A MARK-RECAPTURE CENSUS AND DENSITY ESTIMATE FOR A COASTAL MOUNTAIN GOAT POPULATION

Christian A. Smith and Kent T. Bovee, Alaska Department of Fish and Game, Ketchikan, Alaska 99901.

ABSTRACT

A mark-recapture study was conducted on a mountain goat (Oreamnos americanus) population in southeastern Alaska during September 1982. Thirteen adult goats were captured and fitted with orange radio collars, and 3 aerial samples were taken approximately 60 days after capture. Size of the adult population was estimated using a modified Petersen estimate for the individual samples and a joint probability density function for the combined samples. The resulting estimates (±95% C.I.) were 149 (±70), 103 (±47), and 145 (±68) for aerial samples 1, 2 and 3, respectively and a combined estimate of 145 (±21) adults. The size of the kid portion of the population was estimated by applying the proportion of the kids observed in aerial surveys to the estimated number of adults. The total population was estimated at between 159 and 239 ($p=0.90$). Densities of goats on winter and year-round range were estimated at 4.4 and 2.3 goats/km^2, respectively. The increasing trend of this population at these densities indicates that coastal ranges may be capable of supporting higher goat densities than previously believed.

INTRODUCTION

Eastman's (1977) survey of research needs for mountain goat (Oreamnos americanus) management concluded that improved inventory methods were the highest priority in many areas. The problems associated with sex and age classification, as well as bias resulting from seasonal and diurnal timing and type of survey (e.g. helicopter, fixed wing or ground count) were cited as difficulties affecting inventory results. The inability to estimate goat numbers and lack of knowledge of habitat use/requirements have limited the development and application of reliable density estimates (Hebert and Turnbull 1977).

Subsequent work by Nichols (1980) and others has led to improved methods for classifying goats, and several authors have made suggestions to improve survey methodology based on behavioral research (Fox 1977, Foster 1982) or comparisons of various types of surveys (Ballard 1977). To date, however, advanced survey techniques are based on the questionable assumption, either stated (Nichols 1980) or implied, that virtually all goats in the survey area are seen by observers, or that sightability is consistent among all sex/age classes.

In southcoastal Alaska and British Columbia, where goats spend considerable time in forested habitats (Schoen and Kirchhoff 1982, Fox 1983, Smith 1983, Hebert and Turnbull 1977, Foster 1982) goat sightability is generally low. Foster (1982) reported an average sightability of only 42% for ground surveys in west central British Columbia. From fixed wing aircraft even when aided by telemetry, Smith (1983) averaged only 30% sightability in coastal Alaska. Thus, when it became desirable to estimate the actual size of a goat population prior to mineral development in an area southeast of Ketchikan, Alaska, an alternative method had to be employed.

One of the commonly used techniques for censusing hard to observe species is the mark-recapture, or Petersen estimate method (Seber 1982). To date, the only published capture mark-recapture (CMR) census of goats was conducted by Stevens and Driver (1978). Unfortunately, that study population was experiencing a high rate of dispersal and no attempt was made to evaluate the equality of catchability (Caughley 1977) in the population. For these reasons several of the critical assumptions in a CMR census were potentially violated. Nevertheless results indicated that if properly applied this technique might be useful for estimating goat numbers in areas where any single survey is likely to miss a significant proportion of the population.

Goats radio collared as part of a major study of habitat use (Smith 1983) in the vicinity of the Quartz Hill mine impact area provided the opportunity to attempt a mark-recapture census of this population. Monitoring the radioed goats prior to and following the survey permitted detailed evaluation of the assumptions made in the CMR method.

In addition, detailed knowledge of habitat availability in the area provided the opportunity to calculate relatively accurate seasonal density estimates. The purpose of this paper is to report these results.

STUDY AREA

The 197 km^2 study area is located in southeastern Alaska, 80 km southeast of Ketchikan within Misty Fjords National Monument (Figure 1). The portion of the area surveyed is bounded by Smeaton Bay, the Blossom River and Keta River drainages, and is separated from the remainder of the ridge complex by valleys with a maximum elevation of 400 m. The terrain is predominantly steep and broken quartz diorite and granodiorite formations which have been heavily modified by glacial action (Jacques 1963).

Annual precipitation of over 300 cm, the majority of which is rain, allows for dense mixed stands of Western hemlock (Tsuga heterophylla), Sitka spruce (Picea sitchensis), and Alaska cedar (Chamaecyparis nootkatensis) in the valleys. Treeline occurs at elevations of 750 to 900 m and alpine vegetation continues to the summits of the 1200+ m mountain range.

