

Wrecks and residents: the fossil gadfly petrels (*Pterodroma* spp.) of the Chatham Islands, New Zealand

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ABSTRACT - During some 40 years' research, ten species of gadfly petrel, *Pterodroma* spp., have been reported from Holocene fossil assemblages from the Chatham Islands, New Zealand. Statistical analysis of the assemblages' species composition and a critical appraisal of all claimed identifications have resulted in a re-assessment of fossil *Pterodroma* diversity prior to human arrival. Three species are confirmed as original breeding residents; the endemic *Pterodroma magentae* and *P. axillaris*, and the undescribed extinct *Pterodroma* sp.1. Additionally, *P. nigripennis* is confirmed as a vagrant. Possible records of further vagrant species, *P. inexpectata*, *P. macroptera* or *P. lessonii* and *P. neglecta* cannot yet be confirmed.

Key words: Chatham Islands, Holocene, *Pterodroma*, identification

Migrants et résidents: les pétrels fossiles (*Pterodroma* spp.) des Iles Chatham, Nouvelle-Zélande

– En 40 ans de recherche, dix espèces de pétrel *Pterodroma* spp., ont été signalées dans les assemblages fossiles holocènes aux Iles Chatham (Nouvelle-Zélande). Une analyse statistique de la composition spécifique et un examen critique de toutes les identifications proposées permettent de réinterpréter la diversité des *Pterodroma* avant l'arrivée de l'homme.

INTRODUCTION

The archipelago of the Chatham Islands (44°S, 176°W) lies some 860 km east of New Zealand, straddling the oceanic Subtropical Convergence. Deposits of Holocene fossil bird bones were first discovered there in the early 1890s, and following more than a century of research, extremely abundant assemblages of Holocene bird remains are now known from Chatham, Pitt and Mangere Islands. Although a formerly rich endemic terrestrial avifauna has been documented, the assemblages are dominated by the remains of a diverse seabird community, including some 20 members of the Procellariidae and a total of about 30 Procellariiformes (Millener, 1999). Amongst the most abundant are the remains of gadfly petrels *Pterodroma* spp., of which up to ten taxa have been claimed as occurring within the assemblages. At present, the islands support three breeding species of *Pterodroma*; *P. nigripennis* and the critically endangered endemic *P. magentae* and *P. axillaris* (fig. 1), with a further six species occurring as vagrants (Imber, 1994).

Accurate species identification of Chatham Island fossil *Pterodroma* material is problematic; the genus is osteologically conservative, there are few recent comparative specimens of several species, fossils are normally found as isolated elements rather than associated skeletons, fossil skulls (the most diagnostic element) are rare, and the fossil assemblage is diverse. A first attempt to quantify the complete petrel assemblage was made by Bourne (1967), result-

ing in identification of four species of *Pterodroma*. Bourne admitted being hampered by a lack of comparative material, but did publish measurements of both fossil and comparative specimens. Subsequent fossil checklists including *Pterodroma* species have generally appeared in overviews of the assemblages, without any additional justification for the identifications made. A summary of key works and identifications is shown in Table 1. This highlights the problem of a proliferation of *Pterodroma* taxa in lists and their subsequent disappearance in later lists, leading to confusion as to which records should be accepted.

A further complication is the possible occurrence of a third endemic species, now extinct, originally suggested by Bourne (1967) and also noted by later authors (e.g. Tennyson & Millener, 1994; Millener, 1999; Holdaway et al., 2001). This putative taxon is a medium-sized species, falling between the large *P. magentae* (420-560g, wingspan 102cm) and the small *P. axillaris* (c.200g, wingspan 63-71cm), and it has often been compared with *P. inexpectata* (c.315g, wingspan 85cm) (Marchant & Higgins, 1990).

Here we critically review all claimed identifications of fossil *Pterodroma* species from the Chatham Islands.

METHODS

Extensive collections of Chatham Islands fossil birds are held by The Natural History Museum, London (NHM) and the Museum of New Zealand Te Papa Tongare-



Figure 1 - Chatham Island Petrel *Pterodroma axillaris*. Photo: Alan J.D. Tennyson.

wa, Wellington (MNZ). The NHM collections consist primarily of material collected on Chatham Island during the late 1800s; those of MNZ primarily of material excavated during the 1980s-1990s from Chatham, Pitt and Mangere Islands. Analysis of the collections followed two main lines of investigation.

Firstly, previously identified *Pterodroma* remains in both collections were reviewed, in order to locate material referred to in earlier publications and assess the reliability of their identifications.

Secondly, fossil remains in the collections of MNZ and recent comparative specimens in both MNZ and NHM were used to carry out a statistical survey of the fossil assemblage. The principle aim of this survey was to compare fossils potentially referable to the putative medium-sized species to the larger *Pterodroma magentae* and smaller *P. axillaris* specimens. Morphometric comparisons were also made with recent *Pterodroma* taxa, in particular New Zealand region breeding species and also New Zealand region vagrants. Greatest element length (GL) was the principle focus of our analysis - a technique which has been applied previously to fossil *Pterodroma* assemblages to determine the likely species composition of an assemblage (e.g. Worthy & Jouventin, 1999). The fossil assemblage consisted almost entirely of material identified as three taxa by previous work-

ers: *Pterodroma magentae*, *Pterodroma axillaris* and those referred to either *Pterodroma inexpectata*, *P. > inexpectata*, *P. ?inexpectata*, *Pterodroma* sp.1 or *P. cf. inexpectata* - which we collectively refer to hereafter as *?Pterodroma* sp.1.

Using the GL data generated from the collective 'all fossil' assemblage, histograms of the frequency distribution of GL were generated for each element, including separate plots for right and left specimens, and a third including all specimens. Histograms provided a convenient means of considering the composition of the assemblage without relying on the accuracy of individual species identifications.

Key statistics for recent comparative specimens were also compiled; the same information was also produced for fossils assigned to *P. magentae*, *P. axillaris* and *?Pterodroma* sp.1.

Measurements were taken as follows, using callipers accurate to 0.1mm; greatest length of humerus (GL Hum), ulna (GL Uln), radius (GL Rad), carpometacarpus (GL Cmc), femur (GL Fem), tibiotarsus (GL Tbt) (measured from the proximal articular surface to the distal end), tarsometatarsus (GL Tmt).

Summaries of statistics from fossil and recent comparative taxa are given in Appendix 1. Appendix 2 lists recent comparative specimens used; Appendices 3 and 4 give further details on fossil *Pterodroma* specimens held by the NHM and MNZ.

