An infra-red scope for assessing sooty shearwater burrow occupancy

Sheryl Hamilton, Justine de Cruz, Christine Hunter and Henrik Moller
Department of Zoology
David Fletcher
Department of Mathematics and Statistics
University of Otago
PO Box 56
Dunedin

Published by
Department of Conservation
Head Office, PO Box 10-420
Wellington, New Zealand

This report was commissioned by the Science & Research Division

ISSN 1171-9834

Reference to material in this report should be cited thus:

Hamilton, S., de Cruz, J., Hunter, C., Moller, H. and Fletcher, D. 1998
An infrared scope for assessing sooty shearwater burrow occupancy. *Conservation Advisory Science Notes No. 187.* Department of Conservation, Wellington.

Keywords: *Puffinus griseus,* muttonbirds, burrow occupancy, burrowscope reliability, Rakiura Ecological Region

Abstract

The *Kia Mau Te Titi Mo Ake Tonu Atu (Keep the Titi Forever)* research programme aims to investigate the sustainable harvesting of titi (sooty shearwater) chicks as well as monitoring mainland colonies which are threatened due to predation from introduced mammals. An infra-red burrowscope is used to determine breeding success and to assess population trends and is fundamental to the whole research programme. There have been preliminary indications that the burrowscope fails to detect some titi chicks in their burrows. This pilot study illustrated the potential complexity of burrow systems and gave strong indications that the current burrowscope methodology and analysis of burrowscope data for detecting titi eggs, young chicks and pre-fledging chicks is inaccurate and imprecise.

1. Introduction

The *Kia Mau Te Titi Mo Ake Tonu Atu - Keep the Titi Forever* research programme aims to investigate the sustainable harvesting of titi (sooty shearwater, *Puffinus griseus)* chicks ("muttonbirding") on Rakiura Titi Islands. Monitoring and comparing titi ecology and behaviour at both harvested and non-harvested sites complements measures of reproductive and survival parameters to predict population trends. The long-term study will help ensure the persistence of both the bird and the practice of muttonbirding, which is a culturally important traditional practice of Rakiura Maori.

The *Kia Mau Te Titi Mo Ake Tonu Atu* research programme is also concerned with the conservation of mainland breeding colonies of titi. Although there is no concern for the persistence of the abundant offshore island titi populations (Warham and Wilson 1982), many mainland breeding colonies of titi are thought to have become extinct (Jackson 1957, Hamilton *et al.* 1997) due to predation by introduced small mammals (Hamilton, subm.). The importance of mainland conservation in general is becoming increasingly recognised (Clout 1989). Detailed information on mainland and near-shore island colonies is scarce (Hamilton *et al.* 1997) and, before conservation effort can be directed towards protecting colonies, trends in the size of colonies need to be confirmed and any threats to their long-term persistence quantified.

When studying the breeding biology of titi, a burrow-nesting seabird, accurate identification of burrow occupants and ascertaining nest presence is essential. This can be extremely difficult, especially for burrows up to three metres long (Hamilton, subm.). Traditional methods to determine occupancy from sound, smell, sign at burrow entrance, or probing with a stick or wire have proved to be far too inaccurate to reliably index population size or breeding success (Hamilton, subm.). The principal method for determining burrow occupancy in recent years for Procellariiformes has been to use a "burrowscope" (Dyer and Hill 1991; Hamilton, subm.). The burrowscope has an infra-red lit camera at the end of a three metre length of hose that can be pushed down a burrow tunnel while a picture of the burrow contents is projected on to a video monitor at the burrow entrance. Despite increasing international use of burrowscopes, there have been no published formal checks of their reliability. There are already preliminary indications in our titi studies that the burrowscope fails to detect some chicks (Hamilton et al. 1996). It is critical, therefore, to assess the error rate of the burrowscope in order to obtain accurate estimates of burrow occupancy, breeding success, proportion of chicks harvested, and titi population abundance.

While assessing burrow occupancy, there have been indications that sometimes layers of tunnels overlie one another. It is possible that the burrowscope misses a higher proportion of the eggs and chicks at lower levels than at upper levels of this complex structure. The quality of nesting chambers and the birds using them may also vary amongst layers, so that the burrowscope may underestimate either the number of birds at hand, or bias measures of the quality of the ones present. Potentially, both factors will affect estimates of the impact of harvesting on the titi population, as well as the assessment of threats to mainland colonies.

To assess the reliability of the burrowscope, we investigated two types of error. Firstly, the precision of the burrowscope was assessed by determining how consistent the results were among repeated burrowscope checks from the burrow entrance on a fixed sample of nests. Secondly, we determined the accuracy of the burrowscope (i.e., whether or not we were able to correctly detect the presence of a nest). If precise, the burrowscope method has utility as a relative population index for monitoring trends. However, accuracy is also needed in order to estimate the proportion of chicks harvested and the absolute abundance in different colonies. Good precision is also needed to reliably estimate breeding success and the timing of any egg/chick losses.

