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A SURVEY OF THE DISTRIBUTION, SEASONAL ACTIVITY AND ROOST SITES OF NEW ZEALAND BATS

Summary: The lesser short-tailed bat *(Mystacina t. tuberculata)* has been found in 18 locations in indigenous forest in North Island since 1961, mainly in Northland kauri forest (including Little Barrier Island), on the volcanic plateau (including Tongariro National Park), Urewera National Park and in Tararua Range. In South Island this bat has only been reported once since 1961, in North West Nelson Forest Park, and must be regarded as endangered. It is present also on Codfish Island, but is thought to have become extinct on Big South Cape and Solomon Islands about 1967.

The greater short-tailed bat *(Mystacina t. robusta)* survived in historical times only on two rat-free islands off southwest Stewart Island, Big South Cape and Solomon Islands, where it was sympatric with the lesser short-tailed bat, until the ship rat *(Rattus rattus)* irruption in the early 1960s. Classified in the Red Data Book of New Zealand in the "indeterminate" category, this bat was last positively recorded in 1965 and is now believed to be extinct on its last two known refuges.

The long-tailed bat *(Chalinolobus tuberculatus)* is widely distributed in a variety of indigenous and man-made habitats in both North and South Islands and is the only common species of bat in New Zealand. It is also found on Little Barrier Island, probably on Great Barrier Island, and is present on Kapiti Island and on the northeast corner of Stewart Island.

A major advance of this. survey over that reported by Dwyer in 1962 is that far more bat sightings and positively identified specimens are now available for analysis. This collection of distribution records now gives a clearer understanding of the distribution of the New Zealand bats than was possible in the earlier survey.

Seasonal activity, roost sites, predation and competition for food by introduced rats, and the conservation status of the bat fauna, are discussed.

Keywords: Chiroptera; New Zealand; Mystacinidae; *Mystacina tuberculata*; Vespertilionidae; *Chalinolobus tuberculatus*; distribution; seasonal activity; predation of bats; conservation status.

Introduction

The systematic mapping of the distribution of selected taxa of a country's fauna and flora has become an increasingly widely-used and valuable technique for biological resource management following the publication of the *Atlas of the British flora* by Perring and Walters (1962). The method used has been to plot the presence of a species on 10 km squares of the national grid. While most recent mapping studies of bird and mammal distribution in, for example, Britain (Corbet, 1971; Sharrock, 1976), Tasmania (Thomas, 1979) and Switzerland (Schifferli et aI., 1980) have used 10 km squares, other distribution surveys in continental areas such as Australia (Busby and Davies, 1977), North America (Robbins and Van Velzen, 1969), and Canada (Erskine, 1978) have used one-degree squares of latitude and longitude.

In New Zealand, the provisional atlas of bird distribution (Bull, Gaze and Robertson, 1978) used the 10000 yard squares of the national grid instead of 10 km squares because a complete series of metric maps for the whole of New Zealand was not then available. This study of the distribution of bats in New Zealand also uses 10000 yard squares for the same reason.

The New Zealand bat fauna

The New Zealand bat fauna comprises two genera of microchiroptera with a total of only two species which are the country's sole native terrestrial mammals: the short-tailed bat *(Mystacina tuberculata* Gray 1843) of the endemic family Mystacinidae, and the long-tailed bat *(Chalinolobus tuberculatus* Forster 1844), an endemic species belonging to the most widespread of all chiropteran families, Vespertilionidae (Fig. 1). The genus *Chalinolobus* includes five other species in Australia, Papua-New Guinea, New Caledonia and Norfolk Island (Hall and Richards, 1979), with a subgenus *Glauconycteris* of about eight species in tropical Africa (Koopman, 1971).

Simpson (1945) assigned Mystacinidae to the superfamily Vespertilionoidea, but the origin and relationship of this mono typic family to other families of bats has been debated without satisfactory resolution for over a century (see Daniel, 1979). Fleming (1975, 1979) included *Mystacina* as a member of the archaic or endemic element of the New Zealand vertebrate fauna along with ratite birds, tuatara *(Sphenodon punctatus)* and leiopelmid frogs. Recent biochemical evidence and a re-examination of morphological evidence have unequivocally placed

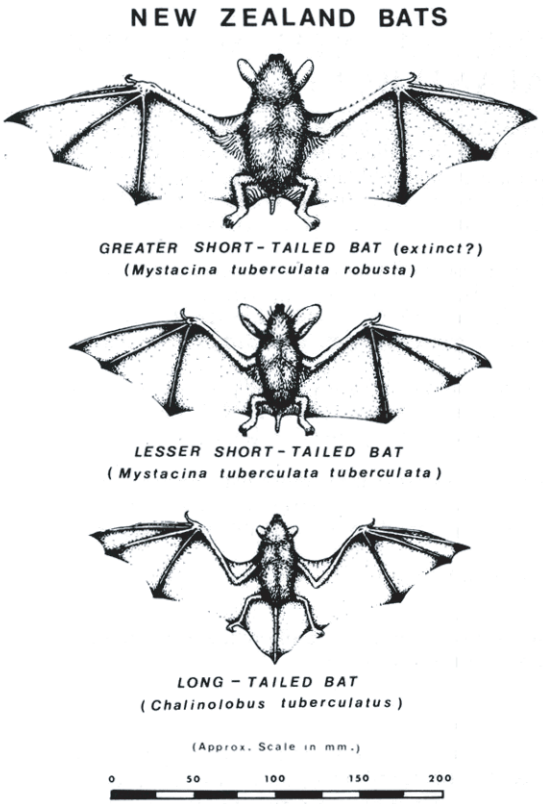

Figure 1: *The three New Zealand bats (dorsal view) showing their relative size.*

Mystacina as an early offshoot of the superfamily Phyllostomoidea, with close relationships to only the South American bat families Noctilionidae, Mormoopidae and Phyllostomidae (Pierson et aI., 1982 and unpubl.).

Two subspecies of *Mystacina tuberculata* are currently recognised (Dwyer, 1962): the lesser short-tailed bat *(M. t. tuberculata)* (Fig. 2) and the greater short-tailed bat *(M. t. robusta)* (Daniel, 1979). Recent research has shown that both races were sympatric on two islands off southwest Stewart Island until the rat irruption in the early 1960s. This fact, and the marked morphological differences between the two forms, supports the currently held view (Daniel, 1979; J. E. Hill, pers. comm.) that both are valid species and that they should be raised to full specific status. A taxonomic review of *Mystacina* is at present under way (Hill and Daniel, in press).

The three bats are small (Fig. 1); *Mystacina t. tuberculata* weighs 12-15 g, *M. t. robusta* c.30 g and *Chalinolbus tuberculatus* 8-10 g. *Mystacina* has a broad diet of ground and flying arthropods, nectar, fruits and pollen; but *Chalinolobus* is exclusively insectivorous. Bats of both genera roost mainly in hollow trees, under loose bark and in caves. Further details on the biology and ecology of the species have been given by Daniel (1976,1979, 1981), Daniel and Williams (198.1, 1983) and Dwyer (1960, 1962).

Why is the bat fauna so impoverished?

