

BIRD EXTINCTIONS AND FOSSIL BONES FROM MANGERE ISLAND, CHATHAM ISLANDS

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ABSTRACT

Fossil bones and earlier observations indicate that up to 22 species of bird have become extinct on Mangere Island. The extinctions appear to have been primarily a result of predation by cats, but human hunting and bush clearance are likely to account for the disappearance of some species. A crested penguin *Eudyptes* ?n.sp., two species of *Pterodroma* petrel, a shelduck *Tadorna* ?n.sp., Dieffenbach's Rail *Gallirallus dieffenbachii*, and a kaka *Nestor* ?n.sp. are present in fossil deposits on Mangere Island, but have not been reported from the island before. The relative proportion of remains in the deposits suggest that Blue Penguins *Eudyptula minor*, Broad-billed Prions *Pachyptila vittata* and Sooty Shearwaters *Puffinus griseus* have become more common on the island. Any such increases on Mangere Island, could have been a response of a few species to the large decrease in numbers and diversity that has affected seabirds as a whole at the Chathams. Some seabird species may have been able to increase because of reduced competition for food.

INTRODUCTION

The Chatham Islands (44°S 176°W) have abundant fossil deposits that have revealed much about the past fauna of the islands. The remains of petrels (Order Procellariiformes) dominate the deposits, which also include the remains of a wide range of extinct terrestrial bird species (e.g., Oliver 1955; Bourne 1967; Atkinson & Millener 1991; Meredith 1991). Fossils described from the Chathams have been mostly been from the main island. The only details of fossil bird bones from Mangere Island (141 ha) previously presented (Turbott 1990; Marchant & Higgins 1990, 1993), refer to material in the present study.

Humans have greatly altered Mangere Island's natural ecosystem, probably over several hundred years. Polynesians are thought to have arrived on the Chathams about 400-450 years ago (McFadgen 1994) and are likely to have visited Mangere regularly to collect birds or seals (e.g. Cockayne 1901; King 1989). Europeans first reached the Chathams in 1791 (Richards 1982). During the 19th century, especially the early 1800s, there was much activity by foreign sealers and whalers at the Chathams (Richards 1982); it is likely that Mangere was often visited by these groups.

In 1871 the island was still 'nearly covered with low rigid scrub' (Travers & Travers 1872) and the 1898 series cadastral maps show reasonably large areas of Mangere still under forest cover (Fyfe 1978). However, farming had begun by 1892 (Forbes 1893), the island was 'under settlement' by 1895

(Kirk 1895), in 1897 vegetation was being burnt for farming (Fleming 1982) and by the early 1900s sheep, goats, and rabbits had been introduced and the island was largely denuded (Fleming 1939; Ritchie 1970).

The earliest published records of bird species on Mangere Island were based on birds collected by C. Traill in 1868 and on observations and collections made by H. Travers in 1871-72 (Travers & Travers 1872; Buller 1873, 1888; Oliver 1955; Fleming 1982). From then until the end of the 19th Century, commercial bird collectors were very active (Kirk 1895; Oliver 1955) and cats were introduced to control the rabbits (Forbes 1893). Large numbers of seabirds were still being killed by cats in 1923 (Archev & Lindsay 1924), but the cats died out about 1950 (P.T. Nielsen to D. Merton pers. comm. to AJDT).

There are some accounts of rats on Mangere (e.g., Richards 1952: 72, 78, 131; Oliver 1955: 490), but the presence of rats has not been confirmed. The record may have originated from a letter from the collector W. Hawkins to Rothschild stating that cats had been introduced 'to destroy rats and rabbits' (Rothschild 1907: 15). Rothschild (1907: 21) also mentioned that weasels had been released on Mangere Island, but King (1990) and Lavers & Clapperton (1990) found no records of any mustelids having been released on the Chathams.

The last sheep were removed from Mangere Island in 1968, leaving the island free of all introduced mammals (Ritchie 1970; Bell 1974). Since then, the vegetation has begun to regenerate, assisted by planned plantings (Bell 1974) and several species of bird have been successfully reintroduced or have recolonised the island by themselves (Table 1).

METHODS

AJDT recorded the birds on Mangere Island and collected fossil bones from two sites on the island between October 1987 and March 1988. All exposed unbroken bones and many fragments were collected; little excavation was done. The material is now in the collection of the Museum of New Zealand Te papa Tongarewa, where PRM assisted with the identification of bones. Most bones collected were identified and recorded as total elements and minimum number of individuals (number represented by the element with the greatest number of ipsilateral units, see Appendix).

SITES

Sites collected from

Site 1: 100 - 110 m a.s.l. On western side of Douglas Basin, on a cliff edge above west-facing gut. Exposure a fairly hard, greyish-brown, eroding loess face, up to c.2 m deep. Site 2: 100 m a.s.l. North-facing bank in slump on eastern end of Douglas Basin. Exposure a loose, dark-brown, surface soil layer, up to c.60 cm deep.