The only way of assessing burrowscope accuracy was to dig up study burrows to confirm their contents after they had been surveyed from the surface with the burrowscope. As the time it takes for titi to recolonise a disturbed area is unknown (Richdale 1963), monitoring the area after reconstruction will answer questions of great concern to the Kaitiaki of the titi harvest, the Department of Conservation, and researchers interested in restoring depleted colonies. In addition, as the pilot study described here required disruption of breeding attempts, we took the opportunity to measure stage of egg development as well as recording the proportion of viable eggs.

2. Objectives

- To measure the precision of the burrowscope for determining burrow occupancy.

- To measure how accurately the burrowscope detects the number of nests at the incubation stage by excavating all the study burrows after surveying with a burrowscope.

- To predict sample sizes required for future replication and refinement of this experiment to more accurately estimate the precision and accuracy of the burrowscope.

- To measure and describe the status of eggs removed from nests.

- To describe bird activity in the study plot after excavation of all burrows by the research team.

- To summarise banding data for adults originally nesting in the study plot, and the proportion of birds remaining in the area during the rest of the season, so that the impact of the excavation can be monitored.

- To provide detailed maps and photographs of the study plot before, during, and after the excavation.

3. Methods

3.1 GENERAL LONG-TERM STUDY PROGRAMME

On Northeast Island in The Snares (48°01'S, 166°36'E) and Whenua Hou (Codfish Island, 46°45'S, 167°38'E), titi study sites were monitored during the 1996/97 breeding season as part of the long-term research programme. For instance, Snares A contained 311 marked study burrow entrances and Whenua Hou A contained 174 marked study burrows. At these two sites, nest checks were made using the burrowscope during incubation (2 December 1996 - 9 January 1997), young chick stage (16 January - 11 February 1997) and pre-fledging chick stage (4 - 10 April 1997). Amongst burrows that could have observation holes dug to the nesting chamber (i.e., those burrows in flatter areas and not too obstructed by tree roots), a random two-thirds had observation holes established as close to the nesting chamber as possible. These observation holes were covered with either a wooden hatch or a plug of soil, sticks and debris (see Hamilton et al. 1996 for Whenua Hou A details).

3.2 THE SNARES INTENSIVELY STUDIED SITE (SNARES C)

In November/December 1996 on Northeast Island, The Snares, a small plot (approximately 10 m x 10 m) containing 100 burrow entrances was marked out, and all entrances were mapped relative to each other (the plot was designated Snares C in the overall research programme). After familiarisation with a large area of Northeast island, the area for the plot was arbitrarily chosen as appearing to have similar burrow density to the majority of areas under *Olearia* *lyallii* canopy (the dominant canopy covering about 80% of the island; Rance and Patrick 1988) and for its proximity to the hut. A sample size of 100 burrow entrances was arbitrarily chosen. During incubation, all burrow entrances were checked, using the burrowscope three times over approximately a two-week period, for occupancy, the presence and location of nests, and the presence/absence of an egg (23, 24, 25 November 1996 for the first check; 28, 29 November for the second check and 8, 9 December for the third check). The same two researchers (S. Hamilton and N. Alterio), using the same burrowscope, carried out all three checks, although for the first check N.A. operated the camera hosing and S.H. operated the monitor, while for the second and third checks S.H. operated the camera hosing and N.A. operated the monitor.

After the third burrowscope check, the study plot was excavated between 10 and 15 December (see Photos 1 and 2) to determine the proportion of nests missed or recorded more than once by the burrowscope surveys. From each burrow entrance, the tunnel direction was identified and a hole was excavated into the tunnel at arm's length from the entrance. This was repeated along the remainder of the tunnel so that all walls of the tunnel and associated tunnel branches could be confirmed. Every egg found was defined as a "nest". Eggs were often incubated by an adult and were usually on a pile or scattering of *O. lyallii* leaves and sticks. Each nest site was mapped and measured from any entrances which could possibly have been associated with that nest. All adults removed from nests were banded and released away from the study site at the cliff edge. All eggs were weighed and measured (length x breadth). The approximate embryo length in centimetres and the presence/absence of an egg tooth and feather follicles on the embryo were recorded (photographs and records of the embryo stages are held by the research team).

On 16 January 1997, during a subsequent field trip to The Snares, the study plot was photographed (Photo 3). On 21 January 1997, the excavation holes were filled-in using soil that had been originally removed during the excavation and piled at the study plot edges. The boundary of the study plot was marked with numbered aluminium stakes. One half of the plot was left with 22 of the original burrow entrances (with approximately 20 cm long tunnels) in order to potentially provide stimulation for enhanced recolonisation of the area (Photo 4). The other half of the plot was filled-in and left with no "starter" entrances. Part of the post-hoc excavation analysis required dividing the study plot into four 5 m x 5 m areas (areas a,b,c,d) so that variation in burrow accuracy results between these areas could be measured.

On 25, 26 and 29 January 1997, the study plot was visited at night to observe adult titi behaviour, to recapture and record previously banded adults, and to catch and band any new adults using the area. On a subsequent field trip in April/May 1997, random banding of adults caught on the surface was carried out in the area surrounding the study plot. All burrows in Snares C were probed with the burrowscope on 30 January and 12 April 1997 to see if there were any burrow occupants and to measure the length of new tunnels. The study plot will be monitored for use and recolonisation over the next ten years and burrows near the study plot will be checked to see if they are being used by displaced adults.