All fossil *Pterodroma*

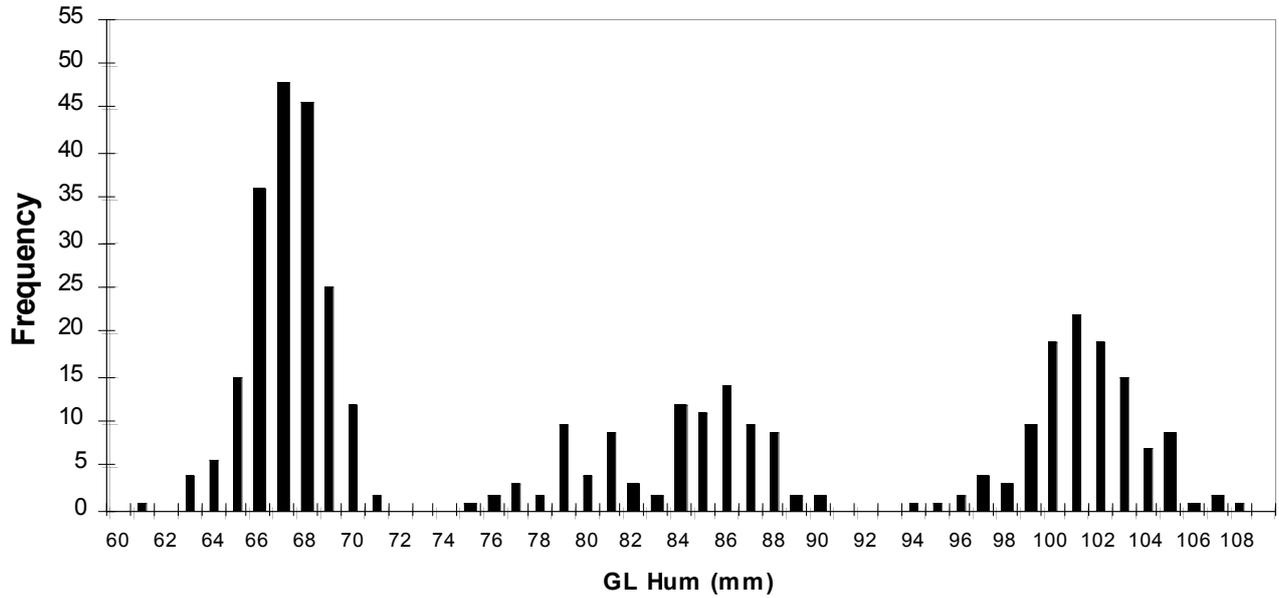


Figure 2 - Frequency distribution of 'all' *Pterodroma* GL Hum

All fossil *Pterodroma*

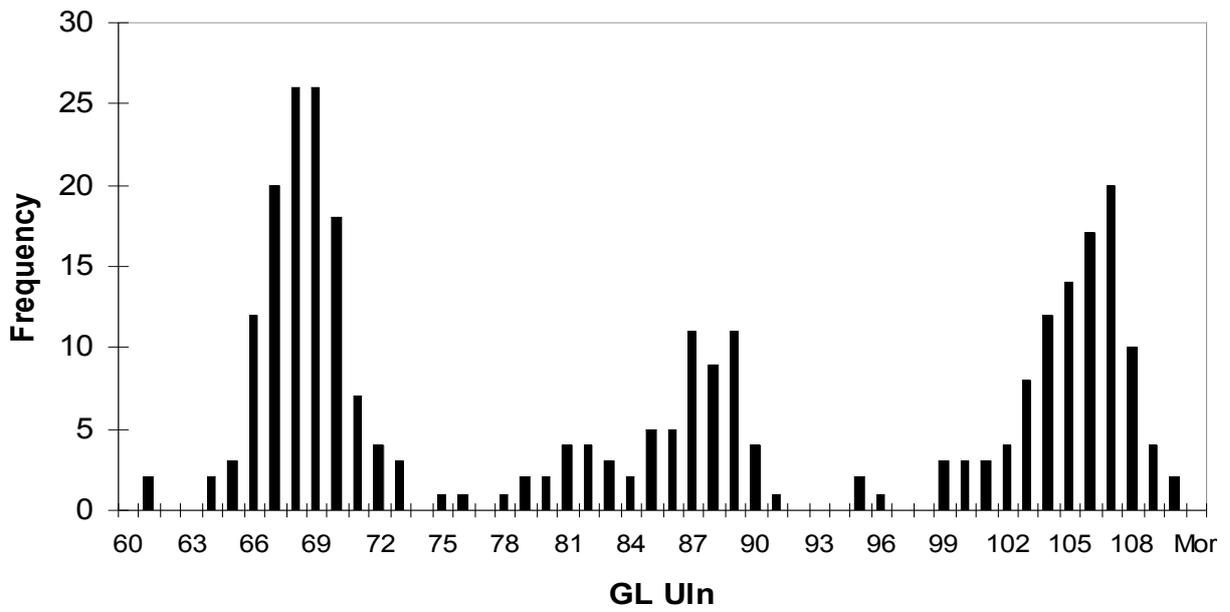


Figure 3 - Frequency distribution of 'all' *Pterodroma* GL Uln

All fossil *Pterodroma*

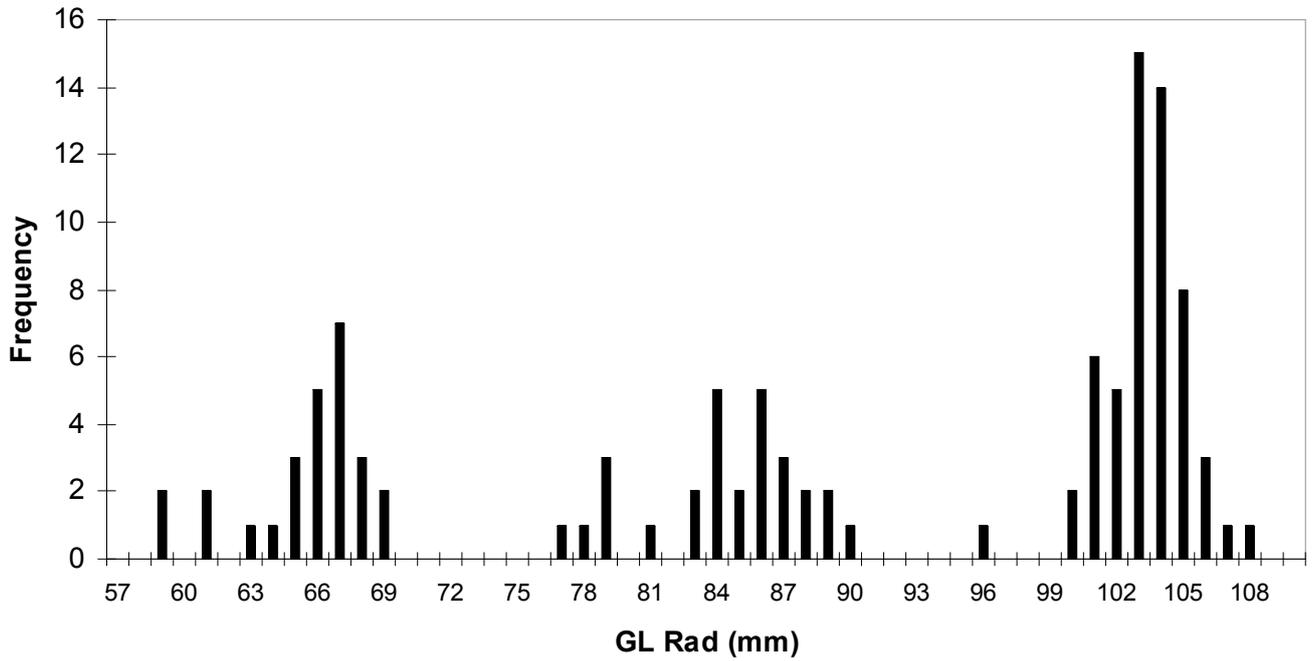


Figure 4 - Frequency distribution of 'all' *Pterodroma* GL Rad

All fossil *Pterodroma*

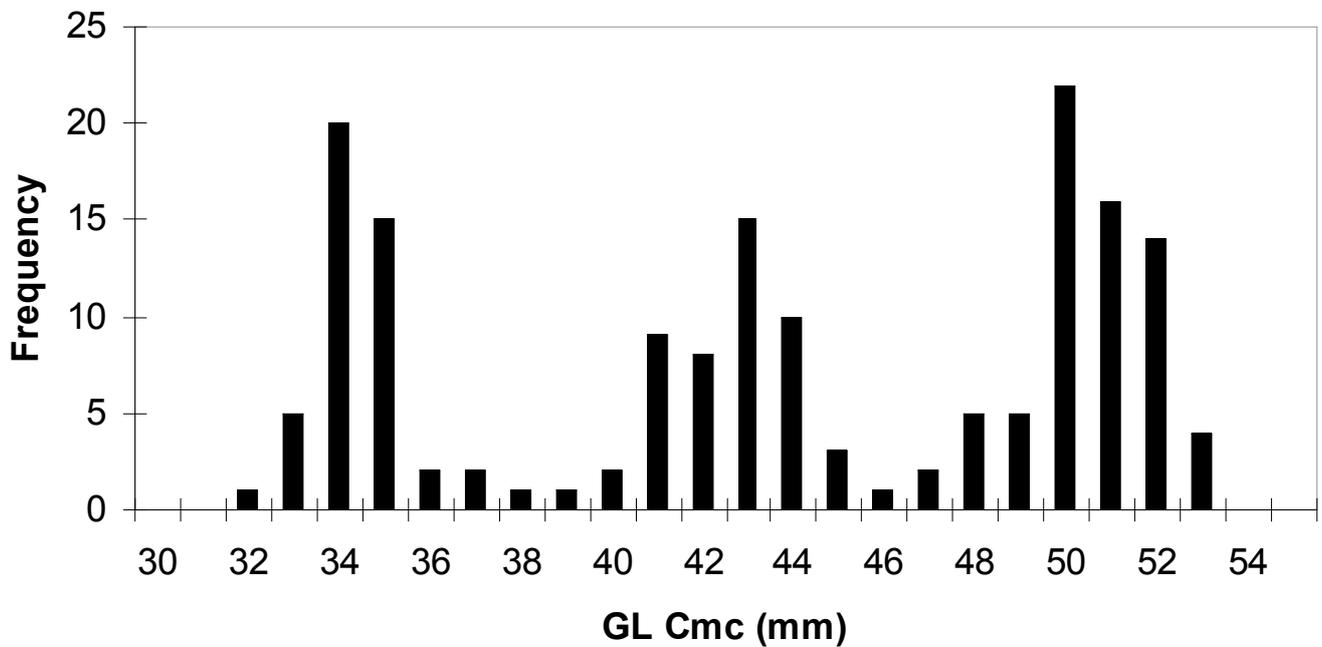


Figure 5 - Frequency distribution of 'all' *Pterodroma* GL Cmc

RESULTS

Histograms of GL from 'all fossil' humeri, ulnae, radii and carpometacarpi showed clear separation of three size categories (figs. 2 to 5). We consider that these mainly represent *P. magentae* (largest), ?*Pterodroma* sp.1 (medium) and *P. axillaris* (smallest). In all cases, similar patterns of distribution were observed in the separated right and left element histograms; consequently right and left elements were combined for analysis. Normal distributions with a slight positive skew were observed in the largest and smallest sample-groups, but the pattern of the medium-sized group was more confused. Indeed, several histograms of the medium-sized group appear to show a bimodal distribution, albeit rather indistinct (see in particular figs. 2 and 3). In these cases, more specimens fell into the upper size range. Furthermore, the coefficients of variation on wing elements from the medium-sized sample were also significantly larger than either other fossil samples, and also than most of the recent modern taxa.

Considerably different patterns were apparent in the histograms plotted for femora, tibiotarsi and tarsometatarsi (figs. 6 to 8). These showed less distinct separation into the three size groupings. Although the *P. axillaris* sample was readily distinguishable in all cases, the two larger taxa-groups apparently overlapped considerably and resulted in these elements showing a single distribution with a pronounced positive skew.

Examining the samples of identified specimens and their measurements against the histograms indicated a number of suspected misidentifications, with specimens of one taxon embedded well within the size range of another. In extreme cases, this had the effect of significantly extending the upper or lower size limits of the species concerned, suggesting overlapping size ranges where no overlaps were indicated by the histograms. Suspected misidentifications were removed from samples prior to generating the final statistics for each sample group, but were retained in the histograms.

Comparison of the maximum, minimum and mean GL measurements of the fossil taxa with modern specimens emphasized the occurrence of distinctive size-groupings within New Zealand region *Pterodroma* species (figs. 9 to 15). Forming the larger group are: *Pterodroma macroptera gouldi*, *P. lessonii*, *P. magentae*, *P. cervicalis*, *P. externa*, *P. neglecta* and *P. solandri*. In the medium group are: *Pterodroma mollis* and *P. inexpectata*, while the small group consists of: *P. nigripennis*, *P. axillaris*, *P. leucoptera caledonia*, *P. cookii* and *P. pycrofti*. The upper range of the fossil ?*Pterodroma* sp. 1 wing elements occupies a gap in the size gradient between the medium and large taxa. The three size groups are not as clear in the leg elements. It is apparent that whilst each size-group of taxa are widely separated by their wing element lengths, leg element lengths are considerably less distinctive.

DISCUSSION

Systematic list

Pterodroma leucoptera

One furcula in the NHM (BMNH A977) has been referred to this taxon by an unknown worker. At a later date, Bourne added his opinion to the label that it was from the "*Cookilaria* group, near *P. leucoptera masafuera*". The specimen appears to be entirely consistent with *P. axillaris*.

Pterodroma nigripennis

This species appeared first on Chatham Island fossil lists in Scarlett (1982), and on subsequent checklists between 1990 (Millener, 1990; Millener in OSNZ Checklist Committee, 1990) and 1999 (Millener, 1999). The lengths of fossil elements previously identified as *P. nigripennis* were compared to those of fossil and recent *P. axillaris* and recent *P. nigripennis*. These species overlap in size but *P. nigripennis* is on average larger (see Appendix 1). Our comparison showed that all of the post-cranial fossils previously identified as *P. nigripennis* fell within the size range of both modern *P. nigripennis* and *P. axillaris* (see fig. 16 for example using humeri, the most abundant fossil element identified as *P. nigripennis*). Fossil specimens previously identified as *P. nigripennis* fall into the upper size range of the *P. axillaris* fossil sample. This suggests that size was used as the primary identifying characteristic but that the range of *P. axillaris* was underestimated. Notably, both of the longest fossil humeri previously assigned to *P. nigripennis* (MNZ S.25470) and *P. axillaris* (MNZ S.31969) are the same length (fig. 16), strongly suggesting that most of the '*P. nigripennis*' material is in fact *P. axillaris*. However, the presence of *P. nigripennis* in the Chatham Islands fossil avifauna can be confirmed by a skull (MNZ S.32199), which can be distinguished from those of *P. axillaris* by its shorter premaxilla. A live *P. nigripennis* was collected at the Chatham Islands in 1900 and since 1984 small breeding colonies have been found on two of the Chatham Islands (Merton, 1984; Tennyson, 1991; Imber, 1994), making these its most southerly breeding localities (Marchant & Higgins, 1990). This probably recent colonisation by *P. nigripennis* (Holdaway et al., 2001) may result from the species moving into a vacant niche, following the near-extinction of *P. axillaris*. A similar colonisation may have occurred on Norfolk Island following the local extinction of *P. pycrofti* (Worthy & Holdaway, 2002). Although *P. nigripennis* clearly reached the Chatham Islands on a regular enough basis prehistorically to permit fossilisation of some specimens, it seems unlikely that it would have been able to establish a breeding presence prior to human arrival, given the abundant presence of *P. axillaris* as the resident small petrel. As a fossil species, *P. nigripennis* is therefore best regarded as a vagrant.

