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No. 26

BREEDING COLONIES OF TITI, *PUFFINUS GRISEUS,* ON THE OTAGO COAST IN 1992/93

(Short Answers in Conservation Science)

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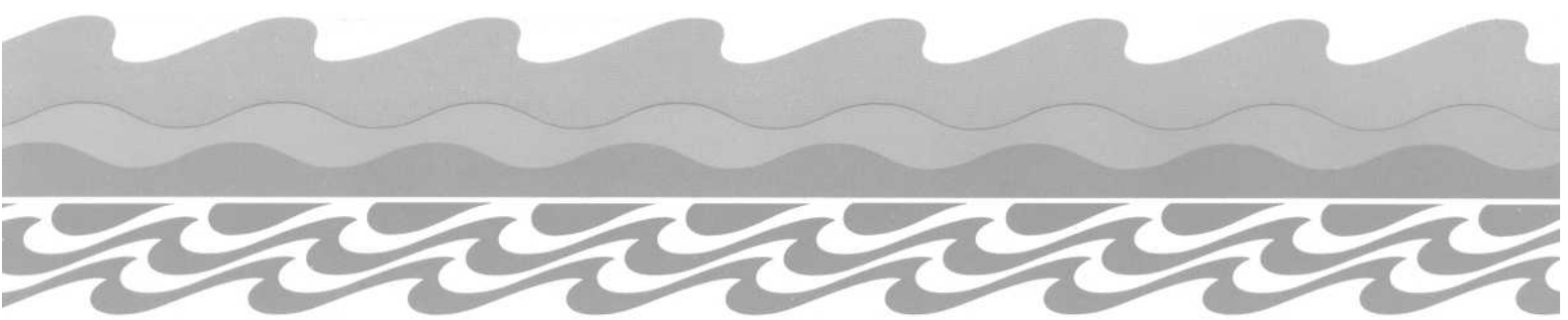

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Breeding colonies of titi, *Puffinus griseus*, on the Otago coast in 1992/93.

A Contract Report to the Department of Conservation
DOC S & R External Unprogrammed Science Advice Ref. No. 6

by

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University of Otago Wildlife Management Report Number 36

June 1993

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EXECUTIVE SUMMARY

EXTERNAL UNPROGRAMMED SCIENCE ADVICE REF.NO.:	6
INVESTIGATION TITLE:	Breeding colonies of titi, *Puffinus griseus,* on the Otago coast in 1992/1993.
STUDY VENUE:	Otago coast
INVESTIGATION LEADER:	S. Hamilton (Otago University)
ASSOCIATED RESEARCHERS:	H. Moller (Otago University) C. Lalas C.J.R. Robertson (DoC, Wellington)
INVESTIGATION STATUS:	Preliminary
CLIENT:	Department of Conservation
FINISH DATE:	5 June 1993

INVESTIGATION OVERVIEW:

Mainland breeding colonies of titi *(Puffinus griseus)* are thought to be in decline although there is no concern for the overall population of these burrow-nesting seabirds. This preliminary study set out to survey remaining mainland colonies and to establish their current status and productivity.

OBJECTIVES:

1. Locate breeding colonies of titi in Otago and describe current land status and habitat threats to colonies.
2. Assess the current status of each of the colonies in terms of numbers and productivity for the 1992/93 breeding season.
3. Describe evidence of adult and chick predation at mainland colonies.
4. Recommend future research and management options for this species in the Otago Conservancy.

METHODS:

Burrow occupancy and fledging success were determined for five mainland colonies and one island colony along the Otago coast using short burrows, wooden "observation hatches", and a fibre optics "burrowscope". Burrow numbers and estimated occupancy were found for a further seven mainland colonies. A further two island colonies were visited and productivity was estimated to be low. Chick survival was monitored and cause of death ascertained.

RESULTS & CONCLUSIONS:

1) Habitat threats to the studied titi colonies are minimal with the main one being burrow collapse due to human disturbance.
2) The remaining mainland colonies which were studied are relatively small (< 100 burrows) with the exception of one on private land at Taiaroa Head (> 600 burrows).

3) A number of problems were encountered when determining burrow occupancy (i.e. the number of burrows containing an attempted nest). Methodological problems will be refined for the long-term monitoring programme which has been initiated with this study.
4) Burrow occupancy ranged from 32 - 58% for the intensively studied sites. There may be a negative correlation between percentage burrow occupancy at colonies and the amount of predation.
5) Fledging success at the three Nugget Point sites ranged from 0 - 41%. Fledging success was mainly affected by predation with chick predation ranging from 43 - 69%.
6) At Taiaroa Head and Tuhawaild Island, fledging success ranged from 64 - 100%. Predator numbers are probably low at these three sites which may be a reason for the high fledging success.
7) One colony at Nugget Point (Site 5) suffered high adult mortality which was all attributed to predation.

RECOMMENDATIONS:

1) Apply Population Viability Analysis to gain information on factors affecting the long-term survival of titi breeding populations.
2) Genetics study determining immigration rates to mainland titi colonies.
3) Diet study during titi breeding season.
4) Prepare inventory of colonies that existed in the past and survey to determine their current status.
5) Monitoring the impacts on titi colonies needs to be continued.
6) Predator control may be a future option.
7) Modelling to look at sustainable harvesting levels with the possibility of an experimental harvesting regime initiated in the future.
8) Restricted access to fragile colonies susceptible to habitat destruction.