4. Results

4.1 PRECISION OF THE BURROWSCOPE FOR DETERMINING OVERALL BURROW OCCUPANCY

At the long-term monitoring site Snares A, the occupants of 101 nests were recorded on each of three checks (incubation, young chick, and pre-fledging chick) during the breeding season (Table 1). If an egg or chick was recorded during at least one scoping period (120 eggs or chicks; columns 1 - 6 from Table 1), then we considered this to be evidence of a nesting attempt. Therefore, there were a possible total of 221 nesting attempts at Snares A. Grouping the data where a chick was recorded at the pre-fledging chick stage (i.e., columns 3, 4, 5, 7 fromTable 1), there were 128 pre-fledging chicks produced in the study site. Since column 1 could indicate failure of eggs and columns 2 and 6 could indicate death of chicks (before the pre-fledging scope check), they cannot necessarily be assumed to be signs of inaccuracy of the burrowscope. Ignoring columns 1 and 6, we missed a minimum of 14% and 6% at the egg and young chick stages, respectively, at this site (i.e., columns 2, 3,4 divided by column 8 for eggs; columns 3,5 divided by column 8 for young chicks). If there were no egg and chick losses, we missed 14%, 27%, and 42% at the egg, young chick, and pre-fledging stages, respectively (i.e., columns 2, 3, 4 divided by column 8 for eggs; columns 1, 3, 5 divided by column 8 for young chicks; columns 1, 2,6 divided by column 8 for pre-fledging chicks).

At Whenua Hou A, 32 nests were recorded on each of three checks (incubation, young chick, and pre-fledging chick) throughout the season (Table 2). There were possibly another 39 nesting attempts consisting of nests where an egg or chick was recorded at some stage during the breeding season (i.e., columns 1 - 6 fromTable 2). Grouping the data where a chick was recorded at the pre-fledging chick stage (i.e., columns 3, 4, 5, 7 from Table 2), there were 46 pre-fledging chicks produced in the study site. Ignoring columns 1 and 6 (see previous paragraph), we missed a minimum of 20% and 7% of eggs and young chicks, respectively, at this site (i.e., columns 2, 3, 4 divided by column 8 for eggs; columns 3, 5 divided by column 8 for chicks). If there were no egg and chick losses, we missed 20%, 35%, and 35% at the egg, young chick, and pre-fledging stages, respectively (i.e., columns 2, 3,4 divided by column 8 for eggs; columns 1, 3, 5 divided by column 8 for young chicks; columns 1, 2, 6 divided by column 8 for pre-fledging chicks).

For the first burrowscope check at Snares C, 68 nests were recorded (7 incorrectly); for the second check 76 nests were recorded (16 incorrectly); and for the third check 95 nests were recorded (22 incorrectly) giving a 28% error rate in the number of nests recorded between the three consecutive burrowscope checks (Table 3). Of 91 nests containing eggs at Snares C (known from the later excavation of the study plot), the proportion of nests that were correctly recorded using the burrowscope varied by 14% during the three consecutive burrowscope checks over a two-week period (Table 3).

4.2 ACCURACY OF THE BURROWSCOPE IN DETECTING NEST NUMBER DURING INCUBATION

Of the 91 nest sites at Snares C, 15 (16.5%) were not found during any of the three surveys made with the burrowscope. Only 46 (50%) were recorded correctly during on all three burrowscoping checks. The first two burrowscope checks gave similar proportions of correctly identified nests (67% and 66% respectively) (Table 3). The proportion of correctly identified nests increased to 80% for the third burrowscope check. However, the third burrowscope check also had the highest number of nests that were recorded twice from two different entrances. For each of the three burrowscope checks, one nest was recorded when it did not actually exist (Table 3) and these were from a different burrow entrance for each check.

At Snares A during the young chick burrowscope check in January/February 1997, of 56 burrows containing nests and with established observation holes, six nests (11%) were only detected using the observation holes rather than by burrowscoping via the burrow entrance. At Snares A during the pre-fledging chick check (in April 1997), of 42 burrows containing nests and with established observation holes, 7 nests (17%) were only detected using the observation holes rather than by burrowscoping via the burrow entrance.

4.3 SAMPLES NEEDED TO BETTER ESTIMATE BURROWSCOPE ACCURACY

For Snares C, the % error in the total number of nests recorded decreased for each subsequent burrowscope check. The % error was 25% for the first scope check, 16.5% for the second scope check, and 4% for the third scope check (i.e., $[(A+B^{-}V) - (C+D)]/(C+D) \times 100^{-1}$ from Table 3).

To simulate replicated plots and their variation, we divided Snares C into four 5 m x 5 m areas (as 5 m x 5 m plots would be more practical and appear to be sufficient in size for future replicated sampling) which gave a mean % error in total of -14.4% and a standard deviation of 22.6%. If three such 5 m x 5 m plots are sampled, the 95% confidence interval (CI) results in an estimate for % error in accuracy of 26% (Fig. 1). Thirteen samples (5 m x 5 m plots) are needed to reduce this to a 10% error in accuracy, and 56 samples are needed to achieve a 95% CI with 5% error. Relatively little gain in accuracy is achieved once 20-30 samples are obtained (Fig. 1).