Many authors have commented on the impoverished endemic mammal fauna of New Zealand (e.g. Fleming, 1975, 1979; Stevens, 1980). Caughley (1963), in a paper discussing the probable vertebrate fauna of New Zealand, thought that at least four genera of bats instead of two would have been likely on zoogeographic principles. It is indeed surprising that apparently only the genus *Chalinolbus,* of at least 10 genera of insectivorous microchiroptera in eastern Australia, has successfully crossed the Tasman Sea to New Zealand. The New Zealand archipelago extends for some 3000 km, from the Kermadec Islands (lat. 30°S) in the north to Campbell Island (lat. 53°S) in the south, and is orientated across the main prevailing winds. It is thus likely to receive wind-blown vagrants from Australia, 1600 km to the west. The Australian element in the New Zealand avifauna is well documented (e.g. Falla, 1953, 1958; Fleming, 1962), and each year several records of Australian Lepidoptera are obtained in New Zealand (Ramsay and Ordish, 1966; Dugdale, 1969; Gibbs, 1969). Compared to the frequency of wind-blown Australian birds and Lepidoptera, however, reports of Australian bats are surprisingly few, considering that Australia has over 56 species of bats belonging to 19 genera (Hall, 1981).

At least 10 genera of insectivorous microchiroptera as well as one genus *(Pteropus)* of frugivorous megachiroptera are widespread in eastern Australia: *Chalinolobus, Miniopterus, Nycticeius, Eptesicus, Myotis, Pipistrellus, Tadarida, Rhinolophus, Taphozous,* and *Nyctophilus* (Hall and Richards, 1979). Many of these are strong fliers and undertake considerable migrations in other parts of the world. It is surprising that of this list of possible vagrants to New Zealand, only *Chalinolobus* and *Pteropus* (one record) appear to have been successful by 'sweepstake' dispersal.

Figure 2: A *lesser short-tailed bat photographed on Little Barrier Island. The characteristic stocky body shape, prominent ears, short, erect and speckled brown fur and robust left hind leg and foot, are clearly shown. The left wing is not tightly furled and protected as it is for terrestrial locomotion. (Photo: J. L. Kendrick, Wildlife Service)*

Several genera of Australian bats have, however, been wind-blown part-way across the Tasman. On Lord Howe Island c. 480 km from Australia, recent *Eptesicus sagittula,* subfossil *Nyctophilus howensis* and an unconfirmed fruit bat (probably *Pteropus)* in 1882, have been reported (McKean, 1975). A single species of bat, *Chalinolobus gouldii,* is present on Norfolk Island c. 1300 km from Australia, but *Tadarida norfolkensis* is known from only one definite island specimen, and is apparently now extinct on Norfolk Island (Troughton, 1965; Hall and Richards, 1979). *Chalinolobus gouldii, Miniopterus, Emballonura, Pteropus* and *Notopteris* (Carter, Hill and Tate, 1945) are present on New Caledonia, also c. 1300 km from Australia. The presence of *Chalinolobus* on Norfolk Island, New Caledonia and New Zealand, c. 1300, 1300 and 1600 km respectively from Australia, demonstrates that the powers of dispersal and survival of this genus of small wattled bats over wide expanses of sea are apparently greater than those genera of other similar-sized or even larger Australian microchiroptera.

It is possible that other genera of insectivorous and fruit-eating bats have, in fact, been blown across the Tasman several times in the past, but have died soon after arrival from exhaustion or cold, and hence passing unnoticed. Records of other bats in New Zealand are few and poorly documented. The large bats mentioned by Stock (1875) at Paekakariki, Wanganui and Clarence River may have been chance sightings of Australian bats or, indeed, even birds. The only documented record of an Australian bat reaching New Zealand alive in European times is that of a red fruit bat *(Pteropus scapulatus* Peters) discussed by Daniel (1975). The report of a live Australian grey-headed flying fox *(Pteropus poliocephalus)* being seen recently in New Zealand (Hand, 1984), is now known to be a mistake, resulting from confusion with Daniel's 1930s record of P. *scapulatus* (S. Hand, in litt. 3 December 1983). New Zealand museum collections of subfossil bats from caves, fissures and swamp deposits were examined to check for exotic bats. All the c.l 00 specimens found and examined to date are referable to the two forms of *Mystacina tuberculata* and to *Chalinolobus tuberculatus* (Daniel, unpubl.). However, it is possible that with the present greater awareness and interest by speleologists and the general public in reporting the presence of live bats or of small bat skeletons (compared to the more abundant moa and other avian fossil material), other live or subfossil species of bats new to New Zealand may yet be discovered.

Introduction of bats to New Zealand

Unlike Hawaii, where two species of bats (*Tadarida brasiliensis* and *Pipistrellus javanicus*) were introduced in 1895 for the biological control of insect pests of sugar cane (Tomich, 1969), there has not, to our knowledge, been any intentional introduction of exotic bats to New Zealand. However, during the height of the acclimatisation fervour last century, the importation of English bats (species not mentioned) was apparently seriously considered in New Zealand for the biological control of codling moths in orchards (Henry, 1903). The only reason given for not introducing them at that time was the fear that they might spread diseases, such as anthrax, by feeding on flies from infected livestock (Henry, 1903).

The only documented record of an accidental introduction of an exotic bat to New Zealand is of a Japanese pipistrelle *(Pipistrellus javanicus abramus)* found dead in 1981 in a package of car parts from Japan (Daniel and Yoshiyuki, 1982). A second dead exotic bat was found in July 1983 in a load of Australian hardwood timber imported by a Hamilton firm (W. Bennett, pers. comm.). This bat was identified by MJD as an adult male Australian lesser long-eared bat *(Nyctophilus geoffroyi)*. This species is widespread throughout Australia in all habitats except on Cape York Peninsula (Hall and Richards, 1979).

Previous bat surveys

Although the first distribution survey of the two species of bats was made by Mr W. Phillipps from 1945 to 1949 (unpubl. Dominion Museum file), Dwyer (1960, 1962) was the first to prepare a comprehensive review of bat distributions. He divided the data into two time periods - up to 1930, and 1931-1960 (Figs. 3,4). The main conclusions were that: (a) the range of both species had declined markedly since European settlement and these changes were correlated with an accompanying reduction in the extent of native forest; (b) sightings made up to 1930 were scattered and generally nearer coasts, towns and cities than were those made between 1931 and 1960; (c) there was no indication that the population density of either species had decreased

within unmodified native forest (although there was no firm evidence to support this); (d) the tree and alpine scrub line (c. 1000 m a.s.l.) limited altitudinal distribution; and (e) both species had failed to adapt to life in urban areas, unlike many of the bats in Europe and North America.

environmental changes he considered likely to affect the numbers and distribution of bats have continued: the area of indigenous lowland forest (below 500 m a.s.l.) has been further reduced, modification by milling or browsing by introduced animals has continued, and the exotic

