

Mountain Goat Population Trends in the Olympic Mountain Range, Washington

Abstract

We conducted an extensive aerial census of introduced mountain goats (*Oreamnos americanus*) in the Olympic Mountains during July 1990 to track population trend. The population in the 50,063 ha census zone was estimated with a stratified random block design at 389 ± 106 (SE) goats, significantly lower than an estimate in 1983. The large SE occurred despite improved information on goat densities being used to stratify the census blocks, and could reflect greater relative clumping of goats at lower population levels. The smaller 1990 population probably resulted from removals by the National Park Service combined with more severe winters.

Introduction

Mountain goats have colonized virtually the entire Olympic Mountain Range since their introduction in the 1920's (Moorhead and Stevens 1982). Olympic National Park was established as a natural area in 1938; goats are viewed now as an undesirable, introduced species by the National Park Service (NPS, Environmental assessment on mountain goat management in Olympic National Park 1981, 1987). In 1981, the NPS launched a program to remove goats from the park, which continued with varying intensity through 1989 (Houston *et al.* 1991). Determining goat population levels and trends is important to park managers. An initial helicopter census conducted in July 1983 returned an estimate of 1175 ± 171 (SE) goats (Houston *et al.* 1986). Here we report the results from a second range-wide census conducted during July 1990.

Study Area and Methods

The rationale for choosing the particular helicopter census design has been previously described (Houston *et al.* 1986). Briefly, most goats are seasonally migratory and visible mainly during mid-summer on subalpine ranges above 1500 m. The census zone included all of the 50,063 ha of land free of glacial ice above 1520 m (5000 feet) in the Olympic Mountains. About 87% of the area is now within the park; a slight increase (ca. 2%) over 1983 resulted from 1986 boundary changes with Olympic National Forest (readers need to be aware of these changes if maps of the 1983 and 1990 counts are compared). A block count sampling method was used and four census strata were recognized:

(1) Known or suspected high density goat areas: Olympus, Chimney, Flapjack, Royal, Constance, Buckhorn (Figure 1). 6229 ha total area. Aerial total counts were conducted in each of these units.

(2) Known or suspected medium density goat areas. 12,267 ha. These were divided into 24 blocks of about 500 ha each. Sixteen blocks (66%) were chosen randomly and censused.

(3) Known or suspected low density goat areas (densities thought to be 0.20 goats/km² or less). 29,570 ha. These were divided into 59 blocks of about 500 ha each. Fifteen blocks (25%) were chosen randomly and censused.

(4) Klahhane Ridge. 1997 ha. An aerial total count was conducted. This stratum was retained because it has been the focus of intensive population (Houston and Stevens 1988) and vegetation studies (Pfitsch and Bliss 1985, E. C. Schreiner pers. comm.) and a total count was considered necessary, although goat numbers were now thought to be very low.

The population estimate for strata 2 and 3 was calculated with Jolly's (1969) method for unequal-sized sample units, as outlined by Norton-Griffiths (1976:72). This approach uses the density of goats rather than the number observed per block to produce estimates, which was necessary due to the variation in block sizes ($\bar{X} = 504 \pm 52.9$ SD ha). As in 1983, the counts for strata 1 and 4 were added, without variances, to the estimates for strata 2 and 3, a move analogous to "stratifying out large herds" (Norton-Griffiths 1978:84).

Several steps were taken to maintain comparability between counts and to attempt to improve the precision (repeatability) of the 1990 count:

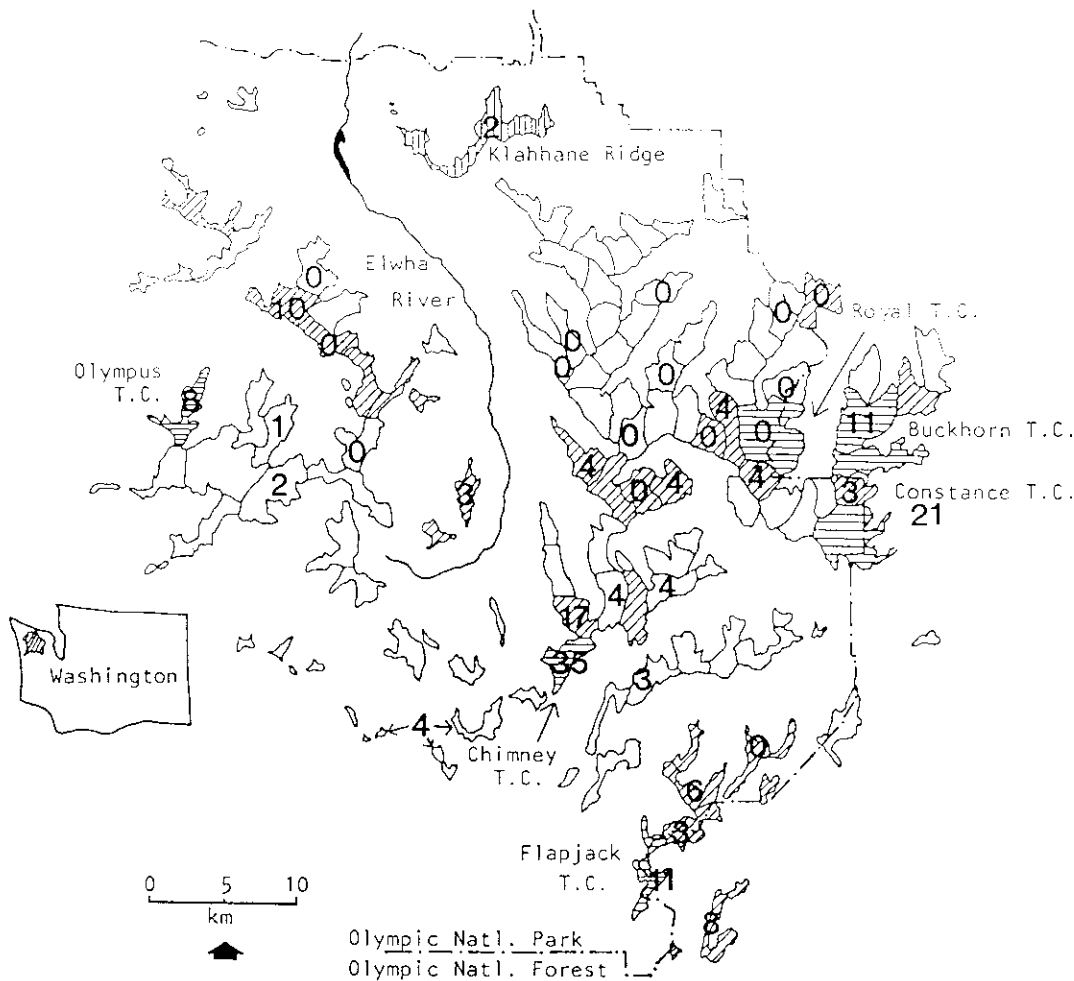


Figure 1. Number of mountain goats counted per census unit. Olympic Mountains, July 1990. Total count (T.C.; horizontal hatch), Klahhane Ridge, medium density (diagonal hatch) and low density (open) areas are indicated. Extensive areas of glacial ice are not shown.

(1) Census procedures were similar. Lower boundaries of each unit were flown first, and the unit was then searched upslope at 70-100 m intervals at speeds of 40-70 mph. A maximum of 30 minutes was allocated for counting each block; actual counting time averaged 18.8 ± 7.15 minutes ($0.044 \pm .036$ min/ha; which compares to about 0.038 min/ha in 1983). No time limit was placed upon counting the units in strata 1 and 4, but search effort was similar to the blocks ($.041 \pm .015$ min/ha).

(2) The three person census team was composed, for the most part, of the same individuals in both counts. However, during 1990 a Hughes

500-D helicopter was used instead of the Aerospatiale A-Star 350D of 1983.

(3) Generally, the boundaries of the counting units were the same in both censuses. However, by 1990, more information on relative goat densities was available throughout the park following extensive aerial capture efforts conducted from 1985 to 1989 (ca. 50-60 flight hours/year). Presumptive goat densities in all park units, therefore, were reevaluated and, where necessary, units were restratified by density class. Information on goat harvest trends and hunter observations of goats (Washington Dept. Wildlife, Unpubl.) was used to re-stratify units outside the park.

