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SHORT COMMUNICATION

AN IMPROVED TECHNIQUE FOR INDEXING ABUNDANCE OF HIMALAYAN THAR

Summary: Current monitoring of Himalayan thar (*Hemitragus jemlahicus*) populations in New Zealand involves a technique based on repeated observations by different, experienced observers. The method gives no measure of error and hence does not allow for statistical comparison of repeated surveys. We outline a faster and cheaper technique that enables statistical comparison between surveys based on mark-recapture theory. Two counts can be made by the same observer on subsequent evenings, or can be conducted simultaneously by two observers of differing experience provided they do not cue each other to the location of animals. As an example of the use of the technique, we monitored a control operation aimed at reducing thar impact on alpine flora. We recorded a non-significant ($P = 0.27$) decline in thar abundance from 38 (± 27; 95% C.L.) to 28 (± 19) females (including kids) in the survey area.

Keywords: control; Himalayan thar; index; Landsborough River; monitoring; Southern Alps.

Introduction

The Himalayan thar (*Hemitragus jemlahicus* Smith) is an introduced ungulate pest of the alpine zone in New Zealand's Southern Alps. Considerable money is spent attempting to mitigate their effects on indigenous flora (Tustin, 1990). Current management focuses on maintaining thar densities below specified densities by a combination of recreational, commercial, and government-funded hunting (Department of Conservation, 1993). Management thus requires extensive monitoring of thar densities.

Thar are typical of alpine ungulates in that they are difficult to survey accurately (Hutchins and Geist, 1987). Their montane habitat, crepuscular activity (Tustin and Parkes, 1988) and helicopter-shyness (Tustin, 1990), coupled with the vagaries of alpine weather, makes censusing of thar populations difficult. However, the Himalayan Thar Control Plan (Department of Conservation, 1993) requires indices of thar densities if "unacceptable damage to conservation values" is to be avoided.

The current method of surveying thar defines the location and size of thar groups on the basis of 'the largest count and most confident classification' (hereafter termed the 'largest-count' method) after at least two independent periods of observation by different observers (Challies, 1992 unpublished report; see also Tustin and Challies, 1978; Baddeley, 1985). Density is then calculated as the sum of the groups divided by the search area. Because thar occupy habitats that are difficult to search (e.g., subalpine scrub and rock bluffs) and observers have different searching abilities, this technique cannot be considered a true *census* (i.e., "the total enumeration of the animals in the area"; Caughley and Sinclair, 1994). Rather, it provides a more-or-less repeatable *index* of thar abundance.

Although the largest-count method allows rate of increase over time (r) to be estimated, it does not enable statistical comparisons of changes in population density over time to be made. Clearly, a more rigorous method of sampling population density incorporating some measure of sampling error at each sampling time would be advantageous.

We describe the application of a double survey estimate of population size (Magnusson, Caughley and Grigg, 1978) to a South Westland thar population that was controlled in 1994. The objective of the study was to develop an index (Caughley and Sinclair, 1994) of thar density such that the effectiveness of the control operation could be evaluated.

Methods

When individuals within a population can be identified, Caughley (1974) showed that, based on mark-recapture theory, two counts could be used to estimate population size. Magnusson *et al.* (1978) refined Caughley's equation so that the two counts could be made using different observers or techniques such that the probabilities of seeing individuals were unequal in the two surveys.

Because thar are social ungulates with groups >30 common in moderate and high density populations (Tustin and Challies, 1978; Tustin, 1990), grouping will lead to violation of the simple random sample assumption that all members within a survey have similar sighting probability. Consequently, the number of groups, G, in the population is estimated (rather than the number of individuals) and population size estimated as the number of groups in the population multiplied by mean group size (e.g., Choquenot, 1990). In moderate and high density thar populations, identifying groups is likely to be more accurate than identifying individual animals.