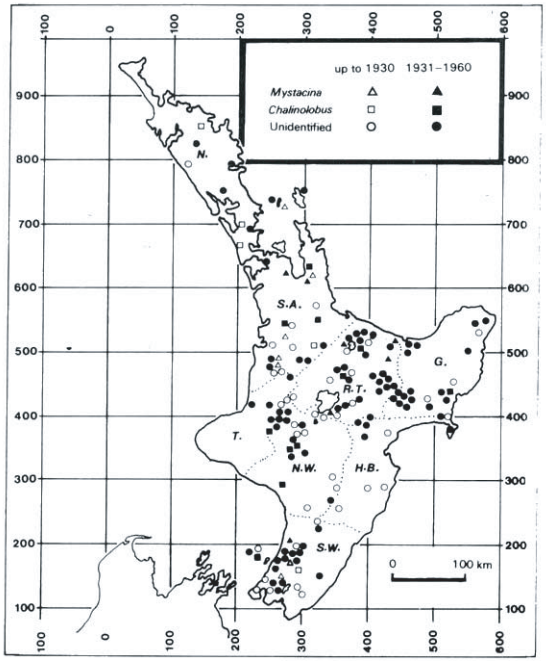

Figure 3: *North Island of New Zealand, showing distribution of bats pre-1930 and 1931-1960 (modified from Dwyer, 1962). Abbreviations: N., Northland; S.A., south Auckland; R. T., Rotorua and Taupo districts; G., Gisborne; T., Taranaki; H.B., Hawke's Bay; N. W., north Wellington; S. W., south Wellington.*

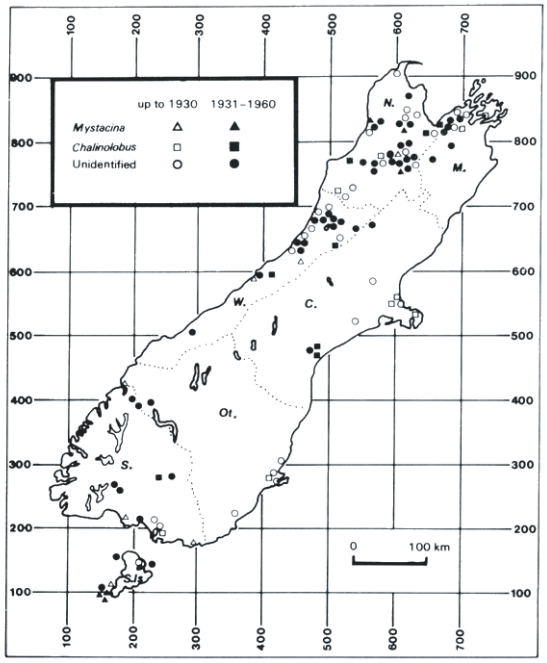

Figure 4: *South Island of New Zealand, showing distribution of bats pre-1930 and 1931-1960 (modified from Dwyer 1962). Abbreviations: M., Marlborough; N., Nelson; W., Westland; C, Canterbury; Ot., Otago; S., Southland; S.Is., Stewart Island and adjacent islands.*

As one would expect, most of Dwyer's bats were unidentified, since it is very difficult to distinguish between the species in flight. However, as most sightings were at dusk or just before, and *Mystacina* usually emerges to fly only after dark, it is likely that the majority of the unidentified animals were *Chalinolobus*. Some of Dwyer's records may have been of birds or moths. This source of error is discussed below for our records.

In the almost quarter-century between the publication of Dwyer's survey and this one, those

forests - mainly of *Pinus radiata* - have matured and more have been planted. The total land area planted in *Pinus radiata* by January 1984 reached one million hectares (located mainly in the centre of North Island).

Aims of the present study

The aims of the present investigation were to bring information on distribution up-to-date (to the end of 1983), to assess changes since 1960, to document seasonal activity and roost sites, and to collect and treat data systematically so that more

precise assessments and comparisons may be made in future.

Methods

One major change from Phillipps' and Dwyer's surveys has been the plotting of records by using the national grid and the NZMS 1 series of maps. The 100000 yard squares shown on our maps each contain one hundred 10000 yard squares (the basic unit for this survey) and of these smaller units, 1614 cover North Island, 2016 South Island and 42 Stewart Island and adjacent islands (Bull et al., 1978). Most records could be assigned with certainty not only to the appropriate square, but also to a particular area within it according to the standard six-figure grid reference system, although some records may be in error to the extent of one square in any direction.

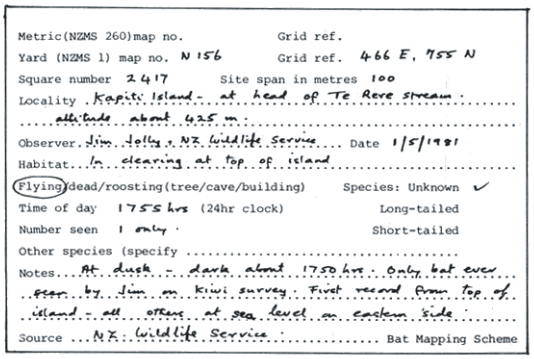
Metric(NZMS 260)map no. Grid ref.
Yard (NZMS 1) map no. N 156 Grid ref. 466 E, 755 N
Square number 2417 Site span in metres 100
Locality Kapiti Island - at head of Te Rere stream
altitude about 425 m
Observer Jim Jolly, NZ Wildlife Service Date 1/5/1981
Habitat In clearing at top of island
(Flying)/dead/roosting(tree/cave/building) Species: Unknown ✓
Time of day 1755 hrs (24hr clock) Long-tailed
Number seen 1 only Short-tailed
Other species (specify
Notes At dusk - dark about 1750 hrs. Only bat ever seen by Jim on Kiwi survey. First record from top of island - all others at sea level on eastern side
Source NZ. Wildlife Service Bat Mapping Scheme

Figure 5: *The bat distribution card designed for this survey was adapted from the card used for the New Zealand bird distribution mapping scheme (Bull et al., 1978).*

Another major change has been to design a standard record card (Fig. 5) on which first-hand, as well as second-hand, data have been recorded. The master bat record collection is held at Ecology Division, DSIR. As well as observers' reports, we have used records in scientific journals, government department files and specialised journals such as that of the New Zealand Speleological Society. We have also used television, radio, newspapers and visits to areas in which bats are known or suspected to occur to encourage public interest and cooperation. In spite of the amount of publicity given to the investigation over the last five years or so, it is still very likely that our distribution maps reflect to some extent the distribution and seasonal activities of observers rather than precisely those of the bats themselves, especially in forested and mountainous regions. Some flight records at dusk may be of birds such as fantails *(Rhipidura fuliginosa),* or welcome swallows *(Hirundo tahitica)* or even puriri moth *(Aenetus virescens).* We have no reason to suspect that such records are common. The welcome swallow would have been unlikely to have complicated Dwyer's records, as it arrived in 1958 and has become common and widespread in many parts of the country only since 1965.

To compare our maps with Dwyer's we have not plotted his data directly on to the national grid, as some of his original information is not available to us. Instead, his maps have been brought to the same scale as ours and the locality points then traced on to gridded maps. The accuracy of the transfer is probably within one 10 000 yard square in any direction and will not invalidate comparisons we have made.

Our records have been divided into three periods; (i) up to 1930, (ii) 1931 to 1960 and (iii) 1961 to 1983. This has been done to allow direct comparisons to be made with Dwyer's distribution data for his tWo periods. Subfossil records, although included in Dwyer's original maps, have not been used and will be reported separately (Daniel, unpubl.).