4.4 STATUS AND MEASUREMENTS OF EGGS REMOVED

Ninety-one eggs were removed from the excavated site. Of these, 89% (81) were fertile and contained developing embryos. The average egg length was 75.89 mm (N = 88, SD = 3.6, range 56.0 - 81.8), the average breadth was 49.46 mm (N = 88, SD = 1.3, range 47.0 - 52.6), and the average weight was 96 g (N = 58, SD = 7.2, range 82 - 112). Sixty-eight of the eggs had adults with them and another 17 eggs were still warm from incubation but the adult had moved off during the excavation process. The Snares egg dimensions appeared to be similar to eggs measured by Richdale (1963) from Whero Island in length (Snares 75.9 mm; Whero 77.4 mm, N = 72, SD = 2.9, range 72 - 88), breadth (Snares 49.5 mm; Whero 48.3 mm, N = 65, SD = 1.8, range 44 - 52), and weight (Snares 96g; Whero 92.9g, SD = 8.5, range 70-115).

4.5 BANDING DATA AND POST-EXCAVATION ACTIVITY IN SNARES C

From 0330 hours to 0530 hours (standard time) on 25 January 1997, 43 days after the Snares C excavation was completed and four days after the excavation was filled-in, pairs of adult titi were observed mutual-preening, vocalising and sitting close together on the surface within the Snares C study plot. One copulation was observed between a pair of titi at approximately 0430 hours (S. Hamilton, pers. obs.). Over the two hour period, 42 adults were caught within the 10 m x 10 m plot (Table 4). Of these, 45% were adults that had been banded when they were removed from nests during the December excavation.

From 0230 to 0500 hours on 26 January 1997, and from 2040 to 2140 hours on 29 January 1997, an additional 16 banded adults that had been removed during the excavation were recaught. An additional 64 new adults were also caught and banded (Table 4).

On 30 January 1997, nine days after Snares C had been filled-in, the burrows in the study plot were burrowscoped. On one half of the plot (Side A), in addition to the 22 "starter" burrows, 14 new burrow entrances had been established by titi. On Side B, which had been left with a smoothed surface, 28 new burrow entrances had been established by titi. The 22 "starter" entrances had an average tunnel length of 80 cm (SD = 23) and the 42 new entrances had an average tunnel length of 82 cm (SD = 35). These lengths were not significantly different from the 138 unoccupied burrow tunnels (average length = 88 cm, SD = 30) at Snares A at the same time of year (t-test). Adult titi were present in 12 (19%) of the 64 burrows at Snares C in January.

On 12 April 1997, the burrows in Snares C were again burrowscoped. An additional 15 new burrow entrances were discovered to have been dug since the last site check. This gave a total of 79 entrances in the plot (including the "starter" entrances; see Fig. 3), compared with the 100 burrow entrances that were there before the excavation. All 79 burrows were unoccupied. While banding in the area around Snares C in April/May 1997, no banded titi from the study plot were caught.

4.6 MAPS AND PHOTOGRAPHS

The complexity of the titi burrow systems in the excavated Snares C study plot is illustrated in Fig. 2. Only five out of the 100 entrances led to a self-contained burrow and were not connected to any other burrow entrance. The most complex system connected 37 burrow entrances and contained 36 nests (containing eggs). Many nests could be reached (and therefore burrowscoped) from more than one entrance, which meant that sometimes nests were recorded more than once from different entrances during burrowscope checks. Some nests were around awkward corners or at such distances from burrow entrances that they were not reached at all during burrowscope checks. A large *O. lyallli* tree was located in the middle of the study plot and it was impossible to reach all spaces underneath the tree. Therefore, it is possible that additional nests under the tree were not located. In three locations in the study plot, there were ramp systems leading to levels lower down. The first example was for burrow entrance #16 which had a ramp leading to a nest beneath nest site 55. At burrow entrance #22, there was a 20 cm step down from nest site 6 to nest site 5 (Fig. 2). Burrow entrance #161 led to an upper and lower level with nest site 67 located on the upper level.

The excavation photographs are shown in Photos 1 - 4. The excavation process is shown in Photo 2 where spades and small trowels were used for digging and tape measures were used to measure distances from burrow entrances to nest sites. Photo 3 illustrates some of the square spade holes dug to locate the walls of a burrow tunnel. Photo 4 shows Snares C the day the excavation holes were filled-in (21 January 1997) using soil that had been originally removed and piled just outside the study plot in December 1996. Owing to strong winds that day, many *O. lyallii* leaves quickly fell to cover the ground surface.

