The Origins Of Muttonbirding In New Zealand

Atholl Anderson[1]

ABSTRACT

Evidence of systematic muttonbirding in the pre-European era is scarce and enigmatic. This paper contributes new information and propositions to three older questions about the origins of muttonbirding in mainland New Zealand: when did systematic muttonbirding begin, why is it distributed archaeologically towards the south, and when did the historical industry begin in Foveaux Strait and Rakiura? Radiocarbon determinations are reported on Sooty shearwater (*Puffinus griseus*) bone samples from two archaeological deposits. They indicate that muttonbirding began in the colonisation era, 600–800 BP, in Foveaux Strait. The arrival with Polynesian settlement of the Pacific rat, *Rattus exulans*, may have restructured the density distribution of petrel colonies to favour southern muttonbirding. The antecedents of the historical industry, despite some recent archaeological research in Rakiura, remain obscure and need to be approached through a systematic programme of research.

Keywords: MUTTONBIRDING, TIWAI POINT, LEE ISLAND, ARCHAEOLOGY, RADIOCARBON DATING, *RATTUS EXULANS*.

INTRODUCTION

There is an extensive literature on the New Zealand muttonbirding industry in Foveaux Strait and Rakiura, including its historical significance since the early nineteenth century as a source of subsistence and trade items for southern Maori (see references in Anderson 1995, 1998). Its pre-European antecedents, however, remain obscure. They are the subject of much conjecture proceeding informally from different perspectives in ecology (Richdale 1963), archaeology (Coutts 1972; Sutton and Marshall 1980; Anderson 1995), European historical observation (references in Anderson 1980, 1998) and Maori tradition and modern history (Wilson 1979; Beattie 1994). The origins of muttonbirding in Foveaux Strait and elsewhere are not just a matter of historical curiosity, but are also relevant to interests ranging from archaeological enquiry about the development of indigenous trading patterns and the nature of culture contact, to modern academic and tribal formulation of management strategies for long-term sustainable harvesting.

This paper takes up three pertinent questions, canvassed in earlier discussion (Anderson 1995, 1996a) about the origins of muttonbirding. How early did muttonbirding begin in New Zealand? Why was mainland muttonbirding more intensive toward the south? When did the historical industry begin in Foveaux Strait? The basic chronological question is tested by new radiocarbon determinations; the distributional issue has been sharpened by

[1] Centre for Archaeological Research, RSPAS, Australian National University, Canberra ACT 0200, Australia. e-mail: aja@coombs.anu.edu.au

recent debate about the period at which *Rattus exulans* was introduced to New Zealand, and there are some additional archaeological data bearing on the development of the historical industry.

Before coming to those questions, the terminology needs to be specified. The term "muttonbird" seems to have been recorded first on Norfolk Island in AD 1790 (Skira 1993), where the providence petrel (*Pterodroma solandri*), wedge-tailed shearwater (*Puffinus pacificus*) and other burrowing petrels were taken in large numbers to sustain the newly-established penal colony (Anderson and White n.d.). Muttonbird is taken here as synonymous with "petrel" which, in its broad sense, includes all the petrels, prions, shearwaters, etc., of Procellariidae, plus the storm petrels, Hydrobatidae, and diving petrels, Pelecanoididae. "Muttonbirding" has no precise definition, but it has come to mean the capture of petrel squabs, usually from large rookeries, with the intention of processing for preservation.

CHRONOLOGY OF MUTTONBIRDING

In terms of muttonbird abundance (measured by total MNI, figures in brackets), the most important archaeological sites known currently are, in order: Old Neck, Rakiura (684), Tiwai Point, Southland (180), Parangiaio, Ruapuke, Foveaux Strait (49), Shag River Mouth, Otago (44), West Point, Ruapuke, Foveaux Strait (34), The Gutter, Mason Bay, Rakiura (34) and Lee Island, Ruapuke, Foveaux Strait (30), followed by Parker's Midden, Coromandel (26+) and Long Beach, East Otago (21) (Anderson 1995; Anderson *et al.*, 1996a; Symon n.d.; Worthy 1998, 1999, pers. comm. 13 September 2000). It is not clear how much of this bone was from immature birds. In most cases the identification of muttonbirding is made upon characteristic breakage patterns (e.g. Coutts and Jurisich 1972; Worthy 1998), but in the one large assemblage where the matter was addressed, at Tiwai Point, it was shown that at least 78% of the bone was from immature birds (Sutton and Marshall 1980).