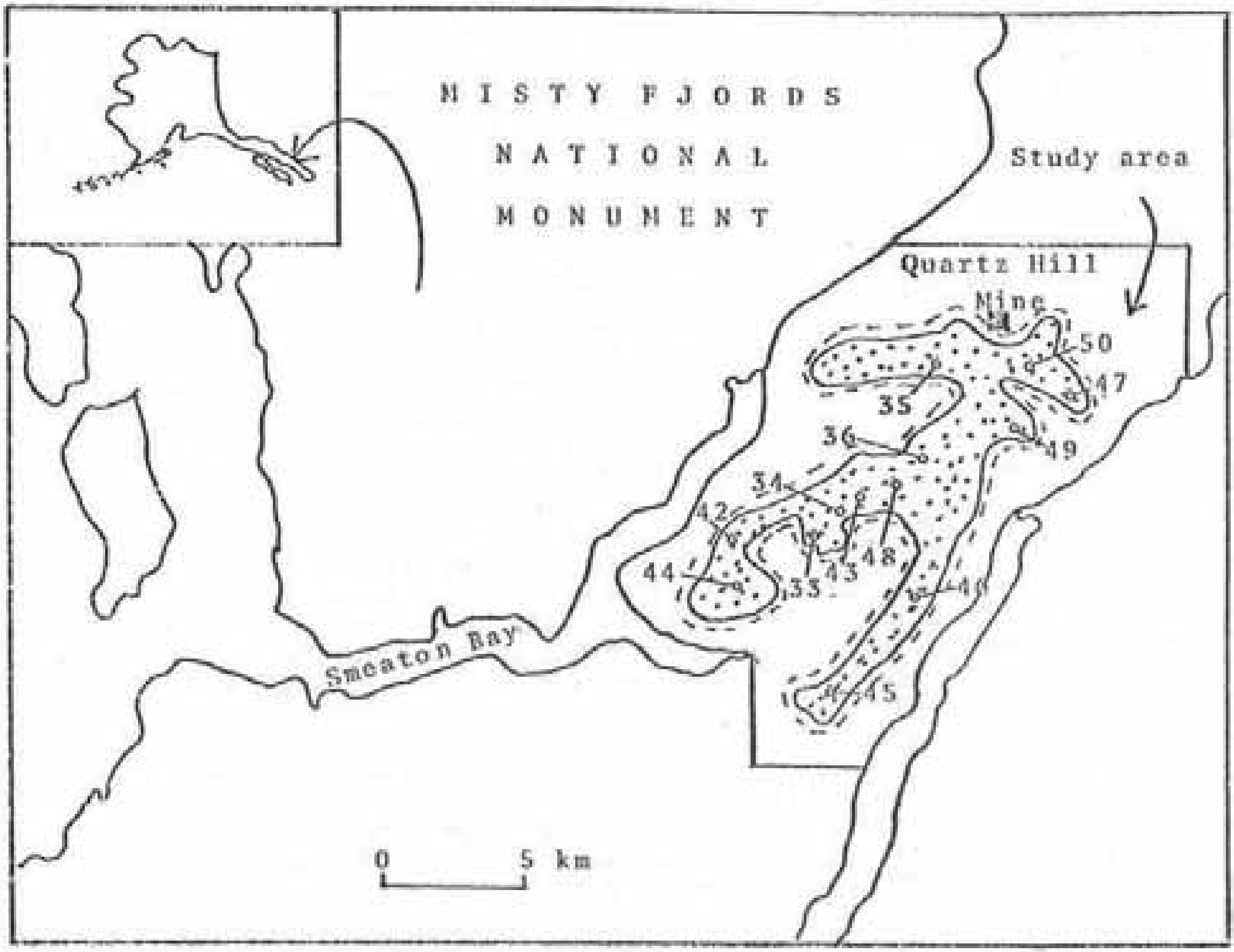

Fig 1. Study area showing alpine region (⁚⁚⁚), flight pattern (----) and goat capture locations.

METHODS

POPULATION ESTIMATES

Goats were captured in July 1982 using the helicopter darting technique described by Nichols (1982) with a standard dosage of 4 mg of M99 (etorphine) or by use of a Coda Net Gun (Coda Enterprises, Mesa, AZ), as discussed by Barrett et al (1982). Individuals over one year of age were selected at random as encountered. Ages of captured goats were determined by counting horn annuli, standard horn and body measurements were taken, and general condition of body and dentition, lactative status of females, and presence of ectoparasites or anomalies were noted. Goats were marked with large, orange ear tags and fitted with orange radio collars (Telonics, Mesa, AZ).

