

## An Aerial Census of Mountain Goats in the Olympic Mountain Range, Washington

### Abstract

Mountain goats were introduced into the Olympic Mountains, Washington, during the late 1920s and are now considered an exotic species in Olympic National Park. We report the results from the first extensive aerial census of this introduced population. A series of population reductions in the Klahhane Ridge area of the park was used to estimate a census efficiency of 66 percent. The goat population in the 50,063 ha census zone was estimated at  $1175 \pm 171(\text{SE})$  during July 1983.

### Introduction

Mountain goats (*Oreamnos americanus*) were introduced into the Olympic Mountains from 1925-29 and have since dispersed throughout the range (Moorhead and Stevens 1977; Stevens 1979, 1983). Olympic National Park was established in 1938 to be managed as a natural area with the primary purpose of preserving representative natural ecosystems. Goats are now seen as an exotic species with the capacity to alter pristine ecological relationships (National Park Service 1981).

The National Park Service initiated a three-year experimental goat management program in Olympic National Park during 1981. One aspect of the program involved removing goats from an area to measure the population's response to control (Aho *et al.* 1982, 1984). This experimental approach to management, where small scale management operations are used to test research hypotheses and to guide operational management (Macnab 1983), seems to have the potential to provide additional useful information on goat ecology. Development of reliable population inventory techniques for mountain goats has been identified recently as the most important research priority (Eastman 1977). We report here the results from the first extensive aerial census of mountain goats in the Olympic Range, where population reductions are used to estimate census efficiency.

Stevens (1980) estimated that goat population in the Olympic Mountains at about 550-880 animals in 1980; about 85-90 percent were thought to occur within the park. These estimates were based upon ground censuses of 10 subpopulations, field surveys of goat distribution,

and educated guesses for other areas based upon reports of hikers and hunters. Since park managers were considering an extensive goat removal program as one management option, a more comprehensive population estimate was needed.

### Study Area and Methods

Previous studies have shown that the mountain goat population is distributed discontinuously as "nodes" or subpopulations throughout the Olympics. They are seasonally migratory, with summer ranges mostly above 1,500 m. Summer and winter ranges overlap for some subpopulations, although seasonal ranges may be separated by as much as 8 km in other areas. Goats may occupy winter ranges above 1,500 m, although others winter on rock outcrops as low as 300 m (Stevens 1979, 1980, 1983).

The census zone included all of the 50,063 ha of land free of glacial ice above 1,520 m (5,000 feet) in the Olympics (Figure 1). About 85 percent of the zone is within Olympic National Park. A block count sampling method was chosen because of the extremely precipitous terrain and the highly variable goat densities. We drew heavily upon past studies (Stevens 1979, 1980, 1983) and the extensive knowledge of V. Stevens and her co-workers to delineate four census strata:

- (1) Known high density goat areas: Royal Basin, Appleton Pass, Lake Constance-Charlia Lakes. 5,071 ha (Figure 1). Aerial total counts were attempted in each unit.
- (2) Known or suspected low density goat areas: 13,135 ha. (Densities guessed to be 0.20 goats/km<sup>2</sup> or less). These were divided into 26 blocks of about 500 ha each. Six blocks (23 percent) were chosen randomly and censused.

