Records of the Australian Museum, Supplement 27 (2001): 85–100. ISBN 0 7347 2305 9

# Avifauna from the Emily Bay Settlement Site, Norfolk Island: A Preliminary Account

RICHARD N. HOLDAWAY[1] AND ATHOLL ANDERSON[2]

[1] Palaecol Research, PO Box 16569, Christchurch, New Zealand
piopio@netaccess.co.nz

[2] Department of Archaeology & Natural History, Research School of Pacific and Asian Studies, Australian National University, Canberra ACT 0200, Australia
aja@coombs.anu.edu.au

ABSTRACT. The avifauna of the Emily Bay settlement site, Norfolk Island, southwest Pacific, is described. Most of the remains, which consisted of nearly 10,000 identifiable bones (mostly fragmentary) and several thousand unidentifiable elements and fragments, were of several species of petrel and shearwater (Procellariiformes) and boobies (Sulidae), but some land birds were also represented in small numbers. Two species of migratory wading bird (Charadriiformes) were identified in the deposits, but no terns, which are dominant members of the present avifauna. The taphonomy of the remains indicates intensive use of birds as food, but some material of other than cultural origin was also present. Remains were not distributed evenly throughout the excavated parts of the site, and were concentrated in areas where other evidence such as post holes and fires scoops indicated points of occupation. Some species that are present on the island and palatable were not represented in the collections: possible reasons for their absence are canvassed. An estimate of the biomass is presented, with the proviso that the variation in density of deposition made extrapolation to the remainder of the site problematic. The size of the sample, the preservation of elements such as vertebrae of small petrels, and the good condition of material of apparent natural (non-cultural) origin indicate that the collection represents a good sample of the avifauna used as food by the Polynesian inhabitants of Emily Bay.

HOLDAWAY, RICHARD N., AND ATHOLL ANDERSON, 2001. Avifauna from the Emily Bay settlement site, Norfolk Island: a preliminary account. In *The Prehistoric Archaeology of Norfolk Island, Southwest Pacific*, ed. Atholl Anderson and Peter White, pp. 85–100. *Records of the Australian Museum, Supplement* 27. Sydney: Australian Museum.

Norfolk Island is one of the "mystery islands" of the South Pacific that has evidence of former human occupation, but which had been abandoned by its Polynesian inhabitants before European discovery (Kirch, 1988). Even the most apparently pristine of these islands usually has evidence of the use of natural resources such as birds, and often of the extinction of a range of bird species (Steadman and Olson, 1985). The ability of such islands to sustain a human population in the long term has been questioned (Kirch, 1988; Anderson, in press), because of the probable scarcity of food resources. Faunal remains in archaeological sites on the islands can reveal much about the interaction of people and pristine environments.

Norfolk Island is at the southern edge of the sub-tropics. The nearest substantial land masses are Lord Howe Island (900 km to the southwest), New Caledonia (700 km to the north), New Zealand (800 km to the southeast), and the Kermadecs (1300 km to the east): Australia is 1300 km to the west. The Norfolk Island group is so placed that it has an avifauna with links to all the surrounding faunal regions, the Australian, New Zealand, and Pacific faunas (Holdaway *et al*., 2001). In particular, the seabirds breeding on the group are a mixture of species from the sub-tropical and tropical Pacific and from the cooler waters around the northern part of New Zealand. The Norfolk Island group is the only available nesting ground for seabirds over a substantial area of ocean.

Seabirds (petrels, sulids, and terns) are the most conspicuous component of the present-day avifauna. There are, however, no gulls or cormorants and most littoral birds are migratory visitors or rare vagrants. There was little open land and no large permanent areas of fresh water before Europeans dammed two small streams at Kingston and The Cascades. A large area of swamp behind the beach at Slaughter Bay was recorded as being open land by the first Europeans to land on that side of the island in 1788. Temporary pools of water and wet grassland on Kingston Common provide the largest area of habitat for wading birds on the island today (Wakelin, 1968; Schodde *et al*., 1983).

In contrast to the marine species, most of which bred over large areas of the South Pacific and beyond, the few Norfolk Island land birds are mostly endemic (Holdaway *et al*., 2001). Norfolk Island is remote enough from adjacent sources of terrestrial birds to have received only occasional successful colonizations of terrestrial birds. As the islands are about 3 million years old, there has been sufficient time for distinctive species to evolve in several groups, including rails, pigeons, parrots, and passerines.

The present fauna is relict, following the extinction of some taxa (such as *Pterodroma pycrofti*) after Polynesian settlement, and further losses (such as *Nestor productus* and *Lalage leucopyga*) in the nineteenth and twentieth centuries after the establishment of a series of European settlements. Fossil deposits of late Quaternary age containing bird remains are known from both natural and archaeological contexts in the Kingston area, on the southern side of Norfolk Island itself, and on Nepean Island about 1 km off the southern coast (Meredith, 1985, 1991; Anderson, 1996).

Bird remains have been found in archaeological deposits of two ages: a Polynesian site at Emily Bay (Anderson, 1996), and in a First (European) Settlement site dating from the late 1790s. The First Settlement site contained many petrel bones (Meredith, 1985). Some of those which were retained in the Commissariat Museum at Kingston, Norfolk Island, were examined in December 1995. During a famine arising from the wreck of the supply ship HMS *Sirius* at the island in March 1790, the convicts, military, and free settler population relied on the birds for sustenance until supplies could be obtained from the host colony at Sydney (Hoare, 1987).

The present analysis is based on bird fossils collected during archaeological investigations of the Polynesian site at Emily Bay. This was discovered in December 1995 (Anderson, 1996), and further, more extensive, excavations took place in the same area in 1996 and 1997, resulting in the retrieval of the large amount of mainly fragmentary avian material that is discussed here. The analysis deals with collections from Trenches EB96:10, EB96:11, EB97:21, EB97:22, EB97:23, and EB97:24 in Emily Bay. Distribution of material is presented for the largest collection, that from Trench EB97:23. The composition of the archaeological avifauna is reported and discussed both in the contexts of the past and present avifauna of the island and of the resource that the birds represented to the Polynesian population.

People are part of an island ecosystem but they also interact with the ecosystem in different ways than other species, especially on islands with no history of human occupation. A point of major consequence for faunal analysis of archaeological deposits is that people interact with living birds and whole avifaunas, not with the bones that remain as evidence of the interaction. Hence, this preliminary analysis of the avifaunal remains associated with the archaeological deposit at Emily Bay, Norfolk Island goes some way beyond simple lists of bones and species. The differences in composition between an archaeological fauna and that of the total avifauna of the island can provide information such as the fowling strategy of the people, their food preferences (Worthy, 1998), and the time of year that the site was occupied. To that end, some attention is paid here to the breeding season of the species that are best represented in the deposits, and of the likely season of passage or residence of migrants.

Before the archaeological avifauna can be compared with the original avifauna, the composition of that original fauna must be known. For Norfolk Island, determining which species bred there at the time of Polynesian contact is made more difficult by extinctions that occurred both before and after the first written records were made in the late eighteenth century. To provide a basis for the inclusion or exclusion of species from the avifaunal list, problems of identification of fossil material and background information on the identification of species known from early European records are dealt with in some detail in the Appendix to this paper.

The Appendix also discusses the present distributions of species, which can also provide clues as to the identification of species. Breeding distributions that enclose but do not include Norfolk Island suggest that some species might have been part of the Norfolk Island fauna, whereas others whose distributions are marginal might be less likely to have bred there in the past.

Extinctions are important because they indicate the possible effects of human impact on the Norfolk Island environment, and also have a major bearing on the identification of the species in fossil deposits. Extinctions are part of the process of human interactions with the environment throughout the history of the Pacific (Steadman, 1997) and so the loss of species that people used for food, and those that went extinct in the same period but for which there is no archaeological record of human exploitation, are also discussed.

## Methods

The excavation and collection techniques are described in Anderson (1996), and Anderson, Smith and White (this vol.). Material was identified to species using morphological characters if preserved, otherwise the material was taken to the lowest taxonomic rank that could be supported (e.g., *Pterodroma* petrel, or "other petrel" which included petrels such as *P. neglecta* and *P. solandri* which are larger than *P. pycrofti* as well as *Puffinus assimilis*—see below), or left as unidentified. Minimum numbers of individuals (MNI) were determined for each taxon in each spit of each square, using the maximum number of ipsilateral examples of the commonest element. Crude estimates of biomass were developed from the total numbers of individuals of each species or taxonomic group, to give an order of magnitude assessment of the resource represented in each excavated area. Note that this calculation gives the greatest MNI and biomass; quantification by layer or trench would reduce the numbers considerably (cf. Table 1; Fig. 2, *above*).

**Comparative material**. Identifications were made with reference to voucher specimens in the Museum of New Zealand Te Papa Tongarewa (MNZ: Wellington, New Zealand) and the Canterbury Museum (CM: Christchurch, New Zealand). There is little skeletal material for some of the most significant species of petrel expected in the Norfolk Island deposits. In particular, only three specimens of *Pterodroma solandri* (MNZ S23504; and two unregistered individuals in MNZ, and three of *Pterodroma neglecta* (MNZ S23720, CM Av 5201 and Av 27263 were available. The paucity of material contributed to the difficulty of identification of petrel remains. A full study of natural material from the island in conjunction with a satisfactory comparative collection will be necessary before the present group taxon "other petrels" can be re-analysed with confidence. Meredith (1985, 1991) has provided a useful baseline but present knowledge of the South Pacific petrel fauna is insufficient to justify confidence in identification of the medium-sized petrels of the group.

Material consulted included representatives of all relevant species held in MNZ, and the following specimens from CM: *Puffinus bulleri* (Av36803), *Puffinus gavia* (Av12158), *Gallirallus philippensis* (Av36805), *Gallirallus australis* (Av5187), *Porphyrio porphyrio* (Av22392), *Coenocorypha huegeli* (Av5200), *Limosa lapponica* (Av36583), *Cyanoramphus novaezelandiae* (Av5163), *Cyanoramphus auriceps* (Av5194), *Nestor meridionalis* (Av9956), *Ninox novaeseelandiae* (Av22387), and *Eudynamys taitensis* (Av14854). The archaeological material from Emily Bay will be accessed to the collections of the Norfolk Island Museum.

**Biomass**. Body masses cited are from Heather and Robertson (1996) or Marchant and Higgins (1990). For large petrels, a mean body mass of 500 g was assumed, the normal mass of the three largest species. As most of the animal appears to have been consumed, including much of the bone (and presumably the viscera), the total meat mass was taken to be the normal body mass. The estimate is therefore high by an unknown amount. The total amount of avian biomass represented in the excavations was calculated and extrapolated to the whole Emily Bay site.

**"Natural" versus "archaeological" deposits**. The distinction is made between "natural" and "archaeological" deposits, as a convenient shorthand to describe the taphonomic processes involved in the development of the deposit. While there is clearly a case for considering humans to be a natural part of the environment, the distinction is useful not least because non-archaeological ("natural") deposits can be formed by several different processes. Not all of these are immediately obvious, and each involves its own biases. "Natural" deposits are formed regardless of human presence. For example, much of the "natural" fossil material on Norfolk Island appears to have been accumulated beneath feeding stations of the one or more species of *Accipiter* that once lived there (RNH, unpubl. data). It is therefore biased by the time of hunting, maximum and minimum prey size, agility of prey, and probably other factors including preferences of individual predators. Other bones were preserved as a result of mortality unrelated to predation, such as burrow collapse or pathology. In contrast to the variety of possible origins of the "natural" fossil avifauna, the "archaeological" material was assembled as a result of by a single process, the collection of birds by people for food or other resources. That material yields information on the choices of prey by people, and other factors, such as seasonality, which are useful in reconstructing human associations with the environment.

The term "petrel" is used for brevity in the broad sense of all Procellariiformes and includes shearwaters, species of *Pterodroma*, and other genera that may have been present in the past. As well as the unknown range of species that may be involved and the paucity of comparative material for many, and the fragmentary nature of almost all the petrel (and other) material from the archaeological deposit, the catch-all headings serve the purpose of archaeological analysis while not conveying a false sense of exactitude in identification. Only *P. pycrofti* was determined to species, on the basis of size for small fragments. The term "other petrel" indicates all the other species of petrel that bred on Norfolk Island, which were known to be present in the archaeological fauna, but which could not be positively identified regularly enough for quantitative analysis. Sufficient elements of these other petrels could be identified to species with greater or lesser confidence, to support their inclusion in the list of species counted as present in the deposit.

