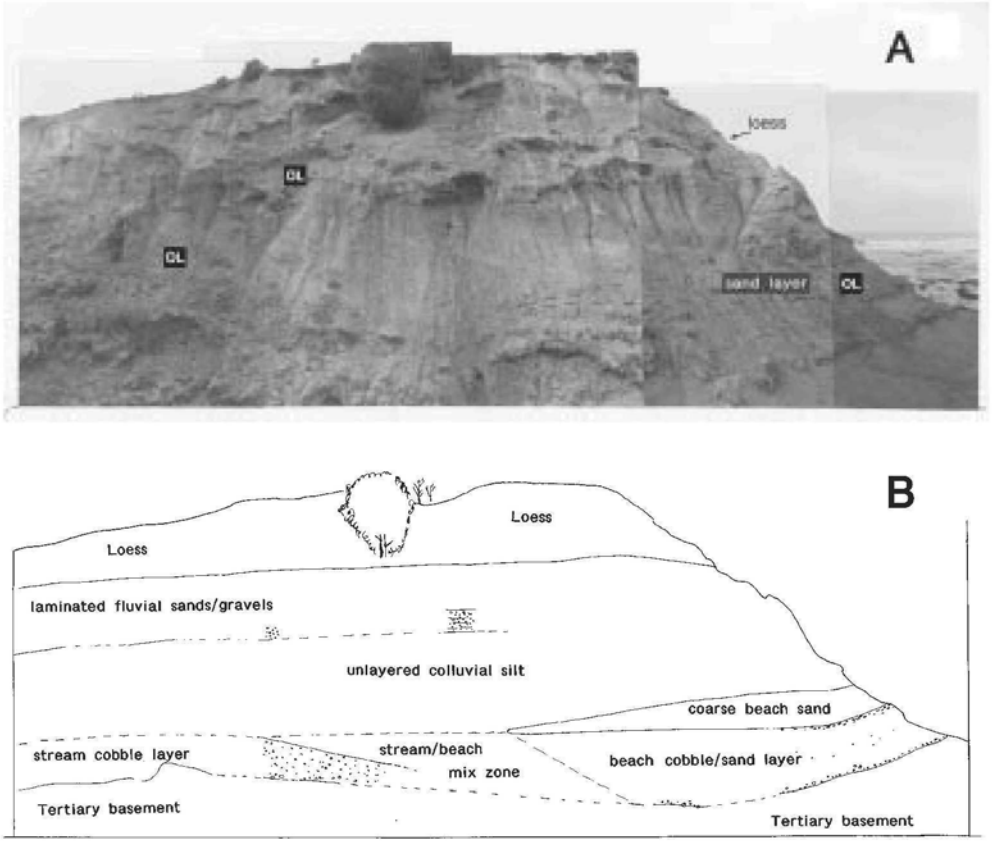


Fig. 9 A photo-montage panoramic view of the eastern wall of Ruby Gully (**A**) interpreted (**B**) to show the position of the beach gravels, beach sand, and colluvial infill. Note the figure, centre left, for scale. Photographed July 1999 (THW). OL, site of samples taken for optical dates.

recovered on a single level about 3 m above the yellow sand near the coast and probably reflect a single individual.

Twenty metres to the east of the mouth of Ruby Gully the 1.2-m-thick basal beach-laid conglomerate consists of spheroidal unweathered quartz and greywacke pebbles and deeply weathered angular pebble to boulder-sized clasts derived from the underlying volcanics. It is overlain by 1.2 m of crudely bedded sand, poorly exposed so that its depositional origin is difficult to ascertain, but on the basis of its lateral equivalents west of Ruby Gully, it is likely to be of beach and dune origin. It in turn is overlain by reworked loess, which would correlate with the colluvial silt in Ruby Gully. In the top 0.5 m of this sand and below the loess, a rich avifauna has been collected (J41/f8230) along with rare marine bivalves and land snails.

The sub-Hillgrove erosion surface extends as a horizontal line in the cliff for 30 m east of the mouth of Ruby Gully and then rises sharply at ~60° to the cliff top, with the Quaternary sequence banked against it.

Three representative stratigraphic sections from the south side of Cape Wanbrow allow correlation of the units and indicate the location of major fossil collections by their Fossil Record Numbers (f****) (Fig. 10).

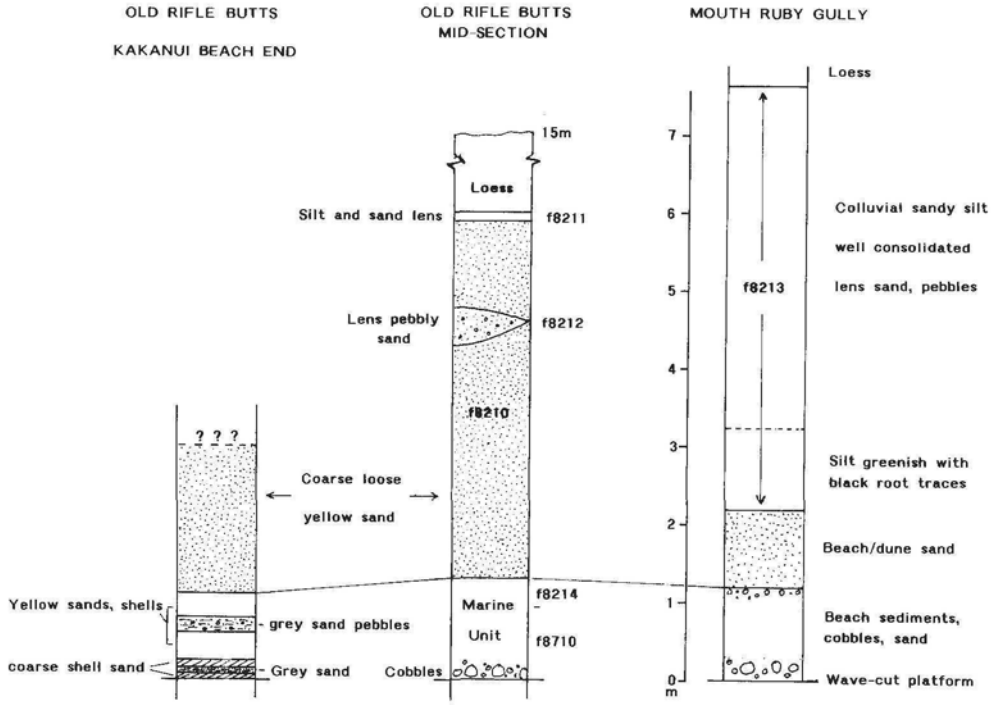


Fig. 10 Representative stratigraphic sections from the Hillgrove Formation on the south side of Cape Wanbrow, with the horizons for fossil collections indicated by their fossil record numbers (J41/f****).

SYSTEMATIC PALAEONTOLOGY

Introductory notes for each species can be found in Worthy & Holdaway (1993, 1994). A full faunal listing for each site is given in Appendix 1, in which all specimens are listed. In this systematic section, the number of bones (x) and the MNI this represents (y) is given (x/y) for each fossil site identified by its Fossil Record Number. Only material certainly identified to taxon is listed in this section. If x/y is preceded by "?", it means that the material was not relocated and checked. A few minor sites listed here for completeness of the avifaunal record of the area are of Holocene age, so are not strictly comparable to the sites discussed above.

Class Reptilia, Order Sphenodonta

Family Sphenodontidae

Genus *Sphenodon*, Gray

Two extant tuatara species are recognised from New Zealand: *S. punctatus* and *S. guntheri*, with the latter species distinguished by allozyme differences (Daugherty et al. 1990). THW cannot differentiate bones of *S. guntheri* from those of *S. punctatus* (Worthy 1997a). Moreover, mitochondrial DNA analyses do not distinguish *S. guntheri* [known only from the Brothers Islands] from other Cook Strait tuatara that are considered typical *S. punctatus* (Hay et al. 2001), thus *S. guntheri* is a doubtfully distinct species. Tuatara bones are therefore referred only to *Sphenodon* species indeterminate.

Sphenodon species indeterminate (tuatara)

MATERIAL: Cliffs at Old Rifle Butts: J41/f8210, present; J41/f8212, 1/1. North-east of Ruby Gully: J41/f8230, 34/2. Boatmans Harbour: J41/f9637, 2/1; J41/f9641, 2/1; Marples's colln in CM, 4/1.

Class Aves

Family Emeidae

Genus *Pachyornis*, Lydekker

Pachyornis elephantopus (Owen, 1856) (heavy-footed moa)

MATERIAL: Loess: J41/f50, 7/1; South of Awamoa Stream, 1/1; Cape Wanbrow, 1/1. Cliffs at Old Rifle Butts: J41/f134, 26/1; J41/f8214, 1/1. North-east of Ruby Gully: J41/f8230, 1/1. Ruby Gully: J41/f8213, 8/3.

Genus *Euryapteryx*, Haast

Euryapteryx geranoides (Owen, 1848) (stout-legged moa)

MATERIAL: Cliffs at Old Rifle Butts: J41/f133, 11/1. North-east of Ruby Gully: J41/f8230, 1/1.

Genus *Emeus*, Reichenbach

Emeus crassus (Owen, 1846) (eastern moa)

MATERIAL: Cliffs at Old Rifle Butts: J41/f8212, ?2/1; J41/f8213, 3/1; J41/f8710, 1/1. North-east of Ruby Gully: J41/f131, 1/1. Boatmans Harbour: J41/f9641, 1/1.

Emeid species indeterminate

MATERIAL: Indeterminate moa remains were found in 10 Pleistocene sites as listed in Appendix 1. These include loess sites, those at Boatmans Harbour, the cliffs at Old Rifle Butts, and at Ruby Gully.

Family Dinornithidae

Genus *Dinornis*, Owen

Dinornis leg bones were identified according to criteria given for each species by Worthy (1994).

Dinornis struthoides Owen, 1844 (slender moa)

MATERIAL: Boatmans Harbour: Marples's colln in CM, ?1/1—a phalanx. Awamoa Creek: J41/f138, 1/1. The stratigraphy of the Awamoa Creek site suggests it is of Holocene age.

Dinornis giganteus Owen, 1844 (giant moa)

MATERIAL: North-east of Ruby Gully: Only one diagnostic bone, an upper cervical vertebra, of this species was located in J41/f9723.

Family Apterygidae

Genus *Apteryx*, Shaw & Nodder

To date, only *Apteryx owenii* can be reliably identified from its bones, which are smaller than those of other species of kiwi. Bones of other *Apteryx* species cannot be reliably separated using shape or size characters (THW pers. obs.). There is much overlap in adult size, as measured by bone length, between the various brown kiwis *Apteryx mantelli* (North Island brown kiwi), *A. australis* (South Island brown kiwi), and the great spotted kiwi (*Apteryx*

haastii). The largest *A. mantelli* is as big as any *A. australis*. In addition, fossils from eastern regions of the South Island that are shorter yet stouter than typical *A. australis* bones are thought to be an undescribed taxon of brown kiwi (Worthy 1997a, 1998a).

Apteryx species indeterminate (eastern kiwi)

MATERIAL: North-east of Ruby Gully: J41/f8230, 4/1. Ruby Gully: J41/f8213, 3/1.

NOTES: While these bones derive from two separate collections, their preservation features are similar and the tarsometatarsus articulates perfectly with the tibiotarsus making it likely they are from one individual. These bones are smaller than bones of recent *Apteryx haastii* (Table 1). While the femur and tibiotarsus are near the lower end of the range in length of *A. australis*, the tarsometatarsus is shorter than that of any recent *A. australis* specimen (Worthy 1998a). The Cape Wanbrow femur is a little shorter than maximum length, and the tibiotarsus and the tarsometatarsus are midway between the mean and maximum values for lengths of eastern kiwi bones from Castle Rock (Worthy 1998a, table 3). The relative proportions of these three leg bones thus fit better with eastern kiwi (for which no associated skeleton is available) than they do with *A. australis*.

Family Diomedeidae

Genus *Thalassarche*, Reichenbach

Thalassarche cf. *bulleri* (Rothschild, 1893) (Buller's mollymawk)

MATERIAL: North-east of Ruby Gully: J41/f8230, 4/1.

NOTES: These *Thalassarche* bones are referred to *T. bulleri* as they are of appropriate size for that species and this is the most common and only breeding species of that size in New Zealand.

Family Procellariidae

Genus *Pelecanoides*, Lacépède

Pelecanoides urinatrix (Gmelin, 1789) (common diving petrel)

MATERIAL: Cliffs at Old Rifle Butts: J41/f8211, 1/1; J41/f8212, 10/4; J41/f8214, 4/1; 30 m west of Ruby Gully, 8/1; Loc E, CM colln, 1/1. Cave at Old Rifle Butts: J41/f8226, 1519+/53. North-east of Ruby Gully: J41/f8230, 218/18. Ruby Gully: J41/f8213, 23/2. Boatmans Harbour: J41/f9637, 8/2; Marples's colln in CM 13/3.

NOTES: In New Zealand, two species of diving petrel (*Pelecanoides urinatrix* and *P. georgicus*) are currently recognised (Turbott 1990). Recently, *P. georgicus* has been shown to be the main species represented in dune deposits on Stewart Island (Worthy 1998d), and *P. urinatrix*,

Table 1 Measurements (mm) of bones from a probable individual kiwi from Cape Wanbrow.

Cat. no.	Element	Length	Proximal width	Shaft width	Distal width
AU11252	Femur	100.0	24.8	11.1	28.7
AU11252	Tibiotarsus	142.1	20.8	11.1	18.7
AU9724	Tarsometatarsus	70.6	20.4	12.2	24.0

as presently recognised, probably contains at least two taxa, with the southern form (*P. u. chathamensis*) distinctly smaller than its northern counterpart (Worthy & Jouventin 1999). *P. georgicus* is distinguished most easily from diving petrels in the *P. urinatrix* group by the distinctive morphology of its premaxilla (Worthy 1998d). All premaxillae and crania from these Wanbrow sites (e.g., in AU11252, and particularly from within the cave location, AU4986, 4158–9) are *P. urinatrix*. As a result, all *Pelecanoides* bones from the sites are here referred to *P. urinatrix*.

Genus *Pterodroma*, Bonaparte
Pterodroma inexpectata (Forster, 1844) (mottled petrel)

MATERIAL: Cliffs at Old Rifle Butts: Loc E, CM colln, 1/1.

Genus *Puffinus*, Brisson

NOTES: The three small shearwaters of the *Puffinus gavia* superspecies, *P. gavia*, *P. huttoni*, and *P. spelaeus* once had allopatric breeding distributions on the New Zealand mainland (Holdaway & Worthy 1994). All have discrete cranial morphology and *P. spelaeus* is significantly smaller than the other two species, but significant size overlap between all species often precludes specific identification of some bones. Those listed in Appendix 1 were larger than most bones of *P. spelaeus* but as all were isolated postcranial elements, could not be referred to a single species.

Puffinus gavia (Forster, 1844) (fluttering shearwater) or *Puffinus huttoni* (Mathews, 1912) (Hutton's shearwater)

MATERIAL: Cliffs at Old Rifle Butts: J41/f8210, 11/3; J41/f8212, 24/5; J41/f8214, 3/1; Loc E CM colln, 3/1. North-east of Ruby Gully: J41/f8230, 13/3. Boatmans Harbour: J41/f9637, 9/3; J41/f9638, 2/1; J41/f9641, 1/1; Marples's colln in CM, 6/1.

Puffinus griseus (Gmelin, 1789) (sooty shearwater)

MATERIAL: Cliffs at Old Rifle Butts: J41/f8210, 3/2; J41/f8212, 7/2; J41/f8214, 2/1; Loc E CM colln, 1/1. Cave at Old Rifle Butts: J41/f8226, 4/1. North-east of Ruby Gully: J41/f8230, 4/1. Ruby Gully: J41/f8213, 1/1. Boatmans Harbour: J41/f9641, 1/1.

Puffinus tenuirostris (Temminck, 1835) (short-tailed shearwater)

MATERIAL: Boatmans Harbour: J41/f9637, 1/1. Cliffs at Old Rifle Butts: J41/f8212, 1/1.

NOTES: The two bones are an ulna, with an estimated length of 91 mm, and a left carpometacarpus of length 47.9 mm. These are too small to be *Puffinus griseus* but are within the size range of *P. tenuirostris*, of which migrating birds are commonly beach-wrecked in New Zealand, despite it not being a breeding species here.

Genus *Pachyptila*, Illiger
Pachyptila turtur (Kuhl, 1820) (fairy prion)

MATERIAL: Cliffs at Old Rifle Butts: J41/f8210, 3/1; J41/f8212, 2/1; 30 m west of Ruby Gully, 1/1. Cave at Old Rifle Butts: J41/f8226, 27/4. North-east of Ruby Gully: J41/f8230, 7/1. Ruby Gully: J41/f8213, 2/1.

NOTES: All the prion material listed here is within the size range of *P. turtur*, and, so, is assumed to be referable to this species, which is the common prion breeding in New Zealand. Other species that broadly overlap in size distribution with *P. turtur*, such as *P. desolata*,

P. belcheri, and *P. salvini*, are considerably smaller than the other prion breeding in New Zealand (*P. vittata*), and are often found as beach wrecks in New Zealand. Their representation in this material cannot be ruled out.

Family Hydrobatidae

Genus *Pelagodroma*, Reichenbach

***Pelagodroma marina* (Latham, 1790) (white-faced storm petrel)**

MATERIAL: Boatmans Harbour: J41/f9637, 2/2.