1. INTRODUCTION

The sooty shearwater or titi *(Puffinus griseus)* is probably the most abundant of New Zealand seabirds (Warham and Wilson 1982). The highest abundance is on islands around Stewart Island where numbers reach the millions. Although there is no concern for the overall population of titi on offshore islands, breeding colonies that once existed on many headlands of the North and South Island have apparently disappeared (Jackson 1957). However, detailed information on both mainland and near-shore islet colonies is scarce. Before conservation effort is directed towards protecting mainland colonies, trends in colony sizes need to be confirmed and threats to their long-term persistence identified.

Maintaining colonies on the mainland is important for tourism, aesthetic and maybe biological reasons, and eventually indigenous harvest, since these colonies are so much more accessible than those found on offshore islands. Failure of mainland colonies of titi may be attributed to predation, but other potential threats to colonies include illegal harvesting of chicks, burrow collapse and habitat modification.

The breeding season for titi begins in late September/early October when adults return to breeding colonies for courtship and burrow preparation. Burrows can be up to three metres long and end in an enlarged nesting chamber. Egg-laying occurs between late November and early December and hatching between late January and early February (Warham 1990). Fledging is from around 20 April until mid-late May and chicks come to the surface after dark for a few days before leaving.

The aims of this research are to:

1. Locate breeding colonies of titi in Otago and describe current land status and habitat threats to colonies.
2. Assess the current status of each of the colonies in terms of numbers and productivity for the 1992/93 breeding season.
3. Describe evidence of adult and chick predation at mainland colonies.
4. Recommend future research and management options for this species in the Otago Conservancy.

2. STUDY SITES

This study took place in 6 areas (12 sites) on the mainland and on 3 near-shore islets along the Otago coast (Map 1). The mainland areas were Bushy Beach Reserve (Oamaru), Shag Point, Taiaroa Head, Sandymount, Nugget Point, and Tunnel Rocks. At Nugget Point there were 5 separate sites ("Nuggets 1 - 5") although Nuggets 3 and 4 were less than 50 m apart and on adjacent rank grass spurs. One study site at Taiaroa Head was within the Nature Reserve (referred to as Taiaroa Head (Reserve)) and the other site was about 500 m southeast of the Head on private land owned by Mrs S. McGrouther (referred to as Taiaroa Head (Private)). The islet sites were Green Island, Moturata (Taieri) Island and Tuhawaiki (Jack's) Island.

Map 1: The Otago coastline showing the location of the 9 study areas (marked with *).

3. METHODS

3.1 Site Descriptions.

The studied titi breeding colonies were described under the following categories:

Vegetation: Dominant vegetation type in the vicinity of the titi colony.

Habitat Threats: **Trampling** = trampling of vegetation from humans or seals.
Burrow collapse = collapse of burrows due to stock or humans.
Stock = grazing of area by sheep.
Erosion = erosion, caused by a number of factors, which may lead to an increase in the fragility of soil and subsequent burrow collapse.

Predators: Presence or absence of known seabird predators (cats, mustelids).
Present = predators known to be active in an area via sightings or trapping, and/or evidence of predation.
Absent = predators known not to be active, or no evidence of predation.
Vulnerable = currently assumed to be predator-free but vulnerable to invasion from predators.

Trapping Effort: H = high; permanent predator trapping year-round on a regular basis.
M = medium; trapping during yellow-eyed penguin breeding season.
L = low; sporadic trapping.
nil = no trapping.

3.2 Burrows and occupancy.

All burrows were counted at each colony and study burrows were individually marked at all colonies except for Tunnel Rocks. At Taiaroa Head (Private) and Tuhawaiki Island, all burrows in a section of the colony were marked as well as a number of burrows (23 and 10 respectively) spaced throughout the colony which were known to contain a chick. Burrows that were identified as having two entrances were counted as one burrow.

3.2.2 Intensively studied sites.

Burrows were checked once a week at Nuggets 1,3,4,5 and Taiaroa Head (Private), and once a month at Tuhawaiki Island and Taiaroa Head (Reserve) from November 1992 until mid-May 1993. Burrow occupancy was defined as burrows containing an

attempted nest. Occupancy was determined by probing down the burrow with a stick to elicit a "peck" and by using "sign" around the burrow entrance (i.e. smell, faeces, scratches, diggings, feathers, down). Burrow entrances were also "barricaded" using small sticks and revisited a few days later to determine whether the burrow had been entered or not.

For some burrows, it was possible to directly identify the occupants in the nesting chamber using specialised fibre optics equipment (a "burrowscope"). The "burrowscope" consisted of a fibre optics camera at the end of a 2m length of drainage hose (diameter = 5 cm). The camera could be pushed down the tunnel of the burrow via the entrance and the burrow contents could be viewed on a video monitor outside.

Burrows were recorded as producing an egg if egg remains were found in the tunnel (after being cleared from the nesting chamber by the adults) or if an egg was viewed using the "burrowscope".

