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Fossils indicate *Pelecanoides georgicus* had large colonies at Mason Bay, Stewart Island, New Zealand

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ABSTRACT

Osteological characters distinguishing the South Georgian Diving Petrel (*Pelecanoides georgicus*) from the Common Diving Petrel (*P. urinatrix*) are described. *P. georgicus* is shown to be the main diving petrel in Holocene fossil deposits at Mason Bay, Stewart Island, New Zealand, where it is represented by thousands of bones. *P. georgicus* is also recorded from dune deposits on Chatham Island. The Codfish Island population is thus a remnant of a formerly large Pacific population that bred on Macquarie Island, Auckland Islands, Stewart Island and Chatham Island, and is therefore of high conservation priority.

KEYWORDS: *Pelecanoides georgicus*, Holocene fossils, Stewart Island, New Zealand.

INTRODUCTION

The Common Diving Petrel (*Pelecanoides urinatrix* (Gmelin, 1769)) is well known to observers of seabirds in New Zealand as one of the common inshore species. Turbott *et al.* (1990) and Heather & Robertson (1996) recognised only two subspecies from the New Zealand region, namely *P. u. exsul* Salvin, 1896 from the subantarctic islands and *P. u. urinatrix* (Gmelin, 1789) from around mainland New Zealand, the Snares and the Chatham Islands. However, I follow Murphy & Harper (1921), Oliver (1955) and Marchant & Higgins (1990) in recognising *P. u. chathamensis* Murphy & Harper 1916 to differentiate birds from Solander, Snares, Chatham Islands, and islets around Stewart Island, on account of their significantly smaller size. *P. u. chathamensis* has shorter wing and leg bones than *P. u. urinatrix*; however, while there is no overlap of the ranges of wing bone lengths between these taxa, there is overlap in the ranges of leg bone lengths (Worthy & Jouventin in press). These observations indicate unexamined proportional differences in these birds' skeletal morphology, which would further support their taxonomic differentiation.

A further species of diving petrel lives in the New Zealand region. The first evidence of this was when Murphy & Harper (1921) identified two specimens of the South Georgian Diving Petrel (*Pelecanoides georgicus* Murphy & Harper 1916) in the Natural History Museum (Tring) that had been donated by H. Travers, and were collected at Macquarie Island in October 1899. Murphy & Harper identified a third specimen in Tring from an "Is S. of New Zealand", which they assumed was also from Macquarie Island. However, the first specimens to be collected were two, by the *Erebus* and *Terror* Expedition in 1840 at Enderby I., Auckland Islands, and deposited in the British Museum of Natural History (now at Tring). They were subsequently identified as *P. georgicus* by R. A. Falla (as written on the labels), who localised the place of collection (labels give only Auckland Isles). M. J. Imber later concurred in the identification, and noted they were an adult (BMNH 1842.12.16.41) and a fledgling with some down still adhering to it (MJI pers. comm.). *Pelecanoides georgicus* was discovered breeding on Dundas Island, Auckland Islands by Falla in 1943 (Oliver 1955; Imber & Nilsson 1980; Dundas specimen – MNZ 21631, collected by Falla). It is now extinct there. Mammalian predators subsequently introduced to Macquarie have almost certainly eliminated that population of *P. georgicus* (Imber & Nilsson 1980). On Enderby, extinction of the diving petrels was the result of a combination of trampling by cattle and sea lions and interference by rabbits (Heather & Robertson 1996). On Dundas, extinction was due to the large and recently increased population of sea lions occupying the dunes and so trampling any burrows on this small island (A. J. D. Tennyson, pers. comm.). However, 1997-98 photos seen by M. J. Imber suggest that the habitat is not so damaged and there appears to be space left (under *Stilbocarpa*) for Diving Petrels to burrow (MJI pers. comm.). A colony of about 30-35 pairs of *P. georgicus* was discovered on Codfish Island off Stewart Island in 1978, where they coexisted with *P. urinatrix chathamensis* (Imber & Nilsson 1980). Burrows were in the sand dunes from 1-5 m above the high-tide line, so there, as elsewhere in the range of this species, the birds nested in unstable ground generally lacking plant cover (Murphy & Harper 1921). In preferring unstable nesting sites *P. georgicus* differs markedly from *P. urinatrix* subspecies, which all prefer burrowing in stable soils (Murphy & Harper 1921, Imber & Nilsson 1980).

Pelecanoides georgicus, while of similar size to *P. u. chathamensis*, is differentiated by having a white rather than smudgy grey underwing, considerable areas of white on the inner web of the outer three primaries vs dusky coloured, and differing nostril and bill shapes (Murphy & Harper 1921, Oliver 1955, Imber & Nilsson 1980, Marchant & Higgins 1990). Fossil bones of these two species could thus be expected to be difficult, if not impossible, to discriminate correctly.

Bones of *Pelecanoides* dominate the fossil avifaunas from Stewart Island in their numerical abundance. The majority of these faunas are from Mason Bay (46° 55' S 167° 46' E) on the western coast of Stewart Island. D. Crockett collected the first of these faunas on 27 January 1956 and, thereafter, R. J. Scarlett and B. Chapman made notable collections in 1972 and 1977 (Canterbury Museum records). In these collections, *Pelecanoides* bones were identified as *P. u. chathamensis*, and the collection locality is given only as in the dunes or on a 'raised beach'. Mason Bay is about 10 km long with the main dune area extending 2.25 km north and 1.75 km south of Duck Creek and up to about 2 km inland. At the southern end of the beach, three smaller areas of dunes lie between Wreck and Cavalier Creeks, immediately north of Leask Creek, and about The Gutter (Fig. 1).

I made further collections from all dune areas in Mason Bay during December 1997. At sites more than about 100 m inland, which are largely beyond reach of wind-blown bones from beach-wrecked birds, *Pelecanoides* was often the only taxon present and always accounted for more than 95% of all bones. Where fossils were *in situ* they were most often found eroding from dune sands 0-2m above a gravel layer that Bishop and Mildenhall (1994) showed was deposited at the Last Glacial – Holocene boundary. The fossils are thus of Holocene age.

The fact that, at Mason Bay bones of *Pelecanoides* are super-abundant suggested to me that there could have been a colony there in the past. Further, that the bones were in dunes and in light of the above-described preference for unstable breeding sites by *P. georgicus*, it seemed possible that the taxon in question was this species. I, therefore, sought skeletal differences between *P. georgicus* and *P. urinatrix* using recent skeletons, then applied the criteria for distinction to the fossils. This paper describes how bones of the two species differ and reports the discovery of *P. georgicus* from Mason Bay dunes.