For two independent surveys let B be the number of groups seen in both surveys, S_1 be the number of groups seen only in the first survey, and S_2 the number of groups seen only in the second survey. Hence, P(group being seen in both) = P(being seen in the first) x P(Being seen in the second), or:

$$\frac{B}{G} = \frac{(B+S_1)}{G} \cdot \frac{(B+S_2)}{G} \qquad (1)$$

To remove bias associated with situations when no groups are seen in both surveys (B=0):

$$\hat{G} = \frac{(B+S_1+1)\,(B+S_2+1)}{(B+1)} - 1 \qquad (2)$$

The number of animals in the population, N, is estimated as the product of the number of groups, $\hat{G}$, and mean group size, $\hat{\mu}$:

$$\hat{N} = \hat{G}\hat{\mu} \qquad (3)$$

The variance of the population estimate, Var($\hat{N}$), is the variance of a product of independent random variables (Goodman, 1960):

$$Var(\hat{N}) = \hat{G}^2 Var(\hat{\mu}) + \hat{\mu}^2 Var(\hat{G}) - Var(\hat{G})Var(\hat{\mu}) \qquad (4)$$

where:

$$Var(\hat{G}) = \frac{S_1 S_2 (S_1+B+1)(S_2+B+1)}{(B+1)^2(B+2)} \qquad (5)$$

and if X_1, X_2, ..., X_i are the group sizes seen in both surveys, then:

$$Var(\hat{\mu}) = \frac{\sum(X_i-X)^2}{n^2-n} \qquad (6)$$

Confidence limits were calculated for each population estimate by:

$$\hat{N} \pm z_{\alpha/2} se(\hat{N}) \qquad (7)$$

Note that N is a mark-recapture estimator, with the marked sample the animals seen in the first survey. The critical assumptions of the method are: (1) that the population is closed or subject to additions or losses, but not both; (2) the second count is a simple random sample of all groups in the population; (3) that we can identify groups seen in both samples (Seber, 1982). These assumptions are discussed below.

The abundance of thar in a region of the upper Landsborough Valley, South Westland (43°47'S, 169°51'E) was assessed using this technique in January 1994 and 1995, before and after thar were controlled by a three month period of intensive recreational hunting during winter 1994. The details and results of the control programme will be reported in full once further control has been completed.

For each survey two counts were completed during clear conditions from the same place by the same author (DMF) using 10X binoculars. The counts were one day apart and each count began four hours before sunset to encompass the period when thar are most active (Tustin and Parkes, 1988). Observed thar groups were then classified using a 20-60X spotting scope as either predominantly 'female (including kids)' or 'male' on the basis of body-size, presence of kids or a mane, and horn-size. During October - March the sexes are segregated into same-sex groups (Tustin, 1990; D.M. Forsyth, unpubl. data). For the purposes of this paper we report the results only for 'female (including kids)' groups; few males were seen in either year. Sightings of thar were plotted on enlarged aerial photographs and B, S_1 and S_2 were calculated based on each individual's location. Although female thar have a home range of *c*. 2 km^2 (Tustin 1990), the core use area will be considerably smaller, and from one day to the next female groups are unlikely to move the full distance of their home range.

The statistical significance of the change in abundance between the 1994 population estimate, $\hat{N}_1$, and 1995 population estimate, $\hat{N}_2$, was assessed using the z-test:

$$z = \frac{(\hat{N}_2-\hat{N}_1)}{se(\hat{N}_2-\hat{N}_1)} \qquad (8)$$

where:

$$se(\hat{N}_2-\hat{N}_1) = \sqrt{Var(\hat{N}_1)+Var(\hat{N}_2)} \qquad (9)$$

Abundance was also estimated using the largest-count method, so that the two methods could be compared. Two observers conducted post-dawn and pre-dusk counts for a maximum of four hours (duration was variable due to rapidly changing weather conditions). The two observers searched from four different sites, and sometimes searched simultaneously from the same site. They then consulted between each other at the end of the day as to which animals seen had been sighted before on the basis of location. The survey ended when the observers considered that the different group sizes had been accurately estimated; the sum of these group sizes was taken as the abundance measure for the survey area. This method is the current standard method for monitoring thar (D. Anderson; J. Mead, *pers. comms.*; Department of Conservation). Here we only report on thar seen in the same area that was surveyed using the double-count method.

Results

Numbers of females (including kids) seen in the 1994 and 1995 surveys, and abundance indices derived using the double-count technique, are shown in Table 1. The control work reduced the population to an estimated 74% of its pre-control level after one year, but this reduction was not statistically significantly ($z = 0.60$, one-tailed $P = 0.27$).