Old Neck has one radiocarbon determination (NZ 422, 687 ± 40 BP, calibrated [Anderson 1991: 775] as AD 1273–1395 at 2SD), and there are seven for Tiwai Point. Those for area X, in which the muttonbird bone was concentrated, are in the range AD 1285–1400 at 2SD (Anderson 1991: 774). Shag River Mouth has numerous radiocarbon determinations indicating occupation in or about the fourteenth century AD (Anderson *et al.* 1996b). Of the others, Lee Island contained moa eggshell and a cache of Archaic phase adzes (Coutts and Jurisich 1972: 31), and Parker's Midden is similarly Archaic (Davidson 1979). The ages of Parangiaio and West Point are uncertain, but prehistoric (Coutts and Jurisich 1972). The Gutter site is late prehistoric (Anderson and O'Regan n.d.), while the provenance of muttonbird bone to either or both late and early layers at Long Beach is unpublished. Of the other sites containing MNI=10 or more muttonbirds (Anderson 1995), all are Archaic (Kaupokonui, Crescent Midden at Black Rocks, Pounawea and Riverton). The early aspect to muttonbirding in mainland New Zealand is consistent with the evidence of relatively intensive muttonbirding in sites of the colonisation era on each of the main outlying groups, the Chathams (Sutton 1979; Tennyson and Millener 1994), Kermadecs (Anderson 1981) and Norfolk Island (Anderson and White n.d.). These data as a whole show that muttonbird dominance in early middens is a particular feature of the smaller islands rather than the mainland.

While these data present a strong case prima facie for an early emphasis on muttonbird exploitation in the New Zealand region as a whole, consideration of the circumstances of stratigraphy and sample collection at some of the main sites left some room for doubt. Old Neck is a sand-dune site, heavily deflated, and most of the bird bone was surface collected between 1954 and 1993 (Worthy 1998: 56). At Tiwai Point the bones were in a shallow deposit just under the ground surface. The Ruapuke Island and Mason Bay sites are in mobile sand dunes prone to deflation. Since muttonbird bone was confined to upper layers at Shag River Mouth, virtually absent in the deeper, undisturbed stratigraphy at Papatowai (Anderson and Smith 1992), and not especially abundant at Pounawea (Hamel 1980), the question remained whether the instances of abundant muttonbird bones in Foveaux Strait sites perhaps represented fairly recent deposition. It was possible, for example, that late prehistoric or historical muttonbirding had discarded remains on some localities of much older sites. The obvious way to test this question was by direct radiocarbon dating of muttonbird bone (cf. Anderson *et al.* 1995).

Sooty shearwater bones from the Tiwai Point and Lee Island excavations were obtained from the Southland Museum and Art Gallery. The element representation and breakage patterns in these bones, analysed by Sutton and Marshall (1980) and Coutts and Jurisich (1972), describe patterns expected in the historical processing of muttonbirds. The bones had been sorted into skeletal groups.

The Tiwai Point site lies near the distal tip of Tiwai Peninsula, Bluff Harbour. Excavated by Park (1978), it is essentially an extensive adze-manufacturing site with associated middens. Excavation area X, which extended over 181 m^2, had a stratigraphically undifferentiated, 10–15 cm thick deposit (Layer 2) containing faunal remains (Park 1978). From the Tiwai Point material, I chose samples of humeri from the centre of density of each of the two muttonbird bone concentrations in area X, these being squares Q27 and X30 (Sutton and Marshall 1980: Figure 5). They comprised whole bones for the former square and proximal and distal fragments for the latter (Table 1). The material had been identified as immature by the excavators.