During September 1982, 2 aerial surveys were flown in a PA-18-150 Super Cub and a third survey was flown in a Huges 500 "D" helicopter. Each flight began at the northwest end of the ridge complex and kept the ridge to the right of the aircraft. A single contour that permitted viewing the portion of the slope above treeline was flown. All goats seen were identified as either collared or uncollared adults and kids. The location of each goat was recorded on a 1:63,360 topographical map to avoid duplicate counting. When a collared goat was seen it was individually identified by checking its radio frequency.

The critical importance of "equal catchability" of individuals to mark-recapture studies requires that data be analysed for this property before population estimates are made (Caughley 1977). Accordingly, frequency of capture (i.e. resighting of collared individuals) data were evaluated to determine whether or not their distribution differed significantly from an approximation of a zero-truncated Poisson as described by Caughley (1977 p 137).

By noting the location of each goat seen and flying a single contour on each survey, thus preventing duplicate counting, sampling without replacement was assumed. That being the case, use of the hypergeometric distribution model was approriate. For the individual survey results, an approximation of the hypergeometric maximum likelihood estimator:

$$Pr\left[X_i = x_i\right] = \frac{\binom{m}{X_i}\binom{N-m}{n_i-x_i}}{\binom{N}{n_i}}$$

was calculated using the formula:

$$N^* = \frac{(m+1)(n_i+1)}{(x_i+1)} - 1$$

which has a standard error of:

$$SE = \sqrt{\frac{(m+1)(n_i+1)(m-x_i)(n_i-x_i)}{(x_i+1)^2(X_i+2)}}$$

where m = number of collared goats in the population, n_i = number of goats seen on the survey and x_i = number of collared goats seen (Seber 1982).

To increase the accuracy of the estimate, results of the 3 surveys were combined in a joint probability density function,

$$L(N) = \prod_{i=i}^{k} Pr\ (X_i = x_i)$$

where 'k' was the number of aerial samples and L(N) was the probability of x_i, x_2, and x_3 occurring, given the values of N, m_i, and n_i. This equation was solved by iteration with various values of N and interpreted using calculus in SAS computer programs developed by B. C. Dennis (Department of Statistics, University of Idaho). The first derivative of this equation is the maximum likelihood estimate and the second derivative of this equation is the variance of the estimate.

Because kids are not collared and were classified separately in the surveys, the foregoing analysis provided estimates of the number of adults only. Thus, in order to estimate the total population it was necessary to estimate the total number of kids. This was accomplished by estimating the proportion of kids in the herd from observations from the three surveys and applying this proportion to the estimated total number of adults.

The 95% level was used in establishing confidence limits for the estimates of total number of adults and proportion of kids in the herd. As a consequence of using these estimates to derive the total population figure, the degree of confidence in the estimate of the total population is reduced to 90%.

DENSITY

Smith (1983) identified 51 km^2 of potential goat winter range in the study area based on a discriminant function analysis model. Those results were preliminary, however, and the model used identified approximately 6 km^2 of non-forested alpine slopes as winter range. Inasmuch as goats in this area are rarely found above treeline in winter and no goats or tracks were observed in these areas during 2 winters of radio-tracking (author's unpubl. data), these areas were excluded from the winter range category for the density calculations presented here. Thus total winter range area was estimated at 45 km^2. Year-round habitat was considered to be all areas above the 800 m contour, plus lower elevation winter range. The total was estimated to be 86 km^2. All area figures used represent 2 dimensional map areas measured planimetrically corrected for the third dimension using the arcsine of the mean slope of 33° (A.D.F. & G. unpubl. data).

RESULTS

POPULATION ESTIMATES

Between 21 and 29 July 1982, 6 female and 7 male goats aged 2-9 years old were captured in the study area. Ten goats were captured with the dart gun, 2 with the net gun and 1 with a combination of both. The locations of captures are shown in Figure 1.

The 2 fixed wing aerial samples were taken on 22 and 29 September 1982, with 74 and 72 adult goats being counted, respectively. On each flight 25 kids were seen. On 23 September 1982, 50 adult goats and 20 kids were counted via helicopter. In each of these samples, 6 collared goats were seen and identified (Table 1). The survey conditions varied from poor to excellent. The estimated population sizes ($\pm$95% C.I.) from these surveys were 149 ($\pm$70), 103 ($\pm$47) and, 145 ($\pm$68) (Table 2). Using the joint probability distribution function, the combined estimate was 145 ($\pm$21). There were no significant differences between these estimates of N. Because the combined estimate is the most precise, it is used in all subsequent analyses.