Both sites may be part of the previously described 'Douglas Basin midden' (archaeological site C240/717), which is at 110-120 m a.s.l. and up to 30 cm deep, covering 200 + m² (Fyfe 1978). During AJDT's visit fossil bones were not visible over the surface of the Douglas Basin which was overgrown with vegetation. R. Fyfe (in litt.) regarded sites C240/714,

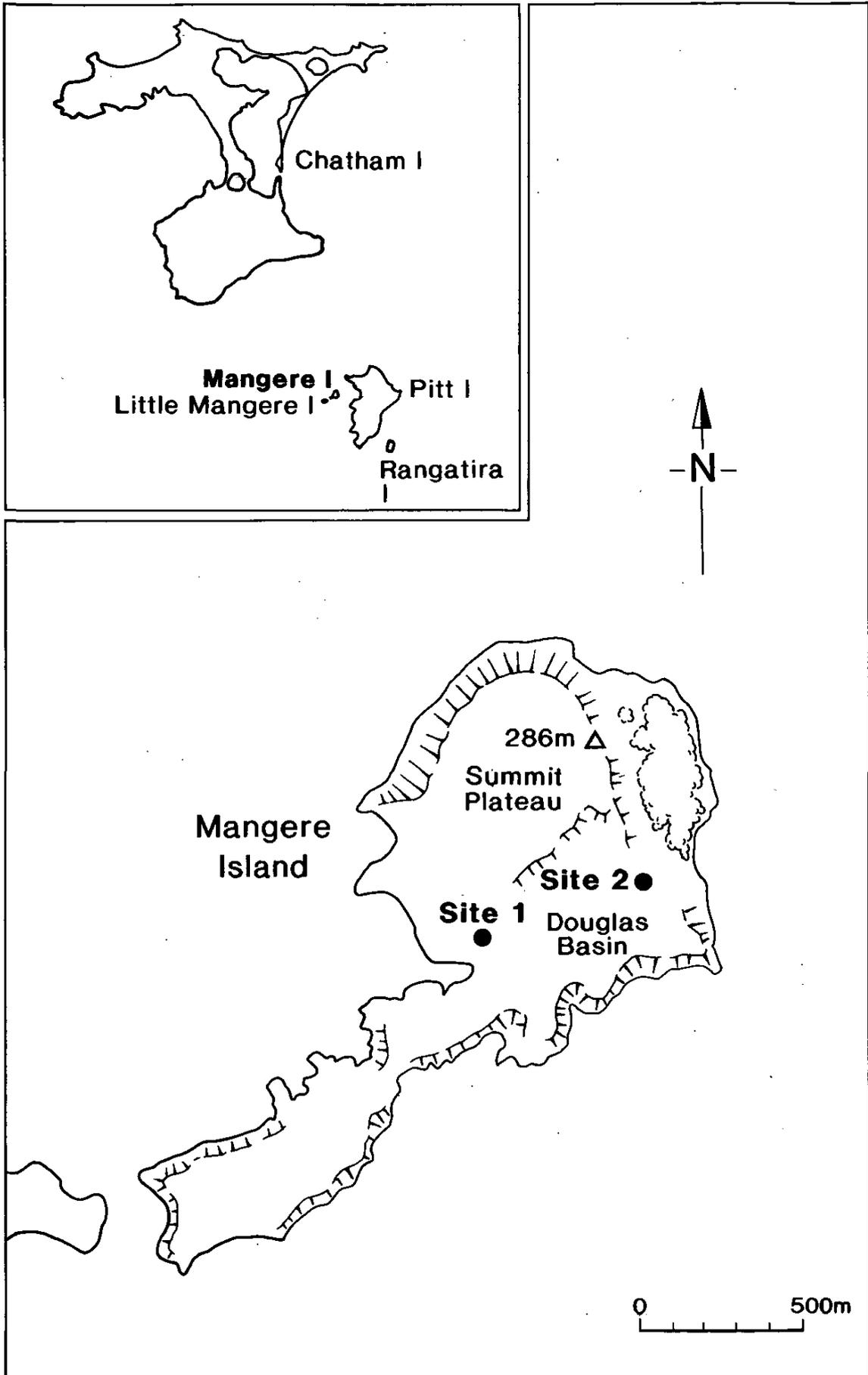


FIGURE 1 – Mangere Island, showing the location of the Douglas Basin and Sites 1 and 2. Insert: Location within Chatham Islands.

C240/715 and C240/716 (Sutton 1983) as part of site C240/717. However, the boundaries of C240/717 remain unclear. The presence of bone deposits at the western (Site 1) and eastern (Site 2) sides of the Douglas Basin suggests that extensive bone sites occur over the basin.