## Results

**General**. A total of 8699 bones and bone fragments was identified to taxon (20 fragments of *Sula dactylatra* were not included in the determination of MNI and are not included in tabulated values); at least that number again of unidentified fragments and small elements such as vertebrae was also examined. For example, in Square E12 in Trench EB97:23, there were 155 identifiable elements, representing a minimum of 27 individuals, but there were 145 elements such as quadrates, vertebrae, and fragments that could not be certainly assigned to taxon within the constraints of the present study. The bird bone collection also contained material of the Pacific rat *Rattus exulans*, and fish, which had been hidden among the bulk of the fragmentary bird bones.

**Preservation/taphonomy**. The presence of large numbers of small, fragile elements, and the occasional cranium or other fragile elements demonstrated that the preservation conditions were optimal for small bird bones. Most of the damage to material that caused difficulties of identification resulted from modification by human activities such as heating, burning, breakage during dismemberment of the carcass, and chewing. Immature bones were more affected than adult bones. Some avian material, particularly in Trench EB97:24, was clearly of natural origin and showed no sign of human handling. Some of the "natural" material was recorded as having been deposited in posthole features or burrows and appears to post-date Polynesian occupation of the site. Some elements showed signs of damage by an avian predator (either the owl *Ninox novaeseelandiae* or goshawk *Accipiter* cf. *A. fasciatus*), on the basis that the damage was similar to that characteristic of butchering by accipitrid hawks, as observed in material from natural sites in New Zealand whose accumulation has been attributed to the extinct harrier *Circus eylesi* (RNH, unpubl. data).

Complete bones, particularly long bones, were rare. Most individuals were represented by proximal humeri, fragmentary coracoids, anterior sterna, furcular symphyses, proximal scapulae, or distal tibiotarsi or tarsometatarsi. Most MNI were based on the proximal humeri and coracoids for *Pterodroma pycrofti* and on coracoids and fragments of coracoids for the other petrels. The waders were best represented by coracoids (*Pluvialis fulva*) and distal tarsometatarsi (*Limosa lapponica*). Of the two largest common terrestrial species, the most common distinguishing elements were the coracoid and distal tibiotarsus for the large parrot *Nestor productus* and the coracoid for the pigeon *Hemiphaga spadicea*. Two taxa that differed from the pattern were *Sula dactylatra* and *Accipiter* cf. *A. fasciatus*: the first was best represented by fragments and vertebrae, and most hawk elements were pedal phalanges, fibulae, and distal tibiotarsi. These remains made estimates of numbers of individuals suspect as the smaller, more numerous bones in the body may have been widely spread through the site.

**Emily Bay bird sample**. The number of identifiable elements and minimum numbers of individuals (MNI) of taxa represented in the archaeological collections from Trenches EB96:10, EB96:11, EB97:21, EB97:22, EB97:23, and EB97:24 at Emily Bay, Norfolk Island are shown in Table 1. The 14 taxa or group taxa (e.g., "other petrels") differed in their proportions in the samples (Table 2). "Other petrels", *Pterodroma pycrofti* and the Norfolk Island pigeon (*Hemiphaga spadicea*) contributed most individuals (Table 1) and elements (Table 3). Their representation in the smallest sample (Trench EB97:21) was skewed in comparison to those in the larger samples and reflects the heterogeneity of the distribution of material throughout the site. The heterogeneity within a large part of the area (Trench EB97:23) was marked, both in terms of elements (Fig. 1) and individuals (Fig. 2). Most squares in Trench EB97:23 had fewer than 100 elements (Fig. 3, above) and fewer than 20 individuals (Fig. 3, below). Squares D10, D13, and E10 in Trench EB97:23 contained the greatest concentration of bones (Fig. 1, below).

The concentrations of material appear to coincide with the location of post-holes and a fire scoop (Anderson, Smith and White, this vol.). Six of the 42 squares contained most of the elements, and three, most of the individuals. The heterogeneity of the distribution within Trench EB97:23 shows that estimates of concentration over the whole Emily Bay area must take into account the clumping of dense deposits amid a much lower density of material over most of the site. Squares D10, D13, and E10 in Trench EB97:23 contained the greatest numbers of identifiable individual birds (Fig. 1, above).

**Table 1**. Minimum number of individuals (*above*) and number of identified bones (*below*) for each taxon or group of taxa in each excavation in Emily Bay. Totals in parentheses are MNI calculated on representation in all trenches combined (every element potentially from same bird regardless of position in excavated area).

| | trench | | | | | | |
|---|---|---|---|---|---|---|---|
| | **EB96:10** | **EB96:11** | **EB97:21** | **EB97:22** | **EB97:23** | **EB97:24** | **totals** |
| *Pterodroma pycrofti* | 8 | 3 | 3 | 3 | 108 | 25 | 150 (141) |
| | 79 | 19 | 9 | 17 | 980 | 276 | 1380 |
| other petrels and shearwaters | 47 | 6 | 1 | 9 | 663 | 89 | 815 (807) |
| | 356 | 52 | 2 | 42 | 5599 | 544 | 6595 |
| *Limosa lapponica* | 2 | 2 | — | — | 12 | 8 | 24 (23) |
| | 13 | 8 | — | — | 112 | 59 | 192 |
| *Pluvialis fulva* | 1 | 2 | 1 | 1 | 8 | 5 | 18 (13) |
| | 1 | 8 | 2 | 3 | 41 | 47 | 102 |
| *Nestor productus* | 2 | 2 | — | — | 2 | 1 | 7 (3) |
| | 3 | 3 | — | — | 9 | 6 | 21 |
| *Hemiphaga spadicea* | 5 | 2 | — | 1 | 28 | 12 | 48 (46) |
| | 19 | 4 | — | 2 | 136 | 40 | 201 |
| *Sula dactylatra* | 2 | 2 | — | 1 | 16 | 5 | 26 (25) |
| | 4 | 7 | — | 2 | 82 | 18 | 113 |
| *Gallirallus* Norfolk | — | — | — | 1 | 3 | — | 4 (3) |
| | — | — | — | 1 | 6 | — | 7 |
| *Cyanoramphus novaezelandiae* | — | 1 | 1 | — | 4 | 2 | 8 (5) |
| | — | 3 | 1 | — | 12 | 4 | 20 |
| passerines | 1 | 1 | — | — | 2 | 2 | 6 (3) |
| | 1 | 1 | — | — | 9 | 10 | 21 |
| *Gallirallus* cf. *G. philippensis* | 1 | — | — | — | 2 | 1 | 4 (3) |
| | 2 | — | — | — | 6 | 1 | 9 |
| *Accipiter* cf. *A. fasciatus* | — | — | — | 1 | 1 | — | 2 (1) |
| | — | — | — | 1 | 8 | — | 9 |
| *Gallicolumba* cf. *G. norfolciensis* | — | — | — | — | 1 | — | 1 (1) |
| | — | — | — | — | 2 | — | 2 |
| *Porphyrio* sp. | — | — | — | — | 2 | — | 2 (2) |
| | — | — | — | — | 7 | — | 7 |
| total | 69 | 21 | 6 | 17 | 852 | 150 | 1115 |
| | 478 | 105 | 14 | 68 | 7009 | 1005 | 8679 |

**Table 2**. Percentage of individuals in each excavation represented by each taxon or group of taxa.

| | trench | | | | | | |
|---|---|---|---|---|---|---|---|
| | EB96:10 | EB96:11 | EB97:21 | EB97:22 | EB97:23 | EB97:24 | total |
| *Pterodroma pycrofti* | 11.6 | 14.3 | 50.0 | 17.6 | 12.7 | 16.7 | 13.5 |
| other petrels | 68.1 | 28.6 | 16.7 | 52.9 | 77.8 | 59.3 | 73.1 |
| *Limosa lapponica* | 2.9 | 9.5 | 0 | 0 | 1.4 | 5.3 | 2.2 |
| *Pluvialis fulva* | 1.4 | 9.5 | 16.7 | 5.9 | 0.9 | 3.3 | 1.6 |
| *Nestor productus* | 2.9 | 9.5 | 0 | 0 | 0.2 | 0.7 | 0.6 |
| *Hemiphaga spadicea* | 7.2 | 9.5 | 0 | 5.9 | 3.3 | 8.0 | 4.3 |
| *Sula dactylatra* | 7.2 | 9.5 | 0 | 5.9 | 1.9 | 3.3 | 2.6 |
| *Gallirallus* Norfolk | 0 | 0 | 0 | 5.9 | 0.4 | 0 | 0.3 |
| *Cyanoramphus novaezelandiae* | 0 | 4.8 | 16.7 | 0 | 0.5 | 1.3 | 0.7 |
| passerines | 1.4 | 4.8 | 0 | 0 | 0.2 | 1.3 | 0.5 |
| *Gallirallus* cf. *G. philippensis* | 1.4 | 0 | 0 | 0 | 0.2 | 0.7 | 0.4 |
| *Accipiter* cf. *A. fasciatus* | 0 | 0 | 0 | 5.9 | 0.5 | 0 | 0.2 |
| *Gallicolumba* cf. *G. norfolciensis* | 0 | 0 | 0 | 0 | 0.1 | 0 | 0.01 |
| *Porphyrio* sp. | 0 | 0 | 0 | 0 | 0.2 | 0 | 0.02 |

**Patterns of representation of taxa within the site**. *Pterodroma pycrofti* was found in 76 (87.4%) of the squares; other species of petrel were found in 78 squares (89.7%). Least common were the Norfolk Island Ground Dove (*Gallicolumba* cf. *G. norfolciensis*) and Swamphen (*Porphyrio* species), elements of which were found in three squares only.

Squares contained up to 11 taxa, with the mode at seven (Fig. 4). The bimodality of the distribution results from the greater abundance of material in squares in Trench EB97:23, and the greater chance of finding more species in a larger sample; the lower tail of the distribution reflects the small number of species in the poorer parts of the deposit.

**Biomass**. Calculations of body mass represented by the individuals of the different taxa are given in Table 4, percentages of total biomass by trench in Table 5. By far the greatest contribution to biomass was by the petrels, over 80% when *Pterodroma pycrofti* are pooled with "other petrels". The Booby *Sula dactylatra* (Sulidae) contributed significantly to the total biomass because of its greater individual mass, although it was difficult to assess the total numbers concerned because many examples were juvenile and hence more poorly preserved.

All other taxa combined contributed less than 10% of the biomass represented in the site. Of the terrestrial species, only the Norfolk Island Pigeon *Hemiphaga spadicea* was important in the diet. Apparently vulnerable and palatable species such as the flightless Norfolk Island Rail and the Norfolk Island Kaka contributed less than the more common of the two migrant wading birds (*Limosa lapponica*). The smaller species contributed negligible amounts to the total biomass and were not favoured prey. The rarity or absence of some palatable species (such as snipe and rails) and of other species that might have been used for ornament, if not for food, is noteworthy. In view of the common presence of strongly flying species such as the two migrant waders, the absence of snipe, for example, begs the question of availability during the period of occupation.