The estimated proportion of kids in the herd ($\pm$95% C.I.) was .262 ($\pm$.043). Thus the total population of goats in the study area was estimated to be 197 (145 adults + 52 kids). The 90% C.I. for this estimate is from 159 (124 adults +35 kids) to 239 (166 adults + 73 kids).

Winter range density was calculated to be 4.38 $\pm$ .89 goats/km^2 at the 90% confidence level. Year-round habitat density was 2.29 $\pm$ .47 goats/km^2, and density of goats over the entire study area was 1.0 goat/km^2 at 90% confidence level.

DISCUSSION

The validity of CMR estimates for N relies upon certain assumptions (Caughley 1977). A discussion of these assumptions follows.

ASSUMPTION 1:

The population was geographically and demographically closed so that N remained constant.

The factors potentially affecting the assumption of closure were natality, mortality, immigration and emigration. Natality does not occur in September and mortality other than hunting, is negligible (A.D.F. & G. unpubl. data). No goats were reported taken by hunters in this area during the study period. The short span of 7 days between samples, geographic isolation of the ridge and limited movement of goats in September (A.D.F. & G. unpubl. data) would have tended to reduce or eliminate biases due to immigration and emigration.

ASSUMPTION 2:

The average probabilities of capturing and sighting collared and uncollared goats were equal (i.e., collared goats were representative of the "true" population).

The validity of every CMR study depends heavily upon assumption 2. If the marked population is not representative, the data gained from the marked individuals will be biased. The composition, behavior and catchability of the marked goats should match those of the population as a whole.

With respect to the composition, the initial sampling and marking of goats were assumed to be done in a random manner. The location, sex and age distribution of captured goats support this assumption. As for behavior, two

Table 1. Results of aerial surveys of mountain goats in the vicinity of the Quartz Hill mine, southeast Alaska, 1982.

Date	Method	Survey Time	Collars Seen	Goats observed Adults/Kids	Survey Condition	Cost
9-22-82	FW	1830-1945h	33 36 45 46 48 49	74/25	Excellent	$380
9-23-82	H	1800-1915h	33 35 42 45 46 48	51/20	Poor	$1002
9-29-72	FW	1810-1930h	42 44 45 46 47 49	72/25	Fair	$360

1. FW - fixed wing, H - helicopter
2. For elabortion see Smith (1984b)

Table 2. Estimated number of adult mountain goats in the vicinity of the Quartz Hill mine, southeast Alaska, 1982.

Sample	m	x	n	N*	SE	95% C.I.
1	13	6	74	149	35.7	79-219
2	13	6	51	103	24.2	55-150
3	13	6	72	145	34.7	76-213
Combined				145	10.6	124-166

1. No significant differences between estimates at $p<.05$.

years' radio tracking data on seasonal movements, home ranges and habitat use suggest that these individuals are representative of goats in the area (Smith 1983, ADF&G unpubl. data).

The re-sightings of collared goats were tested to evaluate the assumption of equal catchability (Caughley 1977). The null hypothesis of equal catchability was not rejected ($p>.05$). Considering the small sample size, however, this does not represent a rigorous test and equal catchability remains the weakest assumption in the analysis.

ASSUMPTION 3:

Collars were not lost.

Monitoring of the goat's radio collars prior to and following the surveys (Smith 1983) assured that the assumption that all collars were retained was valid.

ASSUMPTION 4:

Goats were not counted more than once during a sample.

By recording each goat seen on a topographical map, multiple counting was largely avoided. However, some goats observed on or near the ridgeline may have moved across the divide when disturbed by the aircraft resulting in multiple counts when the flightline contoured the other side of the ridge. This was minimized through careful observation and recording and the senior author's familiarity with the terrain.

ASSUMPTION 5:

No collars on goats were overlooked in the aerial samples.

Considering the experience of the observer, it is reasonable to assume that if a collared goat were visible, its collar was seen and identified correctly. However, for future studies, the visibility of the collar should be increased to further reduce the chance of missing a collar. In addition, if brighter markings were used, the distance of observation could be increased to avoid disturbing goats, thus reducing flight responses which could lead to violation of assumption 4.

ASSUMPTION 6:

Aerial samples were independent.