Other fossil bone deposits

The following deposits have been recorded from Mangere Island but were not collected from and are not discussed further in this paper: a) 140 m a.s.l. Found by AJDT on the seaward (southerly) edge of the highest knoll on the southern side of the Douglas Basin. Exposure is a surface soil layer up to about 40 cm deep. This site contained human bones, including a skull; b) 20 m a.s.l. Previously described: 'North shore midden', archaeological site C240/718. Rock shelter midden site, c.30 x 15 m (Fyfe 1978). Site not seen during AJDT's visit.

RESULTS AND DISCUSSION

The 2022 fossil bird bones collected from two deposits on Mangere Island represent at least 352 individuals (285 at Site 1, 67 at Site 2) of at least 26 species. All bird bones recovered and scientific and common names of bird species referred to in Table 1 are given in the Appendix. Taxonomy is according to Turbott (1990), but we follow Marchant & Higgins (1990) for the Common Diving Petrel and Olson (1973) and Marchant & Higgins (1993) for the two rails.

All native bird species recorded on Mangere Island, excluding rare vagrants and natives that established on the Chatham Islands during this century, are listed in Table 1. Data are from: 1871-1872, Travers & Travers (1872); 1892, Forbes (1893); 1923, Archey & Lindsay (1924), C. Lindsay's unpublished diary held in Museum of New Zealand; 1961, B.D. Bell (pers. comm. and unpubl. data); 1987-1988, AJDT (pers. obs.).

Taxonomic questions

Further work is required to determine the taxonomic status of *Pterodroma* sp. 1, the crested penguin, shelduck, and kaka. Preliminary studies suggest that at least the latter three were distinct Chatham Island forms.

Pterodroma sp. 1 does not agree with any of the *Pterodroma* species (*P. magentae*, *P. axillaris*, *P. nigripennis*) which currently breed on the Chathams. It is slightly larger than *P. inexpectata*.

Fossil bones of crested penguins from the Chathams have been referred to Erect-crested Penguin *Eudyptes sclateri* (e.g., Sutton 1979) or Fiordland Crested Penguin *E. pachyrhynchus* (e.g., Scarlett 1982), but the bones do not fit either of these species. Travers & Travers (1872) held a crested penguin from the Chathams in captivity for several weeks between 1867 and 1872. They referred to it as *E. pachyrhynchus* but as all crested penguins in New Zealand were referred to by that name at the time, it is possible they would not have recognised a different species. If this specimen survives it should be re-examined.

TABLE 1 – Fossil and historical records of birds from Mangere Island. Status of birds is based on observer's comments: B, breeding; ?B, probably or possibly breeding; R, recorded but not breeding; N, not recorded; -, insufficient information. Fossil site entries are given as percentage of minimum number of individuals (%MNI) represented by bones found at that site. Material of other animals given as present (P) or absent (A).

Taxon	Site 1 %MNI	Site 2 %MNI	1871-72	1892	1923	1961	1987-88
<i>Puffinus griseus</i>	0	3	?B	-	B	B	B
<i>Pelecanoides urinatrix</i>	36	6	?B	-	N	N	N ^a
<i>Macronectes</i> spp.	0	1	?B	-	N	-	N
<i>Pachyptila turtur</i>	48	33	?B	-	B	B	B
<i>Pachyptila vittata</i>	1	13	?B	-	B	B	B
<i>Pterodroma</i> sp. 1	1	0	N	N	N	N	N
<i>Pterodroma axillaris</i>	2	3	N	-	N	N	N
<i>Oceanites nereis</i>	<1	0	N	-	N	N	B ^a
<i>Pelagodroma marina</i>	0	9	?B	-	?B	N	R ^a
<i>Eudyptula minor</i>	0	10	-	-	B	-	B
<i>Eudyptes</i> ?n. sp.	1	7	N ^b	-	N	N	N
<i>Stictocarbo featherstoni</i>	0	1	-	-	B	-	B
<i>Tadorna</i> ?n. sp.	<1	0	N	-	N	N	N
<i>Circus approximans</i>	0	0	-	-	R	-	R
<i>Gallirallus dieffenbachii</i>	5	0	N	N	N	N	N
<i>Gallirallus modestus</i>	<1	0	B	B	N	N	N
<i>Haematopus chathamensis</i>	0	0	-	N	R	?B	B
<i>Thinornis novaeseelandiae</i>	0	0	?B	?B	N	N	N
<i>Coenocorypha pusilla</i> ^c	<1?	0	B	-	N	N	B ^d
<i>Coenocorypha chathamica</i> ^c	<1?	0	N	N	N	N	N
<i>Catharacta skua lonnbergi</i>	0	4	?B	-	B	-	B
<i>Larus dominicanus</i>	<1	0	-	-	?B	-	R
<i>Larus novaehollandiae</i>	<1	1	-	-	B	-	B
<i>Sterna striata</i>	0	1	-	-	?B	-	B
<i>Hemiphaga novaeseelandiae</i>	1	1	B	-	N	N	N
<i>Nestor</i> ?n. sp.	<1	0	N	N	N	N	N
<i>Cyanoramphus novaeseelandiae chathamensis</i> ^c	1?	0	?B	N	?B	N	B ^d
<i>Cyanoramphus auriceps forbesi</i> ^c	1?	0	?B	?B	N	R	B ^d
<i>Anthus novaeseelandiae chathamensis</i>	0	0	?B	?B	B	?B	B
<i>Bowdleria rufescens</i>	1	1	?B	N	N	N	N
<i>Gerygone albofrontata</i>	0	0	?B	-	-	?B	B
<i>Rhipidura fuliginosa penita</i>	0	0	?B	-	-	-	N
<i>Petroica macrocephala chathamensis</i>	0	0	?B	-	?B	- ^e	N
<i>Petroica traversi</i>	<1	0	?B	?B	N	N	B ^d
<i>Zosterops lateralis lateralis</i>	0	0	?B	-	?B	-	?B
<i>Anthornis melanura melanocephala</i>	<1	1	?B	?B	N	N	N
<i>Prosthemadera novaeseelandiae chathamensis</i> ^f	0	0	N	-	R	N	R

