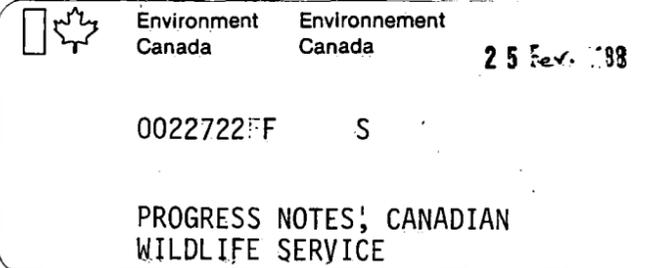


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The use of knock-down tags to detect changes in occupancy among burrow-nesting seabirds: What is an adequate sample size?

by A.J. Gaston¹ and B.T. Collins¹**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 with certainty 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 with which burrow tags were knocked down to monitor year-to-year changes in the proportion of burrows occupied. In this paper we use observed frequencies of knock-downs at known occupied and unoccupied burrows to predict the sample sizes necessary to detect a given level of change. For a given reduction in the proportion of burrows occupied we ask, "Using only knock-down tags, how many burrows must be monitored nightly and for how long to detect the change with 80% power?"

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).

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However, irrespective of conditions, knock-downs were approximately twice as frequent at occupied burrows as at unoccupied burrows. This was true at both plots, despite the fact that frequencies for both types of burrow were consistently higher at one plot than at the other. In our study, two visits—the first to set up the tags at a burrow entrance and the second the next day to record the knock-downs—constituted one night of observation.

Assuming that F is the unknown proportion of burrows that are occupied, we considered a model in which knock-downs at both types of burrow occurred randomly, the frequency at occupied burrows being P_o and that at unoccupied burrows P_u . The probability of observing x knock-downs in K nights at a randomly selected burrow is then given by:

$$P(x) = F \binom{K}{x} P_o^x (1 - P_o)^{K-x} + (1 - F) \binom{K}{x} P_u^x (1 - P_u)^{K-x} \quad [1]$$

which is a mixture of two binomial distributions. Let G denote the probability of observing c or more knock-downs at a randomly selected burrow:

$$G = \sum_{x=c}^K P(x) \quad [2]$$

For a large sample of burrows, the proportion that had c or more knock-downs over K nights would follow a binomial distribution. This proportion can be compared between two surveys of the same colony using the arcsine square root transformation (Sokal and Rohlf 1982). The sample size required to detect a given change in proportion occupied with a fixed probability can be calculated using a formula given by Mace (1964). We performed a series of calculations to observe how changes in different variables affect the number of burrows and the number of nights of observations required to detect with 80% power a given change ($D = F_1 - F_2$) between one survey and the next. (A subscript has been added to the proportion of burrows occupied to indicate first and second surveys). In the calculations that follow all comparisons between colonies were assumed to be done using two-sided t-tests at the 5% significance level, and sample sizes were selected to achieve 80% power.

Results

We first examined the effect of the initial proportion of burrows occupied (F_1) on the sample size required to detect a given change in occupancy. It is desirable that F_1 not affect the required sample size too much, because when F_1 is unknown it is necessary to select the largest required sample size over all possible values of F_1 . If the required sample size varies substantially with F_1 , then unnecessarily large data requirements can be imposed. Sample sizes were lower as F_1 approached 0 and 1, with a maximum near the centre of the range. There was little variation over

the range 0.5–0.8 (Fig. 1). In subsequent results presented, all sample sizes given are the maxima calculated for F_1 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_1 (Fig. 1); the value of F_1 , 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 (Fig. 2). It also decreased with an increase in the ratio P_u/P_o (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 30% 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 50–70%, 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 visits 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_u . Both these variables and F_1 are likely to be specific to particular species or colonies. If P_o and P_u 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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Figure 1

Required sample size for a two-sided test at the 0.05 significance level with power = 0.80 plotted against initial proportion of burrows occupied using 10 nights of observation and assuming $P_o = 0.5$ and $P_u = 0.25$

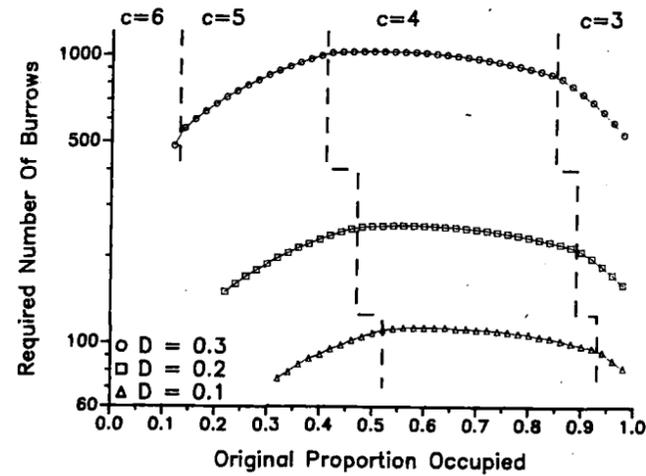


Figure 2

Required sample size for a two-sided test at the 0.05 significance level with power = 0.80 plotted against difference in proportion of occupied burrows required to be detected using 10 nights of observation and assuming $P_u = P_o/2$