Family Spheniscidae

Genus *Eudyptula* (Forster)

***Eudyptula minor* (Forster, 1781) (blue penguin)**

MATERIAL: Cliffs at Old Rifle Butts: J41/f8210, 11/1; J41/f8211, 1/1; J41/f8212, 25/3; J41/f8214, 4/1; J41/f8710, 2/1; 30 m west of Ruby Gully, 1/1; Loc E CM colln, 10/1. Cave at Old Rifle Butts: J41/f8226, 1050+/26. North-east of Ruby Gully: J41/f8230, 72/5. Ruby Gully: J41/f8213, 19/4. Boatmans Harbour: J41/f9637, 19/2; J41/f9638, 4/1; J41/f9641, 5/2; Marples's colln in CM, 56/7.

NOTES: The bones in the cave at Old Rifle Butts are derived mainly from whole individuals as shown by the presence of all body parts (Appendix 1). There is no taphonomic evidence that a predator accumulated these bones: no greenstick fractures, no evidence of digestion, and no preferential loss of body parts. Therefore, it seems most probable that the cave acted as a pitfall trap on the old coastal hillside. However, the presence of whole eggs indicates the cave's subsequent use as a nesting site. The more complete specimen (Fig. 8A) came from the top of the deposit and is 57.5 mm long and 41 mm diam. at its widest point; one end is slightly but visibly more pointed than the other. The second specimen is less than half the original egg but is otherwise entirely comparable (Fig. 8B). They are the correct size and shape for *E. minor* (Marchant & Higgins 1990) and are here accepted as belonging to that species. They constitute significant finds, being the only fossil penguin eggs known (Fordyce & Jones 1990) and, together with juvenile penguin bones, clearly indicate the presence of a breeding site.

Genus *Eudyptes*, Vieillot

***Eudyptes pachyrhynchus* (Gray, 1845) (Fiordland crested penguin)**

MATERIAL: Cliffs at Old Rifle Butts: J41/f8210, 1/1; J41/f8212, 2/1. Cave at Old Rifle Butts: J41/f8226, 1/1. North-east of Ruby Gully: J41/f8230, 2/1. Ruby Gully: J41/f8213, 4/2. Boatmans Harbour: Marples's colln in CM 7/2.

NOTES: Worthy (1997b) reported methods for identifying isolated bones of *Megadyptes* and *Eudyptes* accepting only *M. antipodes* and *E. pachyrhynchus* as present in the New Zealand fossil fauna. The material listed includes cranial material and other diagnostic bones, but other bones not diagnostic to genera are listed only as "big penguin" in Appendix 1.

Grant-Mackie & Scarlett (1973) reported an undescribed species of *Eudyptes*. A left tibiotarsus AU4141.3 is labelled as "*Eudyptes* n.sp.". The bone looks like a tibiotarsus of *Eudyptes pachyrhynchus*, but at 105.2 mm long is slightly smaller than modern specimens (107.2–119.0 mm, $n = 28$; Worthy 1997b). A specimen of *E. pachyrhynchus* from Milford Sound (MNZ 9126) has tibiotarsi of near identical shape that are only 1.8 mm longer. We do not consider that the slightly smaller size of the fossil indicates specific distinction, so it is referred to *E. pachyrhynchus*.

Genus *Megadyptes*, Milne-Edwards
Megadyptes antipodes (Hombron and Jacquinot, 1841) (yellow-eyed penguin)

MATERIAL: Cliffs at Old Rifle Butts: J41/f8212, 7/2; J41/f8214, 3/1; J41/f8710, 1/1. North-east of Ruby Gully: J41/f8230, 3/1. Ruby Gully: J41/f8213, 4/1. Boatmans Harbour: J41/f9637, 1/1; Marples's colln CM 3/2.

NOTES: The material listed includes cranial material and other diagnostic bones having the distinguishing characters outlined in Worthy (1997b): other bones not diagnosable to genera are listed only as "big penguin" in Appendix 1.

Family Phalacrocoracidae

Genus *Phalacrocorax* (Brisson)
Phalacrocorax varius (Gmelin, 1789) (pied shag)

MATERIAL: Ruby Gully: J41/f8213, 1/1. Boatmans Harbour: Marples's colln in CM, 3/2.

NOTES: This species roosted on or above the fossil sites on the south side of the Cape in the late 1990s. It is probable that some material of this species is listed as "shag species indet" in the faunal lists for several sites in Appendix 1. It has wing bones of similar size to *Stictocarbo*.

Genus *Stictocarbo*, Bonaparte
Stictocarbo punctatus (Sparrman) (spotted shag)

MATERIAL: Cliffs at Old Rifle Butts: J41/f8210, 9/2; J41/f8212, 26+1/2; J41/f8214, 4/1. Cave at Old Rifle Butts: J41/f8226, 3/2. North-east of Ruby Gully: J41/f8230, 44/4. Ruby Gully: J41/f8213, 31+?2/3. Boatmans Harbour: J41/f9637, 6/1; J41/f9641, 14/2; Marples's colln in CM, 47/6.

NOTES: This species is abundant in the area now and roosts on the cliffs above the fossil sites.

Genus *Leucocarbo*, Bonaparte
Leucocarbo carunculatus (Gmelin, 1789) (New Zealand king shag)

MATERIAL: Cliffs at Old Rifle Butts: J41/f8210, 5/2; J41/f8212, 8/1. North-east of Ruby Gully: J41/f8230, 11/3. Ruby Gully: J41/f8213, 9/2. Boatmans Harbour: J41/f9637, 3/1; Marples's colln in CM, 18/2.

Family Anatidae

NOTES: Grant-Mackie & Scarlett (1973) referred to the presence of one or more undetermined species of duck and listed "*A*[*nas*] n.sp.". Many bones in the Canterbury Museum were labelled as "*Anas* sp." or "anatid sp.", and none bore a label indicating it was an undescribed species. All identifiable bones were found to be referrable to known taxa.

Genus *Cnemiornis*, Latham
Cnemiornis calcitrans Owen, 1865 (South Island extinct goose)

MATERIAL: Cliffs at Old Rifle Butts: J41/f134, 2/1; J41/f8210, 1/1; J41/f8212, 1/1. North-east of Ruby Gully: J41/f8230, 15/1. Ruby Gully: J41/f8213, 9/1.

NOTES: The position of the goose bones in Ruby Gully suggests that, although they were exposed over a period of several years, the bones of only a single individual are represented. These were strewn over a 5-m-length of valley floor when it was 4–5 m above the marine conglomerates. It is possible that the bones from "Cliffs East of Ruby Gully" (J41/f8230) are also the same individual, as no elements are duplicated, and the radiocarbon ages of the sites do not preclude their being contemporaneous. The sites are only 5–8 m apart.

Genus *Chenonetta*, Brandt
Chenonetta finschi (Van Beneden, 1875) (Finsch's duck)

MATERIAL: Cliffs at Old Rifle Butts: J41/f8210, 2/1; J41/f8212, 11/2. Cave at Old Rifle Butts: J41/f8226, 17/1. North-east of Ruby Gully: J41/f8230, 13/3. Ruby Gully: J412/f8213, 1/1. Boatmans Harbour: J41/f9637, 2/1; Marples's colln in CM, 4/1.

NOTES: Finsch's duck has recently been transferred from *Euryanas* to *Chenonetta* by Worthy & Olson (2002). The wing bones of *Chenonetta finschi* vary in size over the period late Pleistocene to late Holocene. While body size as measured by leg bones remained unchanged, the length of the wing bones was reduced by c. 10% (Worthy 1988, 1997c). The measurements of the Cape Wanbrow *Chenonetta* bones (Worthy & Olson 2002, table 1) fall within the range of those for Late Glacial sites in north-west Nelson. Because of their length, these wing bones had previously been referred to *Anas superciliosa*, but are easily distinguished from that species as follows.

In *C. finschi*, the humerus has a marked capital shaft ridge and the *tuberculum dorsale* is raised above the plane of the surrounding bone. The *crista deltopectoralis* is concave on its lateral surface rather than convex. The fossa situated above the *epicondylus ventralis* is deeper and the shaft immediately above this fossa and adjacent to the *fossa brachialis* is much more cranio-caudally compressed. The dorso-lateral surface of the distal end is in a line with the distal half of the shaft, not protruding significantly dorsad of the line of the shaft.

The ulna of *C. finschi* has a well-defined ridge on its dorsal surface leading from the *cotyla dorsalis*, making the shaft very angular dorsally immediately distad of the dorsal cotyla. At its distal end the *condylus dorsalis ulnaris* extends proximally a much shorter distance than the maximum distal width of the ulna, rather than equal as in *Anas*. The *tuberculum carpale* is much thicker dorso-ventrally through its base in *Chenonetta*, creating a marked flat area that is oriented medio-proximally at its base rather than being convex.

The carpometacarpus is more robust and shorter than in *A. superciliosa*, the proximal extent of the *spatium intermetacarpale* is nearly level with the base of the *processus alularis*, not markedly distad of it, and the *synostosis metacarpalis distalis* is relatively shorter. The coracoid of *C. finschi* has a noticeably more medially tapered *angular medialis* which has a distinct fossa above the ventral articular facet, and the sternal articulation is more curved. The much more robust leg bones of *Chenonetta finschi* are not mistakable for those of *Anas superciliosa*.

Worthy & Olson (2002) considered that, as the elements of the individual at f8226 are each more slender than they are in Late Pleistocene and, especially, Holocene birds, they represent an earlier stage in the evolution of *Chenonetta finschi* from the common ancestor between it and *Chenonetta jubata*.

Genus *Hymenolaimus*, Gray
Hymenolaimus malacorhynchos (Gmelin, 1789) (blue duck)

MATERIAL: North-east of Ruby Gully: J41/f8230, 1/1.

NOTES: The right tarsometatarsus in AU11252 (J41/f8230) has the following dimensions: length 47.9 mm, proximal width 9.9 mm, shaft width 4.2 mm, distal width 10.2 mm. Compared with the similar sized tarsometatarsi of *Anas superciliosa*, trochlea 2 (T2) is too shallow, in anterior view T3 is more squared, the space between T2 and T3 is greater, and the hypotarsal ridge is less hooked anteriorly. In all these features the bone compares favourably with *Hymenolaimus malacorhynchos* MNZ12042 and 19801.

Genus *Tadorna*, Lorenz von Oken
Tadorna variegata (Gmelin, 1789) (paradise shelduck)

MATERIAL: Cliffs at Old Rifle Butts: J41/f8210, 3/1; J41/f8212, 10/2; Loc E, CM colln, 1/1. North-east of Ruby Gully: J41/f8230, 2/1.

Genus *Cygnus*, Bechstein
?*Cygnus atratus* Latham, 1790 (black swan)

MATERIAL: MNZ S35474 is a right ischium that is tentatively identified as a swan. It was found 30 m west of Ruby Gully. Further material is required before *Cygnus atratus* can be verified from the faunas at Cape Wanbrow.

Genus *Anas*, Linnaeus
Anas chlorotis Gray, 1845 (brown teal)

MATERIAL: Cliffs at Old Rifle Butts: J41/f8210, 1/1; J41/f8212, 4/1. North-east of Ruby Gully: J41/f8230, 8/2. Ruby Gully: J41/f8213, 1/1.

Genus *Mergus*, Linnaeus
Mergus australis Hombron & Jacquinot, 1841 (Auckland Island merganser)

MATERIAL: Cliffs at Old Rifle Butts: J41/f8210, 1/1; J41/f8212, 4/1; Loc E, CM colln, 1/1. North-east of Ruby Gully: J41/f8230, 6/2. Boatmans Harbour: Marples's colln in CM, 2/1.

Family Accipitridae

Genus *Harpagornis*, Haast
Harpagornis moorei Haast, 1872 (Haast's eagle)

MATERIAL: Cliffs at Old Rifle Butts: J41/f213, 8/1; J41/f8212, 14/1; J41/f8710, 1/1. North-east of Ruby Gully: J41/f8230, 12/1. Ruby Gully: J41/f8213, 2/1.

NOTES: Grant-Mackie & Scarlett (1973) referred to the presence of an undescribed species of small eagle. A distal left tibiotarsus AU4100.1 from the basal conglomerates at Old Rifle Butts (J41/f8710) is the basis of this claim. It is indistinguishable in form and size, however, from smaller individuals of *Harpagornis moorei* from the Holocene Enfield site in South Canterbury and is probably from a small male. It is the oldest Haast's eagle bone known from New Zealand, and indicates that the eagle was present there in interglacial conditions (Oxygen Isotope Stage 5), unlike all other records from the Wanbrow deposits, which date to the last glacial period (Stages 2–4).

Family Falconidae

Genus *Falco*, Linnaeus
Falco novaeseelandiae Gmelin, 1788 (New Zealand falcon)

MATERIAL: Cliffs at Old Rifle Butts: J41/f8212, 4/1. North-east of Ruby Gully: J41/f8230, 4/2.

NOTES: The presence of small and large bones indicates that both sexes are represented in this material.

Family Phasianidae

Genus *Coturnix*, Bonnaterre
Coturnix novaezelandiae Quoy & Gaimard, 1830 (New Zealand quail)

MATERIAL: Cliffs at Old Rifle Butts: J41/f8212, 2/1. North-east of Ruby Gully: J41/f8230, 1/1. Ruby Gully: J41/f8213, 2/1. Boatmans Harbour: J41/f9637, 1/1.

Family Rallidae

Genus *Gallirallus*, Lafresnaye

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

MATERIAL: Loess: J41/f129, 1/1. Cliffs at Old Rifle Butts: J41/f8210, 3/1; J41/f8211, 1/1; J41/f8212, 15+1/3; Loc E, CM colln, 2/1. Cave at Old Rifle Butts: J41/f8226, 6/1. North-east of Ruby Gully: J41/f8230, 68/7. Ruby Gully: J41/f8213, 11/3. Boatmans Harbour: J41/f9637, 3/1; Marples's colln in CM, 6/1.

Genus *Gallinula*, Brisson

***Gallinula hodgenorum* (Scarlett, 1955) (Hodgens' rail)**

MATERIAL: Cliffs at Old Rifle Butts: J41/f8212, 2/1. North-east of Ruby Gully: J41/f8230, 4/1.

Genus *Fulica*, Linnaeus

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

MATERIAL: North-east of Ruby Gully: J41/f8230, 2/1.

NOTES: No evidence was found for an undescribed species of *Fulica* as suggested by Grant-Mackie & Scarlett (1973).

Family Aptornithidae

Genus *Aptornis*, Mantell

***Aptornis defossor* (Owen, 1871) (South Island adzebill)**

MATERIAL: Cliffs at Old Rifle Butts: J41/f8212, 2/1. Boatmans Harbour: Marples's colln in CM, 1/1.

Family Haematopodidae

Genus *Haematopus*, Linnaeus

***Haematopus finschi* Martens, 1897 (South Island pied oystercatcher)**

MATERIAL: North-east of Ruby Gully: J41/f8230, R hum.

NOTES: The South Island pied oystercatcher is elevated from subspecific status in *H. ostralegus* to a full species following Marchant & Higgins (1993) and Holdaway et al. (2001).

Haematopus finschi has smaller humeri than *H. unicolor* and the fossil humerus listed here is, at 77.1 mm long, a good match for recent material. This implies that *H. finschi* has been in New Zealand since at least the Otiran glaciation.

***Haematopus unicolor* J.R. Forster, 1841 (variable oystercatcher)**

MATERIAL: Cliffs at Old Rifle Butts: J41/f8210, 3/1; J41/f8212, 1/1. North-east of Ruby Gully: J41/f8230, 3/2. Ruby Gully: J41/f8213, 1/1.

NOTES: The specimens from north-east of Ruby Gully (AU4141.20–22) include a left humerus 81.4 mm long and a left ulna 84.2 mm long. The ulna from f8212 is 85.1 mm long. These specimens are of similar size to that of *H. unicolor* CM Av26367.

Family Charadriidae

Genus *Charadrius*, Linnaeus

***Charadrius bicinctus* Jardine & Selby, 1827 (banded dotterel)**

MATERIAL: North-east of Ruby Gully: J41/f8230, AU9724, 1 dL ulna.

***Charadrius obscurus* Gmelin, 1789 (New Zealand dotterel)**

MATERIAL: North-east of Ruby Gully: J41/f8230, AU9723, 1dR 1pR hum.

Family Scolopacidae

Genus *Coenocorypha*, G.R. Gray

***Coenocorypha iredalei* Rothschild, 1921 (South Island snipe)**

MATERIAL: North-east of Ruby Gully: J41/f8230, 4/2. Ruby Gully: J41/f8213, 1/1.

NOTES: The specific identity of the snipes formerly occurring on the mainland of New Zealand has been recently revised by Worthy et al. (2002), and we follow the nomenclature advocated therein.

Family Laridae

Genus *Larus*, Linnaeus

***Larus dominicanus* (Lichtenstein, 1823) (southern black-backed gull)**

MATERIAL: Cliffs at Old Rifle Butts: J41/f8210, 2/1; J41/f8212, 5/1; Loc E, CM colln, 1/1. North-east of Ruby Gully: J41/f8230, 1/1. Boatmans Harbour: Marples's colln in CM, 1/1.

***Larus novaehollandiae* Stephens, 1826 (red-billed gull)**
or *Larus bulleri* Hutton, 1871 (black-billed gull)

MATERIAL: Cliffs at Old Rifle Butts: J41/f8210, 1/1; J41/f8212, 3/1. North-east of Ruby Gully: J41/f8230, 2/1.

NOTES: Grant-Mackie & Scarlett (1973) referred to the presence of an undescribed species of *Larus*. The left humerus and left ulna CM Av24924 were labelled as "*Larus* n.sp." but are identical in form and size to some larger individuals of *L. scopulinus*, for example, CM Av19872. The elements provide no basis for recognising a new species of gull.

