Fossil distribution of brown teal (*Anas chlorotis*) in New Zealand

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ABSTRACT

The distribution and relative frequency of brown teal (*Anas chlorotis*) among duck remains in Holocene fossil deposits on the North, South, and Stewart Islands of New Zealand are reviewed. Remains of brown teal, representing 641 birds, are reported from 73 widely distributed sites throughout New Zealand. The fossil sites indicate the prehistoric use of a large range of palaeohabitats including coastal sites, lakes, swamps, and forests as diverse as wet podocarp and dry beech forests up to 700 m altitude. There is often no direct association of these forest sites with aquatic habitats such as rivers or ponds, indicating that brown teal were foraging often at considerable distances from such features while in forests. In the seasonally drier eastern regions, brown teal were confined more to aquatic habitats. This may have been the result of competitive exclusion with Finsch's duck, which dominated terrestrial habitats, rather than habitat incompatibility.

Keywords: brown teal, *Anas chlorotis*, fossil deposits, distribution, palaeohabitats.

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1. Introduction

The brown teal (*Anas chlorotis* G.R. Gray, 1845) is a small duck endemic to the main islands (North Island, South Island, Stewart Island, and associated islets) and the Chatham Islands of New Zealand. It is recognised as a distinct species as originally described following Oliver (1955), Kennedy & Spencer (2000), and Holdaway et al. (2001), Worthy & Holdaway (2002). Its nearest relatives are flightless congeners on Auckland Island and Campbell Island.

Brown teal were abundant historically throughout the North and South Islands. It was common in kahikatea (*Dacrycarpus dacrydioides*) forest swamps. It was most commonly found by day sheltering beneath overhanging vegetation in quiet waterways, and was known to feed by night in a variety of habitats including lakes and in drains (e.g. Buller in Turbott 1967). However, within 40 years of Buller's 1888 account, brown teal were noticeably declining in numbers, a trend that was related to loss of habitat (Oliver 1955, Turbott 1967). The wide variety of habitats used is summarised by Marchant & Higgins (1990), but includes estuaries, tidal flats, beaches, rivers, hill swamps, gully-heads, mountain lakes, pasture, and forest.

The decline in numbers of brown teal has continued until the present day (Oliver 1955, and references in Williams 2001), a decline described most recently as 'arguably, more dramatic than any other of New Zealand's endemic birds' (Williams 2001). At present (2002), the species exists in the South Island as a very few birds in Fiordland, and in the North Island by small and declining populations in Northland. Even the population on the apparent stronghold of Great Barrier Island is declining, with all populations in imminent danger of extinction.

The aim of the present report is to clarify the prehistoric distribution of brown teal and the broad habitat (plant/landscape) characters with which remains have been associated throughout New Zealand, through an examination of fossil evidence. From these data I comment on the habitat preferred by brown teal prehistorically.

2. Methods

The fossil distribution is only assessed for the main islands of New Zealand (North, South, and Stewart Is); records from Chatham I. are not assessed. Figure 1 shows the distribution of fossil sites that were assessed for the presence of brown teal.

Data on the frequency and distribution of brown teal and other anatids were extracted from a database maintained by Palaeofaunal Surveys. Constituent data are derived from all published literature, particularly Worthy (1997a, 1997b, 1998a, 1998b, 1998c, 1998d); Worthy & Holdaway (1993, 1994, 1995, 1996,

2000); Worthy & Swabey (2002), Worthy et al. (2002) and unpublished theses and reports, particularly Millener (1981) and McGovern-Wilson (1986). All major sources are listed in the references. Archaeological data are based on Worthy (1999) and all the references cited therein.

Data from all sites (Appendix 1) are compiled into regional categories for the following selected anatids to show their relative abundance as fossils in each region (Table 1): Finsch's duck (*Chenonetta finschi*), formerly in the endemic genus *Euryanas*, but recently referred to the Australian wood duck genus *Chenonetta* (Worthy & Olson 2002), grey teal (*Anas gracilis*), grey duck (*Anas superciliosa*), blue duck (*Hymenolaimus malacorhynchos*), scaup (*Aythya*

TABLE 1. FREQUENCY OF SELECTED ANATIDS IN FOSSIL SITES BY REGION IN NEW ZEALAND. SITES WHICH ARE KNOWN TO BE EXCLUSIVELY OLDER THAN HOLOCENE IN AGE ARE EXCLUDED. DATA, FROM PALAEOFAUNAL SURVEYS DATABASE, ARE AVAILABLE ON REQUEST.

	BROWN TEAL[1]	FINSCH'S DUCK	GREY TEAL[2]	GREY DUCK	BLUE DUCK[3]	SCAUP[4]	MERGANSER[5]	TOTALS
Northland dunes	12	4	5	4	0	4	1	27
Waitomo karst	50	36	0	2	6	3	0	94
Hawke's Bay	7	14	0	2	1	3	1	26
Lake Poukawa (Horn 1983)	421	46	338	355	0	165	2	1327
Inland Wairarapa	10	294	0	1	0	0	0	305
Coastal Wairarapa/ Wellington	3	1	0	4	1	0	0	9
Takaka Hill & Valley	47	5	0	1	12	0	0	64
Mt Arthur/Owen	0	3	0	0	0	0	0	4
West Coast karst	4	2	0	0	2	0	0	8
Inland North Canterbury	16	100	3	4	0	5	0	128
Inland South Canterbury	9	133	0	0	3	0	0	145
North Otago	8	57	0	2	0	1	0	68
Central Otago	1	60	0	0	0	0	0	61
Southland	13	270	0	0	3	0	3	289
Coastal (Delaware /Marfells Bch)	27	3	2	15	1	12	10	70
Stewart I. (Masons Bay/Native Island)	13	0	0	0	0	0	9	22
Total	641	1028	348	390	29	193	26	2655

[1] Brown teal have been recorded from 11 North Island, 16 South Island, and 1 Stewart Island (Old Neck) archaeological sites in addition to the natural fossil sites (Worthy 1999) (Fig. 3).

[2] In addition to the natural sites listed in Appendix 1, this species has been recorded in archaeological sites as follows: Taranaki (Kaupokonui, P21/3; Ohawe, N129/77); Coastal northern South Island (Marfells Beach P29/2; Haulashore Island, Nelson 027/56); North Canterbury (Redcliffs, S84/76; Whalers Bay Cave, 031/12); South Canterbury (Gooseneck Bend, H39/16, 1); North Otago (Pleasant River; Shag Mouth, J43/2); Southland (Riverton, D46/35; Tiwai Point, E47/13; Lee Island S131/4). Most if not all these records need to be treated with caution as the basis on which they were separated from brown teal was not given, and it is now known that the wing elements of both taxa widely overlap in size and are generally not distinguishable.

[3] Archaeological records for this species include at least one site in Central Otago (Hawksburn).

[4] Some of the Waitomo karst and Northland dune records require reassessment as Millener (1981) often confused scaup with brown teal (THW pers. observ.).

[5] Additional records of this taxon are known from archaeological sites in the Hauraki Gulf (Ponui Island N43/1), Wellington coast (Paremata N160/50), Marfells Beach P29/2, North Otago (Kakanui J42/4, Shag Mouth J43/2), and Old Neck on Stewart Island.

novaeseelandiae), and merganser (*Mergus* sp.). The Auckland Island merganser (*Mergus australis*) was known historically only from the Auckland Is. Fossil *Mergus* bones of Holocene age from Chatham I. have been suggested to be from a distinct taxon (Millener 1999), but no comparative study of the available material has been completed yet. *Mergus* bones of Holocene age from widespread sites in mainland New Zealand have not been studied, and so may be referable to *M. australis*, the Chatham I. form if it is indeed distinct, or to a third distinct taxon.