Pterodroma axillaris

Pterodroma axillaris has been listed in all Chatham Island fossil checklists. The species was described in

All fossil *Pterodroma*

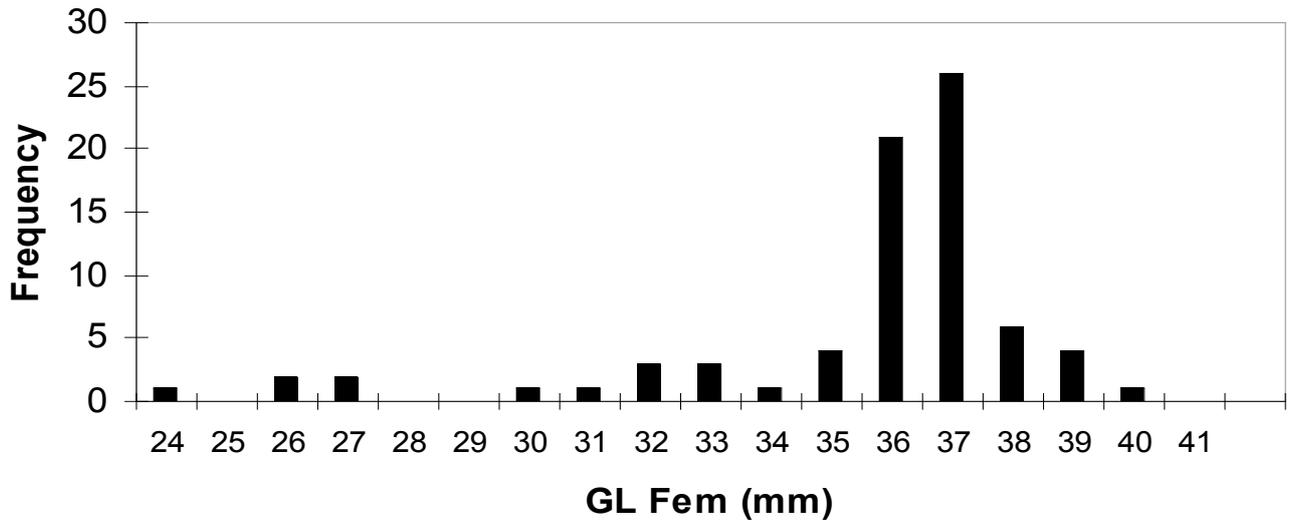


Figure 6 - Frequency distribution of 'all' *Pterodroma* GL Fem

All fossil *Pterodroma*

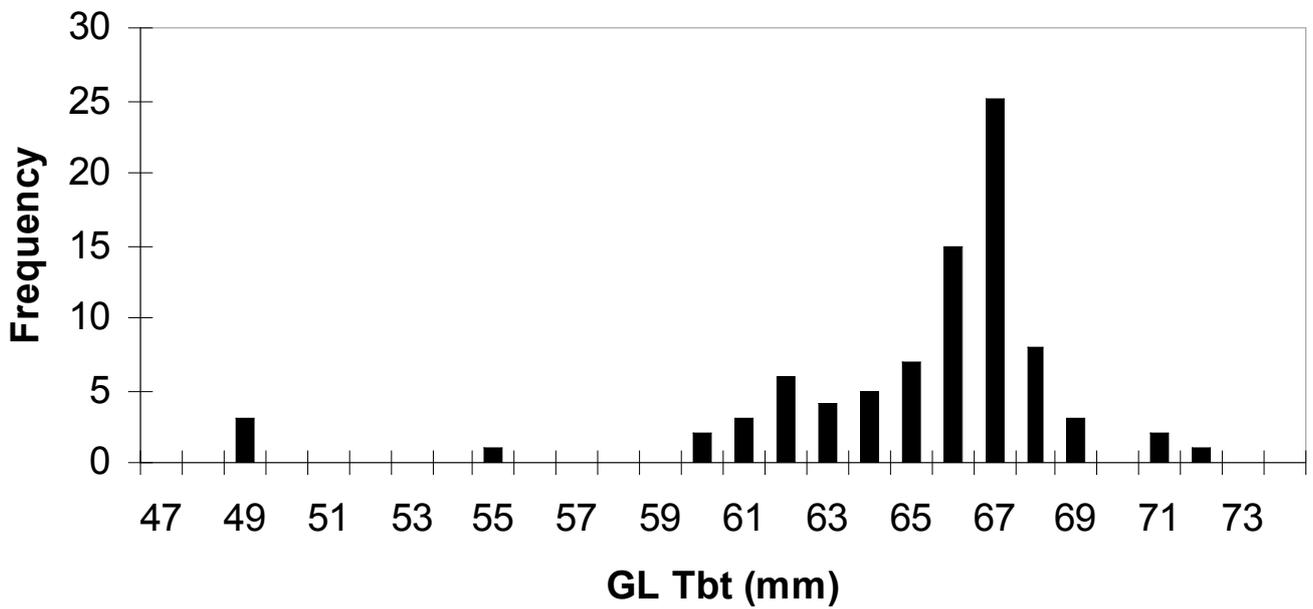


Figure 7 - Frequency distribution of 'all' *Pterodroma* GL Tbt

1892, so was a well-known part of the fauna before any of the lists were made. Its remains have been identified from main Chatham, Pitt and Mangere Islands, and clearly it was formerly abundant (Tennyson & Millener, 1994; Millener, 1999; Tennyson, 1999).

Whilst the 'all fossil' histograms for humeri, ulnae and carpometacarpi show normal distributions for *P. axillaris* material, the radii histogram displays an outlying peak of particularly small specimens, contrasting with the apparently normal distribution in the upper end of the range. On further investigation, all four outliers (MNZ S.25308, S.25001, S.31348 and S.31938) proved to be misidentified specimens of *Pachyptila vittata*, and were excluded from subsequent analyses. That such specimens can be readily noticed from the histograms demonstrates their value as a means of assessing the species composition of an assemblage. It also highlights the fact that other outlying specimens need close inspection in subsequent analyses.

No overlap occurs between *P. axillaris* and the medium-sized fossil material. A particularly small humerus noted by Bourne (1967) as a possible dwarf specimen of *P. axillaris* or undescribed taxon (BMNH A4179) can be re-assigned on the basis of its distinctive morphology to *Puffinus assimilis*.

Pterodroma inexpectata

Fleming (1939) was the first to suggest that fossils on the Chathams could be *P. inexpectata*. Bourne (1967) included possible *P. inexpectata* in his fossil list on the basis of measurements, though he had only a small sample of recent comparative specimens available. Scarlett (1982) was the first to list it as certainly being present, with subsequent appearances on checklists in 1990 and 1991 (OSNZ Checklist Committee, 1990; Millener, 1991; Meredith, 1991). However, it is not included in Millener (1999); instead *P. cf. inexpectata* is used to refer to the putative undescribed species.

Histograms from the humeri and ulnae of the so-called *?Pterodroma* sp.1 sample revealed a distinct bimodal distribution, dividing the material into two size categories. This separation was less evident in other wing elements, however these samples were considerably smaller. Size overlaps in the leg elements mask any pattern of size separation. The contrast between the bimodal distribution of the *?Pterodroma* sp. 1 sample with the normal distributions of the larger *P. magentae* and smaller *P. axillaris* material, together with the significantly larger coefficient of variation recorded for *?Pterodroma* sp.1, strongly suggests the presence of two taxa within the sample.

Comparison of the size range of humeri and ulnae of *?Pterodroma* sp.1 to those of modern *Pterodroma* taxa (figs. 9 and 10) shows an overlap with *P. inexpectata* in the lower end of the size range; and in the mid-range, an overlap with *P. mollis*. Further overlaps occur with *Lugensa brevirostris* and *Daption capense*, but both can be separated with care from *Pterodroma* on morphology. *Pterodroma mollis* is probably a recent colonist in New Zealand (Holdaway et al.,

2001), leaving *Pterodroma inexpectata* as the only New Zealand region original breeding species that compares closely with the smaller material in the *?Pterodroma* sp. 1 sample. Additionally, comparison of the frequency distribution of GL Hum in *P. inexpectata* and *?Pterodroma* sp. 1 shows a close association between the distribution of the former with the smaller peak of the latter (fig. 17), and suggests an overlap in size between the taxa included within *?Pterodroma* sp. 1. Although *P. inexpectata* appears to be the strongest candidate for the smaller taxon, further analysis is required to enable the separation of the material and confirm its identification.

Pterodroma inexpectata was formerly one of the most abundant birds on the North and South Islands of New Zealand (Worthy & Holdaway, 2002). Fleming (1939) included *P. inexpectata* in his description of the birds of the Chatham Islands, based on fossils and his interpretation of local descriptions on the presence of a large, grey-bellied petrel. Subsequently, these descriptions have been linked to *P. magentae* (Bourne, 1967). However, *P. inexpectata* does reach the Chatham Islands as a modern vagrant (Imber, 1994). Given its once huge numbers in the New Zealand region, there is a high probability of it having occurred as a regular visitor to the Chatham Islands. It may not have bred on the Chatham Islands because of the presence of a similar-sized, now extinct species.

Pterodroma externa

The tentative inclusion of *P. externa* in the Chatham Islands' fossil avifauna relies solely on identifications by Millener (1990, 1991). Only one fossil specimen has been located with a previous identification of cf. *P. externa* (MNZ S.31884, radius). It is also included as a possible species on a number of other specimens not referred to an individual species, e.g. cf. *P. externa/neglecta* (MNZ S.23945, distal humerus and MNZ S.23946, ulna). We can find no grounds on which to separate these specimens from *P. magentae*, so *P. externa* should not be considered a component of the Chatham Islands fossil record. At present, *Pterodroma externa* occurs as an irregular vagrant to the Chatham Islands (Imber et al., 1991; Imber, 1994).

Pterodroma neglecta

This species was first listed in Scarlett's (1982) Chatham Island fossil list, and was subsequently also included by Millener (1990, 1991). A tentative identification was given in Meredith (1991). Fossil specimens referred to *P. neglecta* have been found in the NHM (BMNH A997, 6 furculae), but their label has been annotated by W. R. P. Bourne with "or *P. magentae*". These specimens were identified prior to the discovery of *P. magentae* in the Chatham Islands, and Bourne's is undoubtedly the correct identification. *P. neglecta* is included as one of several possible species on additional specimens in MNZ, all of which are inseparable from *P. magentae*. If any MNZ specimens were originally referred confidently to this taxon, they appear to