TABLE 1

Puffinus griseus humeri samples and ^{14}C AMS determinations on them

Sample Code	**Site area**	**Square & Layer**	**Humerus part**	**Weight**
TIWAI-1	Area X	Q27 Layer 2	1R + 2L	11.1 g
TIWAI-2	Area X	X3 Layer 2	1Rprox, 3L+2Rdist	5.7 g
LEE IS	n.d.	n.d. Lower layer	4R	11.4 g

Sample Code	**Lab Code**	**$\delta^{13}C$ BP**	**CRA Age at 2 SD**	**Calibrated**
TIWAI-1	OxA 9147	-14.7 ‰	1274 ± 40	AD 1011–1194
TIWAI-2	OxA 9148	-15.8 ‰	1170 ± 40	AD 1084–1285
LEE IS	OxA 9146	-15.6 ‰	1123 ± 39	AD 1169–1304

The site excavated as "Lee Island" by Coutts and Jurisich (1972) is actually on Ruapuke Island, Foveaux Strait, in sand dunes which lie adjacent to a narrow strait separating the main island from a small islet offshore, Lee Island. The bird bone from the site had not been identified as immature, but the samples chosen had the characteristic pitted surface of bone from young birds. The excavators had sorted the bone into two groups, "Upper layer" and "Lower layer". These represent, presumably, Layers 2A and 2B in the 4.3m^2 excavation by Coutts and Jurisich (1972). Faunal remains had been concentrated in Layer 2B but this merged with Layer 2A in places, so the chronological distinction is probably insignificant.

The muttonbird bone samples were washed, scraped to remove inked accession numbers, and then broken up, cleaned on inner surfaces where some dirt had penetrated, and crushed to a fine powder in a ceramic mortar. From each sample, 300 mg of bone powder was extracted for submission to the Oxford University Radiocarbon Accelerator Unit. Pretreatment consisted of the standard routine of acid-base-acid reduction and filtration to a gelatin product suitable for combustion and age estimation.

The AMS radiocarbon results are shown in Table 1. Since muttonbirds have a marine diet, the Conventional Radiocarbon Ages need to be corrected for marine reservoir depletion, as indicated by the $\delta^{13}C$ values. The calibrated ages in Table 1 were calculated by Dr Fiona Petchey (pers. comm. 2 May 2000) at the Waikato Radiocarbon Laboratory, using the Calib 4.12 programme and a 95% marine correction. The results should be regarded as approximate because there are significant local offsets to the general marine reservoir depletion of radiocarbon values which, in the present case, are not yet known. The calibrated ages seem too old, quite probably because of the unknown marine reservoir offset values, but they are at least close to the calibrated ages on charcoal samples from excavation area X at Tiwai Point. The Lee Island result (OxA 9146) is similar and quite plausible.

The new radiocarbon determinations remove any doubt that muttonbirding in its systematic historical form goes back to the early stages of human colonisation in mainland New Zealand.

DISTRIBUTION OF MUTTONBIRDING

Historically and by tradition, muttonbirding occurred in localities the length of mainland New Zealand but the frequency of references and detail of information is weighted toward the south (references in Anderson 1995). Muttonbird bones are similarly widespread in archaeological sites but there is also a distributional skew toward the South Island. Worthy (1999: Appendix 2) records the distribution by number of sites. The main species are as follows (species, the total number of sites in which it occurs, South Island sites [data from Worthy 1999 plus recent data from Rakiura] in brackets): *Puffinus gavia/huttoni* 64 (46), *Pelecanoides urinatrix* 42 (34), *Pachyptila turtur* 36 (27), *Puffinus griseus* 30 (24), *Pachyptila vittata* 19 (15) and *Pterodroma inexpectata* 18 (16).

Why should muttonbirding have been deployed more commonly and intensively toward the south? One possibility is that muttonbirds were more abundant there. The diving petrels, Sooty shearwater, prions and *Puffinus gavia* and *Puffinus huttoni* all breed from the Marlborough Sounds south. However, fossil evidence indicates that *Pterodroma cookii* and *Pterodroma inexpectata* were formerly widespread in the North Island and *Pterodroma macroptera*, *Pterodroma pycrofti*, *Puffinus assimilis*, *Puffinus bulleri*, and *Puffinus carneipes* breed in the northern region today. Natural frequency distribution can be only a part of the answer, at best.