5. Discussion

5.1 PRECISION OF THE BURROWSCOPE FOR DETERMINING BURROW OCCUPANCY

It is difficult to interpret breeding success from the data obtained using the burrowscope at Snares A and Whenua Hou A. This is due to the large proportion of nests missed at least once during burrowscope checks made at three different breeding stages. Excluding nests where only the egg was recorded (i.e., nests which may have had hatching failures) and nests where no "pre-fledging chick" was recorded (i.e., these chicks may have died), 17% of nests at Snares A and 23% of nests at Whenua Hou A had no nest occupant recorded at an earlier check but then recorded an occupant existing at a later check. Because of the obvious inaccuracies of burrowscoping, the proportion of true failures in the "egg only recorded" and "pre-fledging chick missed" categories would be unknown compared with those that were just unrecorded. This pilot study indicates a potential lack of precision that could render current estimates of breeding success from study burrows unreliable.

It could be expected that a higher number of young chicks than pre-fledging chicks would be missed by the burrowscope, as young chicks are small, usually unaccompanied by an adult, and often hidden in large amounts of leaves and other nesting materials. Pre-fledging chicks are large and easier to see in the burrow tunnel, and sometimes move closer to the burrowscope camera.

However, owing to the mobility of pre-fledging chicks, they may also move further down burrow tunnels and, if burrows are connected as they were for Snares C, they could become more visible from other burrow entrances. It may also be possible that, by the pre-fledging chick check, a few chicks may have surfaced from underground and moved into another burrow tunnel.

The preliminary results presented in this report indicate that, for repeated checks of the same nest sample, the burrowscope missed a large proportion of nests that were present (up to 34%), and that repeated checks using the same burrowscope and the same researchers over a short period gave widely varying results. The same two researchers carried out all three repeated burrowscope checks (precision checks), although for the first check N.A. operated the camera hosing and S.H. operated the monitor. For both the second and third checks, S.H. operated the camera hosing and N.A. operated the monitor. There was no evidence that switching jobs affected the results, as the first two repeated checks gave similar results. The third repeated check gave a much higher proportion of correctly recorded nests, as well as a higher number of double recordings of the same nest from more than one entrance. Although attempts were made to put the same amount of time and effort into each repeated check, these may have varied, in particular according to how cold, wet and uncomfortable conditions were for burrowscope operators at the time. Likewise, although researchers attempted to treat each repeated check as new and independent so as not to be biased by prior knowledge of occupied burrows and nest locations from the previous checks, it is likely that some bias would have occurred. This may partly explain why the third repeated check yielded the most successful results in terms of correctly finding nests.

Occasionally a nest that did not exist was recorded using the burrowscope and this was probably due to researchers misinterpreting other objects on the video monitor (e.g. the light colour of large *0. lyallii* leaves) as an egg under an adult. During short-tailed shearwater *(Puffinus tenuirostris)* nest checks, chicks, which were easier to locate than eggs, were sometimes found in burrows where no egg had been recorded (Serventy & Curry 1984).

Another source of burrowscope error was recording the same nest more than once from different burrow entrances. It is usually difficult to tell the exact direction underground to which the burrowscope is being manoeuvred, and therefore it is difficult to ascertain whether the same nest site is being repeatedly recorded.

5.2 ACCURACY OF THE BURROWSCOPE IN DETECTING NEST NUMBER AT INCUBATION

Ninety-one nests (eggs laid) were uncovered when the experimental plot was excavated. Only 50% of the 91 nests were correctly recorded during all of three repeated burrowscope checks at Snares C. The most accurate burrowscope check (third repeated check) recorded only 80% of the nests present. Data from observation holes at Snares A showed that during the young chick check, 11% of nests were missed using the burrowscope from the burrow entrance, and during the pre-fledging chick check, 17% of nests were missed. The proportion of missed nests is likely to be affected by the complexity of the burrow system and the number of connections between burrows. Our preliminary surveys for Whenua Hou A and Snares A suggest that the inaccuracy observed at the single excavated site will recur elsewhere. However, it is clear that, to continue using the burrowscope as the principal method for determining burrow occupancy in the titi research programme, an understanding of the representativeness of these results is needed.

Continued improvement of the burrowscope design may increase the success rate in detecting nests. One possible improvement is to incorporate a thermo-indicator (Paul Jansen, pers. comm.) or heart-beat recorder (Dr Jim Gaw, pers. comm.) in the casing that surrounds the camera and lighting, so that it provides an additional indicator of whether there is an animal present down the burrow. However, these additional devices alone would not provide any useful data on the burrow occupants, as the species and age of the occupant would be unknown.

5.3 EXTENT OF SAMPLING

This pilot study gives grounds for optimism that disrupted areas will be rapidly restored by the titi themselves. The amount of activity that was observed at Snares C only a month post-excavation was extremely encouraging, especially since 36% of the original adults were still present. Recolonisation of different areas may be affected by the size and density of the titi population there. On The Snares, an estimated 2.75 million pairs of titi breed (Warham & Wilson 1982) and it may be that a large number of adults that are of breeding age but are restricted by competition for burrows and nesting space, will recolonise a new area quickly. Likewise, at other study sites, other species (e.g. *Eudyptula minor* and other petrel spp.) may be able to colonise an excavated area before titi have a chance to recolonise. In view of the highly invasive nature of the excavation at Snares C, monitoring to follow re-use and recolonisation of Snares C has been instigated as part of the long-term *Kia Mau Te Titi Mo Ake Tonu Atu* programme. Any extension of this study to other areas must also incorporate a follow-up programme to monitor the rates of recolonisation of the areas. Studying the variation between sites in these rates of re-use of excavated areas is in itself interesting, as it may reveal density-dependence in re-use rates. If present, density-dependence has profound implications for the overall predictions of harvesting impacts. Therefore, studies of burrowscope accuracy can concurrently address different questions using the same data. Experimentation with and without "starter" entrance holes and different filling-in regimes may also reveal valuable lessons on how to facilitate colony restoration. Such lessons may assist conservation programmes for other species.