The absence of terns from the sample might be explained by the very small meat content of the species present, and the fact that all but the Sooty Tern (*Sterna fuscata*) nest in trees. Sooty Terns breed on beaches or open ground, and lack of open areas in Polynesian times except for the beaches in the Kingston area (which were subject to disturbance by people), suggests that Sooty Terns might not have bred in

**Table 3**. Percentage of elements in each excavation represented by each taxon or group of taxa.

| | trench | | | | | | |
|---|---|---|---|---|---|---|---|
| | EB96:10 | EB96:11 | EB97:21 | EB97:22 | EB97:23 | EB97:24 | total |
| *Pterodroma pycrofti* | 16.5 | 18.1 | 64.3 | 25.0 | 14.0 | 27.5 | 15.9 |
| other petrels | 74.5 | 49.5 | 14.3 | 61.8 | 79.9 | 54.1 | 76.0 |
| *Limosa lapponica* | 2.7 | 7.6 | 0 | 0 | 1.6 | 5.9 | 2.2 |
| *Pluvialis fulva* | 0.2 | 7.6 | 14.3 | 4.4 | 0.6 | 4.7 | 1.2 |
| *Nestor productus* | 0.6 | 2.9 | 0 | 0 | 0.2 | 0.6 | 0.2 |
| *Hemiphaga spadicea* | 4.0 | 3.8 | 0 | 2.9 | 1.9 | 4.0 | 2.3 |
| *Sula dactylatra* | 1.9 | 6.7 | 0 | 2.9 | 1.3 | 2.2 | 1.3 |
| *Gallirallus* Norfolk | 0 | 0 | 0 | 1.5 | 0.1 | 0 | 0.1 |
| *Cyanoramphus novaezelandiae* | 0 | 2.9 | 7.1 | 0 | 0.2 | 0.4 | 0.2 |
| passerines | 0.2 | 1.0 | 0 | 0 | 0.1 | 1.0 | 0.2 |
| *Gallirallus* cf. *G. philippensis* | 0.4 | 0 | 0 | 0 | 0.1 | 0.1 | 0.1 |
| *Accipiter* cf. *A. fasciatus* | 0 | 0 | 0 | 1.5 | 0.1 | 0 | 0.1 |
| *Gallicolumba* cf. *G. norfolciensis* | 0 | 0 | 0 | 0 | <0.1 | 0 | <0.1 |
| *Porphyrio* sp. | 0 | 0 | 0 | 0 | 0.1 | 0 | 0.1 |

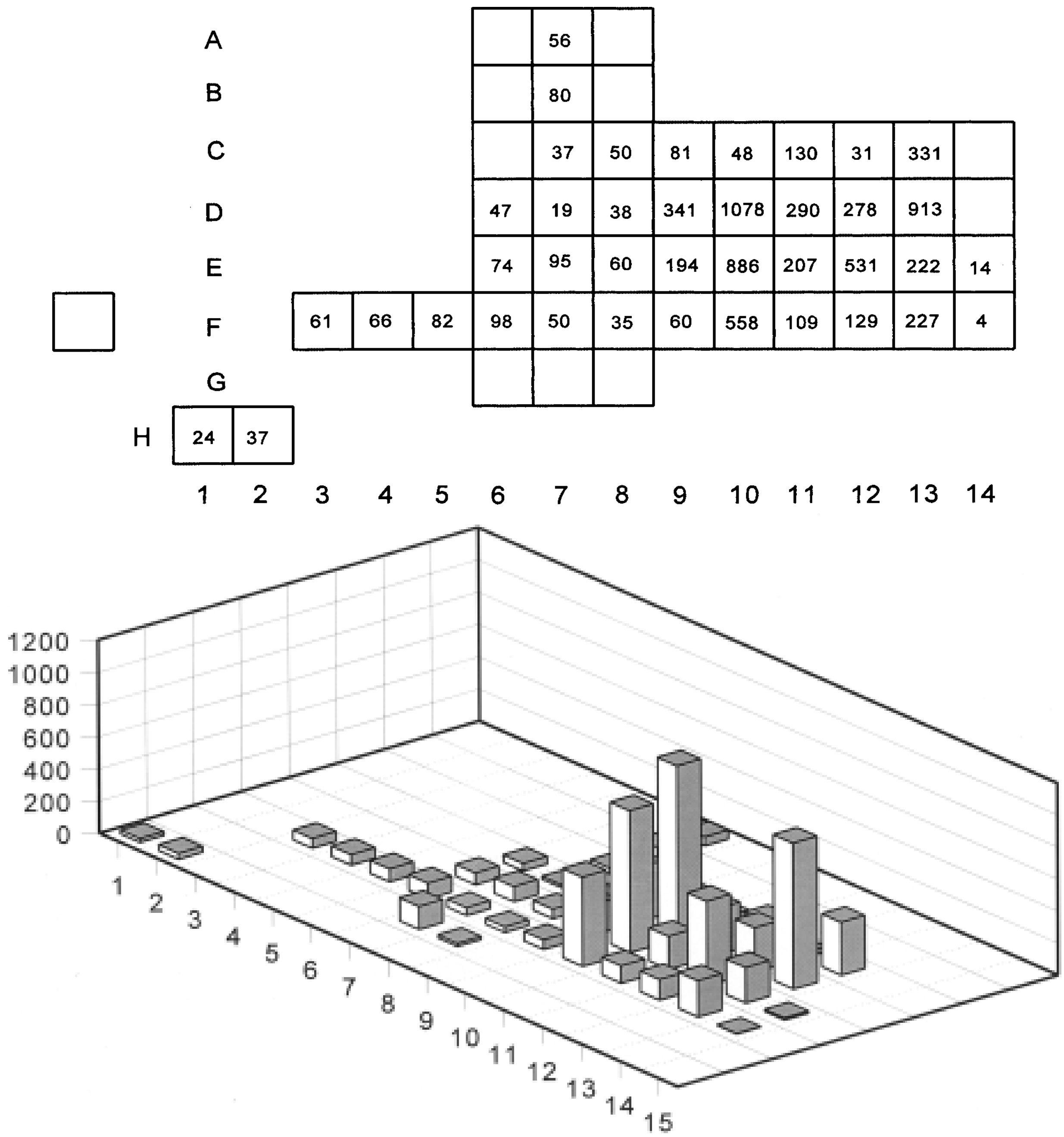


**Figure 1**. Plan of excavated squares in Trench EB97:23, Emily Bay, Norfolk Island, showing number of bird elements identifiable to taxon or taxon group, all spits in each square pooled (*above*). Isometric representation of number of identifiable bird elements in Trench EB97:23, Emily Bay, Norfolk Island, showing concentration of material in a few squares centred on D10–13 to F10–13 (*below*).

numbers on the main island in the past. In any event, larger species that were easier to catch were abundant in and near the occupation site. The archaeological sample is a subset of the breeding bird fauna: many species, particularly terns and tropicbirds, are not represented at all (Table 6).

**Seasonality**. Some impression of the time of year that the site was inhabited can be obtained from the composition of the faunal remains, most of which represent seabirds whose abundance on the island fluctuates greatly with the seasons. Many, including the most important taxa, were absent for at least half the year while on non-breeding migration to the Northern Hemisphere or elsewhere in the Pacific. Different taxa can be defined as summer- or winter-breeding. Two of the terrestrial species were also migratory, being present in the southern summer. The present status and usual breeding season of Norfolk Island birds are given in Table 6.

## Systematic list of species represented in the Emily Bay settlement site

The following descriptions provide the mean individual body weight of live birds, the proportional distribution of remains in the excavations and pertinent zoological and behavioural information.

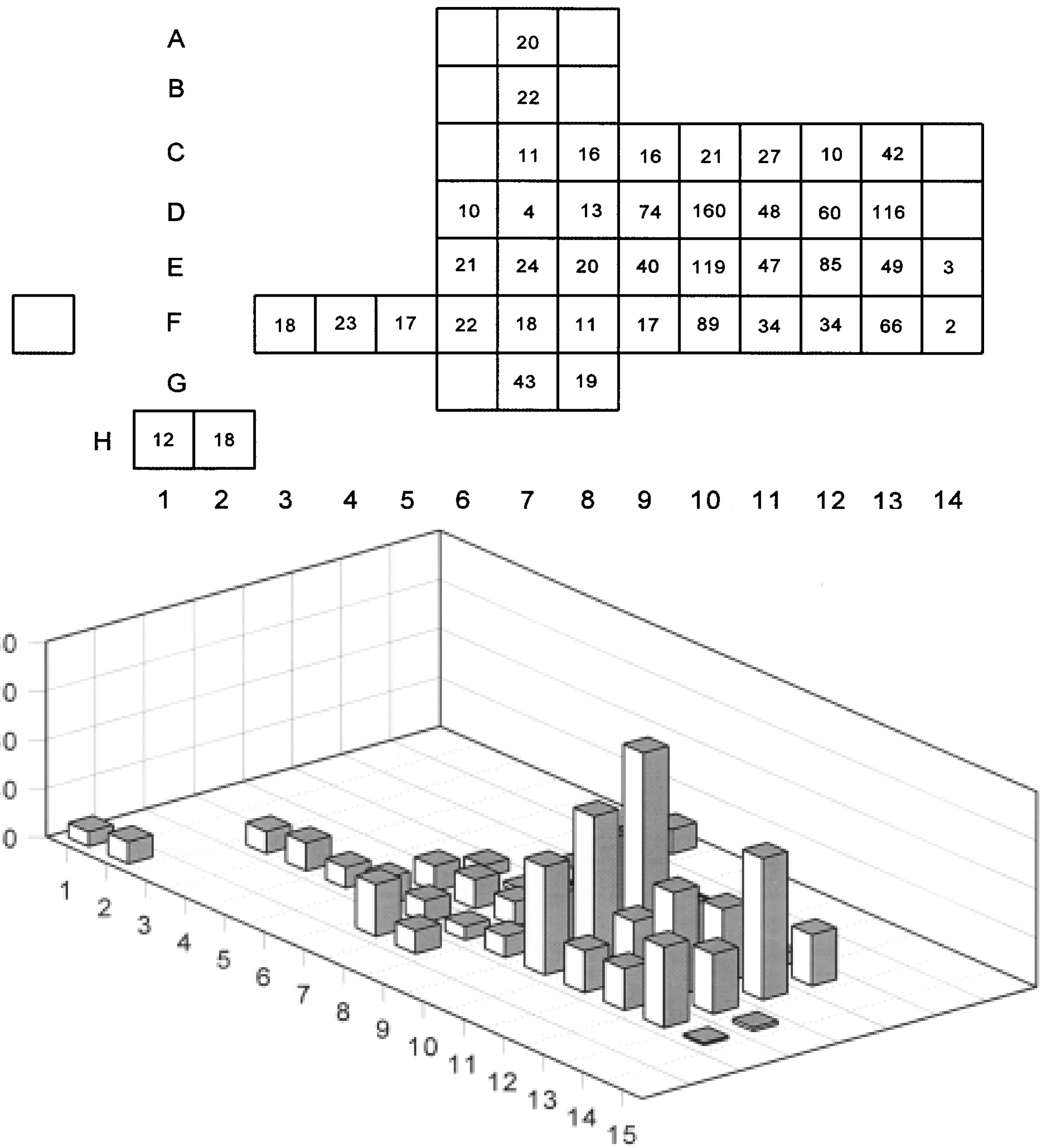


**Figure 2**. Plan of excavated squares in Trench EB97:23, Emily Bay, Norfolk Island, showing the minimum number of individuals represented by identifiable bones, all spits in each square pooled (*above*). Isometric representation of minimum number of individuals represented by identifiable bones in Trench EB97:23, Emily Bay, Norfolk Island, all spits in each square pooled. Individuals were also concentrated in one section of the excavation (*below*).

PROCELLARIIDAE—PETRELS AND SHEARWATERS
(89.7% OF SQUARES)

*Pterodroma pycrofti* Pycroft's Petrel 160 g (87.4% of squares). The smallest petrel breeding in significant numbers on Norfolk Island. The history of its discovery is discussed in the Appendix.

*Pterodroma solandri* Providence Petrel or Solander's Petrel 500 g. These and the other petrels cannot be assigned a representation by square, because their records were necessarily pooled (see Methods and Appendix). At the time of European settlement, *P. solandri* seems to have been largely, if not entirely, confined to the forest on Mt Pitt and Mt Bates. Petrel bones of the size range of *P. solandri* are abundant in the archaeological collections from Emily Bay. Either the species had a wider geographical range on the island before Europeans arrived, or the Polynesians collected birds from farther afield on that island than the environs of the Kingston flat. *Pterodroma* petrels can be attracted to the ground from flight by making various loud sounds (Tennyson and Taylor, 1990) so it is impossible to tell from the presence of *P. solandri* in the Emily Bay site, just where the birds were nesting and being hunted in Polynesian times.