Prey-choice reasoning has been advanced by Anderson (1995); the proposition being that subsistence attention shifted according to the relative efficiency of harvesting different resources. Muttonbirds and other colonial-nesting birds were targeted once populations of the larger-bodied cursorial birds (especially moas) had become depleted. This is a plausible economic argument which might account for some local differences, such as the relative emphasis upon muttonbirds in Rakiura where few or no moas existed (Worthy 1998), compared to muttonbird scarcity in Catlins sites that are rich in moa bone. However, it is not clear that petrels were necessarily more abundant in southern districts than elsewhere in New Zealand at the point of human discovery, so the regional argument needs to be reconsidered. Recent research on the age and ecological significance of the introduction of the Pacific rat, *Rattus exulans*, suggests a mechanism for the creation of regional variation in muttonbird availability.

The rat had a potentially devastating impact on small petrels. Holdaway (1999b) argues that small-bodied petrels, especially chicks, and petrel eggs of less than about 60 mm length were especially vulnerable. At serious risk were the storm petrels, diving petrels, small prions, and *Pterodroma pycrofti* and *P. cookii*, plus *Puffinus gavia*, *P. huttoni*, *P. spelaeus* and *P. assimilis*, all of which have body mass of <350 g and egg length <60 mm. *Pterodroma inexpectata* and possibly *P. macroptera* were on the margin of vulnerability (egg length >60 mm but body mass 350–500 g). Only the larger muttonbirds such as *Puffinus griseus* (800 g) and the black petrels, *Procellaria parkinsoni* (700 g) and *P. westlandica* (1100 g) were relatively safe (Holdaway 1999b: 224–227). This is a convincing proposition, but the critical issue is when rat predation came into operation.

Two hypotheses have been advanced. One proposes that *Rattus exulans* may have been introduced as early as 150 BC (Holdaway 1996, 1999a), allowing more than a millennium of rat predation prior to the advent of successful human settlement by AD 1100–1300. However, the evidence of petrel distribution by taxa in early archaeological sites dated to the thirteenth to fifteenth centuries AD shows little sign of the progressive depletion of species. Four of the six petrel species represented most widely in archaeological sites are within the most vulnerable group (above), and three of them are the most widely recorded archaeologically of all petrels, especially in the South Island (*Puffinus gavia/huttoni*, *Pelecanoides urinatrix* and *Pachyptila turtur*, above). *Puffinus gavia/huttoni* is the second most abundant petrel in the New Zealand mainland data, although its numbers are relatively small (total MNI 115, cf. *Puffinus griseus* total MNI 755, of which 449 are from Old Neck).

Pelecanoides is mostly represented at <3 individuals (Worthy, pers. comm. 28 April 2000), except at Old Neck (MNI=199 and most of those might be from skua kills deposited secondarily on the site). It is important to note that most sites are on the mainland (at least 37 sites with *P. gavia/huttoni*, and at least 32 sites with *Pelecanoides* sp.) rather than on offshore islands and are scattered throughout New Zealand.

Consequently, while it is possible that populations of these taxa were significantly depleted by or during the early Maori settlement era, the distributional evidence implies, equally, that the petrel taxa most vulnerable to rat predation were still widely available to early Maori fowling. In other words, rats may been abroad long enough to deplete breeding populations but not long enough to reduce severely the breeding ranges of the birds most vulnerable to their predation. If initial settlement began in New Zealand about AD 1150 (Anderson 1991), then rats would have been operating for about a century before the formation of the early sites in which muttonbird bones are recorded (above). The rapid depletion of muttonbirds is consistent with evidence from throughout the Pacific showing that "seabird colonies vanished soon after human arrival" (Martin and Steadman 1999: 28).

Most importantly, the proposition that *Rattus exulans* reached New Zealand substantially earlier than archaeologically-demonstrated human colonisation has never been without contradiction (Anderson 1996b) which, as research has proceeded, now indicates that the early radiocarbon determinations on rat bone gelatin are anomalous. It should be emphasised that this is not just a problem in the archaeological radiocarbon ages on *Rattus exulans* bone. A virtually identical pattern of anomalous results, in which radiocarbon age is correlated with the sequence of laboratory processing, is evident to the same extent in rat bone samples from natural sites (Anderson 2000). How the problem arose is uncertain, but there remains no compelling evidence of pre-twelfth century AD liberation of rats.