3.2.3 Remaining study sites.

At Bushy Beach Reserve, Shag Point, Sandymount, Nuggets 2, and Tunnel Rocks (2 sites), estimating burrow occupancy was complicated by the length of the burrows. At all these sites the burrows were too long to accurately determine occupancy. Past surveys of titi have used the distinctive "musky" smell of the birds to determine occupancy of burrows (C. Lalas, pers.comm). Therefore, burrow occupancy was roughly estimated using the smell of burrows. "Estimated occupancy" was recorded as the proportion of total burrow numbers that smelled of titi at the time of surveying and "mortality" was recorded as the number of dead titi found at the colony at the time of surveying.

3.3 Fledging success (Nuggets 1,3,4; Taiaroa Head; Tuhawaiki Island).

Fledging success was estimated using burrow occupancy at the end of the season (late April) compared with the early chick stage (February). If a chick was present after 20 April 1993 and if no evidence of mortality was found, it was assumed it had successfully fledged. Some colonies (Taiaroa Head; Nuggets 1,3,4; Sandymount; Bushy Beach Reserve) were visited at night during fledging to band chicks which came to the surface. Chicks were classed "no. fledged" if they were alive after 20 April (beginning of fledging) and where no sign of predation near the burrow entrance was found after that date.

3.4 Evidence of predation.

"Observation hatches" were established over the nesting chamber of 10 burrows at "Nuggets 5" and 20 burrows at "Taiaroa Head (Private)" to directly observe chick survival. The "observation hatches" consisted of a hole (diameter = 15 cm) above the nesting chamber, covered with a 30 cm x 30 cm wooden slab. The "burrowscope" was also useful in following chick survival. At all sites, the cause of any observed mortality (adult or chick) was estimated Carcasses were often found at or near a burrow entrance.

The number of chicks preyed upon was determined from circumstantial evidence. Chicks that were "presumed dead" were ones that were confirmed to be in burrows at the start of the season and ceased to peck a stick well before fledging but whose bodies were not recovered. "Unknown cause of death" were the number of chick carcasses that were either too far decayed to ascertain cause of death or where there was no outward sign of cause of death. Chicks from "collapsed burrows" were covered over and probably died from suffocation. Chicks that were "preyed upon" consisted of those where a body was found and where sign of wounds were apparent.

4. RESULTS

4.1 Site descriptions of titi colonies.

All studied breeding colonies of titi in Otago, with the exception of the colony on private land at Taiaroa Head, are within Department of Conservation reserves (Table 1). Moturata Island had the most severe habitat threat of burrow collapse due to human activity.

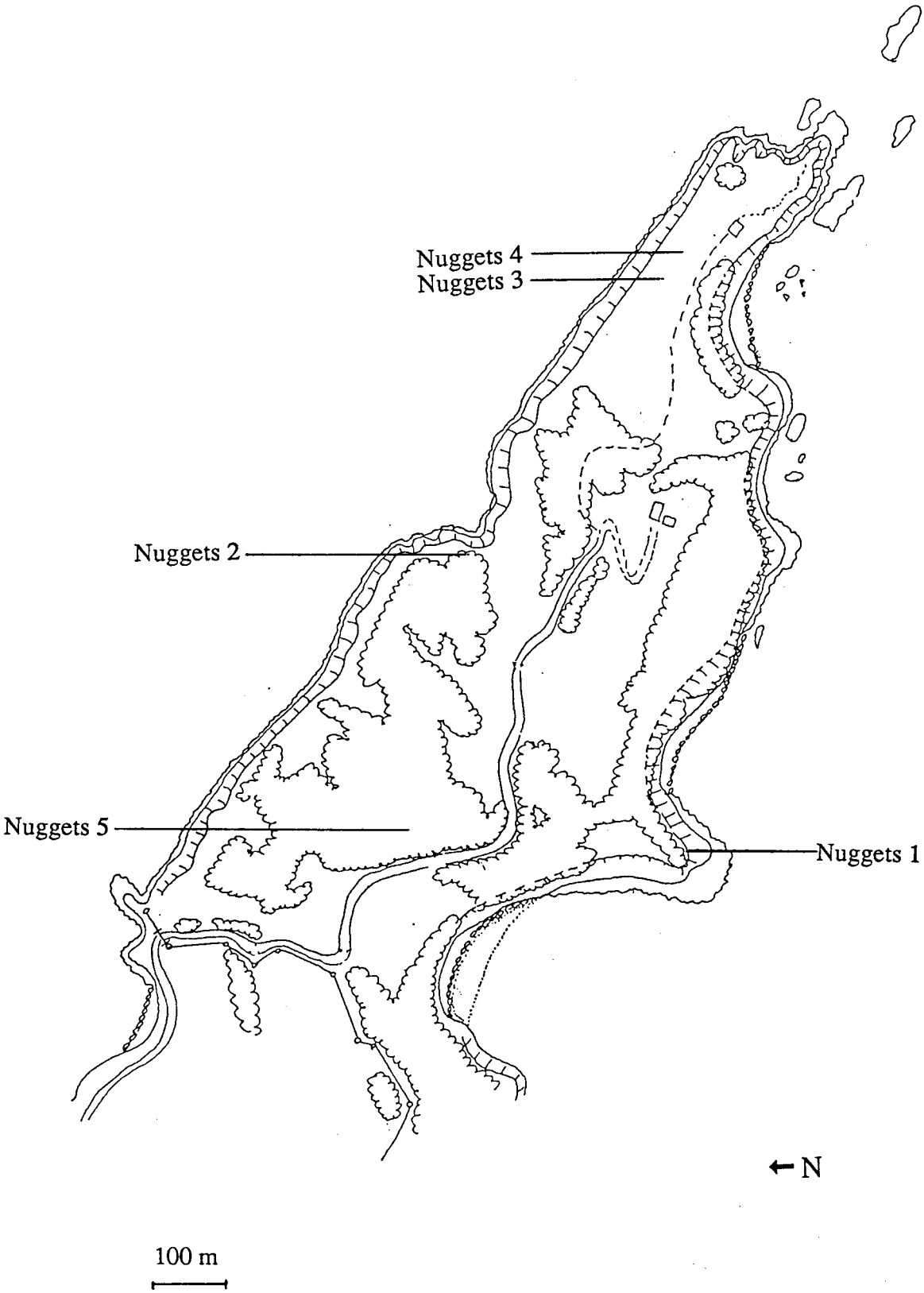
Detailed site localities are provided for the colonies at Nugget Point (Map 2) and Tuhawaiki Island (Map 3).