*Pterodroma neglecta* Kermadec Petrel 500 g. The Kermadec Petrel has not been recognized from Norfolk Island fossil deposits before, although it has now been recorded breeding on Philip Island (Moore, 1999). A

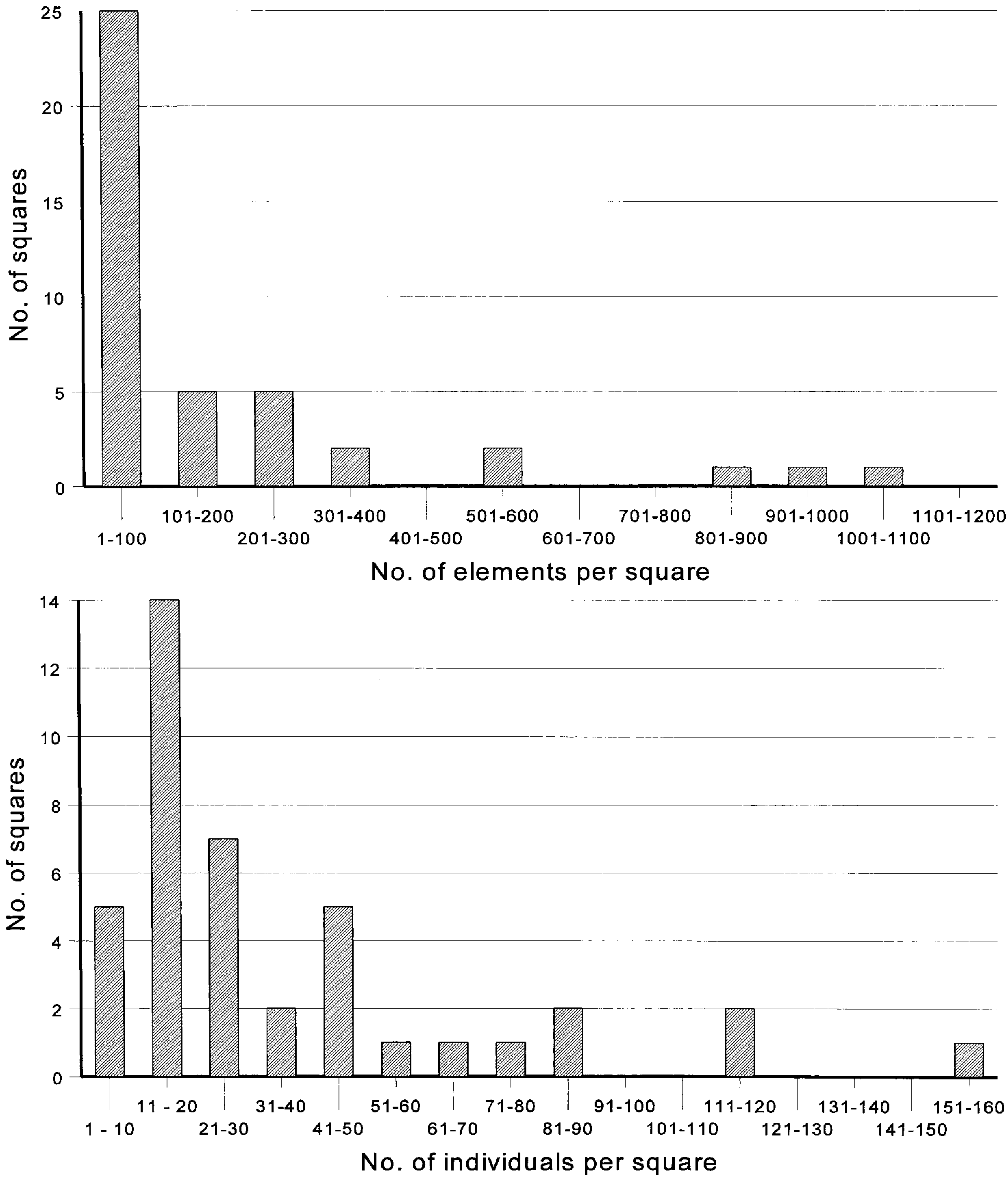


**Figure 3**. Pattern of distribution of identifiable elements per square in Trench EB97:23, Emily Bay, Norfolk Island (*above*). Pattern of distribution of individuals represented of identifiable elements per square in Trench EB97:23, Emily Bay, Norfolk Island (*below*).

summary of the reasons for including *P. neglecta* in the avifauna of Norfolk Island is given in the Appendix. The absence of reports of ground-nesting petrels in the notes and diaries of the first European settlers may result from the rarity of the species as a result of predation by Pacific rats, or because *P. neglecta* on Norfolk Island used different nest sites to those in other populations. Kermadec Petrels nest on the surface at the present colonies (Heather and Robertson, 1996), but at none of these sites are the birds hunted by diurnal birds of prey. On Norfolk Island at least one large raptor was capable of killing *P. neglecta*; a petrel population there would have had many thousands of years to adopt a burrowing habit.

*Puffinus pacificus* Wedge-tailed Shearwater 450 g. This is the common summer-breeding large petrel surviving on Norfolk Island. It still attempts to breed on headlands on the main island, but cats take many birds, and the population is probably declining. Although they could not be quantified, both adult and juvenile bones of *P. pacificus* were obviously abundant in the remains, supporting the view established

**Table 4**. Biomass (kg) represented by minimum number of individuals in each excavation at Emily Bay, based on normal body masses given in text.

| | trench | | | | | | |
|---|---|---|---|---|---|---|---|
| | **EB96:10** | **EB96:11** | **EB97:21** | **EB97:22** | **EB97:23** | **EB97:24** | **total** |
| *Pterodroma pycrofti* | 1.28 | 0.48 | 0.48 | 0.48 | 17.28 | 4.0 | 24.0 |
| other petrels | 21.15 | 2.70 | 0.45 | 4.05 | 298.35 | 40.05 | 36.75 |
| *Limosa lapponica* | 0.6 | 0.6 | 0 | 0 | 3.6 | 2.4 | 7.2 |
| *Pluvialis fulva* | 0.13 | 0.26 | 0.13 | 0.13 | 1.04 | 0.65 | 2.34 |
| *Nestor productus* | 1.0 | 1.0 | 0 | 0 | 1.0 | 0.5 | 3.5 |
| *Hemiphaga spadicea* | 2.5 | 1.0 | 0 | 0.5 | 14.0 | 6.0 | 24.0 |
| *Sula dactylatra* | 3.4 | 3.4 | 0 | 1.7 | 27.2 | 8.5 | 44.2 |
| *Gallirallus* Norfolk | 0 | 0 | 0 | 0.25 | 0.75 | 0 | 1.0 |
| *Cyanoramphus novaezelandiae* | 0 | 0.075 | 0.075 | 0 | 0.3 | 0.15 | 0.6 |
| passerines | 0.09 | 0.09 | 0 | 0 | 0.18 | 0.18 | 0.54 |
| *Gallirallus* cf. *G. philippensis* | 0.17 | 0 | 0 | 0 | 0.34 | 0.17 | 0.68 |
| *Accipiter* cf. *A. fasciatus* | 0 | 0 | 0 | 0.5 | 0.5 | 0 | 1.0 |
| *Gallicolumba* cf. *G. norfolciensis* | 0 | 0 | 0 | 0 | 0.2 | 0 | 0.2 |
| *Porphyrio* sp. | 0 | 0 | 0 | 0 | 1.6 | 0 | 1.6 |
| total | 30.32 | 9.61 | 1.14 | 7.61 | 366.34 | 62.6 | 477.61 |
| biomass $m^{-2}$ | 2.76 | 3.2 | 0.19 | 7.61 | 8.76 | 2.72 | 5.55 |

by the presence of migratory wading birds that part of the deposit was laid down in summer. *Puffinus pacificus* is migratory in the opposite sense to the Bar-tailed Godwit and Golden Plover, breeding on the islands and migrating to the North Pacific in the southern winter. They are large and aggressive petrels and are not known to be attracted to strange noises so must have been collected at the breeding colonies.

*Puffinus assimilis* Norfolk Island Little Shearwater 200 g. Holdaway *et al*. (2001) recognize the Norfolk Island form of little shearwater as a separate species from others at the Kermadecs, northern New Zealand, and the New Zealand subantarctic. On this view, *P. assimilis* is a rare and endangered species, as most breeding attempts on the main island are thwarted by cats and rats. Only the population breeding on Philip Island has both the space and freedom from predation to be sure of survival in the medium to long term. Although this species is not abundant in the archaeological samples, *P. assimilis* was certainly part of the diet of the Emily Bay people. Both *P. assimilis* and the similar-sized *P. auricularis newelli* may have bred on the island formerly (Appendix). Their size makes both species vulnerable to predation by Pacific rats (Booth *et al*., 1996) and hence they may have suffered more from rat predation than from human exploitation when there were larger species to concentrate on.

### SULIDAE—GANNETS AND BOOBIES

*Sula dactylatra* Masked Booby 1700 g (73.6% of squares). Boobies were the largest terrestrial prey available on the Norfolk Island group. It is not surprising that they were relatively common in the deposit (26 individuals; 2.6% of total birds; 9.25% total body mass). At about four times the mass of a large petrel, the boobies would have been attractive and easy prey. At first contact, it is likely that *S. dactylatra* nested on open, flat areas such as the tops of stacks (to which they are largely confined today by human persecution) and on the sandy beaches so would have been extremely vulnerable. It is unlikely that beach colonies of *S. dactylatra* could have survived the first year of human occupation of Norfolk Island. Masked Boobies elsewhere

**Table 5**. Percentage of biomass contributed by each taxon or group of taxa in the excavations at Emily Bay.

| | trench | | | | | | |
|---|---|---|---|---|---|---|---|
| | **EB96:10** | **EB96:11** | **EB97:21** | **EB97:22** | **EB97:23** | **EB97:24** | **total** |
| *Pterodroma pycrofti* | 4.22 | 5.00 | 42.29 | 6.31 | 4.72 | 6.39 | 5.03 |
| other petrels | 69.76 | 28.11 | 39.65 | 53.22 | 81.44 | 63.98 | 76.79 |
| *Limosa lapponica* | 1.98 | 6.25 | 0 | 0 | 0.98 | 3.83 | 1.51 |
| *Pluvialis fulva* | 0.43 | 2.71 | 11.45 | 1.71 | 0.28 | 1.04 | 0.49 |
| *Nestor productus* | 3.30 | 10.41 | 0 | 0 | 0.27 | 0.80 | 0.73 |
| *Hemiphaga spadicea* | 8.25 | 10.41 | 0 | 6.57 | 3.82 | 9.58 | 5.03 |
| *Sula dactylatra* | 11.21 | 35.40 | 0 | 22.34 | 7.42 | 13.58 | 9.25 |
| *Gallirallus* Norfolk | 0 | 0 | 0 | 3.29 | 0.20 | 0 | 0.21 |
| *Cyanoramphus novaezelandiae* | 0 | 0.78 | 6.61 | 0 | 0.08 | 0.24 | 0.13 |
| passerines | 0.30 | 0.94 | 0 | 0 | 0.05 | 0.29 | 0.11 |
| *Gallirallus* cf. *G. philippensis* | 0.56 | 0 | 0 | 0 | 0.09 | 0.27 | 0.14 |
| *Accipiter* cf. *A. fasciatus* | 0 | 0 | 0 | 6.57 | 0.14 | 0 | 0.21 |
| *Gallicolumba* cf. *G. norfolciensis* | 0 | 0 | 0 | 0 | 0.05 | 0 | 0.04 |
| *Porphyrio* sp. | 0 | 0 | 0 | 0 | 0.44 | 0 | 0.34 |

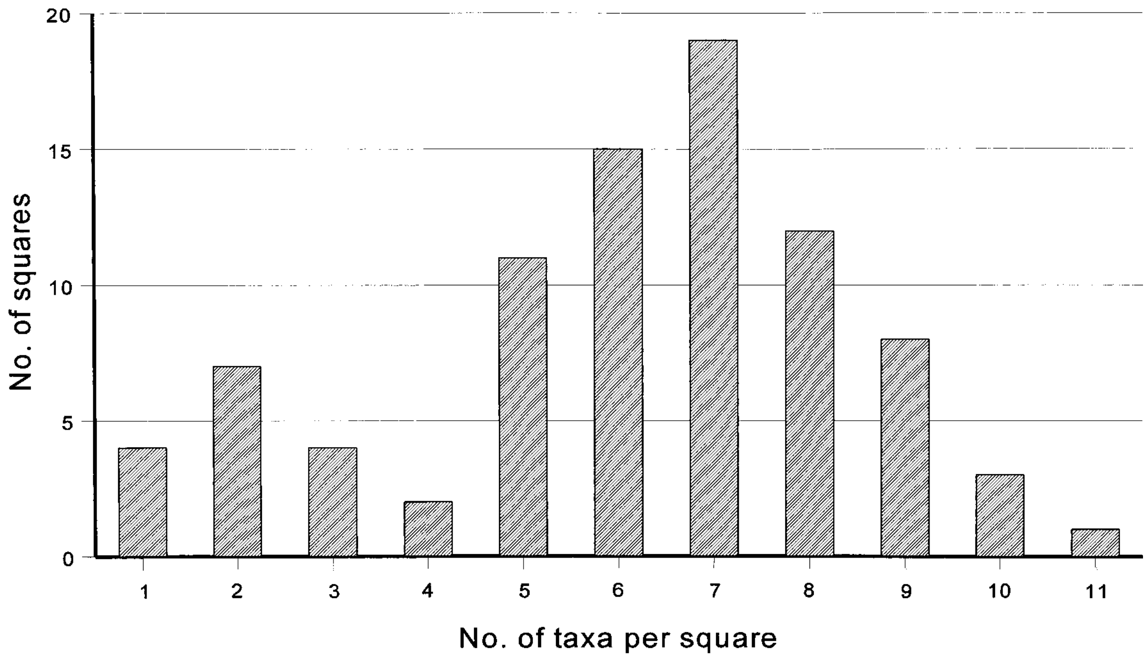


**Figure 4**. Distribution of taxa in squares in Trenches EB96:10, EB96:11, EB97:21, EB97:22, EB97:23, and EB97:24, Emily Bay, Norfolk Island.

nest mainly on low islands and amid dunes (Serventy *et al*., 1971). A larger species described from the island is not accepted here (Appendix).