Table 1: *Abundance estimates for 'female (including kids)' thar in 1994 and 1995 using the double-count method. The survey area was controlled by recreational hunters in winter 1994.*

Variable	Jan. 1994 (Pre-control)	Jan. 1995 (Post-control)
B	2	2
S_1	2	3
S_2	2	1
G	7.33	7.00
Var(G)	2.78	2.00
μ	5.25	4.00
Var(μ)	2.13	1.32
N	38.5	28.0
Var(N)	185.2	94.0
se(N)	13.6	9.7

Table 2: *Comparison of the abundance of 'females (including kids)' estimated by the two techniques and the survey effort expended. See text for explanation of methods.*

Technique	Population estimate	Mean hours observing	% reduction 1994	% reduction 1995
Largest-count	61[1]	44[1]	23	28
Double-count[2]	38 (± 27)	28 (± 19)	8	26

[1] This technique does not enable confidence limits to be calculated.
[2] Presented ±95% C.L.

The abundance estimates given by the two methods were similar (Table 2), with the largest-count estimates lying within the 95% confidence limits of the double-count method. We emphasise, however, that the largest-count estimate is not necessarily more accurate than the mean of the double-count estimate (see below). Furthermore, the double-count method took only two person-days (8 hours observation) compared to an average of eight person-days (23 hours observation) for the largest-count method (excluding days on which no observations were made due to poor visibility).

Discussion

In these surveys, N does not represent the total number of thar in the survey area. Some thar live in habitats that are difficult to search visually so any visual count technique can only provide an *index* (Caughley and Sinclair, 1994) of population size. An assumption required in applying the double-count method to assessing population change is that the proportion of the thar population able to be observed must be the same for the two periods being compared. This assumption was not tested; we assumed it to be met.

Magnusson *et al*. (1978) specified three assumptions that should be met if the double-count model is to provide an unbiased estimate of N. Firstly, the 'entities' must be individually recognisable so that they can be classified into those seen on one survey and not the other. Female thar in New Zealand are sedentary on rock bluffs (Tustin and Parkes, 1988) with home-ranges of *c*. 2 km^2 (Tustin, 1990). Hence females are consistently seen within a small area, making groups of females identifiable by their location. The largest-count method also assumes that thar seen in the same location are the same individuals, so both techniques are prone to error from incorrectly identifying individuals. Using the double-count method, this error can be minimised by conducting the two counts on consecutive days, or as closely as weather conditions permit. There is also likely to be less error in identifying groups (double-count) from one day to the next compared to identifying individuals (largest-count), especially in moderate and high-density populations. Horn length and pelage enable consistent identification of adult males.

The second assumption is that the probability of sighting in the second survey is independent of whether it was seen in the first. Care was taken not to spend more time searching where thar groups were seen the previous evening; a consistent search path covering the entire scanning area was followed.

Finally, the probability of seeing each individual should be the same within each four hour count, although Magnusson *et al.* (1978) used simulated data to show that this assumption is not critical. The sighting probability, however, may differ between each four hour count. It is likely that thar were more visible in some areas than in others. This variability in the visibility of thar could be minimised by excluding habitat with poor visibility from the search area, or by modifying estimates for different habitats with visibility-bias correction factors (see, for example, Choquenot, 1995).

Although in the example used here one observer counted thar on two consecutive nights from the same observation point, the same model could be applied to two observers counting thar at the same time from the same observation point (Caughley, 1974). Current monitoring surveys by the Department of Conservation typically utilise two people for safety reasons, so the simultaneous double-count method may be particularly useful. Furthermore, simultaneous counting would eliminate error from incorrectly identifying individuals. However, the observers must not communicate the location of animals to each other if the second assumption discussed above is to hold. The technique need not be based on just two counts; it could be extended for three or more periods and standard mark-recapture methods of analysis applied.

Given that there is likely to be wide inter-observer variation in ability to locate thar, we believe that the technique used here is an improvement on the current method for monitoring trends in thar abundance. Thar monitoring surveys are plagued by poor weather conditions for visual searching and in this situation the double-count method provides a statistically interpretable estimate from only one (using two observers simultaneously) or two days' observation. A major drawback of the largest-count technique is that the team leader does not know when to stop the survey; in practice many surveys end when weather conditions change for the worse (D.M. Forsyth, *pers. obs.*)

The double-count method will provide a faster and more statistically robust index of thar population size than has previously been available. More precise methods are available (see Seber, 1982; 1992 for reviews) but these generally require more than two counts of an individually-identifiable population which is a significant disadvantage in an alpine area.

Abundance surveys are important in determining when damage-thresholds are exceeded in different management units (Department of Conservation, 1993) as well as for evaluating the effectiveness of various new control strategies. Use of methods requiring more effort than the double-count technique is unlikely to be affordable for such surveys over large areas. We encourage managers to consider the technique presented here as providing data that are more readily interpretable at considerably less cost than the current method.

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