Table 1: Description of the studied titi colonies along the Otago coast. (Refer to Methods 3.1 for glossary of key terms.)

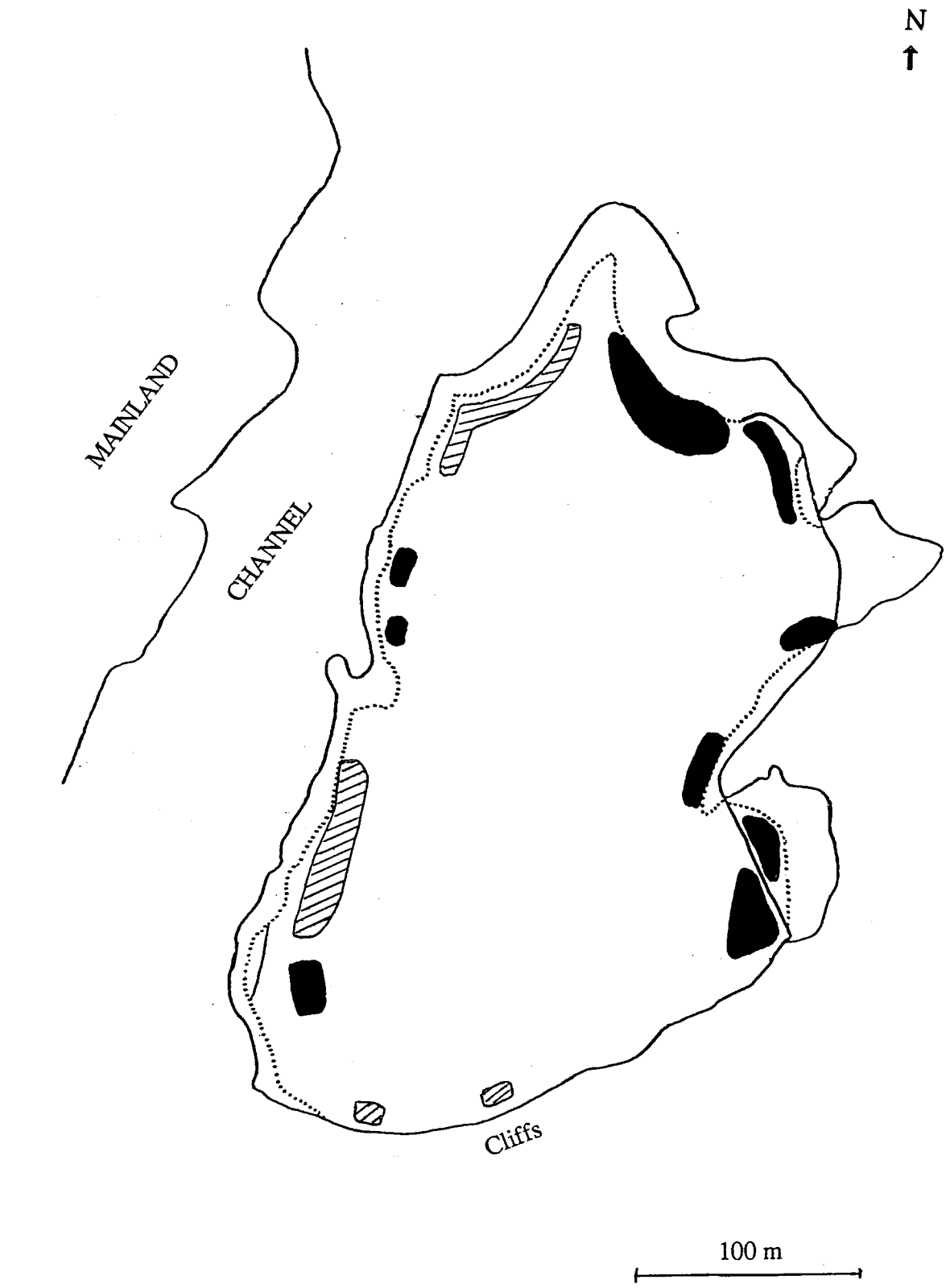
SITE	Land Status	Vegetation	Habitat Threats	Predators	Trapping Effort	Distance offshore
Nuggets 1 (Roaring Bay)	Scientific Reserve	Rank exotic grass	Trampling (human)	present	M	–
Nuggets 2	Scientific Reserve	*Hebe elliptica, Coprosma propinqua*	Burrow collapse	present	M	–
Nuggets 3 (Lighthouse)	Scientific Reserve	Rank exotic grass	None	present	M	–
Nuggets 4 (Lighthouse)	Scientific Reserve	Rank exotic grass	Trampling (seals)	present	M	–
Nuggets 5	Scientific Reserve	Halls totara, peppertree, mahoe, marbleleaf, supplejack, broadleaf	None	present	M	–
Taiaroa Head (Private)	Private land	Marram grass Sandhills	Trampling (human) Burrow collapse, Stock	present	L	–
Taiaroa Head (Reserve)	Nature Reserve	Rank exotic grass, iceplant	Erosion	present	H	–
Bushy Beach Reserve, Oamaru	Scenic Reserve	Ngaio, broadleaf, mahoe	None	present	M	–
Shag Point	Recreation Reserve	Shrubland	None	present	M	–
Sandymount, Otago Peninsula	Recreation Reserve	Flax *(Phormium tenax)*, elderberry, tussock	None	present	nil	–
Tunnel Rocks, Jack's Blowhole	Scenic Reserve	*Hebe elliptica*	None	present	L	–
Green Island	Nature Reserve	Taupata	Burrow collapse	absent	nil	2 km
Moturata Island, Taieri Mouth	Scenic Reserve	Bare soil Flax *(P. tenax)*	Burrow collapse Erosion	vulnerable	nil	1 km
Tuhawaiki Is., Jack's Bay	Recreation Reserve	Rank exotic grass	Burrow collapse	vulnerable	nil	50 m