### PHAETHONTIDAE—TROPICBIRDS

Only *Phaethon rubricauda*, the Red-tailed Tropicbird at 900–1,000 g approached the mass of a Masked Booby. At twice the mass of a large petrel, and in relative abundance around the islands, it is surprising that Red-tailed Tropicbirds do not figure in the food remains. Their tails are highly prized elsewhere in Polynesia (Steadman, 1997) and it might have been expected that some birds would have been taken for that purpose, but if so their remains were not found at the Emily Bay site.

### ACCIPITRIDAE—HAWKS AND EAGLES

*Accipiter* cf. *A. fasciatus* Brown Goshawk 350–500 g (9.2% of squares). Remains of the goshawk were rare in the site, but most had clearly been cooked and eaten. Remains of harriers (*Circus* species) are occasionally found in Polynesian sites in New Zealand and appear to have been eaten there as well.

### RALLIDAE—RAILS

*Gallirallus philippensis* Banded Rail 170 g (9.2% of squares). The status of the Banded Rail on Norfolk Island has been the subject of debate (e.g., Schodde *et al*., 1983), but fossil remains reported by Meredith (1985, 1991) and in this paper show that it was present in pre-European times in sufficient numbers for it to be available as a resource for the Polynesian inhabitants. It was therefore sympatric with the undescribed endemic flightless species of *Gallirallus* and was possibly a relatively recent arrival.

*Gallirallus* new species ?250 g (5.7% of squares). Meredith (1985, 1991) reported the presence of a rail larger than *Gallirallus philippensis* in fossil collections from Norfolk Island, but did not describe or name it. He referred it to *Gallirallus* and suggested that it was flightless. A rail painted during the first European settlement of Norfolk Island (no. 79 in the "Sydney" series, Hindwood, 1965) has been identified as *G. philippensis* but could equally be this species.

*Porphyrio* species Swamphen 800 g (3.4% of squares). Races of *Porphyrio porphyrio* and other species of *Porphyrio* are widespread in the Pacific (Ripley, 1977; Steadman, 1988). Ramsay (1888) was the first to record Swamphens (*Porphyrio porphyrio*) on Norfolk Island in historic times. By 1978 the species was still regarded as an "uncommon, restricted self-introduced resident" (Schodde *et al*., 1983). Meredith (1985, 1991) did not record fossil material of *Porphyrio*. A few bones of a small *Porphyrio* found in Trench EB97:23 constitute the only evidence for the former presence of Swamphens on the island. Unfortunately, there is insufficient material for a statistical analysis, but comparison with an individual of the New Zealand population suggests that the Norfolk Island *Porphyrio* were smaller than New Zealand birds and perhaps more similar to the small races of the islands to the north than to the Australian and New Zealand forms. The presence of more than one individual of *Porphyrio* at the Emily Bay site indicates the presence of a population and hence that suitable habitat for the species was present during the Polynesian occupation.

Norfolk Island had at least four species of rail, a high diversity of rails for its area. Besides the three discussed here, the Spotless Crake (*Porzana tabuensis*) was also present (Meredith, 1991, and Appendix).

### SCOLOPACIDAE—SNIPE AND GODWIT

*Limosa lapponica* Bar-tailed Godwit 300 g (65.5% of squares). *Limosa lapponica* migrates each year from the breeding area on the Siberian tundra to wintering grounds that include the estuaries of New Zealand. They occur on Norfolk Island from September to March (Schodde *et al*., 1983). The number of individuals in the Emily Bay deposit

**Table 6**. The late Holocene avifauna of Norfolk Island, with representative body mass (g), present status at Norfolk Island, representation in the Emily Bay archaeological site, and breeding season. EB, present in the Emily Bay fauna; *E*, now extinct as a breeding species.

| | | mass | status | EB | season |
|---|---|---|---|---|---|
| Procellariidae (petrels and shearwaters) | | | | | |
| *Pterodroma neglecta* | Kermadec Petrel | 500 | recolonizing | Y | all year |
| *Pterodroma solandri* | Providence Petrel | 500 | recolonizing | Y | Winter |
| *Pterodroma pycrofti* | Pycroft's Petrel | 160 | extinct | Y | Summer |
| ?*Pterodroma nigripennis* | Black-winged Petrel | 175 | ?recolonizing | | Summer |
| *Puffinus pacificus* | Wedge-tailed Shearwater | 450 | breeding | Y | Summer |
| *Puffinus assimilis* | Norfolk Island Little Shearwater | 200 | breeding | | Winter |
| Hydrobatidae (storm petrels) | | | | | |
| *Pelagodroma albiclunis* | Kermadec Storm Petrel | 45 | extinct | | Summer |
| ?*Fregetta grallaria* | White-bellied Storm Petrel | 50 | ?extinct | | late Summer |
| Sulidae (gannets and boobies) | | | | | |
| *Sula dactylatra* | Masked Booby | 1700 | breeding | Y | all year |
| Phaethontidae (tropicbirds) | | | | | |
| *Phaethon rubricauda* | Red-tailed Tropic Bird | c. 900 | breeding | | Summer |
| Accipitridae (hawks and eagles) | | | | | |
| *Accipiter* cf. *A. fasciatus* | ?Brown Goshawk | 500 | extinct | Y | ? |
| Rallidae (rails) | | | | | |
| *Gallirallus* undescribed sp. | Norfolk Island Rail | 250? | extinct | Y | ? |
| *Gallirallus philippensis* | Banded Rail | 170 | vagrant | Y | Summer |
| *Porzana tabuensis* | Spotless Crake | 45 | *E*, vagrant | | Summer |
| *Porphyrio* sp. | Swamphen | 800 | extinct | Y | Spring–Summer |
| Scolopacidae (snipe and godwits) | | | | | |
| *Coenocorypha* undescribed sp. | Norfolk Island Snipe | 100 | extinct | | Summer |
| *Limosa lapponica* | Bar-tailed Godwit | 300 | migrant | Y | Summer |
| *Numenius phaeopus* | Whimbrel | 450 | migrant | | Summer |
| Charadriidae (dotterels and plovers) | | | | | |
| *Pluvialis fulva* | Pacific Golden Plover | 130 | migrant | Y | Summer |
| Laridae (gulls and terns) | | | | | |
| *Sterna fuscata* | Sooty Tern | 210 | breeding | | Spring–Summer |
| *Anous stolidus* | Common Noddy | 200 | breeding | | Spring–Summer |
| *Anous minutus* | Black Noddy | 100 | breeding | | Spring |
| *Procelsterna cerulea* | Grey Ternlet | 75 | breeding | | Spring |
| *Gygis alba* | White Tern | 110 | breeding | | Spring |
| Columbidae (pigeons and doves) | | | | | |
| *Hemiphaga spadicea* | Norfolk Island Pigeon | 650 | extinct | Y | all year? |
| *Gallicolumba* cf. *G. norfolciensis* | Norfolk Island Ground Dove | 200? | extinct | Y | ? |
| Psittacidae (parrots and parakeets) | | | | | |
| *Cyanoramphus novaezelandiae cookii* | Norfolk Island Green Parrot | 75 | endangered | Y | Spring–Summer |
| *Nestor productus* | Norfolk Island Kaka | 400 | extinct | Y | Summer |
| Cuculidae (cuckoos) | | | | | |
| *Eudynamys taitensis* | Long-tailed Cuckoo | 125 | migrant | | Summer |
| Strigidae (typical owls) | | | | | |
| *Ninox novaeseelandiae* | Southern Boobook | 175 | endangered | | Summer |
| Alcedinidae (kingfishers) | | | | | |
| *Halcyon sancta* | Sacred Kingfisher | 65 | breeding | | Summer |
| **Songbirds** | | | | | |
| Campephagidae (trillers) | | | | | |
| *Lalage leucopyga* | Long-tailed Triller | 50? | extinct | | ? |
| Muscicapidae (northern flycatchers) | | | | | |
| *Turdus poliocephalus* | Grey-headed Blackbird | 90? | extinct | | Spring? |
| Pachycephalidae (thickheads) | | | | | |
| *Pachycephala pectoralis* | Golden Whistler | 50? | breeding | | Spring? |
| Acanthizidae (flyeaters) | | | | | |
| *Gerygone modesta* | Norfolk Island Gerygone | 6.5 | breeding | | Spring? |
| Monarchidae (monarch flycatchers) | | | | | |
| *Rhipidura fuliginosa* | Grey Fantail | 8 | breeding | | Spring? |
| Petroicidae (southern robins) | | | | | |
| *Petroica multicolor* | Pacific Robin | 11 | breeding | | Spring? |
| Zosteropidae (silvereyes) | | | | | |
| *Zosterops tenuirostris* | Slender-billed White-eye | 15 | breeding | | Spring? |
| *Zosterops albogularis* | White-chested White-eye | 16 | breeding | | Spring? |
| Sturnidae (starlings) | | | | | |
| *Aplonis fusca* | Norfolk Island Starling | 80? | extinct | | Spring? |

suggests that *L. lapponica* was taken from migrating flocks, as relatively few birds would have been resident on the island when it was still mainly forested.

CHARADRIIDAE—PLOVERS

*Pluvialis fulva* Pacific Golden Plover 130 g (48.3% of squares). Less common than the godwit in the samples, *Pluvialis fulva* was nevertheless more abundant than resident land birds such as the parrot and parakeet. Because this species is a strong-flying migrant, the degree of representation is rather anomalous, even though the birds are much tamer on smaller islands than they are on the New Zealand mainland (Heather and Robertson, 1996) and might therefore have been easier to catch. The identification is based on the likelihood of occurrence of the two species of golden plover in the Pacific. The species is listed in older literature as *Pluvialis dominica*, but that is now regarded as a separate species with allopatric non-breeding distributions (Connors, 1983).

COLUMBIDAE

*Hemiphaga spadicea* Norfolk Island Pigeon 650 g (73.6% of squares). The Norfolk Island Pigeon was very similar to *Hemiphaga novaeseelandiae*, the New Zealand Pigeon, of which it has been regarded as a subspecies by some authors (Schodde *et al*., 1983). The New Zealand bird was a regular item in the diet of Polynesians there (Oliver, 1955). *Hemiphaga spadicea* survived on Norfolk Island into the early nineteenth century. It is the most abundant of the terrestrial birds in the archaeological avifauna, in which young birds as well as adults were represented.