In order to better associate fossil localities with palaeohabitats, the analysis was restricted so far as practical to sites known or likely to be of Holocene age, as then palaeovegetation is much easier to reconstruct. Sites or faunas (if there are discrete faunas in a single site) known to be older than 10 000 years were not included. However, as surface-collected bones from some caves may include older material because time-averaged deposits are common in New Zealand caves (Worthy & Swabey 2002), undated individual bones/skeletons that are actually older than 10 000 years may be included.

3. Results

3.1 DISTRIBUTION OF BROWN TEAL

Brown teal bones representing at least 641 individuals are recorded from 73 fossil sites (Figs 1, 2). The given frequency data is an under-estimate as data for three significant sites (Honeycomb Hill Cave complex, Megamania Cave, Poukawa N141/1-2) were not available. As these data are mainly based on literature records, there will likely be other unpublished records available from museum collections, but those given reveal the pattern of distribution and relative frequency of brown teal in relation to other anatids. The distribution of archaeological sites with brown teal remains is shown in Fig. 3.

3.2 NORTHLAND DUNES

The Northland dunes that have revealed most fossil deposits in the Far North of New Zealand include the dune fields of Doubtless Bay (Tokerau Beach) and others on the Karikari Peninsula, and those along the east coast of Aupouri Peninsula to North Cape and around to Cape Maria Van Diemen. All fossil deposits are in palaeosols developed under terrestrial vegetation; none are swamp or lake deposits. The data here are based on Millener (1981), who provided the latest summaries for each site. A considerable amount of more recent collecting by Brian Gill (Auckland Institute and Museum), Alan Tennyson (Museum of New Zealand Te Papa Tongarewa [MNZ]), and Worthy (MNZ) has occurred, but summary data are not yet available. Anatids are a minor component of these faunas as shown by the total minimum number of individuals (MNI) of just 27. However, brown teal was the most abundant anatid

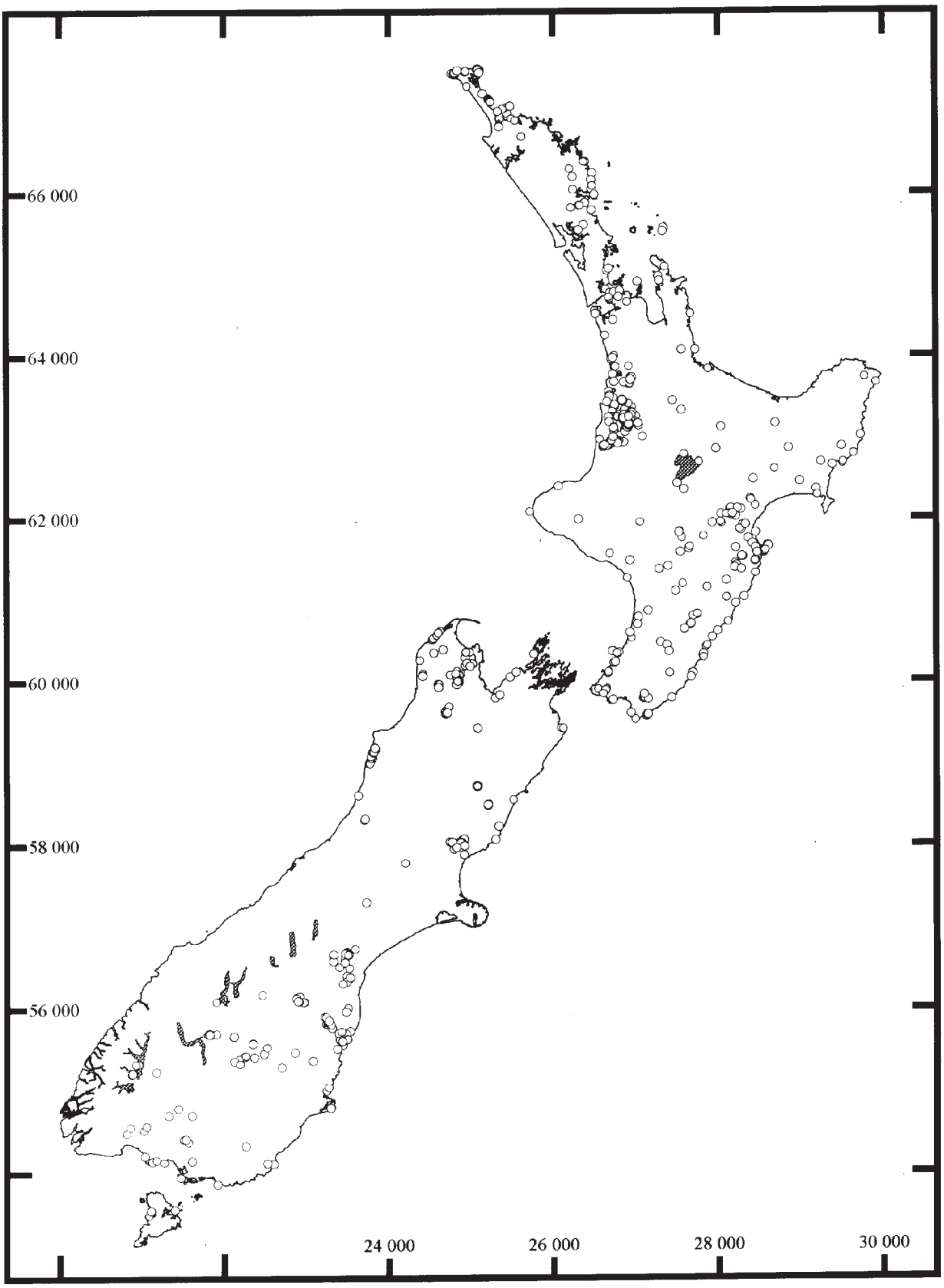

Figure 1. Map of New Zealand showing the location of all fossil sites whose faunas were assessed for the presence of *Anas chlorotis*. The NZMS 260 map grid is indicated on the border.

Figure 2. Map of New Zealand showing the fossil sites where remains of *Anas chlorotis* are reported herein, with the 1000 m contour.