4) Wide variation in goat densities counted during 1983 within putative medium density areas contributed substantially to a standard error that was about 15 percent of the population estimate (Houston *et al.* 1986). In addition to restratifying the counting units in 1990, we increased both the intensity of sampling for medium density blocks (66% in 1990 vs. 47% in 1983) and the number of high density total count units (6 vs. 3) to attempt to reduce the SE.

Bias errors. Aerial census is known generally to underestimate the actual numbers of animals present (e.g., Caughley 1977, Norton-Griffiths 1978), and this is true for mountain goats as well (Houston *et al.* 1986). Three estimates of the bias error for goats in the census zone were available: (1) Johnson (1983:68) used ratios of marked to unmarked goats observed during a 1981 helicopter count to calculate a bias error of .37 (i.e., a "sightability" or census efficiency of .63) in the Charlia Lakes area of the northeast Olympics. (2) Houston *et al.* (1986) estimated a mean bias of $.34 \pm .05$ (.66 sightability) from 3 "index-manipulation-index" estimates (Caughley 1977:47) for Klahhane Ridge using the extensive goat removals of 1981-1983. (3) Hoffman (1987) estimated a bias of $.29 \pm .17$ (.71 sightability) using up to 7 radio-collared goats/count during 5 censuses of the Mt. Appleton and Mt. Carrie areas during 1985-1986.

Sightability probably varies among counting units in the census zone (Houston *et al.* 1986) and within the same unit over time; however, the available estimates of bias error are broadly similar. Consequently, we used the estimate of 0.66 sightability (also used in 1983) to produce a more accurate estimate (i.e., nearer the true total) for the 1990 count. The number of goats observed in each census unit was therefore multiplied by 1.52 (the reciprocal of 0.66). Clearly, use of the bias error constant only expands the estimates

uniformly; it does not otherwise enhance aspects of statistical rigor.

Results and Discussion

The census was conducted in seven early morning flights between 16-31 July. Total census time (including travel among counting blocks and refueling stations) was 21.3 hours.

A total of 172 goats (136 adults, 36 kids) was counted in the 4 strata (Fig. 1, Table 1). Counts were highly variable within the medium density stratum and total count units.

The estimated goat population for strata 2-3 (\hat{Y}_{2-3}) was calculated as:

Stratum	\hat{Y}_k	$\text{Var}(\hat{Y}_k)$
2 (low density)	104.3	1.095.1
3 (medium density)	150.5	10.157.8
Total	255	11.252.9

The standard error (\hat{Y}_{2-3}) is $\sqrt{\text{Var}(\hat{Y}_{2-3})}$ or 106 goats. When the 131 goats in the high density units and the 3 from Klahhane Ridge are added, \hat{Y}_{1-4} totals 389 ± 106 (SE) goats for the population in the census zone during July 1990.

We were unsuccessful in reducing the relative SE (27% of the estimated population) by restratifying the blocks and re-allocating the sampling effort. This may reflect greater relative clumping of goats at lower population levels. It *may* be possible to reduce the SE in future counts by modifying the census design. This could include conducting restratification flights immediately prior to the census and attempting to optimize sampling effort during the count (Gasaway *et al.* 1986).

Despite the large standard errors, the 1990 population estimate differed significantly from the 1983 estimate of 1175 animals (t test $\alpha_{0.05(2)}$, $t_{calculated} = 3.90$, Norton-Griffiths 1978:80, Gasaway *et al.* 1986:62) and we conclude that goat numbers declined considerably over the seven

TABLE 1. Area sampled and mountain goats counted in the Olympic Range, July 1990.

Stratum	Area (ha)	No. Blocks	Area Sampled	Blocks Sampled	Goats Counted	Adjusted Goat Numbers ¹
1) High Density	6.229	--	6.229	--	86	130.7
2) Low Density	29.570	59	7.686	15	18	27.1
3) Medium Density	12.267	24	8.158	16	66	100.1
4) Klahhane	1.997	--	1.997	--	2	3.0

¹Numbers observed x 1.52 for all strata.

years. Striking differences occurred between counts in five of seven large areas censused both years (Table 2). There were no differences, however, in group sizes ($n = 162 \bar{X} = 2.74 \pm 3.51$ goats in 1983; $n = 84 \bar{X} = 2.05 \pm 1.80$ in 1990; Mann-Whitney, $P > 0.05$) or in the estimated ratios of kids to older animals ($0.217 \pm .036$ and $0.265 \pm .041$ yg/ad, respectively; t test for Ratio Estimators, $P > 0.05$, Cochran 1977) between the censuses.