*Gallicolumba* cf. *G. norfolciensis* Norfolk Island Ground Dove 200 g (3.4% of squares). The status of the small doves on Norfolk Island has yet to be resolved. Whether *Chalcophaps indica* was resident before habitat destruction became important in the European era is not known. Although fossils have been found (Meredith, 1991), none has been dated. The presence of a species of *Gallicolumba* was confirmed by Meredith (1985, 1991). It is probably this species which was mentioned in the diaries of the first European settlers and is the subject of a painting done before 1800 (no. 89, "Sydney" series, Hindwood, 1965). Bones of a dove-sized pigeon, apparently this species, were rare in the archaeological fauna. The fragmentary material did not allow complete certainty of the identification.

PSITTACIDAE

*Nestor productus* Norfolk Island, or Long-billed, Kaka 400 g (18.4% of squares). Although *Nestor productus* was apparently common when Europeans reached the island and therefore was likely to have been a prominent component of the avifauna exploited by Polynesians, surprisingly few were represented in the archaeological deposits. The New Zealand species *N. meridionalis* was a favoured item in the diet of Maori from settlement to historic times, and its feathers were used in cloak manufacture (Oliver, 1955): *N. productus* was even more colourful so Polynesians may have caught it for its feathers as well as the meat.

*Cyanoramphus novaezelandiae cooki* Norfolk Island Green Parrot; Norfolk Island Red-crowned Parakeet 75 g (21.8% of squares). Green Parrots are rare in the archaeological record and constituted only a minor and opportunistic food source.

PASSERINES (20.7% OF SQUARES)

The Grey-headed Blackbird *Turdus poliocephalus* (?90 g) and other species such as the Norfolk Island Starling *Aplonis fuscus* represented a tiny percentage of the total biomass in the deposits. Their presence is important mainly as an indication of the eclectic diet of the inhabitants, which again parallels that observed in New Zealand sites where even *Petroica*s (New Zealand Robins) were consumed.

## Discussion

The faunal remains in the archaeological site at Emily Bay are confined mainly to birds, fish, and introduced Pacific rats. The dominance of seabirds is understandable, because the species were very abundant, easy to catch, and mostly large enough to constitute worthwhile additions to the diet. It appears that the larger petrels were, indeed, a staple food for the early Polynesian inhabitants of the island, as one species was for Europeans for a short period in the early part of their occupation. Other marine species, and most of the land birds, appear to have been included in the diet only as adjuncts, probably when they could be caught with little or no effort. As most of the *Pterodroma* petrels can be called from the sky during the breeding season, food gathering on Norfolk Island—while the petrel populations survived—would have been remarkably easy; but the diet might have been rather monotonous.

**Taphonomy, butchering, and consumption**. Patterns of survival of elements confirmed that most of the deposit accumulated as debris from human occupation. The pattern of bone breakage and survival was typical of a large predator that could process and remove as much of the available nutrients from each carcass as possible. For the major long bones, such as tibiotarsus, humerus, and ulna, only one end (often the proximal) is well represented, indicating that the sections holding the most meat have been removed, and probably consumed along with the meat. Interestingly, the pattern of archaeological bone survival is quite similar to that found in deposits accumulated by the large extinct harrier *Circus eylesi* in New Zealand (RNH, unpubl. data) in which the larger long bones and most bones from the body are not present, and peripheral, even tiny, elements are well-represented in the sample.

The taphonomic processes contributed to the difficulty of assigning most petrel material to species, apart from the very small *P. pycrofti*, exacerbating the already difficult task of separating closely similar species with inadequate reference material. However, the lumping of petrel taxa into two groups should not have altered the main conclusion of the study, that petrels were the main item of diet of the people who lived at the site.

**Limited avifauna as part of a limited natural food supply**. Polynesians living on Norfolk Island had a much smaller choice of natural foods than they did on other island groups elsewhere in the Pacific. In particular, most of the coastline consists of steep slopes above a rocky shore or vertical cliffs. There are few beaches (Anson Bay, Cemetery Bay, Emily Bay, Slaughter Bay), and the littoral zone has very few species of (small) mollusc and echinoderms. The small area of reef at Slaughter Bay meant that only fishing in deep water was likely to be productive enough to support a human population. That in turn meant that the birds would have been proportionately more important than on most other islands. Their importance is reflected in their relative abundance in the food remains at Emily Bay. Although the avifauna was limited in variety, some species, including two or three petrels, were extremely abundant. Others, including all the terns that are such a feature of the present avifauna, were, for whatever reason, virtually ignored for food.

**Choice versus availability of food**. The biases in the avian remains from the archaeological excavations could indicate either that the people actively selected a limited range of species from those available on the island, or took by default those species that were most abundant and easy to catch. In general, most species in the deposits could have been collected within 500 m of the site. The two most abundant species were both *Pterodroma* petrels that could be harvested from the surface or from burrows in the neighbourhood of Emily Bay, and which could also have been called down from the sky by shouting or hand-clapping (Tennyson and Taylor, 1990).

Meredith (1985) reported that both *P. pycrofti* and his *Pterodroma* new species were rare in the First Settlement deposits that he examined. As the former, which is the smaller of the two, is well within the size range for predation on adults, eggs, and young by Pacific rats (Holdaway, 1999), its rarity by the late eighteenth century is not surprising. The apparently low abundance of the larger, *Pterodroma* new species (probably *P. neglecta*) at European contact is more difficult to explain. *Pterodroma neglecta* survived in the presence of Pacific rats on Raoul Island from about 650 years ago (Anderson, 1980) into the early twentieth century, so apparently can cope with some predation even though its egg is just within the ability of Pacific rats to open (Holdaway, 1999). High numbers of rats maintained by the year-round availability of animal and vegetable food might have created conditions that allowed rat predation to be more severe than it might have been otherwise. Another possible factor in the rarity of *P. neglecta* in the First Settlement deposits was the degree to which it might have been taken as a preferred food by the Polynesians. Unfortunately, identification problems for the petrels made quantification of their relative representation impossible.

**Seasonality**. It is apparent that food was harvested throughout the year at Emily Bay: *P. pycrofti*, a summer breeder (Heather and Robertson, 1996), is a major part of the sample, as is *P. solandri*, which breeds in the southern winter. The young of *P. pycrofti* would be available up to the time of their fledging in late summer and autumn. Again, although *P. neglecta* has been recorded nesting at most times of the year in various parts of its huge breeding range, birds in the remaining colonies usually lay their eggs from October to March, so that species and *Puffinus pacificus* would have supplemented the supply of *P. pycrofti*, which as a smaller bird would provide less meat per animal.

A greater variety of birds would be available in summer, with the presence of the migrant waders and several species of petrel. In winter, the people would have had to depend on *P. solandri* and *Puffinus assimilis*. That dependence, at a time of greater frequency of storms and hence lower availability of fish, may have limited the human population that could be supported on the island over a period of years. The population of *P. solandri* on the higher areas of the island could not sustain predation by the few hundred people of the First Settlement for more than a few years.

**Species representation and extinction**. There were substantially fewer species represented in the Emily Bay archaeological site than were available in the local environment. To some extent, the comparison is unequal, because the natural bone deposits from which the composition of the late Holocene avifauna of Norfolk Island has been established (Meredith, 1985, 1991) accumulated over thousands of years, whereas the archaeological site may have existed for less than 200 years and, in addition, only about 3.5% of it was excavated. While it is unlikely that the avifauna found by the first Polynesian settlers differed greatly from that reported by the earliest European inhabitants—plus the known extinct species—it is difficult to tell whether the archaeological absence of the more than half of the late Holocene avifauna (excluding songbirds) can be explained by sampling biases during the prehistoric fowling or during archaeological recovery, or by other factors.

The rarity of terrestrial species in the deposit is noteworthy. Contrary to Meredith (1985), it is likely that *Rattus exulans* was responsible for the extinction of several of the smaller, terrestrial birds on Norfolk Island. No other environmental factors are known which could have affected small species, and terrestrial as well as oceanic species. In fact, the extinctions of small vertebrates on Norfolk Island parallels the far more extensive extinctions attributed to the Pacific rat in New Zealand (Holdaway, 1999). Species lacking from the archaeological collection but known from natural fossil deposits at Cemetery Bay and elsewhere include a prion (*Pachyptila* species), a storm petrel (*Pelagodroma* species, presumably *P. albiclunis*, the Kermadec Storm petrel), and a southern snipe (*Coenocorypha* new species), all of which were palatable to both humans and rats.

The absence of Norfolk Island Snipe (*Coenocorypha* new species) from the archaeological deposits is particularly noticeable as there are remains of two shorebirds (*Pluvialis fulva*, *Limosa lapponica*) that should have been harder to catch. *Coenocorypha* new species and *P. fulva* had roughly the same body mass (105 g vs 130 g). The former is unlikely to have been missed in recovery of material, because passerine bones were recovered and many elements smaller than snipe bones were common in the collection. Given the size of the sample, it is unlikely that *Coenocorypha* new species was present when the archaeological deposits were formed. Why this should be, when other wading birds were eaten regularly, is unknown, although the Pacific rat and snipe of the genus *Coenocorypha* have been unable to coexist elsewhere (Holdaway, 1999). If the rat population rose to and was sustained at a high level by abundant petrels, as it would have been on Norfolk Island, then extinctions could have occurred extremely rapidly, as occurred when *Rattus rattus* reached the Big South Cape Islands off southern New Zealand in the early 1960s (Bell, 1978).

Various scenarios are possible in relation to the absence of snipe and other taxa in the archaeological assemblage. The lack of terns, which are the most obvious seabirds on Norfolk Island today, may be related to the cost and benefits of harvesting. Some species, such as the Sooty Tern, may have been more limited in numbers on the island in the past. Tropicbirds are used by Pacific peoples for ornamentation as well as for food, so the absence of this presently common species from the archaeological avifauna is rather surprising. It is unfortunate that the archaeology of Norfolk Island does not, so far, offer later prehistoric settlement sites with bird bone middens in which to test some of the propositions suggested here. The only comparisons possible at present are with the records made by the first European settlers (Meredith, 1985) and the material in the deposits of that date.

## Conclusions

In terms of body mass, and therefore available meat value, the archaeological avifauna from Emily Bay discloses a strong predominance of petrels and boobies, as might be predicted from the relative body mass and probable abundance of these taxa in the local environment. Larger forest birds are relatively scarce, especially the rails, Norfolk Island Kaka, and Norfolk Island Ground Dove. Some small terrestrial taxa are absent and either were not sought or may have become extinct so rapidly (probably as a result of predation by the Pacific rat, *Rattus exulans*) that they were not incorporated in the Emily Bay deposits. The archaeological fauna of Norfolk Island includes species such as Pycroft's Petrel (*Pterodroma pycrofti*) that were either locally extinct, or at least very rare, when Europeans reached the island. It is apparent, therefore, that Norfolk Island fits the pattern of other Pacific Islands, where early contact by Polynesian settlers resulted in the extinction of the more vulnerable of the resident bird species (Steadman, 1997).

ACKNOWLEDGMENTS. RNH thanks the New Zealand Foundation for Research, Science & Technology for support for this work, undertaken as part of Contract PLC501. Thanks are also due to Alan Tennyson and Geoff Tunnicliffe for access to the collections in their care at the Museum of New Zealand Te Papa Tongarewa and Canterbury Museum, respectively. Alan Tennyson and Trevor Worthy provided most helpful advice and discussion on the sorrows and joys of the identification of petrel bones and the species that may have bred on the island.

## References

Anderson, A.J., 1980. The archaeology of Raoul Island (Kermadecs) and its place in the settlement history of Polynesia. *Archaeology and Physical Anthropology in Oceania* 15: 131–141.

Anderson, A.J., 1996. Discovery of a prehistoric habitation site on Norfolk Island. *Journal of the Polynesian Society* 105: 479–486.

Anderson, A.J., in press. No meat on that beautiful shore: the prehistoric abandonment of subtropical Polynesian islands. In *Zooarchaeology of Oceanic Coasts and Islands*, ed. A.J. Anderson and B.F. Leach. *International Journal of Osteoarchaeology*.

Bartle, J.A., D. Hu, J-C. Stahl, P. Pyle, T.R. Simons and D. Woodby, 1993. Status and ecology of gadfly petrels in the temperate North Pacific. In *The Status, Ecology, and Conservation of Marine Birds of the North Pacific*, ed. K. Vermeer, K.T. Briggs, K.H. Morgan and D. Siegel-Causey, pp. 101–111. Ottawa: Canadian Wildlife Service special publication.