A second hypothesis suggests contemporary depletion. Rats were introduced at the same time as Polynesian settlers, in the twelfth century AD (Anderson 1991), and had a rapidly significant impact on muttonbirds, perhaps outrunning the spread of human settlement (McGlone *et al.* 1994). Given Holdaway's (1999b) size-vulnerability model, above, it could be predicted that the petrel species which survived the early onslaught by rats in the largest numbers would have been the largest-bodied taxa. Of these, the black petrels are less accessible to human predation, breeding on high ground inland, whereas the sooty shearwater (*Puffinus griseus*) breeds on coasts and small islands south of latitude 44 degrees and reaches "extreme density of population" in Foveaux Strait (Falla *et al.* 1979: 52). Next to those taxa is the grey-faced petrel, *Pterodroma macroptera*, which at 500 g and with an egg length of 67 mm (Holdaway 1999b: 227) was relatively immune to Pacific rat predation. It is another coastal and island breeding species, and *Puffinus griseus* and *Pterodroma macroptera* were the main muttonbird species traditionally in the South and North Island respectively (Anderson 1995). The proposition here, then, is that *Rattus exulans* quickly reduced the population densities of the smaller petrels, leaving the largest taxa relatively more prominent in the human prey environment, and this density-distribution is reflected in the archaeogeography of muttonbirding. The southern species, *Puffinus griseus*, came by this process to be the most concentrated and abundant, and one of the most accessible, muttonbirds left in the resource environment. Concentrated exploitation of it matches similar behaviour evident in early archaeological sites throughout the subtropical islands (Anderson 1996a).

FOVEAUX STRAIT ORIGINS

The new radiocarbon dates confirm the early existence of systematic muttonbirding on each side of Foveaux Strait, but whether exploitation of the muttonbird colonies on islands to the southwest of Rakiura was contemporaneous remains uncertain. There are no data from archaeological sites on the southwest islands, but recent archaeological research in "The Southern Margins Project" (Anderson and O'Regan 1999) has established that there was early occupation on the southern Rakiura mainland; one rock shelter and open midden site in Port Pegasus dates to about 600–800 BP. However, it contains few muttonbird remains (MNI= 6), of which only *Pelecanoides* sp. and *Pterodroma inexpectata* are each represented by two individuals. On the west coast of Rakiura, one of the best harbours for canoes en route to and from the muttonbird islands was at The Gutter, Mason Bay, where multiple canoe channels can still be observed. Excavations in a shallow but extensive midden, dating to the late prehistoric or early historical era, produced muttonbird remains (Anderson and O'Regan n.d.). They are, however, mainly of *Pelecanoides* sp. Only one specimen is from *Puffinus griseus*, overwhelmingly the most important muttonbird taken in the southwest islands (Symon n.d.).

Since reported archaeological remains from the muttonbird (titi) islands in general (Anderson 1995) are undiagnostic as to age or associations with muttonbirding, and there are no recorded muttonbird middens on these islands, the history of the southern industry is uncertain. It may have extended throughout the southwest islands from the beginning. Alternatively, it might have expanded into them quite recently. It is possible that the late prehistoric arrival of Ngai Tahu in Murihiku, by providing a social means and economic motive for the re-distribution of muttonbirds in an exchange network that extended from Foveaux Strait to Cook Strait (Anderson 1980, 1998; Coutts 1972), increased the demand and forced an extension in the range of exploitation. Alternatively, the arrival of European sailing technology, notably the adaptable, seaworthy and capacious sealing and whale boats, may have provided better and safer access to the southern islands than was possible with traditional canoes (Anderson 1980; Bathgate 1969). Any more definite understanding of the historical industry will require systematic archaeological research on the muttonbird islands.

