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CHANGES IN THE GREY-FACED PETREL POPULATION ON MOUTOHORA (WHALE ISLAND) (1982-1991)

by

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CONTENTS

CHANGES IN THE GREY-FACED PETREL (Pterodroma macroptera gouldi) POPULATION ON MOUTOHORA (WHALE ISLAND) (1982-1991)

by

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ABSTRACT

A formerly exploited breeding population of Grey-faced petrel (*Pterodroma macroptera gouldi*) on Moutohora has undergone substantial changes in its breeding performance. These changes have been monitored since 1968. The techniques and the results of the monitoring are discussed. The measurement of population trends showed the dramatic and immediate rise in chick production after rat control. Chick production is expected to settle into a steady upward trend with fluctuations caused by weather, availability of food and variations in recruitment of breeding birds produced during the rat plagued era but any such recovery cannot be expected to begin until 1993-94.

1.INTRODUCTION

The purpose of this report is to bring together anecdotal and researched information relevant to the management of Grey-faced petrels on Moutohora, as outlined in the Moutohora draft management plan second draft for public submissions section 2.2.10.1.

A steady decline in the petrel population on Moutohora was officially acknowledged in 1962. At this time the island was a privately owned, largely grass- and sedge-covered island infested with goats, rats and, shortly after, rabbits. Goats were finally eradicated in the mid 1970s, rabbits in 1986 and rats by 1987. Now the island is a crown reserve covered mostly in kanuka, mahoe and pohutukawa. After periods of control, the rabbits, rats and goats have all been completely eradicated.

The changes that have taken place on Moutohora in the last 30 years have been dramatic in their potential to affect the breeding population of Grey-faced petrels. Some, such as changes in, and then the eradication of, the rat population, have shown quick effects. Others, such as the eradication of goats and rabbits, are having a more unpredictable, long term and indirect effect through changes in vegetation and soils and possibly ending competition for, and trampling of, burrows.

In 1969 the N.Z. Wildlife Service embarked on a concerted programme to band large cohorts of petrel chicks on Moutohora. The main objectives were to find out about dispersal, to gauge longevity and to determine age at first breeding. It was as an adjunct to these objectives that banding became concentrated in, but by no means confined to, one specific part of the island thus allowing a monitor to be kept on the island's petrel population. In 1982 a 1.4 ha study area with marked boundaries was established. Focusing on one particular area also meant a regular search for adult recaptures was concentrated where they were most likely to return to breed.

The main parameter used to measure annual breeding success of the petrels was the number of chicks being raised to fledging stage in this study area. Eradication of rats started in 1985 and was completed by 1987 (Appendix 1). An outline of the breeding cycle of the Grey-faced petrel is given (Appendix 2).

2.METHODS

Banding is the fundamental method used. From about late November until they fledge chicks come out of their burrows at nights to exercise, banding begins about half an hour after dark (9.30 pm DST) and continues through until about 2.00 am. Birds are spotted with a headlamp, captured before they can retreat into a burrow and banded on the right leg (convention for unsexed chicks) or, if already banded, the band number is recorded and the bird is released. Dark, wet and windy nights have more chicks out than fine moonlit nights.

Nearly-fledged chicks can only be distinguished from adults by subtle differences in the colour of the plumage and the bill. On rare occasions when there was doubt about the age, the bird was not banded. Chicks are found in a variety of states of plumage. The youngest are largely covered in down and as they develop they lose down from the head, back, wings and finally the belly, nape and rump.

2.1Birds Handled Per Unit Banding Effort

In the early stages of study an assessment of chick production was made from general impressions of how many birds were seen flying in at night to feed chicks and how many chicks had been banded in similar efforts. In 1982 a 1.4 ha. study area in mature vegetation was marked out above the cliffs to the immediate south of Sulphur Bay (Fig 1). It was divided into three longitudinal strips to record the approximate location of captures and recaptures. To avoid handling birds outside the area the boundaries of the study area were marked with flagging tape. Banding in the study area was carried out as a series of systematic sweeps.

2.2 Capture/Recapture of Chicks

From 1983 onwards records were kept of all recaptures in the study area. The approximate locations were recorded along with the band number and date. The daily tally of birds banded (=captures), birds recaptured and the cumulative total of birds banded to date was used to calculate an estimated population and binomial theory was applie