All fossil *Pterodroma*

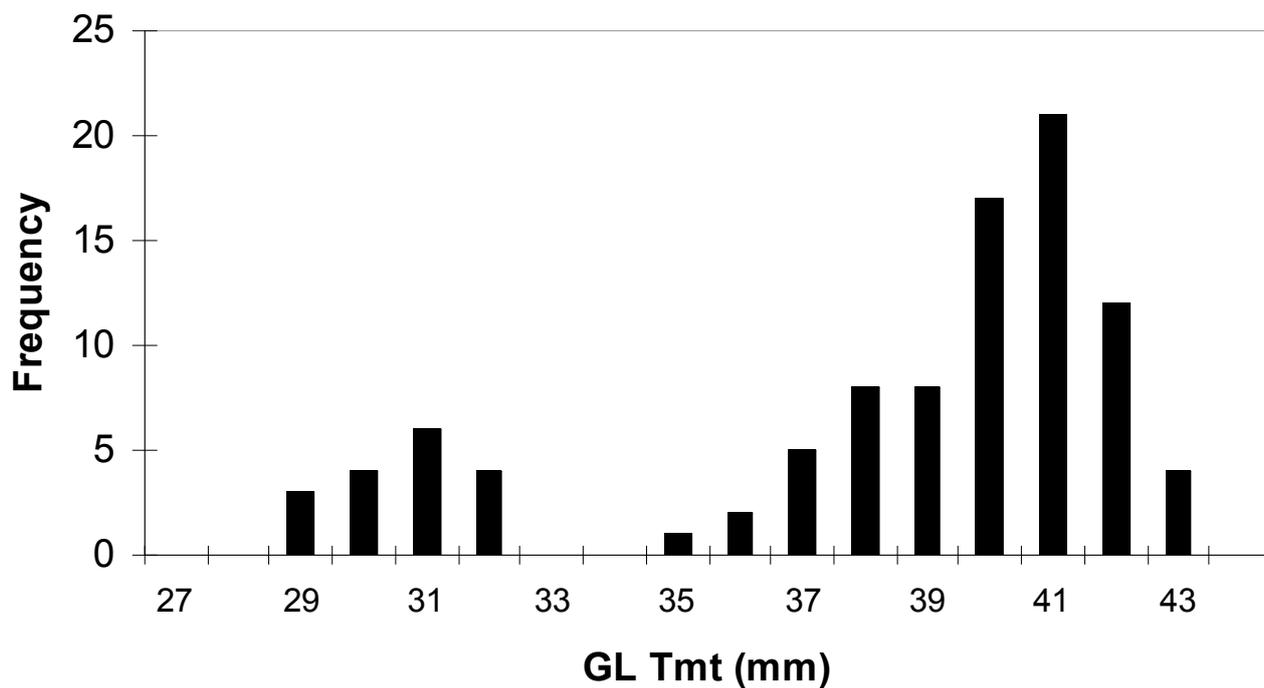


Figure 8 - Frequency distribution of 'all' *Pterodroma* GL Tmt

Range GL Hum

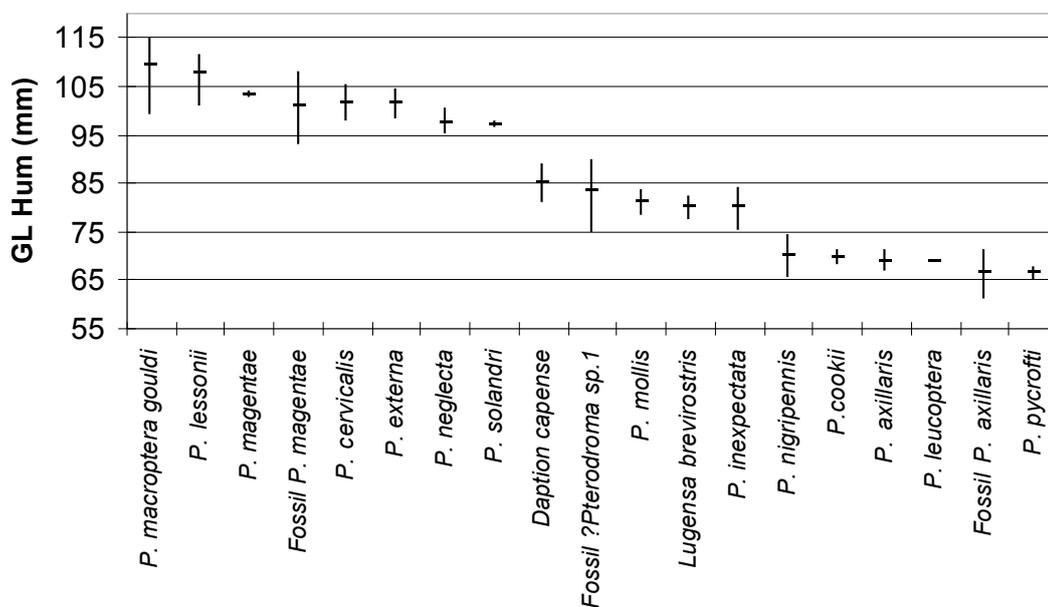


Figure 9 - Comparison of GL Hum of fossil *Pterodroma* spp. with recent taxa

have been re-identified. However, nine specimens identified by R. J. Scarlett as *P. neglecta* were located in the Canterbury Museum, New Zealand (CM). Curiously, GL measurements from the majority of these specimens appear to place them between the upper end of the ?*Pterodroma* sp.1 sample and the lower range of *P. magentae*. It is therefore not clear what taxon these specimens can be reliably referred to, but it seems unlikely that they are *P. neglecta*, being rather smaller. Two specimens (CM Av31674 and Av31268, both ulnae) fall just within the lower range of *P. neglecta*, but may be small *P. magentae*. We recommend they be referred to as *P. cf. neglecta/magentae* until further analysis can be carried out, and note that *P. neglecta* cannot yet be considered a definite component of the Chatham Island fossil avifauna.

There is only one modern record of *P. neglecta* at sea in the vicinity of the Chatham Islands (Imber, 1994).

Pterodroma macroptera

Pterodroma macroptera first appeared on Chatham Islands fossil checklists in 1990, appearing both as *P. macroptera* (Millener, 1990, 1991) and *P. m. gouldi* (OSNZ Checklist Committee, 1990) and subsequently as *P. m. gouldi* in Millener (1999). There are specimens in the NHM collections identified as *P. macroptera* by E. Dawson, in the course of his work on Henry Ogg Forbes' Chatham Island collections (see Dawson, 1958; Bourne, 1964). Significantly, these identifications were made prior to the identification of *P. magentae* as the mysterious large, Chatham Islands Taiko. Bourne later examining the same collection annotated some of the specimen labels with "similar to *Pterodroma macroptera*". However, these specimens were later on published as *P. magentae* (Bourne, 1964, 1967). Although Bourne (1967) does not list registration numbers, the total number of identified specimens present in the collection tallies with numbers given in the paper. But, as with the NHM specimens of *P. neglecta*, the specimens have not yet been re-labelled, and it remains a possibility that they have entered the literature via other researchers' investigations. All specimens currently attributed to *P. macroptera* in the NHM appear to be *P. magentae*. In the collections of MNZ, eight specimens were found identified as *P. macroptera gouldi*. The majority of these specimens could not be reasonably separated from *P. magentae*; however, one large humerus (MNZ S.25181) falls outside the range recorded for *P. magentae* and within the size overlap of *P. macroptera* and *P. lessonii*. Other specimens at MNZ and CM can be included in this overlap; see entry on *P. lessonii* below.

Two *Pterodroma macroptera gouldi* were beach-washed at the Chatham Islands in 1987 (Imber, 1994). It must be considered as a likely candidate for inclusion in the assemblages.

Pterodroma magentae

The relatively recent confirmation of *P. magentae* as the enigmatic Chatham Islands Taiko clearly had an influence on early interpretation of the archipelago's fossil *Ptero-*

droma assemblage, through the lack of a clear candidate for the very abundant remains of a large gadfly petrel. Bourne (1967) was the first to suggest that the large fossils were *P. magentae* but this and subsequent identifications could only be confirmed in 1998, when the first modern skeletal material of *P. magentae* became available (Imber et al., 1998). Its fossil remains are known from main Chatham and Pitt Islands but it has not been found on Mangere. *P. magentae* and *P. axillaris* are the most abundant *Pterodroma* species in the Chatham Islands' fossil assemblage.

The size ranges of the humeri, ulnae and radii of *P. magentae* do not appear to overlap those of ?*Pterodroma* sp. 1. However, from the GL Cmc histogram (fig. 5), there seems to be a degree of overlap between their carpometacarp; on the range graphs an extensive overlap is apparent. It would appear that as the carpometacarp from these two taxa approach each other in size, some misidentifications have occurred. Furthermore, the ranges of their femora, tibiotarsi and tarsometatarsi also show considerable overlap, with the histograms incorporating the material from both the large and medium-sized taxa into a single distribution with a pronounced positive skew. Additional morphometric and morphological analysis will be required to accurately separate both the carpometacarp and leg elements of these taxa.

Pterodroma lessonii

Fossil *P. lessonii* first appeared in Scarlett's (1982) checklist, then subsequently in Millener (1990, 1999), OSNZ Checklist Committee (1990) and Meredith (1991). No specimens referred to this taxon could be located in the NHM. Two specimens previously identified as *P. lessonii* were found in MNZ (MNZ S. 29441, ulna and femur). Both specimens have greatest lengths in excess of those recorded for *P. magentae*, and fall within the size overlap between *P. lessonii* and *P. macroptera gouldi*. Additionally, there are three further very large *Pterodroma* specimens in the collections of Canterbury Museum, New Zealand, that also fall within this overlap (CM Av9935, ulna; Av28579, ulna; Av33443, carpometacarpus). Together with the humerus formerly identified as *P. macroptera*, all these specimens require further examination to confirm their identities. Until additional information is available, we suggest they be referred to as *P. cf. lessonii/macroptera*.

Fleming (1939) recorded wrecked specimens of *P. lessonii* found on the Chathams, and noted their regular occurrence offshore. Although not listed as a Chatham vagrant by OSNZ Checklist Committee (1990), Fleming's records have been corroborated by recent observations (Imber, 1994).

Pterodroma mollis

This species is not given in any published fossil Chatham Island lists but two fossil specimens in MNZ have been tentatively compared to this taxon (MNZ S.28546 and MNZ S.23947). However, there are no reasonable grounds to distinguish these specimens from the medium-sized species

Range GL Uln

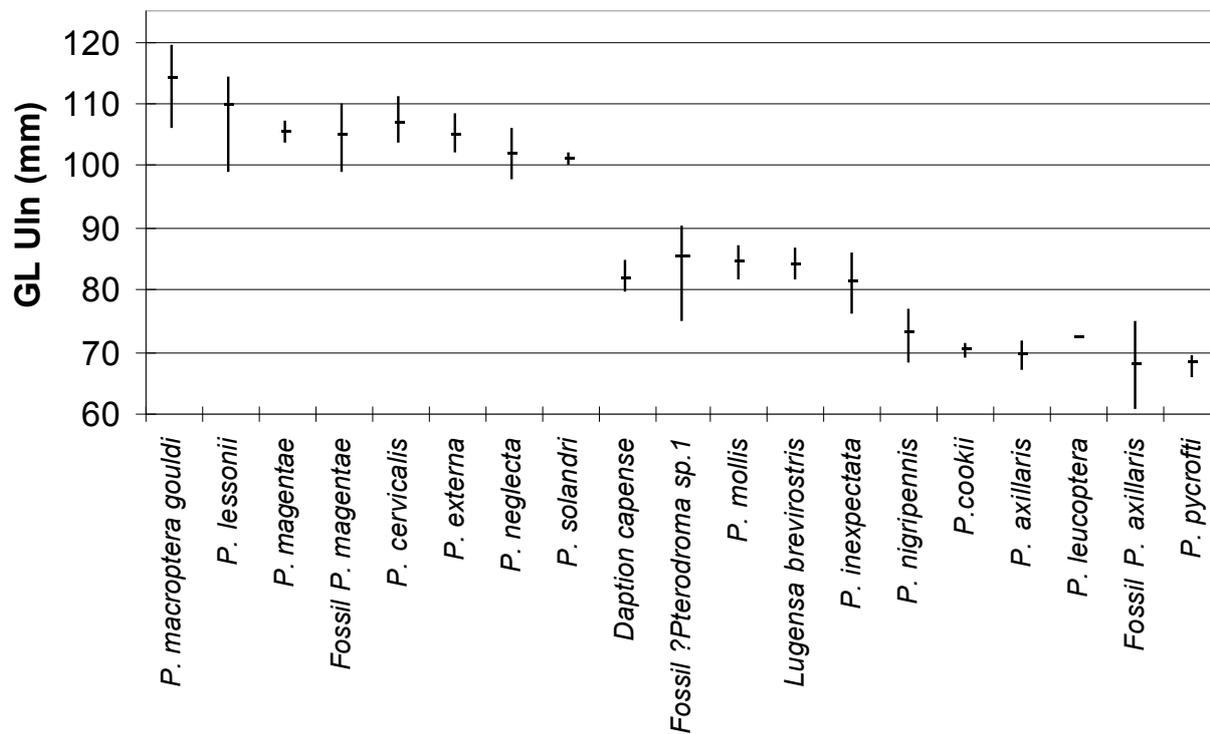


Figure 10 - Comparison of GL Uln of fossil *Pterodroma* spp. with recent taxa

Range GL Rad

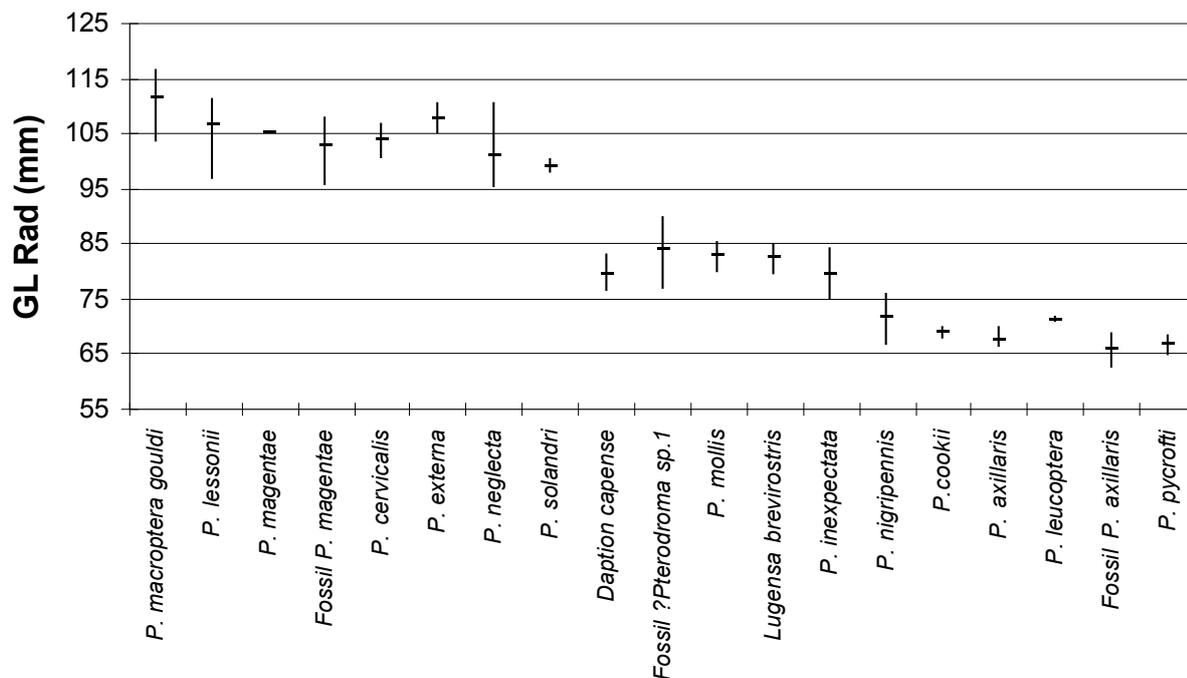


Figure 11 - Comparison of GL Rad of fossil *Pterodroma* spp. with recent taxa

taxa group, i.e. *?Pterodroma* sp. 1 or *P. inexpectata*. They therefore do not constitute reliable records of *P. mollis*.