Reliability of identifications

Positive identifications of bats seen in flight, even with only two species to choose from, is seldom possible and flight records have been listed as unidentified. However, long-tailed bats seen in flight by experienced observers at close range and in good light conditions can occasionally be identified by the v-shaped tail membrane. When this is mentioned on the record card by an experienced observer known to us, the record is accepted. Identifications of bats found dead or held briefly in the hand before release have been accepted by us only if a full description of reliable morphological characters has been given, or a clear photograph is available, or where we could examine the specimen. All doubtful records have been included in the "unidentified" category.

Distribution of the Short-Tailed Bat

(Mystacina tuberculata)

The distribution of *Mystacina* in North Island for the three time periods is shown in Figure 6. Only 26 10000 yard squares are reliably known to be or to have been occupied by this species, of which 18 (69%) are recent records from the period 1961-1983. In Northland only one colony is known, in Omahuta kauri sanctuary, Puketi State Forest (Daniel, 1976, 1979), but further colonies are believed to be present in other parts of this large podocarp/kauri *(Agathis australis)*/ hardwood forest. Although we have no positive records from Waipoua State Forest, this species probably also occurs there. *Mystacina* is present on Little Barrier Island and may also be present in the kauri forests on Great Barrier Island, but this has not yet been confirmed. There is only one identified museum specimen of *Mystacina* from Coromandel Peninsula, from late last century, but some of the unidentified bat sightings in kauri forest on the peninsula may be of this species, although most are probably *Chalinolobus*.

The cluster of recent records on and adjacent to the volcanic plateau of central North Island, from Waitaanga State Forest, Taranaki, in the west, through Tongariro National Park, Kaimanawa Forest Park, Mamaku plateau, Urewera National Park and at East Cape, confirm that *Mystacina* is still widespread in many of the indigenous forests of this area. We have no confirmed records from Raukumara Range, but *Mystacina* probably occurs there, as the one record at East Cape was of a specimen tangled in a barbed-wire fence during a westerly storm.

One other area in North Island where *Mystacina* has not yet been positively identified but is probably present, is Pureora State Forest. There are a few records both old and recent, from T ararua Range but none from Ruahine Range to the north. The absence of any positive *Mystacina* for any time period in the forests

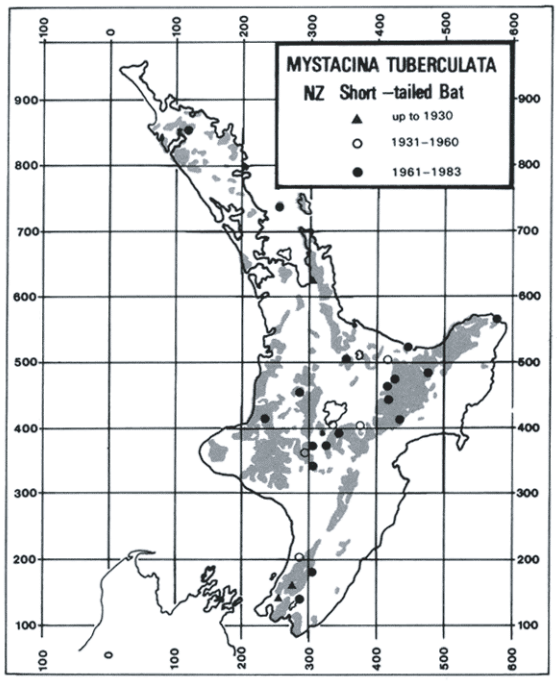

Figure 6: *The distribution of* Mystacina tuberculata *in North Island for three time periods in relation to the present distribution of lowland and montane indigenous. forest (forest distribution redrawn from Nicholls, 1980).*

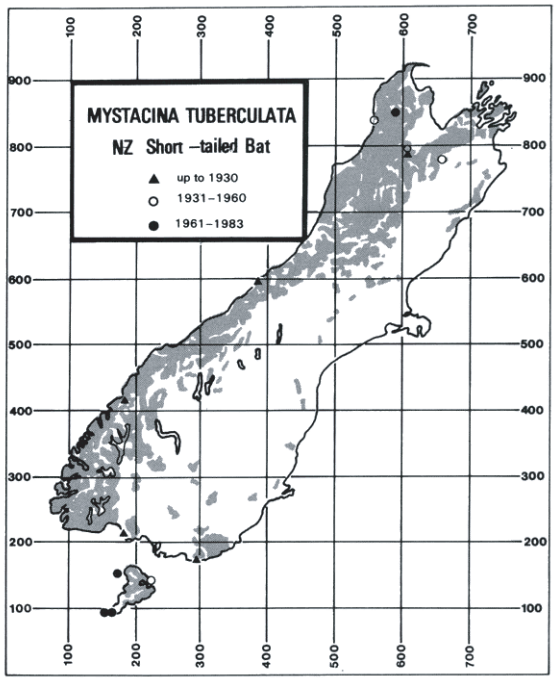

Figure 7: *The distribution of* Mystacina tuberculata *in South Island for three time periods in relation to the present distribution of lowland and montane indigenous forest (forest distribution redrawn from Nicholls, 1980).*

adjacent to Wanganui River is of interest, and may indicate that these forests are occupied solely by *Chalinolbus*.

In South Island (Fig. 7), positive records of *Mystacina* are very few and mostly from last century. The only recent record was from North-West Nelson Forest Park where a bat was found dead on a cyanide possum line, photographed and discarded. The only south Westland record was in 1895 in Okarito forest and the only Fiordland record was even older, in 1871, in Milford Sound when a few *Mystacina* were found in the furled sails of H.M.S. *Clio*. The coastal records from Southland were also last century. Because of the small number of positive records of *Mystacina* in South Island, mainly from last century, we believe that the only extant colony of lesser short-tailed bats is in the forests of northwest Nelson, with possibly another colony in or near Nelson Lakes National Park.

No positively identified specimens of either race of *Mystacina* have definitely been collected from Stewart Island. The two records of the greater short-tailed bat from Stewart Island reported by Dwyer (1962) and repeated by Daniel (1979), are now known to be in error; the specimens actually came from either Big South Cape Island or Solomon Island, the last refuges of this race until the rat irruption in the early 1960s. As we discuss below, we believe that the greater short-tailed bat may have become extinct on Stewart Island, as well as on both North and South Islands, before European settlement. The lesser short-tailed bat, present on Codfish Island and found in the 1930s and 1940s on Jacky Lee Island, was also sympatric with the greater short-tailed bat on Big South Cape and Solomon Islands until about 1965. This bat was almost certainly present at one time on Stewart Island itself, but may have succumbed shortly after European settlement by predation and competition for invertebrate food by ship rat and Norway rat *(Rattus norvegicus)* and possibly feral cats *(Felis catus)*. Unlike the greater short-tailed bat, the lesser short-tailed bat is able to survive in the presence of kiore *(Rattus exulans),* as on Codfish and Little Barrier Islands today, but may have been unable to survive in some areas, such as Stewart Island, when the other two species of rats were introduced by the early European settlers.