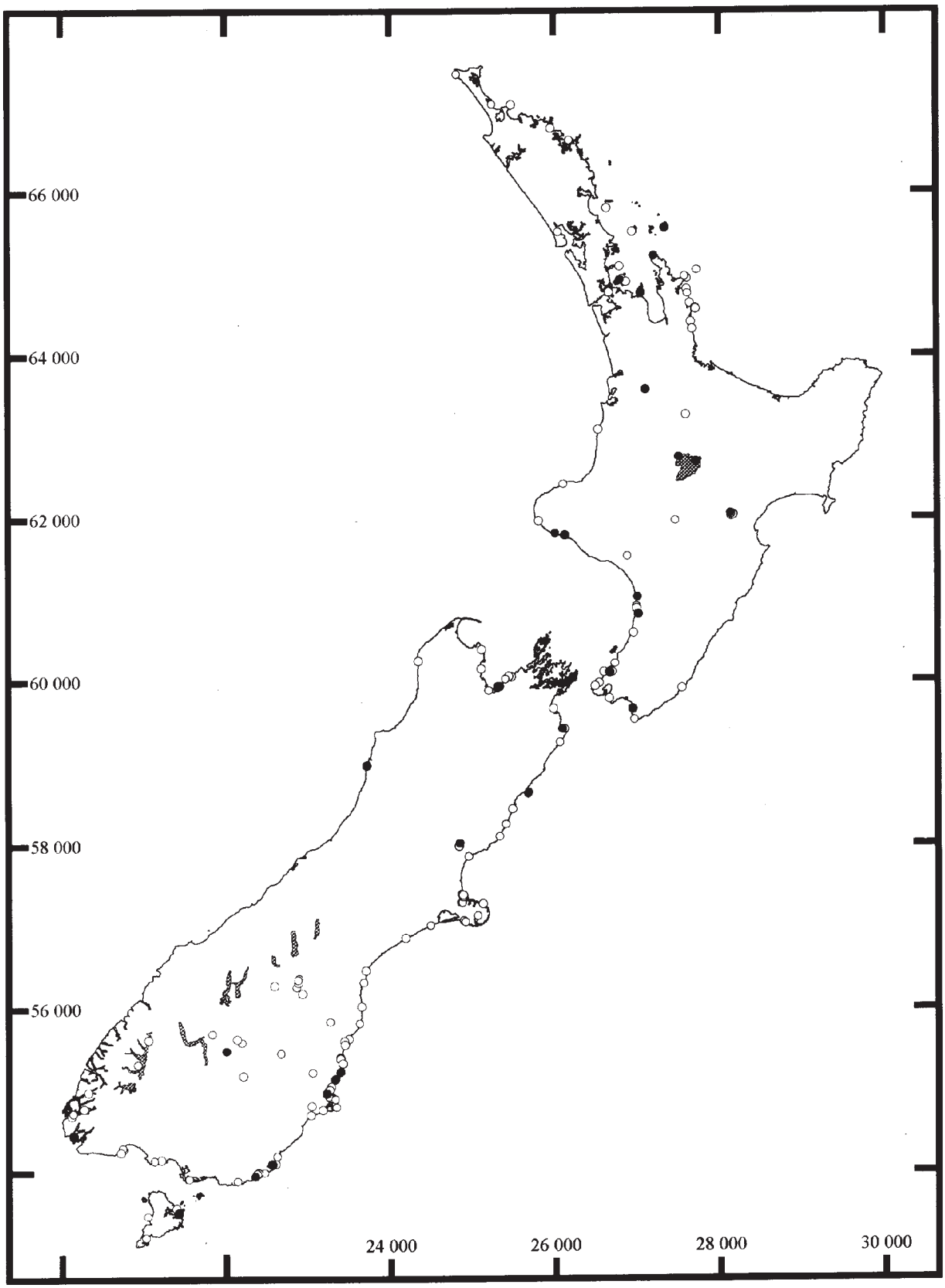

Figure 3. Map of New Zealand showing sites where archaeological faunas have been obtained (open circles), with those containing *Anas chlorotis* (filled circles). The NZMS 260 map grid is indicated on the border.

species, and is likely to be underscored as the records of grey teal probably pertain to brown teal.

The palaeovegetation of the dunes in the Far North were reconstructed by Atkinson & Millener (1991) as a mosaic of coastal broadleaf/podocarp forest, coastal scrub, and dune grasslands. Most dune sites were not directly associated with wetlands, though small streams flowed through some areas, e.g. the Tokerau Beach dunes, and swamps and small lakes backed on to some areas, e.g. Cape Maria van Diemen. Atkinson & Millener (1991) listed brown teal and Finsch's ducks as aquatic insectivores that were forest inhabitants. As brown teal was 3–4 times more abundant than typical aquatic ducks (grey duck, scaup), the suggestion that it was of more than incidental occurrence in these deposits is supported.

3.3 WAITOMO KARST

The Waitomo karst is in the area between the Awakino and Waikato Rivers west of the Waipa River centred on Waitomo Caves in the west of the North Island. The karst landscape is developed mainly between the altitudes of 300 and 500 m a.s.l. Anatids are relatively abundant in fossil sites in the Waitomo karst and brown teal is the most abundant species overall. All fossil faunas come from cave deposits, which are often time-averaged (Worthy & Swabey 2002). This means, specimens of disparate ages are often grouped as single faunas. As Finsch's duck was mainly a shrubland inhabitant, most of the Waitomo records for this species may be of Pleistocene age, and so the true frequency of Finsch's duck in the Waitomo karst during the Holocene may be lower than indicated in Table 1.

One of the most important sites for brown teal fossils in the Waitomo area is F1c Cave (Worthy 1984). There, brown teal were abundant in the upper layers, Layers 2 and 4. The site is a pitfall trap adjacent to a small (10 × 30 m) flat depression in a broad valley floor. This depression was assumed by Worthy (1984) to have been a swampy and relatively open area that seasonally held water. While *Carex* sedges and treeferns were on the margins of this 'wetland', a podocarp forest (matai *Prumnopitys taxifolia*, rimu *Dacrydium cupressinum*) with associated hardwoods like tawa (*Beilschmiedia tawa*) formed a tall closed canopy forest all around the site. No streams flow on the surface in the valley around the site, and the nearest is 1–2 km distant.

While the presence of Finsch's duck in the Holocene is verified by its bones in the stratified sequence in F1c Cave (Worthy 1984; Worthy & Swabey 2002), the data from F1c cave show changes in relative frequency of brown teal and Finsch's duck over time. In the 1500–2000 ^{14}C years BP Layers 2 and 4, brown teal were three times as abundant as Finsch's duck, whereas in the 12 000 ^{14}C years BP Layer 8, there were three Finsch's duck and only one brown teal. This faunal change is paralleled by other changes in the compared avifaunas which Worthy & Swabey (2002) related to changes in the vegetation around the site. Regionally, the vegetation was dominated by shrubs in the late glacial, which were rapidly replaced by a closed forest in the earliest part of the Holocene. In the Pleistocene deposits of Gardners Gut Cave (Worthy & Swabey 2002),

Finsch's duck dominates the anatid fauna. The presence of Finsch's duck at F1c in the late Holocene may relate mainly to the presence of the small forest opening that was postulated to have been around the site.

Atkinson & Millener (1991) reconstructed the palaeovegetation of the Waitomo karst for most of the Holocene as a rimu/tawa forest. Podocarps, mainly rimu with some miro (*Prumnopitys ferriginea*), and northern rata (*Metrosideros robusta*) emerged over a tawa canopy. Hinau (*Elaeocarpus dentatus*) and mangeao (*Litsea calicaris*) were also common canopy components, with kamahi (*Weinmannia racemosa*) on steeper slopes. Shrublands and grasslands were absent or very rare in this area during the Holocene, and the only wetlands were small streams. The incidence of brown teal fossils can be interpreted a lot more strongly than that they 'may have used vegetated areas beyond stream courses' (Atkinson & Millener 1991). Most fossil sites in the Waitomo karst are of pitfall origin, with none known to have been accumulated by predators. As such, fossils have an origin as a live bird at the cave entrance, and as most sites are not stream submergences, and usually are tens to hundreds of metres from streams, it must be presupposed that the birds were using forest near these entrances before they were entrapped.

3.4 HAWKE'S BAY (EXCLUDING LAKE POUKAWA)

The sites grouped under the umbrella of Hawke's Bay include coastal dune sites at Ocean Beach and inland rockshelters. The coastal dune sites were probably formerly vegetated in coastal broadleaf forest dominated by kohekohe (*Dysoxylum spectabile*) and karaka (*Corynocarpus laevigatus*) and were not associated with wetlands. The faunas in the inland sites were accumulated by avian predators, so the teal could have been taken either on wetlands (streams) or in forest glades. There are very few pitfall sites in which to trap faunas, so a direct comparison with Waitomo is not possible.