Map 2: Detailed map of five breeding colonies of titi at Nugget Point .

Five colonies of titi exist at Nugget Point (Nuggets 1 - 5). Nuggets 3 and 4 are on adjacent spurs near the lighthouse. Map modified from Seddon et al 1989.



Map 3: Detailed map of Tuhawaiki Island titi colony showing study areas.



A number of other mainland colonies have existed around the Otago coast within the last 50 years but were not surveyed in this study. These colonies include:

Oamaru:	Boatman's Harbour (D. Houston, DoC, pers.comm.).
Moeraki:	Maukiekie Island - titi present in 1980's (C. Lalas, pers.comm.)
Otago Harbour:	Goat Is., Quarantine Is., Pudding Is., Heyward Point (information given to A. Wright by S. Sharpe, pers.comm.)
Otago Peninsula:	Mt Charles, Grassy Point, Lawyers Head, Maori Head, Highcliff, "Double Bay", The Chasm, Cape Saunders, Titikoraki - Ohinepuha, Penguin Beach (information given to A. Wright by S. Sharpe, pers.comm.); Pipikaretu (M. Ellison, pers.comm); Wharekakahu Island - 2 titi nests in 1980's (C. Lalas, pers.comm.).
Catlins:	Cosgrove Island (C. Lalas, pers.comm.); Rainbow Isles, Long Point (B. Murphy, DoC, pers.comm.).

4.2 Productivity of colonies.

4.2.1 Burrow occupancy at intensively studied sites.

Most mainland breeding colonies of titi are small (<100 burrows) with the exception of the colony on private land at Taiaroa Head (Table 2).

Burrows of "unknown" status were usually too long to accurately determine occupancy but they appeared to have been relatively active throughout the breeding season. Burrows which were presumed unoccupied were ones which had rarely been entered during the breeding season. Burrows which were occupied were those which contained an attempted nest. At Taiaroa Head (Reserve), another 16 burrows were found (aside from the 21 burrows studied) which were either rabbit or potential titi burrows. "Egg (no chick)" burrows were confirmed to contain an egg but no chick was produced. "Chick" burrows were the total number of burrows that had a chick found in them at some point from February to March 1993.

Table 2: The status of study burrows from six titi breeding colonies along the Otago coast. Burrow occupancy is given as a percentage of the number of study burrows minus the number of burrows where status was "unknown".

SITE	Total no. burrows	(No.study burrows) _ (unknown status)	Occupied burrows (% occupancy)	Egg (no chick)	Chick
Nuggets 1	122	116 - 25 = **91**	29 (32%)	4	25
Nuggets 3	19	19 - 6 = **13**	5 (38%)	2	3
Nuggets 4	50	50 - 8 = **42**	23 (55%)	4	19
Taiaroa Hd (Private)	620+	104 - 19 = **85**	39 (46%)	4	35
Taiaroa Hd (Reserve)	21 (+16?)	21 - 2 = **19**	11 (58%)	0	11
Tuhawaiki Island	1050+	44 - 6 = **38**	21 (55%)	2	19

4.2.2 Burrow occupancy at remaining study sites.

Rough estimates of occupancy at the remaining mainland sites varied from 0 - 62% (Table 3). Both Bushy Beach Reserve and Sandymount sites were observed for one evening each during fledging time (when chicks come to the surface) and no chicks were observed. Survey dates are given to indicate the varying levels of effort at each site and the time during the breeding season when estimates were obtained.

Table 3: Burrow numbers and occupancy estimates for some mainland sites. Question marks represent no available data.