Both subspecies of *Mystacina* are known to have been present in several parts of North Island (to at least latitude 38°S) and in South Island until comparatively recently. Subfossil remains referable to both subspecies confirm that this was so at least within the past 3000 years (Daniel, 1979; Daniel and Williams, 1981; Dwyer, 1970). Because no live specimens are known to have been collected or reported from North Island, South Island, or from Stewart Island since European settlement, we believe that the greater short-tailed bat may have become extinct on the three main islands of New Zealand before the arrival of ship and Norway rats, feral cats and stoats *(Mustela erminea)* last century. It is possible that this bat became extinct over most of its former range before European settlement, by predation or competition for food (or both), by kiore (Daniel, 1979). This will be discussed more fully in a forthcoming paper on the distribution of subfossil New Zealand bats. (Daniel, in prep.).

A comparison of the distributions of indigenous forest and *Mystacina* (Figs. 6, 7), shows a strong relationship, particularly for North Island. Our experience of *Mystacina* over the last 10 years convinces us that this species can be described as a 'deep forest' bat, in marked contrast to *Chalinolobus* which is invariably a 'forest edge' bat. Where these two species are sympatric, as in Puketi State Forest and on Little Barrier Island and elsewhere, *Mystacina* roosts and feeds within indigenous forest, while *Chalinolobus* roosts in the forest and feeds outside along the forest edge.

The only major difference between Dwyer's distribution maps of *Mystacina* and the present survey is the greater number of recent specimens and records now available for study. We have rejected some of Dwyer's records as positive identification was not secure and we have not, as he did, plotted any subfossil records. We now have a much clearer indication as to where *Mystacina* is found and we have indicated other areas where they may survive, as in Waipoua and Pureora forests, but where positive identification is lacking. We are well aware that this forest-dwelling species is less likely to be observed and reported than is *Chalinolbus,* and that despite the increased number of records the maps may not yet reflect entirely the true extent of *Mystacina* distribution. Future surveys for *Mystacina* in areas of indigenous forest where they have not yet been reported, will be greatly assisted by the use of ultrasonic bat detectors. Preliminary findings (Daniel, unpubl.) using a QMC minidetector and a QMC model S100 detector indicate that the echolocation calls of cruising *Mystacina* can be distinguished in the field from those of *Chalinolobus*. The frequency

with maximum energy used by cruising *Mystacina* appears to be in the range of 60-65 kHz, while that of *Chalinolbus* is 40-45 kHz. Further research to test the reliability of these findings is needed.

Distribution of the Long-tailed Bat
(Chalinolbus tuberculatus)

The distribution of *Chalinolbus* in North Island (Fig. 8) and of unidentified North Island bats (Fig. 10) will be discussed together because a high proportion of the unidentified bat sightings were undoubtedly *Chalinolbus*. In North Island, *Chalinolbus* is widespread, and has been reported from a range of habitats which includes lowland and montane indigenous forest, exotic pine forest, scrubland, farm shelterbelts, farm buildings, and even the outskirts of some cities (e.g. Whangarei) and towns. In some areas, such as the forests bordering Wanganui River and in the isolated pockets of indigenous forest in Hawke's Bay, *Chalinolbus* is the only species known to be present. Because of its wide distribution and the fact that this species flies before or at dusk, it is the bat most frequently seen and reported by the public.

In South Island, *Chalinolbus* is also widely distributed (Figs. 9, 11), except for the eastern side where populations are widely scattered in the Catlins, near Geraldine and on Banks Peninsula. Except for North-West Nelson Forest Park, where *Mystacina* still survives, we believe that *Chalinolbus* is the only species of bat present over the greater part of South Island. We would have expected to find both *Chalinolbus* and *Mystacina* in the extensive indigenous forests of south Westland and Fiordland National Park, but a complete lack of positive *Mystacina* records there since last century, strongly suggests that only *Chalinolobus* may now survive there. A small population of *Chalinolobus* is present in and around Half Moon Bay on Stewart Island but there have been no other bat sightings over the rest of Stewart Island in spite of extensive searches by Wildlife Service field parties.

The only major differences between the results of this survey and that of Dwyer (1962), apart

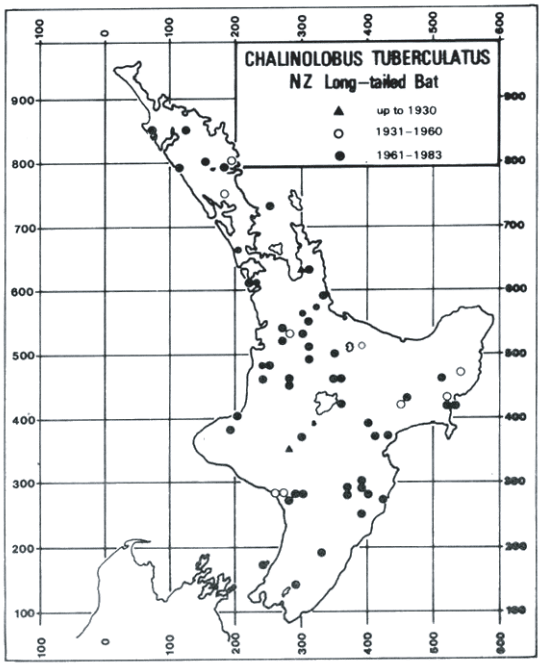

Figure 8: *The distribution of* Chalinolobus tuberculatus *in North Island for three time periods.*

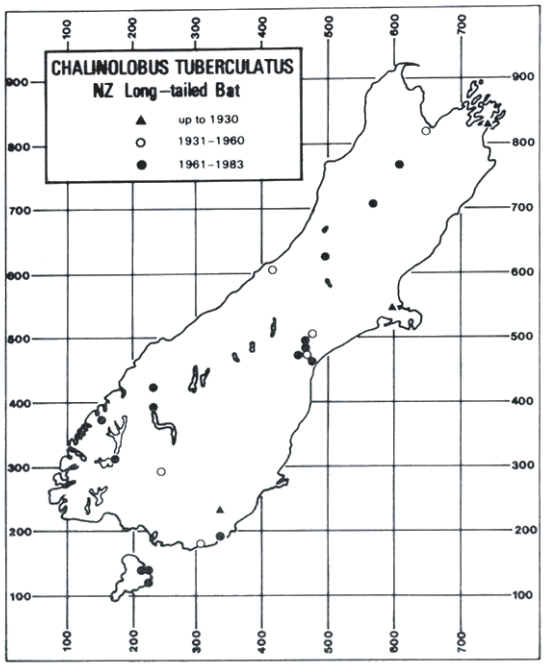

Figure 9: *The distribution of* Chalinolobus tuberculatus *in South Island and on Stewart Is/and for three time periods.*

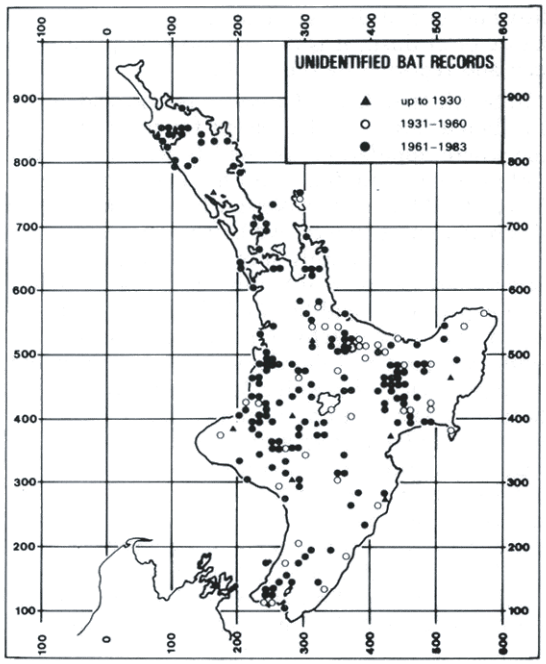

Figure 10: *The distribution of unidentified bat records in North Island for three time periods.*