3.5 LAKE POUKAWA

The fauna from the Holocene deposits of Lake Poukawa, Hawke's Bay, includes the largest collection of anatid remains known from New Zealand. There are two main and several minor sites at this locality and the fauna of only one (N141/12) has been described (Horn 1983). In Table I the values for the named taxon are the total for Layers 1–3 from Horn (1983). However, Horn also listed shoveler (*Anas rhynchotis*) and blue-billed duck (*Oxyura australis*). Specimens attributed to the latter are all now considered to be other taxa but mainly scaup (Holdaway et al. 2000). Several bones of the large extinct anatid, Scarlett's pink-eared duck (*Malacorhynchus scarletti*) were unrecognised as such and were confused with grey duck (pers. obs.). Horn did not state how grey teal was separated from brown teal, but it was probably on size, and as lengths of wing bones (most common elements by far) overlap in their ranges considerably (Worthy & Holdaway 1994) the identity of all small *Anas* bones needs reappraisal.

In the early 1980s, the entire collection from all Poukawa sites was identified by P.R. Millener, but summary data have not been generated from these identifications (some 20 000 specimens). Recent reappraisals of some of the identifications show many problems that preclude an accurate assessment of the anatid fauna. Firstly, several rare taxa have been either overlooked (e.g. *Malacorhynchus scarletti*), or infrequently recognised (e.g. *Mergus*, *Biziura delautouri*). Smaller anatids were generally not identified and were labelled only as 'anatid sp.', and where identities were given, much confusion between shoveler, brown teal, grey teal and scaup bones is apparent. The Poukawa collection is in urgent need of reappraisal so that the relative frequency of anatids in a prehuman lacustrine fauna can be quantified.

However, brown teal were a very abundant component of the Poukawa fauna. It remains to be seen whether grey teal and shoveler were as abundant as Horn's data suggest. Throughout the Holocene, Lake Poukawa was a shallow lake surrounded by tall podocarp forest dominated by matai, with a few forest openings (Wilmshurst et al. 1997).

3.6 INLAND WAIRARAPA

Only a single site has revealed brown teal bones in the inland karst ranges of the Wairarapa. Karst areas occur mainly in the Waewaepa and Puketoi Ranges near Makuri, and in the Ruakokoputuna–Haurangi Range area. Sites in these regions are mainly pitfall traps. There are two major sites, each with thousands of bones: the Coonoor site on the Waewaepa Range, a pitfall trap excavated about 1914; and Martinborough #1 (Haurangi Range), which was discovered in 1901 and excavated at various times, notably 1920, 1956, and in the 1960s. While much material from each site remains to be identified and accessioned into the collections, the many hundreds of bones that have been catalogued probably fairly indicate the composition of the source faunas. Brown teal are only known from Coonoor, and, while the fauna is undated, a site in the impure limestone of this area is likely to be geologically young (a few thousands of years at most) and can be expected to be of Holocene age. The Holocene vegetation in this area was a closed-canopy podocarp forest in a fairly wet climate (c. 2000 mm per annum).

The absence of brown teal from Martinborough #1 probably means the species was absent from the surrounds of this site, as many hundreds of other individual birds were represented. The site is located on a ridge in the Haurangi Range, which has a much lower rainfall than the Waewaepa Range. Finsch's duck was common in Martinborough #1, with Millener (1981) recording a minimum of 277 individuals. An extensive series of radiocarbon dates on the site (R.N. Holdaway pers. comm.) indicates the material accumulated only in the last 3000–4000 years, so we can assume the present climate and nearby vegetation is representative of that which surrounded the site during deposition of the fauna. Seasonal drought is common and. the nearby forest is dominated by mountain beech (*Nothofagus solandri*) with a few podocarps such as totara (*Podocarpus totara*) likely to have been emergent.

3.7 COASTAL WAIRARAPA/WELLINGTON

I have separated out the sites in the coastal fringe of the Wairarapa–Wellington region as the moa fauna of this zone indicates a different environment from that immediately inland. There was a thin zone of dune grassland and coastal scrub that backed onto a broadleaf forest (karaka/kohekohe) along much of this coast. The fossil sites are all in the dunes or swamp deposits behind beach ridges. Fossil faunas are only just beginning to be developed from the sites in this zone, as in the past only moa bones were routinely collected. As a result, very small non-moa faunas are as yet available.

A diverse fauna from high dunes north of the Mataikona River, deposited under a coastal forest or scrub with no associated wetlands at about 100 m a.s.l., includes brown teal. In contrast, at Te Kaukau Point a swamp deposit behind a raised beach ridge preserves a mixture of wetland and terrestrial species, including brown teal. Most recently, brown teal has been recorded from a coastal swamp deposit at Tora on the Wairarapa coast (A. Tennyson, pers. comm.). So it may be expected that brown teal used the coastal forest and swamps along the foot of the hill behind coastal terraces along the Wairarapa coastline.

3.8 TAKAKA HILL

All the brown teal listed for the Takaka region are from pitfall sites on Takaka Hill (Worthy & Holdaway 1994). None of these sites are near streams and the area was or is vegetated in a silver beech forest (*Nothofagus menziesii*), with some cedar (*Libocedrus bidwilli*) and rare podocarps such as totara (*Podocarpus totara*) contributing to the canopy. The most important site is Hobsons Tomo, which had a spectacular assemblage of small birds including many ducks. Radiocarbon dating of the main deposits (Worthy & Holdaway 1994) indicates deposition has occurred from the present day back in time to at least 14 000 ^{14}C years BP. The old date was on a Finsch's duck bone, and it is assumed from morphometrics that all four Finsch's duck individuals, none of which was visible on the surface, were of pre-Holocene age. But there were also three blue duck and 38 brown teal present, most if not all of which will be of Holocene age. There is no wetland of any sort near the site, and the nearest is over 1 km distant. The evidence of this and several similar sites with fewer birds shows that brown teal and blue ducks were using areas far from streams on Takaka Hill.

3.9 MT ARTHUR AND MT OWEN, NORTHWEST NELSON

These two localities have been separated out because they provide samples from the subalpine zone above the treeline, an area otherwise rarely represented in fossil deposits. No brown teal are known from sites close to or above the treeline in New Zealand, but that Finsch's duck did use these habitats

is shown by its presence in at least three sites. This is not just a function of taphonomy as other similar-sized birds such as kakapo (*Strigops habroptilus*), weka (*Gallirallus australis*), and kiwi (*Apteryx* spp.) are common in subalpine sites.

3.10 WEST COAST KARST

The data for the West Coast in Table I do not include any individuals from the Honeycomb Hill Cave System in the Oparara River headwaters. Some 20 km of surveyed passages in this system contain at least 70 discrete fossil sites known to be up to 20 000 years old (Worthy & Mildenhall 1989; Worthy 1993). Brown teal are known from some of these sites, but summary data are not available. Similarly, Megamania Cave in the Gunner River has many discrete fossil sites and I observed brown teal in several of these in 1998, though most were not collected. Both these cave systems lie in a mixed podocarp/ beech forest in a high rainfall area (c. 3000 mm per annum) at low altitude. The main canopy trees are rimu and red beech (*Nothofagus fusca*), with kamahi and rata on higher or steeper slopes, and there is a dense understorey with abundant lianas (kiekie *Freycinetia banksii* and supplejack *Rhipogonum scandens*), and moss covers most surfaces.

The rest of the data from the West Coast are derived from studies in the Punakaiki karst, mainly between Charleston and Fox River (Worthy & Holdaway 1993). Anatids were rare in the combined fauna from this area, which may be partly because rich pitfall faunas of birds smaller than moa were lacking. The Holocene vegetation is assumed to be much like that present in the area now and is very similar to that in the Gunner River and the Oparara, described above.