Genus *Sterna*, Linnaeus

***Sterna striata* Gmelin, 1789 (white-fronted tern)**

MATERIAL: Cliffs at Old Rifle Butts: J41/f8212, Av24915, 1L hum.

Family Columbidae

Genus *Hemiphaga*, Bonaparte

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

MATERIAL: Cliffs at Old Rifle Butts: J41/f8210, 1/1; J41/f8212, 2/1. North-east of Ruby Gully: J41/f8230, 5/1. Boatmans Harbour: J41/f9637, 1/1; J41/f9638, 2/1; Marples's colln in CM, 3/1.

NOTES: Grant-Mackie & Scarlett (1973) reported an undescribed species of large pigeon. The basis of this claim lies in the right humerus catalogued as CM Av24934 from Loc E. Scarlett had subsequently re-identified this specimen as "*Nestor*" on its label, but not altered the catalogue. It is referable to *Nestor notabilis*.

Family Psittacidae

Genus *Nestor*, Lesson

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

MATERIAL: Cliffs at Old Rifle Butts: J41/f8210, 2/1; J41/f8212, 13/3; J41/f8214, 1/1; 30 m west of Ruby Gully, 1/1. Cave at Old Rifle Butts: J41/f8226, 1/1. North-east of Ruby Gully:

J41/f8230, 44/5. Ruby Gully: J41/f8213, 8/1. Boatmans Harbour: J41/f9637, 7/2; Marples's colln in CM, 1/1.

NOTES: Grant-Mackie & Scarlett (1973) referred to the presence of an undescribed species of *Nestor*. This nominal taxon arose because Scarlett consistently referred bones of *Nestor meridionalis* from the South Island to a new species, and labelled *N. notabilis* bones as *N. meridionalis* (Holdaway & Worthy 1993). There is no evidence of an unnamed species of *Nestor*.

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

MATERIAL: Cliffs at Old Rifle Butts: J41/f8212, 14/3; Loc E, CM colln, 4/1. North-east of Ruby Gully: J41/f8230, 12/2. Ruby Gully: J41/f8213, 1/1.

NOTES: All bones previously identified by Scarlett as *Strigops* were found to be *Nestor notabilis*.

Genus *Cyanoramphus*, Bonaparte
***Cyanoramphus* species indeterminate**

MATERIAL: Cliffs at Old Rifle Butts: J41/f8210, 2/1; J41/f8212, 2/1. Cave at Old Rifle Butts: J41/f8226, 1/1. North-east of Ruby Gully: J41/f8230, 11/2. Ruby Gully: J41/f8213, 2/1. Boatmans Harbour: J41f9637, 1/1; J41/f9641, 1/1; Marples's colln in CM, 2/1.

NOTES: Bones of the three parakeet species *C. auriceps*, *C. novaezelandiae*, and *C. malherbi* known from the New Zealand mainland are indistinguishable morphologically, and their size ranges overlap broadly (Worthy & Holdaway 1994), so material is not referred to species here.

Family Strigidae

Genus *Sceloglaux*, Kaup
***Sceloglaux albifacies* (Gray, 1844) (laughing owl)**

MATERIAL: Cliffs at Old Rifle Butts: J41/f8212, 1/1; J41/f8214, 1/1. North-east of Ruby Gully: J41/f8230, 4/1. Boatmans Harbour: J41f9637, 3/1; Marples's colln in CM, 1/1.

NOTES: Grant-Mackie & Scarlett (1973) referred to the presence of an undescribed species of owl. No evidence of this was found in the collections. Although the bones are bigger than those of the fossil skeleton (Av16685) from Harwoods Hole, Takaka Hill, which probably was Scarlett's reference specimen, the Cape Wanbrow fossils are not bigger than most other fossils of this species.

Family Aegothelidae

Genus *Aegotheles*, Vigors & Horsfield
***Aegotheles novaezealandiae* (Scarlett, 1968) (New Zealand owlet-nightjar)**

MATERIAL: Cave at Old Rifle Butts: J41/f8226, 1/1.

Family Monarchidae

Genus *Rhipidura*, Vigors & Horsfield
***Rhipidura fuliginosa* (Sparrman, 1787) (New Zealand fantail)**

MATERIAL: Boatmans Harbour: Marples's colln in CM, 3/1.

Family Petroicidae

Genus *Petroica*, Swainson

***Petroica australis* (Sparrman, 1788) (South Island robin)**

MATERIAL: Cliffs at Old Rifle Butts: J41/f8212, 1/1. North-east of Ruby Gully: J41/f8230, 1/1. Boatmans Harbour: J41/f9637, 2/1; Marples's colln in CM, 1/1.

Family Meliphagidae

Genus *Anthornis*, Gray

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

MATERIAL: Cliffs at Old Rifle Butts: J41/f8212, 1/1. North-east of Ruby Gully: J41/f8230, 4/1.

Genus *Prosthemadera*, Gray

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

MATERIAL: Cliffs at Old Rifle Butts: J41/f8212, 1/1. Cave at Old Rifle Butts: J41/f8226, 1/1. North-east of Ruby Gully: J41/f8230, 1/1. Ruby Gully: J41/f8213, 1/1.

Family Callaeidae

Genus *Callaeas*, J.R. Forster

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

MATERIAL: Cliffs at Old Rifle Butts: J41/f8212, 1/1. North-east of Ruby Gully: J41/f8230, 2/1. Ruby Gully: J41/f8213, 1/1. Boatmans Harbour: Marples's colln in CM, 1/1.

Genus *Philesturnus*, Geoffroy St.-Hilaire

***Philesturnus carunculatus* (Gmelin, 1789) (South Island saddleback)**

MATERIAL: Cliffs at Old Rifle Butts: J41/f8212, 1/1; J41/f8226, 2/1. Cave at Old Rifle Butts: J41/f8226, 2/1. Ruby Gully: J41/f8213, 1/1.

Family Turnagridae

Genus *Turnagra*, Lesson

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

MATERIAL: North-east of Ruby Gully: J41/f8230, 6/2.

NOTES: Recent molecular studies using DNA suggest that *Turnagra* is basal to the bowerbird and catbird lineage, i.e., *Turnagra* is the sister-group of these taxa, and is not related to the birds of paradise or pachycephalines (Christidis et al. 1996). Based on characters of the juvenile plumage and skeletal features, Schodde & Mason (1999, p. 432) included *Turnagra* within the Pachycephalidae. Pending resolution of its affinities, we retain *Turnagra* in its own discrete family.

Family Corvidae

Genus *Corvus*, Linnaeus

***Corvus moriorum* Forbes, 1892 (New Zealand crow)**

MATERIAL: Cliffs at Old Rifle Butts: J41/f8210, 3/1; J41/f8212, 17/2; Loc E, CM colln, 1/1. Cave at Old Rifle Butts: J41/f8226, 14/2. North-east of Ruby Gully: J41/f131, 1/1; J41/f8230, 35/3. Ruby Gully: J41/f8213, 12/2.

RESULTS

Radiocarbon dating

The various radiocarbon ages obtained on materials from Cape Wanbrow are presented in Appendix 2. The exact provenances of NZ3092 and 3093 are not recorded. Both came from along the cliff path (Grave's Walk) 150–200 m south of Caledonian Road. Here, both the Hillgrove Formation and loess deposits are present. NZ3092, at 20 233 ± 386 yr BP, is consistent with a derivation from loess and NZ3093, at 32 415 ± 1746 yr BP, is of appropriate age for a derivation from the Hillgrove deposits. The percentage insolubles after the acid wash, or what is now termed "%collagen", for the latter sample was 19.2%, which is typical of reasonably well preserved moa bones. The residue termed "%collagen" contains the bone proteins that are about 20–21% of the weight of fresh bone plus all the lipids and other non-collagenous bone material. In the best preserved bones "%collagen" ranges up to 32%, e.g., NZA11600 (Worthy 2002), and a value of 19.2% suggests that the date is believable. Humic and similar organic acid contamination result in artificially younger ages (Stafford et al. 1988). Heavily weathered bones, where organic contaminants may reach significant proportions, have low "%collagen" yields, usually <1 or none (THW unpubl. data). It is most unlikely, if the specimen dated was near 100 kyr old, that it would produce any "%collagen" yield at all. The two results underscore the necessity for correct stratigraphic interpretation and detailed locality data.

The only sample dated from a known position in loess at Boatmans Harbour is NZ4743 (22 576 ± 352 yr BP) from a skeleton of *Pachyornis elephantopus* (AU4458) collected from the loess behind the railway line (J41/f50). It had a "%collagen" yield of 22.5%, which is relatively high, which we consider means the date is probably reliable.

The three ages obtained on peat from Ruby Gully (NZ3142, 3143, 3144) gave widely differing and stratigraphically mixed ages. The samples were pre-treated only by washing in boiling water and then in hot H_3PO_4. NZ3142 was on the soil from immediately above the peat and the samples 3143 and 3144 were the upper and lower halves of the 8-cm-thick layer of peat. NZ3143 is obviously too young for loess, much less any underlying sediment. Hammond et al. (1991) found that pre-treatment of peat samples before 1990 was usually inadequate to remove mobile carbon fractions such as fulvic and humic acids, and suggested that the best pre-treatment was hydrolysis with 70% HNO_3. These authors did not compare the effectiveness of the method with that of boiling in H_3PO_4, but if the latter was not as efficient at removing fulvics or humics, the young date of NZ3143 may be explained. The other two ages suggest the base of the peat may be 27 000–33 000 years old.

Three radiocarbon ages stratigraphically in accordance with one another and with the age from the overlying loess are pertinent to the age of the Hillgrove Formation. NZ1587 was on shell from the basal marine conglomerate so should be a maximal age for the deposit. It gave an age of 33 186 ± 1264 yr BP, which for that time was a limital age for the technique, and so is an underestimate of the age and better described as "infinite". The age of these beach conglomerates is 110–130 kyr old, inferred from the last time sea level was sufficiently high for their deposition (Pillans 1991; Nelson et al. 1993) and by direct amino acid dating of *Tawera* shell (Forsyth 2001).

A moa bone from 20 m east of Ruby Gully collected from 3–3.5 m above the base of the Hillgrove Formation was dated at 26 457 ± 846 yr BP (NZ4753). The high "%collagen" yield (26%) supports this age and would be most unlikely in a bone 100 kyr old.

A mixed sample of *Eudyptula* bones from J41/f8226, which is the cave site formed "within the Hillgrove Formation", gave an age of 30 180 ± 440 yr BP (NZA3609). The collagen yield for this sample was low at 1.25% and the sample was only acid washed, so it

is possible that organic contamination may have been significant in relation to preserved collagen. If this age is not a serious underestimate then we conclude that the deposit was emplaced within a fissure formed by partial collapse and so is not strictly comparable in age to the Hillgrove beach conglomerate deposits below it. Surrounding dune or lacustrine deposits at the same level as the cave may correlate best with the valley infill event recorded from Ruby Gully at 30–35 cal kyr BP.

DISCUSSION

Age of the faunas

Several radiocarbon ages are presented above that pertain to the ages of units attributed in the past to the Hillgrove Formation on either the north or south sides of Cape Wanbrow. The radiocarbon ages for samples within Ruby Gully and NZ4753 from east of Ruby Gully indicate that the colluvial deposits that extend out unconformably over the beach sands at the gully mouth were probably deposited between 34 and 27 kyr BP. This colluvium probably derives from mobilisation of Loess 2 thought to have been deposited before 31 000 years ago (Eden & Froggatt 1988). For the colluvium to have accumulated, it must have been impounded behind an obstacle, which we suggest was the massive dunes formed against Cape Wanbrow at this time, as indicated by the upper Hillgrove Formation along Old Rifle Butts, while sea level was perhaps 50 m lower than the present.

There is probably another unconformity, indicated by the peat band observed in Ruby Gully, between the valley-fill deposits and deposition of Loess 1 (Eden & Froggatt 1988) that occurred over the Glacial Maximum. The conventional radiocarbon age of NZ4743 (22 576 ± 352 yr BP) for a bone from loess at Boatmans Harbour is consistent with it being from Loess 1, which caps the hills around Ruby Gully.

Within the Hillgrove Formation at Old Rifle Butts is the Cave site f8226 with a single age NZA3609 (30 180 ± 440) that, if correct, indicates deposition coeval with that in Ruby Gully. Its position 3–4 m above the base of the Hillgrove Formation is below the uppermost deposits in the sequence (e.g., f8210, 8211) and may indicate that the site was overwhelmed by sediment deposition shortly after this time. The alternative explanation for the sequence of events is that the Hillgrove Formation dune and interdune deposits were all emplaced long before that of the Cave site f8226, which resulted from a later rockfall creating a fissure. However, this is not supported by the presence of undisturbed horizontal Hillgrove sediments near the cave which would have been destroyed by such a slip. If our contention that the Cave site f8226 was overwhelmed by the primary deposition of the Hillgrove Formation is correct, then the ages of all the faunas at Old Rifle Butts (f130, 131, 8210, 8211, 8212, 8230, and collections with no fossil record numbers identified as "cliffs at Old Rifle Butts") that were collected from more than 2 m above the undoubted beach deposits in the sands and gravels deposited within terrestrial environments, are probably not much older than, or coeval with, f8226 and deposition within Ruby Gully. They would, therefore, all be mid-Otiran in age. However, faunas, e.g., f8214, 8227, 8228, 8229, 8710, which are from within the beach deposits, or immediate back-beach deposits, are of last interglacial (Oturian) age (Forsyth 2001), as interpreted by Grant-Mackie & Scarlett (1973).

The ages from moa bones from along Grave's Walk on the north side of Cape Wanbrow do not pertain to adequately provenanced samples. The sample submission form records that the bone dated NZ3092 (R4813/1) was derived from loess, at the base of the last loess and above the penultimate loess, or at the base of Loess 1 in the terminology of Eden & Froggatt (1988). Its age (20 233 ± 386 yr BP) is consistent with this reported stratigraphy. The other sample, NZ3093 (R4813/2), was selected to date the end of the penultimate (Loess 2)

Table 2 Summary of species and their incidence in the avifaunas of the Hillgrove Formation at Cape Wanbrow, and of the Boatmans Harbour equivalent. The Ruby Gully fauna is separated from the rest of the sites from the coastal cliffs, which were in a different taphonomic setting. The MNI (minimum number of individuals) is the sum of MNIs from constituent fossil sites within the Hillgrove Formation: faunas from loess sites are not included. *Sphenodon* is included to provide a complete list of land vertebrates.

Species	Hillgrove: open sites	Ruby Gully	Hillgrove: cave site f8226	Boatmans Harbour
Pachyornis elephantopus	3	3	–	–
Euryapteryx geranoides	2	–	–	–
Emeus crassus	3	1	–	1
Dinornis giganteus	1	–	–	–
Apteryx australis ssp.	1	1	–	–
Thalassarche cf. *T. bulleri*	1	–	–	–
Pterodroma inexpectata	1	–	–	–
Puffinus griseus	7	1	1	1
Puffinus gavia/huttoni	13	–	–	6
Puffinus tenuirostris	1	–	–	1
Pelecanoides urinatrix	26	2	53	5
Pelagodroma marina	–	–	–	2
Pachyptila turtur	4	1	4	–
Eudyptula minor	14	4	26	12
Eudyptes pachyrhynchus	3	2	1	2
Megadyptes antipodes	5	1	–	3
Phalacrocorax varius	–	1	–	2
Leucocarbo carunculatus	6	2	–	3
Stictocarbo punctatus	9	3	2	8
Cnemiornis calcitrans	4	1	–	–
Tadorna variegata	4	–	–	1
Chenonetta finschi	6	1	1	2
Hymenolaimus malacorhynchos	1	–	–	–
Anas chlorotis	4	1	–	–
Mergus australis	5	–	–	1
Falco novaeseelandiae	3	–	–	–
Harpagornis moorei	4	1	–	–
Coturnix novaezelandiae	2	1	–	–
Gallirallus australis	13	3	1	2
Gallinula hodgenorum	2	–	–	–
Fulica prisca	1	–	–	–
Aptornis defossor	1	–	–	–
Haematopus finschi	1	–	–	–
Haematopus unicolor	4	1	–	–
Charadrius bicinctus	1	–	–	–
Charadrius obscurus	1	–	–	–
Coenocorypha iredalei	2	1	–	–
Larus dominicanus	4	–	–	1
Larus novaehollandiae/bulleri	3	–	–	–
Sterna striata	1	–	–	–
Hemiphaga novaeseelandiae	3	–	–	3
Nestor notabilis	6	1	–	–
Nestor meridionalis	11	1	1	3
Cyanoramphus spp.	4	1	1	3
Aegotheles novaezealandiae	–	–	1	–
Sceloglaux albifacies	3	–	–	2
Rhipidura fuliginosa	–	–	–	1

Table 2 (*continued*)

Species	Hillgrove: open sites	Ruby Gully	Hillgrove: cave site f8226	Boatmans Harbour
Petroica australis	2		–	2
Anthornis melanura	2		–	–
Prosthemadera novaeseelandiae	2	1	1	–
Callaeas cinerea	2	1	–	1
Philesturnus carunculatus	2	1	1	–
Turnagra capensis	2		–	–
Corvus moriorum	9	2	2	–
Sphenodon sp.	3	–	–	3
Total birds	215	40	96	68

deposition, and gave a much older age (32 415 ± 1746). At the time of determination, this age was considered limital to the technique and so the true age was considered unknown. However, in view of its high "%collagen yield" it may be near correct: the age does accord with that of Loess 2 (Eden & Froggatt 1988). It does indicate deposition coeval with that in Ruby Gully and the cave f8226, in the mid Otiran. However, neither NZ3092 or 3093 pertain to the Hillgrove Formation.

