The use of knock-down tags to detect changes in occupancy among burrow-nesting seabirds: What is an adequate sample size?

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Introduction
A major problem in taking a census of burrow-nesting seabirds is to decide what proportion of burrows is actually occupied. Where burrows are long, it may be necessary to dig one or more access tunnels to find the nest chamber and determine whether it is occupied by a bird, egg or chick. The disturbance thus created may cause birds to desert and may alter the structure of the breeding habitat. In either case this affects the chances of future occupation. If the census is being conducted to detect population trends, such disturbances will reduce the validity of subsequent observations. Hence, there is a definite need for a method of determining burrow occupancy with minimum disturbance.

Small markers, such as toothpicks, twigs or plastic tags, set up in burrow entrances are frequently used to establish whether a burrow is entered (Boersma and Wheelwright 1979, Grant et al. 1983, Jones 1985). However, not all occupied burrows are entered nightly, and some unoccupied burrows will be entered by prospecting birds. Occupied burrows cannot therefore be distinguished from unoccupied burrows by this technique.

While studying the breeding biology of Ancient Murrelets (Synthliboramphus antiquus) at Reef Island, British Columbia, we found that any investigation of burrows that involved digging caused some birds to desert (Gaston et al. in press). In an attempt to avoid desertions, we examined the feasibility of using the mean frequency of knock-downs at a randomly selected burrow:

Methods
We recorded tag knock-downs nightly over three breeding seasons at two study areas each containing about 40 burrows, about 60% of which were occupied. The status of all burrows was determined by direct inspection. The proportion of burrows where knock-downs occurred varied with date and weather, reflecting the frequency with which birds visited the colony (Gaston et al. In press).

Results
We first examined the effect of the initial proportion of burrows occupied (F1) on the sample size required to detect a given change in occupancy. It is desirable that F1 not affect the required sample size too much, because when F1 is unknown it is necessary to select the largest required sample size over all possible values of F1. If the required sample size varies substantially with F1, then unnecessarily large data requirements can be imposed. Sample sizes were lower as F changed from 0.1 to 0.5 at the centre of the range. There was little variation over

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the range 0.5-0.8 (Fig. 1). In subsequent results presented, all sample sizes given are the maxima calculated for \( F_i \) in the range 0.2-0.8 and hence represent the worst possible cases. The value of \( c \) that requires the smallest sample size to achieve the required power varies with \( F_i \) (Fig. 1); the value of \( F_i \), where the changes in the optimum \( c \) value occur, varies with \( D \). The maxima, however, tend to occur within the same value for \( c \) for varying values of \( D \). For example, in Figure 1, selecting \( c = 4 \) provides the minimum sample size for all values of \( D \) presented. This is advantageous because one value of \( c \) can be chosen that provides the required power independent of the difference to be detected. Required sample size decreased with increasing values of \( P_o \). It also decreased with an increase in the ratio \( P_o/P_i \) (Fig. 3) and with an increase in \( K \), the number of nights of observations (Fig. 4). To detect a difference \((D) \) of 0.2 between one survey and the next, where \( P_o = 0.5 \), we require a sample of 450 burrows if checking is carried out for 5 nights, 250 burrows for 10 nights, 180 burrows for 15 nights or 150 burrows for 20 nights.

Discussion

For Ancient Murrelets, the probability of a knock-down increases slightly over the breeding season. Consequently, for this species, it would be necessary to make comparisons at the same stage of breeding. However, the seasonal effect is fairly slight (Gaston et al. in press). Provided that observations are made when fewer than 25% of chicks have left the colony, our results should give a fair indication of the accuracy that might be expected for a given level of effort. Our experience with the Reef Island colony suggests that 250 Ancient Murrelet burrows is probably about the maximum that can be conveniently checked nightly. In a denser colony the number might be considerably higher. With a sample of 250 burrows, at least 10 nights of observations are required to detect a difference of 20% in the proportion occupied. A difference of 20% in occupancy between one year and another at a colony where 60% of the burrows were occupied originally is equivalent to a 33% change in the population. If we used a sample sufficient to detect only a 20% difference in occupancy, we could not be sure that anything was changing until half the population had gone, which would surely be too late. In the Queen Charlotte Islands, occupancy rates are generally 30-70%, except at Langara Island, where they are considerably lower (M. Lemon and M. Rodway pers. comm.). The colony at Langara Island has declined considerably over the past 20 years (Nelson and Myres 1976, Vermeer et al. 1984). Hence, an occupancy rate of 50-70% is probably normal for a stable population. If this is the case, a monitoring program based on 10 nights of observations at 250 burrows would probably provide proof of declines amounting to a one-third reduction in the population.

Our results suggest that knock-downs can provide statistically meaningful results with manageable sample sizes. The method has some potential for detecting changes in population that are not reflected in changes in the number of burrows or in the total area of the colony. Because non-breeding prospectors enter unoccupied burrows from time to time, these burrows may retain the outward appearance of occupancy for some years after they have ceased to be used. It is possible, but unproved, that declining colonies continue to appear active until most of the population has gone; then suddenly fall into decay when close to extinction because visitors by prospectors become too infrequent to keep burrow entrances from being clogged by falling leaves, twigs and other debris. In this sort of situation, changes in knock-down frequencies could provide a useful early warning of population decline.

Similar techniques might be appropriate for other burrow-nesting seabirds that are susceptible to disturbance. Prior observations at burrows of known occupancy would be necessary to determine the relationship between \( P_o \) and \( P_i \). Both these variables and \( F_i \) are likely to be specific to particular species or colonies. If \( P_o \) and \( P_i \) can be estimated or are known from observations elsewhere, Figures 2 and 3 should provide a rough guide to the sample sizes required.

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References


Appendix 1
Calculation of required sample size for the binomial distribution
using the arcsine square root transformation

Given the parameters \( F_1, D, P_1, P_2, K \) and \( c \), the probability of \( c \) or more knock-downs at colonies 1 and 2 \((D_1, D_2)\) respectively can be calculated using equations [1] and [2]. The arcsine square root transformation changes a binomial random variable into an approximately normally distributed random variable with variance 1. The required sample size \( n(n) \) for a two-sided t-test with significance level \( a \) to achieve power \( b \) can then be calculated as:

\[
n = 2 \left( \frac{u(a/2) + u(b)}{d} \right)^2
\]

where \( u(a/2) \) denotes the lower \( a/2 \) percentile of the normal distribution,
\( u(b) \) denotes the lower \( b \) percentile of the normal distribution,
and \( d = 2\arcsine(G_1) - \arcsine(G_2) \).

For example, assume that the knock-down rate at occupied burrows \( (P_1) \) is 0.50 and that at unoccupied burrows \( (P_2) \) is 0.25. We want to calculate the number of burrows required to attain a power of 80% in detecting a change in occupancy from \( F_1 = 0.60 \) to \( F_2 = 0.40 \), using a two-sided t-test at the 5% significance level when observing for 10 nights and setting \( c = 4 \).

The probability of observing four or more knock-downs at a random nest selected from colony 1 is 0.5865 and from colony 2 is 0.4657. Using the arcsine square root transformation gives \( d = 0.2425 \). From tables of the normal distribution, \( u(0.25) = 1.96 \) and \( u(0.10) = 0.85 \). The required sample size is then calculated:

\[
n = 2 \left( \frac{1.96 + 0.85}{0.2425} \right)^2
\]

\[
= 268
\]