Kina (sea urchin)	A	P
Mollusca	A	P
Fish	P	P
Skink	P	A
Rabbit <i>Oryctolagus cuniculus</i>	A	P
Sheep <i>Ovis aries</i>	P	P
Cattle <i>Bos taurus</i>	A	P
Seal	A	P

^aVeitch (1985): Common Diving Petrels and Grey-backed Storm Petrels recolonizing Mangere I. Bell (1974), Veitch (1985): White-faced Storm Petrels had recolonized; Merton & Bell (unpubl. data), Butler & Merton (1992): White-faced Storm Petrels reappeared in 1970. However, in 1987-88 (AJDT pers. obs.) Common Diving Petrels and White-faced Storm Petrels apparently had not recolonized; White-faced Storm Petrels visited occasionally on dark, misty nights when attracted to lights; large numbers of Grey-backed Storm Petrels breeding; either this species recolonized much faster or small numbers survived presence of cats. ^bTravers & Travers (1872) recorded only one crested penguin. ^cSpecies at Site 1 not determined. ^dSuccessfully reintroduced or recolonised by itself (Bell 1974; Taylor 1985; Butler & Merton 1992). ^eLindsay *et al.* (1959): tomtits present in 1957. ^fVeitch (1985): Tui "locally extinct; now re-colonizing"; authors: may have bred on Mangere but no records found.

Age of sites

No material was dated by radiocarbon. Relative ages were inferred from species compositions. Site 1 contained six or seven species of bird not recorded in 1871-72 (Table 1), whereas Site 2 contained only two species not recorded then. Most of Site 1 is probably older than Site 2; both probably include material older than 1871.

Site 1 contained a few sheep bones. Their presence was not surprising as sheep bones were scattered widely over the surface of Mangere Island. Compared to most bird bones at this site, the sheep bones appeared fresh. Site 2 contained many bones of introduced mammals (rabbits, sheep, cattle). The different proportions of mammal bones in the two sites suggest that most of Site 1 was deposited before terrestrial mammals were introduced to Mangere by Europeans, and that much of Site 2 was deposited after European settlement.

We have not been able to find exact dates of introduction for the mammals. Rabbits were present on Mangere in 1892 (Forbes 1893), but had probably been on the island for only a short time. Travers & Travers (1872) did not comment on their presence in 1871-72. By a 1948 account, they had been released about 1900 ('about 50 years ago', Wodzicki (1950)). According to Gibb & Williams (1990), rabbits were introduced about 1890 and were exterminated by cats by about 1895. Archey & Lindsay (1924) did not mention rabbits' being present in 1923.

The presence of cattle bones at Site 2 suggests that cattle may have been farmed on Mangere, along with sheep and goats. Cattle were introduced to the Chatham group in 1841 (Cockayne 1901; Thomson 1922) and were and are farmed widely on the group, including on Pitt and Rangatira Islands (Butler & Merton 1992; AJDT pers. obs.). We have, however, found no reference to their having been present on Mangere. Sheep were present on the Chatham Island group by about 1842 (Richards 1952: 110), and had been released on Mangere by 1892 (Forbes 1893).