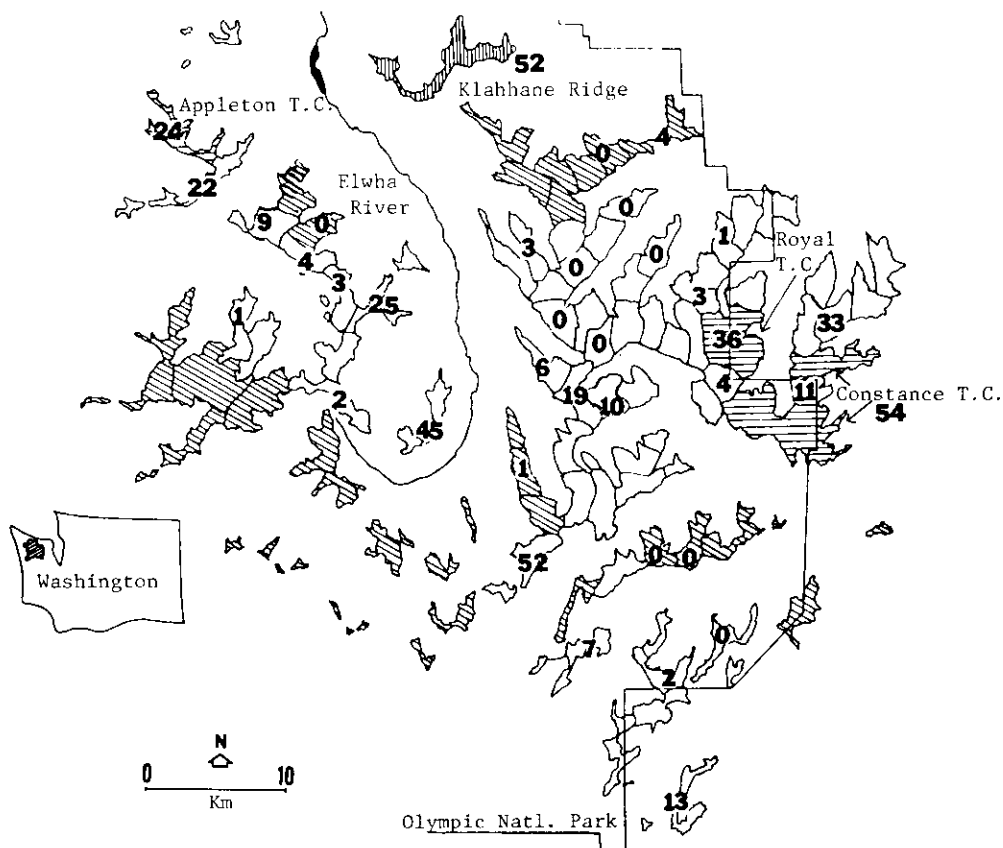


Figure 1. Mountain goat census units and numbers counted by unit, Olympic Mountains, July 1983. Total count (TC), Klahhane Ridge, low density (diagonal cross hatch), and medium density units are indicated. Extensive areas of glacial ice in some units are not shown.

(3) Known or suspected medium density goat areas: 29,860 ha. These were divided into 59 blocks of about 500 ha each. Twenty-eight (47 percent) were chosen randomly and censused.

(4) Klahhane Ridge: 1,997 ha. Censused separately using the "Index-Manipulation-Index" technique (see below).

The census design requires explanation. Late July was chosen to conduct the census because most goats occupy open summer ranges above timberline and they are conspicuous against the low, green vegetation. Also, increased temperatures during August often drive goats back down into forests. The 500 ha blocks

represented a compromise between goat home range size (Stevens 1980), the amount of area to be sampled, and the observation that lower sampling errors usually occur when many small units are counted rather than a few large ones (Norton-Griffiths 1978). Information on goat densities, though extensive, was still limited for certain areas. Thus, sampling intensity also represented a series of compromises. Six blocks sampled in the putative low density stratum represented a guess at the minimum required to calculate an acceptable estimate. Great variation was expected among the supposed medium density blocks (representing all areas between the high density stratum of perhaps 3-6 goats/km<sup>2</sup>

and the low density stratum of 0.2/km<sup>2</sup>); 28 blocks were chosen as the maximum that was economically feasible to count.

Census blocks were delineated on 1:62,500 scale contour maps with an Apple II graphics digitizer. Blocks were designed to include as many slopes and aspects as possible. This design was chosen because goats move frequently about the different slope exposures in response to short-term changes in temperature, snow melt, and vegetation growth.

Conspicuous terrain features (glaciers, rock outcrops, trails, forest strips) were used as block boundaries. Lower boundaries of each block were checked in the field against the aircraft altimeter. Occasionally, a block was produced by combining the areas of several disjunct peaks or ridges (Figure 1). Block size averaged 506 ± 52 ha. A maximum of 30 minutes was allocated to census each block; actual counting time averaged 19.3 ± 6.9 minutes (0.038 min/ha). No time limit was placed on counting the three high density areas, but search effort was similar to the blocks (0.034 min/ha). Lower boundaries of each unit were flown first, at about 1,570 m, and then the unit was searched upslope at 75-100 m intervals. Airspeed during census was about 40-70 mph using an Aerospatiale A-Star 350D helicopter. The census team included the pilot, two observers, and one navigator—the latter responsible for locating units, directing the pilot along block boundaries, and timekeeping.

The population total was calculated using Jolly's (1969) method for unequal sized sample units, as outlined by Norton-Griffiths (1978:72). This approach, applied to the medium and low density strata, uses the density of animals rather than the number observed per block to produce the estimates. This was necessary because of the variation in block size; we were only modestly successful in producing uniform 500 ha census blocks that could be recognized from the air. The counts for the three high density areas (stratum 1) and the calculated total for Klahhane Ridge (stratum 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).