The above discussion reveals that the Hillgrove Formation contains strata of discordant ages: a lower unit of beach sands and gravels capped by a thin band of shelly back-beach deposits that together are c. 130 kyr old (Forsyth 2001), and overlying dune, inter-dune water-laid deposits, and reworked sands and silts, that may be as young as 35 000–27 000 years old. If the upper non-marine unit of the Hillgrove Formation and the Ruby Gully colluvium are indeed of mid-Otiran age, the proximity of the shoreline is relevant as the presence of breeding penguins, shags, gulls, and bivalves indicates that it was relatively close. The present bathymetry does not support this, as allowing for a 50 m depression of the sea level (Shackleton 1987), the present 50 m isobath indicates that the shoreline may have been 16 km from Cape Wanbrow. Sea level depression was much greater over the Glacial Maximum, but, from then to the present, vast amounts of gravels have been transported seaward from the Southern Alps. The seabed about Cape Wanbrow is flat and probably represents an aggraded surface of outwash gravels, similar to the Canterbury Plains. Our data suggest that the shoreline was close to Cape Wanbrow 30–40 kyr BP, which is quite possible if, as the sea level rose after the Glacial Maximum, the seabed rose in response to the huge sediment loads being delivered by the rivers. We await independent dating of the sediments by, for example, OSL techniques, to verify our conclusions.

Palaeofaunal reconstruction

The Hillgrove Formation has revealed the most diverse mid-Otiran bird faunas known from New Zealand and a small avifauna of Last Interglacial (Oxygen Isotope Stage 5, Oturian) age. Only the small avifauna from the combined collections of f8214, f8227, and f8710, which are from 0 to 1.5 m above the base of the Hillgrove, is as old as the highstand of the Last Interglacial 110–130 kyr BP (Forsyth 2001). All others are younger, and it remains to be seen whether there is a significant temporal unconformity between the beach deposits and the higher sands and gravels as the available dates suggest.

We have amalgamated faunas from the Hillgrove Formation on the south side of Cape Wanbrow that were in the cliff above the beach (sites listed above as "Cliffs at Old Rifle Butts" and "North-east of Ruby Gully") in one faunal unit termed Hillgrove open sites in Table 2. Faunas from Ruby Gully, the cave site f8226, and Boatmans Harbour are compiled separately (Table 2). There are no significant differences in the faunal composition of these data sets. Fifty-three species of bird, a tuatara, and an indeterminate skink were represented in these faunas, plus indeterminate seals. All of the taxa were present in Late Holocene avifaunas in eastern South Island regions. There is no evidence for undescribed avian species as previously stated by Grant-Mackie & Scarlett (1973) and Fordyce (1982, 1991).

The proximity of the seashore to the deposition sites was indicated by the high numbers of sea birds, particularly penguins (*Eudyptula*, *Eudyptes*, *Megadyptes*) and marine shags (*Stictocarbo* and *Leucocarbo*). The diverse fauna and high numbers of charadriiforms and procellariids also support this contention, but it is acknowledged that most petrels breed inland. Occasional marine shells and fish and seal bones also support the suggestion that the deposition sites were close to the shorelines. Scavengers, such as gulls, regularly move fish remains or shells from the shore during feeding. The numbers of *Pelecanoides urinatrix* and *Eudyptula minor*, and the presence of juvenile bones of both species and eggs of the latter, indicate that these species were breeding around the deposition sites.

The fauna from the Cave site f8226 provides especially compelling evidence for breeding colonies of these species. The co-occurrence of comparably abundant bones of these two species in J41/f8226 strongly suggests either their sympatry on the slopes of the immediate hillside, or their co-occupancy of this cave, during the Last Glacial period. However, the sheer abundance of both *Pelecanoides* and *Eudyptula* bones, including all parts of their skeletons indicating that whole carcasses were in the cave, and the presence of several other taxa, e.g., *Chenonetta*, *Gallirallus*, and *Aegotheles*, suggests that the site functioned as a pitfall trap. While the penguins certainly nested in the cave later in its period of deposition, many died in it first, so it seems the cave trapped both *Pelecanoides* and *Eudyptula* beneath their breeding colonies on the hill above.

Thirty-two land and freshwater taxa were represented. Few moas were present but those that were (Table 2) are indicative of grassland and shrubland habitat. The presence of *Coturnix*, *Chenonetta*, *Cnemiornis*, *Harpagornis*, and the rail fauna is also concordant with this habitat (e.g., Worthy 1997a; Worthy & Holdaway 1996). The unusually high anatid diversity of six species is due to the coastal location of the sites. *Mergus* was a sea duck and *Tadorna* probably had a mainly coastal distribution in prehuman New Zealand (Worthy 1998d). *Cnemiornis*, *Chenonetta*, and *Anas chlorotis* were common in terrestrial faunas elsewhere, e.g., Worthy & Holdaway (1993, 1994, 1996), so are unremarkable in the Hillgrove faunas, but *Hymenolaimus malacorhynchos* was unexpected. In the prehuman environments of New Zealand this duck was very much more widespread, for example, in about 1840, Percy Early collected a specimen from Waikouaiti on the east coast of Otago well outside of its commonly accepted historical range (Oliver 1955, p. 420), and it often foraged at distances from streams (Worthy & Holdaway 1994). The parrot fauna included *Nestor notabilis* and *N. meridionalis* and parakeets (*Cyanoramphus* spp.). In lowland eastern sites, for example, Pyramid Valley and Glencrieff in North Canterbury, both larger parrots were also present together (Worthy & Holdaway 1996). In higher altitude sites, e.g., Merino Cave at 440 m (Otiran age) and Earnscleugh at ~400 m (late Holocene age), only *N. notabilis* was present (Worthy 1998b; Worthy & Holdaway 1995). The presence of *N. notabilis* probably indicated that some shrubland and/or grassland was present. Predators included *Harpagornis moorei*, *Falco novaeseelandiae*, and *Sceloglaux albifacies*. *Circus eylesi* was

not present, but it was present in the similar-aged Merino Cave site, indicating that it was part of the New Zealand fauna at that time. The passerine fauna was dominated by the large, usually coastally distributed *Corvus moriorum*, but several other species are recorded. Only one small species (*Rhipidura*) is recorded, and this is probably related to the deposition conditions: small bones would be hard to find even if present.

Although the fossil landsnails have not been studied in detail, they can provide additional useful palaeoecological data, so comments based on small collections are worth recording here (N. Gardner pers. comm. Jun 1974; F. M. Climo pers. comm. Apr 1983). There appears to have been scrubby vegetation cover (e.g., indicated by the snails *Charopa coma* (Gray), *C. montivaga* Suter, *Mocella rakiura* (Powell), *Thalassohelix igniflua* (Reeve), *Phrixgnathus phrynia* Hutton, *P. titania* Hutton), with some damper areas indicated by *Allodiscus planulatus* (Hutton), and *Thalassohelix zelandiae* (Gray). Also present were *Therasia thaisa* Hutton, usually associated with monocotyledons on steep rocky slopes, and *Paralaoma lateumbilicata* (Suter), another coastal slope species. This fauna was found in Hillgrove localities above the level of the marine deposits along the Old Rifle Butts coast (e.g., J41/f8126, f8211). The landsnail fauna east of Ruby Gully, at J41/f8230, was similar to the above but is thought to represent more open scrub and a drier site, as might be expected on the steeper more exposed outer part of Cape Wanbrow. *Allodiscus adriana* (Hutton) was common here and today is found in cabbage tree (*Cordyline*) litter on the Port Hills section of Banks Peninsula, near Christchurch and throughout the drier parts of Otago in matagouri/tussock associations with rocky outcrops. No landsnails have been identified in Boatmans Harbour or Ruby Gully collections.

Comparison with other regions

There are many pitfall cave sites on Tuarangi Station in South Canterbury, and at least three, Tomo 1, Tomo 2, and Tuarangi Cave, have preserved Pleistocene faunas (Worthy 1997a). Tomo 1 had a deep deposit of loess sediments that ranged from at least 21–31 kyr BP. Birds other than moas included *Cnemiornis*, *Apteryx*, and *Chenonetta*. Tomo 2 is adjacent to Tomo 1 and had an undated fauna. The gravel deposits in Tuarangi Cave returned a radiocarbon date on bone collagen of 47 500 ± 3600 yr BP. This was doubtless limital for the technique and so the real age could be older. It is noteworthy that while the fauna is generally indicative of a shrubland (*Cnemiornis*, *Aptornis*, *Coturnix*), there were no bones of *Chenonetta finschi* despite small bones of equivalent-sized species being relatively abundant. *Chenonetta* was present in all eastern pitfall sites where the faunas include small birds and it was in many of the predator sites as well (Worthy & Holdaway 1995, 1996; Worthy 1997a, 1998a). Because the flight ability of *Chenonetta* had been regressing since at least 30 000 years ago (Worthy 1988, 1997c; Worthy & Olson 2002), it is possible that the absence of *Chenonetta* from Tuarangi Cave gravels may be because the ancestor of *Chenonetta* had not yet colonised New Zealand.

In North Canterbury, only one fauna of similar age to those from the Hillgrove Formation is known. This is the older layer, or "East" deposit, in Merino Cave, on Annandale Station, dated to c. 38 kyr BP (Worthy & Holdaway 1995). The fauna in this site, now at 440 m above sea level, was dominated by *Pachyornis elephantopus*, but included several other moa species including *Megalapteryx didinus*, which together indicates the presence of open grassland or low shrubland vegetation in the area at that time. Other birds in the fauna including *Circus eylesi*, *Aptornis defossor*, a large kiwi, *Gallirallus australis*, *Coturnix novaezelandiae*, *Chenonetta finschi*, *Nestor notabilis*, *Sceloglaux albifacies*, and *Aegotheles novaezealandiae* also imply a shrubland-grassland vegetation.

Palaeoenvironmental reconstruction

Climate

Oamaru and nearby Cape Wanbrow are in the rainshadow area of the Southern Alps and presently have a markedly lower rainfall than the New Zealand average of c. 1200 mm. At Oamaru, mean annual rainfall 1982–94 was 508 mm (range 304–700 mm) and mean daily air temperature was 11°C (min. 6.7°C for Jul; max. 15.6°C for Jan) (National Institute of Water and Atmospheric Research Limited 1995). Summer drought and winter frosts are common, but at the low elevations on Cape Wanbrow snow is rare.

Because Otago and Southland were centres of plant endemism and include some of the discontinuous parts of the distribution of some species, Wardle (1963) suggested that they represented refuge areas where much of the present flora survived the glaciations. Wardle (1963, fig. 2) suggested that eastern parts of Otago as far north as Oamaru were in forest "including a few montane species" during the height of the last (Otiran) glaciation.

During the Glacial Maximum (22–14 kyr BP), the tree line or snowline in the central section of the Southern Alps was depressed by 800–830 m and annual temperature was depressed by c. 4.5–5.0°C (McGlone 1988). Loess was deposited widely in eastern areas at this time. McGlone (1988) described no pollen assemblages from the Glacial Maximum in southern South Island, but assemblages from mid and North Canterbury were dominated by herbs and grasses. Late Glacial to early Holocene assemblages from central Otago led McGlone et al. (1995) to conclude that a grassland and shrubland vegetation at most 1–2 m high dominated there before 11 000 yr BP. It seems probable that a similar, open vegetation would have been present through this period in the Oamaru area.

The Last Glacial period extended from 70 to 10 kyr BP, but within it were three warmer interstadials separated by cold stadials. During the interstadials, forest covered much of the North and South Islands (Stevens et al. 1995, p. 89). The most recent stadial was between 25 and 14 kyr BP when sea level dropped by at least 120 m (Shackleton 1987) and, as seen above, vegetation in south-eastern regions was restricted to grasslands and low shrublands. In the preceding interstadial, sea level was c. 50 m lower than at present suggesting that climate was considerably milder than during the Glacial Maximum yet significantly cooler than the present. No relevant data from pollen analyses are available for this period, but the fauna described above allows some predictions on the vegetation cover. The absence of species typical of closed-canopy, tall forests, such as *Anomalopteryx didiformis* and *Strigops habroptilus*, and the relative rarity of *Apteryx* species, suggest that such habitat was absent. Rather, the species present included *Pachyornis elephantopus*, *Euryapteryx geranoides*, *Emeus crassus*, *Nestor notabilis*, *Harpagornis moorei*, *Cnemiornis calcitrans*, *Chenonetta finschi*, and *Coturnix novaezelandiae* which were all typical of faunas of shrublands or mosaics of drier types of forest, shrubland, and grassland (Worthy 1999). The presence of *Nestor meridionalis* and of the passerines other than *Corvus moriorum* indicates the presence of woody vegetation at least as tall as shrubland up to 3–4 m high rather than grassland. Therefore, it is likely that the rolling hills and valleys of Cape Wanbrow, while some 50 m higher above the sea at 30–40 kyr BP, were vegetated in a mosaic of dry shrubland, grassland, and forest.

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Appendix 1 List of faunas from Cape Wanbrow

In the following faunas, material that was not identifiable to a taxon is not listed, nor are modern bones that had recently been incorporated in the sediments as determined by their recent appearance, e.g., those of European passerines. NISP is the number of identified specimens in a sample.

Holocene or Late Pleistocene sites

Site description **Awamoa Creek on NW side of South Oamaru Road**
GRID REFERENCE J41/476608
COLLECTOR P. Robinson, 5/69
STRATUM in alluvium, probably a Holocene assemblage.
FOSSIL RECORD NUMBER J41/f138

Cat. no.	Species	Specimens	NISP
AU4167.1–2	*Pachyornis elephantopus*	Tmt, phal L4.1	2
AU4167.3–4	*Emeus crassus*	L tt, L fib	2
AU4167.5	*Dinornis struthoides*	SR fem	1
AU4167.6	Moa sp.	Vert	1

Site description **Russell Rd extension, Oamaru, in hillside cutting**
GRID REFERENCE J41/522709
COLLECTOR JAGM & students, 5/69
STRATUM In subsoil, this is a Holocene fauna.
FOSSIL RECORD NUMBER J41/f126

Cat. no.	Species	Specimens	NISP
AU4166.2–7	Moa sp.	L fib, 2 ribs, shaft tt frags	4
AU4166.1	*Eudyptes pachyrhynchus*	R fem	1

Site description **Oamaru gull site, just north of sewer pipe**
GRID REFERENCE J41/495624
COLLECTOR PRM 11/78
STRATUM In peat horizon c. 1 m above beach gravel, probably Holocene.

Cat. no.	Species	Specimens	NISP
AU9717	*Larus dominicanus*	Skeleton	40

Site description **1/3 south of Ruby Gully**
GRID REFERENCE ?
COLLECTOR PRM 11/78
STRATUM Base of midden, Late Holocene

(*continued over page*)

Appendix 1 (*continued*)

Cat. no.	Species	Specimens	NISP
AU9722	*Coturnix novaezelandiae*	R hum	1

Site description	**Low cliffs east of Shirley Stream, by golf course**
GRID REFERENCE	J41/496627
COLLECTOR	JAG-M, PRM 5/75
STRATUM	Late Pleistocene/early Holocene alluvium
FOSSIL RECORD NUMBER	J41/f133

Cat. no.	Species	Specimens	NISP
AU4463	*Euryapteryx geranoides*	dL tt, LR fib, 4 phal, L tmt, 1 thor vert, 1 rib, pelvis frags, frags	11

Site description	**Low cliffs east of Shirley Stream, 5 m north of J41/f133**
GRID REFERENCE E	J41/f496627
COLLECTOR	JAGM, PRM 5/75
STRATUM	Late Pleistocene/early Holocene alluvium
FOSSIL RECORD NUMBER	J41/f134

Cat. no.	Species	Specimens	NISP
AU4464	*Pachyornis elephantopus*	L tmt, L fem, pt mand, pmx, pel, 7 thor ribs, 3 stern ribs, 7 phal, 4 vert, frags	26
AU4464	*Cnemiornis calcitrans*	dL tt, pt dR tmt	2

Site description	**Back of beach by Shirley Stream**
GRID REFERENCE	J41/498627
COLLECTOR	JAG-M 1/83
STRATUM	Lagoon/estuary deposit of probable Holocene age at former stream mouth.
FOSSIL RECORD NUMBER	J41/f213

Cat. no.	Species	Specimens	NISP
AU12247	*Harpagornis moorei*	R ulna, mand tip	2
AU12247	Moa sp.	2 thor ribs, 1 cerv vert, 2 thor vert, 2 phal	7

Site description	**Back of beach by Shirley Stream**
GRID REFERENCE	J41/498627
COLLECTOR	Bruce McCulloch 1979
STRATUM	Collected from layer c. 1 m from top of cliff which was c. 5 m high (since backed up with sand, so in 1999 was c. 3 m high) c. 30 m north-east of Shirley Stream (= Kaierero Stream).
FOSSIL RECORD NUMBER	?J41/f134

Cat. no.	Species	Specimens	NISP
North Otago Museum	*Harpagornis moorei*	L cor, L rad, LR tmt, R tt, L ulna	6

Loess sites

Site description	**South of Awamoa Stream**
GRID REFERENCE	J41/c.472603
COLLECTOR	PRM 11/78
STRATUM	Just above basal conglomerate, ?loess

Cat. no.	Species	Specimens	NISP
AU9716	*Pachyornis elephantopus*	1dL tt	1

Site description	**Cape Wanbrow**
GRID REFERENCE	?
COLLECTOR	?
STRATUM	Loess

Appendix 1 (*continued*)

Cat. no.	Species	Specimens	NISP
MNZ S38	*Pachyornis elephantopus*	1p+sL tt	1

Site description	**Boatmans Harbour, behind railway line**
GRID REFERENCE	J41/508645
COLLECTOR	JAGM, PRM 5/75
STRATUM	Loess above Boatmans Fmn
FOSSIL RECORD NUMBER	J41/f129

Cat. no.	Species	Specimens	NISP
AU4457.1–3	Moa sp.	Ischial frag, uncinate proc, pubis frag	3
AU4457.1–3	*Gallirallus australis*	1dR tt	1

Site description	**Boatmans Harbour, behind railway line**
GRID REFERENCE	J41/508645
COLLECTOR	JAGM, PRM 5/75
STRATUM	Loess
FOSSIL RECORD NUMBER	J41/f128

Cat. no.	Species	Specimens	NISP
AU4456.1	Moa sp.	1sL tt	1

Site description	**Boatmans Harbour, behind railway line**
GRID REFERENCE	J41/508645
COLLECTOR	PRM 4/76
STRATUM	Loess; fallen from J41/f128
FOSSIL RECORD NUMBER	J41/f50 given to dated femur (NZ4743)

Cat. no.	Species	Specimens	NISP
AU4458	*Pachyornis elephantopus*	RL tt, R fib, frags LR fem, 2 phal	7

Site description	**30 m west of Ruby Gully**
GRID REFERENCE	J41/501627
COLLECTOR	JAGM, PRM
STRATUM	Top of loess
FOSSIL RECORD NUMBER	J41/f49

Cat. no.	Species	Specimens	NISP
AU4484	*Dinornis giganteus*	Ltt	1

NOTE: ^{14}C sample submitted but sample lost, no result obtained. Identity in doubt, may have been *P. elephantopus*.