The species is currently a rare visitor to the Chatham Islands (Imber, 1994).

Pterodroma ultima

P. ultima was tentatively listed as being in the Chatham Island fossil fauna by Millener (1990). No fossil specimens of this large gadfly petrel were located in either MNZ or NHM and the species is not even known as a vagrant within the New Zealand region (OSNZ Checklist Committee, 1990). It seems likely that material originally referred to this taxon was subsequently re-identified. There is no current evidence for its occurrence in the Chatham Islands fossil avifauna.

Pterodroma sp. 1

The possible existence of a previously unknown species of *Pterodroma* in the Chatham Islands was first suggested by Bourne (1967), with the identification in the NHM of 75 humeri somewhat smaller than *P. magentae* but apparently larger than *P. inexpectata*. No species diagnosis was attempted. Published works including Chatham Islands fossils then make little or no reference to the unidentified species until the referral of material from Mangere Island to *Pterodroma* sp.1 by Tennyson & Millener (1994). It is characterized as being 'slightly larger than *P. inexpectata*', but no additional details are given (Tennyson & Millener, 1994, p.168). Most recently, Millener (1999) designated it as *P.* cf. *inexpectata* while Worthy & Holdaway (2002) referred to it as *Pterodroma* sp., but emphasized an affinity with *P. inexpectata*. Remains of this putative taxon are now known from Chatham, Pitt and Mangere Islands.

Results of the statistical analysis of this so-called *?Pterodroma* sp. 1 sample revealed a division of the material into two size categories. As discussed, the smaller end of the sample's range most closely fits the size of *P. inexpectata*, but the remains of birds apparently larger than this taxon are more abundant. Comparison of the total size ranges of the wing elements of the *?Pterodroma* sp. 1 sample with modern taxa shows that the upper end of the range does not overlap with any modern New Zealand region species, though there are clearly some overlaps in leg elements (figs. 9 to 15).

Within the Chatham Island assemblages, there is clearly potential for confusion between *P. magentae* and the medium taxon. The histograms suggest that there should be no overlap between greatest lengths of humeri, ulnae or radii and that there may be some degree of overlap in carpometacarpus. However, measurements of a small number of ulnae and carpometacarpus identified as *?Pterodroma* sp. 1 embedded them firmly within the range of *P. magentae*. Several examples of the reverse situation were also discovered; in all cases specimens were discounted in range analyses. By contrast, considerable overlaps are apparent in all leg elements, which are echoed by the range graphs, particularly for tibiotarsi (fig.14).

From the combination of data presented in the histograms and range comparisons, it does seem that the larger material present within the *?Pterodroma* sp. 1 sample represents a medium-sized *Pterodroma* of distinctive proportions not encountered in the modern New Zealand avifauna. Therefore, from these first basic statistics, it would appear that a third *Pterodroma* was a breeding resident of the Chatham Islands. It was clearly on average larger than *P. inexpectata*, especially in wing length. However, in the lower end of its size range it overlapped with larger specimens of *P. inexpectata*. At present, material falling within this overlap cannot be accurately assigned to one taxon or another. Additional morphological analysis and more detailed morphometric analysis will be required to separate these two taxa, and also better define the osteology of *P. magentae*. Until suitable analyses can be presented, we suggest acknowledging the existence of the undescribed species by continuing to refer to it as *Pterodroma* sp.1.

Lugensa brevirostris

Lugensa brevirostris was formerly placed within the genus *Pterodroma* (Imber, 1985) and therefore it is considered in this review. The species has not been included in published Chatham Island fossil checklists but numerous specimens identified as this taxon were located amongst Chatham Island fossil material held by MNZ and CM.

Additionally, new specimens of *Lugensa* were found at MNZ amongst material previously identified as *Pterodroma*, mainly *?Pterodroma* sp. 1. From its measurements, there is clearly potential for confusion with the smaller material of the *?Pterodroma* sp. 1 sample. However, *Lugensa* was found to be morphologically distinct from *Pterodroma* in all major skeletal elements, though the differences can be subtle and consequently may not be preserved. Direct access to sufficient modern comparative material should be considered essential for identification of any Procellariidae from the Chatham Islands.

L. brevirostris is presently an irregular winter vagrant to New Zealand, but may occur in wrecks of several hundred birds and has reached the Chatham Islands (OSNZ Checklist Committee, 1990; Imber, 1994). Its fossil record appears to be consistent with vagrancy.

Daption capense

The medium-sized petrel *Daption capense* has appeared on most Chatham Island fossil checklists (Scarlett, 1982; OSNZ Checklist Committee, 1990; Millener, 1990, 1991; Meredith, 1991; Millener, 1999). Again, it can be distinguished with care from *Pterodroma*, but potential for confusion between these taxa was demonstrated by the discovery of a small number of *Daption* specimens amongst material previously identified as *?Pterodroma* sp. 1. *Daption* arguably poses a more significant problem than *Lugensa*, as its measurements indicate that it is most likely to be confused with *Pterodroma* sp. 1. This further emphasizes the importance of using comparative specimens during identification.