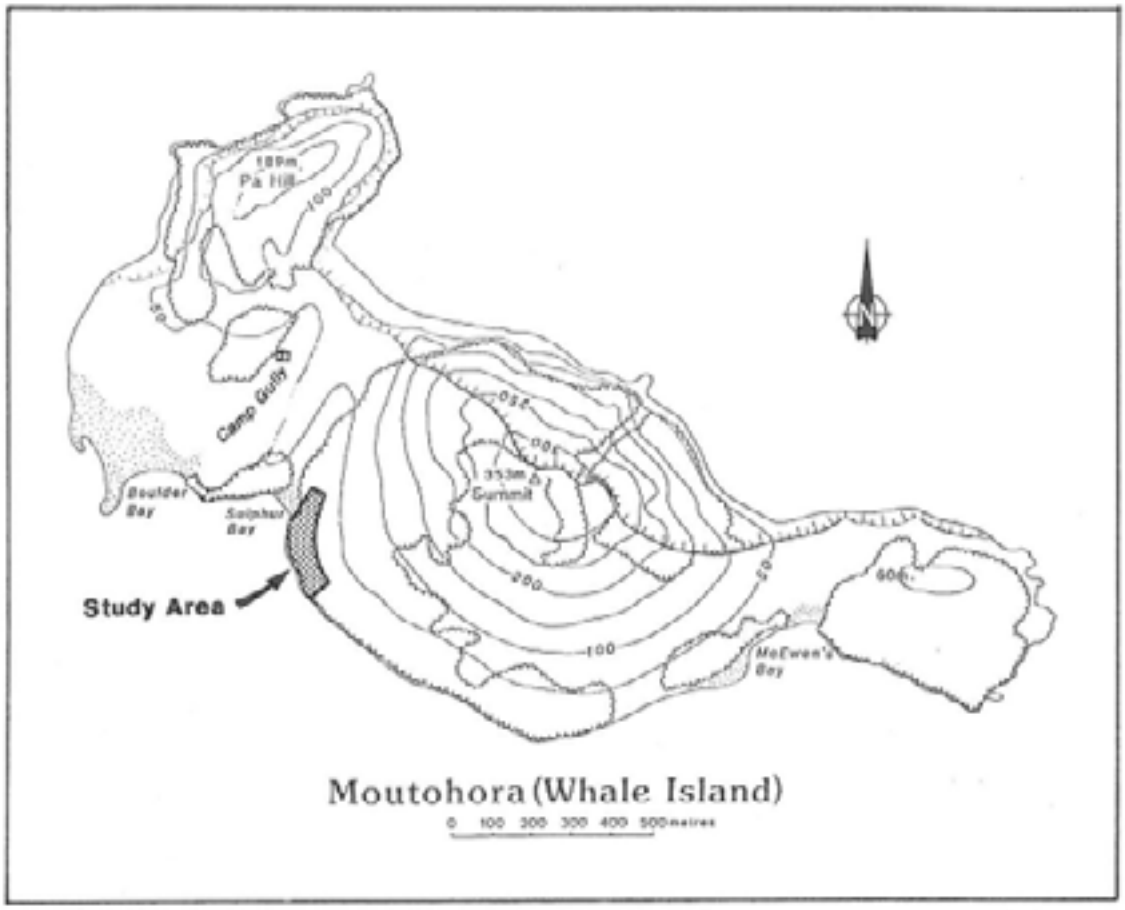

Figure 1 - Map of Moutohora.

to the capture/recapture ratio to determine 95% confidence intervals. Duplicate recaptures of the same bird on the same night were not counted. The method relies on two major assumptions: that the study population is closed (i.e. that birds do not leave nor are they recruited during the sampling period) and that each bird in the study area has an equal chance of being sampled and/or resampled throughout the study. Population estimates relate to the study area but could be subject to variation resulting from movement of chicks into or out of this area. To detect and measure the distances involved the approximate location of banding and subsequent recapture(s) was recorded.
Because of operational and practical circumstances capture/recapture data could not always be gathered at the same time in December each year.

2.3 Adults Flying In

The chick population can be assessed by observing adult birds. Just on dusk parents returning from foraging at sea to feed their chicks can be seen against the evening sky or heard flying overhead. Not all parents return each day but it provides a good indication of both their numbers and where on the island they are landing. Birds without chicks do not come to the island so there is a direct relationship between the numbers of adults flying in and the numbers of chicks in their burrows.

2.4 Burrow Counts and Occupancy Rates

There are documented methods for counting the number of burrows in unit areas. Skira and Wapstra (1980) counted burrows along two metre wide straight transects up to 500 metres long. On Moutohora systematic sampling of two metre diameter plots provides a practical size to make accurate burrow counts; the sampling pattern provides a good measure of variance, is repeatable and similar samples from different parts of the island can be compared.

Associated with the burrow counts is the occupancy rate. Occupancy can usually, but not always, be determined by probing burrows with a flexible stick. Occupied burrows can be identified by the sound of a chick moving about or pecking the stick, or from down adhering to the stick. Some burrows are too deep or the passage is too convoluted to be probed properly so occupancy is understated by an unknown amount. It is not always possible to judge occupancy from the state of the burrow entrance because parents sometimes do not return for several days and entrances can appear disused after a short period.

2.5 New Localities for Chicks

Each year the whole island was checked for the presence of chicks. Some areas of the island have been considered poor for chick production but in recent years chicks have been found in them; this may indicate a rise in the island's overall population. While not conclusive, the presence of chicks in hitherto non-productive areas can be used as supporting evidence of trends detected by other methods.

3. RESULTS

There has been petrel research work on Moutohora each year since 1968 except 1979 and 1989. Although the work in the earlier years was not directed specifically towards the current goals that are the subject of this report it does provide useful anecdotal material. This material is summarised in Table 1.

Banding records show how many birds were marked each year (Appendix 3). However, they do not provide data from which to derive catch-per-unit-effort data, because the work of a number of banding operators was recorded under the name of only one operator - the project leader. Also, until 1982, the number of birds banded per unit effort could not be derived because influential factors such as the vegetation and terrain of the area being worked, the ability of the operator and the adequacy of the operator's light were neither constant nor recorded. Although more than 14,000 petrels have been banded on the island there have been too few recoveries so far to estimate mortality or longevity.

3.1Birds Handled per Unit Effort

In the course of banding a consistent effort was maintained for each night spent in the study area. The average number of birds handled per night (Fig 2) shows a dramatic fall in 1983 and 1984 when there was no rat control. Otherwise there is no evidence that the numbers of chicks are increasing at present.