Aerial census is known to underestimate the actual numbers of animals present (Caughley 1977, Norton-Griffiths 1978). Consequently, the "index-manipulation-index" (IMI) method of

population estimation (Caughley 1977) was used during the 1981-83 period of goat removal to estimate a bias error for the overall census. Population size was estimated from an index of density (helicopter counts) before and after a known number of animals was removed by trapping from the Klahhane Ridge (census stratum 4). Counting procedures were generally similar to those described above; except, a Bell Jet Ranger III helicopter was used in 1981, and a Hughes 500D in 1982. Two censuses (one morning, one evening) were made before and two after the goats were removed in 1981 to test the "repeatability" of the counts. One count was made before and one after the removals of 1982 and 1983. Flights were made during periods of maximum daily goat feeding activity (Stevens 1979).

## Results and Discussion

*Establishing a bias error.* The IMI method requires that goat habitat use and avoidance behavior remain constant, and that corrections can be made for mortality occurring between counts. Studies have shown that goat use of open vegetation types on Klahhane Ridge is consistently high during the late June-mid-July periods of IMI census (Stevens 1979). Daily field observations made each year between the flights suggested that no major changes occurred in goat use of vegetation types. Goats may learn to seek cover if approached frequently by aircraft, and helicopters were used to remove trapped goats. However, pilots were instructed to fly directly from the low elevation staging area to the capture site, thus avoiding adjacent goat habitat. Observations of goat behavior, plus the continued successful trapping suggest that the effects of local helicopter traffic were minimal. Mortality of neonates occurred between IMI censuses and this was corrected as described below. We consider that the conditions necessary to use the IMI method were met to the extent that a useful bias error was generated.

Counts and population estimates for the Klahhane unit are summarized in Table 1. Only two age classes of goats could be distinguished reliably from the air, young-of-the-year and all older animals. Counting time (mean ± SD) was 88 ± 16 minutes for the eight flights. Overall repeatability of the 1981 attempts was high: total counts varied by only two goats between

TABLE 1. Mountain goats observed during helicopter counts of Klahhane Ridge, 1981-83.

Year	Date	Time	Number of Goats			Total Goats Removed	Total Population <sup>2</sup>
			Adults and Yearlings	Young	Total		
1981	<i>Pre-removal</i>						
	24 June	0718-0828	130	24	154		229(198 ± 31) <sup>1</sup>
	26 June	1752-1909	135	17	152	52(50 + 2) <sup>1</sup>	
	<i>Post-removal</i>						
	16 July	1833-1955	103	14	117		171(148 + 23)
	17 July	0648-0804	95	17	112		
1982	<i>Pre-removal</i>						
	23 June	0626-0819	97	28	125		176(137 + 39)
						51(41 + 10)	
	<i>Post-removal</i>						
19 July	0645-0820	68	21	89		126(96 + 30)	
1983	<i>Pre-removal</i>						
	21 June	0628-0822	68	22	90		147(111 + 36)
						52(39 + 13)	
	<i>Post-removal</i>						
19 July	0637-0825	44	8	52		85(72 + 13)	

<sup>1</sup>Total (adults and yearlings + young).

<sup>2</sup>Adults and yearlings calculated using IMI census.

pre-removal flights, and five goats between post-removal flights. Differences within age classes were greater: the number of young observed varied as much as seven between pairs of flights, adults and yearlings, as much as eight. Neither morning nor evening counts produced consistently better results; however, morning counts were preferred because of better light conditions and calmer air.

Ground observations of tagged females showed that some mortality of young occurred during the 22 days between the 1981 censuses (Stevens 1981, personal communication). A less biased estimate should result from using only the adults and yearlings observed during aerial census, avoiding the effects of neonatal mortality. The numbers of young were estimated separately from the observed ratios of young to adults. Calculations follow Caughley (1977:47) and are presented in detail elsewhere (Aho *et al.* 1984). Fifty-two goats (50 adults and yearlings, 2 young) were removed from the subpopulations 30 June-8 July. The mean numbers of adults and yearlings observed during the pairs of flights were used in the calculations, even though we suspected goats were somewhat more disturbed during the

second flight of each pair. The adult and yearling pre-removal population was calculated as 198 goats; post-removal, 148.

Mean young/adult-and-yearling ratios for pre-removal and post-removal counts were 0.155 and 0.157, respectively. The higher post-removal ratio is reasonable, because females with young at heel were not removed in proportion to their occurrence in the population. The estimate of the total pre-removal population using the IMI technique is 229 (198 adults and yearlings + 31 young); postremoval, 171 (148 + 23). Similar calculations were used to determine population size in 1982 and 1983 even though neonatal mortality appeared to be very low (Table 1).