3.11 COAST OF NORTHERN SOUTH ISLAND

Around the coast of the northern South Island from Nelson to Marlborough there are a number of fossil sites in dunes. The most significant of these are Delaware Bay, Marfells Beach, and an eroding dune south of Mussel Point, just east of Marfells Beach. All have brown teal remains in them. The Delaware Bay site is on a spit between the estuary and the ocean, so the presence of brown teal indicates probable use of the estuary. The Marfells Beach site is similarly located on a spit seaward of an extensive shallow lagoon, while the site south of Mussel Point is on a coastal flat beside a rocky shore. All three sites indicate the late Holocene use of coastal habitats by brown teal. The extensive data for the Marfells Beach site in particular (Worthy 1998c) shows that brown teal were the most numerous anatid in a very diverse fauna (Table 2). It was markedly more common than any of the more aquatic ducks, and only the paradise shelduck (*Tadorna variegata*) approached it in abundance, perhaps reflecting the presence of a large area of saltmarsh in which to graze.

TABLE 2. A COMPARISON OF THE ANATID FAUNAS FROM PYRAMID VALLEY AND MARFELLS BEACH.

	PYRAMID VALLEY	MARFELLS BEACH
Brown teal	11	39
Finsch's duck	5	3
Paradise shelduck	5	33
Grey duck	3	8
Grey teal	3	2
Scaup	5	5
Scarletts pink-eared duck	7	1
Black swan	0	22
Blue duck	0	1
Merganser	0	2
Musk duck	0	1

3.12 INLAND NORTH CANTERBURY

Within the North Canterbury region I am including sites on Mt Cookson and others around Waikari described in Worthy & Holdaway (1995, 1996). Holocene Hole is a pitfall trap on the Mt Cookson plateau, and the surrounding area was vegetated in a mountain beech forest in the late Holocene, while this deposit accumulated. No wetland is near this site, in which two brown teal were present. All the other records come from sites near Waikari. Three (Glencrieff, Pyramid Valley, and The Deans) are wetlands—a spring, a lake, and a swampy earth flow, respectively. The fourth site, Waikari Cave, is a pitfall (the only one in the area), but is within a few tens of metres of a stream.

The anatid fauna of Pyramid Valley lake (Table 2) is significant as it shows that, in this shallow pond that was surrounded by tall matai forest during the period of deposition, brown teal were the most common duck. The absence of an aquatic macroflora is probably the reason why black swans (*Cygnus atratus*) were absent. One of the significant aspects of recent reassessment of the fauna at Pyramid Valley was that it revealed that grey teal were present prehistorically (Worthy & Holdaway 1996; Holdaway & Worthy 1997), apparently living with brown teal. While the regional fauna appears to be dominated by Finsch's duck, this is mainly due to the large numbers from the pitfall site of Waikari Cave. Finsch's duck was derived from the wood duck (*Chenonetta jubata*) of Australia and is inferred to have been a grazing duck of terrestrial habitats (Worthy & Olson 2002). The drier regions in the east of the South Island afforded far greater areas of open vegetation, for example, scrub and grassland on the extensive river beds and on the higher slopes of hills, or on poorer soils, on which a grazing duck could feed. The Waikari Cave sample shows that in the Waikari area, Finsch's duck dominated anatid faunas away from wetlands: it is much less common than brown teal in Pyramid Valley.

3.13 INLAND SOUTH CANTERBURY

The faunas for inland South Canterbury are derived from the limestone areas of the inland downlands (Worthy 1997a). The sites include a mixture of swamp springs, pitfall traps in caves, and many predator sites accumulated by laughing owls or falcons. The area is gentle rolling hill country 200–400 m a.s.l., and during the late Holocene was probably vegetated in podocarp forest (matai-dominant), with river flats containing areas of shrubland and grassland.

Most brown teal records came from the rich pitfall trap of Kings Cave. This site is located on the side of a hill about 100 m distant from a small valley and stream. Three dates are available from the site which all show a late Holocene period of accumulation (Worthy 1997a). Of the 281 birds represented in the fauna, 100 are Finsch's duck, 68 are kiwi, 20 weka, and 38 are kakapo (*Strigops habroptilus*), demonstrating the overall terrestrial nature of this fauna. The only typically dabbling duck was grey duck represented by one modern bone, but there were at least three blue ducks and seven brown teal, illustrating the propensity of these species to be found distant from waterways.

3.14 NORTH OTAGO

The North Otago faunas are derived from the area south of the Waitaki River that lies towards the coast from Duntroon in the limestone downlands (Worthy 1998a). Here, brown teal occur in at least two of the several fossil-bearing swamp deposits that have been discovered in the valleys between low limestone hills. In some valleys there are limestone cliffs in which predator accumulations have been found, and brown teal are in two of these sites. There is only a single pitfall site (Ngapara), which is located a few hundred metres from any stream and is not near any ponds. The Ngapara site accounts for most of the Finsch's duck individuals, indicating that, in this region as in inland Canterbury, Finsch's duck dominates the anatid fauna of terrestrial ecosystems.

The rolling hills of this area were probably vegetated much the same as the inland South Canterbury region discussed above. However, in the broad swampy valleys that typically lie between the hills, a swamp forest probably dominated by kahikatea was present, although other wetland podocarps such as yellow silver pine (*Lepidothamnus intermedius*) may have been present.

3.15 CENTRAL OTAGO

The single record of brown teal for central Otago comes from Earnscleugh Cave near Alexandra (Worthy 1998a). The fauna in this site is derived from both a pitfall and a predator accumulation. The site is several hundred metres up the side of a slope from the nearest stream. This site trapped most of the individual Finsch's duck represented in the combined fossil fauna of the region, again reaffirming the dominance of this duck in dry eastern terrestrial ecosystems.

3.16 SOUTHLAND

In Southland, most of the brown teal bones come from pitfall sites in low limestone ridges east of Winton (Worthy 1998b). While no brown teal bones are known from the several fossiliferous swamps in the region, this is probably more due to inept collection of material than their absence, as virtually no birds other than moa have been obtained from such sites. The 'site' termed Forest Hill Tomos is a general name for an unknown number of tomos or vertical pitfalls at Forest Hills, from which all the separate faunas were amalgamated as one, by the time of their study in the Otago Museum in 1997 (Worthy 1998b). Castle Rocks is the only one of the brown teal-bearing faunas to have been dated: a large series of radiocarbon dates indicates deposition during the late Holocene (R.N. Holdaway pers comm.). However, as most of the other collections are from surface deposits, a Holocene age is probably applicable to all. During this period the limestone ridge east of Winton (wherein lie the Forest Hills and McKerchars Cave sites) was clothed in tall rimu-dominated podocarp, forest.

In the regional avifauna, Finsch's duck dominate the anatid fauna as they do in other eastern areas with low rainfall, because of their abundance in some tomos.

3.17 STEWART ISLAND

Natural fossil sites are rare on Stewart Island, with the main locality being the dunes of Mason Bay. However, seabirds dominate there, with few land or freshwater birds recovered to date (Worthy 1998f). The most important site otherwise is a dune site on Native Island which is accessible from the main Stewart Island by wading at low tide (Worthy 1998d). There is no freshwater on Native Island, so the ducks present must have either been using the vegetated island habitat or the shoreline, which is very sheltered, being within Paterson Inlet. On Native Island, brown teal were associated with mergansers, grey ducks, paradise shelducks, and black swans, all known to use or have used marine habitats. Finsch's duck is not recorded from Stewart Island.