Table 1: Anecdotal summary of events on Moutohora.

YEAR	CHICK PRODUCTION	RAT CONTROL
1968	Good	No
1969	Good	Yes
1970	Good	Yes
1971	Very good	Yes
1972	Moderate	Yes
1973	Very Poor	No
1974	Poor	No
1975	None	No
1976	Very Poor	No
1977	Poor	Yes
1978	Good	Yes
1979	NO STUDY	No
1980	Good	Yes
1981	None	No
	STUDY AREA ESTABLISHED	
1982	Good	Yes
1983	Poor	No
1984	None	No
1985	Good	Yes
1986	Moderate	Yes
1987	Moderate	Yes
1988	Moderate	N/A (rats eradicated)
1989	NO STUDY	
1990	Good	N/A
1991	Good	N/A

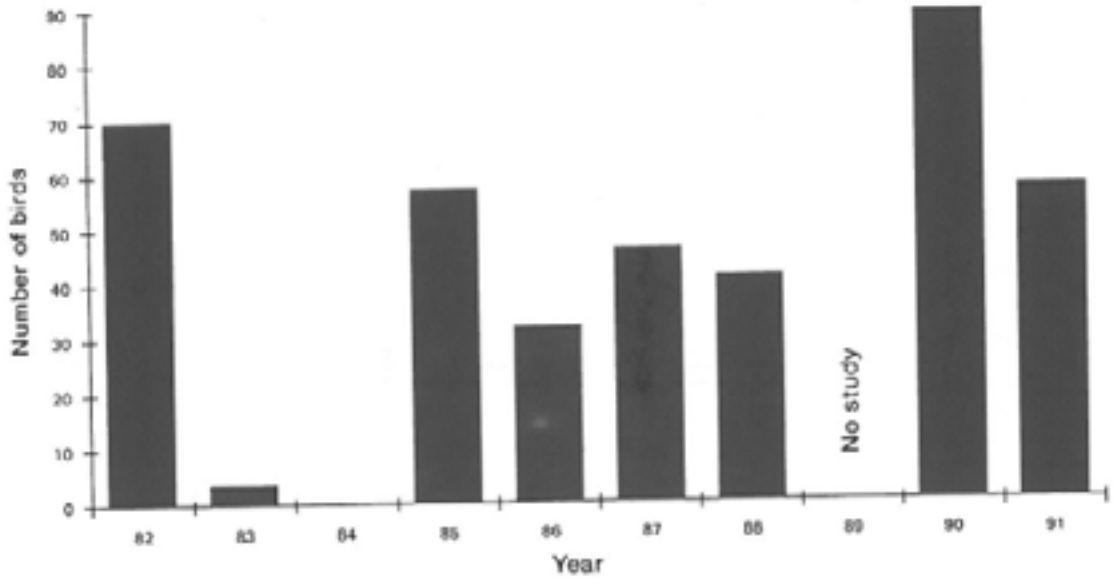

Figure 2 - Average number of birds handled per night in the study area.

The number of birds handled per night is, in part, a measure of extra-burrow petrel activity. What is required is an ability to distinguish between a situation where a relatively few chicks are frequently out of their burrows and a situation where many chicks are occasionally out of their burrows. Such a distinction can be made by examining the ratio of captures (unbanded) to recaptures (banded) handled per night. The rate at which the ratio of recaptures to captures increases could be proportional to extra burrow activity. In this study about half the study population was marked after several nights work.

3.2 Capture/Recapture Estimates

Population estimates of the study area have been made for the years between 1982 and 1991 except for 1989 when there was no study, 1984 when no petrels were seen on the island and 1983 when only 10 could be found in the study area.

A characteristic of the population estimates for each year is their steady increase until about mid December, after which there is a rapid increase. This was most pronounced and consistent in 1991. Another departure from the expected pattern was the rising proportion of captures to recaptures. In 1986, 1987, 1988 and 1990 the number of new bands (captures) shows, as expected, a diminishing proportion of the birds handled each night (more pronounced in some years than in others). In 1991 the proportion of captures drops until mid December and then begins to rise. In 1990 the expected pattern is pronounced until mid December and then levels out. In 1985 the pattern is followed until the 11th and then both birds handled and captures rise.

On nine occasions during the periods shown in Figure 4 there was no disturbance in the study area for one or more nights while work was being carried out in other parts of the island. It is notable that on eight of the nights immediately following these breaks the number of birds handled increased. On one night the number decreased but only marginally. Immediately before the breaks the number handled had been decreasing on five occasions, increasing on one and static or not able to be measured on three.

3.3 Adults Flying In

The summary of chick production (Table 1) gave an anecdotal assessment of chick production based on a combination of factors including chicks seen, chicks banded and adults flying in. Personal observations by different observers on the island at different times of the season did not suggest differences in the numbers of adults flying from year to year at the beginning of the breeding season, but at later stages of the season there were large changes from year to year (few or no birds in some years) depending on chick predation by rats. These changes were similar to those observed when measuring yearly chick populations using banding methods.

3.4 Burrow Counts and Occupancy Rates

In 1982 (2 December) a burrow count of the study area was estimated from 16 circular plots of two metres radius (12.57 m^2) to be 3000 (with a 95% confidence interval from 1830 to 4140) in the 1.4 ha. Occupancy rates were estimated to be 40% (with a 95% confidence interval of 26% to 57%) giving a mean estimate of chicks in the study area of 1200 (95% confidence interval 475 - 2360).