METHODS

Modern skeletons of *P. urinatrix* and *P. georgicus* were studied in the Canterbury Museum and Museum of New Zealand Te Papa Tongarewa. I prepared additional skeletons of *P. u. chathamensis* from specimens collected dead off the beach at Mason Bay and identified by grey underwing plumage and bill shape. The only skeletal specimens of *P. georgicus* that were available were collected from a boat off Heard Island. The sample is small and from one time and place and so is not likely to be representative of the variation in this species. While size range is thus likely to be under-represented, differences in shape of the Heard Island birds from *P. urinatrix* are likely to be species specific, and so found in conspecific populations elsewhere. Study skins from Codfish Island were available for both taxa (Appendix 1).

Fossils from Mason Bay in the Canterbury Museum collections were examined. The fossils collected from the dunes at Mason Bay in December 1997 by the author are catalogued in the MNZ collection with the numbers S35960-36011 and 36104-36183.

Measurements were made with TESA dial callipers to the nearest 0.01 mm and later rounded to 0.1 mm. Summary statistics were prepared where samples were sufficiently large. Latitude and longitude of fossil sites in the dunes at Mason Bay were determined with a Garmin 38 GPS instrument. Radiocarbon dating was done at the Rafter Laboratory, Lower Hutt, New Zealand, using Accelerator Mass Spectrometry on a gelatin extraction of the collagen component of the bone.

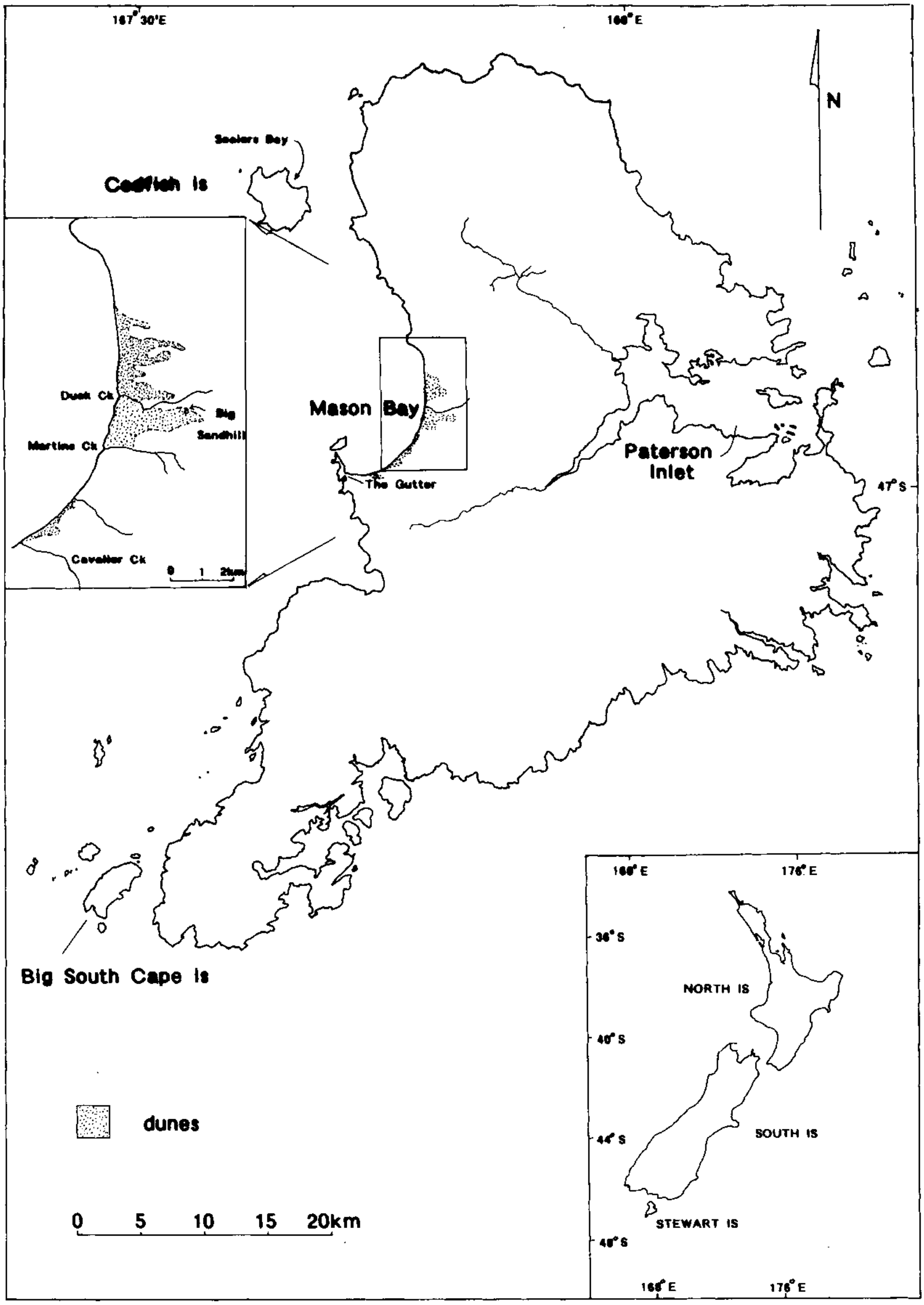

FIGURE 1 – Location of Mason Bay, on Stewart Island in New Zealand.