Bell, B.D., 1978. The Big South Cape Islands rat irruption. In *The Ecology and Control of Rodents in New Zealand Nature Reserves*, ed. P.R. Dingwall, I.A.E. Atkinson and C. Hay, pp. 33–40. Wellington: New Zealand Department of Lands and Survey Information Series no. 4.

Booth, A.M., E.O. Minot, R.A. Fordham and J.G. Innes, 1996. Kiore (*Rattus exulans*) predation on the eggs of the little shearwater (*Puffinus assimilis haurakiensis*). *Notornis* 43: 147–153.

Brooke, M. de L., and G. Rowe, 1996. Behavioural and molecular evidence for specific status of pale and dark morphs of the Herald petrel *Pterodroma heraldica*. *Ibis* 138: 420–432.

Connors, P.G., 1983. Taxonomy, distribution, and evolution of golden plovers (*Pluvialis dominica* and *Pluvialis fulva*). *Auk* 100: 607–620.

Gurney, J.H., Sr., 1854. Note on *Nestor productus*, the extinct parrot of Philip Island. *The Zoologist 1854*: 4298.

Harrison, P., 1983. *Seabirds: An Identification Guide*. Wellington: Croom Helm and A.H. and A.W. Reed.

Hawkins, J., 1988. The Farewell Spit gannetry—A new sea level colony. *Notornis* 35: 249–260.

Heather, B.D., and H.A. Robertson, 1996. *Field Guide to the Birds of New Zealand*. Auckland: Viking.

Hermes, N., O. Evans and B. Evans, 1986. Norfolk Island birds: a review 1985. *Notornis* 33: 141–149.

Hindwood, K.A., 1940. The birds of Lord Howe Island. *Emu* 50: 1–86.

Hindwood, K.A., 1965. The "Sydney" bird paintings. *The Australian Zoologist* 13: 83–92.

Hindwood, K.A., and D.L. Serventy, 1943. Further notes on *Pterodroma leucoptera*. *Emu* 42: 153–155.

Hoare, M., 1987. *Norfolk Island: An Outline of its History 1774–1987*. St Lucia: University of Queensland Press.

Holdaway, R.N., 1999. Introduced predators and avifaunal extinction in New Zealand. In *Extinctions in Near Time: Causes, Contexts, and Consequences*, ed. R.D.E. MacPhee, pp. 189–238. New York: Kluwer Academic/Plenum Press.

Holdaway, R.N., T.H. Worthy and A.J.D. Tennyson, 2001. A working list of breeding bird species of the New Zealand region at first human contact. *New Zealand Journal of Zoology* 28: 119–187.

Kirch, P.V., 1988. Polynesia's mystery islands. *Archaeology* May/June: 26–31.

Marchant, S., and P.J. Higgins, co-ordinators, 1990. *Handbook of Australian, New Zealand & Antarctic Birds, vol. 1—Ratites to Ducks*. Melbourne: Oxford University Press.

Mathews, G.M., 1912. The geographic relationships of the birds of Lord Howe, Norfolk and Kermadec Islands. *Australasian Record* 1: 121–122.

Meredith, C.W., 1985. The fossil fauna of Norfolk Island, Southwest Pacific, and a review of the phylogeny of the genus *Pterodroma*. Unpublished PhD thesis, Department of Zoology, Monash University, Clayton, Victoria, Australia.

Meredith, C.W., 1991. Vertebrate fossil faunas from islands in Australasia and the southwest Pacific. In *Vertebrate Palaeontology of Australasia*, ed. P. Vickers-Rich, J.M. Monaghan, R.F. Baird and T.H. Rich, pp. 1345–1382. Melbourne: Monash University Publications Committee.

Moore, J.L., 1999. Norfolk Island bird notes, 1977–1997. *Notornis* 46: 354–364.

North, A.J., 1890. Nests and eggs of birds found breeding in Australia and Lord Howe and Norfolk Islands. *Australian Museum Catalogue* 12: 372–379, 412–414. Sydney: Australian Museum.

Oliver, W.R.B., 1955. *New Zealand Birds*. Wellington: A.H. & A.W. Reed.

Ramsay, E.P., 1888. *Tabular List of All the Australian Birds at Present Known to the Author, Showing the Distribution of the Species Over the Continent of Australia and Adjacent Islands*. Sydney: The author.

Ripley, S.D., 1977. *Rails of the World: a Monograph of the Family Rallidae*. Boston: Godine.

Saunders, H., and O. Salvin, 1896. *Catalogue of the Gaviae and Tubinares in the Collection of the British Museum (Catalogue of the Birds in the British Museum Vol. XXV)*. London: British Museum (Natural History).

Schodde, R., P. Fullagar and N. Hermes, 1983. *A Review of Norfolk Island Birds: Past and Present*. Australian National Parks & Wildlife Service, Special Publication 8. Canberra: Australian National Parks & Wildlife Service.

Serventy, D.L., V. Serventy and J. Warham, 1971. *The Handbook of Australian Sea-birds*. Sydney: A.H. & A.W. Reed.

Steadman, D.W., 1988. A new species of *Porphyrio* (Aves: Rallidae) from archaeological sites in the Marquesas Islands. *Proceedings of the Biological Society of Washington* 101: 162–170.

Steadman, D.W., 1997. Extinctions of Polynesian birds: reciprocal impacts of birds and people. In *Historical Ecology in the Pacific Islands: Prehistoric Environmental and Landscape Change*, ed. P.V. Kirch and T.L. Hunt, pp. 51–79. New Haven and London: Yale University Press.

Steadman, D.W., and S.L. Olson, 1985. Bird remains from an archaeological site on Henderson Island, South Pacific: Man-caused extinctions on an "uninhabited" island. *Proceedings of the National Academy of Sciences, U.S.A.* 82: 6191–6195.

Tennyson, A.J.D., 1991. The black-winged petrel on Mangere Island, Chathams Islands. *Notornis* 38: 111–116.

Tennyson, A.J.D., and G.A. Taylor, 1990. Behaviour of *Pterodroma* petrels in response to "war-whoops". *Notornis* 37: 121–128.

van Tets, G.F., C.W. Meredith, P.J. Fullagar and P.J. Davidson, 1988. Osteological differences between *Sula* and *Morus*, and a description of an extinct new species of *Sula* from Lord Howe and Norfolk Islands, Tasman Sea. *Notornis* 35: 35–57.

Wakelin, H., 1968. Some notes on the birds of Norfolk Island. *Notornis* 15: 156–174.

Whitley, H.P., 1938. Naturalists of the First Fleet. *Australian Museum Magazine* 6: 291–304.

Worthy, T.H., 1998. A remarkable fossil and archaeological avifauna from Marfells Beach, Lake Grassmere, South Island, New Zealand. *Records of the Canterbury Museum* 12: 79–176.

## Appendix

Problems of identification, reasons for inclusion or exclusion of taxa from the Norfolk Island avifauna, and comments on the time of some extinctions.

**Petrels**. There have long been problems in identifying the species of petrel that originally bred on Norfolk Island, notwithstanding the copious fossil remains and the existence of paintings from the early period of European occupation. All the *Pterodroma* petrels are difficult to separate on fragmentary material such as is normal in middens. It is usually necessary to examine crania of species that are closely similar in post-cranial dimensions.

Meredith (1991) recorded three species of *Pterodroma*—*Pterodroma solandri*, *P. pycrofti*, and an undescribed species—from Norfolk Island. *P. solandri* and *P. pycrofti* are now extinct on Norfolk Island itself. *Pterodroma solandri* breeds at Lord Howe Island 900 km to the west, and a small breeding population has recently been found on Philip Island (Hermes *et al*., 1986). It is not known whether the Philip Island colony represents a recolonization of the Norfolk Island group from the Lord Howe population or is a remnant of the population that was otherwise extirpated on the Norfolk Island group during the early years of European settlement.

The only large *Pterodroma* to be recorded as definitely breeding on Norfolk Island is *Pterodroma solandri*, the Bird of Providence, Providence Petrel, or Solander's Petrel. Meredith (1985, 1991) recorded this species as being common in fossil deposits on Norfolk Island. He also recorded an unnamed *Pterodroma* of intermediate size (*Pterodroma* new species), but listed mainly leg elements; wing elements from other collections were referred. In the present study, it became apparent that, although all *Pterodroma* humeri larger than those of *P. pycrofti* were of a size range consistent with specimens of *P. solandri*, there were two size classes in the leg elements. The longer femora, tibiotarsi, and tarsometatarsi were long enough to be of *P. solandri* but others were more comparable to elements of *Pterodroma inexpectata* and therefore were at first attributed to *Pterodroma* new species of Meredith (1985, 1991). The absence of wing bones in the intermediate size range was problematic, and other possibilities were explored.

Two other species of *Pterodroma* in the Pacific have humeri of about the same length as that of *Pterodroma solandri*, but shorter, thinner legs. These are *P. neglecta* (Kermadec Petrel) and *P. arminjoniana* (Herald Petrel). The Pacific populations of Herald Petrel have been recognized as a separate species (*P. heraldica*) and Brooke and Rowe (1996) split that species into white-bellied (*P. heraldica*) and dark-plumaged birds (*P. atrata*). The presence of any of these species would explain the anomalous pattern of smaller leg elements but larger humeri and ulnae. Measurements of leg elements of both these species (T.H. Worthy, pers. comm.) are similar to those in the collection considered here. The material is referred to *P. neglecta* on the basis of present breeding range. Harrison (1983) gave the breeding range of *P. arminjoniana* (*P. heraldica*) in the Pacific as including Chesterfield Reef, Tonga, Marquesas, Tuamotus, Gambier Islands, Pitcairn group, and Easter Island. The putative *P. atrata* is confined to the Pitcairn Islands. These islands are all either north of, or are very close to, the Tropic of Capricorn: none of those in the western South Pacific is south of 23°S. The range of *P. neglecta* includes Lord Howe, Kermadecs, Austral, Pitcairn, and Easter groups, and islands off Chile. In the southwestern Pacific its range is well south of that of *P. arminjoniana* (*P. heraldica*) (Lord Howe is at 32°S, and Raoul Island is at 28°S, roughly the same as Norfolk Island). As Norfolk Island lies between two of the present breeding stations of the Kermadec Petrel, it is reasonable to suspect that *P. neglecta* formerly bred there. Hindwood (1940) pointed out that two specimens taken by Dr P.H. Metcalfe in the 1880s referred to *P. solandri* by North (1890) were in turn referred by Mathews (1912) to *P. neglecta*, which, if correct, would constitute the first record of that species from Norfolk Island, and add weight to the conclusion that bones referred to an "intermediate" *Pterodroma* (Meredith, 1991) are actually of *P. neglecta*.

A further point that may aid in distinguishing between the two species in old accounts is that *Pterodroma neglecta* usually nests on the surface and does not burrow like *P. solandri* (Bartle *et al*., 1993). Records of surface-nesting petrels in early accounts are likely to refer to *P. neglecta*. A confounding factor may be the former presence on the islands of at least one species of *Accipiter*, whose predation could conceivably have forced *P. neglecta* to nest under cover.

The identity of the small species of *Pterodroma* that formerly bred in large numbers on Norfolk Island has been especially problematic. Until Meredith (1985, 1991) established that the small *Pterodroma* bones from the island represented a previously unknown and very large population of *P. pycrofti*, it was thought that *P. nigripennis* was probably present at the time of European settlement. *Pterodroma pycrofti* is now absent from the Norfolk Island group: it breeds on small islands off the northeastern coast of the North Island of New Zealand (Heather and Robertson, 1996). There are too few *P. pycrofti* on the present breeding islands (1500+ pairs, Heather and Robertson, 1996) for there to be any pressure for young birds to find new breeding sites.

Part of the reason for suspecting the former presence of *P. nigripennis* was that, by analogy with the present small population of *P. solandri*, the *P. nigripennis* presently breeding on Philip Island and attempting to breed on Norfolk Island have been taken to be a recolonization after extermination in the 1790s (Schodde *et al*., 1983). In fact, *P. nigripennis* was first identified on Norfolk Island in 1965 (Serventy *et al*., 1971). It has not been identified among the fossils in either natural or archaeological contexts (Meredith, 1985, 1991; this study), so it is likely to be instead a recent colonist, as it is in northern New Zealand and the Chatham Islands (Tennyson, 1991) where there also no records of former breeding.