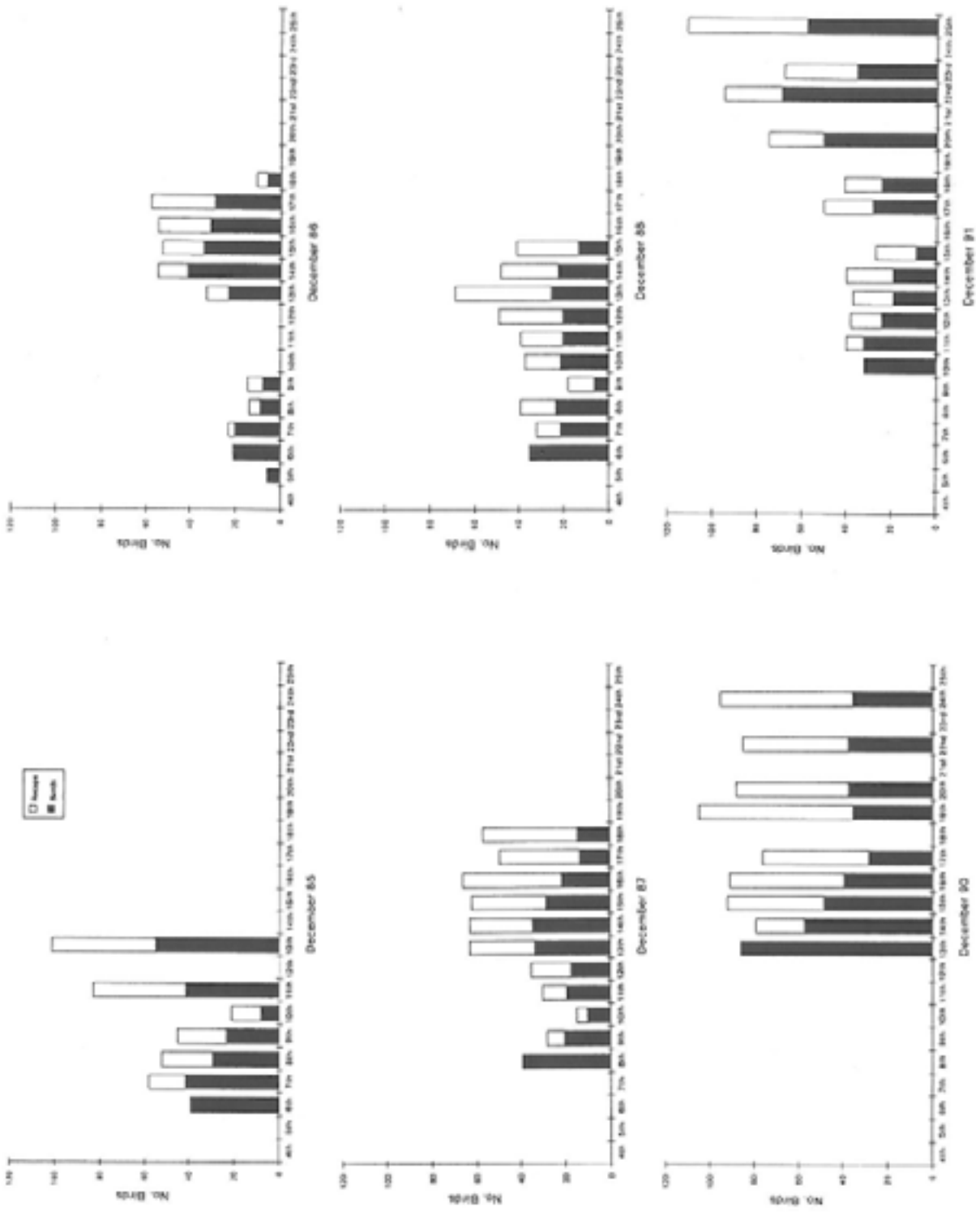

Fig 3 – Number of birds captured and recaptures each night in the study area

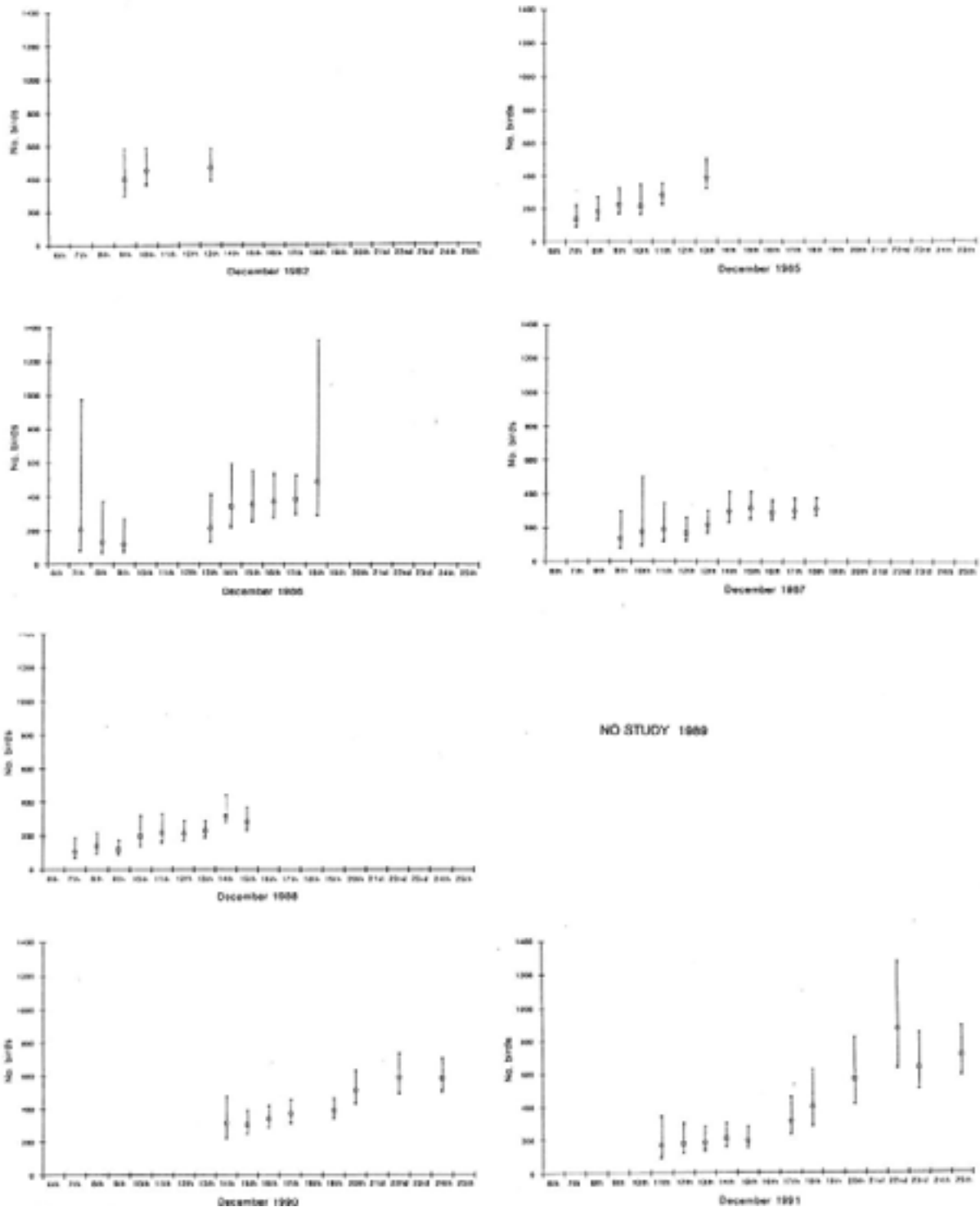

Fig 4 – Chick population estimates of the study area calculated from capture/recapture ratios and showing 95% confidence intervals.

In 1985 (16 December) the burrow count in the study area was estimated at 2000 (95% interval 1400 - 2600) from 31 sample plots of two metres radius. Occupancy was not measured.

In 1986 (13 December) the mean estimate for burrows in the study area was 820 (95% confidence interval 670 - 940) from 49 sample plots of three metre radius (28.27 sq. metres). The occupancy rate of 57% (much higher than the 30% recorded by Imber.1976) giving a mean estimate of the chick population of 470 (95% confidence interval 300 - 630).

In 1991 (23 December) a burrow count was estimated from a sample of 80 two metre radius sample plots (12.57 sq. metres) and the occupancy of each burrow within the samples tested. The burrow counts followed a poisson distribution with a mean of 0.93 burrows per sample. This was extrapolated to 1036 burrows in the 1.4 hectare study area with a 95% confidence interval between 810 to 1260 burrows. Occupancy also followed a Poisson distribution. There were 16 occupied burrows in the 80 samples giving a mean occupancy rate of 0.22 per burrow. The number of occupied burrows in the study area was estimated at 227 with a 95% confidence interval between 178 and 277.

Table 2 - Summary of burrow counts.

	BURROWS			CHICKS		
	Mean	95% Confidence			95% Confidence	
YEAR	(Est.)	Lower	Upper	Mean	Lower	Upper
1982	3000	1830	4140	1200	475	2360
1985	2000	1400	2600	-	-	-
1986	820	670	940	470	300	630