We now propose that this pilot study be repeated and replicated on other study islands in order to quantify the burrowscope error in determining burrow occupancy. We wish also to ascertain whether or not the errors shown in this pilot study are representative. To minimise disturbance, we suggest that the size of plots be reduced to 5 m x 5 m. Dug-up plots will be needed on a variety of sites with different slopes, burrow densities and occupancy rates (because the accuracy of the method may vary with these parameters). Detectability is likely to vary between egg and chick stages. Accordingly we urge that the dug-up plots are replicated within The Snares and Whenua Hou (where burrow density is comparatively low, Hamilton *et al.* 1996).

These estimates (from Fig. 1) suggest that at least 13 areas (5 m x 5 m plots) should be sampled per level investigated (e.g. different islands, different breeding stages) but that 50 areas would nearly achieve a 95% confidence interval for a 5% error in accuracy. The 10 m x 10 m plot (the equivalent of four plots of 5 m x 5 m) took four person-days to set up and complete one burrowscope check (assuming replicates of this pilot study require only one burrowscope check per plot), 12 person-days to excavate, and two person-days to fill-in. This amounts to a total of 18 person-days. Therefore, 13 and 50 plots (5m x 5m) would take 58 and 225 person-days respectively, repeated for each parameter tested (e.g., different islands, different breeding stages). This amount of effort is obviously far too large to be practical or desirable if an attempt is made to estimate all island and egg/chick stage effects. Alternatives may be to use an analysis of covariance or multiple logistic regression approach to explain some of the variation in accuracy between plots from burrow topography and dimensions. It is hoped that, with additional excavated study plots on a number of study sites, we may be able to develop a correction factor for the proportion of nests that the burrowscope misses.

Although dividing the 10 m x 10 m excavated area into four 5 m x 5 m plots allowed us to simulate four replicates, it did not give true replication. Therefore, the estimates using the variation between these four pseudo-replicates are not as robust as estimates from true random replicate plots. As the calculations in Figure 1 are based on the four pseudo-replicates, more data should be obtained before the final sampling design is chosen to assure sufficient accuracy in the results. Accordingly, we recommend that this pilot study be used to design the first year of a follow-up study with true replicates on different islands. The results should then be re-evaluated to decide whether a second year of sampling is desirable and, if so, at what scale. The final year should measure accuracy on three plots per level (different islands and breeding stages).

5.4 BURROW COMPLEXITY AND ITS IMPLICATIONS

The extreme complexity of the burrows excavated at The Snares forces re-evaluation of the meaning and value of measuring burrow entrance abundance, and especially of the whole concept of "burrow occupancy". If subsequent studies reveal similar levels of complexity elsewhere, the "burrow occupancy" concept may have to be abandoned altogether in favour of a more direct measure of the number of eggs or chicks per unit ground area.

The burrowscope is used to determine breeding success and to assess population trends and is fundamental to the whole *Kia Mau Te Titi Mo Ake Tonu Atu* research programme. This pilot study demonstrates an urgent need to investigate alternative methods of burrowscope sampling and/or statistical treatment of the data. At the very least, more extensive checks of the precision and accuracy of the technique must be obtained to judge whether or not the data are sufficiently robust to be usable. It may be that the high density of titi on The Snares has caused extreme complexity in burrow architecture and geometry, and that these changes make the technique unusable there, whereas burrowscoping may still be useful elsewhere.

This preliminary study also signals the potential need for care in interpretation of burrow occupancy scores for threatened burrow-nesting seabirds, such as the Chatham Island taiko *(Pterodroma magentae)* or Hutton's shearwaters *(Puffinus huttoni)*. Burrowscopes have also recently become widely used around the world for studies of small Procellariiformes species. Checks of the accuracy and precision of the results obtained from burrowscopes in other studies are therefore valuable and highly recommended.

6. Acknowledgements

This project was funded by a Foundation for Research, Science and Technology (FRST) grant to the Rakiura Titi Committee for the Kia Mau Te Titi Mo Ake Tonu Atu research programme, administered by the University of Otago. We would like to thank Nic Alterio, Matt Charteris, Keryn Squires, Gen Taylor, Joe Hayes, Ray Guse and Martin Renner for their help with field work on The Snares and Whenua Hou. We would also like to thank Murray McKenzie, Ian Dickson and Matthew Dooher for constructing the "burrowscopes", Ken Miller for drawing Fig. 2, and John von Tunzelman for providing Photo 3.

7. References

Clout, M.N. 1989. Conservation of New Zealand forest birds - the next decade. Pp 59-61 *in* Management of new Zealand's Natural Estate (D.A. Norton, ed.) N.Z. Ecol Soc. Occasional Publication No. 1.