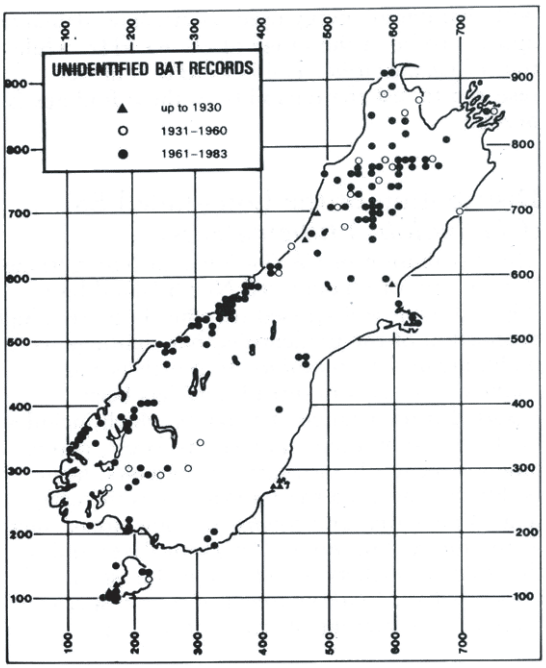

Figure 11: *The distribution of unidentified bat records in South Isand and on Stewart Isand for three time periods.*

from the greater number of bat records now available, are that *Chalinolbus* has now been confirmed on Little Barrier Island and on the north-east part of Stewart Island where Dwyer reported unidentified bats. The recent sightings on Banks Peninsula are also likely to be *Chalinolbus* and are the first bats reported there since last century.

Distribution of Bats on Offshore and Outlying Islands

Evidence of the historical presence or absence of bats and the present status of bats on islands of the New Zealand region is presented in Appendix 1.

Altitudinal Range

Many of the bat localities recorded are sufficiently precise to determine altitude. Both species will range up to the tree line during the warmer months. It is not possible to make any reliable comparisons between species or between islands or seasons. The highest altitudinal records we have are as follows: *Chalinolbus,* North Island - Lake Waikareiti c. 700 m; South Island - Waimakariri River headwaters c: 900 m. *Mystacina,* North Island - Whakapapa village, Mt Ruapehu, c. 1100 m; South Island - upper Wairau River, Marlborough, c. 450 m. Unidentified species, North Island - Mangaiti hut, Mt Ruapehu, c. 1130 m; South Island - Flora hut, Mt Arthur, c. 915 m.

All these records are below the bushline which agrees with Dwyer (1962).

Both species occur at, or near sea level. *Chalinolbus* has been reported flying low over the sea about 100 m off Kapiti Island (Daniel, 1970), and *Mystacina* has been seen (by MJD) near the lights of fishing boats anchored c.200 m off Codfish Island.

Seasonal Activity

We have 328 useable records (where sufficient information including month and year is given) of sightings of bats engaged in what were assumed

to be feeding flights, although a few may have been the result of human disturbance. Of these, 207 (63 %) were of unidentified bats, probably *Chalinolobus*. Of the 121 records involving identified bats, 79% were reported to be *Chalinolobus* and 21 % *Mystacina*. There were 207 North Island records and 121 from South Island, and of the latter only three were *Mystacina*. The data for species and for North and South Island for all years are summarised in Table 1.

Table 1 shows that the monthly distribution of *Chalinolobus* sightings, combined for both islands, was not even ($X^2 = 56.6$, $p < 0.001$), the summed May to August sightings on both islands being significantly less than expected ($X^2 = 22.68$, $p<0.001$). The South Island records for *Chalinolobus* are not significantly different in their monthly or May to August distributions from those taken in North Island. The drop in records for unidentified bats over autumn and winter was less marked and difficult to interpret. The peak period for sighting *Chalinolobus* is in summer between December and February.

Table 1: *Seasonal activity of flying* Chalinolobus, Mystacina *and unidentified bats for North and South Islands. Records for all years combined.*

	Chalinolbus		*Mystacina*		Unidentified	
	NI	SI	NI	SI	NI	SI
Month	N	N	N	N	N	N
January	16	6	2	0	14	22
February	14	2	4	1	18	18
March	2	2	1	0	13	6
April	6	4	3	1	10	3
May	2	0	0	0	4	1
June	3	2	1	1	7	4
July	2	0	0	0	2	3
August	1	0	4	0	8	5
September	3	3	2	0	12	1
October	8	5	1	0	5	6
November	7	3	2	0	2	8
December	5	0	2	0	21	14
Totals	69	27	22	3	116	91

These records suggest that although *Chalinolobus* may undergo extended hibernation for four-five months in South Island and in the colder inland areas of North Island (Dwyer, 1962), individual bats may awake from torpor and feed during favourable weather in autumn and winter. Records of *Chalinolbus* at Puketitiri, Hawke's Bay, reported by Dwyer (1962) also show that a few bats may be seen feeding during winter. *Chalinolobus* in the warmer parts of North Island, such as Northland, may not hibernate for periods longer than a few weeks at a time, as they have regularly been reported in some areas (e.g. on the edge of Puketi State Forest) in most months of the year (Daniel, unpubl.).

The records for *Mystacina* (Table 1) are difficult to interpret because of the small numbers involved. The monthly distribution of sightings of *Mystacina* was not significantly different from an even distribution nor was the May-August distribution. This is in direct contrast to that observed for the *Chalinolbus* sightings which suggests no seasonal variation in activity of *Mystacina*. Observations of *Mystacina* in Northland and on Codfish Island, and of specimens held in captivity at ambient temperatures, confirm that *Mystacina* is regularly more active during autumn and winter than *Chalinolobus* and awakes from torpor when minimum night temperatures during winter rise to about 9∞C(Daniel, 1979). It would be surprising if *Mystacina* did not take advantage of occasional mild weather in winter to feed, in view of its wide range of feeding behaviour on ground and flying arthropods and fruit and nectar (Daniel, 1976, 1979).