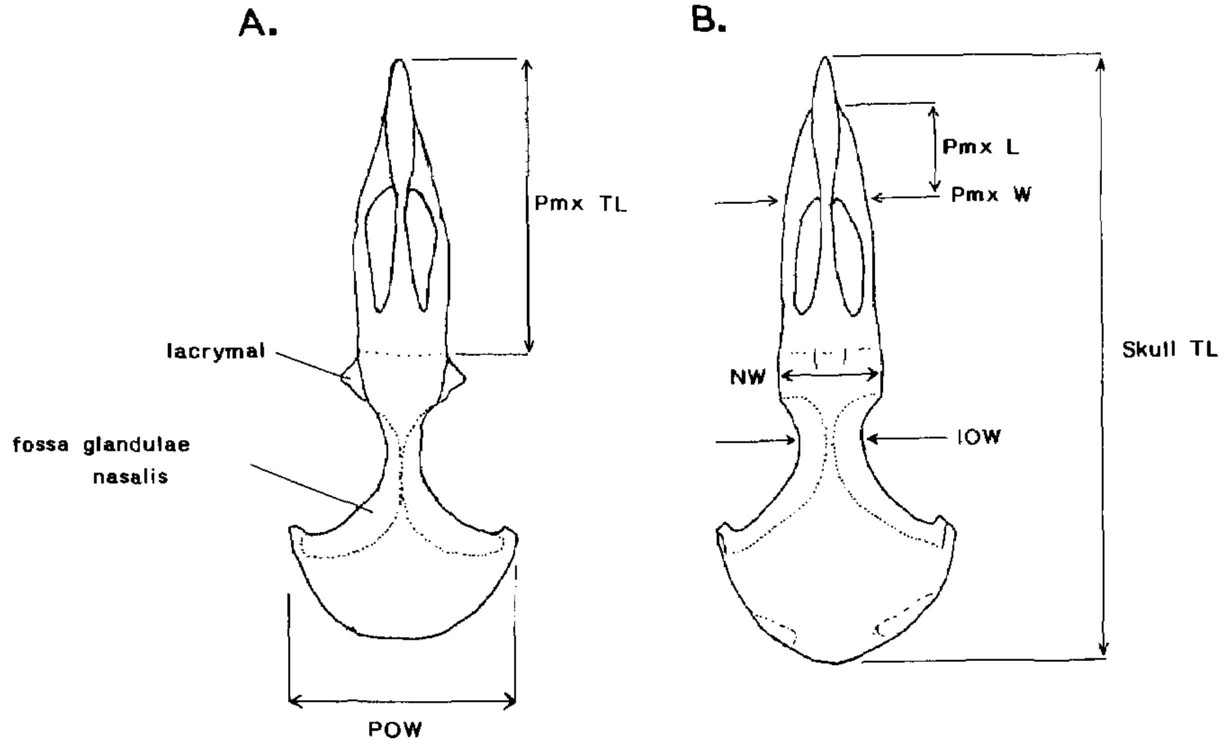

FIGURE 2 – Dorsal views of Pelecanoides skulls showing major diagnostic features and measurements used in this study. A. *P. georgicus* MNZ 24818 from Heard Island, B. *P. urinatrix urinatrix* MNZ 16602. NW is nasal width, IOW is interorbital width, POW is post-orbital width, Pms is premaxilla.

Abbreviations: MNZ – Museum of New Zealand Te Papa Tongarewa, Wellington; CM – Canterbury Museum, Christchurch; MNI – minimum number of individuals; NSP – number of specimens; yrs BP – radiocarbon years before present (1950); Cal BP – calendar years before present.

Skeletal elements: TL – total length, L – length, W – width, POW – postorbital width, ZPW – squamosal width, IOW – interorbital width, NW – width of nasals between lacrymals, Hum – humerus, Cmc – carpometacarpus, Pmx – premaxilla, Fem – femur, Tib – tibiotarsus, Tmt – tarsometatarsus, Cor – coracoid.

RESULTS

Osteological comparisons

The only feature that separates *P. georgicus* from *P. urinatrix* that is likely to be reflected in the skeletal anatomy is bill shape. As Murphy & Harper (1921: figs 2, 3) and Oliver (1955) noted, the bill of *P. georgicus* in study skins is wider and tapers towards the tip rather than being narrower and parallel-sided near the base as in *P. urinatrix*. Specifically, as Murphy & Harper's figures clearly show, in *P. georgicus*, the width of the premaxilla across the nares is about equal to the length from the posterior nares to the point where the sides of the premaxilla reach the

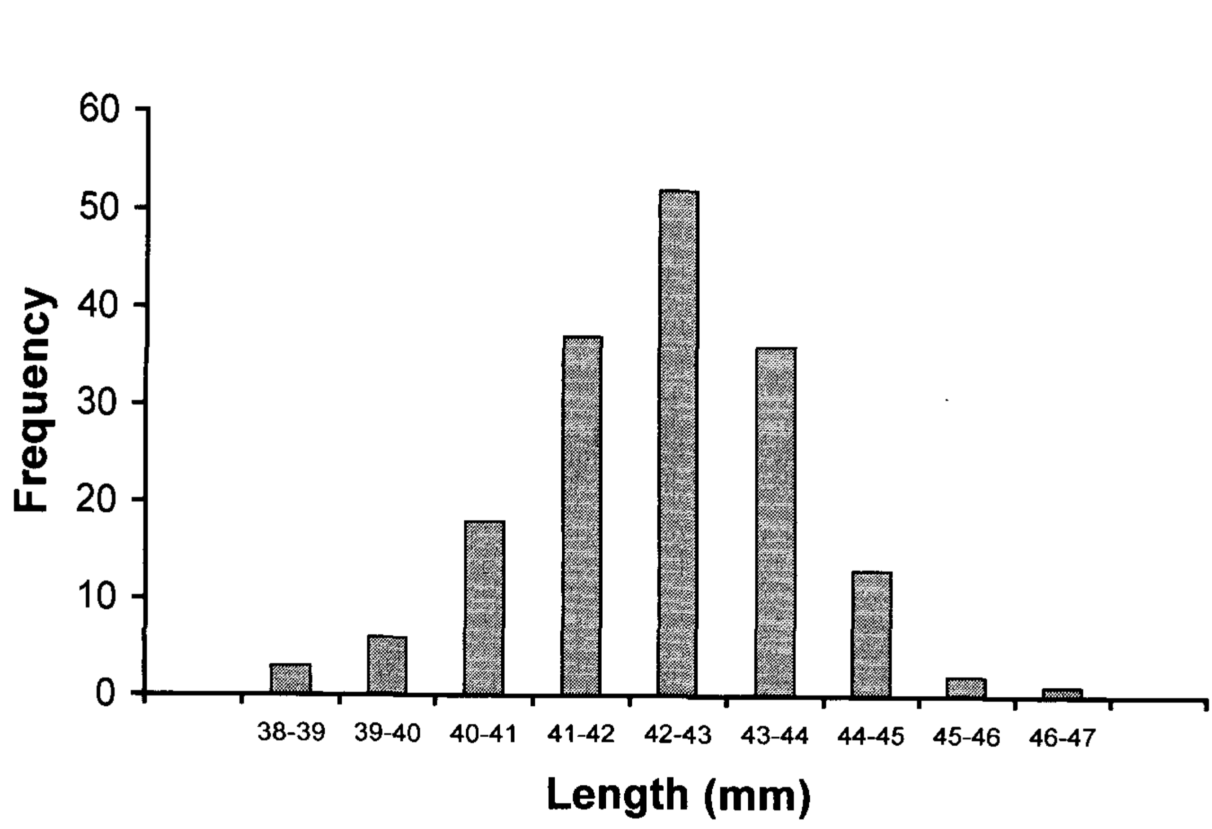

FIGURE 3 – Length frequency histogram for fossil humeri from Masons Bay, Stewart Island. N = 168. Specimens from lots CM Av14478, Av26138.

culmen. In *P. urinatrix* the width is much less than this length value. Examination of skulls of *P. georgicus* revealed parallel differences in premaxillae skeletal morphology despite the taxa being of similar size as measured by skull total length or postorbital width. The sides of the premaxilla in dorsal view are straight, and converge forward of the mid-point of the nasal cavity. The nasal cavity is markedly wider in its anterior third, and beyond it the premaxilla is short. This was demonstrated by the combination of width taken at the anterior end of the nasal cavity and length from there to where the sides of the premaxilla meet the culmen (Fig. 2). In *P. georgicus*, this premaxilla width was greater than the length measure and generated a W/L ratio that ranged from 105.0 to 126.5% with a mean of 111.5% (Table 1). In comparison, premaxillae of *P. u. chathamensis* are parallel sided towards their base, have nasal cavities that are not distended anteriorly, and are longer than wide anterior of the nasal cavity – W/L ratio 73.75-98.24, mean 87.17% (Table 1). Premaxillae of *P. u. urinatrix* and *P. u. exsul* are similar in shape to *P. u. chathamensis*, but are larger.