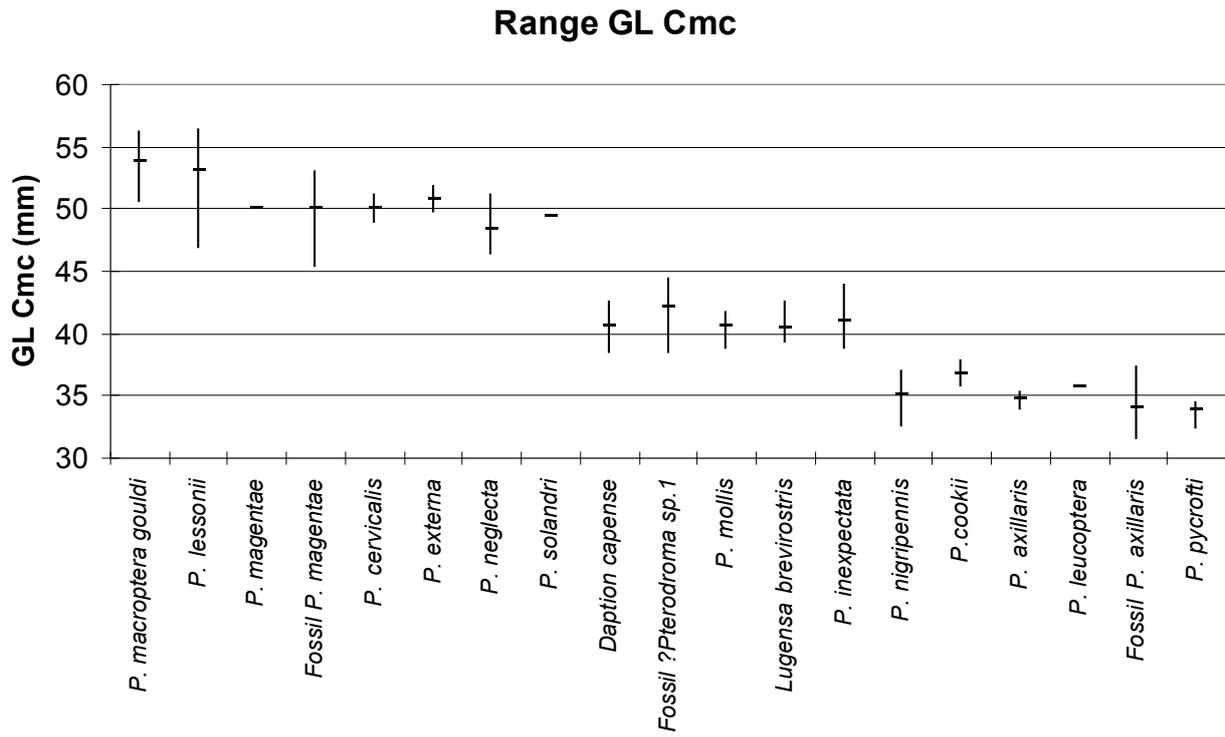


Figure 12 - Comparison of GL Cmc of fossil *Pterodroma* spp. with recent taxa

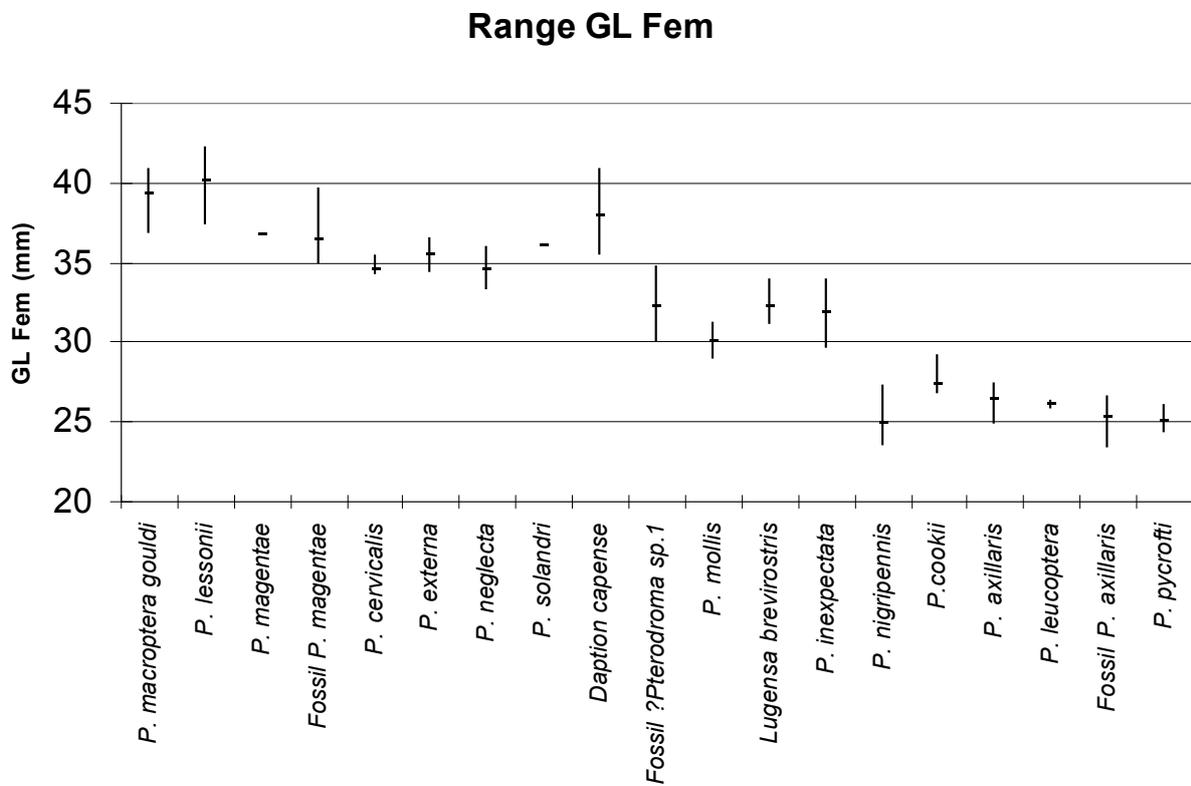


Figure 13 - Comparison of GL Fem of fossil *Pterodroma* spp. with recent taxa

Range GL Tbt

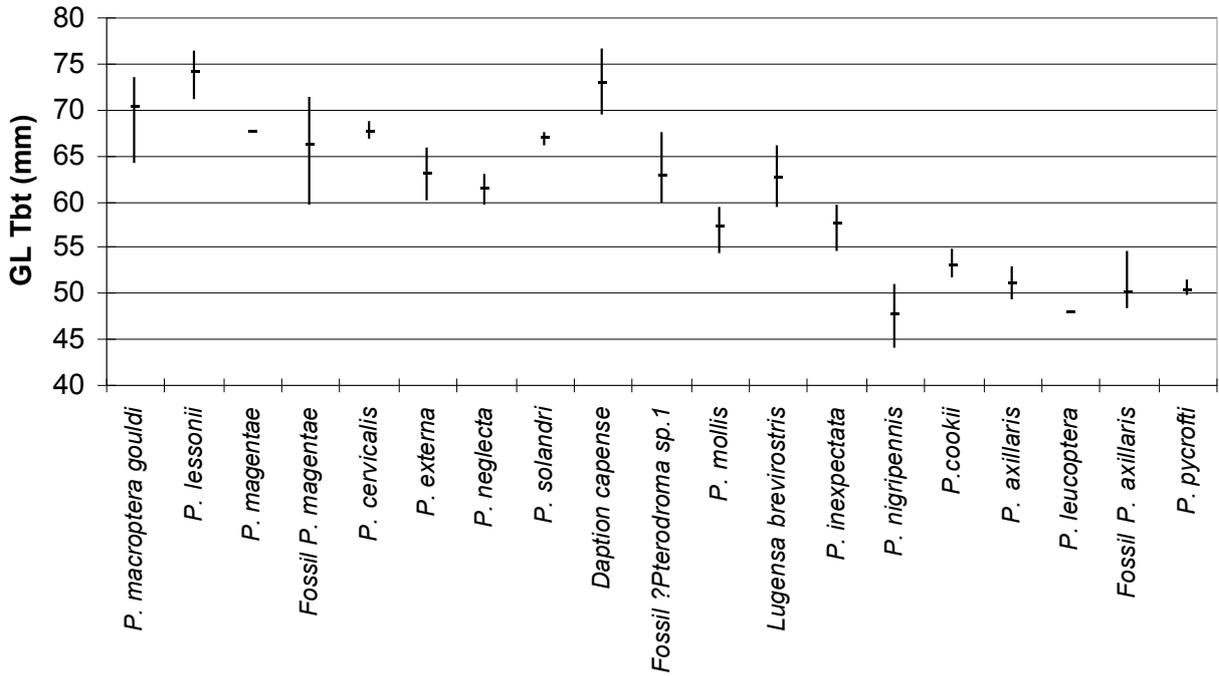


Figure 14 - Comparison of GL Tbt of fossil *Pterodroma* spp. with recent taxa

Range GL Tmt

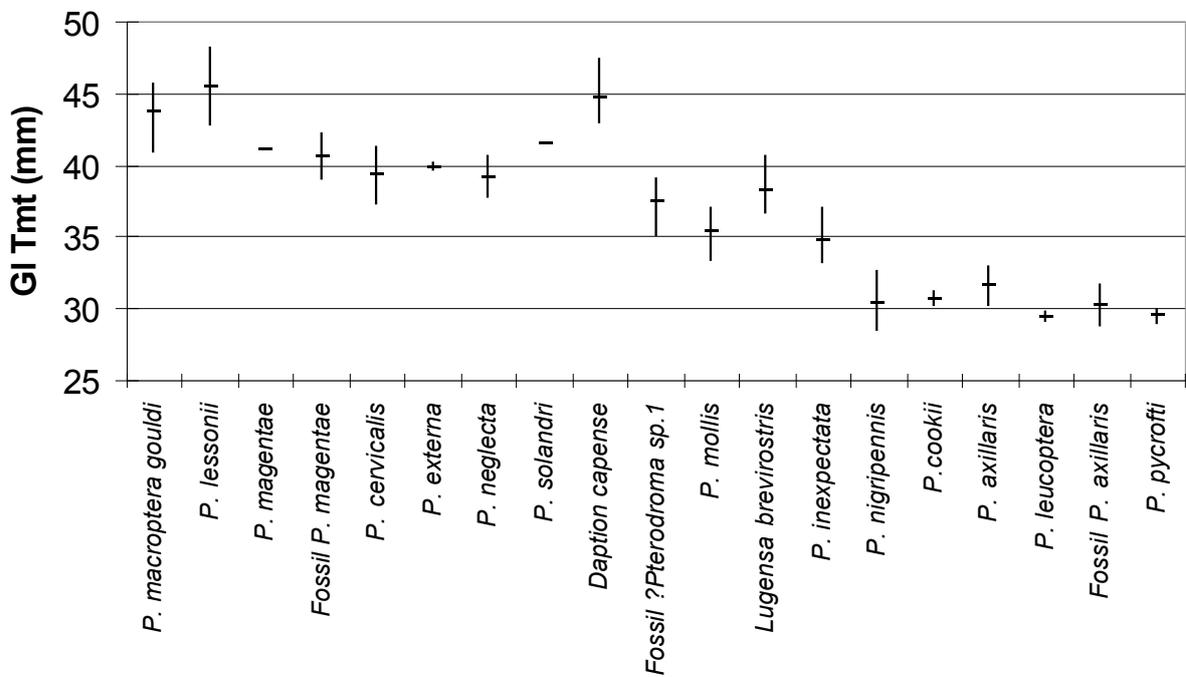


Figure 15 - Comparison of GL Tmt of fossil *Pterodroma* spp. with recent taxa

GL Humerus *P. nigripennis* vs. *P. axillaris*

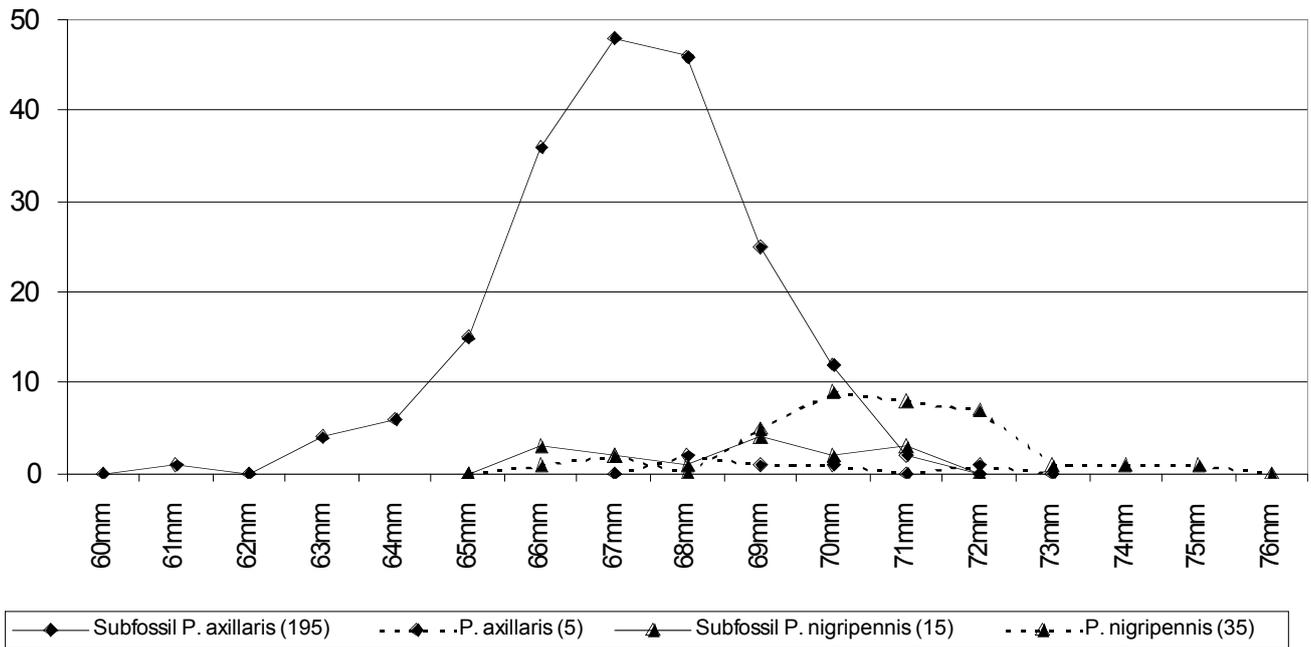


Figure 16 - Comparison of GL Hum *Pterodroma nigripennis* with *Pterodroma axillaris*

GL Humerus *P. inexpectata* vs. ?*Pterodroma* sp. 1

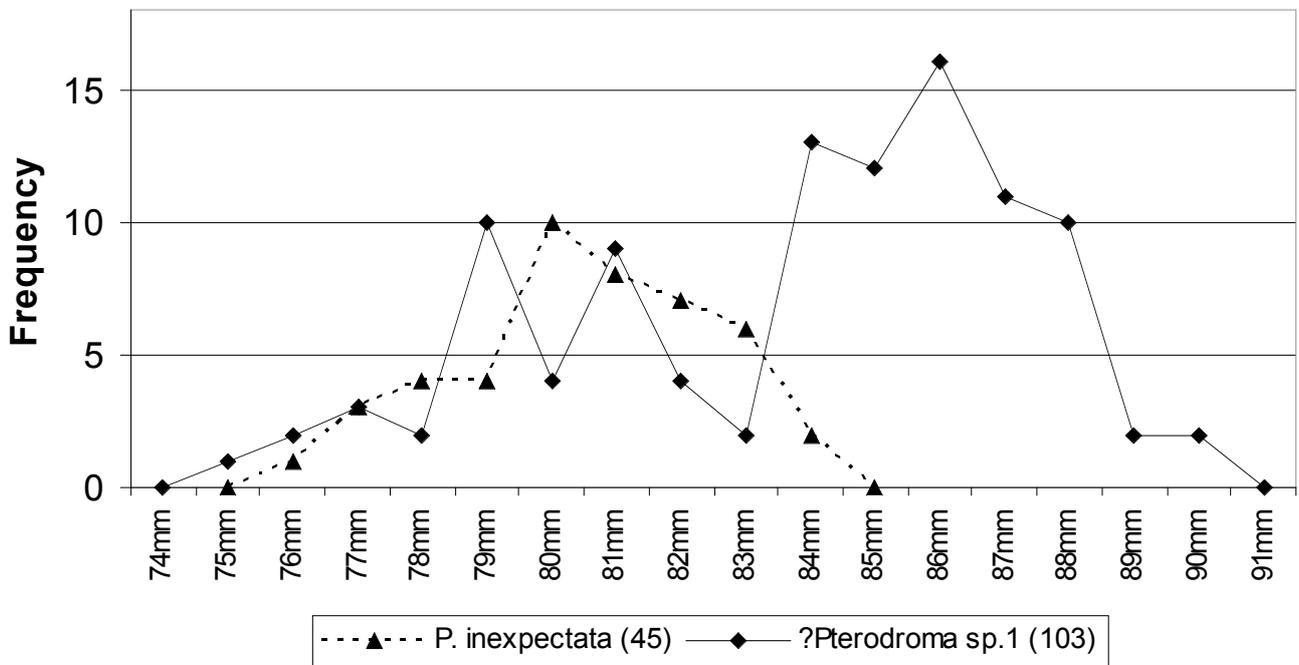


Figure 17 - Comparison of GL Hum ?*Pterodroma* sp. 1 with *Pterodroma inexpectata*

Although *Daption capense* seems to have been regularly present at sea off the Chatham Islands, it has only established breeding on some of the outlying islands within recent times (Fleming, 1939; Imber, 1994). Fossil specimens are therefore likely to represent vagrants.