Roost Sites

Three main types of roost site have been reported; the majority being in hollow trees or under flaking bark, but they were also found in limestone or pumice caves and rock crevices, and in buildings or under bridges. These data are detailed in Table 2 for *Mystacina, Chalinolobus* and for unidentified bats. A wide range of tree species, both indigenous and exotic, are used by New Zealand bats. Although *Chalinolobus* has been reported from nine species of indigenous trees and from six species of exotic vegetation, including *Pinus radiata* (two records), *Mystacina* has been found only in indigenous forest, the majority of records coming from totara *(Podocarpus totara* and P. *hallii),* kauri and rimu *(Dacrydium cupressinum).*

Table 2: *Bat roost sites*

Species	Total number of reported sites N	Hollow trees or under bark N	Limestone or pumice caves or seabird burrows N	Buildings, bridges or under jetty N
Mystacina	30	18[1]	5	7
Chalinolobus	52	31[2]	12	9
Unidentified	47	26[3]	15	6

1 (a) Indigenous tree species used: kauri *(Agathis australis),* rimu *(Dacrydium cupressinum),* totara *(Podocarpus to tara* and *P. hallii),* southern rata *(Metrosideros umbellata),* southern beech *(Nothofagus* sp.)
(b) Exotic tree species used: none reported
2 (a) Indigenous tree species used: kauri, rimu, totara, kahikatea *(Dacrycarpus dacrydioides),* rata *(Metrosideros* sp.), taraire *(Beilschmiedia tarairi),* puriri *(Vitex lucens),* kanuka *(Leptospermum ericoides),* kamahi *(Weinmannia racemosa).*
(b) Exotic tree species used: eucalypt *(Eucalyptus* sp.), wattle *(Acacia* sp.), macrocarpa *(Cupressus macrocarpa),* poplar *(Populus* sp.), radiata pine *(Pinus radiata),* elm *(Ulmus* sp.).
3 (a) Indigenous tree species used: kauri, rimu, totara, kahikatea, matai *(Podocarpus spicatus),* beech, broadleaf *(Griselinia* sp.)
(b) Exotic tree species used: eucalypt, radiata pine.

We have learned by experience that deliberate searching for bat colonies in indigenous lowland forest can be a most unrewarding activity. Only on Codfish Island (1500 ha) have we been successful by systematically checking some 2000 trees, mainly totara, rimu and rata *(Metrosideros umbellata).* One of us (MJD) found 24 hollow totara that had been used by bats for varying lengths of time and two large hollow totara (about 2 km apart) each containing about 150-200 lesser short-tailed bats. In wet weather, a strong smell of ammonia from urine and guano in a large bat roost can be very noticeable at least 100 m away, but in dry, hot weather, it is possible to walk past a hollow tree containing bat~ without smelling them.

Although limestone caves are found in many parts of New Zealand, particularly in the Te Kuiti-Waitomo and north-west Nelson regions, few live or subfossil bats have been reported by speleologists (Daniel and Williams, 1983). The microclimate of most caves may not be suitable for the two species of bats either for nursery roosts or as hibernation sites. This is discussed in greater detail by Daniel and Williams (1983) in relation to a population of *Chalinolbus* in Grand Canyon cave near Te Kuiti. Live *Mystacina* have not yet been reported from limestone caves, but both M. *t. tuberculata* and M. *t. robusta* were reported from granite sea-caves on Big South Cape and Solomon Islands before the rat irruption in the early 1960s. Pumice caves and tomos are sometimes used by *Mystacina* and by *Chalinolobus* (one unconfirmed record) on the volcanic plateau of central North Island, possibly because suitable limestone caves in this area are scarce. Another unusual roost site used by *Mystacina,* but not by *Chalinolbus,* which may be unique to *Mystacina* among all Chiroptera, is in burrows made by sooty shearwater *(Puffinus griseus)* in the thick peat covering the islands west of Stewart Island. This unusual underground site is not unlike that reported for a nursery colony of lesser short-tailed bats in tunnels in rotten wood on the floor of a fallen hollow kauri by Daniel (1979).

Several records for both species were reported from buildings (Table 2). However, only *Chalinolbus* has been reported from buildings, mainly farm sheds, well away from forest (Daniel and Williams, 1981), and under bridges and under a boat jetty (one record). The few records for *Mystacina* were either from ski or tramping huts in forested mountain areas or from houses adjacent to large areas of indigenous forest, such as Mamaku village near Rotorua. In Britain, Europe and United States, many species of bats seasonally inhabit the attics of houses where high ambient temperatures are favoured for nursery roosts. We have no records, from this or Dwyer's survey, of nursery colonies of either species having been found in New Zealand buildings. The few records for both species in Table 2 are all of single torpid bats in autumn and winter (Daniel and Williams, 1981). A few records of *Chalinolbus* and of unidentified bats (probably *Chalinolbus)* have been reported from under timber road or railway bridges. The best known

record was of a colony of *Chalinolobus* under the bridges over the River Avon in Christchurch late last century. However, as Daniel and Williams (1981) commented, most of the old wooden bridges in New Zealand were replaced many years ago by concrete or steel bridges, neither of which are apparently favoured by bats as roost sites.

In New Zealand lowland forest many hollow podocarp and broadleaf trees apparently suitable for bat roosts are occupied by brush-tailed possums *(Trichosurus vulpecula)*. Little is known about the effects of disturbance to bat roosts by possums (see Daniel 1970 for discussion of bats and possums on Kapiti Island). Colonies of wild bees are also found in hollow trees and are particularly common in south Westland where many hollow rimu, matai and kahikatea trees were found by MJD to contain large colonies of wild bees. Whether or not prior occupation of suitable hollow trees by possums or wild bees is limiting the number of available roost sites for bats in areas like south Westland is not known.

Causes of Death of Bats Found Freshly Dead

We have records of 62 bats found freshly or recently dead: 36 *Chalinolobus,* 23 *Mystacina* and three unidentified. Of the 36 *ChaJinoJobus,* 10 had been killed by domestic cats, one was killed on a barbed wire fence, one hit a shed in a storm, five were killed when their tree roosts were cut down, one was shot, and two were probably killed by moreporks *(Ninox novaeseelandiae)*. Causes of death of the remaining 16 are unknown, but the majority were probably killed when their tree roosts were cut down.

Of the 23 *Mystacina,* six had been killed by domestic cats, one *M. t. robusta* was killed by a dog on Solomon Island in 1961, two were caught on barbed-wire in strong winds and one by hitting a television aerial in a storm. One was found dead, presumably poisoned, on a cyanide bait laid for possums, one was shot by a duck hunter, one died by falling into a bath of hot printer's metal (see Daniel and Williams 1981), one was killed by a morepork, at least three were killed when their kauri roost was blown down in a storm, and two were found dead locked together by claws and wings on Little Barrier Island. The causes of death of the other four bats are unknown.

Of the three unidentified bats, one had been shot by a duck hunter, the other two died of unknown causes.

Thus, of the 40 bats for which causes of death are known or postulated, 40% were killed by cats, 3% by dogs, 13% died in storms, at least 13% were killed when tree roosts were cut down in forestry operations, 5% were shot by duck hunters, 5% were killed by moreporks and 3% was poisoned by a cyanide possum bait.

The high proportion of deaths attributable to domestic cats may partly reflect the greater chances of such kills being found, as most cats left the un-chewed bodies in conspicuous places near houses, or even carried them inside. One cat near Geraldine killed three *Chalinolobus* (two adult females and one juvenile); the bats were apparently feeding on night-flying insects attracted to an outside light (Daniel and Williams, 1981).

The surprisingly high number of both species of bats killed by domestic cats in this study is cause for concern, because it suggests that feral cats, which are widely distributed on the three main islands and on many off-shore islands (Collins and Charleston, 1979; Fitzgerald and Karl, 1979), may be a significant cause of mortality, particularly near accessible roosts. The higher proportion of *Chalinolobus* killed by domestic cats - 50%, compared to 32% for *Mystacina* - may indicate that *Chalinolobus* is more frequently attracted to moths near lighted buildings than is *Mystacina*. In indigenous forest, however, *Mystacina* would be much more vulnerable to predation because of its unique terrestrial behaviour (Daniel, 1979).