SITE	Survey date(s)	Total no. burrows	Estimated occupancy	Mortality
Bushy Beach Reserve, Oamaru	Nov/Dec. 1992 Feb. 1993	56	34%	?
Shag Point	Nov. 1992 Mar. 1993	11	0%	2 adults
Sandymount, Otago Peninsula	Feb/Mar. 1993	49	59%	?
Nuggets 2	Throughout season	36	39%	1 chick
Tunnel Rocks 1, Jack's Bay	Nov. 1992	21	62%	?
Tunnel Rocks 2, Jack's Bay	Nov. 1992	84	55%	?

At Nuggets 5, 60 burrows were found and marked. The presence of an egg was only able to be confirmed in one of these burrows. High adult mortality occurred at this colony early on in the breeding season and negligible activity (i.e. the odd burrow being entered between each visit) was observed after 9 January 1993. Therefore, burrow occupancy (i.e. proportion of attempted nests) was probably < 2% (N=1).

At Green Island and Moturata Island, estimating burrow occupancy was complicated by the interaction between little blue penguins and titi and, at Moturata Island, by the extreme fragility of the soil causing burrow collapse. No estimate for burrow occupancy was obtained for either site.

Fifty burrows were marked on Green Island in mid-October 1992. It was difficult to determine whether burrows were occupied by little blue penguins or titi. However, it is thought that the number of nesting pairs and productivity of titi was probably very low on Green Island. A total of 18 adult titi were banded in mid-October and 3 more in early February. Copulation was observed between a pair of adults in the mid-October field-trip which would indicate that breeding was occurring on the island. Only one burrow was confirmed to contain a chick in early February.

Determining burrow occupancy was also difficult on Moturata Island due to the fragility of the island and the interaction between little blue penguins and titi. Three chicks were found in burrows during February so breeding is occurring on the island. Two groups of people sat out after dark on the island on 21 February 1992. Fifty-four birds were observed landing at the north end of the island and 3 at the south end

4.2.3 Fledging success at intensively studied sites.

Fledging success of titi varied from 0 - 100% (Table 4) with the colonies at the Nuggets having the lowest fledging success and Taiaroa Head and Tuhawaiki Island having relatively high fledging success. Nuggets 3 and 4 were clumped together due to small sample size and because they were adjacent colonies encountering the same conditions.

Table 4: Fledging success for five breeding areas of titi along the Otago coast. All % are a proportion of the total number of chicks.

SITE	No. of chicks	Presume dead	Unknown cause of death	Collapsed burrows	Preyed upon	No. fledged	Fledging success
Nuggets 1	28 *	10(36%)	6(21%)	0	12(43%)	0	0 %
Nuggets 3&4	22	3(14%)	1(4%)	0	9(41%)	9	41%
Taiaroa Head (Private)	58 * *	17 (29%)	2(3.5%)	2(3.5%)	0	37	64%
Taiaroa Head (Reserve)	11	0	0	0	0	11	100%
Tuhawaiki Island	29 **12	-(7%)	2(7%)	0	0	25	86 %

* includes 3 dead chicks from unknown burrows
** includes extra confirmed occupied burrows

4.3 Evidence of predation.

4.3.1 Adult predation.

Evidence of adult mortality from predation by cats or mustelids was recorded at Shag Point and Nuggets 5. At Shag Point, two adult carcasses were found in the entrances of 2 out of the 11 burrows. There appeared to be little other activity at this site so adult mortality may have been 100%.

At Nuggets 5, adult mortality occurred between November 1992 and 9 January 1993. One dead adult was removed from 12 (20%) of the burrows; 2 dead adults from 2 (3%) of the burrows; and one burrow (2%) had 3 dead adults removed from the burrow entrance between November and January. Two dead adults were found unassociated with a burrow. Therefore, the total number of dead adults found at Nuggets 5 was 21.

All mortality at Nuggets 5 was attributed to predatoon from cats or mustelids. Most adults were found in the burrow entrance with a head and/or neck wound. On 17 November 1992, a dead adult was extracted from the entrance of a burrow which revealed an adult ferret inside. On 29 November 1992, a lactating female ferret was trapped in the near vicinity of the burrow and 5 days later a dead baby ferret was found in the same burrow entrance indicating the burrow had become the ferret's den. Many predators drag prey off into holes to feed (Bomberg 1937; Campbell et al 1984) which would explain the occurrence of 3 adult carcasses being found at one burrow. Robertson (1976) indicated that titi chicks were susceptible to predation from ferrets.

There was no sign of adult predation at any of the other study sites although most sites in Table 3 were infrequently visited.

4.3.2 Chick predation.

Chick mortality at Nuggets 1 and Nuggets 3 & 4 ranged from 59 - 100%. Chick predation rates (number of chicks preyed upon as a proportion of number of dead chicks) at these sites ranged from 43 - 69% (see Table 4). The number of chicks preyed upon was determined from circumstantial evidence. Most "preyed upon" chicks were found in the entrance of burrows with head and/or neck wounds. Chick predation occurred at Nuggets 1 between late February and late April 1993 and at Nuggets 3 and 4 between mid-April and mid-May 1993.

One dead chick was also found at Nuggets 2 (see Table 3) but the cause of death was unknown.

In contrast, the sites at Taiaroa Head and Tuhawaiki Island had extremely high fledging success with no chick mortality being attributed to predation (Table 4).