TABLE 2. Number of mountain goats counted in seven areas of the Olympic Range during July 1983 and 1990 censuses. Numbers represent actual counts and were not adjusted for sightability.

Area	1983	1990
Klahhane	52	2
Dana-Wilder	45	3
Chimney	52	35
Royal Basin	36	0
Constance/Charlia	65	24
Buckhorn	33	11
Pershing/Washington	13	8

Relative contributions to the apparent decline in goat numbers by the NPS removal program or other forces are unclear, and are considered in detail elsewhere (Houston *et al.* 1991). Known goat removals totaled 326 animals from autumn 1983 through autumn 1989 [245 (75.2%) removed by NPS, 80 (24.5%) legally harvested outside the park, 1 (0.3%) illegally killed in the park]. Annual removals were highly variable ($\bar{X} = 46.6 \pm 34.7$ goats/year, range 8-91), and would have averaged about four percent of the estimated 1983 population.

However, such summary calculations may be misleading because: (1) removals were not distributed across the population in relation to goat densities, but were sometimes concentrated on particular subpopulations (Houston *et al.* 1991), (2) NPS removals could have been effectively greater than the totals indicate. In relation to subpopulations (point 1), NPS removals were probably the force driving the decline of the Klahhane Ridge goats (Table 2, 43 animals removed 1984-89), but even there goat numbers continued to decline when removals were discontinued from 1985 to 1987 (Houston and Stevens 1988). Similarly, park

removals probably contributed to substantial declines at Dana-Wilder (43 goats removed 1983-89) and Royal Basin (14 removed).

In relation to the effectiveness of removals (point 2), aerial darting and net gunning were used to capture goats from 1985-1989 (Houston *et al.* 1991); only rarely were kids captured with these techniques during the July (primarily) operations. About 66% of the 102 adult females captured were lactating, and we suspect that few of their kids, if any, survived. Moreover, some yearlings may continue to depend heavily on maternal females (Hutchins 1984). Consequently, the population effects of NPS removals were likely somewhat greater than indicated.

Still, the indicated population declines seem disproportionate to the removals imposed in several other areas of the park. For example, Stevens (1983) estimated the Mt. Appleton subpopulation at about 35-60 goats in 1980, and 46 were counted during the 1983 census. However, only 13-21 goats were recorded during 4 subsequent censuses from 1984-1986 (the area was not drawn for census in 1990). Eleven animals were removed (9 in 1988). By 1989, no goats, or their sign, were observed during the removal program despite three aerial searches. We suspect that substantial winter mortality may have affected this, and other, subpopulations as winter snowpack returned to more "normal" levels, following unusually low levels from about 1976 to 1981 (Stevens 1983). Such patterns are not unusual for mountain goats: Smith (1984), for example, documented strong density-independent mortality among goat populations in southeast Alaska during severe winters.

Mountain goats in the Olympic Range appear to have declined considerably from 1983-1990, but the large standard errors for overall population size (and for Klahhane Ridge—a major subpopulation, Houston and Stevens 1988) makes us wary of proposing detailed "explanations" for these changes. Park managers, moreover, should recognize that the uncertainty associated with the population estimate translates directly to uncertainty in the scale of removal efforts required in the future.

Alien species, such as goats in the Olympics, pose special management problems for national parks because they often disrupt established biological processes. Few people appreciate the scale of this problem: In a 1980 report to Congress 300 NPS areas reported 602 "threats" to natural

resources that involved alien plants and animals (NPS State of the parks—1980). Threats were particularly severe in the Hawaiian parks. Introduced mammals have been surprisingly difficult to control, due in part to their versatile life history patterns and to an increase in political, economic, and social concerns. It remains to be seen if the NPS will receive the required support for control of alien mammals as public awareness increases on the value of conserving the natural biotic diversity in national parks.

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