1991	1036	810	1260	227	178	277

3.5New Localities for Chicks

In 1985 two chicks were banded in Camp Gully for the first time in years. However, in the same year a search of the McEwans Bay (eastern) end of the island failed to find chicks nor were any adults seen flying in at dusk. The following year, 1986, numerous adults were seen flying in at the McEwans Bay end and a chick was banded there in spite of the bright moon on the night of the search. A chick was also banded in Camp Gully that year. In 1990 two chicks were banded in Camp Gully. In 1991 a chick was banded at the McEwans Bay end of the island and numerous adults were seen flying in at dusk. Chicks were also banded at the head of Camp Gully.

4.DISCUSSION

The issues affecting the population of Grey-faced petrels on Moutohora Island are many. Some, such as the weather and food supply, are factors about which nothing can easily be done. Others, such as predation by rats, have been managed practically to their ultimate conclusion; all that remains to be done now is to maintain present conditions.

Vegetation will be a constantly changing factor for some time as a result of the eradication of rabbits and goats. This changeability makes it awkward if not impossible to incorporate consideration of vegetation into any management scheme; never the less, it is a factor that should be of management concern. The assumption that a reversion of the island's vegetation to its former pristine state would be to the advantage of the petrels has still to be proven. The management options for the island must also consider other objectives as well as the welfare of the Grey-faced petrels but in carrying them out the petrel population should be monitored.