The shape of the cranium also differs between these taxa (Fig. 2). The nasal – lacrymal symphyses converge posteriorly in *P. georgicus*, but are parallel in *P. urinatrix*. Perhaps the most obvious difference is the shape of the interorbital area where deep fossae for salt glands (*fossae glandulae nasalis*) are present. The anterior-medial margin of these converge posteriorly, defining anteriorly narrow fossae in *P. georgicus*, compared to *P. urinatrix* in which the anterior margin of the fossae

TABLE 1. – Summary statistics of cranial measurements (mm) of modern skeletons of *Pelecanoides georgicus* from Heard Island and *P. urinatrix chathamensis* from the Chatham Islands and Mason Bay, Stewart Island. Measurements are defined on Figure 2.

Pelecanoides georgicus

	Skull TL	POW	IOW	Pmx W	Pmx L	IOW Pmx W/L	Pmx W/L %
Mean	48.11	19.80	3.31	6.25	5.63	16.85	111.50
Std Dev	0.84	0.42	0.43	0.39	0.52	2.53	8.07
Minimum	47.0	19.2	2.7	5.8	4.6	13.70	105.00
Maximum	49.2	20.3	3.8	6.8	6.2	19.76	126.54
Number	7	6	7	7	7	6	7
CV	1.76	2.11	13.04	6.31	9.27	15.00	7.24

P. urinatrix chathamensis

	Skull TL	POW	IOW	Pmx W	Pmx L	IOW /POW%	Pmx W/L %
Mean	49.54	20.06	4.43	6.06	6.98	22.18	87.17
Std Dev	1.30	0.68	0.42	0.33	0.58	1.91	6.23
Minimum	45.9	18.8	3.6	5.6	5.7	17.47	73.75
Maximum	51.2	20.9	5.1	6.8	8.0	24.80	98.24
Number	14	13	14	14	14	13	14
CV	2.62	3.39	9.45	5.51	8.38	8.63	7.14

are at first nearly parallel to the nasal-premaxilla hinge, and the fossae are wide anteriorly. Contingent with this feature, the inter-orbital width is relatively narrower in *P. georgicus*, although this was somewhat variable as indicated by the high coefficient of variation (CV) values. The variability could be related to age as younger birds probably have incomplete ossification of the orbital margin.

The long bones of *P. georgicus* from Heard Island were generally about 6% shorter than those of *P. u. chathamensis* although the ranges of all measurements overlapped (Table 2). However the mean humeral length was only 2.21% smaller, revealing a difference in skeletal proportions, as shown in Table 2. Thus, the ulna and carpometacarpus compared to the humerus were relatively shorter in *P. georgicus* than they were in *P. u. chathamensis*. The ulna/humerus ratio is therefore likely to be particularly useful for identification of skeletons, in the absence of cranial material, as these are the two most frequently preserved elements and the ranges for the two taxa were nearly non-overlapping.

Identification of fossils

The fossil bones from the Mason Bay dunes were examined and where crania or premaxillae were present their identity assessed with the characters outlined above. In the CM collections, there were six skulls (cranium associated with its premaxilla) (part of CM Av26138, 26165, 26174, 26177, 26373, 32447), nine crania (part of CM Av26125, 26138, 26161, 26165, 26174, 26218, 26219), and 19 premaxillae

TABLE 2. Summary statistics and derived ratios for long bones of *Pelecanoides georgicus* from Heard Island and *P. urinatrix chathamensis*.

Pelecanoides georgicus

	Hum L	Ulna L	Cmc L	Fem L	Tib TL	Tmt L	Cor med L	Ulna %Hum	Cmc %Hum	Cor %Hum	Hum %Fem	Tmt %Fem	Ulna %Fem
Mean	40.18	30.30	21.79	21.60	43.75	23.44	22.54	75.41	54.24	56.21	186.01	108.74	140.27
Std Dev	0.67	0.70	0.47	0.23	0.69	0.50	0.65	1.54	1.30	1.97	3.52	1.79	3.76
Minimum	39.3	29.4	21.1	21.2	42.6	22.5	21.6	72.81	51.97	54.27	181.94	105.14	134.98
Maximum	41.0	31.1	22.5	21.9	44.8	23.9	23.7	77.50	55.47	60.31	193.40	110.65	145.28
Number	8	8	8	8	8	7	7	8	8	7	8	7	8
CV	1.66	2.30	2.17	1.08	1.57	2.13	2.90	2.05	2.40	3.51	1.89	1.64	2.68

Pelecanoides urinatrix chathamensis

	Hum L	Ulna L	Cmc L	Fem L	Tib TL	Tmt L	Cor med L	Ulna %Hum	Cmc %Hum	Cor %Hum	Hum %Fem	Tmt %Fem	Ulna %Fem
Mean	41.07	32.33	23.17	22.91	46.21	25.03	22.84	78.72	56.53	55.58	179.48	109.38	141.33
Std Dev	0.84	0.69	0.47	0.88	1.37	0.73	0.64	1.23	1.08	1.13	5.04	2.83	4.03
Minimum	39.5	30.8	22.3	21.3	43.7	23.5	21.2	76.85	54.98	53.74	172.95	104.62	135.50
Maximum	42.4	33.3	23.8	24.5	48.1	26.3	23.6	81.02	58.42	57.20	185.54	112.73	150.00
Number	14	14	13	13	13	14	13	14	13	13	13	13	13
CV	2.05	2.13	2.04	3.86	2.96	2.94	2.79	1.56	1.92	2.04	2.81	2.58	2.85

(part of CM Av14813, 26118, 26125, 26138, 26165, 26174, 26218, 26236) that were identified as *P. georgicus*, compared to one premaxilla of *P. urinatrix chathamensis* (part CM Av26255). In the collections I made in December 1997, a single skeleton of *P. urinatrix chathamensis* (MNZ S35989) was found in a site where no other bones were present. In the numerous sites where *Pelecanoides* bones were abundant, not a single cranial element was identified as *P. urinatrix*, but nine skulls, 25 crania, and 35 premaxillae were identified as *P. georgicus* (Appendix 3).

Four partial skeletons were found, three with associated cranial elements thereby confirming their identity, which allowed examination of the relative lengths of the long bones. Measurements show these four individuals were larger than the Heard Island birds (Table 3). The three specimens with crania had the distinctive anteriorly-short premaxilla, distinctive shape to the salt gland fossa, and relatively narrow IOW. All had a relatively long humerus, which as shown by the various ratios, was in the same proportion with other elements as it was in *P. georgicus*, but outside of the range for *P. urinatrix chathamensis*.