CONCLUSIONS

This paper represents another step towards comprehending the origins of muttonbirding in New Zealand. The new radiocarbon determinations offer direct support to earlier claims that systematic muttonbirding began in southern New Zealand very early in the prehistoric settlement sequence. In regard to regional variation in muttonbirding, subsistence efficiency can be assumed to shape long term patterning of economic behaviour, but it operates in a volatile ecological environment where predator-prey relationships may change significantly and differentially. The size-dependent model of rat predation on petrels devised by Holdaway (1999b) offers, in this connection, some additional insight into the distributional characteristics of prehistoric muttonbirding. Recent archaeological fieldwork in southern Rakiura is pertinent to questions about the origin of the southern historical muttonbird industry, but provides no further clarity. We still lack basic archaeological evidence from the titi islands—and casual or hearsay reports are simply inadequate. It is time to relinquish the casual approach and tackle the issues systematically by undertaking intensive archaeological survey, and excavations if warranted, on representative islands. That is a matter for the traditional owners and users to decide, of course, but one which ought to be brought under consideration. Valuable comparative cases would be provided by similarly systematic research on the offshore islands of northern New Zealand and those in the Cook Strait region.

ACKNOWLEDGEMENTS

I thank Fiona Petchey for assistance with calibrating radiocarbon determinations and Trevor Worthy for correspondence about muttonbird data and for his thoughtful comments on both an earlier and different version of this paper and the current version.

REFERENCES

Anderson, A.J. 1980. Towards an explanation of prehistoric social organisation and settlement patterns amongst the southern Ngai Tahu. *New Zealand Journal of Archaeology* 2: 3–23.

Anderson, A.J. 1981. The archaeology of Raoul Island and its place in the settlement history of Polynesia. *Archaeology and Physical Anthropology in Oceania* 15: 131–41.

Anderson, A.J. 1991. The chronology of colonization in New Zealand. *Antiquity* 65: 767–95.

Anderson, A.J. 1995. Historical and archaeological aspects of muttonbirding in New Zealand. *New Zealand Journal of Archaeology* 17: 35–55.

Anderson, A.J. 1996a. Origins of Procellariidae hunting in the Southwest Pacific. *International Journal of Osteoarchaeology* 6: 1–8.

Anderson, A.J. 1996b. Was *Rattus exulans* in New Zealand 2000 years ago? AMS Radiocarbon ages from Shag River Mouth. *Archaeology in Oceania* 31: 178–84.

Anderson, A.J. 1998. *The Welcome of Strangers: an ethnohistory of southern Maori AD 1650–1850*. University of Otago Press, Dunedin.

Anderson, A.J. 2000. Differential reliability of ^{14}C AMS ages of *Rattus exulans* bone gelatin in south Pacific prehistory. *Journal of the Royal Society of New Zealand* 30 (3): 243–61.

Anderson, A.J., Head, J., Sim, R. and West, D. 1995. Radiocarbon dates on shearwater bones from Beeton shelter, Badger Island, Bass Strait. *Australian Archaeology* 42: 17–19.

Anderson, A.J. and Smith, I.W.G. 1992. The Papatowai Site: new evidence and interpretations. *Journal of the Polynesian Society* 101: 245–70.

Anderson, A.J., Allingham, B. and Smith, I.W.G. (eds) 1996a. *Shag River Mouth: the archaeology of an early southern Maori village*. Research Papers in Archaeology and Natural History 27, ANH Publications, Australian National University, Canberra.

Anderson, A.J., Smith, I.W.G. and Higham, T.F.G. 1996b. Radiocarbon chronology. *In* A.J. Anderson, B. Allingham and I.W.G. Smith (eds), *Shag River Mouth: the archaeology of an early southern Maori village*, pp. 60–69. Research Papers in Archaeology and Natural History 27, ANH Publications, Australian National University, Canberra.

Anderson, A.J. and O'Regan, G.R. 1999. *The Maori Archaeology of Southern Rakiura: an initial report*. Southern Margins Project Report 1. Ngai Tahu Development Corporation, Dunedin.

Anderson, A.J. and O'Regan, G.R. n.d. Excavations at the Gutter, Mason Bay, Rakiura. Southern Margins Report 3, in preparation.

Anderson, A.J. and White. J.P. (eds) n.d. *The Prehistory of Norfolk Island*. Supplement to the Records of the Australian Museum, in press.