Hillgrove Formation sites

Site description	**Ruby Gully**
GRID REFERENCE	J41/500627
COLLECTOR	PRM 4/76
STRATUM	East side, on seaward corner, 4 m above conglomerate
FOSSIL RECORD NUMBER	J41/f130

Cat. no.	Species	Specimens	NISP
AU4480	*Cnemiornis calcitrans*	L fem	1

Site description	**Ruby Gully**
GRID REFERENCE	J41/500627
COLLECTOR	AU12259: JAGM and PRM 1/83; AU12850 JAGM 10/5/90; AU4093 JAG-M 1–2/9/1970; AU4144 JAG-M, RJS 1/9/70; AU4147 JAG-M 28/11/73; AU4156 JAG-M, PRM 5/75; AU15054 JAG-M 5/12/96; CM Av C. Burrows 21/6/73, RJS, –/5/75; MNZ–THW 24/7/93, 8/12/94, 18/9/95, 28/10/96, Dec 1988, P. R. Millener 11/12/87;

(*continued over page*)

Appendix 1 (*continued*)

STRATUM Hillgrove Fmn, 0.5–5 m above basal conglomerates. Valley-fill deposits.
FOSSIL RECORD NUMBER J41/f8213

Cat. no.	Species	Specimens	NISP	Notes
MNZ S35468	*Emeus crassus*	R fem	1	c. 5 m above conglomerate
AU4093.1	*Emeus crassus*	pL tt	1	
MNZ S35895	*Emeus crassus*	dR tt	1	
AU4093.2–3	*Pachyornis elephantopus*	R fem and frags	1	
MNZ S35897	*Pachyornis elephantopus*	L tmt	1	
MNZ S35449	*Pachyornis elephantopus*	pt cran	1	
MNZ S25862	*Pachyornis elephantopus*	dL tt, L tmt	2	
MNZ S35469	?*Pachyornis elephantopus*	sL tt	1	c. 4 m above conglomerate
MNZ S35896	?*Pachyornis elephantopus*	juv R fem	1	near top of Hillgrove Fmn
MNZ S35898	?*Pachyornis elephantopus*	dR tt	1	1 m above base of Hillgrove Fmn
MNZ unreg	*Pachyornis elephantopus*	L fem	1	15 cm above sand layer at gully mouth
AU12259	Moa sp.	vert adult	6	
AU12850	Moa sp.	dR tt juv	1	
AU12850	Moa sp.	dR tt adult	1	
AU4093.4	Moa sp.	indet tt frag		
AU4093.5	Moa sp.	indet frag juv		
AU4988	Moa sp.	L tmt	1	NE face, 10 m from entrance and 3 m above conglomerate, 2/09/76
AU4989	Moa sp.	L fib , aff. *Pachyornis elephantopus*	1	SW side, c. 2 m above basal conglomerate, 2/09/76
AU4156.1–14	Moa sp.	dL tt and frags, pt rib	2	
AU4147.11	Moa sp.	juv dR tt	1	
AU4147.1–5	Emeid sp.	sL fem	1	
AU4147.8	Moa sp.	caudal vert	1	
MNZ S35445	*Apteryx australis/haastii*	R fem	1	
MNZ S35446	*Apteryx australis/haastii*	L tt	1	1 m above conglomerate
MNZ S35447	*Apteryx australis/haastii*	pR tt	1	c. 3 m above conglomerate
AU4144.13	*Megadyptes antipodes*	dR tt	1	
AU12850	*Megadyptes antipodes*	dR fem	1	
MNZ S35450	*Megadyptes antipodes*	pelvis	1	
MNZ S35901	*Megadyptes antipodes*	R tmt	1	
AU4144.1	*Eudyptes pachyrhynchus*	dL tt	1	
AU4144.14	*Eudyptes pachyrhynchus*	sL tt	1	
AU4147.12–13	*Eudyptes pachyrhynchus*	R fem, R fib	2	
AU4147.14	*Eudyptula minor*	pt stern	1	
AU4156.15–16	*Eudyptula minor*	L innom, frag	2	
AU4144.3–9	*Eudyptula minor*	R cor, 1L2pL hum, 1L1pR tt, 1 vert	7	
CM Av29692	*Eudyptula minor*	1L fem, 1 ant sac	2	
CM Av29876	*Eudyptula minor*	1pL hum	1	
CM Av29879	*Eudyptula minor*	1dL tt	1	
MNZ S35123	*Eudyptula minor*	dL fem	1	
MNZ S35453	*Eudyptula minor*	1 thor vert	1	

Appendix 1 (*continued*)

MNZ S35457	*Eudyptula minor*	R cor	1	
MNZ S35466	*Eudyptula minor*	dL tt, L ramus	2	
AU4144.15	*Pelecanoides* sp.	pR tmt	1	
AU4147.15–16	*Pelecanoides* sp.	R ulna, R rad	2	
AU4147.22–23	*Pelecanoides* sp.	dL tt	1	
AU4156.17–23	*Pelecanoides* sp.	LR cmc, pLdL hum, L fem, dL tt, L tmt, dL ulna	8	
AU4156	*Pelecanoides* sp.	dR ulna, dL tt	2	
MNZ S35126	*Pelecanoides* sp.	1 bone	7	
MNZ S35906	*Pelecanoides* sp.	stern, R scap	2	
MNZ S35459	*Pachyptila turtur*	synsacrum, R ulna	2	
AU4144.16	*Puffinus griseus*	R cmc	1	
AU4147.17–18	*Stictocarbo punctatus*	dLdR hum	2	
AU4144.11	*Stictocarbo punctatus*	pR ulna	1	
AU4144.22	*Stictocarbo punctatus*	pR ulna	1	
AU4144.24	*Stictocarbo punctatus*	dR tmt	1	
CM Av29695	*Stictocarbo punctatus*	1L cor	1	
CM Av29696	*Stictocarbo punctatus*	1dL ulna	U	
CM Av29877	*Stictocarbo punctatus*	1dR tt	U	
MNZ S35125	*Stictocarbo punctatus*	7 bones	7	
AU12259	*Stictocarbo punctatus*	L hum, dR tt, dL tmt, pt pR hum, sL fem, pR rad	6	
MNZ S35451	*Stictocarbo punctatus*	pR fem	1	
MNZ S35458	*Stictocarbo punctatus*	dL hum, pL ulna	2	
MNZ S35460	*Stictocarbo punctatus*	pL tt	1	
MNZ S35465	*Stictocarbo punctatus*	dLdR ulna, dL tmt	3	
AU4156.34–37	*Stictocarbo punctatus*	L tmt, dR tt, dL rad	3	
AU15054	*Stictocarbo punctatus*	dL ulna	1	
MNZ S35904	*Stictocarbo punctatus*	R quad	1	
MNZ S35124	*Phalacrocorax* cf. *varius*	pR fem	1	
AU4156.38	Shag sp. large	pR cor	1	
AU4144.19–20	Shag sp. large	dLdR ulna	2	
AU4144.2	Shag sp. large	s+d L ulna	1	
AU4144.23	Shag sp. large	dL tt	1	
CM Av29694	Shag sp. large	1pL hum	1	
CM Av29878	Shag sp. large	1dL rad	1	
MNZ S35461	Shag sp. large	pL ulna	1	
MNZ S35452	*Leucocarbo carunculatus*	1R cor	1	
MNZ S35456	*Leucocarbo carunculatus*	pmx, pL cor	2	
AU4156.29–30	*Leucocarbo carunculatus*	pmx, L rad	2	
AU4156.39	*Leucocarbo carunculatus*	pL tt	1	
AU4153.1–3	*Leucocarbo carunculatus*	L tmt, pel, frags	2	
AU12850	*?Leucocarbo*	pL cor	1	
MNZ S35905	*Haematopus unicolor*	dL rad	1	
AU4156	*Coenocorypha iredalei*	dR ulna	1	
AU12850	*Cnemiornis calcitrans*	R hum	1	
MNZ S35444	*Cnemiornis calcitrans*	pelvis	1	4.5 m above conglomerate
MNZ S35448	*Cnemiornis calcitrans*	1 phal 3.1, dR fem	2	
MNZ S35467	*Cnemiornis calcitrans*	pt R side sternum	1	
AU4144.21	*Cnemiornis calcitrans*	dR tmt	1	Other half is AU4156.27
AU4147.6	*Cnemiornis calcitrans*	phal 3.1	1	
AU4156.27	*Cnemiornis calcitrans*	pR tmt	1	See AU4144.21 for other half

(*continued over page*)

Appendix 1 (*continued*)

AU4144.12	*Chenonetta finschi*	L tmt	1	
MNZ S35455	*Anas chlorotis*	1dL tt	1	
AU12259	*Nestor meridionalis*	L hum, pmx	2	
AU4144.18	*Nestor meridionalis*	1dL ulna	1	
AU4144.25	*Nestor meridionalis*	1dR fem	1	
MNZ S35464	*Nestor meridionalis*	1pL ulna	1	
MNZ S35902	*Nestor meridionalis*	L cmc	1	
AU4147.9	*Nestor meridionalis*	dR tt	1	
AU4156.25	*Nestor meridionalis*	dR fem	1	
CM Av29693	*Nestor notabilis*	1dL fem	1	
AU12259	*Cyanoramphus* sp.	R hum	1	
AU4156	*Cyanoramphus* sp.	ant stern	1	
MNZ S35463	*Gallirallus australis*	1pR tt, pL fem	2	
MNZ S35899	*Gallirallus australis*	L tmt, dL tmt, 2dL tt, 1pL1pR tt, 1R cor	7	
AU4156	*Gallirallus australis*	p+d R ulna	1	
AU4147.10	*Gallirallus australis*	L tmt	1	
MNZ S35903	*Coturnix novaezelandiae*	L cmc	1	
AU4156.31	*Coturnix novaezelandiae*	L tmt	1	
CM Av29875	*Prosthemadera novaeseelandiae*	Stern	U	
AU4144.10	*Callaeas cinerea*	1dL hum	1	
AU4156.26	*Corvus moriorum*	1dR ulna	1	
AU4156.28	*Corvus moriorum*	1sR hum	1	
MNZ S35127	*Corvus moriorum*	1dL ulna	7	
MNZ S35900	*Corvus moriorum*	L cmc	1	
MNZ S35454	*Corvus moriorum*	2dR cor	2	
MNZ S35462	*Philesturnus carunculatus*	1dL fem	1	c. 1.5 m above conglomerate
AU4147.7	Seal			
AU4156.32–34, 40	Seal			

Site description	**Cliffs east of Ruby Gully**
GRID REFERENCE	J41/501627
COLLECTOR	PRM 4/76
STRATUM	2–3 m above basal conglomerate
FOSSIL RECORD NUMBER	J41/f131

Cat. no.	Species	Specimens	NISP
AU4479.1–2, .5–5	Moa sp.	L fib, phal, 2 frags	4
AU4479.3	*Emeus crassus*	1dL fem	1
AU4479.10	*Corvus moriorum*	L ulna	1
AU4479.6–9	*Eudyptula minor*	L cor, R hum, LR tt	4
AU4479.11	Anatid sp.	pL hum	1
AU4479.12	*Gallirallus australis*	L ulna	1
AU4479.13	*Coturnix novaezelandiae*	1 dL hum	1
AU4479.14	*Sceloglaux albifacies*	1 dL tt	1
AU4479.15–17	Shag sp.	1 pL hum, pR tt, rib	3

NOTE: Only specimens AU4479.3 and AU4479.10 were seen, the others were taken from the catalogue.

Site description	**Cliffs east of Ruby Gully**
GRID REFERENCE	J41/501627
COLLECTOR	PRM 11/78
STRATUM	3.0–3.5 m above base of Hillgrove Fmn
FOSSIL RECORD NUMBER	J41/f131 and J41/f8230

Appendix 1 (*continued*)

Cat. no.	Species	Specimens	NISP
AU9723	Moa sp.	cerv vert, phal	2
AU9723	*Megadyptes antipodes*	L fem	1
AU9723	*Eudyptula minor*	3L fem, 1L tt, LR hum, L tmt, 3R rami, 2R1Ldent, 1L scap, 1 vert, 1 phal, 1L cmc, 1 ulna	18
AU9723	*Pelecanoides* sp.	1L hum, 1R1dR ulna, 1L1R fem, 1L tmt, 1L cmc, 1L cor, 1L ramus, 2 pts fur, 2 phal, 1 syn, 1 ant stern	15
AU9723	*Stictocarbo punctatus*	1dL hum, R tt, R tmt, R cmc	4
AU9723	Shag sp. large	1dR tt	1
AU9723	*Coenocorypha iredalei*	1pR cmc	1
AU9723	*Charadrius obscurus*	1dR1pR hum	1
AU9723	*Chenonetta finschi*	L ulna	1
AU9723	*Anas chlorotis*	L fem	1
AU9723	*Harpagornis moorei*	1 cerv vert, 1 thor vert, LR fem, pedal phal III.2, manus phal II.2	6
AU9723	*Falco novaeseelandiae*	R tmt (small sex)	1
AU9723	*Nestor meridionalis*	L ulna, pmx, frags L fem	3
AU9723	*Nestor notabilis*	1dR fem	1
AU9723	*Gallirallus australis*	1pRpL tt, pL fem, dLpL tmt, dR hum, L rad, 2R scap, pt dR tmt	10
AU9723	*Gallinula hodgenorum*	1pR tt	1
AU9723	*Corvus moriorum*	1pL tt, R cmc	2
AU9723	*Sphenodon* sp.	L dent	1

Site description **Cliffs east of Ruby Gully**
GRID REFERENCE J41/501627
COLLECTOR AU4154 JAG-M 11/12/73; AU4157 JAG-M, PRM 5/75; AU4987 PRM 2/9/76; AU9720, 9724 PRM 11/78; AU11522 JAG-M, PRM 1/83; AU12847 JAG-M 10/5/90;
STRATUM 3–3.5 m above base of Hillgrove Fmn
FOSSIL RECORD NUMBER J41/f8230

Cat. no.	Species	Specimens	NISP	Notes
AU4157.52	*Pachyornis elephantopus*	R fem	1	Coll 2.5 m above shelly sand; = NZ4753
AU4154.1	*Euryapteryx geranoides*	R tt	1	3–3.5 m above base
AU11252	*Dinornis giganteus*	cerv vert 3 or 4	1	
AU11252	Moa sp. ad	2 tracheal rings	2	
AU11252	Moa sp. ad	phal	1	
AU4157.16–17	Moa sp.	frags rib	2	
AU4154.50	Moa sp.	phal	1	3–3.5 m above base
AU4154.55	Moa sp.	frag		3–3.5 m above base
AU4154.15	Moa sp.	phal L2.1	1	3–3.5 m above base
AU12847	Moa sp. ad	1 vert	1	
AU9720	Moa sp.	vert, stern rib	2	NE face
AU9724	*Apteryx australis* ssp.	L tmt	1	
AU11252	*Apteryx australis* ssp.	1pR1L tt, 1L fem	3	
AU11252	*Megadyptes antipodes*	1L ramus, 1R dent	2	
AU11252	*Eudyptes pachyrhynchus*	1L cor, pmx	2	

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Appendix 1 (*continued*)