5. DISCUSSION & CONCLUSIONS

5.1 Remaining Otago titi colonies.

All titi colonies studied are on secure land tenure except for the one on S. McGrouther s private land at Taiaroa Head. Habitat threats are minimal at most colonies although Moturata Island (and Taiaroa Head (Private) to a lesser extent) is subject to burrow collapse. Moturata Island is presently too fragile for any intensive study to investigate titi productivity. The high level of predator control around the albatross colony at Taiaroa Head may influence the success of the titi breeding colonies in the area. The high level of fledging success at Taiaroa Head (Reserve) of 100% could be attributed to its locality within the Nature Reserve where there are high levels of predator control and low human disturbance or trampling.

5.2 Productivity of Otago titi colonies.

This preliminary study initiates a long-term monitoring programme of titi in Otago. A number of methodological problems were encountered in this study which will be refined for the long-term monitoring.

The problem of determining the occupancy of titi burrows is compounded by long burrows, interactions between titi and other burrow-nesting seabirds (eg. little blue penguins), burrow collapse, and chicks potentially moving between burrows during fledging. Using "barricade" knockdown was helpful in determining occupancy if burrows were checked regularly but an unknown proportion of burrows are used by pre-breeders. Other animals, such as rabbits, are also likely to enter burrows. The fibre optics "burrowscope" was useful for confirming the occupancy of burrows less that 1.5 m long. However, the "burrowscope" used was not entirely appropriate for checking the occupancy of a large number of burrows as it was relatively cumbersome and difficult to manoeuvre down long or curving tunnels. Burrows up to 3 m long were virtually impossible to study without installing "observation hatches" over the nesting chamber. This was only practical at sites which were not steep and was also inappropriate for some burrows which curved or were obscured with rocks and tree roots.

Estimates of occupancy did not include burrows of "unknown" status (i.e. burrows too long to accurately determine occupancy) so may be an underestimate of occupancy. A high proportion of adult breeding pairs return to the same burrow each year (Warham 1990) and may lengthen the burrow from year to year during nest preparation. Therefore, longer burrows may potentially be more successful as they may be occupied by older, more experienced breeding pairs.

Burrow occupancy at Tunnel Rocks is probably over-estimated as it was based on smelling the burrows near the start of the season (early November) when a high proportion of pre-breeding adults are active. From the intensively studied burrows it was found that not all occupied burrows smelled all the time. Determining whether a burrow smells is subject to weather conditions (i.e. smell was less obvious when ground was wet) and observer variability. The problems of using burrow smell as a survey method is compounded when other animals, such as rabbits or little blue penguins, use the same burrows. Therefore, the "musky" smell of titi burrows is probably only useful as an indicator of occupancy rather than a method on its own.

Alternative methods of determining occupancy are being investigated and funding applications will now be prepared to build a "burrowscope" which is more appropriate for this type of work. Until the robustness of cruder measures of occupancy are checked, the estimates given here must be considered approximate.

The remaining mainland breeding colonies of titi around Otago are all small with the exception of the relatively large colony on private land at Taiaroa Head. Smaller colonies may not currently be large enough to maintain long term persistence.

Egg loss at studied colonies appeared to be quite low but was probably underestimated as it was difficult to determine whether burrows contained eggs. The majority of burrows with "eggs" recorded were ones which had egg remains found in the tunnel after having been cleared out from the nesting chamber by the adult. Therefore, there may have been other burrows with egg remains which were not cleared from the nesting chamber or which were not brought near enough to the burrow entrance to be visible from outside. It is also unknown how long egg remains last, so the ones recorded may not necessarily have been from the 1992/93 breeding season.

Burrow occupancy (proportion of burrows with an attempted nest) ranged from 32 - 58% for the intensively studied sites (Table 2) and ranged from 34 - 62% for the infrequently visited sites (Table 3). There may be a negative correlation between % burrow occupancy at colonies and amount of predation. Tuhawaiki Island colony is relatively large (> 1060 burrows) and had high burrow occupancy (55%) and high fledging success (86%) for the 1992/93 breeding season. Tuhawaiki Island was assumed to be predator-free although may be vulnerable to invasion from predators due to its proximity to the mainland. Taiaroa Head also had high productivity and low predation rates.

5.3 Evidence of adult and chick predation at mainland colonies.

Fledging success was mainly affected by predation. However, at Taiaroa Head (Private) two chicks (9.5% of dead chicks) died after burrow collapse. A proportion of chick carcasses were too decayed to ascertain cause of death so some of these may also have been preyed upon. It is also likely that some of the birds whose deaths were attributed to predation, died from other causes and were scavenged by predators post-humously.

The four intensively studied sites at Nugget Point appear to be under considerable threat from mammalian predation. Titi are a long-lived seabird with delayed maturity and low productivity so adult mortality has a high impact on the breeding population. Nuggets 5 suffered high adult mortality due to predation near the start of the 1992/93 breeding season and before any chicks were produced. This colony may not be a self-sustaining breeding colony but may mainly be composed of pre-breeders. It could be that pre-breeders spend a higher proportion of time at the surface than would a breeding population and therefore the predation level would be high. C. Lalas (pers. comm.) found 120 "occupied" burrows (determined from their smell) at the site in the mid-1980's as well as evidence of adult and chick predation. Therefore, the colony may have previously been a productive and self-maintaining population which is now heading for extinction. As young birds do not come back to breed for probably 5 or 6 years (Warham 1990), recruitment back into this population may still be possible.