Considering the disarticulated material next, measurements of all sufficiently complete cranial bones were made and summary statistics of these generated (Table 4). The cranial measurements again indicated that, while the Mason Bay birds were slightly bigger than the Heard Island *P. georgicus*, they had a similarly narrow inter-orbit, and a similarly foreshortened premaxilla. The W/L ratios derived from all 55 available premaxillae were outside the range for recent *P. u. chathamensis*, and there was barely any overlap in the IOW/POW ratios (Table 1).

As all cranial material from the fossil deposits at Mason Bay was identified as *P. georgicus*, all associated post-cranial material was referred to this species (Appendix 2, 3). A sample of complete, adult, unworn long bones was chosen and measured (Table 5), which showed the same trend as the cranial measurement data, namely that the fossils were bigger than Heard Island bones. Because the specimens were mixed bones from many individuals, ratios could not be determined in the same way as for individual skeletons. However, the large samples for humeri and ulnae meant that the ratio of the means probably reflected an average of mean ratios for individuals. The ulna/humerus ratio so determined was 0.744, within the range for *P. georgicus* individuals from Heard Island (Table 2) and Mason Bay (Table 3), but outside that for recent *P. u. chathamensis* (Table 2). A plot of the length distribution of humeri (Figure 3) has an apparently normal distribution, thereby showing that all specimens in the range probably belonged to the population.

Age of fossil deposits

The stratigraphic location of the fossil bones of *P. georgicus* in the dunes above the gravel layer indicates they are of Holocene age (Bishop & Mildenhall 1994). An ulna from the individual found articulated *in situ* at site 1 (MNZ S35966) gave a conventional radiocarbon age of 1015±76 yrs BP, 720-499 Cal BP, NZA8406.

TABLE 3. – Measurements (mm) from four part skeletons of *Pelecanoides georgicus* from Mason Bay, Stewart Island.

Specimen	Skull TL	NW	POW	ZPW	IOW	Pmx W	Pmx L	IOW /POW%	Pmx W/L %
MNZ S35966			20.8	18.3	3.4	6.9	5.8	16.17	118.27
MNZ S36008	48.6	7.9	20.6	18.1	3.5	6.2	5.4	16.81	114.07
MNZ S36138						6.2	5.6		112.23
MNZ S35991									

Specimen	Hum L	Ulna L	Cmc L	Fem L	Tib L	Tmt L	Cor L	Ulna /Hum%	Cmc /Hum%	Hum Fem%
MNZ S35966	42.3	32.1	22.6	22.8	45.3	25.8	23.5	75.93	53.50	185.28
MNZ S36008	43.9	33.3	23.5	23.4	47.5	24.9	23.2	75.88	53.58	187.28
MNZ S36138	42.2	31.5	22.9	22.7		24.7		74.68	54.41	185.73
MNZ S35991	43	32.1					23.3	74.65		

Associated faunas

The deposits with *P. georgicus* bones contained relatively few bones of other species (Appendix 4). Most were seabirds of species commonly wrecked on the beach in the recent past, so these few bones of other species could all be explained as derived from birds blown inland. The single collection made from gullies behind the high tide line was probably derived in a large part from beach-wrecked birds that had decomposed and had their bones blown inland. It does not represent species that were living in the dunes, with the exception of the bones attributed to *Pelecanoides georgicus*, which almost certainly were derived from eroding sand dunes exposed right behind the beach.

Terrestrial species were very rare in the fossil deposits. Out of some 10 220 bones recorded from the Mason Bay dunes in the combined collections of the Canterbury Museum and my December collections only the following were noted: single bones of Saddleback (*Philesturnus carunculatus* MNZ S36130), Morepork (*Ninox novaeseelandiae* CM Av26234), Kaka (*Nestor meridionalis* CM Av14859), Tomtit (*Petroica macrocephala* CM Av26233), and two bones of snipe (*Coenocorypha aucklandica* CM Av37349) and parakeet (*Cyanoramphus* sp. CM Av14844, 26128). Pipit (*Anthus novaeseelandiae*) and Weka (*Gallirallus australis*) were represented by few bones. This fauna suggests that the depositional environment was open exposed sand dunes not much frequented by forest species.

Occasional bones of Pacific Rat (*Rattus exulans*) were present in the surface collections of bones from some sites. Because of the strong winds prevalent during the period of collection and the preservation of the bones, I consider that these rat bones were eroded from the same deposits as the diving petrel bones. Pacific Rats

TABLE 4. – Summary statistics for cranial measurements (mm) for fossils of *P. georgicus* from Mason Bay. The data are from all available CM (listed 'Identification of fossils' section) and MNZ specimens (Appendices 2, 3).

	Skull TL	NW	POW	ZPW	IOW	Pmx TL	Pmx W	Pmx L	IOW /POW %	Pmx W/L %
Mean	49.17	7.32	20.64	18.12	3.36	23.89	6.29	5.52	16.35	114.57
Std Dev	1.38	0.50	0.56	0.45	0.30	0.80	0.26	0.44	1.15	7.45
Minimum	45.8	6.3	19.5	17.5	2.7	22.8	5.6	4.3	13.17	100.30
Maximum	51.7	8.5	21.5	19.2	4.2	25.6	6.9	6.6	18.14	136.36
Number	13	26	18	23	38	28	56	55	18	55
CV	2.81	6.89	2.73	2.48	8.86	3.36	4.20	8.04	7.03	6.50

arrived in New Zealand with people, but the widely held assumption that this was with Maori colonists 700-1000 years ago (Anderson 1991) has recently been challenged by radiocarbon dating of rats from natural sites, which suggests they arrived about 2000 years ago (Holdaway 1996). If of contemporary age with the diving petrel bones, these rat bones indicate some of the deposits are certainly less than 2000 years old and probably less than 1000 years old. The single date for site 1 supports this inference.

DISCUSSION

Dune deposits of Holocene age at Mason Bay, Stewart Island, contain abundant fossils of a diving petrel identified by cranial characters as the South Georgian Diving Petrel (*Pelecanoides georgicus*). The bones were 2.5-5.9% longer than those from birds collected off Heard Island, southern Indian Ocean, and show that the Mason Bay population comprised larger individuals than birds from Heard Island. Differences of this magnitude are normal within other diving petrel species, as shown by the size differences between *P. urinatrix* populations that are accepted as discrete subspecies (Murphy & Harper 1921, Marchant & Higgins 1990, Worthy & Jouventin in press). Marchant & Higgins (1990) presented measurement data for various populations of *P. georgicus*, which suggest that the birds from Heard Island are generally smaller than those from Iles Crozet and South Georgia. It is, therefore, not surprising that Heard Island birds are of different size from the population formerly living at Mason Bay.

Pelecanoides georgicus has a relatively longer humerus than *P. u. chathamensis*. In an otherwise similar sized bird this results in *P. georgicus* having a relatively longer wing, which may be related to preferred differences in feeding grounds between these species. *P. urinatrix* is a near-shore feeder, whereas the stomach contents of the few examined specimens of *P. georgicus* from Codfish Island suggested that this species fed at localities distant from the island along the edge of the continental shelf (Imber & Nilsson 1980).