4. Discussion

The interpretation of the fossil deposits rests on the assumption that the birds represented were living in the immediate environment of the fossil site at the time of their death. In no site in New Zealand is there evidence that brown teal bones were washed a significant distance, and so we can assume that the birds lived in the habitats surrounding the site. Secondly, it is also assumed that while the presence of one or two individuals may represent a random event, such as a storm-blown bird, the presence of several birds suggests that a population was present in the area of the site. This further necessitates acceptance that the birds were at home in the surrounding environment.

In this review of the distribution of brown teal fossils, I have compiled data for 641 birds from 73 sites of mostly Holocene age. Finsch's duck excluded, brown teal were the most abundant anatid in all regions of New Zealand. Because of the difficulties of identifying the exact habitat that surrounded a fossil site during the period of deposition, and as fossil sites, with few exceptions, do not have more than one or two individual brown teal, a tight correlation between habitat type and relative frequency of anatids cannot be made. However, some useful insights into the variety of habitats brown teal used were obtained from amalgamating faunas from relatively small geographic regions likely to have had similar vegetation and climatic characteristics.

5. Broad trends from regional analyses

Brown teal were the most abundant species in all lacustrine habitats for which fossils are available, so they were formerly common on lakes. The data, especially those from sites such as Lake Poukawa and Pyramid Valley, support the historical observations that brown teal preferred deep and quiet waterways with overhanging vegetation and dense kahikatea swamps. However, brown teal used to occupy a very much broader range of habitats than lakes and rivers, a range that was wider than that of any other anatid in New Zealand. Such additional habitats included coastal dunes, lagoons, and swamps, inland forests as diverse as wet rimu forests and seasonally dry matai forests in low rainfall areas, to montane silver beech and dry mountain beech forests up to 800 m altitude. Use of such forests was not restricted to swamps or streams within them, as some fossil sites located several kilometres from any wetland indicate use of forest habitats far removed from wetlands. Generally, within a region, and in all habitats where brown teal occur, there is no predilection for water evident in the data. Thus, the historical observations that suggested a preferred habitat of quiet waterways and similar sites are doubtless the result of ease of observations from waterways compared with those made deep within forests.

The only places brown teal may have usually avoided were the subalpine zone above the tree line and perhaps also the driest forests of eastern regions such as on the Haurangi Range in the Wairarapa. In the dry eastern regions, where mosaics of forest, grassland, and shrubland occurred widely during the Holocene, Finsch's duck dominated terrestrial sites and was apparently very abundant. As such it may have competed with brown teal, excluding it from the more terrestrial habitats in these regions.

That the decline in brown teal numbers was first noticed not long after the introduction of mustelids suggests that predation by these was at least partly responsible for this decline. However, that the species went extinct on both Chatham I. and Stewart I., and are declining on Great Barrier Island, all places where mustelids are absent, suggests they are not the sole cause. The main predators on Stewart I. and Chatham I. are cats (*Felis catus*), Norway rats

(*Rattus norvegicus*), and ship rats (*R. rattus*), indicating that brown teal populations cannot tolerate predation by one or other, or a combination of, these predators.

The fossil data cannot be analysed with statistical rigour that might lead to significant correlations with habitat types on a site-by-site basis. However, when site data are amalgamated into regions wherein constituent sites have similar climate and vegetation variables, patterns if present should be evident. For example, we then see that Finsch's duck is a common and abundant species only in areas with mosaics of shrubland and forest, mainly the drier eastern regions. The dominance of brown teal relative to other anatids (exclusive of Finsch's duck) in composite faunas from each of the regions for which data are available, shows that brown teal was at home in a wide variety of habitats. The principal conclusion from these data is that brown teal did not have a preference for any specific habitat. It was a habitat generalist that could use any forest or wetland habitat below about 800 m, with the exception perhaps being the dry forests in areas receiving less than about 1000 mm rain annually. Therefore, the decline in brown teal populations throughout the last 100 years cannot be linked solely to loss of habitat. Conversely any of a wide range of surviving forest and wetland habitats should be suitable for the survival of populations of brown teal if mammalian predation is removed.

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Appendix 1

LIST OF FOSSIL SITES AND MINIMUM NUMBER OF INDIVIDUALS (MNI) FOR DUCK SPECIES NAMED IN TEXT

Under 'Notes' the reference to the original data source or a Waitomo Caves Museum catalogue number is given (WO). Grid north and Grid east values are from the NZMS 260 series maps.

SITE	MNI	NOTES	GRID N	GRID E
Brown teal (*Anas chlorotis*)				
Albury Park, spring site	1	Worthy (1997a)	56662	23327
Aussie Cave	1	Millener (1981)	62890	26662
Babylon Cave – Passage of Thoth	1	Worthy & Holdaway (1993)	59063	23788
Barnes Cave	1	Millener (1981)	63243	26921
Blacksands Cave, Waikorea Valley = site 29	1	WO181	63954	26711
Bone Cave, Canaan	1	Worthy & Holdaway (1994)	60289	25011
Bushface 1	3	Worthy & Holdaway (2000)	62052	28173
Cairn's Tomo	1	Worthy & Holdaway (1993)	58995	23777
Cave on Kape Te Kanawa's farm, Waitomo	3	WO190	63254	26916
Cave on Mahoe Rd, Waitomo	1	WO73	63236	26860
Cobden Quarry site	1	Pers. obs. THW	58605	23634
Coonoor	10	Millener (1981)	60824	27744
Cutthroat Cave, Waitomo	1	Millener (1981)	63115	26901
Dartmoor Rockshelter	1	Worthy & Holdaway (2000)	61853	28274
Delaware Bay, dunes	1	THW coll MNZ	60050	25483
Earnscleugh Cave	1	Worthy (1998a)	55387	22189
Earthquakes #1, all excav. units	5	Worthy (1998a)	55901	23224
Flc Cave, L2+4	12	Worthy & Swabey (2002)	63117	26903
Footwhistle Cave	1	WO57	63232	26941
Forest Hill tomos	11	Worthy (1998b)	54380	21570
Fred Cave area, tomo 30 m north of 53 m entrance pitch	1	WO14	63117	26903
Gardners Gut, Zweiholen PRM coll.	4	Worthy & Swabey (2002)	63243	26916
Glencrieff Moa Swamp	1	Worthy Holdaway (1996)	58042	24747
Haggas Hole	1	WO133, WO232	63251	26890
Haggas Hole	1	WO159	63251	26890
Hamilton Hole	1	WO74	63146	26917
Henderson Bay, south	3	Millener (1981), loc 25	67150	25240
Hobsons Tomo	38	Worthy & Holdaway (1994)	60209	25017
Holocene Hole	2	Worthy & Holdaway (1995)	58496	25214
Honeycomb Hill Cave	Present	Worthy (1993)	60092	24421
Kings Cave	7	Worthy (1997)	56511	23402
Little Winter Cave	1	Worthy & Holdaway (1994)	60192	24995
MacDonalds Mud Cave	2	WO168	63972	26726
Maniapotos Cave	1	WO80	63194	26995
Marfells Beach	25	Worthy (1998c)	59421	26095
Mason Bay General	8	Worthy (1998d)	53540	21114
Masons Dry Cave	1	Millener (1981), WO398	63174	26924