Bathgate, M.A. 1969. Maori river and ocean-going craft in southern New Zealand. *Journal of the Polynesian Society* 78: 344–77.

Beattie, J.H. 1994. *Traditional Lifeways of the Southern Maori: The Otago University Museum Ethnological Project, 1920* (edited by A.J. Anderson). Otago University Press, Dunedin. 636 pp.

Coutts, P.J.F. 1972. The emergence of the Foveaux Strait Maori from prehistory: a study of culture contact. Unpublished PhD thesis, University of Otago.

Coutts, P.J.F. and Jurisich, M. 1972. *Results of an archaeological survey of Ruapuke Island.* Studies in Prehistoric Anthropology 5. University of Otago.

Davidson, J.M. 1979. Archaic middens of the Coromandel region: a review. *In* A.J. Anderson (ed), *Birds of a Feather: osteological and archaeological papers from the South Pacific in honour of R.J. Scarlett*, pp. 183–202. British Archaeological Reports International Series 62, Oxford.

Falla, R.A., Sibson, R.B. and Turbott, E.G. 1979. *The New Guide to the Birds of New Zealand.* Collins, Auckland.

Hamel, G.E. 1980. Pounawea: The last excavation. Unpublished report to the New Zealand Historic Places Trust.

Holdaway, R.N. 1996. The arrival of rats in New Zealand. *Nature* 384: 225–26.

Holdaway, R.N. 1999a. A spatio-temporal model for the invasion of the New Zealand archipelago by the Pacific rat *Rattus exulans*. *Journal of the Royal Society of New Zealand* 29: 91–105.

Holdaway, R.N. 1999b. Introduced predators and avifaunal extinction in New Zealand. *In* R.D.E. MacPhee (ed.), *Extinctions in Near time: causes, contexts and consequences. Advances in Vertebrate Paleobiology*, pp. 189–238. Kluwer Academic, New York.

Martin, P.S. and Steadman, D.W. 1999. Prehistoric extinctions on islands and continents. *In* R.D.E. MacPhee (ed), *Extinctions in Near time: causes, contexts and consequences. Advances in Vertebrate Paleobiology*, pp.17–55. Kluwer Academic, New York.

McGlone, M., Anderson, A.J. and Holdaway, R. 1994. An ecological approach to the early settlement of New Zealand. *In* D.G. Sutton (ed), *Origins of the First New Zealanders*, pp. 136–63. Auckland University Press, Auckland.

Park, G.S. 1978. Radiocarbon dates from Tiwai Point, Southland. *New Zealand Archaeological Association Newsletter* 21: 143–45.

Richdale, L.E. 1963. Biology of the sooty shearwater, *Puffinus griseus*. *Proceedings of the Zoological Society of London* 141: 1–117.

Skira, I. 1993. Tasmanian aborigines and muttonbirding. Unpublished PhD thesis, University of Tasmania.

Sutton, D.G. 1979. Island and coastal fowling strategies of the prehistoric Moriori. *In* A.J. Anderson (ed.), *Birds of a Feather: osteological and archaeological papers from the South Pacific in honour of R.J. Scarlett*, pp. 123–40. British Archaeological Reports, International Series 62.

Sutton, D.G. and Marshall, Y.M. 1980. Coastal hunting in the subantarctic zone. *New Zealand Journal of Archaeology* 2: 25–49.

Symon, A. n.d. Faunal analysis, The Gutter, Mason Bay (D49/28). Unpublished report, Ngai Tahu Development Corporation.

Tennyson, A.J.D. and Millener, P.R. 1994. Bird extinctions and fossil bones from Mangere Island, Chatham Islands. *Notornis* 41 (supplement): 165–78.

Wilson, E.H. 1979. *Titi Heritage: the story of the muttonbird islands*. Craig, Invercargill.

Worthy, T.H. 1998. Fossil avifaunas from Old Neck and Native Island, Stewart Island — Polynesian middens or natural sites. *Records of the Canterbury Museum* 12: 49–82.

Worthy, T.H. 1999. What was on the menu? Avian extinction in New Zealand. *New Zealand Journal of Archaeology* 19 (1997): 125–60.

Received 25 May 2001
Accepted 16 June 2001