This monitoring of the petrel population is confounded by many circumstances. The population does not show rapid, perfectly correlated response to changed conditions but rather has long reaction times due to the seven year period it takes for chicks to reach breeding age.

Some Moutohora banded birds have been recovered seven kilometres away on the Rurimas, one 75 kilometres away on Mount Maunganui (Graeme Taylor pers. comm.) and some 420 kilometres away in the Hokianga harbour. The birds may not have been breeding in all these other places, merely visiting. It is already proven that the majority of birds return to their natal colony to breed (Imber 1976) but not **all** will return at seven years; some will never breed and others will breed sometime after seven years so it is very likely that the effect of rat eradication will not **even begin** to be an influence until 1992/93 - seven years after the rats were eradicated. In the meantime natural fluctuations in the food supply and the weather patterns will continue to affect the population, thus confounding measurement of the effect of management practices on the petrels.

4.1Rats

A dramatic effect of rats on chick production could be inferred by looking at Figure 2. Since 1982 there has been rat control in all years shown except 1983 and 1984. In 1983 only four or five birds were handled each night in the study area and in 1984 not a single chick was found on the whole island. In other years when rat control was exercised the average numbers of birds handled per night varied from more than 30 to about 90.

The allantoic membranes from a sample of petrel egg shells found littered about the breeding area in 1984 were examined and found to have been gnawed by rats (in most cases before the chicks had hatched).

Anecdotal information in Table 1 also condemns rats. Chick production rating during the eight study years in which no rat control was exercised and the 11 years in which rat/petrel rat control was exercised are summarised in Table 3.

The slight discrepancies in the correlation between rat control and chick production could be attributed to departures from the critical timing of poisoning in the relationship. The

Table 3: Chick production rating x number of years vs. rat control.

	NONE	VERY POOR	POOR	MODERATE	GOOD	VERY GOOD
Rat control	-	-	1	3	6	1
No control	3	2	2	-	1	-

logical time to poison is in April/July before eggs are left unattended but the rat population fluctuates so that their menace to petrels is greater during shortages of alternative food and/or peaks in rat numbers. Poison laid in April/July is likely to be more effective than poison laid at another time.

The role of rats is hoped to be one of the past apart from the impact they will have on the size of breeding cohorts joining the population during the next score of years.

4.2 Rabbits

Apart from possible secondary effects on petrels by rabbits modifying the vegetation, rabbits had a direct effect on nesting petrels. Many petrels deserted their nests at the head of camp gully when rabbits occupied their burrows (M.J.Imber pers.comm.).

4.3 Goats

Goats are likely to have trampled burrows and, like rabbits, may have had a secondary effect on petrels by modifying the vegetation. The major cull of goats was completed before the intensive study of petrels began.

4.4 Vegetation

No direct correlation between vegetation and chick production has been attempted. In the early 1970s there were many chicks to be found on the "pasture" (grazed by goats and rabbits) near the summit of the main hill. Now that "pasture" is rank grass and sedge with nettles abundant and fewer birds are seen there.

Both adults and chicks have been found dead from entanglement in vegetation apparently while they were attempting to fly away or land. Others have been found dead with their wings caught in roots on the surface of the ground.

4.5 Burrow Counts and Occupancy

Occupancy rates vary from season to season and from area to area. In high density areas in good years the occupancy rate has been about 0.33 (M.J.Imber pers comm).

There has been a considerable reduction in the burrow density since the 1982 estimate of 3000 in the study area. The 1985 count of 2000 could be considered a reasonable variation over a three year period when rabbits were in abundance.

The year 1986 was the first one virtually free of rabbits. Until that time there had been rabbits throughout the study area, and it is very likely that many of the burrows counted were those of rabbits rather than petrels. It seems that rabbits cause petrels to abandon

their burrows (M.J.Imber pers.comm.), which is consistent with the subsequent increase in petrel burrows between 1986 and 1991 after rabbits were eradicated.

The other, and perhaps more relevant, measure is chick numbers. The reduction of mean chick estimates from 1200 in 1982 to 227 in 1991 is of most concern between 1986 and 1991. In part this reduction could be attributed to the different dates in December on which the counts were made. In 1986 the counts were made on December 13 but the 1991 counts were ten days later in December by which time many of the chicks could reasonably be expected to have fledged. (The fledging of chicks also explains why the population estimates from capture/recapture methods increase with date in December.)

4.6 Birds Handled per Unit Effort and Capture/Recapture

One fundamental assumption of the capture/recapture method is that the population is closed. However, this may not be true; new birds may enter the study area population, or marked birds may leave it. This could account for the apparent increase in the population late in December. Birds could enter either by coming in from outside the study area or by coming in as chicks which have remained in their burrows during the early part of December and suddenly emerged in the later part.

4.6.1 Birds Entering from Adjoining Areas

The study area is on a cliff edge with only one major outside area from which birds could enter. Analysis of banding and recapture data showed no detectable differences in the proportions of new birds (recaptures) between the three sub-areas of the study area even though each was a different distance from the outside boundary. Nor did this analysis show any tendency for birds to move down through the study area to the cliff edge. There is no evidence of recruitment from outside the study area.