SITE	MNI	NOTES	GRID N	GRID E
Brown teal (*Anas chlorotis*)				
Mataikona high dune	1	THW pers. obs.	60434	27865
McKerchars Cave	2	Worthy (1998b)	54414	21537
Megamania Cave	Present	Worthy (1998e)	60257	24383
Mt Harris Swamp	1	THW/RNH coll MNZ	55966	23485
Mudball Cave, upper level	1	WO275	63202	26868
Native Island, Stewart Island	5	Worthy (1998d)	53552	21402
Nettletrench Cave	1	Worthy & Holdaway (1993)	59129	23821
Ocean Beach, site 7	1	THW coll MNZ	61594	28556
Ocean Beach, site 7b (by fence just north of site 7)	1	THW coll MNZ	61595	28556
Porthole Cave	1	Millener (1981)	62967	26714
Pothole 3, Canaan	4	Worthy & Holdaway (1994)	60289	25011
Poukawa N 141/12	421	Horn (1983)	61523	28283
Poukawa, N 141/1–2	Many	THW	61525	28296
Prydes Gully Road Swamp	1	Worthy (1998a)	55841	23262
Pukeroa Cave System (Friendly Passage)	1	THW, 1991, WO54	62950	26704
Pyramid Valley	11	Worthy & Holdaway (1996)	58038	24772
Ratite Hole	1	Worthy & Holdaway (1994)	60217	25007
Robbers Hole	1	Millener (1981)	62894	26629
Shangrila Cave	1	WO223	63202	26944
Small cave, Awamoko River	1	Worthy (1998a)	55847	23277
South of Mussel Point, Marfells Beach	1	THW, & Nicholl coll MNZ	59416	26121
St Benedicts Cavern	6	Millener (1981), AU7091 (3), WO399 (2), 410 (1)	63235	26885
St Benedicts Cavern, south passage	3	WO78	63235	26885
Struthoides Cave	2	Worthy & Holdaway (1994)	60189	25000
Te Kaukau Point (White Rock A)	2	Millener (1981)	59569	27127
The Deans, upper Waipara River	1	Worthy & Holdaway (1996)	57958	24794
Tokerau, General	1	Millener (1981)	66993	25447
Tokerau, Main	1	Millener (1981)	66993	25447
Tokerau, South	2	Millener (1981)	66925	25500
Tollops Aven, Mangawhitikau	1	THW, WO11	63180	26934
Tom Bowling, Central	3	Millener (1981), loc 5	67532	25094
Tom Bowling, West	1	Millener (1981), loc 4	67529	25085
Tomo A. near Spotlight	1	Millener (1981)	62930	26791
Totara Swamp Site	1	Worthy (1998a)	55624	23411
Totoro Rd Cave	1	Millener (1981)	62927	26757
Waikaremoana, caves	1	Millener (1981)	62600	28684
Waikari Cave, Waituna Station	1	Worthy & Holdaway (1996)	58063	24894
Whareana Beach	1	Millener (1981), loc 20	67490	25112
Grey teal (*Anas gracilis*)				
Henderson Bay, south	1	Millener (1981), loc 25	67150	25240
Kowhai Beach	1	Millener (1981), loc 26	67135	25248
Marfells Beach	2	Worthy (1998c)	59421	26095
Poukawa N 141/12	338	Horn (1983)	61523	28283
Pyramid Valley	3	Worthy & Holdaway (1996)	58038	24772
Tom Bowling, general	2	Millener (1981), loc 3, probably *A. chlorotis*	67535	25090
Waikuku Bch, North/all	1	Millener (1981)	67526	25119

SITE	MNI	NOTES	GRID N	GRID E
Grey duck (*Anas superciliosa*)				
80 Acre Cave (= PT6, hole the bullock fell down)	1	Millener (1981)	60694	27660
Cutthroat Cave	1	WO1	63115	26901
Enfield Swamp ex NHM coll via Dawson	1	Worthy (1998a)	55722	23431
Falcon Site #1	1	Worthy & Holdaway (1995)	58484	25208
Henderson Bay, south	1	Millener (1981), loc 25	67150	25240
Kairuru Extension	1	Worthy & Holdaway (1994)	60215	25020
Marfells Beach	13	Worthy (1998c)	59421	26095
Ngahau Bay	Present	Millener (1981)	66388	26376
Porthole Cave	1	Millener (1981)	62967	26714
Poukawa N 141/12	355	Horn (1983)	61523	28283
Poukawa, N 141/1–2	Present	THW	61525	28296
Puheke dunes	1	Millener (1981), loc 32	67042	25389
Pyramid Valley	3	Worthy & Holdaway (1996)	58038	24772
South of Mussel Point, Marfells Beach	2	THW, & Nicholl coll MNZ	59416	26121
Te Aute Holocene	2	Worthy (2000)	61425	28224
Te Kaukau Point (White Rock A)	4	Millener (1981)	59569	27127
Tokerau, Main	1	Millener (1981)	66993	25447
Totara Swamp Site	1	Worthy (1998a)	55624	23411
Whareana Beach	1	Millener (1981), loc 20	67490	25112
Scaup (*Aythya novaeseelandiae*)				
Bushface 1	2	Worthy & Holdaway (2000)	62052	28173
Bushface 3	1	Worthy & Holdaway (2000)	62041	28168
Enfield Swamp	1	Worthy (1998a)	55722	23431
Henderson Bay, south	1	Millener (1981), loc 25	67150	25240
Luckie Strike Cave	1	WO5, check	63197	26868
Marfells Beach	12	Worthy (1998c)	59421	26095
Masons Dry Cave	1	Millener (1981)	63174	26924
Poukawa N 141/12	165	Horn (1983)	61523	28283
Poukawa, N 141/1–2	Present	THW	61525	28296
Pyramid Valley	5	Worthy & Holdaway (1996)	58038	24772
Spotlight Cave	1	CM Catalogue	62930	26751
Tokerau, Sth Urlich Rd	2	Millener (1981)	66978	25449
Waikuku Bch, South	1	Millener (1981)	67514	25114
Finsch's duck (*Chenonetta finschi*)				
Albury Park, spring site	9	Worthy (1997a)	56662	23327
Ardenest, Arden Stn	1	Worthy & Holdaway (1996)	58073	24916
Aurora Cave	1	WO205	55327	20958
Bird Rockshelter, Craigmore	2	Worthy (1997a)	56398	23490
Bluegum Cave	1	Millener (1981)	62967	26714
Bohemia Cave, Mt Owen	1	THW pers. obs.	59598	24698
Braeburn Stn, Falcon site	1	Worthy (1997a)	56631	23475
Bushface 1	2	Worthy & Holdaway (2000)	62052	28173
Castle Rocks	218	Worthy (1998b)	54788	21444
Cave on Mahoe Rd	1	WO73	63236	26860
Chatto Creek, site 1	1	Worthy (1998a)	55577	22351
Chatto Creek, site 2	1	Worthy (1998a)	55580	22351
Cobden Quarry site	2	Pers. obs. (MNZ)	58605	23634
Colac Bay dunes (= Tihaka)	1	Worthy (1998b)	54158	21180