Independence of samples is a major assumption with multiple sampling. Violation of this assumption will produce deceptively small confidence intervals for N^*, but will not bias N^* if assumption 2 is valid (Rice and Harder 1977). The time span between surveys was adequate to permit "mixing" of the population, and the varying survey conditions contribute further to independence. However, to increase sample independence in future studies, flight patterns, time of day, or observers could be varied (Rice and Harder 1977).

ASSUMPTION 7:

Sample size did not bias the population estimates downward.

The major drawback to the estimates resulting from this study is the possible bias due to the small sample size. Many studies have shown that small values of n/N and/or m/N tend to inflate the estimates (Robson and Regier 1964, Rice and Harder 1977, and Seber 1982). Seber (1982) suggested that the 'x' value should be 10 or greater; 'x' in this study was 6 for the individual studies.

Rice and Harder (1977) have determined minimum values for m/N and k (number of samples) which, with given values for N* and n_i/N*, will provide estimates that are accurate to within ±10% at the 95% confidence level. Using the values m/N*, N* and n/N* from this study (0.1, 145 and approximately 0.5, respectively), over 20 flights would be required to attain an estimate accurate within 10% at the p=0.95 level. This seems high inasmuch as our results provide an estimate accurate to within 15% at the p=0.95 level for the adult segment and within 20% at the p=0.90 level for the total population with only 3 surveys. Stevens and Driver (1978) indicated an accuracy of only 35% at p=0.95 for their population using multiple ground observations and sampling with replacement. Nevertheless the accuracy of future estimates could be enhanced if a greater number of surveys were flown.

The accuracy of future CMR estimates in this area could also be significantly improved if m/N were increased. Helicopter-darting and radio collaring may be prohibitively expensive, and an inexpensive alternative could be to uniquely mark goats by aerially applying dye. However, this approach would not facilitate evaluation of assumptions 1, 3, 4, and 5.

In spite of the limitations on accuracy and the relatively high cost, in situations where estimates of the actual size of coastal goat populations are needed, some type of CMR census may be required. Given the limited and variable sightability of coast goats to either ground or aerial surveys (Ballard 1977, Fox 1977, Hebert and Langin 1982) no uncorrected count should be taken as more than an index of the actual population size.

As Hebert and Turnbull (1977) indicated, density has been rarely reported in the literature on mountain goats. Furthermore, the variation in how densities are calculated limits comparisons of the published estimates. Some studies report densities for specific habitat types (Hjeljord 1971) and others refer only to general elevational zones or seasonal ranges (Hebert and Turnbull 1977, McCrory et al. 1977, Stevens 1983) or the overall area observed to be used by goats year-round (Foster 1982). Furthermore, the reliability of population estimates is generally undetermined, and often density figures are useful only for relatively crude comparisons between areas of "high", "medium" or "low" density (Hoefs et al. 1977, MacGregor 1977).

Although density estimates from various studies may not be generally comparable for the reasons mentioned, it appears reasonable to compare density estimates from this study with some of those developed in Yoho National Park, British Columbia by McCrory et al. (1977). These authors also used a population estimate corrected for sightability and applied it to their total study area and potential year-round goat habitat. Their values were 0.45 and

1.5 goats/km^2, which are both well below the values of 1.0 and 2.3 goats/km^2 found here. In view of the fact that the Quartz Hill population is rapidly increasing (r=0.21 for 1975-1983), and currently only about 60% of past numbers (Smith 1984), the potential density of this coast population may greatly exceed that of Yoho National Park. This appears to contradict the general theme of Hebert and Turnbull's (1977) evaluation of the differences between "coastal" and "interior" ecotypes, specifically that coastal populations which winter in lower elevation, often forested habitats, are generally of lower density, less productive and more sensitive to harvest than interior ones which have access to higher, wind blown winter ranges. Stevens (1983) also reported phenomenally high densities for goat populations in the Olympic Mountains of coastal Washington.

The high productivity of forage biomass and heavy use by goats of forested winter ranges in coastal Alaska have recently been confirmed (Fox et al. 1982, Fox 1983, Schoen and Kirchoff 1982, Smith 1983). The value of forested winter range in the interior as well is supported by McCrory et al. (1977) who found that those portions of Yoho National Park where goats wintered in timbered areas well below treeline, as well as alpine zones, supported higher densities of goats than mountain blocks without low elevation winter range.

The mountain goat evolved from forest-dwelling ancestors (Schaller 1977, Chadwick 1983) so it should not be surprising that they can successfully utilize such areas, so long as the terrain is steep and broken (Fox 1983). Considering the accelerating human exploitation of timber resources in the range of this species, further assessment of the value of forested winter range to mountain goats is warranted.

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