The Common Diving Petrel population appears to have been lower when material in Site 2 was being laid down (Table 1). Cats - liberated on Mangere shortly before 1893 (Forbes 1893) - have been implicated in this decline. The lower proportion of Diving Petrel bones in Site 2 suggests that some of the site was deposited after cats were introduced. The presence of nails and pieces of china and glass confirms that much of Site 2 was deposited after European colonisation.

In the absence of absolute dates, the total times of deposition in the two sites must remain conjectural. However, it is likely that much of Site 2 was deposited in the late 1800s, after about 1865, whereas most of Site 1 was deposited before the mid 1800s. Hence, much of the material at Site 1 may be considerably older than that at Site 2, and may have been deposited before human settlement of the Chathams.

Examination of a range of bone deposits could help determine the time of avian extinctions, colonisations, or distribution changes throughout the Chatham Islands. The thick deposit in Site 1 could, with adequate chronological control, reveal much about the faunal history of the Chathams. Dating of material from Site 2 would help determine whether or not the crested penguin and the Chatham Petrel survived on Mangere Island into the late 1800s.

Human influences and biases in preservation

There were clear signs of human influence in Site 2, whereas Site 1 appeared to be a natural deposit, with few human influences. At least part of Site 2 may be a human food midden, because some bird bones - mainly from large species - had been burnt. The burnt bones included a minimum of: 2 Fairy Prions (3 humeri); 2 Blue Penguins (3 humeri, 2 ulnae, 1 tibia); 1 crested penguin (1 scapula, 1 humerus, 1 radius, 1 femur, 2 tibiotarsi); 1 Brown Skua (1 tibiotarsus); and 1 Red-billed Gull (1 humerus). A higher proportion of bird bones in Site 2 were broken than in Site 1. Most Site 2 broken bones had 'green fractures', which are characteristic of bones broken when a bird is living or recently dead. Such breaks may suggest a human influence; perhaps resulting partly from chewing by cats.

The nails, china, and glass at Site 2 suggest that there could have been a European-era dwelling there. Chatham Islanders believe that a hermit lived at or near Site 2 in about 1900 (B.D. Bell, pers. comm.). A Wildlife Service party found human bones at or near Site 2 (D. Crouchley, pers. comm.). The faunal composition of a few bones (representing at least 1 Fairy Prion, 2 Blue Penguins, 1 crested penguin, 1 Brown Skua, 1 rabbit, and 2 sheep, AJDT pers. obs.), collected by Crouchley at that site in September 1981 (deposited in Museum of New Zealand) and the attached dark-brown soil, also suggest that Crouchley's site is the same locality as Site 2. However, AJDT did not find human bones at Site 2. The apparent human influences suggest that the composition of the Site 2 fauna is likely to be biased towards species favoured as human food, e.g., large species. It is also possible that some species in the deposit may have been captured elsewhere and transported to the island for food.

Parts of the species assemblages at both sites may have been accumulated by Brown Skuas. Skuas' prey remains commonly accumulate as middens and skua can transport material to a site from other areas. Birds that do not breed on Mangere Island and fresh sheep remains were found in skua middens on Mangere in 1987-88 (AJDT, pers. obs.). It is difficult to determine if parts of skua middens were preserved at Sites 1 or 2. However, the presence at both sites of small landbirds (e.g., parakeet, fernbird, robin and bellbird) that are not normally found in modern skua middens (AJDT pers. obs.), and several large mammal bones at Site 2, show that at least part of these deposits did not originate from skua middens.

Another bias in the deposits was towards the preservation of larger, more solid and durable bones. Delicate bones such as crania and sterna were relatively less abundant than major wing and leg elements.

Changes in the avifauna of Mangere Island

Although it is difficult to interpret the deposits at Sites 1 and 2 because of preservation biases, the collections do indicate that the avifauna of the island has changed more than had been realised. Up to 22 species of bird have become extinct on Mangere (Table 1). At least seven of these taxa are now totally extinct: the crested penguin (?sp.n.), two rails, shelduck (?sp.n.), kaka (?sp.n.), fernbird, and bellbird. The extinct *Coenocorypha chathamica* may have been present too. At least three quarters of the bird species, including all landbirds, found at the earliest site (Site 1) became locally extirpated or totally extinct (Table 1).

Seven or eight species may have become extinct on Mangere Island before Travers recorded the birds present in 1871-72: the two *Pterodroma* petrels, Grey-backed Storm Petrel, crested penguin (?sp.n.), shelduck (?sp.n.), Dieffenbach's Rail, kaka (?sp.n.), and (if it was present) *C. chathamica*. None, apart from the storm petrel, has been reported from Mangere before, but they have all been reported from fossil deposits elsewhere in the Chatham group (PRM unpubl. data). Olson (1975) suggested that '[*Gallirallus dieffenbachii*... may have been in competition with the smaller and more specialized *modestus* and had all but replaced it except on the islet of Mangere'. It is now clear that *G. dieffenbachii* and *G. modestus* co-existed on Mangere.