SITE	MNI	NOTES	GRID N	GRID E
Finsch's duck (*Chenonetta finschi*)				
Commentary Cave – Kiwi Aven	1	Worthy & Holdaway (1994)	60191	24934
Companionway Cave	1	Worthy (1987), WO172	62971	26724
Coonoor	5	Millener (1981)	60824	27744
Craigmore Stn, site 1	1	Worthy (1997a)	56406	23497
Cutthroat Cave	1	Millener (1981)	63115	26901
Davis System	1	Millener (1981)	62956	26769
Deb's Cave	1	Worthy & Holdaway (2000)	62115	28150
Dinornis Cave, MF91	1	Millener (1981)	63001	26737
Earnscleugh Cave	48	Worthy (1998a)	55387	22189
Earthquakes #3, near Duntroon	2	Worthy (1998a)	55903	23228
Euan Murchison's Rockshelter, Weka Pass	2	Worthy & Holdaway (1996)	58001	24853
Exhale Air	1	THW pers. obs., *Notornis 36*:191–196	59957	24833
Flc Cave, L 2 + 4	4	Worthy & Swabey (2002)	63117	26903
F1c Cave, RF	2	Worthy & Swabey (2002)	63117	26903
Fissure 1A	9	Millener (1981)	59783	27101
Forest Hill tomos	28	Worthy (1998b)	54380	21570
Gabriele's Cave	4	Worthy & Holdaway (2000)	62116	28152
Gardners Gut Bone Passage, sites 1–16, 19	1	Worthy & Swabey (2002)	63243	26916
Gardners Gut Bone Passage, ZW4	2	Worthy & Swabey (2002)	63243	26916
Goddards Cave	1	Millener (1981)	63261	26731
Gordons Valley Stn, site 2	1	Worthy (1997a)	56371	23526
Gordons Valley Stn, site 5 – falcon site	1	Worthy (1997a)	56368	23523
Gordons Valley Stn, site 7	1	Worthy (1997a)	56379	23527
Haggas Hole	1	WO155	63251	26890
Hamilton Swamp		Worthy (1998a)	55468	22862
Harwoods Hole	1	Worthy & Holdaway (1994)	60285	24990
Haurangi 12	2	Millener (1981)	59799	27099
Hazelburn, pothole	1	Worthy (1997a)	56637	23475
Holocene Hole	5	Worthy & Holdaway (1995)	58496	25214
Hukanui 1	2	Worthy & Holdaway (2000)	62113	28144
Hukanui 3	1	Worthy & Holdaway (2000)	62113	28144
Hukanui 5	3	Worthy & Holdaway (2000)	62110	28143
Hukanui 7a	5	Worthy & Holdaway (2000)	62112	28147
Hukanui 7b	1	Worthy & Holdaway (2000)	62112	28147
Ida Valley Moa Swamp		Worthy (1998a)	55450	22487
Island Cliff	1	Worthy (1998a)	55828	23271
Kings Cave	100	Worthy (1997a)	56511	23402
Limestone Valley Road, Crack Cave	1	Worthy (1997a)	56495	23525
Macraes, Deepdell Ck, Otago	2	Worthy (1998a)	55365	23084
Marfells Beach	3	Worthy (1998c)	59421	26095
Martinborough #1	277	Millener (1981)	59780	27097
McKerchars Cave	20	Worthy (1998b)	54414	21537
Moonsilver Cave	1	THW pers. obs.	60095	24885
Mt Harris Swamp	4	THW/RNH coll MNZ	55966	23485
Mt Somers, approx.	3	Worthy (1997a)	57306	23732
Mudball Cave, upper level	1	WO281	63202	26868
Ngapara	36	Worthy (1998a)	55811	23296
Opawa, near Albury.	1	Worthy (1997a)	56581	23327
Paerau Moa Swamp		pers. obs. THW	55283	22703
Pareora Stn, Pothole 1	1	Worthy (1997a)	56391	23535
Porthole Cave	3	Millener (1981)	62967	26714

SITE	MNI	NOTES	GRID N	GRID E
Finsch's duck (*Chenonetta finschi*)				
Poukawa N 141/12	46	Horn (1983)	61523	28283
Prydes Gully Cave	9	Worthy (1998a)	55842	23267
Prydes Gully Road Swamp	4	Worthy (1998a)	55841	23262
Pyramid Valley	5	Worthy & Holdaway(1996)	58038	24772
Ratites Rest Home, Mt Arthur	1	THW pers. obs., *Notornis 36*:191–196	59996	24845
Riversdale B, dunes	1	Millener (1981)	60092	27690
Rocky Ridges, Geraldine	4	Worthy (1997a)	56736	23594
Rorisons Quarry	2	Millener (1981), loc 287	62936	26861
Silverstream Station, rockshelter	1	Worthy (1997a)	56306	23445
Site 6, Glendhu Station, Wanaka	6	Worthy (1998a)	56139	22881
Skyline Cave	1	WO137	62876	26609
Small cave, Awamoko River	1	Worthy (1998a)	55847	23277
Spotlight Cave	3	THW dets	62930	26751
St Benedicts Cavern (1)	2	Millener (1981), AU7091	63235	26885
St Benedicts Cavern, south passage	1	WO78	63235	26885
Station Deposit	1	Worthy (1998a)	55657	22118
Takaka Fossil Cave	2	0–50 cm, THW pers. obs.	60184	24994
Te Kaukau Point (White Rock A)	1	Millener (1981)	59569	27127
Te Waka 1	3	Worthy & Holdaway (2000)	62115	28234
Templers Terror Cave	1	WO128	63236	26944
The Deans, upper Waipara River	1	Worthy & Holdaway (1996)	57958	24794
Three Mile Bush Rd	2	Worthy (1997a)	56652	23478
Three Mile Bush Rd, colluvial deposit	1	Worthy (1997a)	56652	23482
Tokarahi	1	Worthy (1998a)	55814	23242
Tom Bowling, Central	1	Millener (1981), loc 5	67532	25094
Tom Bowling, West	2	Millener (1981), loc 4	67529	25085
Tomo B	1	Worthy & Holdaway (1993)	59071	23789
Totara Swamp Site	3	Worthy (1998a)	55624	23411
Totoro Rd Cave	2	Millener (1981)	62927	26757
Tuarangi Stn, Tomo 3, Tuarangi Cave	2	Worthy (1997a)	56386	23532
Tuarangi Stn, Tomo 5	1	Worthy (1997a)	56382	23535
Waewaepa Stn 2	1	Millener (1981)	60800	27695
Waikaremoana, caves	1	Millener (1981)	62600	28684
Waikari Cave, Waituna Station	82	Worthy & Holdaway (1996)	58063	24894
Waikiekie Quarry, Nthld	1	Millener (1981)	65814	26223
Waikuku Bch, North/all	1	Millener (1981)	67526	25119
Waipuna Cave	2	Millener (1981), WO400	63200	26874
Blue duck (*Hymenolaimus malacorhynchos*)				
Aurora Cave	2	WO204,205	55327	20958
Bone Cave, Canaan	1	Worthy & Holdaway (1994)	60289	25011
Castle Rocks	2	Worthy (1998b)	54788	21444
Commentary Cave – Kiwi Aven, Lower Entrance	1	Worthy & Holdaway (1994)	60191	24934
Coonoor	1	Millener (1981)	60824	27744
Gardners Gut Bone Passage, sites 1–16, 19	1	Worthy & Swabey (2002)	63243	26916
Gardners Gut Bone Passage, ZW4	3	Worthy & Swabey (2002)	63243	26916
Hobsons Tomo	3	Worthy & Holdaway (1994)	60209	25017
Honeycomb Hill Cave	Present	Worthy (1993)	60092	24421

SITE	MNI	NOTES	GRID N	GRID E
Blue duck (*Hymenolaimus malacorhynchos*)				
Kings Cave	3	Worthy (1997a)	56511	23402
Kiwi Hole, Canaan	1	Worthy & Holdaway (1994)	60290	25008
Little Winter Cave	1	Worthy & Holdaway (1994) and more recent coll	60192	24995
Marfells Beach	1	Worthy (1998c)	59421	26095
Metro Cave	1	Worthy & Holdaway (1993)	59180	23839
Mudball Cave, upper level	1	WO282	63202	26868
Pothole 3, Canaan	2	Worthy & Holdaway (1994)	60289	25011
Ratite Hole	3	Worthy & Holdaway (1994)	60217	25007
Robbers Hole	1	Millener (1981)	62894	26629
Te Ana Titi	1	Worthy & Holdaway (1993)	59058	23808
Te Aute Holocene	1	Worthy (2000)	61425	28224