Nuggets 1, 3 & 4 are also subject to predation. There was no sign of adult predation at these sites but chick predation ranged from 43 - 69%. Chick predation at Nuggets 1 occurred when chicks were relatively young. However, at Nuggets 3 & 4, chick predation occurred during the 3-4 weeks when fledging occurred. Therefore, estimates of predation may be underestimated at some sites which were not checked regularly before fledging.

In contrast to Nugget Point, the sites at Taiaroa Head and Tuhawaiki Island had extremely high fledging success with no chick mortality being attributed to predation. The site within the albatross colony at Taiaroa Head had the highest fledging success of 100% although the sample size was relatively small (N=11). This area has had intense predator control for a number of years due to the presence of the royal albatross colony. Tuhawaiki Island, which is assumed predator-free, had the next highest fledging success of 86%. The colony on S. McGrouther's farm at Taiaroa Head also had a relatively high fledging success of 64%. This colony is by far the largest mainland colony remaining in Otago (> 620 burrows) and appears to have increased from A. Wright's estimates of 350 - 450 burrows in 1970 (Robertson 1976). At this early stage in the study, it appears this Taiaroa Head colony may be doing well. One possibility is that the sand dune habitat contains a large number of rabbits (Bruce 1991, Ratz et al 1992) so predators may predominantly feed on rabbits and predation may be naturally low. Predator control within the albatross colony (about 500m away) could also have led to a nursery area being established as most chicks return to their natal area to breed. Predator trapping at Taiaroa Head (Private) was voluntarily started in 1992 by Lyndon Perriman which may also be a reason why there was no predation of titi chicks there during the 1992/93 breeding season.

Although it appears that some predation of mainland colonies is ongoing (see Robertson 1976), predation is patchy in time and space. Predation of seabirds is sporadic and can vary greatly from year to year (Moller et al 1992). The proportion of yellow-eyed penguin chicks that were preyed upon in several Otago Peninsula sites varied from 4 - 62% in different years (Darby and Seddon 1990). Therefore, breeding colonies of titi need to be monitored for a few successive years before any concrete conclusions can be made as to the importance of predation.

Many of the small remaining mainland colonies may be sustained by immigration from the large populations around Foveaux Strait or from colonies on near-shore islets around Otago.

6. FUTURE RESEARCH AND MANAGEMENT RECOMMENDATIONS

6.1 Future research

6.1.1 Population Viability Analysis (PVA) is a useful tool in providing a general understanding of what determines the persistence of small populations and in estimating minimum viable population (MVP) sizes (i.e. populations that are large enough to permit long-term persistence). As part of the long-term monitoring programme, population viability analysis, using computer simulations, will now be applied to small mainland and near-shore islet populations of titi. Modelling will be useful in gaining an understanding of factors influencing the survival of titi breeding populations. Information will be gained on the importance of such things as predation and immigration to the long-term survival of these populations. Estimates of MVP can be used as management targets to apportion control efforts amongst colonies. The preliminary model could be up-dated as the long-term monitoring provides more reliable breeding information.

6.1.2 A genetics-based study determining the rates of immigration to mainland colonies from large off-shore colonies.

6.1.3 It has been shown that the reproductive success of seabirds is affected by food availability. Long-term monitoring of the survival of titi will provide information on marine food-chain fluctuations which may be also influencing the survival of other endangered seabirds, for example the yellow-eyed penguin. There is detailed knowledge of titi diet in the northern hemisphere but more data is needed on their diet during the breeding season in the southern hemisphere. Indicators of marine-food failure will assist conservation managers in deciding when to intervene in other threatened seabird recovery programmes, and to discern reasons for changes in unmanaged populations.

6.2 Management recommendations

6.2.1 Colonies that have been known to exist in the past (eg. within the last 50 years) need to be visited and surveyed. In particular other productive mainland colonies may exist on private land in Otago.

6.2.2 Monitoring the impacts on titi colonies needs to be continued. Although predation has been confirmed as a threat during this past breeding season, long-term monitoring is needed so predation, along with other threats can be put into context. Monitoring sites where these threats appear during the next two seasons will also allow better targeting of where to apply management effort in the future.

6.2.3 Some mainland colonies may already be too small to be self-sustaining but predator control may be an option in the future to quickly boost these colonies, as young birds may still return to attempt breeding. This will be important if immigration is a significant contributor to population size. Monitoring breeding success and survival of titi needs to continue for the next two years before recommendations on predator control can be given effectively.

6.2.4 Two further years of monitoring, and the refining of a preliminary PVA model would allow the effects of differing levels of titi harvest to be simulated. If legal harvesting was to commence, the model could estimate maximum sustainable yields. The model could then focus an experimental harvest management regime, which when coupled with ongoing population monitoring could check the validity of the model and efficacy of harvest management protocols. Sustainability of the resource can thereby be assured while the tangata whenua gain access to their traditional food species. In view of the small size of mainland colonies, experimental harvest is only likely to be viable and sustainable on near-shore islets of the Otago coast. Until long-term predator control and habitat management has built-up numbers there seems little prospect of sustainable harvest on mainland colonies.

6.2.5 There are no immediate land tenure issues associated with the colonies studied in this report although other small colonies may exist on private land around Otago.

6.2.6 Access to fragile colonies such as Moturata Island needs to be restricted to reduce habitat destruction.

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