CONCLUSIONS

In the course of some 40 years' research on the Holocene fossil *Pterodroma* assemblages of the Chatham Islands, the presence of a prolific number of taxa has been claimed. Few of these records have proved reliable. The inherent difficulties presented by an osteologically conservative genus are compounded by the almost total absence of associated elements within the fossil assemblage and the relative scarcity of skulls. Researchers have been hampered by the early confusions regarding the modern resident Chatham Islands *Pterodroma* species and also the restricted availability of key recent comparative specimens. Most published records of Chatham Islands' fossil *Pterodroma* species consist only of checklists, giving no details of specimens or the criteria used in their identification. This has made it extremely difficult to assess the accuracy of the taxa claimed.

Following our analysis of all previously claimed taxa, we recommend that the following taxa be recognised as having occurred as breeding residents of the Chatham Islands prior to human colonisation: *P. magentae*, *P. axillaris* and *Pterodroma* sp. 1. Additionally, we accept fossil records of *P. nigripennis* as representing vagrants. There is a high likelihood that some fossil specimens represent *P. inexpectata* but further work is required to establish whether its presence can be confirmed. Remains of *Lugensa brevirostris* and *Daption capense* also apparently represent vagrants, and their presence must be taken into account when identifying medium-sized petrels from the Chatham Islands' assemblages.

The similarity of post-cranial *Pterodroma* bones means that identification of *Pterodroma* fossil remains inevitably involves consideration of the likelihood of a given taxon's presence at the depositional locality (e.g. Worthy & Jouventin, 1999). Realistically, the inclusion of scarce vagrants within a fossil assemblage is extremely unlikely; however, it is not impossible. In extremely abundant assemblages such as the Chatham Islands' avifauna, there is a higher possibility of finding vagrants. Indeed, both *P. nigripennis* and *P. inexpectata* fossils probably represent vagrants. Although we have dismissed most of the previously claimed fossil records of vagrants, we do not rule out their inclusion within the assemblages. The majority of specimens of supposed vagrant taxa examined to date appear to represent common breeding species. However, further analysis of certain unusually sized fossil specimens may yet confirm the presence of *P. lessonii* or *P. macroptera*, and *P. neglecta*.

Only three *Pterodroma* species appear to have bred at the Chatham Islands prior to human colonization: *P. magentae*, *P. axillaris* and *Pterodroma* sp.1. The presence of

a large, medium and small species, suggests that these taxa had evolved into a size-divided guild at the island group. Furthermore, the relative abundance of each fossil taxon from Chatham, Pitt and Mangere Islands may indicate a relationship between the diversity of *Pterodroma* colonies with island size, with only Chatham Island being large enough to support abundant colonies of all three species (tabl. 2).

Despite their former abundance, *P. magentae* and *P. axillaris* persisted into modern times only in small colonies on Chatham Island and South East Island respectively (Aikman & Miskelly, 2004). Both are critically endangered, and without the intervention of intensive conservation programmes within the last 20 years, both taxa could well now be extinct (Imber et al, 1994; West, 1994). *Pterodroma* sp.1 is considered extinct but it may have survived into at least the 1890s on Mangere Island (Tennyson & Millener, 1994).

It is even possible that *Pterodroma* sp. 1 was still present on Chatham Island into the mid-1900s. Fleming (1939) included details of an enigmatic species of gadfly petrel known locally as 'taiko' in his catalogue of Chatham Island birds. Eventually, efforts to identify this mystery petrel led to the re-discovery of *P. magentae* at its breeding grounds in 1978, though a link between the 'taiko' and *P. magentae* had already been suggested on the basis of fossil evidence (Bourne, 1964; Crockett, 1994). Fleming himself initially suggested an identification of *P. inexpectata* for the 'taiko', based on local descriptions of a reasonably large petrel of a "dundy grey" colour ventrally' (Fleming 1939, p. 405). The description was later interpreted as referring to *P. magentae* (Bourne, 1967). However, *P. magentae* has a distinctive white breast and belly, not the grey underparts that led Fleming to suggest the identification of *P. inexpectata*. It therefore seems possible that Fleming's notes may refer to another scarce species of gadfly petrel, one closely approaching *P. inexpectata* in appearance; this could in fact be a reference to *Pterodroma* sp. 1. However, unlike the other endemic Chatham Island *Pterodroma* species, no live specimens appear to have ever been encountered by ornithologists. A unique *Pterodroma* specimen collected well south of the Chatham Islands in 1926 (Bourne, 1995) appears to be too large to be *Pterodroma* sp. 1.

Having now firmly established the existence of a medium-sized *Pterodroma* amongst the fossil *Pterodroma* assemblage, a more detailed morphological and morphometric analysis of it is required.

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	Bourne (1967)	Scarlett (1982)	Millener (1990)	OSNZ (1990)	Millener (1991)	Meredith (1991)	Tennyson & Millener (1994)*	Millener (1999)	Holdaway <i>et al</i> (2001)	Worthy & Holdaway (2002)
<i>P. inexpectata</i>	?	●		●	●	●				
<i>P. magentae</i>	●	●	●	●	●	?		●	●	●
<i>P. axillaris</i>	●	●	●	●	●	●	●	●	●	●
<i>P. macroptera</i>			●	● ssp. <i>gouldi</i>	●			● ssp. <i>gouldi</i>		
<i>P. lessonii</i>		●	●	●	●	●		●		
<i>P. externa</i>			?		?					
<i>P. neglecta</i>		●	●		●	?				
<i>P. ultima</i>			?		?	cf.				
<i>P. nigripennis</i>		●	●	●	●	●		●	?	
<i>Pterodroma</i> sp.	Med. - large						'Sp. 1'	cf. <i>inexpectata</i>	●	●

* Mangere Island only

Table 1 - Previous checklists including Chatham Islands fossil *Pterodroma* species.

Island	Taxon		
	<i>P. magentae</i>	<i>Pterodroma</i> sp.1	<i>P. axillaris</i>
Chatham	abundant	common	common
Pitt	very rare	common	common
Mangere	not recorded	rare	common

Table 2 - Frequency of breeding *Pterodroma* species in fossil deposits on different Chatham Islands, based on MNZ collections and Tennyson & Millener (1994).

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APPENDIX 1.

1.1 Summary of measurements of fossil Chatham Island *Pterodroma* specimens

TAXON (FOSSIL)	GL HUM <i>n</i> Min-max mean stdev CV	GL ULN <i>n</i> Min-max mean stdev CV	GL RAD <i>n</i> Min-max mean stdev CV	GL CMC <i>n</i> Min-max mean stdev CV	GL FEM <i>n</i> Min-max mean stdev CV	GL TBT <i>n</i> Min-max mean stdev CV	GL TMT <i>n</i> Min-max mean stdev CV
<i>Pterodroma magentae</i>	116 93.2-107.5 100.9 2.45 2.43%	100 99.0-109.8 104.8 2.44 2.33%	56 95.8-107.6 102.9 1.86 1.81%	68 45.4-52.9 50.1 1.39 2.79%	61 35.0-39.6 36.4 0.96 2.63%	63 59.7-71.2 66.1 1.98 2.99%	54 39.0-42.2 40.6 0.90 2.21%
? <i>Pterodroma</i> sp.1	96 74.8-89.6 83.2 3.55 4.27%	64 75.1-89.8 85.2 3.41 4.00%	28 76.9-89.6 84.1 3.45 4.11%	48 38.5-44.3 42.2 1.36 3.21%	10 30.0-34.7 32.2 1.38 4.29%	18 59.9-67.4 62.8 2.20 3.50%	23 35.0-39.0 37.4 1.04 2.79%
<i>Pterodroma 'nigripennis'</i>	15 65.5-71.0 68.3 1.68 2.46%	9 65.4-72.9 70.4 2.24 3.19%	3 66.0-68.4 66.9 1.02 1.51%	7 34.0-37.7 35.5 1.16 3.27%	0 - - - -	0 - - - -	3 29.9-31.8 30.7 0.79 2.58%
<i>Pterodroma axillaris</i>	195 61.0-71.0 66.7 1.63 2.45%	115 60.7-74.6 67.8 1.96 2.89%	22 62.7-68.5 66.1 1.44 2.18%	46 31.6-37.2 34.1 1.04 3.06%	5 23.4-26.5 25.3 1.08 4.25%	2 48.7-54.3 50.1 2.43 4.85%	17 28.7-31.6 30.2 0.87 2.93%

1.2. Summary of measurements of recent specimens of comparative taxa

TAXON (RECENT)	GL HUM <i>n</i> Min-max mean stdev CV	GL ULN <i>n</i> Min-max mean stdev CV	GL RAD <i>n</i> Min-max mean stdev CV	GL CMC <i>n</i> Min-max mean stdev CV	GL FEM <i>n</i> Min-max mean stdev CV	GL TBT <i>n</i> Min-max mean stdev CV	GL TMT <i>n</i> Min-max mean stdev CV
<i>Pterodroma pycrofti</i>	5 65.3-67.4 66.5 0.70 1.05%	5 65.9-69.2 68.1 1.20 1.76%	5 64.9-68.0 66.8 1.08 1.62%	5 32.4-34.4 33.9 0.75 2.22%	5 24.3-26.0 25.0 0.59 2.37%	5 49.8-51.2 50.4 0.55 1.09%	5 29.0-29.9 29.5 0.31 1.06%
<i>Pterodroma cookii</i>	5 68.2-70.9 69.8 0.95 1.40%	5 69.2-71.2 70.1 0.71 1.02%	5 67.9-69.8 68.8 0.67 0.97%	5 35.8-37.8 36.8 0.76 2.05%	5 26.8-29.1 27.4 0.85 3.11%	5 51.7-54.7 52.9 1.02 1.93%	4 30.2-31.1 30.7 0.36 1.09%
<i>Pterodroma leucoptera caledonica</i>	2 68.5-68.6 68.55 - -	2 72.4-72.4 72.4 - -	2 70.7-71.4 71.05 - -	2 35.7-35.7 35.7 - -	2 25.9-26.3 26.1 - -	2 47.8-47.9 47.85 - -	2 29.1-29.7 29.4 - -
<i>Pterodroma nigripennis</i>	35 65.8-74.2 70.15 1.76 2.52%	35 68.1-76.7 72.98 2.02 2.77%	36 66.7-75.6 71.62 2.01 2.81%	35 32.6-36.9 35.13 0.97 1.76%	34 23.6-27.2 24.9 0.81 2.77%	34 44.1-50.7 47.65 1.47 3.29%	33 28.4-32.6 30.4 0.93 3.10%
<i>Pterodroma axillaris</i>	5 67.1-71.1 68.74 1.53 2.24%	3 67.2-71.4 69.6 1.76 2.54%	5 66.2-69.7 67.6 1.30 1.93%	3 33.9-35.2 34.7 0.59 1.70%	5 24.9-27.3 26.42 0.84 3.19%	4 49.3-52.6 51 1.18 2.32%	3 30.2-32.9 31.6 1.10 3.50%
<i>Pterodroma inexpectata</i>	45 75.4-83.7 80.05 1.96 2.45%	42 76.3-85.7 81.12 2.14 2.64%	41 74.8-84.0 79.6 1.99 2.51%	42 38.7-43.8 41.01 1.15 2.80%	41 29.6-33.9 31.84 0.91 2.88%	37 54.5-59.5 57.37 1.22 2.14%	39 33.2-37.0 34.75 0.90 2.60%
<i>Pterodroma cervicalis</i>	7 98.0-104.8 101.6 2.02 1.99%	7 103.9- 110.8 107.0 2.02 1.88%	6 100.6-106.5 103.8 1.75 1.69%	6 48.9-51.1 50.1 0.66 1.31%	6 34.2-35.4 34.6 0.39 1.14%	5 66.8-68.6 67.5 0.63 0.93%	5 37.3-41.2 39.3 1.24 3.15%
<i>Pterodroma externa</i>	2 98.4-104.1 101.25 - -	2 102.3- 107.9 105.1 - -	2 105.2-110.5 107.8 - -	2 49.7-51.7 50.7 - -	2 34.4-36.5 35.45 - -	2 60.2-65.6 62.9 - -	2 39.6-40.1 39.85 - -
<i>Pterodroma neglecta</i>	5 95.1-100.0 97.66 1.81 1.86%	5 97.8-105.7 101.6 2.91 2.87%	5 95.2-110.5 101.1 5.46 5.40%	5 46.4-51.1 48.36 1.74 3.61%	5 33.3-35.9 34.5 0.88 2.57%	5 59.7-62.7 61.28 0.99 1.62%	5 37.8-40.6 39.22 0.95 2.43%
<i>Pterodroma solandri</i>	2 96.5-97.3 96.9 - -	2 100.3- 101.9 101.1 - -	2 98.0-100.2 99.1 - -	1 49.4 49.4 - -	1 36.1 36.1 - -	2 66.1-67.4 66.75 - -	1 41.5 41.5 - -