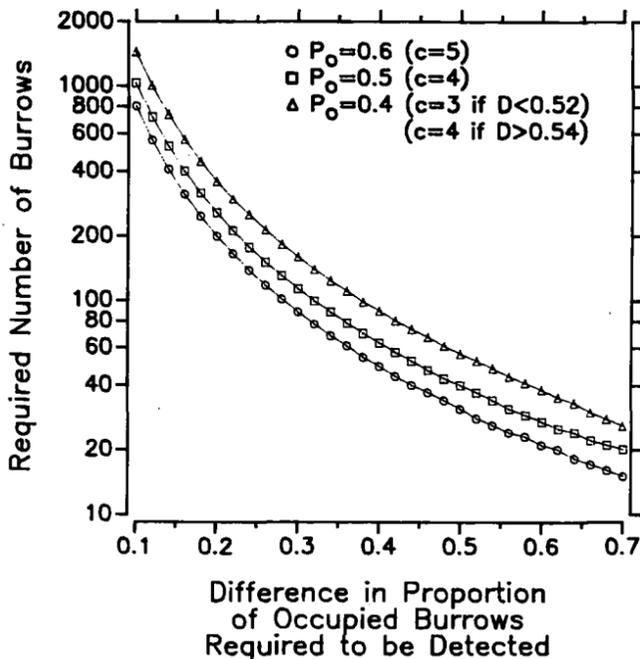


Figure 3

Required sample size for a two-sided test at the 0.05 significance level with power = 0.80 plotted against difference in proportion of occupied burrows required to be detected using 10 nights of observation and assuming $P_o = 0.5$

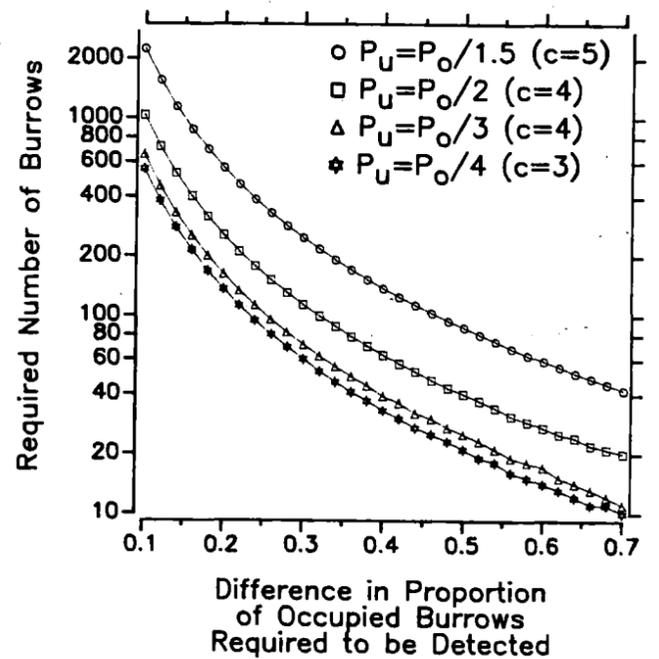
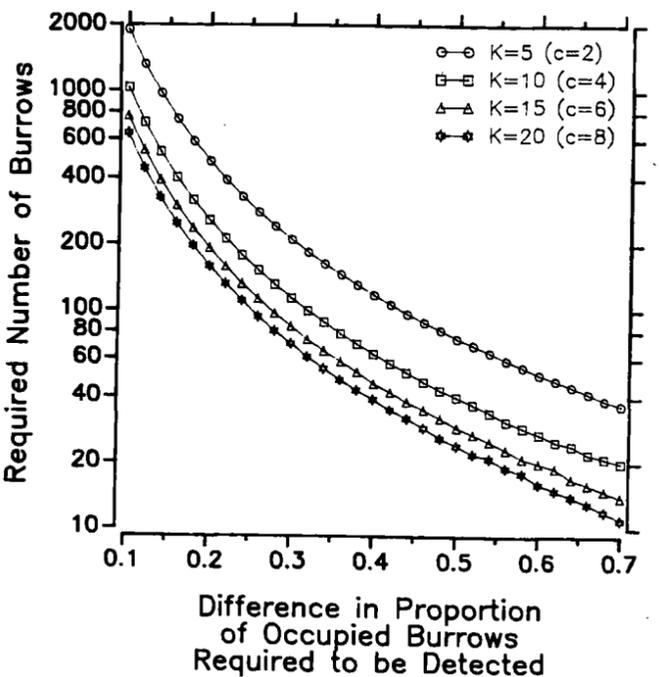


Figure 4

Required sample size for a two-sided test at the 0.05 significance level with power = 0.80 plotted against difference in proportion of occupied burrows required to be detected assuming $P_o = 0.50$ and $P_u = 0.25$



Appendix 1

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

Given the parameters F_1 , D , P_o , P_u , K and c , the probability of c or more knock-downs at colonies 1 and 2 (G_1 and G_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) for a two-sided t-test with significance level a to achieve power b can then be calculated as:

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

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_o) is 0.50 and that at unoccupied burrows (P_u) 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 $d = 0.24255$. From tables of the normal distribution, $u(0.25) = 1.96$ and $u(0.10) = 0.85$. The required sample size is then calculated:

$$\begin{aligned} n &= 2 \frac{(1.96 + 0.85)^2}{0.2425} \\ &= 268 \end{aligned}$$