4.6.2 Recruitment from Within the Study Area

Burrow counts and occupancy rates were carried out at the end of December and showed a population estimate similar to that of the early December capture/recapture population estimate. According to the estimates based on burrow counts there simply is not the number of birds in the area that were estimated by capture/recapture used later in December. But, assuming that the emergence of chicks from their burrows is related to their stage of development, there was nothing to indicate that capture chicks were generally more immature than recapture chicks as the December date advanced. This would be because the older recapture chicks were leaving (from 8 Dec according to Imber 1976) and younger chicks in burrows were emerging for the first time. Thus recaptures will be of similar age (± 20 days) to captures.

4.6.3 Birds Leaving the Study Area

Fledging begins in the first week of December and peaks about 24 December (Imber 1976) so during the recapture period there would have been a steady loss of chicks leaving the island. Since it is likely that chicks become more active outside their burrows as they develop towards fledging it will be mature chicks that are more likely to be captured and marked. It is also more likely that these marked (more mature) chicks will fledge than the less mature chicks and so capture/recaptures ratios are biased towards captures with

consequent overestimation of the population especially towards the end of December.

The data presented in Figure 4 for each year differ in one major respect. In the years 1985, 1986, 1987 and 1988 the study began in the first week of December and stopped about mid December. In 1990 the study started about mid December and continued to the end. In 1991 the study began before mid December and continued through to the end of December. It would seem that the departures from the expected pattern (constant numbers handled per night and diminishing proportion of captures, i.e.new bands, with advancing date) are perturbed by birds beginning to fledge. Chicks depart during the second and third weeks of December until about the end of the third week in January, peaking about 24 December. Those leaving in January probably do not emerge until the end of December, at the earliest, constituting internal recruitment up to about 25 December. The increase in birds handled could be attributed to more birds coming out of their burrows, coming out for longer periods and/or coming out more frequently. The increase in extra-burrow activity could be related to season rather than stage of development which, if true, would account for the apparent lack of change in the age classes of chicks handled later in December compared with those handled earlier.

4.7 Chicks in New Areas

The main areas for remarking on the presence of chicks are the eastern (McEwans Bay) end of the island and Camp Gully. The notable difference between the two is that at the eastern end in "good" years there seem to be many adults flying in (to feed chicks) and in "poor" years there is none. In Camp Gully, however, the difference between "good" and "bad" years is not clearly obvious. The revegetation in Camp Gully in recent years precludes any reasonable search for chicks, but there is little evidence of adults flying in.

4.8 Disturbance Caused by Banding

Disturbance is always a factor which is difficult to measure objectively. The increase in the number of birds handled after a break indicates that the banding programme does disturb birds despite the fact that the process of banding or recording a recapture takes little more than 15 seconds. A very bright light helps the banding process but is likely to add to the trauma for the birds. (See Appendix 4 for a discussion of lights for banding.) One sign of stress occurs when captured birds struggle and regurgitate. This would confuse a predator at sea but for a chick it represents lost food at a critical stage of life. Efficient and practised banding operators can greatly reduce the incidence of regurgitation but it still does occur on 5-10% of bandings.

Recording the band number of a recaptured chick not only prevents its recapture from being counted twice on the same night when analyzing the data but also makes a valuable contribution to other information such as the frequency, duration and range of its excursions from its burrow and its changes in plumage during the study period.

4.9 Future Monitoring

The parameters of the population that need to be measured are changes in the numbers of breeding birds and their success over the next several years. If more information is

required on their longevity and dispersal then it will require not only that the banding programme be maintained but that the proportion of effort directed at recoveries be increased. A large investment was made in the early 1970s in marking a large number of known age birds on the island and that investment could be capitalised upon.

To more quickly assess dispersal and frequency of breeding the banding programme could include banding adults of unknown age. Marked birds of breeding age could be recaptured on their banding/breeding colony thus giving information on breeding frequency and dispersal.

5. CONCLUSIONS

1. Rats almost certainly have a detrimental effect on petrel breeding.

2. Chick production seems to have stabilised since rats were eradicated but it cannot be expected to even begin to recover until 1993-94.

3. Mortality and longevity cannot be derived from existing data at present.

6. RECOMMENDATIONS

- Rats should be kept off the island. If that is not possible then poison should be laid in the petrel breeding areas in July each year.

- Rabbits should be kept off the island.

- Human disturbance in the breeding areas should be minimised at all times of the year. Petrels breed in burrows which are very susceptible to collapse when people walk over them. The soil on Moutohora is friable in most areas so collapsed burrows are difficult or impossible to repair within a breeding season.

- Although some of the variation in chick production has been explained from year to year there is sufficient inexplicable variation remaining to suggest that caution is required before accepting any indication of an underlying recovery trend.

- Any further planting in the few remaining pockets of original mature vegetation should be limited when there are petrel burrows in the vicinity. The already established breeding sites of the Grey-faced petrel should not be modified as the sparsely vegetated ground beneath some of the original kanuka/mahoe/pohutukawa stands over petrel burrows is a natural habitat type.

7. RESEARCH CONSIDERATIONS

It takes many years and considerable effort to collect population data on a species as long-lived and wide ranging as the Grey-faced petrel.

1. The considerable investment made in the 1970s in marking thousands of birds has not been well used. The opportunity to do so will be lost by the end of the 1990s. Searching for adult recoveries during the breeding season - incubation and feeding - would contribute recovery data useful to measuring mortality, longevity and breeding.