Appendix 1.2 (continued)

TAXON (RECENT)	GL HUM <i>n</i> Min-max mean stdev CV	GL ULN <i>n</i> Min-max mean stdev CV	GL RAD <i>n</i> Min-max mean stdev CV	GL CMC <i>n</i> Min-max mean stdev CV	GL FEM <i>n</i> Min-max mean stdev CV	GL TBT <i>n</i> Min-max mean stdev CV	GL TMT <i>n</i> Min-max mean stdev CV
<i>Pterodroma macroptera gouldi</i>	16 99.3-114.7 109.3 3.34 3.06%	16 106.1-118.9 113.95 2.77 2.43%	16 103.6-116.4 111.59 2.72 2.44%	16 50.5-56.2 53.73 1.36 2.53%	16 36.9-40.8 39.24 1.14 2.92%	16 64.3-73.4 70.22 1.94 2.77%	16 40.9-45.6 43.71 1.02 2.36
<i>Pterodroma magentae</i>	2 102.6-103.5 103.5 - -	2 103.7-106.8 105.25 - -	1 105 105 - -	1 50 50 - -	1 36.7 36.7 - -	1 67.5 67.5 - -	1 41 41 - -
<i>Pterodroma lessonii</i>	21 100.8-111.1 107.78 2.92 2.71%	20 98.9-113.9 109.44 3.46 3.17%	21 96.6-111.2 106.61 3.56 3.34%	21 46.9-56.3 53.1 2.10 3.96%	20 37.4-42.2 40.1 1.21 3.03%	20 71.1-76.1 74.05 1.59 2.15%	20 42.8-48.1 45.38 1.23 2.73%
<i>Pterodroma mollis</i>	13 78.5-83.3 81.20 1.72 2.13%	13 81.7-86.8 84.26 1.68 2.00%	13 79.9-85.1 82.67 1.75 2.13%	12 38.8-41.7 40.6 0.88 2.18%	13 29.0-31.2 30.0 0.70 2.33%	12 54.4-59.1 57.22 1.33 2.34%	13 33.4-37.0 35.41 0.97 2.77%
<i>Lugensa brevirostris</i>	23 77.7-82.0 80.22 1.32 1.65%	23 81.5-84.4 84.16 1.40 1.67%	23 79.6-84.9 82.33 1.52 1.85%	23 39.2-42.5 40.46 0.75 1.87%	23 31.2-33.8 32.21 0.66 2.07%	23 59.5-65.8 62.62 1.56 2.50%	23 36.6-40.6 38.18 1.01 2.65%
<i>Daption capense</i>	14 81.1-88.8 85.0 1.96 2.31%	16 79.8-84.6 81.8 1.67 2.03%	16 76.4-82.8 79.4 1.86 2.34%	16 38.5-42.5 40.6 1.10 2.71%	15 35.5-40.8 37.9 1.38 3.65%	16 69.5-76.5 72.8 2.11 2.89%	16 42.9-47.4 44.7 1.39 3.11%

APPENDIX 2

List of recent comparative specimens used.

Abbreviations: BMNH – the Natural History Museum, Tring; MNZ – Museum of New Zealand Te Papa Tongarewa.

Pterodroma pycrofti: MNZ 24370, 26697, 26816, 26817, 26818.

Pterodroma cookii: MNZ 23820, 24043, 24239, 26189, 26820.

Pterodroma leucoptera caledonica: MNZ 22958, 17338, 23141.

Pterodroma nigripennis: MNZ 517-S, 845-S, 11422, 12479, 12480, 13079, 13580, 13581, 13582, 13583, 13584, 13585, 13586, 13705, 13706, 13708, 15610, 15611, 15913, 15914, 16085, 16091, 16216, 16217, 16218, 18325, 18355, 18902, 19278, 23679a, 23949, 23973, 23987, 24056, 24060, 24226. BMNH 1896.7.11.3.

Pterodroma axillaris: MNZ 21543, 24551, 25103, 26699a, 26700a.

Pterodroma inexpectata: MNZ 514-S, 515-S, 621-S, 788-S, 799-S, 11156, 11952/b, 12046, 12047, 13316, 14977, 14984, 15273, 15274, 15909, 15910, 16603, 17594, 19807, 19816, 22127, 22420, 23451, 23457, 23458, 23459, 23460, 23461, 23570, 23914, 23925, 24238, 24686, 25402, 25403. BMNH S/1974.8.1, S/1974.8.2, S/1974.8.3, S/1974.8.4, S/1974.8.5, S/1974.8.6.

Pterodroma cervicalis: MNZ 22410, 22485, 22486, 23145, 23462, 23957, 23983.

Pterodroma externa: MNZ 24356. BMNH S/1983.138.1.

Pterodroma neglecta: MNZ 11423, 23034, 23720, 25216. BMNH 1896.7.11.4.

Pterodroma solandri: MNZ 23504. BMNH S/1974.12.2.

Pterodroma macroptera gouldi: MNZ 540-S, 541-S, 11146, 13597, 13598, 13605, 15903, 21101, 21103, 21419, 23714, 24073, 24076, 24248, 24369, 26374.

Pterodroma magentae: MNZ 23019a, 25209a, 26809.

Pterodroma lessoni: MNZ 500-S, 503-S, 518-S, 889-S 913-S, 12658, 12659, 13304, 13305, 13306, 13307, 14614, 14615, 14625, 15901, 23455, 23886, 25167, 25373. BMNH S/1964.14.9, S/1964.14.10, S/1964.14.11, S/1964.14.12.

Pterodroma mollis: MNZ 16183, 16583a, 21454, 22419, 22423, 22424, 25195a, 26224, 26225, 26226a, 26227a, 26228a. BMNH S/1956.11.1, S/1985.54.2.

Pterodroma ultima: MNZ 24403a.

Lugensa brevirostris: MNZ 502-S, 629-S, 802-S, 17340, 17563/2, 17582, 17583, 17584, 17585, 17586, 17587, 17588, 17589, 18103, 18324, 18416, 18908, 21105, 22071, 22403, 23150, 23157, 24555. BMNH S/1985.54.1.

Daption capense australis: MNZ 920-S, 12849, 20991, 21511, 21549.

Daption capense capense: MNZ 750, 12850, 13301, 13302, 13303, 16510, 19783, 21418, 22033.

Daption capense: MNZ 619-S, 749-S.

APPENDIX 3

List of registered fossil Chatham Islands *Pterodroma* material in the Department of Palaeontology, the Natural History Museum, London.

Reassigned identifications are given in brackets.

Pterodroma leucoptera: BMNH A977 1 furcula (*P. axillaris*).

Pterodroma axillaris: BMNH A4184 17 humeri; A4186 1 coracoid.

Pterodroma neglecta?: BMNH A997 6 furculae (*P. magentae*).

Pterodroma macroptera: BMNH A4180 42 femora

(*P. magentae*).

Pterodroma magentae: BMNH A979 2 sterna; A996 1 mandible; A1000 23 furculae; A3646 1 tibiotarsus; A3648 1 carpometacarpus; A4081 48 coracoids; A4118 250 humeri; A4173 11 skulls; A4174 10 premaxillae; A4175 1 mandible; A4182 5 sterna; A4181 2 tibiotarsi; A4188 350 humeri.

Pterodroma ?inexpectata: BMNH A979 1 sternum; A4176 8 humeri; A4177 2 coracoids; A4183 2 furculae (*Pterodroma inexpectata*/sp.1).

Pterodroma sp.: BMNH A4178 1 sternum; A4187 75 humeri.

APPENDIX 4

Misidentified fossil Chatham Island *Pterodroma* specimens in collections of Museum of New Zealand Te Papa Tongarewa and Canterbury Museum, New Zealand.

Specimens originally identified as *P. magentae*, ?*Pterodroma* sp.1, *P. axillaris* or *P. nigripennis* are not included.

Reassigned identifications are given in brackets.

Abbreviations: MNZ – Museum of New Zealand Te Papa Tongarewa; CM – Canterbury Museum.

Pterodroma cf. *externa*: MNZ S.31884, 1 radius (*P. magentae*)

Pterodroma cf. *externa/neglecta*: MNZ S.23945, 1 distal humerus (*P. magentae*); S.23946, 1 ulna (*P. magentae*).

Pterodroma externa/neglecta/macroptera: MNZ S.24220-S.24222, 3 humeri (*P. magentae*).

Pterodroma externa/neglecta/magentae: MNZ S.-4223-S.24225, 3 ulnae (*P. magentae*); S.24226, 1 carpometacarpus (*P. magentae*).

Pterodroma externa/neglecta/macroptera/magentae: MNZ S.24219, 1 coracoid (*P. magentae*).

Pterodroma neglecta: CM Av31674, 1 ulna (*P. cf. neglecta/magentae*); Av31268, 1 ulna (*P. cf. neglecta/magentae*); Av31269, 2 ulnae (*Pterodroma* sp.); Av31271, 2 humeri (*Pterodroma* sp.); Av31272, 2 humeri (*Pterodroma*

sp.); Av33420, 1 radius (*Pterodroma* sp.).

Pterodroma neglecta/macroptera/magentae: MNZ S.24227-S.24228, 2 femora (*P. magentae*).

Pterodroma macroptera gouldi: MNZ S.24916, 2 humeri (*P. magentae*); S.24916, 1 ulna (*P. magentae*); S.25181, 1 humerus (*P. cf. lessonii/macroptera*); S.25181, 1 carpometacarpus (*P. magentae*); S.25181, 1 coracoid (*P. magentae*); S.26502, 1 femur (*P. magentae*); S.26502, 1 tibiotarsus (*P. magentae*).

Pterodroma macroptera: MNZ S.26128, 1 humerus (*P. magentae*); S.26128, 1 distal humerus (*P. magentae*); S.26594, 1 humerus (*P. magentae*).

Pterodroma cf. macroptera: MNZ S. 26772, 1 ulna (*P. magentae*).

Pterodroma lessonii: MNZ S.29441, 1 ulna (*P. cf. lessonii/macroptera*); S.29441, 1 femur (*P. cf. lessonii/macroptera*). CM Av6946, 2 radii (*P. magentae*); Av11336, 1 distal humerus (*P. magentae*); Av9935, 1 ulna (*P. cf. lessonii/macroptera*); Av28579, 1 ulna (*P. magentae*); Av 28579, 1 radius (*P. magentae*); Av28579, 1 carpometacarpus (*P. magentae*); Av28579, 1 ulna (*P. cf. lessonii/macroptera*); Av33430, 1 radius (*P. magentae*); Av33443, 1 carpometacarpus (*P. cf. lessonii/macroptera*).

Pterodroma cf. lessonii: MNZ S.26056, 1 tibiotarsus (*P. cf. lessonii/macroptera*).

?*Pterodroma mollis*: MNZ S.23947, 1 distal radius (*Pterodroma inexpectata*/sp.1); S.28546, 1 ulna (*Pterodroma inexpectata*/sp.1).