AU11252	*Eudyptes* or *Megadyptes*	L scap, vert, ant stern	3	
AU4154.54	*Eudyptes* or *Megadyptes*	atlas vert	1	3–3.5 m above base
AU11252	*Eudyptula minor*	1L1dL tt, 2 pts cran, 1R1L scap, 3L1R cor, LR fem, 2 syn, 3 phal, LR tmt, 2 pmx, LR cmc, 1 vert + 3 bones	26	
AU12847	*Eudyptula minor*	R tmt, 2R fem, 1L2R scap, LR ulnae, 1 cmc, L acet	10	
AU4987	*Eudyptula minor*	dR fem, L cmc, L tt	3	1–2 m above conglomerate
AU4157.10–14	*Eudyptula minor*	LR cor, L hum, LR tmt	5	
AU9724	*Eudyptula minor*	L hum, sL tt, R tmt, phal	4	
AU4154.42–47	*Eudyptula minor*	R rad, L fem, R tt, R fib, vert	5	3–3.5 m above base
AU4154.21	*Eudyptula minor*	L dent	1	3–3.5 m above base
AU11252	*Thalassarche* sp. aff *bulleri*	R M2.1, R ulna, dR hum, 1 wing phal 2.2	4	
AU11252	*Puffinus griseus*	R hum, R rad, pt stern	3	
AU9724	*Puffinus griseus*	L rad	1	
AU11252	*Puffinus gavia/huttoni*	2L hum, 1L cmc, 1pL ulna, 1R rad, 1dR tmt	6	
AU12847	*Puffinus gavia/huttoni*	R ulna, L scap	2	
AU4157.8	*Puffinus gavia/huttoni*	L M2.1	1	
AU4154.23–26	*Puffinus gavia/huttoni*	L hum, pRdLdR ulna	4	3–3.5 m above base
AU11252	*Pelecanoides urinatrix*	1 pmx, 1 pt mand	2	
AU11252	*Pelecanoides* sp.	5L1dL 6R2pR2dR ulnae, 2L4pL2dL 1R3pR1dR tt, 1R ramus, 2R5pR4dR 2L4pL 1dL hum, 6L2pL 1dL2R1pR 2dR cor, 4L3R scap, 3L7R2pR cmc, 6L4R sides fur, 3 ant stern, 2 syn, 2L4R 1dR tmt, 1L1pL2dL 2R2pR 1dR fem, 2R5dR2dL 8p rad, 1L2R M2.1	132	
AU12847	*Pelecanoides* sp.	5R2pR1dR3L1dL hum, 3L2R ulnae, 1L1R cmc, 1R1dR1dL rad, 2 fur, 1L1pR cor, 3L scap, 1 ant stern, 1R tmt, 1pR fem, 1L1dL1dR tt	35	
AU9724	*Pelecanoides* sp.	3L1R2pR hum, 3L1pL 1dL4R ulnae, 1R tmt, 1R1L1pL cor, 1 fur, RL scap, 1dL fem, 3 pts fur, 1pL1dR tt, 1pL cmc, 1L1dL rad	31	
AU4154.52–53	*Pelecanoides* sp.	1dL hum	1	3–3.5 m above base
AU4157.5–6	*Pelecanoides* sp.	LR hum	2	
AU4157.7	Storm petrel	L fem (L = 17.66 mm)	1	
AU9720	*Pachyptila turtur*	1pL ulna	1	NE face
AU9724	*Pachyptila turtur*	syn, L ramus	2	

Appendix 1 (*continued*)

AU11252	*Pachyptila* sp.	1dL tt, 1dR hum, 1dL tmt	3	
AU12847	*Pachyptila* sp.	1pL hum	1	
AU11252	*Stictocarbo punctatus*	2L rami, 1R quad, 2L cmc, 1pL 1R1pR 1dR tt, 1pR hum, 1L cor, 1dR1pR ulna, LR scap, 1L1dL scap, 1 pmx	18	
AU4157.27–29	*Stictocarbo punctatus*	1sL cor, R fem, dL hum	3	
AU4157.30	*Stictocarbo punctatus*	L ramus mand	1	
AU12847	*Stictocarbo punctatus*	LRdL fem, R cor, R ram, R scap	6	
AU4987	*Stictocarbo punctatus*	R hum (worn before burial), 2pR hum	3	1–2 m above conglomerate
AU9724	*Stictocarbo punctatus*	1pR ulna, R cor, dR tt, vert, L ramus mand	5	
AU4154.60–64	*Stictocarbo punctatus*	1dL cor, 2 ulna frags, LR tmt	4	3–3.5 m above base
AU9724	*Leucocarbo carunculatus*	L fem, dR hum	2	
AU11252	*Leucocarbo carunculatus*	1R1dL tt, 2 pmx, 1R ramus	5	
AU12847	*Leucocarbo carunculatus*	1dL cor	1	
AU4157.20–25	*Leucocarbo carunculatus*	s+dLpR tt, sL tt, pt fur, 2 frags	3	
AU11252	Shag sp. large	fragmented cran, R+L rami mand, L scap, 1dR rad	5	
AU4157.18–19	Shag sp. large	1pR cmc, phal	2	
AU4987	Shag sp. large	1dL ulna	1	1–2 m above conglomerate
AU4154.19–20,22	Shag sp. large	frags mand	1	3–3.5 m above base
AU12847	*Larus novaehollandiae/bulleri*	1dR hum	1	
AU9724	*Larus novaehollandiae/bulleri*	R hum	1	
AU11252	*Larus dominicanus*	L tmt	1	
AU9724	*Charadrius bicinctus*	1dL ulna	1	
AU12847	*Haematopus finschi*	R hum	1	
AU11252	*Haematopus unicolor*	R hum, 1pL1dL rad	3	
AU11252	*Coenocorypha iredalei*	ant stern, R ulna, pR ulna	3	
AU9724	*Cnemiornis calcitrans*	cerv vert #7	1	
AU4154.2–14	*Cnemiornis calcitrans*	1sL tt, L fib, R scap, pt 4 ribs, frag cran, pt 5 vert	13	3–3.5 m above base
AU4154.35	*Cnemiornis calcitrans*	rib	1	3–3.5 m above base
AU9724	*Tadorna variegata*	Ltt	1	
AU12847	*Tadorna variegata*	pelvis syn	1	
AU11252	*Chenonetta finschi*	1dL1R tt, 1R1L cor, 2L ulnae, 1L hum, 2R cmc, 1sR fem	10	
AU9724	*Chenonetta finschi*	pR rad	1	
AU12847	*Chenonetta finschi*	L hum, L fem	2	
AU11252	*Mergus australis*	R cor	1	
AU12847	*Mergus australis*	L fem, pLpR scap, dL tmt	4	
AU4157.44	*Mergus australis*	L tmt	1	

(*continued over page*)

Appendix 1 (*continued*)

AU11252	*Anas chlorotis*	1dL fem, 1dR ulnae, 1L1pR cor, 1LM2.1	5	
AU12847	*Anas chlorotis*	pR hum, dL rad	2	
AU11252	*Hymenolainus malacorhynchos*	R tmt	1	
AU4154.28	Anatid	sR tt	1	3–3.5 m above base
AU11252	*Harpagornis moorei*	L cmc, 1 ungual, R metatarsal, R ulna	4	
AU9724	*Harpagornis moorei*	LR quad	2	
AU11252	*Falco novaeseelandiae*	R tt, dL fem (lge sex)	2	
AU9724	*Falco novaeseelandiae*	L cor (small sex)	1	
AU11252	*Nestor notabilis*	1R ad, 1L juv hum, 1L cmc, 1dR ulna, 2L rad, 2 frags cran	7	
AU4157.39–40	*Nestor notabilis*	pR hum, dR tt	2	
AU12847	*Nestor notabilis*	L fem	1	
AU4154.27	*Nestor notabilis*	1pL tt	1	3–3.5 m above base
AU9720	*Nestor meridionalis*	1dL tt, pR cor	2	NE face
AU11252	*Nestor meridionalis*	RL scap, 2L1pR1dR tt, 1L tmt, 1 ant stern, 1pL1dR ulna, 1L1dL cor, 1 pmx, 1pR1L fem, 1 syn, 1 pt cran, 1L fib	18	
AU4157.36–38	*Nestor meridionalis*	palatine, R cor, L scap	3	
AU4157.41	*Nestor meridionalis*	1pL ulna	1	
AU12847	*Nestor meridionalis*	LR cmc, dR tt, 2pR ulnae, L quad, L scap, pL cor, L M2.1, R ramus	10	
AU9724	*Nestor meridionalis*	2L tt, LR ulnae, dR fem, dL rad	6	
AU4154.59	*Nestor meridionalis*	L cor	1	3–3.5 m above base
AU11252	*Cyanoramphus* sp.	1pR hum 1pL1pR cmc, 1L ulna, 1L tmt, 1dL tt	6	
AU12847	*Cyanoramphus* sp.	1dLdR hum, dL tt	3	
AU9724	*Cyanoramphus* sp.	1dL tt	1	
AU4154	*Cyanoramphus* sp.	L cmc	1	3–3.5 m above base
AU11252	*Sceloglaux albifacies*	1dR hum, 1L fem, 1sL hum	3	
AU12847	*Sceloglaux albifacies*	R scap	1	
AU11252	*Hemiphaga novaeseelandiae*	1pL1dL fem, 1R scap	3	
AU4154.48–49	*Hemiphaga novaeseelandiae*	1pR ulna, pL tmt	2	3–3.5 m above base
AU11252	*Gallinula hodgenorum*	1L fem, 1dL hum, 1dL tt	3	
AU12847	*Gallirallus australis*	1R1dL1dR tt, 1R1pL tmt, 1pR1dL hum, 1dL cor	8	
AU4987	*Gallirallus australis*	pR tt	1	1–2 m above conglomerate
AU12847	*Gallirallus australis*	1dR hum	1	
AU4157.33–34	*Gallirallus australis*	1pRdR tt	2	
AU4157.50	*Gallirallus australis*	1pL tt	1	
AU4157.42	*Gallirallus australis*	1 juv dR tt	1	
AU4154.37–41	*Gallirallus australis*	R hum, R ulna, R rad,	5	3–3.5 m above base

Appendix 1 (*continued*)

		L fib, vert		
AU4154.51	*Gallirallus australis*	1dR hum	1	3–3.5 m above base
AU11252	*Gallirallus australis*	1sR1dR1L1R hum, 1L ramus, 2L1R1 dR1pR cor, 1R tmt, 1 ant stern, 1R rad, 1L1dL2pL 1sR tt, 2dL1dR2L1R fem, 1L1R fib, 1L1R ulna	28	
AU9720	*Gallirallus australis*	pL cor	1	NE face
AU9724	*Gallirallus australis*	1L1dR fem, 1pL1dL 1dR tmt, 1pR tt, 1dR1pR hum, 1L cor	9	
AU12847	*Fulica prisca*	1dR ulna	1	
AU4154.33	*Fulica prisca*	pelvis	1	3–3.5 m above base
AU9724	*Coturnix novaezelandiae*	R tt	1	
AU4157.45	*Alauda arvensis*	R ulna		modern
AU11252	*Turnagra capensis*	1pR1dR hum, 1R scap, 1dL tmt	4	
AU12847	*Turnagra capensis*	2pL tmt	2	
AU12847	*Anthornis melanura*	1dL ulna	1	
AU11252	*Anthornis melanura*	1dR ulna, 1pL cor, 1L scap	3	
AU9724	*Prosthemadera novaeseelandiae*	R scap	1	
AU9724	*Petroica australis*	L tt	1	
AU12847	*Callaeas cinerea*	1dL hum	1	
AU11252	*Callaeas cinerea*	1 ant mand	1	
AU9724	*Corvus moriorum*	pLdL rad, 1R1pL ulna, R cmc, R tmt, pR hum, L ramus mand	8	
AU4154.17–18	*Corvus moriorum*	L cor, L tt	2	3–3.5 m above base
AU4154.36	*Corvus moriorum*	1dL tt	1	
AU4157.26, .31, .43	*Corvus moriorum*	1pR cor, L ulna, s ulna	3	
AU11252	*Corvus moriorum*	1R1L1dL1dR ulna, 1L1R1pL cor, 1R2L cmc, 1L1dR hum, 3dL rad, 1pR rad, 1L scap, 1 ant stern, 1 frag mand	19	
AU12847	*Corvus moriorum*	fragmented cran, R cmc	2	
AU11252	Landsnails			
AU11252	Fish			
AU11252	Seal			
AU4154.16, 34, .56–.58	Seal	frags		3–3.5 m above base
AU11252	Skink	1R fem	1	6.3 mm long
AU11252	*Sphenodon* sp.	6 vert, 1L2R dent, 1R ramus, 1L pmx, 1L1R max, 2R pal, 4 cranial bones, R fem, ulna, rad, phal	23	
AU12847	*Sphenodon* sp.	L hum, p ulna, p fem, 5 cranial bones, pt pel	9	

(*continued over page*)

Appendix 1 (*continued*)

AU4157.48	*Sphenodon* sp.	L hum	1
AU4157.49	Mammal	vert	

Site description **Cliffs at Old Rifle Butts, 30 m west of Ruby Gully**
GRID REFERENCE J41/500627
COLLECTOR 18/9/95, THW
STRATUM in crevice exposed by large slip, ~15 m above beach
FOSSIL RECORD NUMBER J41/f—

Cat. no.	Species	Specimens	NISP
MNZ S35470	*Pelecanoides urinatrix*	8/1	8
MNZ S35471	*Eudyptula minor*	L cor	1
MNZ S35472	*Pachyptila turtur*	1pR hum	1
MNZ S35473	*Nestor meridionalis*	1pR ulna	1
MNZ S35474	?*Cygnus atratus*	R ischium	1

Site description **Cliffs at Old Rifle Butts**
COLLECTOR Ross and Marion Lane, 19/9/70
STRATUM Loc E, site unknown, CM colln

Cat. no.	Species	Specimens	NISP
Av24930	*Eudyptula minor*	2 sac, 2L1R acet, 1dR scap, 1L cor, 1L hum, 1R tt, 1 phal	10
Av24941	*Pterodroma inexpectata*	1L cmc	1
Av24932	*Puffinus griseus*	1R hum	1
Av24931	*Puffinus gavia/huttoni*	1L hum, 1L ulna, 1L tt	3
Av24939	*Pelecanoides urinatrix*	1dR tt	U
Av24936	*Larus dominicanus*	R ulna	1
Av24938	*Mergus australis*	1 fur	1
Av24934	*Nestor notabilis*	1R hum	1
Av24935	*Nestor notabilis*	1L ulna, 1R rad, 1L scap	3
Av24937	*Gallirallus australis*	1pL tt	1
Av24940	*Gallirallus australis*	1dR tt	1
Av24933	*Corvus moriorum*	1L fem	1

NOTE: "U" is unexamined.

Site description **Cliffs at Old Rifle Butts**
GRID REFERENCE J41/501626
COLLECTOR JAG-M 10/5/90
STRATUM 1.3–6 m above base of Hillgrove Fmn
FOSSIL RECORD NUMBER J41/f8210

Cat. no.	Species	Specimens	NISP
AU12298	*Eudyptula minor*	1 ulna	1
AU12298	*Puffinus gavia/huttoni*	L rad	1
AU12298	*Pachyptila turtur*	L ulna, dR rad	2
AU12298	*Stictocarbo punctatus*	Ltt, pmx, L cmc	3
AU12298	*Larus dominicanus*	R hum	1
AU12298	*Tadorna variegata*	R tmt, R cmc	2
AU12298	*Chenonetta finschi*	R cor	1
AU12298	*Mergus australis*	L fem	1
AU12298	*Anas chlorotis*	1pR cmc	1
AU12298	*Nestor meridionalis*	R pal	1
AU12298	*Gallirallus australis*	L hum, L rad	2
AU12298	*Cyanoramphus* sp.	LdL ulnae	2
AU12298	*Sphenodon* sp.	Unknown element, not relocated	
COLLECTOR		JAG-M, PFB 5/61	
STRATUM		Bones from within slumped loess and sand at beach level	

Appendix 1 (*continued*)

Cat. no.	Species	Specimens	NISP
AU4098.1–2	*Stictocarbo punctatus*	L fem, pL tt	2
AU4098.3	*Leucocarbo carunculatus*	R fem	1
AU4098.4	*Corvus moriorum*	1dL tt	1
COLLECTOR		JAG-M and students, 13/5/69	
STRATUM		3–6 m above base of Hillgrove Fmn	
Cat. no.	**Species**	**Specimens**	**NISP**
AU4136.8–.10	*Eudyptula minor*	1pR cor, R hum, L fem	3
AU4136.5	Shag sp. large	1dR cor	1
AU4136.6	*Larus dominicanus*	1pL rad	1
AU4136.7	*Tadorna variegata*	1pR ulna	1
COLLECTOR		JAG-M 1/9/70 collected with RJS	
STRATUM		"Loc B" c. 4–5 m above base of Hillgrove Fmn	
Cat. no.	**Species**	**Specimens**	**NISP**
AU4141.3	*Eudyptes pachyrhynchus*	L tt	1
AU4145.9–12	*Eudyptula minor*	R ramus, L dent, R fem, pt pel	4
AU4141.33–35	*Eudyptula minor*	3 vert	3
AU4141.36	*Pachyptila turtur*	R tmt	1
AU4141.6–16	*Puffinus gavia/huttoni*	fur, L cor, LR hum, R ulna, 1R2L rad, L cmc, carpal phal	10
AU4141.32	*Puffinus griseus*	1pL ulna	1
AU4141.23–24	*Puffinus griseus*	L ulna, pL rad	2
AU4145.4	*Leucocarbo carunculatus*	R fem	1
AU4141.17–19	*Leucocarbo carunculatus*	L hum, L ulna, pL rad	3
AU4145.5–7	*Stictocarbo punctatus*	pmx, L fem, dL tt	3
AU4141.5	*Stictocarbo punctatus*	L scap	1
AU4141.10	*Larus novaehollandiae/bulleri*	R hum	1
AU4141.20–22	*Haematopus unicolor*	L hum, L ulna, dR fem	3
AU4145.3	*Cnemiornis calcitrans*	L tmt	1
AU4145.13	*Chenonetta finschi*	1dL hum	1
AU4141.2	*Gallirallus australis*	R tt	1
AU4141.25	*Nestor meridionalis*	R rad	1
AU4141.4	*Heniphaga novaeseelandiae*	R hum	1
AU4141.1	*Corvus moriorum*	1dL rad	1
AU4145.8	*Corvus moriorum*	L hum	1
AU4141.29	Seal		
AU4145.1–2	Fish		

Site description	**Cliffs at Old Rifle Butts**
GRID REFERENCE	J41/501626
COLLECTOR	JAG-M and students, 13/5/69; JAG-M 28/11/73
STRATUM	10 cm lens, c. 6.5 m above base of Hillgrove Fmn "Loc A"
FOSSIL RECORD NUMBER	J41/f8211

Cat. no.	Species	Specimens	NISP
AU4137.1	Moa sp. ad	phal, size *Emeus*	1
AU4146.2	*Pelecanoides* sp.	L cmc	1
AU4146.3–4	*Eudyptula minor*	1 pt R innom. frag	1
AU4146.1	*Gallirallus australis*	1dR tt	1
AU4137.2–3	Seal		
AU4146.5–6	Bivalve and algae	*Paphies* (*Mesodesma*) *subtriangulata quoyi*	
AU4146.10	Marine snail	*Micrelenchus tenebrosus*	
AU4146.7–9	Landsnails	*Paralaoma lateumbilicata*, *Phrixgnathus phrynia*, *Therasia thaisa*, *Thalassohelix obnubila*	

(*continued over page*)

Appendix 1 (*continued*)

Site description	**Cliffs at Old Rifle Butts**
GRID REFERENCE	J41/500626
COLLECTOR	AU–JAG-M and students, 13/5/69; JAG-M 1/9/70 CM Av RJS, 1–2/9/1970, 18/2/1970
STRATUM	"Loc D", 45 cm lens of pebbly sand 4.5 m above base of Hillgrove Fmn
FOSSIL RECORD NUMBER	J41/f8212

NOTE: U means specimen was not located and remains unexamined.