2. There is a likely opportunity to measure some of the mortality of newly fledged chicks by patrolling the nearby beaches of Ohope and Thornton soon after chicks leave the island - early January. Seabird mortality characteristically becomes constant as birds reach adult age. If this generalisation holds true for Grey-faced petrels then an understanding of early fledged chick mortality should provide an understanding of a significant component of overall mortality. Adult recovery data (see preceding paragraph) would prove much of the rest.

3. If the emphasis of field work were shifted from the study area capture/recapture data to burrow counts and occupancy rates in different parts of the island a better understanding of the relative value of different areas there (for petrel breeding) and a better understanding of total chick production would result from the same effort. What would be lost would be the almost direct comparison of chick production from one year to another in a localised area of stable vegetation.

8. ACKNOWLEDGEMENTS

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APPENDIX 1

Summary of rat control

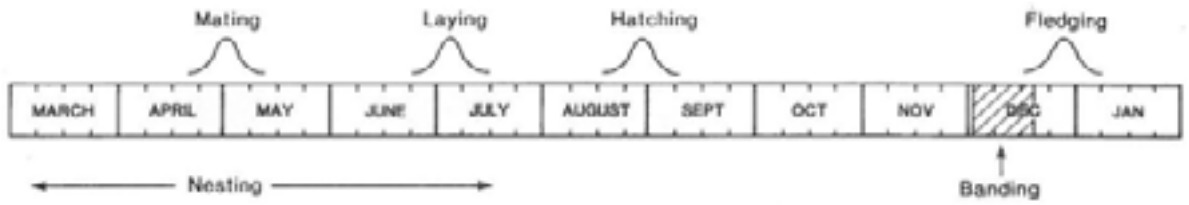
YEAR	RAT CONTROL
1968	None
1969	A few trapped.
1970	Warfarin laid in some areas.
1971	" " " " "
1972	" " " " "
1973	Large 1080 aerial operation.
1974	None
1975	"
1976	"
1977	Epibloc
1978	Racumen
1979	None
1980	Brodifacoum & 1080 jam
1981	None
1982	Brodifacoum
1983	None
1984	None
1985	Talon^{R} & 1080 (large 1080 aerial operation)
1986	Talon^{R} - follow up to areas with continuing sign.
1987	No further rat sign

Note: Brodifacoum is the active ingredient in Talon^{R}.

Major control of rats occurred as a result of Talon^{R} laid extensively across the island in July 1985 and then the possible side effect of an aerial 1080 carrot operation against rabbits in September that year. However, the similar 1080 operation in 1973 had no discernable effect on rat numbers. Intense ground work followed up resulting in the eradication of both rats and rabbits by early 1987.

APPENDIX 2

An outline of the breeding cycle of the Grey-faced petrel (based on Imber 1976).



Nesting - nesting activity has been observed from early March through to mid-July

Mating - takes place on the island during late April and early May.

Laying - concentrates in early July with some birds laying as early as 21 June and others as late as the end of July. Only one egg is laid.

Incubation - shared by both parents taking turns to go to sea to feed or to incubate for about 17 days. Incubation time varies but, typical of petrels and unlike most other birds, eggs will survive in the absence of a parent for some days.

Hatching - begins about mid August and continues through until about 10 September.

Chick growth - both parents spend time at sea to feed themselves and catch food to bring back for their chick. The time between feeds for the chick varies depending on the weather and the proximity of the feeding grounds but usually chicks get fed every few days. Towards the end of November chicks venture out of their burrows at night to stretch their wings and become accustomed to life outside their burrow preparatory to fledging. It is during this stage of their development that they are caught for marking.

Fledging - from about 10 December chicks begin to leave the island. They do not breed until seven years after that.

APPENDIX 3

Banding totals

YEAR	NUMBER BIRDS BANDED **	
	CHICKS	ADULTS
1968	188	88
1969	3065	382
1970	2065	
1971	4596	249
1972		
1973		
1974		
1975		
1976		
1977	41	13
1978	189	
1979	NO STUDY	
1980	720	64
1981		
STUDY AREA ESTABLISHED		
1982	392	
1983	10	
1984		
1985	306	
1986	250	
1987	251	146*
1988	206	
1989	NO STUDY	
1990	404	
1991	481	3

* Adults banded by Robin Johnstone.
** Includes all birds banded (not just within the study area).

APPENDIX 4

Lights for banding.

Over the years the "Winchester" brand of headlamp proved to have the best beam characteristics for banding Grey-faced petrels because of its focused beam with little side flare. Side flare scares birds which are not in the main beam but are nearby. Disturbed chicks creep into their burrows while their neighbour is being banded which consequently greatly reduces banding effectiveness. Last year an "Oldham" miners lamp, modified to six volts instead of its standard four volts, was used. The beam of the "Oldham" was slightly superior to the "Winchester" and the lamp is made of more durable material but cost more than twice as much as a "Winchester". The "Oldham" lamp can be switched to a low wattage, flared light for the actual banding process or note taking with a considerable reduction of power consumption. Halogen bulbs have proved best. The lamps are mounted on a plastic industrial safety bump cap which greatly increases comfort by relieving the pressure of a strong elastic band around the forehead. The bump cap is inexpensive, cool to wear, provides protection from bumps and scratches when scrambling through scrub and functions well as a rain hat. The power supply has evolved from a pack of "D" cells to lantern batteries and finally to a six volt sealed lead acid battery recharged from a solar panel during the day.