Nine to 11 further species were lost from Mangere Island between 1871-72 and 1923, 1-3 more between 1923 and 1961, and one further species was lost between 1957 and 1987-88 (Table 1). However, true extinction dates for relatively inconspicuous species such as the two *Pterodroma* petrels and the two storm petrels remain unclear because these birds could easily have been over-looked by ornithologists. For example, although Merton & Bell (unpubl. data), Veitch (1985), and Butler & Merton (1992) state that White-faced Storm Petrels had gone by about 1924, there are no definite records of the species breeding on Mangere Island. The first specific report of live birds ashore was in 1970 (Merton & Bell unpubl. data; Butler & Merton 1992). There is also little information about the Grey-backed Storm Petrel of which there appears to be no published records for the island until after 1968 (Veitch 1985).

Extinction dates for some bird species on Mangere Island are known more accurately. The Chatham Island Rail became extinct about 1895-1897 (Fleming 1982). The Shore Plover was last seen on Mangere in 1898 (Fleming 1939). The Chatham Island Red-crowned Parakeet disappeared from Mangere in about 1940 (Merton & Bell unpubl. data; Butler & Merton 1992). The Chatham Island Fernbird was gone by about 1892 (Forbes 1893), and the Black Robin by 1894 (Buller 1894). The Common Diving Petrel disappeared about 1900 (Merton & B. Bell unpubl. data; Veitch 1985; Butler & Merton 1992).

Some species - Sooty Shearwater, Broad-billed Prion, Blue Penguin - that are abundant today were rare or absent in the fossil deposits at Site 1 (Table 1). If the faunal composition of the site is representative of the whole island, it may indicate that the three species have increased in number. Such species may even have colonised the island since most of the deposits in Site 1 were laid down. Earlier observations may support this idea (see below). Other seabirds (Black-winged Petrel, Cape Pigeon *Daption capense*) have recently colonised the Chatham Islands (Jenkins & Cheshire 1982; Clark 1989).

The Sooty Shearwater population of nearby Little Mangere Island may have increased during the same period. Flack (1976) stated that 'without concluding that [the Sooty Shearwater] is more abundant on [Little Mangere Island] today than during the last seventy years, it is extremely difficult to explain features of the vegetation and the probable change of the litter fauna since Fleming's [1938] visit'. Flack (1976) also suggested that any increase in Sooty Shearwater numbers on Little Mangere Island probably resulted from the nearly complete absence of muttonbirding during the previous seventy years. However, in 1867, Travers (1868) noted that 'Mutton-birds were extraordinarily numerous on...the Fort [Little Mangere Island]...'. Therefore, if the population has increased, probably it began increasing before the late 1800's.

Deterioration of the forest of Little Mangere Island led the then New Zealand Wildlife Service to remove the Black Robin population from that island in 1976 (Butler & Merton 1992). Butler & Merton (1992: 48) attributed the deterioration to the 'huge numbers' of Sooty Shearwaters. The extinct Chatham Island Bellbird may well have died out on Little Mangere because of this ongoing habitat deterioration despite Fleming's (1939) statement that conditions on the island had not changed between 1906 (when several pairs were seen) and his 1938 visit (when they were absent).

Interspecific competition for burrow sites is affecting the breeding of some burrowing petrel species at the Chatham Islands, especially the endangered Chatham Petrel on Rangatira Island (Imber 1985; Taylor 1991; Tennyson 1991). On Rangatira, this appears to result from an increase in the population size of Broad-billed Prions.

Travers & Travers (1872) noted that the Fairy Prion 'occurs in immense numbers on the islands' but did not remark on the abundance of breeding Broad-billed Prions. Today both prions nest abundantly on Mangere Island, which supports the idea that Broad-billed Prion numbers have increased.

The Blue Penguin may also have increased in numbers. Fleming (1939) noted that there was a 'strongly held opinion among Chatham Islanders that the [Blue] Penguin is very much more plentiful than it was 30 years ago'.

Loss of seabird breeding habitat on the largest two islands in the Chatham group has been accompanied by colonizations or increased populations of some seabird species on the offshore islands such as Mangere, Little Mangere, and Rangatira. The apparent increase in numbers of some species may result largely from a reduction in competition for food. The large decrease in overall numbers and diversity of seabirds at the Chathams noted, for example, by Bourne (1967) may have reduced interspecific and intraspecific competition and led to improved survival rates and breeding productivity at remaining colonies.