TABLE 5. – Summary statistics for post-cranial bones of *P. georgicus* from Mason Bay. The data are derived from CM Av14846 – left ulnae; Av14478 – left humeri; Av14853 – left humeri, Av26138 – left humeri, left ulnae, left & right carpometacarpi, left coracoids, left and right femora, left and right tibiotarsi, left and right tarsometatarsi; Av14852 – left tibiotarsi.

	Hum L	Ulna L	Cmc L	Fem L	Tib L	Tmt L	Cor L
Mean	42.32	31.49	22.88	22.57	46.37	24.91	23.12
Std Dev	1.34	1.39	0.65	0.90	1.41	0.78	0.49
Minimum	38.6	22.3	21.9	20.9	43.8	23.1	22.4
Maximum	46.4	34.6	24.0	23.9	48.9	26.4	24.0
Number	168	86	17	10	31	18	8
CV	3.16	4.42	2.82	4.00	3.04	3.14	2.12

The fossils from Mason Bay have significance in interpreting the origin of the extant colony of *P. georgicus* on Codfish Island. The fossils indicate that the species has a long history in the area and that the Codfish population is a remnant of one much larger that frequented the Stewart Island area until after Polynesians colonized southern New Zealand about 800 years ago (Anderson 1991). They make it unlikely that the Codfish population is a new, establishing colony. The Codfish Island population is, therefore, the last of a Pacific Ocean population, and has significant conservation value.

Its continued survival in the presence of *Rattus exulans* is so far fortunate and very unusual. Elsewhere in the New Zealand region, *P. urinatrix* and other small petrels are common only where *R. exulans* is absent – most colonies listed by Marchant & Higgins (1990) are on rat-free islands, and where rats are/were present diving petrels are rare, e.g. Korapuki, Stanley, Tiritiri and Double Islands. Taylor *et al.* (in press) stated "...in our experience, dense colonies of diving petrels occur only on islands where mammalian predators are absent." Recent records suggest some losses have occurred only in the last few decades. Edgar (1962) reported *R. exulans* to be abundant on Red Mercury Island in 1961 and that the only rat-sign on Stanley Island was some damage to bark attributed to gnawing. At that time there was a colony of >100 burrows of diving petrels on Stanley, but by 1966 *R. exulans* was abundant and the diving petrels gone (Thoresen 1967). The survival of both small diving petrels on Codfish Island therefore suggests a relatively recent arrival (probably <100-200 yrs) for this rodent. Saddleback (*Philesturnus carunculatus*), Robin (*Petroica australis*), Bush Wren (*Xenicus longipes*), and Snipe (*Coenocorypha aucklandica*) were never recorded historically on Codfish (Blackburn 1968). They were probably early victims of *R. exulans* as these same species were exterminated within three years of the introduction of *R. rattus* to nearby Big South Cape Island in the early 1960s (Blackburn 1965), and apart from Robin do not coexist with *R. exulans* now. The planned removal of *R. exulans* from Codfish Island in the interests of Kakapo (*Strigops habroptilus*) conservation is, therefore, timely indeed.

The discovery that *P. georgicus* lived in the sand dunes at Mason Bay means that two more or less identically sized *Pelecanoides* species lived, each in significant numbers, in the Stewart Island area in the past. This needs to be borne in mind when studying faunas from both natural and archaeological sites in the region. Identification of *Pelecanoides* bones needs to be based on the cranial characters outlined above or the relative lengths of the humerus to other elements, particularly the ulna.

The presence of *P. georgicus* bones in Stewart Island dunes, and consideration of this species' preference for dunes as breeding sites, makes it probable that at least some of the abundant diving petrel bones in some of the dunes on Chatham Island could be *P. georgicus*. While it is beyond the scope of this report to examine the huge collections from Chatham Island, I noted that there were few cranial elements in the Canterbury Museum collections from these dunes. However, a cranium and premaxilla from Owenga (CM Av11324), two crania from Long Beach (part CM Av28389 and part CM Av28377), and a cranium from Te One (part CM Av29771) are *P. georgicus*. The numerous diving petrel bones from the cave Te Ana a Moe collected by P. R. Millener, were all *P. urinatrix* (pers. obs.). Thus, both species probably bred on Chatham Island, and *P. georgicus*, because of its preference for dunes, which mainly occur on the now farmed and predator-devastated Chatham Island, is now extinct in the group.

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Appendix 1A. Recent skeletons examined:
Pelecanoides georgicus, all Heard Island.
MNZ24790, MNZ24816, MNZ24817, MNZ24818, MNZ24819, MNZ24820, MNZ24821, MNZ24822,

Pelecanoides urinatrix chathamensis.
MNZ18316, Southeast Is; MNZ18097, Southeast Is; MNZ18267, Southeast Is; MNZ18341, Southeast Is; MNZ18098, Southeast Is; MNZ18315, Southeast Is; MNZ807S, Southeast Is; MNZ811, Whero Is; MNZ812, Whero Is; CM Av32427, Mason Bay Beach; CM Av32459, Mason Bay Beach; CM Av32453, Mason Bay Beach; THW #1, Mason Bay Beach; THW #2, Mason Bay Beach; THW #3, Mason Bay Beach; THW #4, Mason Bay Beach; THW #5, Mason Bay Beach.

Pelecanoides u. urinatrix
MNZ547S, Wellington Beach; MNZ17202, Himatangi Beach; MNZ17198, Himatangi Beach; MNZ16601, Palliser Bay; MNZ13614, Waikanae Beach; MNZ13613, Te Horo; MNZ13610, Pipinui Pt; MNZ546S, Wellington Beach.

Pelecanoides urinatrix exsul
MNZ 908S, 17623, 17624, 17625, 18096 (Auckland I.); MNZ 24785, 24786 (Heard I.).

Appendix 1B. Study skins examined:
Pelecanoides georgicus
MNZ 21031, F; 21057, M; 21058, F; 21070, F; 21071, F.

Pelecanoides urinatrix chathamensis
MNZ 870, ?; 16645, M; 16663, M; 16664, M; 17678, F; 18679, F; 18680, ?; 21072, M; 21618, M; 21619, F.