Cat. no.	Species	Specimens	NISP
Av24890	*Emeus crassus*	1L1.1, 1L1.2	U
AU4138.1	*Pelecanoides* sp.	L tt	1
AU4142.43–46	*Pelecanoides* sp.	LR hum, L ulna, L tt	4
Av24901	*Pelecanoides* sp.	1L2ptL1R hum, 1L rad	5
AU4142.19–22	*Puffinus gavia/huttoni*	R cor, L hum, LR ulna	4
Av32208	*Puffinus gavia/huttoni*	L cmc	1
Av24900	*Puffinus gavia/huttoni*	2L1R1dR hum, 1R1L2dL ulna, 2R cmc, 1R tt, 1Rcor	12
Av24923	*Puffinus gavia*/huttoni	1L hum, 1pR rad, 1L cor, 3R ulna	6
Av24970	*Puffinus gavia/huttoni*	1pL cor	1
AU4142.1	*Puffinus griseus*	R ulna	1
Av32211	*Puffinus griseus*	1pL cmc	1
Av24911	*Puffinus griseus*	1pR hum, 1dR ulna, 1dL1pR rad, 1L tt	5
Av26778	*Puffinus tenuirostris*	1L cmc	1
AU4142.39	*Pachyptila turtur*	pR and dR hum	2
Av24948	*Pachyptila* sp.	1R cor, 1dR tt	U
Av32210	*Pachyptila* sp.	L ulna	U
Av24903	*Megadyptes antipodes*	pt cran, pt pmx, pt mand, pt L ulna, vert	5
Av24904	*Megadyptes antipodes*	pt cran, pt mand	2
AU4142.35–37	*Eudyptes* or *Megadyptes*	cran frag, rib, L cmc	3
Av32209	*Eudyptes pachyrhynchus*	1 phal	1
Av24922	*Eudyptes pachyrhynchus*	mand	1
AU4142.13–15	*Eudyptula minor*	R dent, R hum, vert	3
AU4142.23–28	*Eudyptula minor*	cran frag, pmx, LR cor, L innom, vert	6
AU4142.77	*Eudyptula minor*	pt cran	1
Av24902	*Eudyptula minor*	pt sac, 1R1dR tt, 1pL fem, 1L cor	5
Av29869	*Eudyptula minor*	1R fem	1
Av24920	*Eudyptula minor*	3L hum, 1R acet, 1R ulna, 1L fib, 1R cor, 2L tt	9
AU4142.4	Penguin sp. indet	1 juv R fem	1
AU4142.16	*Larus dominicanus*	1R fem	1
Av24927	*Larus dominicanus*	1L cor, 1pR ulna	2
Av24905	*Larus dominicanus*	1R tt	1
Av32204	*Larus dominicanus*	pL rad	1
Av24924	*Larus novaehollandiae/bulleri*	1L hum, 1L ulna	2
AU4142.63	*Larus novaehollandiae/bulleri*	pL rad	1
Av24928	*Haematopus unicolor*	1R ulna	1
Av24915	*Sterna striata*	1L hum	1
Av24899	*Leucocarbo carunculatus*	1dR rad, 1dR hum, 1pR tt, pt pmx, 1R tmt	5
Av29871	*Leucocarbo carunculatus*	1dR tt	1
Av32202	*Leucocarbo carunculatus*	1dR cmc, pL cmc	2
AU4142.64–69	*Stictocarbo punctatus*	LR fem, dR tt, LdLdR tmt	6
AU4142.9–12	*Stictocarbo punctatus*	RL dent, dL rad, vert	4
Av24898	*Stictocarbo punctatus*	1R1L cor, 1R1L tt, 1L1pR1p+sR hum, 2pR ulna, 1pL tmt, 1sR hum, pt 2 pmx	13
Av24921	*Stictocarbo punctatus*	1 pmx, 1pR scap, 1R tmt	3
Av32212	*Stictocarbo punctatus*	phal	U
Av32215	*Stictocarbo punctatus*	1R scap	1

Appendix 1 (*continued*)

Av24910	Shag sp. large	1dL tmt	1
AU4142.40	*Cnemiornis calcitrans*	mand tip	1
AU4142.70–71	*Chenonetta finschi*	1pL cor, dL rad	2
Av24926	*Chenonetta finschi*	1R cor, 1dR1dL tt, 1dL tmt	4
Av24906	*Chenonetta finschi*	1pR hum, 1R ulna, 1R tt, 1L tmt, 1R scap	5
AU4142.33	*Tadorna variegata*	R tmt	1
AU4142.72	*Tadorna variegata*	post. cran	1
Av24925	*Tadorna variegata*	1R ulna	1
Av24908	*Tadorna variegata*	1pR1dR ulna, 1pR cor, 1pR fem, 1sL tmt	5
Av24909	*Tadorna variegata*	L ulna	1
Av32205	*Tadorna variegata*	1dL tmt	1
Av24945	Species indet	1dR tt	1
Av24919	*Anas chlorotis*	1pR hum, 1L tt	2
Av26777	*Anas chlorotis*	1dR hum	1
Av37298	*Anas chlorotis*	1dR fem	1
Av24919a	*Mergus australis*	1L fem	1
Av24944	*Mergus australis*	1dR tt	1
Av24946	*Mergus australis*	1pL tt	1
Av37328	*Mergus australis*	R cor (L = 44.26 mm)	1
Av32201	Indet anatid	1dR hum, juv	1
Av32206	Indet anatid	1 imm R tmt	1
AU4142.47	*Coturnix novaezelandiae*	R fem	1
Av29870	*Coturnix novaezelandiae*	1dR hum	1
Av24943	*Nestor notabilis*	1dL tt	1
ExAv24906	?*Nestor notabilis*	pt R cmc	U
Av24895	*Nestor notabilis*	1dR1R1sR tt, 1dL tmt	4
Av24968	*Nestor notabilis*	1dL fem	1
Av32199	*Nestor notabilis*	1pL fem, dR tt, pL tt, R cor	4
Av26807	?*Nestor notabilis*	1pL fem	U
Av24929	*Nestor notabilis*	1pL hum	1
AU4142.18	*Nestor notabilis*	sL tt	1
Av24961	*Nestor notabilis*	1pR fem	1
Av37301	*Nestor notabilis*	1pL tt	1
AU4142.17	*Nestor meridionalis*	?	1
AU4142.5–6	*Nestor meridionalis*	1dL hum, dL tt	2
Av24894	*Nestor meridionalis*	1R hum, pt 3 pmx, 1 frag mand, 1pR ulna, 1R fem, 1R tt	8
Av24916	*Nestor meridionalis*	1R tt	1
Av29697	*Nestor meridionalis*	1dL ulna	U
Av32200	*Nestor meridionalis*	1pR hum, pR cor	2
Av24892	*Cyanoramphus* sp.	L hum	1
Av24947	*Cyanoramphus* sp.	1pR ulna	1
Av26806	*Hemiphaga novaeseelandiae*	R ulna	1
Av36567	*Hemiphaga novaeseelandiae*	1dR cmc	1
Av24896	*Sceloglaux albifacies*	1pL tmt	1
Av24887	*Harpagornis moorei*	5 pedal phal, L quadrateojugal, rib, dorsal vert, L fem, fur, LR rad, R scap, stern (14/1)	14
Av24897	*Falco novaeseelandiae*	1L fem, 1R tt, 1R fib, 1dR tmt	4
Av24907	*Aptornis defossor*	1L cor	1
Av24917	*Aptornis defossor*	1R tmt	1
Av24891	*Gallirallus australis*	1dL1pL1R tt, 1R ulna, 1L cor, 1dL hum, 1 ant pel	7
AU4142.29–32, 34	*Gallirallus australis*	pel, pR tt, R tmt, 2 frags	3
Av24918	*Gallirallus australis*	1L tmt	1

(*continued over page*)

Appendix 1 (*continued*)

Av24971	*Gallirallus australis*	2dR tmt	2
Av26775	*Gallirallus australis*	1dR tt	U
Av32198	*Gallirallus australis*	pR fem, pL tt	2
Av32207	*Gallinula hodgenorum*	1 synsacrum	1
Av32214	*Gallinula hodgenorum*	dR tt	1
Av24972	*Petroica australis*	1dL cor	1
Av36910	*Prosthemadera novaeseelandiae*	1pL tt	1
Av32203	*Anthornis melanura*	pR tt	1
Av24893	*Philesturnus carunculatus*	1pL hum	1
Av37247	*Callaeas cinerea*	1pL tt	1
Av26776	*Corvus moriorum*	1R ramus	1
Av24888	*Corvus moriorum*	2R1dL(1sL) hum, 2L fem, 1L scap, 1pR 1pL1sL ulna, 1L1dL tt, 1R M1.1, 1L cmc	13
Av24889	*Corvus moriorum*	1dL hum, 1R tmt	2
AU4142.38	*Corvus moriorum*	LM2.1	1
AU4142.41	*Sphenodon* sp.	L hum	1
AU4142.3, .73–76	Seal		
AU4142.48	Fish		
AU4142.50–58	Bivalves		

Site description **Cliffs at Old Rifle Butts**

GRID REFERENCE J41/500626

COLLECTOR AU12260 JAG-M 1/83; AU4143 JAG-M, RJS 1/9/70; AU4161 JAG-M, PRM 5/75

STRATUM In sands, 0.8–1.3 m above base of Hillgrove Fmn

FOSSIL RECORD NUMBER J41/f8214

Cat. no.	Species	Specimens	NISP
AU4161.1	*Pachyornis elephantopus*	phal L2.1	1
AU4143.1–3	*Megadyptes antipodes*	R hum, L ramus, pt stern	3
AU4143.14	*Eudyptula minor*	M	1
AU12260	*Eudyptula minor*	R cor, pt L tmt	2
AU4161.10	*Eudyptula minor*	L hum	1
AU12260	*Puffinus griseus*	1pR hum	1
AU4143.10	*Puffinus griseus*	R M2.1	1
AU12260	*Puffinus gavia/huttoni*	1dR rad	1
AU4143.4	*Puffinus gavia/huttoni*	L hum	1
AU4161.7	*Puffinus gavia/huttoni*	R scap	1
AU4143.12–13	*Pelecanoides* sp.	R ulna, pR rad	2
AU4143.7	*Pelecanoides* sp.	synsacrum	1
AU4161.6	*Pelecanoides* sp.	L ulna	1
AU4143.5–6	*Stictocarbo punctatus*	L tmt, sL tt	2
AU4161.3–4	*Stictocarbo punctatus*	1pR ulna, pR rad	2
AU12260	Shag sp. large	1pL ulna, pL tt	2
AU4143.11	*Sceloglaux albifacies*	R cmc	1
AU4161.8–9	*Nestor meridionalis*	pt mand	1
AU4161.5	Seal		
AU4143.15	Seal		

Site description **Cliffs at Old Rifle Butts**

GRID REFERENCE J41/502629

COLLECTOR AU4986 PRM 2/9/76; AU9719 PRM 11/78; AU4155 JAG-M 28/11/73; AU4158–4160 JAG-M, PRM 5/75;

STRATUM Cave under Ototara Lst, 3–4 m above base of Hillgrove Fmn

FOSSIL RECORD NUMBER J41/f8226

Appendix 1 (*continued*)

Cat. no.	Species	Specimens	NISP	Subsite
AU11251	*Eudyptes pachyrhynchus*	R fem	1	
AU4986	*Eudyptula minor*	R cor, vert, pt syn, rib	4	
AU9719	*Eudyptula minor*	L fem, 2L hum, R tmt	4	
AU4155.2–43	*Eudyptula minor*	3L2R cor, 1L hum, 1R rad, 1L1R1dR 1dL fem, 4L1pL1dR 2pR tt, 2 fib, 2 syn, 4 frags stern, 2L1R tmt, 1R1L cmc, 1 ulna, 21 vert, plus frags	54	
AU4158.78	?*Eudyptula minor*	pt R cmc	1	Fissure 1
AU4158.79–81	*Eudyptula minor*	3 frags		Fissure 1
AU4158.96–119	*Eudyptula minor*	LR tt, LR tmt, LR ulna, LR rad, LR fib, L innom, 3 caud vert, 2 ribs, LR cmc	36	Fissure 1
AU4159.35–45	*Eudyptula minor*	18 phal 11 sesamoid bones, 2 crania, cran frags, pt 6 sterna	20	Fissure 2
AU4159.54–120	*Eudyptula minor*	9 syn, 5L5R innom, 4L3R cor, 2dR1pR cor, 4L3R hum, 3R1pR3L fem, 9L8R tt, 4L5Rrami, 6 pmx, 11 frags fur, 4L6R scap, 4L3R rad, 3L6R ulnae, 4L5R cmc, 20 carpal phal, 4L2R fib, 6L6R tmt, phalanges, sternal frags, tracheal rings, 14 quadrates, many vert, 3 pygostyles, ribs (176+/9)	200	Fissure 2
AU4159.169	*Eudyptula minor*	eggshell		Fissure 2
AU4160.24	*Eudyptula minor*	rib	1	Fissure 3
AU11251	*Eudyptula minor*	19R, 20L fem; 11R, 11L tt; 470 13R, 15L hum; 12R, 10L cor; 203 vert; 1 sac + 7 frags; 9R, 7L, 36 frags of innom; 17R, 13L ulnae; 11R, 10L, 2 juv. radii; 12R, 9L cmc; 9R, 11L tmt; 1 cran and many frags		
AU11251	*Eudyptula minor*	26 +1 juv. fib; 11R, 14L, 1 juv, 13 blade frags of scap; 14 quadrates; many frags of at least 8 sterna; 6 pygostyles; pt 7 + 9 blade frag. fur; 16 M2.1; 8 M3.1; 115 pedal phal, incl claws; 12 patellae; a few part tracheal rings; 2 pt eggs + eggshell; many rib and mand frags	261+	

(*continued over page*)

Appendix 1 (*continued*)

AU4986	*Pachyptila turtur*	2R ulnae, 1dL1pL 1pR hum, 1R cmc, 1dR tt, 1 syn	8	
AU4986	*Pelecanoides urinatrix*	1 cran, 2 pmx, 1 ant stern, 4 mand frags, 1 syn, 2 vert, 2R1L fem, 1L3dL 1dR2Pl 2pR tt, 1L1R1pL1pR tmt, 4L4R hum, 1L cmc, 3R2L1pL1dL ulna, 1L1dL rad, 2 phal	47	
AU9719	*Pelecanoides* sp.	2L ulnae, 1pL1L hum, L cor, L fem	6	
AU4155.46–83	*Pelecanoides* sp.	1R hum, 2L4R ulnae, 1pL ulna, 1R cor, 1L acet, 2L1dL1R1dR2pR tt, 2L cmc, 2L1R tmt, 1R1pR fem, 1R quad	25	
AU4158.1–64	*Pelecanoides urinatrix*	600+/20	600	Fissure 1
AU4159.26	?*Pelecanoides urinatrix*	p rad	1	Fissure 2
AU4159.29	*Pelecanoides urinatrix*	L rad	1	Fissure 2
AU4159.46–53	*Pelecanoides urinatrix*	4 crania, 3 frags 2 crania, 1 stern, 2 lacrymals	10	Fissure 2
AU4159. 121–163	*Pelecanoides urinatrix*	lacrymals and cran frags, quadrates, 3 pmx, sternal frags, 3 fur, 5L4R scap, 7L8R cor, 7L2R1pR hum, 5L5R ulnae, 4dL1pL rad, 2L3R2pR rad, 6L6R cmc, 9 carpal phal, 4 sac, 11 innom, vert, ribs, 1dL1pL fem, 6L6R1pR fem, 5L4R2dR2pR tt, 4 fib, 6 ulnares, 2dL1pL4L3R 2pR tmt, phalanges (148+/8)	150	Fissure 2
AU11251	*Pelecanoides urinatrix*	10R17L fem; 18R14L tt; 19R12L hum; 16R 20L cor; 100 vert; 9 sac + 6 frags; 6R, 8L, 6–8 frags os innom; 18R20L ulnae; 19R23L cmc; 17R 21L tmt; 6 pmx; 5 crania + many frags	392	
AU11251	*Pelecanoides urinatrix*	18R19L, +32 lacking distal end radii; 31 fib; 9R7L, 2 frags scap, mostly lacking distal end; 7 quad; many frags of at least5 sterna; 1 medial frag fur; 88 pedal phal (incl. unguals); 20 cmc; many mand and rib frags and sternal ribs	239+	
AU4160.1–20	*Pelecanoides* sp.	2R hum, 3 carpal phal, 1R1pR cmc,	49	Fissure 3