The present populations on Lord Howe Island and Balls Pyramid cannot be used as evidence of a former more extensive breeding range of *P. nigripennis*, as can be proposed for *P. neglecta*. The breeding colonies of *P. nigripennis* (Philip Island, Lord Howe Island, Balls Pyramid) are part of the recent and on-going south and southwestward expansion (Marchant and Higgins, 1990). The source is probably the large population (2–3 million pairs, Heather and Robertson, 1996) on Macauley Island in the Kermadecs, 1300 km to the east. *Pterodroma nigripennis* is not mentioned by Hindwood (1940) as being part of the Lord Howe Island fauna, although he records two skins of *Cookilaria* [=*Pterodroma*] *cookii* (under the common name "Blue-footed Petrel"), citing a breeding range that includes the Kermadecs, where *P. cookii* does not breed. The 1965 specimen of *P. nigripennis* on Norfolk Island had blue instead of the typical fleshy pink legs (Serventy *et al*., 1971). A small proportion of *P. nigripennis* individuals has blue legs (Serventy *et al*., 1971) so it is possible that the birds seen by Hindwood were of this form rather than *P. cookii*. The specimens should be re-examined.

The identity of the small *Pterodroma* petrel portrayed in a coloured drawing done at the time of the First Settlement (no. 96 in the "Sydney" collection, Hindwood, 1965) remains an enigma. Whitley (1938) described it as a new species *Cookilaria hindwoodi*. The discovery of a specimen of *P. nigripennis* on Norfolk led Hindwood (1965: 90) to suggest that the "Norfolk Island Dove-Petrel [had] been re-discovered". Earlier, Hindwood and Serventy (1943) considered that the bird "differs from all known species of *Cookilaria* in the brown colour of the upper parts" and considered it to be *incertae sedis*. As painted, the bird appears to lack the "powdering of grey… from the nape down the sides of the upper breast" (Serventy *et al*., 1971) that is characteristic of *P. nigripennis* and the dimensions (if the bird was indeed painted life size) fit with those of *P. pycrofti* (Oliver, 1955). It is possible, contra Serventy *et al*. (1971: 103), that the bird in the painting was *P. pycrofti*. In favour of this interpretation are the dimensions taken by G.M. Mathews from the painting (Hindwood and Serventy, 1943), which are all within the ranges for *P. pycrofti*. In addition, the colour pattern is similar to that species, although the colour itself apparently differs in having a brown back, which could be an artefact of the paint used. The reference in Heather and Robertson (1996) to a "huge" colony of *P. nigripennis* on Norfolk Island being destroyed by cats and rats ignores the fact that the birds were not known to breed there before 1965 and have not been identified in the large fossil collections (Meredith, 1991, and see above). The simplest view, and the one adopted here, is that the late Holocene avifauna of Norfolk Island included one species of small *Pterodroma* petrel, *P. pycrofti*, which became extinct shortly after European settlement, and whose place is now being taken—for whatever reason, and in the absence of a large source population of *P. pycrofti*—by immigrant *P. nigripennis* from the thriving populations on the southern Kermadec Islands.

A recent summary of birds reported from the Norfolk Island group (Moore, 1999) includes references to several other petrels that may well have been part of the original avifauna. These include the Flesh-footed Shearwater (*Puffinus carneipes*: in a burrow on Philip Island), Newells Shearwater (*Puffinus auricularis newelli*: captured, photographed and released on Philip Island), Tahiti Petrel (*Pseudobulweria rostrata*: at sea within 15 km of the island, breeds in the South Pacific), Goulds Petrel (*Pterodroma leucoptera*: one race of which breeds on New Caledonia), White-necked Petrel (*Pterodroma cervicalis*: breeding in large numbers on Macauley Island in the Kermadec group, 1200 km east of Norfolk, and a nesting pair found on Philip Island in 1992), and Kermadec Petrel (*Pterodroma neglecta*: breeding on islets off Raoul Island, Kermadecs, and at Lord Howe Island, found nesting on Philip Island in 1992). Other species, such as the Cape Petrel (*Daption capense*), have been seen near the islands, but their breeding grounds are in the subantarctic and it is highly unlikely that there were breeding populations of these species in the Norfolk Island area at any time in the past.

There appear to be previous records of the occurrence of two of these species on the island. A specimen of *Puffinus carneipes* taken on Norfolk Island by E.H. Saunders (Saunders and Salvin, 1896) is apparently the first record from the island. Meredith (1991) did not list *P. carneipes* in the fossil fauna while Schodde *et al*. (1983) recorded it only as a vagrant before the recent breeding record (Moore, 1999). The breeding distribution of the species includes Lord Howe Island as well as islands off northern New Zealand and many around Australia (Hindwood, 1940; Serventy *et al*., 1971). Hence, as with *P. neglecta*, it is likely on the grounds of a gap in an otherwise continuous distribution that the species once bred at Norfolk Island. For this reason, and as the measurements of *P. carneipes* overlap with those of *P. pacificus* (Oliver, 1955; Serventy *et al*., 1971), it is possible that material of *P. carneipes* exists unrecognized in the fossil collections. If so, it is included here in the unresolved "other petrel" category.

In addition to the petrels dealt with above, it is possible that at least one other subtropical petrel may have had a breeding population in the group: four individuals of the Phoenix Petrel (*Pterodroma alba*) were found ashore on Raoul Island in 1913 (Oliver, 1955), and it is likely that the species bred there before rats and cats were introduced (Holdaway *et al*., 2001). That some of the subtropical species have now been found breeding, or attempting to breed, on Philip Island is evidence that they could have included the group in their breeding range in the past. The possibility of their former presence adds complexity to an already difficult identification problem.

**Sulids**. The sulid presently breeding in the Norfolk Island group is the Masked Booby *Sula dactylatra*. An apparently extinct species of booby (*Sula tasmani*) has been described from fossil remains collected on Norfolk and Lord Howe Islands (van Tets *et al*., 1988). The material in the present collection is attributed to *S. dactylatra* because the mensural differences listed by van Tets *et al*. (1988) are not sufficient to support recognition of a separate taxon and instead represent the upper size range of *S. dactylatra* (Holdaway and Anderson, unpubl. data).

Other differences proposed included choice of nesting habitat, *S. tasmani* apparently differing from *S. dactylatra* in nesting on sand beaches where they were vulnerable to predation by humans (van Tets *et al*., 1988). When undisturbed by humans, even Australasian Gannets (*Morus serrator*), which typically nest on or above high sea cliffs, nest on sand dunes at sea level (Hawkins, 1988).

**Waders**. Although several species of charadriiform have been identified from the island, all are vagrants or regular migrants. Only two species, the Bar-tailed Godwit (*Limosa lapponica*) and Pacific Golden Plover (*Pluvialis fulva*) are regular in numbers on the island. Although Whimbrels (races of *Numenius phaeopus*) have been reported live and as fossil from Norfolk Island, none was recorded in the archaeological collection.

**Hawks**. The only predatory bird on the island today is the Australian Kestrel (Falconidae: *Falco cenchroides*), which became established as a breeding species in the 1970s (Schodde *et al*., 1983). Reports of the presence of "hawks" in the 1790s were confirmed by the discovery of remains of an *Accipiter* very closely related to, if not identical to, the Brown Goshawk *Accipiter fasciatus* of Australia and some islands to the north of Norfolk Island, including New Caledonia (Meredith, 1985, 1991). It has been thought that hawks died out on Norfolk Island very soon after Europeans arrived or were vagrants (Schodde *et al*., 1983), but Gurney (1854) referred to a report by F. Strange that hawks were on Philip Island some time before 1853, presumably during the residence of Strange's informant on Norfolk Island, which may mean that the goshawk survived on Philip Island for several decades after its demise on the main island. Philip Island was still vegetated at that time, and Strange records having met the man "who exterminated the *Nestor productus* of Philip Island". After describing the way that the large parrot used its bill in climbing, Strange reports that "He likewise informed me that there was a large species of hawk that used to commit great havoc amongst them [the parrots], but what species it was he could not tell me."

**Rails**. The flightless endemic *Gallirallus* new species discovered by Meredith (1985) may have survived into the European period. A rail painted on Norfolk Island in the 1790s (no. 79 in the "Sydney" series, Hindwood, 1965) has a plumage pattern similar to that of *G. philippensis*, but it may represent *Gallirallus* new species rather than the extant *Gallirallus philippensis* as has been assumed. Ripley (1977) identified *Rallus tenebrosus* (Gray, 1862), a small rail described from Norfolk Island in 1824, as the Spotless Crake (*Porzana tabuensis*), which is widespread in Australia and the South Pacific. At present, both *P. tabuensis* and *G. philippensis* are vagrants on Norfolk Island, rarely breed there, and their former status has been uncertain (Schodde *et al*., 1983).

**Parrots**. *Nestor productus* survived until the late 1840s on Philip Island (Strange, in Gurney, 1854) after being extirpated on the main island in the early 1800s. By late 1853 the species was known only from Philip Island. No mention of its former presence on the main island is made, although it figures prominently in the collections of paintings made during the first convict settlement. Strange's informant said that "they rarely made use of their wings, except when closely pressed" and that when he went to the island to shoot them, he "would invariably find them on the ground". Such habits are not unusual in species confined to uninhabited islands without mammalian predators and would have made the birds easy prey for people.

Full-text PDF of each one of the works in this volume are available at the following links :

Anderson and White, vol. eds, 2001, *Rec. Aust. Mus., Suppl.* 27: 1–143
http://dx.doi.org/10.3853/j.0812-7387.27.2001.1334

Anderson and White, 2001, *Rec. Aust. Mus., Suppl.* 27: 1–9
http://dx.doi.org/10.3853/j.0812-7387.27.2001.1335

Anderson et al., 2001, *Rec. Aust. Mus., Suppl.* 27: 11–32
http://dx.doi.org/10.3853/j.0812-7387.27.2001.1336

Anderson et al., 2001, *Rec. Aust. Mus., Suppl.* 27: 33–42
http://dx.doi.org/10.3853/j.0812-7387.27.2001.1337

Anderson and Green, 2001, *Rec. Aust. Mus., Suppl.* 27: 43–51
http://dx.doi.org/10.3853/j.0812-7387.27.2001.1338

Marianne et al., 2001, *Rec. Aust. Mus., Suppl.* 27: 53–66
http://dx.doi.org/10.3853/j.0812-7387.27.2001.1339

Schmidt et al., 2001, *Rec. Aust. Mus., Suppl.* 27: 67–74
http://dx.doi.org/10.3853/j.0812-7387.27.2001.1340

Smith et al., 2001, *Rec. Aust. Mus., Suppl.* 27: 75–79
http://dx.doi.org/10.3853/j.0812-7387.27.2001.1341

Matisoo-Smith et al., 2001, *Rec. Aust. Mus., Suppl.* 27: 81–84
http://dx.doi.org/10.3853/j.0812-7387.27.2001.1342

Holdaway and Anderson, 2001, *Rec. Aust. Mus., Suppl.* 27: 85–100
http://dx.doi.org/10.3853/j.0812-7387.27.2001.1343

Walter and Anderson, 2001, *Rec. Aust. Mus., Suppl.* 27: 101–108
http://dx.doi.org/10.3853/j.0812-7387.27.2001.1344

Campbell and Schmidt, 2001, *Rec. Aust. Mus., Suppl.* 27: 109–114
http://dx.doi.org/10.3853/j.0812-7387.27.2001.1345

Neuweger et al., 2001, *Rec. Aust. Mus., Suppl.* 27: 115–122
http://dx.doi.org/10.3853/j.0812-7387.27.2001.1346

Macphail et al., 2001, *Rec. Aust. Mus., Suppl.* 27: 123–134
http://dx.doi.org/10.3853/j.0812-7387.27.2001.1347

Anderson and White, 2001, *Rec. Aust. Mus., Suppl.* 27: 135–141
http://dx.doi.org/10.3853/j.0812-7387.27.2001.1348