Appendix 2. – Specimens in Canterbury Museum referred to *Pelecanoides georgicus*. All were from dunes at Mason Bay, Stewart Island. The 'Check' column indicates the specimens have been examined if a 'Y' is present. Unchecked specimens could not be located, but will probably eventually be found, and are listed to at least demonstrate their former presence. Those listed between Av14808 and Av14853 are obviously parts of a single collection segregated by element and of which only ulnae, tibiotarsi and humeri could be found. NSP is the number of specimens. Abbreviations: hum – humeri, rad – radii, cmc – carpometacarpi, scap – scapulae, cor – coracoids, fur – furculae, fem – femora, tt – tibiotarsi, tmt – tarsometatarsi, cran – crania, pmx premaxillae, mand – mandible, stern - sterna, sac – synsacrum, innom – innominates, vert – vertebrae, L – left, R – right, p – proximal, d - distal

Check	Cat No	Specimens	NSP
Y	Av14132	2L hum, pR tt, R ulna, R cor, L tmt, L cmc	7
Y	Av14478	12R24L hum, 6L4R tt, 4L5R ulna, 1 pelvis, 2L cmc, 1L scap, 1R cor	60
Y	Av14517	Pmx	1
Y	Av14518	R fem	1
	Av14808	Cran, pmx	2
	Av14809	Cran, pmx	2
	Av14810	Cran, pmx	2
	Av14811	Cran	1
Y	Av14813	Pmx	1
	Av14814	Stern	1
	Av14815	Stern	1
	Av14817	Pmx	1
	Av14818	Pmx	1
	Av14819	Mand	1
	Av14820	Pmx	1
	Av14821	Pmx	1
	Av14822	Mand	1
	Av14835	Part pmx	1
	Av14839	Pmx	1
	Av14840	Sac	1
	Av14841	Sac	1
	Av14842	Sac	1
	Av14843	Sac	1
Y	Av14846	95L91R ulnae, 1L rad	187
	Av14847	41 rad	41
	Av14848	6 fur	6
	Av14849	64 tmt	64
	Av14850	47 cor	47
	Av14851	54 cmc	54
Y	Av14852	85R 76L tt	161
Y	Av14853	205R 180L hum	385
	Av17882	dL hum	1
	Av26106	4R5L hum, 7R6L ulna, sac, 2R1L fem, RL tt, 2R tmt, 1R1L scap, 1R cor	32
	Av26111	Cran, pmx, 5R1Lhum, 3R ulna, 2L tt, 3R1L tmt, 1L cmc	18
Y	Av26118	Pmx, pt fur, 45R40L hum, 19R19L ulna, 1R3L fem, 15R10L tt, 6R7L tmt, 6R6L cor, 1R scap, 6R12L cmc, 5L4R rad	207
Y	Av26121	2L hum, 1L ulna, 1L tt	4
Y	Av26125	Cran, pmx, pt stern, 2 fur, 3 sac, 37R33L hum, 14R20L ulna, 3L rad, 5R4L cmc, 1R1L scap, 4R5L cor, 3R3L fem, 6R8L tt, 4R4L tmt, 1 mand	164
Y	Av26138	Cran + pmx, pt 6 mand, pt cran, 3 pmx, 8R11L cor, 5 fur, 36R1dR1pR 33L5pL2dL hum, 9R7L fem, 25R2pR3dR 13L1pL2dL tt, 9R12L tmt, 2 vert, 26L1dL30R1dR ulna, 12R14L rad, 19R15L cmc, 3R2L scap, 1 manus phalanx 2.1, 4 sac	325
Y	Av26148	pt 2 mand, fur, sac, 53R46L hum, 24R26L ulna, 4R3L rad, 2R1L fem,	

		11R8L tt, 2R4L tmt, 1L scap, 7R6L cor, 4R4L cmc	210
Y	Av26152	stern, 3 scap, L innom, 47R48L hum, 22R32L ulna, 5R6L rad, 5R7L cmc, 3R2L cor, 4R4L fem, 9R8L tt, 7R5L tmt	219
Y	Av26161	45R53L hum, cran, mand, pt mand, 25R27L ulna, 2R2L rad, fur, 5R7L cmc, 3R2L cor, 2L fem, 11R7L tt, 4R4L tmt	203
Y	Av26165	3 cran, 7 pmx, pt 8 mand, 98R25dR10pR 78L20dL9pL hum, 93R98L ulna, 20R27L rad, 26R36L cmc, 20R30L cor, 3L4R scap, 2 fur, 9 sac, 1R4L innom, 9R9L fem, 43R38L tt, 18R16L tmt	764
Y	Av26174	3 cran, 5 pmx, 1 pt mand, 4 sac, pt stern, 54R65L hum, 13R22L ulna, 3R3L rad, 1R3L scap, 10R13L cor, 11R10L cmc, 2R6L fem, 5R11L tt, 9R7L tmt, 7 fur	269
Y	Av26177	skull, pmx, 2 pt mand, 2 sac, 3 fur, 2R1L fem, 3R4L hum, 3L ulna, 4L cmc, 1R2L cor, 2R4L tt, 1R tmt	36
Y	Av26181	2R ulna, RL hum, R cor, R tmt	6
Y	Av26185	pmx, 3 frags mand, 93R82L hum, 37R37L ulna, 4R5L rad, ant stern, 10R17L cmc, RL innom, 1L scap, 14R9L cor, 3R3L fem, 16R12L tt, 10R8L tmt	368
Y	Av26194	stern, pt 1 stern, 61R49L hum, 21R36L ulna, 3 pt fur, 6 sac, 10R10L cmc, 7R9L cor, 1R1L scap, 8R6L rad, 6R4L fem, 10R9L tt, 8R9L tmt	276
Y	Av26213	RL ulna, L fem	3
Y	Av26218	pt cran, pmx	2
Y	Av26219	cran	1
Y	Av26225	2R1L hum, 1L ulna, RL rad	6
Y	Av26236	2 pmx, 1L ramus, 9R6L hum, 5L ulna, 2L rad, 2R3L cmc, RL cor, L scap, 4 sac, 1R4L tt	42
Y	Av26245	R hum, RL ulna, R tt, R tmt	5
Y	Av26253	R cor	1
Y	Av26270	pmx, fur, L hum, R ulna, L fem, 2 sac	7
Y	Av26295	L ulna, pL cor, sR pR hum	4
Y	Av26297	L cmc	1
Y	Av26301	R hum, L ulna, R tt	3
Y	Av26305	imm L tt, dR hum	2
Y	Av26307	3R1L tt	4
Y	Av26311	L fem, pL dR tt	3
Y	Av26373	skull, pmx, 4 mand, sac, L innom, 2 fur, 34R45L hum, 15R25L ulna, 3R7L rad, 3R4L cmc, 3R1L scap, 3R9L cor, 6R3L fem, 9R2pR14L tt, 4R4L tmt	204
	Av28306	4R6L hum, 2R1L ulna, R cmc, R tmt	15
Y	Av32447	skull	1
	Av32460	4 cran, 5 pmx, 7 mand, 68R80L hum, 15R25L rad, 26R31L cor, 2 fur, pt pel, ant stern, 24R 19L cmc, 54R46L ulna, 13R5L fem, 31R23L tt, 17R12L tmt	509
Y	Av32595	21R20L hum, 14R11L ulna, 2R1L rad, fur, L scap, 6R2L cor, 6R3L cmc, sac, L fem, 1R12L tt, 3L tmt,	106
Y	Av32597	22R12L hum, 9R4L ulna, 1R rad, 3R2L cor, 1L cmc, 2L fem, 3R4L tt, 1R tmt	64
Y	Av32619	pt mand, 4R10L hum, 5R5L ulna, 2L3R rad, 2L cor, 2R4L cmc, fur, 2R1L fem, 2R5L tt, 3L2R tmt	54
	TOTAL		**5175**

Appendix 3. – List of specimens of *Pelecanoides* collected by T. H. Worthy in December 1997 from dunes at Mason Bay. All are referred to *P. georgicus* except MNZ S36160 which is not referred to species as was not within a fossil colony nor associated with diagnostic elements. Cat. No. is the catalogue number in the MNZ. Site GPS coordinates locate the site. Abbreviations are as in Appendix 2.