Appendix 1 (*continued*)

		1R1dR ulna, L cor, 2R rad, LR fem, 6 phal, 25 vert, 2 syn, 2 innom		
AU4158.65–67	*Pachyptila turtur*	LR hum, dR hum	3	Fissure 1
AU4158.82–89	*Pachyptila turtur*	LR cor, RdL rad, R acet, dR ulna, LR cmc	8	Fissure 1
AU4158.91–95	*Pachyptila turtur*	pLR tt, dL tt, pRL tmt	5	Fissure 1
AU4160.23	*Pachyptila turtur*	R tmt	1	Fissure 3
AU11251.1–2	*Pachyptila turtur*	LR ulnae	2	
AU11251	*Puffinus griseus*	R scap, L rad, phal	3	
AU4158.75	*Puffinus* aff *griseus*	worn R M2.1	1	Fissure 1
AU4159	*Chenonetta finschi*	cranium, LR quad, pt syn	4	Fissure 2
AU4159.1–8	*Chenonetta finschi*	LR scap, pR cor, R hum, L ulna, LR rad, R cmc	8	Fissure 2
AU4159.10–11	*Chenonetta finschi*	L rad, R fem	2	Fissure 2
AU4159.27	*Chenonetta finschi*	L ulnare	1	Fissure 2
AU11251	*Chenonetta finschi*	LdR tmt	2	
AU4155.44–45	*Stictocarbo punctatus*	R hum, dR rad	2	
AU4158.120	*Stictocarbo punctatus*	R hum	1	Fissure 1
AU4158.76	*Aegotheles novaezealandiae*	R rad	1	Fissure 1
AU4158.68	*Nestor meridionalis*	L fem	1	Fissure 1
AU4159.143	*Cyanoramphus* sp.	R cmc	1	Fissure 2
AU4159	*Gallirallus australis*	LM2.1, dL rad	2	Fissure 2
AU4159.30–31	*Gallirallus australis*	pt L cmc, L ulna	2	Fissure 2
AU4160.2	*Gallirallus australis*	pR cor	1	Fissure 3
AU11251	*Gallirallus australis*	R ulna	1	
AU4159.23–24	*Prosthemadera novaeseelandiae*	tt, tmt (not found)		Fissure 2
AU11251.3	*Prosthemadera novaeseelandiae*	sL hum	1	
AU4159	*Philesturnus carunculatus*	pR tmt, ped phal 1.1	2	Fissure 2
AU4159.12–22	*Corvus moriorum*	LR scap, pLdL hum, L ulna, L cmc, LM2.1, pL tmt, 2 ribs	9	Fissure 2
AU11251	*Corvus moriorum*	L tmt, p+sL tt	2	
AU11251	*Corvus moriorum*	cran, pmx, 2 pts mand	3	
AU4155.86	Landsnail	*Therasia thaisa*		
AU4155	Fish			

Site description **Cliffs at Old Rifle Butts**
GRID REFERENCE J41/502629
COLLECTOR JAG-M 28/11/73
STRATUM East of Ototara Lst, 2–3 m above base of Hillgrove Fmn
FOSSIL RECORD NUMBER J41/f8227

Cat. no.	Species	Specimens	NISP
AU4149	Moa sp.	pt dL tmt	1

Site description **Cliffs at Old Rifle Butts**
GRID REFERENCE J41/502629
COLLECTOR JAG-M 1/12/73
STRATUM Cave under Ototara Lst, 0–2 m above base of Hillgrove Fmn
FOSSIL RECORD NUMBER J41/f8228

Cat. no.	Species	Specimens	NISP
AU4152	Seal	2 ribs and innom	3

(*continued over page*)

Appendix 1 (*continued*)

Site description	**Cliffs at Old Rifle Butts**
GRID REFERENCE	J41/502629
COLLECTOR	JAG-M, PRM 5/75
STRATUM	NE of cave, 0–1.5 m above base of Hillgrove Fmn
FOSSIL RECORD NUMBER	J41/f8229

Cat. no.	Species	Specimens	NISP
AU4162	Seal	prox subadult hum	1

Site description	**Cliffs at Old Rifle Butts**
GRID REFERENCE	J41/500629
COLLECTOR	As below
STRATUM	0–1.5 m above base of Hillgrove Fmn
FOSSIL RECORD NUMBER	J41/f8710

Cat. no.	Species	Specimens	NISP	Collector
AU12264	*Emeus crassus*	L tt	1	JAG-M 1/83
AU4100.1	*Harpagornis moorei*	dL tt	1	JAG-M and students, 13/5/69
AU9721	*Eudyptula minor*	pL fem, L tt	2	PRM 11/78
AU9721	*Megadyptes antipodes*	sL fem	1	PRM 11/78

Site description	**"Pleistocene Raised Beach, Oamaru"**
GRID REFERENCE	J41/511644
COLLECTOR	B. J. Marples, c. 1947
STRATUM	Cliff path (Grave's Walk) first 100–200 m

Cat. no.	Species	Specimens	NISP
CM Av21267	Emeid sp. (as *Euryapteryx geranoides*)	L tmt chick	U
CM Av21270	Emeid sp.	2 phal L3.1	U
CM Av21269	Emeid sp.	pL fem frag, phal R3.1, + 2 phal	4
CM Av21271	*?Dinornis torosus*	phal R4.1	U
CM Av21256	*Eudyptula minor*	2L1dL2R2pR tt, 5 vert, 1L2R ramus, 3R2L1dL fem, 2R tmt, 5 ulnae, 3R3L cor, 5R2pR1L1pL hum, pmx, 2R3L cmc, L qoj, 3R3L rad	56
CM Av21257	*Eudyptes pachyrhynchus*	2R hum, L cor, RL rad, 1 manus phal, vert, 1 frag	7
CM Av37368	*Megadyptes antipodes*	2R ulna, 1L cmc	3
CM Av21258	*Pelecanoides urinatrix*	3R1L hum, 2L1R cor, 1 pmx, 1L ulna, 1L scap, 2R tmt, 1R cmc	13
CM Av21260	*Puffinus gavia/huttoni*	R hum, dL hum, R rad, pR tt, R tmt, dR ulna	6
CM Av21265	*Stictocarbo punctatus*	1L1R1dL2dR1pR hum, 5R1L 2dL1dR fem, 1L1dR tmt, 2pR4dL tt, 1pR1pL1dL cor, 1pR1dR2dL ulna, 1L rad, RL scap, 8 vert, 5 phal, 1L side fur	47
CM Av37369	*Leucocarbo carunculatus*	1L fib	1
CM Av21266	*Leucocarbo carunculatus*	2L1pR hum, pt fur, pt 2R cor, 1R1pR1pL ulna, 2 vert, 1dL fem, 1pR tt, 3 phal, pt mand	17
CM Av37370	*Phalacrocorax varius*	2L1R fib	3
CM Av21272	*Larus dominicanus*	R hum	1
CM Av37845	*Tadorna variegata*	pR cor	1
CM Av21262	*Chenonetta finschi*	(R fem), ptR fem, pL hum, dR tmt	3
CM Av37326	*Chenonetta finschi*	dL tt	1
CM Av21264	*Mergus australis*	L hum	1

Appendix 1 (*continued*)

CM Av37325	*Mergus australis*	dL tt	1
CM Av21254	*Gallirallus australis*	pL fem, pR tt, L hum, pt R tmt	4
CM Av21255	*Gallirallus australis*	R fem, pR hum	2
CM Av21268	*Aptornis defossor*	R fem	1
CM Av21263	*Heniphaga novaeseelandiae*	R cor, pt R scap, dL hum	3
CM Av21273	*Sceloglaux albifacies*	dL hum	1
CM Av37846	*Nestor meridionalis*	dR fem	1
CM Av21276	*Cyanoramphus* sp.	R ulna	1
CM Av21277	*Cyanoramphus* sp.	R hum	1
CM Av21261	*Petroica australis*	L tt	1
CM Av36530	*Rhipidura fuliginosa*	LR ulna, pR hum	3
CM Av21274	*Callaeas cinerea*	dR hum	1
CM Av21275	Passeriformes	pRdL hum, R cor, LptR ulna, vert, phal, dR tt, dL tmt	U
CM Rep 320	*Sphenodon* sp.	RL hum, pt pel, sR fem	U

Site description **Boatmans Harbour, cliff path (= Grave's Walk)**

GRID REFERENCE J41/511644

COLLECTOR AU4139–40 JAG-M 1/9/70; AU4148 JAG-M 30/11/73; AU4163 JAG-M, PRM 5/75; AU15053 JAG-M 5/12/96; CM Av B. J. Marples, c. 1947; Av29872–4 RJS, 31/5/75.

STRATUM 3–4 m above base of Boatmans Fmn

FOSSIL RECORD NUMBER J41/f9637

Cat. no.	Species	Specimens	NISP	Notes
AU4163.29	*Eudyptes* or *Megadyptes*	vert	1	
AU4140.11–12	*Eudyptula minor*	2 vert	2	
AU4163.6–13	*Eudyptula minor*	LR fem, R cor, L dent, rad, 2 vert, pt pel	8	
CM Av23152	*Eudyptula minor*	ant stern	1	
CM Av24912	*Eudyptula minor*	1 vert	1	
CM Av24966	*Eudyptula minor*	1R tt, 1 phal	2	
CM Av29873	*Eudyptula minor*	pt L tmt	1	J41/512637
AU4148.9	*Eudyptula minor*	juv R tt	1	
AU4148.11	*Eudyptula minor*	pt L dent	1	
CM Av29874	*Eudyptula minor*	R quad	1	J41/512637
AU4163.14–20	*Puffinus gavia/huttoni*	R cor, pRdR hum, L tt, 2 frags, vert	5	
AU15053	*Puffinus gavia/huttoni*	dL rad	1	
AU4148.5–7	*Puffinus gavia/huttoni*	R hum, dR hum, dL ulna	3	
AU4140.14	*Puffinus tenuirostris*	R ulna	1	
AU4163.33–34	*Pelagodroma marina*	2R tt	2	
AU4140.5	*Pelecanoides* sp.	L tmt	1	
AU4163.22–27	*Pelecanoides* sp.	L cor, R fem, pmx, fur, stern, rad	6	
CM Av29872	*Pelecanoides* sp.	1L cor	1	J41/512637
AU4139.1	*Stictocarbo punctatus*	vert	1	
CM Av23151	*Stictocarbo punctatus*	ant stern	1	
AU4148.2	*Stictocarbo punctatus*	L fem	1	
AU4163.1–2	*Stictocarbo punctatus*	R cor, dR ulna	2	
AU15053	*Stictocarbo punctatus*	pR hum	1	
AU4140.13	*Leucocarbo carunculatus*	L ramus	1	
AU4148.1	*Leucocarbo carunculatus*	pmx	1	
AU4163.3	*Leucocarbo carunculatus*	R tt	1	

(*continued over page*)

Appendix 1 (*continued*)

CM Av23147	*Chenonetta finschi*	1dR hum	1
AU4148.8	*Chenonetta finschi*	L cor	1
AU4140.10	*Gallirallus australis*	dL tt	1
CM Av23150	*Gallirallus australis*	1R cmc	1
AU4163.35	*Gallirallus australis*	sR tt	1
CM Av23146	*Coturnix novaezelandiae*	1R tmt	1
AU4140.8	*Hemiphaga novaeseelandiae*	dL tt	1
CM Av23144	*Nestor meridionalis*	2L1R cmc, 1pL fem	4
AU4148.3–4	*Nestor meridionalis*	dL tt, R tmt	2
AU4163.5	*Nestor meridionalis*	?	
AU4163.30	*Nestor meridionalis*	R scap	1
CM Av23148	*Cyanoramphus* sp.	1R cmc	1
CM Av23149	*Sceloglaux albifacies*	1dR rad, 1R cmc	2
CM Av24913	*Sceloglaux albifacies*	Manus phal L1.1	1
AU4140.1–2	*Petroica australis*	1dL hum, 1 R cor	2
AU4139.2–3	Seal		
AU4140.6–7	Seal		
AU4163.4	Seal		
AU4163.32	*Sphenodon* sp.	vert	1
AU4163.39	*Sphenodon* sp.	L dent	1
AU4163.40	Fish		
AU4148.13–14	Fish		
AU4148.15	Landsnail	*Allodiscus planulatus*	
AU4163.36	Landsnail		

Site description **Boatmans Harbour**
GRID REFERENCE ?
COLLECTOR JAG-M, PRM 5/75
STRATUM Basal conglomerate, 0–2 m above base of Boatmans Fmn
FOSSIL RECORD NUMBER J41/f9638

NOTE: CM Av specimens described as from "shellbed above pillow lava, below cliff walk".

Cat. No	Species	Specimens	NISP
CM Av29868	*Eudyptula minor*	phal	1
CM Av29866	*Megadyptes antipodes*	pt R cor	1
AU4164.1–4	*Eudyptula minor*	dL hum, L tt, pR tt, rib	4
AU4164.5–6	*Puffinus gavia/huttoni*	L ulna, R scap	2
CM Av29867	Shag sp. large	1pR ulna, 1 atlas vert	2
AU4164.7–8	*Hemiphaga novaeseelandiae*	pLdL rad	2
AU4164.10–12	Seal		

Site description **Boatmans Harbour, cliff path (= Grave's Walk)**
GRID REFERENCE J41/511644
COLLECTOR AU4150 JAG-M 30/11/73; AU4165 JAG-M, PRM 5/75; AU9718 JAG-M, 1/83;
STRATUM 5–6 m above base of Boatmans Fmn
FOSSIL RECORD NUMBER J41/f9641

Cat. no.	Species	Specimens	NISP
AU4165.1	*Emeus crassus*	pL fem	1
AU4165.2	Moa sp.	frag	
AU4150.2	*Eudyptula minor*	pR tt	1
AU4165.5	*Eudyptula minor*	carpal phal	1
AU9718	*Eudyptula minor*	R tt, L rad, R fib	3
AU4165.3	*Puffinus gavia/huttoni*	L ulna	1
AU4165.6	*Puffinus griseus*	R tmt	1
AU4165.9–11	*Pelecanoides*	Missing	

Appendix 1 (*continued*)

AU4150.1	*Stictocarbo punctatus*	R tmt	1
AU9718	*Stictocarbo punctatus*	R tt, R fem, R tmt, 9 phal, R scap	13
CM Av36331	*Stictocarbo punctatus*	sL tt, dL tt, dR ulna	3
AU9718	*Cyanoramphus* sp.	R ulna	1
AU4165.12–13	*Sphenodon* sp.	LR dentary	2
AU4165.4	Seal		
AU4150.4	Seal		

Appendix 2 Radiocarbon dates from Cape Wanbrow, Oamaru. The conventional radiocarbon ages (CRA) are revised as defined by Stuiver & Polach (1977). ORB, Old Rifle Butts; NA, not applicable. NZ3142–3144 were from within Ruby Gully.

Lab. no.	Site	Sample	CRA yr BP	Collagen yield
NZ1587	South side of Cape Wanbrow: shelly basal conglomerate of Hillgrove Fmn	Shell *Cucullaea* cf. *worthington*, *Perna canaliculus*	33 186 ± 1264	NA
NZ3092	Oamaru: 150–200 m south of Caledonian Road	Moa bone frags: pooled sample	20 233 ± 386	?
NZ3093	Oamaru: 150–200 m south of Caledonian Road	Moa bone frags: pooled sample	32 415 ± 1746	19.2%
NZ3142	J41/f8215, south side Cape, at entrance to narrow gully at north end of ORB: zone immediately above peat buried by 2 m of loess	Peat	33 711 ± 1215	NA
NZ3143	J41/f8218, south side Cape, at entrance to narrow gully at north end of ORB: upper 4 cm of buried peat at 2 m depth	Peat	11 804 ± 92	NA
NZ3144	J41/f8219, south side Cape, at entrance to narrow gully at north end of ORB; lower 4 cm of buried peat at 2 m depth	Peat	27 438 ± 689	NA
NZ4743	J41/f50, AU4458, loess behind railway line, Boatmans Harbour (original sample from J41/f49, south side of Cape, 30 m west of Ruby Gully, top of loess cliff, AU4484 was lost)	Bone frags *Pachyornis elephantopus*	22 576 ± 352	22.5%
NZ4753	J41/f8230, 20 m east of Ruby Gully, 7 m above base of cliff or 3–3.5 m above base of Hillgrove Fmn	R fem *P. elephantopus*	26 457 ± 846	26%
NZA3609	J41/f8226, fossil cave in Ototara Limestone, west of Ruby Gully	*Eudyptula* bones	30 180 ± 440	1.25%