Causes of extinction

All extinctions on Mangere Island during the last 450 years or so probably resulted from human interference. The absence of rat bones at Sites 1 or 2 supports the current view that rats were never established on Mangere Island: direct human predation, deforestation, and cats were probably the major factors in the extinction or diminution of bird populations. As cats were not introduced until the 1890s, when the forest was cleared as well, the extinctions that occurred before 1871-72 probably resulted from the taking of birds for human food. The crested penguin, shelduck, Dieffenbach's Rail, kaka, and (if it was ever present) the extinct snipe probably became extinct on Mangere Island before 1871-72. Relatively inconspicuous species which Travers did not record - the two *Pterodroma* petrels and the Grey-backed Storm Petrel - were probably present then. Not enough information is available to determine whether Grey-backed Storm Petrels were ever eliminated from Mangere for a period during European times.

The *Pterodroma* petrels may have been eliminated by cats. *Pterodroma* petrels seem to be very vulnerable to cat predation. Cats (but no rats) have been established on Ile aux Cochons in the Crozet Islands since at least 1887 (Derenne et al. 1976) and *Pterodroma* petrels are absent. All other islands in the Crozet group that are free of introduced predators have several breeding species of *Pterodroma* (Jouventin et al. 1984).

Cats were probably the main cause of extinction of a further 12 or so species of bird on Mangere (Bell 1974; Veitch 1985), although forest clearance and collectors may have exterminated some species. The Chatham Island Tomtit survived on the island despite the presence of cats (Archey & Lindsay 1924; Lindsay et al. 1959), until it was removed in 1976 as part of the Black Robin rescue programme (Butler & Merton 1992: 55).

The two most abundant species at Site 1 suffered different fates. Fairy Prions contributed nearly half the number of individuals represented at this site (Table 1) and it was the most common breeding bird on the island in 1987-88 (AJDT pers. obs.). In contrast, Common Diving Petrels accounted for more than a third of the individuals at Site 1 but were extinct by about 1900, presumably killed off by cats. Common Diving Petrels seem to be particularly vulnerable to cat predation whereas some species of prion do

not. Common Diving Petrels were wiped out within 15 years of cats being introduced to Marion Island (Williams 1978). Salvin's Prions *Pachyptila salvini*, however, remained abundant (Cooper & Brown 1990). Cats were introduced to Herekopare Island off Stewart Island in about 1925 and the previously large populations of Common Diving Petrel and Broad-billed Prion were almost gone by 1968, but Fairy Prions remained common (Fitzgerald & Veitch 1985). It is likely that the size, breeding seasons, and patterns of nest attendance of different petrel species are important in determining their vulnerability to cats (Fitzgerald & Veitch 1985).

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APPENDIX

Bird bones from Sites 1 and 2 and scientific and common names of birds listed in Table 1. Bones listed as: Species (total number of bones/minimum number of individuals represented), numbers of each bone. Abbreviations: prem, premaxilla; man, mandible; qua, quadrate; vert, vertebrae; ste, sternum; fur, furcula; sca, scapula; cor, coracoid; hum, humerus; uln, ulna; rad, radius; cpm, carpometacarpus; alpha, alar phalanges; pel, pelvis; pelel, pelvic elements; fem, femur; tbt, tibiotarsus; fib, fibula; tmt, tarsometatarsus; pedphal, pedal phalanges.

Site 1

- Common Diving Petrel *Pelecanoides urinatrix chathamensis* (397/102): man 1, ste 2, sca 2, cor 40, hum 213, uln 72, rad 10, cpm 31, alpha 1, pelel 4, fem 7, tbt 2, tmt 12.
- Fairy Prion *Pachyptila turtur* (686/137): cra 2, man 4, ste 1, sca 2, cor 23, hum 338, uln 150, rad 16, cpm 74, alpha 15, pelel 5, fem 24, tbt 14, tmt 18.
- Broad-billed Prion *Pachyptila vittata* (8/3): hum 3, uln 1, rad 1, cpm 1, tbt 2.
- Gadfly petrel *Pterodroma* sp. 1 (5/2): cor 1, hum 4.
- Chatham Petrel *Pterodroma axillaris* (25/6): cor 3, hum 9, uln 9, cpm 1, tmt 3.
- Grey-backed Storm Petrel *Oceanites nereis* (4/1): uln 1, fem 1, tbt 1, tmt 1.
- Procellariiformes, indeterminate petrel similar to a medium-sized fulmar (*Daption/Fulmarus*), fem 1.
- Pelecanoides* / *Pachyptila* / *Pterodroma axillaris*, sca 5, cor 1, hum 47, uln 60, radii 18, cpm 4, tbt 72, tmt 34.
- Crested penguin *Eudyptes* ?n.sp. (17/3): cra 1, man 1, uln 1, cpm 1, pelel 1, fem 1, tbt 3, tmt 3, pedphal 5.
- Shelduck *Tadorna* ?n.sp. (2/1): uln 2.
- Dieffenbach's Rail *Gallirallus dieffenbachii* (79/14): prem 1, sca 2, cor 3, hum 8, uln 3, cpm 2, pelel 3, fem 25, tbt 20, tmt 12.
- Chatham Island Rail *Gallirallus modestus* (3/1): man 1, cpm 1, fem 1.
- Snipe *Coenocorypha* spp. (1/1): cor 1.
- Southern Black-backed Gull *Larus dominicanus dominicanus* (2/1): tbt 1, tmt 1.
- Red-billed Gull *Larus novaehollandiae scopulinus* (1/1): alpha 1.
- Chatham Island Pigeon *Hemiphaga novaeseelandiae chathamensis* (32/4): ste 1, fur 1, sca 3, cor 3, hum 5, uln 6, rad 1, cpm 6, fem 4, tbt 2.
- Kaka *Nestor* ?n.sp. (1/1): uln 1.
- Parakeet *Cyanoramphus* spp. (3/3): cor 3.
- Chatham Island Fernbird *Bowdleria rufescens* (3/2): tbt 1, tmt 2.
- Black Robin *Petroica traversi* (1/1): hum 1.
- Chatham Island Bellbird *Anthornis melanura melanocephala* (1/1): hum 1, uln 1.
- Unidentified, fur 17, vert 21, rib 3, hum 1, pelel 13, pedphal 11.