Cat. No	Specimens	NSP	Site	Site GPS Coordinates
S35966	85/1	85	Site 1	46° 55' 11.7"S; 167° 46'12.4"E; NZA 8406, CRA 1015+-76 yrs
S35967	9 pmx, 6 cran, 2 cran + pmx, pt 3 mand, 78R74L hum, 71 other bones	243	Site 1	46° 55' 11.7"S; 167° 46'12.4"E
S35977	1 pmx, 12R15L hum + 20 bones	48	Site 2	46° 55' 06.9"S; 167° 46'14.2"E
S35979	LR hum	2	Site 2-3	46° 55' S; 167° 46' E
S35984	2 pmx, pt cran, 19L19R hum, + 118 bones	159	Site 3	46° 55' 51.1"S; 167° 46'14.1"E
S35988	5R2L hum, + 4 bones	11	Site 4	46° 55' 41.6"S; 167° 45' 55.2"E
S35990	12R12L hum + 37 bones	61	Site 6	46° 56' 04.1"S; 167° 46' 21.8"E
S35991	skeleton	25	Site 6	46° 56' 04.1"S; 167° 46' 21.8"E
S35995	1 pmx, 36L33R hum, + 42 bones	112	Site 7	46° 56' 02.0"S; 167° 46' 05.8"E
S36000	cran + pmx, 8L4R hum, + 21 bones	35	Site 8	46° 57' 43.9"S; 167° 43' 40.6"E
S36007	pt 5 cran, 5 pmx, 51L57R hum, + 363 bones	481	Site 9	46° 57' 39.4"S; 167° 43' 48.1"E
S36008	skeleton	23	Site 9	46° 57' 39.4"S; 167° 43' 48.1"E
S36115	2 pmx, 4 cran, 33R40L hum, +201 bones	280	Site 10	46° 57' 38.7"S; 167° 43' 49.3"E
S36116	skeleton	69	Site 11	46° 57' 37.8"S; 167° 43' 51.9"E
S36117	4 pmx, 2 cran, 14L20R hum, + 125 bones	165	Site 11	46° 57' 37.8"S; 167° 43' 51.9"E
S36127	8L9R hum, +58 bones	75	Site 12	46° 57' 33.4"S; 167° 43' 54.0"E
S36129	3 cran+ pmx, 5 cran, 8 pmx, 3 mand, 86L106R hum, + 219 bones	430	Site 13	46° 54' 38.7"S; 167° 46' 15.4"E
S36137	5R2L hum, R tt, L cor,	10	Site 13a, gully 50 m North of Site 13	46° 54' 38.7"S; 167° 46' 15.4"E
S36138	skeleton	30	Site 13a, gully 50 m North of Site 13	46° 54' 38.7"S; 167° 46' 15.4"E
S36143	4R6L hum, + 11 bones	21	Site 14	46° 54' 34.2"S; 167° 46' 07.7"E
S36150	12L8R hum, +19 bones	39	Site 15	46° 54' 32.8"S; 167° 46' 08.1"E
S36154	2 cran, 7R9L hum, + 24 bones	42	Site 16	46° 54' 36.0"S; 167° 46' 12.8"E
S36156	pmx, 27L25R hum, + 69 bones	122	Site 17	46° 54' 41.8"S; 167° 46' 27.3"E
S36158	12L18R hum, 1 skull, 1 pmx, + 51 bones	83	Sites 13 to 17	46° 54' 40"S; 167° 46' 20"E
S36160	4 bones	4	By the Gutter	
S36162	skeleton	11	Exposed below midden, The Gutter	
S36166	22 bones 4 indiv	22	North of Cavalier Ck	46° 57'30" S; 167° 42' 30"E
S36175	12L13R hum, + 20 bones	45	Mason Bay, gullies just back of high tide 1.5 km north of Duck Ck	
S36182	4L2R hum, 2L ulna, stern	9	Mason Bay, south of Duck Creek	c. 46° 55' ; 167° 46' E

Appendix 4. – Minimum number of individuals (MNI) and number of specimens (NSP) of species in dune sites 1-17 at Mason Bay investigated in December 1997. Additional species present in Canterbury Museum collections from dunes in Mason Bay are indicated by Y (NSP). Specimens collected in December 1997 from in gullies close to the high tide line (seaward gullies) are listed separately to illustrate the effect of beach wrecks.

Species	NSP (1-17)	MNI (1-17)	NSP Seaward gullies	MNI Seaward gullies
Apteryx australis	3	1		
Diomedea cauta		Y (7)		
Diomedea bulleri		Y (11)		
Diomedea epomophora/exulans		Y (2)		
Daption capense		Y (4)	3	1
Fulmarus glacialoides		Y (1)		
Pterodroma inexpectata	15	2	1	1
Pterodroma cookii	3	2		
Pterodroma lessonii		Y (8)	1	1
Puffinus griseus	78	15	84	9
Puffinus gavia/huttoni	2	2		
Puffinus assimilis		Y (skel)		
Puffinus bulleri		Y (2)		
Puffinus tenuirostris	26	3		
Pelecanoides urinatrix	20	1		
Pelecanoides georgicus	2651	488	45	13
Pelagodroma marina	11	4	1	1
Garrodia nereis		Y (1)		
Macronectes halli/giganteus		Y (1)		
Pachyptila turtur	23	11	4	1
Pachyptila vittata	15	8	2	1
Eudyptula minor	19	5	2	1
Eudyptes pachyrhynchus		Y (10)	7	1
Leucocarbo carunculatus	27	2		
Stictocarbo punctatus	1	1		
Tadorna variegata		Y (3)		
Anas chlorotis		Y (8)		
Gallirallus australis	20	5		
Porphyrio porphyrio			1	1
Haematopus unicolor	4	1		
Coenocorypha aucklandica		Y (2)		
Catharacta skua	1	1		
Larus dominicanus	4	2		
Larus scopulinus/bulleri	3	3		
Sterna albostriata		Y (1)		
Nestor meridionalis		Y (1)		
Cyanoramphus spp.		Y (2)		
Ninox novaeseelandiae		Y (1)		
Anthus novaeseelandiae	4	4		
Petroica macrocephala		Y (1)		
Philesturnus carunculatus	1	1		
Turnagra capensis		Y (1)		
Rattus exulans	22	8		
Rattus rattus	15	6		