Dyer, P K.; Hill, G.J.E. 1991. A solution to the problem of determining the occupancy status of wedge-tailed shearwater *Puffinus pacificus* burrows. Emu 91: 20-25.

Hamilton, S.A. Submitted. Determining burrow occupancy, fledging success and land-based threats to mainland and near-shore island Sooty Shearwater *(Puffinus griseus)* colonies. Submitted to *N.Z.J. Zool*., May 1997.

Hamilton, S.; Moller, H.; Charteris, M.; Cooper,W 1996. Breeding colonies of Sooty Shearwater *(Puffinus griseus)* on Whenua Hou, Codfish Island. University of Otago Wildlife Management Report Number 77, September 1996.

Hamilton, S.A.; Moller, H.; Robertson, C.J.R. 1997 Distribution of Sooty Shearwater *Puffinus griseus)* breeding colonies along the Otago Coast, New Zealand, with indication of countrywide population trends. *Notornis 44*:15-25.

Jackson, J.R. 1957. Mortality among nesting muttonbirds near Greymouth. *Notornis 7:* 184-186.

Rance, B.D.; Patrick, B.H. 1988. Botany and *Lepidoptera* of The Snares. Published by the Department of Conservation, June 1988.

Richdale, L.E. 1963. Biology of the Sooty Shearwater *Puffinus griseus. Proc. Zool Soc. London Vol. 141:* 1-117.

Serventy, D.L.; Curry, P.J. 1984. Observation on colony size, breeding success, recruitment and inter-colony dispersal in a Tasmanian colony of short-tailed shearwaters *Puffinus tenuirostris* over a 30-year period. *Emu 84:* 71-79.

Warham, J.; Wilson, G.J. 1982. The size of the Sooty Shearwater population at the Snares Islands, New Zealand. *Notornis 29:* 23-30.

8. Appendices

Table 1: At Snares A, the number and proportion of 221 nests that were recorded using the burrowscope during incubation, young chick and pre-fledging chick stages.

1. Egg only recorded	2. Young chick only recorded	3. Pre-fledging chick only recorded	4. Egg not recorded; young chick and pre-fledging chick recorded	5. Young chick not recorded; egg and pre-fledging chick recorded	6. Pre-fledging chick not recorded; egg and young chick recorded	7. Recorded for all three burrow-scope checks	8. TOTAL POSSIBLE NEST NO.
46 21%	11 5%	7 3%	13 6%	7 3%	36 16%	101 46%	221

Table 2: At Whenua Hou A, the number and proportion of 71 nests that were recorded using the burrowscope during incubation, young chick and pre-fledging chick stages.

1. Egg only recorded	2. Young chick only recorded	3. Pre-fledging chick only recorded	4. Egg not recorded; young chick and pre-fledging chick recorded	5. Young chick not recorded; egg and pre-fledging chick recorded	6. Pre-fledging chick not recorded; egg and young chick recorded	7. Recorded for all three burrow-scope checks	8. TOTAL POSSIBLE NEST NO.
20 28%	2 3%	3 4%	9 13%	2 3%	3 4%	32 45%	71

Table 3: Nest data for four 5m x 5m areas (a,b,c,d) making up the intensively studied site, Snares C, showing the number and proportion of nests (containing an egg) which were recorded but not actually present (A), recorded twice from different burrow entrances (B), correctly recorded as being present (C), and present but not recorded (D), for three consecutive burrowscope checks over a two week period during incubation, December 1996.

		First check with burrowscope				Second check with burrowscope				Third check with burrowscope			
area (burrow entrance number)	nest no.	recorded but not present= A	recorded twice= B	correctly recorded= C	present but not recorded= D	A	B	C	D	A	B	C	D
a (21)	14	0	2	9 64%	5 36%	0	2	10 71%	4 29%	1	5	12 86%	2 14%
b (39)	36	1	2	27 75%	9 25%	0	10	27 75%	9 25%	0	10	32 89%	4 11%
c (21)	19	0	1	11 58%	8 42%	0	1	8 42%	11 58%	0	3	12 63%	7 37%
d (19)	22	0	1	14 64%	8 36%	1	2	15 68%	7 32%	0	3	17 77%	5 23%
TOTAL	91	1	6	61 67%	30 33%	1	15	60 66%	31 34%	1	21	73 80%	18 20%

Table 4: Banding data for adults caught at Snares C during the excavation of nests in December 1996 and during a later visit to the study plot in January 1997.