Predation of bats by other introduced mammalian predators such as stoats, ship rats and kiore must certainly occur, but we have little evidence to quantify this. Both greater and lesser short-tailed bats were present on Big South Cape and Solomon Islands before and during the ship rat irruption in the early 1960s (Atkinson and Bell, 1973; Bell, 1978, Daniel, pers. obs.), but they have not been seen there since 1965. Whether their apparent extinction on these islands, the last localities known for the greater short-tailed bat, was due to predation, to competition for food, or to disturbance of nursery roosts by ship rats is not known. It is well known that island populations of landbirds and mammals are particularly prone to extinction, their comparatively small population size making them more vulnerable to predation pressures and other changes which affect their ecology. Ship rats are

also believed to have exterminated two species of bats, the endemic *Nyctophilus howensis* and *Eptesicus pumilus,* on Lord Howe Island early this century after a ship wreck in 1918 (McKean, 1975).

Ship rats have frequently been seen both during the day and at night inside the two hollow fallen kauri trees in Omahuta kauri sanctuary when the trees were occupied by a nursery colony of about 300 lesser short-tailed bats (Daniel, 1976, 1979). Since 1975, about 40 bat skeletons have been found inside these two trees, and of these, 29 (72 %) had a hole chewed in the back of the skull and the brains removed, presumably by ship rats. We do not know whether this is hard evidence of predation by rats or merely the result of scavenging by the rats on bats which had died of natural causes (such as cold or starvation) inside the two tree roosts. Stoats have also been seen within 20 m of this nursery colony, but we have no evidence that they have preyed on the bats; they may just have been attracted by the smell of the guano or the noise of the bats.

Although only one bat, a *Mystacina,* has been reported dead on a cyanide bait line laid for possums (near Roaring Lion River, Karamea, in April 1977), there is a strong possibility that many others of this endangered species may have been poisoned, but not reported, over the last 20 years or so. *Mystacina,* unlike *Chalinolobus,* is at grave risk from cyanide possum baits (many of which are fruit-lured to attract wary possums), because of its unique terrestrial feeding behaviour and because it feeds on fruit and nectar as well as flying and ground arthropods (Daniel, 1976, 1979).

Conservation Status

Both species of New Zealand bats are protected by the Wildlife Act 1953, as are other members of the endemic vertebrate and invertebrate fauna. However, continued clearing of lowland forest habitat for conversion to exotic pine forests and to farmland, predation by feral cats, stoats and ship rats, poisoning by cyanide possum baits, and human interference and disturbance to long-established nursery roosts and hibernation sites, are difficult to prevent or to legislate against.

The status of the long-tailed bat is secure, as this species is widespread in both North and South Islands, on Little Barrier Island, probably on Great Barrier Island, on Kapiti Island, and on Stewart Island, in a variety of habitats, including indigenous and exotic forests, farm shelter belts and reserves.

The status of the lesser short-tailed bat was classified as 'vulnerable' in the *Red data book of New Zealand* by Williams and Given (1981). Although this bat has been found in North Island in 18 lowland and montane forest sites since 1961, we believe that these few records may derive from only about 10 individual colonies which are still at risk from the factors already discussed. We consider that in North Island this bat may well move from the 'vulnerable' into the 'endangered' category within the next decade.

In South Island the status of this bat gives greater cause for concern. It has only been reported once since 1961 (on a cyanide possum line), in north-west Nelson, and we consider that the 'endangered' category should be used for the South Island population of this bat.

On Stewart Islanrl this bat has apparently been extinct since before European settlement, and on the Stewart Island off-shore islands it survives now only on Codfish Island in the presence of kiore and possums. On Jacky Lee Island, Solomon Island and Big South Cape Island, it must now be regarded as extinct.

The greater short-tailed bat was placed in the 'indeterminate' category by Williams and Given (1981) because little was known about it at that time. We believe that this bat was extinct on North, South and Stewart Islands before European settlement. It has not been seen on Big South Cape or Solomon Islands (its last two sanctuaries), or elsewhere, since 1965. Recent expeditions (by MJD) to the three long-established bat caves on these two islands have confirmed that ship rats are present in the caves and that none of the caves has been used by bats for a long time; we therefore regretfully conclude that this bat is now extinct. If, however, one small colony still manages to survive undetected either on Big South Cape Island (in the presence of ship rats) or on the adjacent very rugged coastline of southwestern Stewart Island (in the presence of feral cats, ship and Norway rats, and kiore), their chances of continued survival are very low indeed, and the category 'highly endangered' would have to be applied to them.

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Appendix 1: *The historical presence or absence of bats and the present status of bats on offshore and outlying islands of the New Zealand region.*

Kermadec Islands	No bats reported (Cheeseman, 1888)
Three Kings Islands	No bats reported
Poor Knights Islands	No bats reported
Little Barrier Island	Both *Chalinolobus* and *Mystacina* present (MJD)
Great Barrier Island	Unidentified bats, probably *Chalinolobus*. *Mystacina* may be present in the kauri forest
Tiritiri Matangi Island	Unidentified bat seen in cave (J.L. Craig, pers. comm.)
Mayor Island	No bats reported
Kapiti Island	Only *Chalinolobus* present (Daniel, 1970)
Chatham Islands	No live bats reported (Travers, 1868) or subfossil remains recovered (R.J. Scarlett, pers. comm.)
Stewart Island	Only *Chalinolobus* confirmed around Half Moon Bay. No confirmed *Mystacina* reported since European settlement
Islands east of Stewart Island	
Jacky Lee Island	*Mystacina* reported in 1930s and 1940s (Stead, 1936; Wilson, 1959), none seen since. May be present on nearby Motunui Island
Ruapuke Island	No bats reported
Ulva Island	No bats reported
Bench Island	No bats reported
Pearl Island	No bats reported
Anchorage Island	No bats reported
Noble Island	No bats reported
Islands west of Stewart Island	
Codfish Island	*Mystacina t. tuberculata* present. No records of *Mystacina t. robusta.*
Kundy Island	Unidentified bats (probably *Mystacina*) reported in a cave in 1920s by Guthrie-Smith (Stead, 1936). Other bats seen up to 1940s, none since then.
Big Stage Island	No Maori history of regular bat sightings. One possible unidentified bat seen c. 1950s and one c. 1976
Kaimohu Island	No Maori history of regular bat sightings. Unidentified bats (probably *Mystacina*) in cave in 1930s, none seen since then.
Solomon Island; Pukeweka and Big South Cape Islands	Regular bat sightings reported from about 1912 by Guthrie-Smith, Stead (1936), Wilson (1959) and Maori birders. Both races of *Mystacina* sympatric on these islands until about 1965. One possible bat reported in 1971, only bat seen from 1967 to 1984.
Poutama Island	No Maori history of bat sightings
Big and Little Moggy Islands	No bats reported
Putauhina Island	No bats reported
Pohowaitai and Tamaitemioka Islands	No bats reported
Snares Islands	No bats reported
Subantarctic islands (Aucklands, Campbell, Antipodes and Bounty)	No bats reported