Some approximate 90 percent confidence limits (CL) were calculated for the IMI pre-removal estimates under the assumption that the counts represented Poisson random variables (Eberhardt 1982:735, equation 6). The CL were calculated for the adult and yearling segment of the population. The estimates with CL were: 198(133-326), 137(97-220), 96(68-156) for 1981-83, respectively. The actual number of goats observed was substituted for the calculated lower limit. The CLs declined somewhat over time as

an increased proportion of the population was removed (Eberhardt 1982). Nevertheless the calculated limits remained very broad.

Calculations using the 1981 count of adults and yearlings suggest a bias error of 0.33. This represents a measure of census efficiency, the difference between the goats observed and those actually present, and calculated as  $132.5/198$  or 0.67 of those present were observed. Similar calculations suggest bias errors of 0.29 and 0.39 for 1982 and 1983, respectively. The 3-year mean observability of 0.66 was used to adjust the 1983 overall census.

The main census was conducted in seven early morning flights from 21-31 July 1983. Total census time (including travel between counting blocks and the Hurricane Ridge staging area) was 18.2 hours.

A total of 396 goats (324 adults, 72 kids) was counted in strata 1-3 during the main census (Table 2, Figure 1). As expected, counts in the medium density stratum were highly variable. Observed densities in two blocks exceeded those in the known high density stratum.

The average 66 percent census efficiency from Klahhane Ridge was used to produce a more accurate estimate (*i.e.*, nearer the true total) by initially multiplying the number of goats observed in each block of strata 1-3 by 1.52 (the reciprocal of 0.66). The estimate of 66 percent observability is conservative; the south and southeast portions of the census zone support more shrub and forest cover than Klahhane, and census efficiency is surely lower. Johnson (1983:68) used ratios of marked to unmarked goats observed during an August 1981 helicopter count to calculate a census efficiency of 63 percent for the Iron Mountain-Charlia Lakes area in the northeast Olympics (within the census zone used in this study).

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

Stratum	$\hat{Y}_h$	$\text{Var}(\hat{Y}_h)$	Number of blocks
2 (low density blocks)	35	491	6
3 (medium density blocks)	882	28,875	28
Total	917	29,366	34

The standard error ( $\hat{Y}_{2-3}$ ) is  $\sqrt{\text{Var}(\hat{Y}_{2-3})}$  or 171 goats. When the 173 goats in the high density total count units are added,  $\hat{Y}_{1-3}$  is 1090. Finally, the Klahhane estimate (stratum 4) of 85 goats can be added to give  $\hat{Y}_{1-4} = 1175 \pm 171(\text{SE})$  for the population in the census zone during July 1983. Detailed calculations are presented in Aho *et al.* (1984). This estimate is substantially greater than those made earlier. As mentioned, observed goat densities in two blocks of the putative medium density stratum exceeded those in the known high density stratum (Chimney Peak,  $n = 52$ ; Dana-Wilder,  $n = 45$ ). These rude surprises added considerably to the standard error. If these two blocks are included as part of the known high density stratum, for illustration, and all calculations are repeated,  $\hat{Y}_{1-4}$  is 1,036 goats with the standard error reduced to  $\pm 111$ .

Armed with the results of this first census, the precision of future counts could be improved by restratification and by calculating bias errors for different vegetation types. However, given the precipitous terrain, the highly clumped distribution of mountain goats, and the observation that block counts have inherently larger sampling errors than transects (Norton-Griffiths 1978), future counts can also be expected to return large standard errors. This may be particularly true in the Olympics, where goats are still colonizing the range and many subpopulations have probably

TABLE 2. Area sampled and mountain goats counted in the Olympic Range, July 1983.

Stratum	Area(ha)	No. Blocks	Area Sampled	No. Blocks Sampled	Goats Counted	Adjusted Goat Numbers <sup>1</sup>
(1) Known High	5,071	—	5,071	—	114	173
(2) Low Density	13,135	26	2,847	6	5	7.6
(3) Med. Density	29,860	59	14,251	28	277	421
(4) Klahhane	1,997	—	1,997	—	—	85

1. Numbers observed x 1.52 for strata 1-3. Stratum 4 estimated by IMI, see text.

not yet achieved ecological carrying capacity. Wherever subpopulations grow rapidly, the information on density needed to produce census strata is soon outdated. For all its limitations, the census indicates that the goat management problem facing the National Park Service is very likely larger than anticipated initially.

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