No. of adults removed from nests and banded during excavation, December 1996	Proportion of banded adults caught on study site in January, 1997	No. of new adults banded on study site in January, 1997	TOTAL ADULTS BANDED IN SNARES C FOR 1996/97 SEASON
97	35 (36%)	87	184

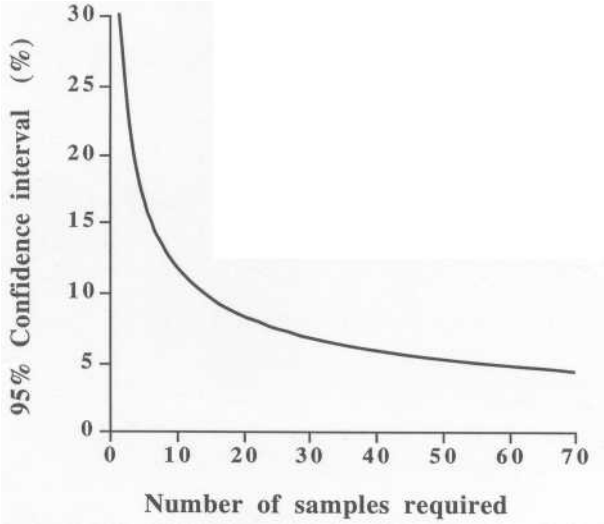

Figure 1: The number of 5m x 5m plot samples required to achieve different levels of % error in burrowscope accuracy with 95% confidence levels.

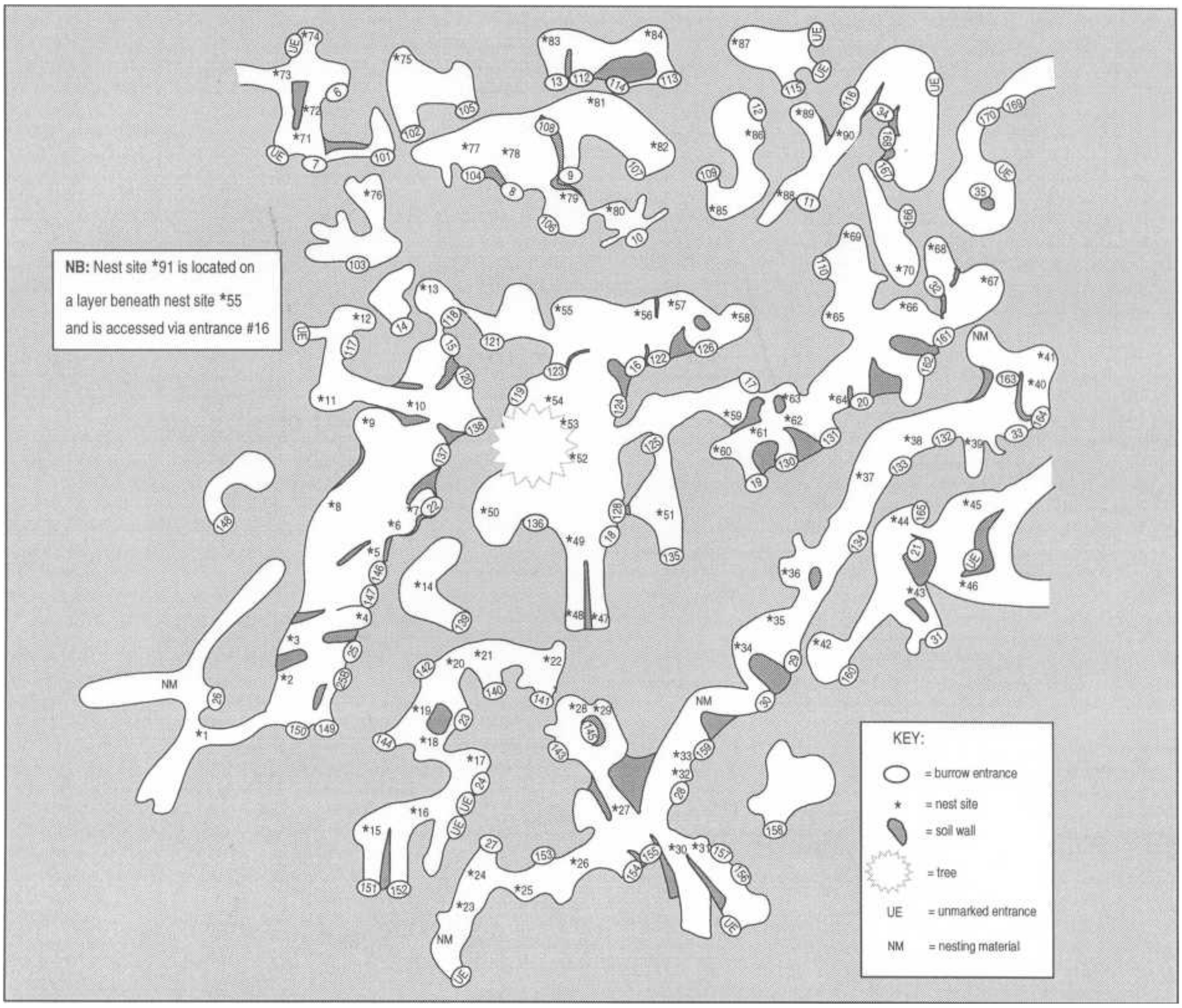
NB: Nest site *91 is located on a layer beneath nest site *55 and is accessed via entrance #16

Figure 2: Birds-eye view of the layout of titi burrows in the 10 m x 10 m Snares C study plot after the December 1996 excavation of burrow tunnels to reveal nest sites. This map clearly illustrates the enormous burrow complexity of this plot, with many different burrow entrances connecting together and leading to many different nest sites. Map not drawn to scale.

Continue to next file: casn187a.pdf