Site 2

- Sooty Shearwater *Puffinus griseus* (6/2): ste 1, sca 1, cor 1, hum 2, fem 1.
- Pelecanoides urinatrix chathamensis* (32/4): ste 2, cor 8, hum 6, uln 6, rad 1, cpm 4, pelel 2, fem 1, tbt 1, tmt 1.
- Giant Petrel *Macronectes* spp. (1/1): hum 1.
- Pachyptila turtur* (128/22): prem 4, man 5, cor 8, hum 34, uln 39, rad 6, cpm 12, alpha 2, pelel 4, tbt 3, tmt 8.
- Pachyptila vittata* (45/9): prem 4, man 7, cor 2, hum 15, uln 14, cpm 2, fem 1.
- Pterodroma axillaris* (5/2): hum 1, cpm 2, pelel 1, fem 1.

- White-faced Storm Petrel *Pelagodroma marina maoriana* (26/6): man 1, sca 1, cor 2, hum 3, uln 1, rad 1, cpm 2, alpha 1, pelel 1, fem 1, tbt 2, tmt 9, pedphal 1.
Pelecanoides / *Pachyptila* / *Pterodroma axillaris*: ste 4, sca 6, cor 3, rad 5, pelel 2, tbt 32, tmt 6.
 Blue Penguin *Eudyptula minor* (33/7): man 2, ste 1, sca 1, cor 1, hum 10, uln 3, rad 2, cpm 1, fem 3, tbt 5, pedphal 4.
Eudyptes ?n.sp. (42/5): man 1, ste 1, fur 1, sca 4, cor 7, hum 6, rad 7, cpm 3, pelel 2, fem 4, tbt 4, tmt 1, pedphal 1.
 Pitt Island Shag *Stictocarbo featherstoni* (2/1): qua 1, tbt 1.
 Brown Skua *Catharacta skua lonnbergi* (13/3): ste 3, fur 1, sca 1, cor 1, hum 2, uln 1, cpm 1, fem 2, tbt 1.
Larus novaehollandiae scopulinus (5/1): cor 1, hum 1, tbt 2, tmt 1.
 White-fronted Tern *Sterna striata* (1/1): hum 1.
Hemiphaga novaeseelandiae chathamensis (1/1): uln 1.
Bowdleria rufescens (1/1): fem 1.
Anthornis melanura melanocephala (1/1): fem 1.
 Unidentified: fur 7, vert 9, ste 9, rib 1, alpha 2, pelel 9, pedphal 6.

Species referred to in Table 1 but not identified in fossil deposits:

- Circus approximans*, Australasian Harrier.
Haematopus chathamensis, Chatham Island Pied Oystercatcher.
Thinornis novaeseelandiae, Shore Plover.
Coenocorypha pusilla, Chatham Island Snipe.
Coenocorypha chathamica, Extinct Chatham Island Snipe.
Cyanoramphus novaeseelandiae chathamensis, Chatham Island Red-crowned Parakeet.
Cyanoramphus auriceps forbesi, Forbes' Parakeet.
Anthus novaeseelandiae chathamensis, Chatham Island Pipit.
Gerygone albofrontata, Chatham Island Warbler.
Rhipidura fuliginosa penita, Chatham Island Fantail.
Petroica macrocephala chathamensis, Chatham Island Tomtit.
Zosterops lateralis lateralis, Silvereye.
Prothemadera novaeseelandiae chathamensis, Chatham Island Tui.