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PRESENT AND FUTURE MOUNTAIN GOAT RESEARCH IN WASHINGTON STATE, USA

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Abstract: Current research on mountain goats in Washington focuses on delineating habitat and the development of a sightability and group size bias model for mountain goat surveys. To that end, in 2002 and 2003, 32 mountain goats in the Cascade Range were captured and fitted with GPS collars. Some preliminary findings are presented here and aspects for further research are identified.

In 2002, the Department of Fish and Wildlife initiated a mountain goat research project. Cooperators in this project include the U.S. Forest Service, the National Park Service, the Sauk-Suiattle Tribe, the Stilliguamish Tribe, and Western Washington University. This study was prompted by concern about declining mountain goat populations in several areas of the state.

In the initial phase of the study, we are focusing on furthering our understanding of mountain goat habitat relations and developing a more robust survey method. Habitat studies will focus on modeling seasonal habitat use and understanding the choices mountain goats make in selecting particular areas. Subsequent areas of research will concern the roles of habitat, environment, and mountain goat social organization on mountain goat populations and evaluate potential population regulatory mechanisms.

Study Area and Methods

Mountain goats are found throughout the Cascade Range in Washington and on the Olympic Peninsula. For the purposes of this study, this range was divided into 4 areas, the Olympic Peninsula, the North Cascades (from Snoqualmie Pass north to the Canadian border and west of the Cascade crest), the South Cascades (from Snoqualmie Pass south to the Oregon border and west of the Cascade crest), and the East Cascades (from the Canadian border to the Oregon Border, east of the Cascade crest). Initial efforts (2002 and 2003) have emphasized the North and South Cascades areas with expansion to the East Cascades expected to take place in 2004 and to the Olympic Peninsula in 2005.

Within each area, a conceptual distinction was made between sites with extensive habitat and substantial numbers of mountain goats (> about 50) and isolated habitats with smaller mountain goat numbers (usually 10-20). This distinction was made for use in study planning to ensure that the results would incorporate potential differences in habitat and survey design considerations for these populations.

The desired distribution of mountain goat collars was determined by convening a working group comprised of study partners for each area. These working groups evaluated the approximate distribution of mountain goats in each area and allocated collars by each habitat area to achieve a representative sample subject to some logistical constraints. One such constraint was the restriction on the use of helicopters for mountain goat capture within designated wilderness. In the North Cascades, the Forest Service supported helicopter captures in wilderness. Due to local concerns, this was not possible in the South Cascades.

Mountain goats were captured by darting with an immobilizing drug, either from a helicopter or on the ground. Generally, we used helicopter darting unless their use was constrained by regulations. Either the experimental drug A3080 (usually 2.5 mg with 50 mg of xylazine) or Carfentenil (usually 1.5 mg) were used. A3080 and Carfentenil were reversed with Naltrexone (usually 250 mg) and the xylazine was reversed with Tolazine (4 ml). Time to recumbency and recovery after reversal were noted when feasible. After helicopter captures, the approximate pursuit path was traced on a topographic map and the distance and elevation change during pursuit and induction were recorded.

Captured mountain goats were fitted with Vectronic GPS Plus 4 D collars, measurements were taken, and many were scored for body condition using the palpation system developed for mule deer by R. Cook (similar to that for elk, Cook 2000). Rump fat thickness and loin muscle depth were measured using an iLook25 portable ultrasound. In some cases, measurements were not taken due to the need to release the animal promptly. Age was estimated based on horn rings.

Herculite was attached to collars to form 3 bands of color on each side to allow individual visual identification. Colors used were red, yellow, black, and light blue. Collars were programmed to attempt a GPS fix every 3 or 5 hours with the exception of 1 collar which was set at a 30 min interval. Fixes stored on the collar were acquired by remote download, usually from fixed-wing aircraft.

GPS fixes were plotted using ArcView (v8.2) and three-dimensional representations were created in ArcScene (3D Analyst extension to ArcView).

During helicopter surveys of Mt. Baker and Mt. Shuksan in the North Cascades, attempts were made to evaluate mountain goat movements in response to survey flights. For the Mt. Shuksan survey, GPS collars on the 2 mountain goats in the survey area were set to collect fixes at 5 minute intervals.

The habitat mapping effort will be involve the development of a statistical model capable of identifying potential mountain goat habitat based on predictor variables derived from satellite imagery and GIS coverages. These spatial databases will provide information about vegetation, escape terrain and other physical characteristics of the environment that may influence habitat quality for mountain goats.

The availability of escape terrain is one of the more important physical attributes of the environment that has been shown to influence mountain goat distribution (Holmes 1993, Gross et al. 2002). The location of escape terrain, as well as elevation and aspect, are derived from Digital Elevation Models (DEMs).

During surveys of mountain goat populations containing collared animals, coviarates of group size and physical terrain attributes will be recorded to develop a sightability model for adjusting mountain goat surveys (Steinhorst and Samuel 1989). As Anderson et al. (1998) pointed out, this approach has the drawback of not including the effects of only partially counting groups. We will evaluate this group size bias by placing ground observers to record (to the extent possible) to actual group sizes during a period before or after the survey flight.

We developed a preliminary population model to explore the potential effects of past harvest on mountain goat population size around Mt. Baker. For this model, we compare survey-based population estimates with a deterministicly modeled population where sport harvest was considered to be additive (Côté and Festa-Bianchet 2003). Population parameters for the model were taken from previous studies.

Past population estimates of mountain goats on Mt. Baker were conducted made in 1961 (Wadkins 1962), and 1985 (unpublished data). However, because the area under consideration varied for the different estimates, there is uncertainty about the size of the population in 1962. While further details will be provided in a subsequent publication, we conducted the model with two likely initial populations of 384 and 419 mountain goats.

Results and Discussion

Captures

Between 26 September 2002 and 26 September 2003, 32 mountain goats were captured between the Canadian border and the southern end of the Goat Rocks Wilderness and fitted with collars during 34 capture operations. One animal was captured in 2002 and again 2003 for collar replacement and one animal (a non-lactating adult female) died during capture. This mortality was the result of an overdose while using the experimental drug A3080 and after this experience we discontinued its use. Helicopter darting was used for 25 of the captures, the remainder were darted from the ground (including the mortality). Despite the precipitous terrain occupied by mountain goats, we had good success in using the helicopter to maneuver them onto safe terrain for darting and constraining their movements during induction.

In the North Cascades, we successfully allocated collars according to the distribution determined desirable by the working group. In the South Cascades, where wilderness captures had to be by ground darting, captured goats in wilderness were underrepresented due to the low efficiency of that method of capture. One female was captured near Easton where its range is expected to overlap with that of collared mountain lions being studied in that area.

Captured mountain goats were of various sex and ages (Table 1). The representation of males was somewhat greater than intended as it proved difficult to distinguish young males from females during approach and pursuit.

The cost of helicopter captures varied greatly depending on the abundance of mountain goats in the area (Table 2). In the vicinity of Mount Baker, captures/hr of flight time were >1, whereas around Darrington, this dropped to <0.5, reflecting costs of about $500-$2,000 per capture.

Table 1. Distribution of mountain goat captures by area, sex, and estimated age.

		Estimated Age								
Area	Sex	1	2	3	4	5	6	8	Not recorded	Total
North	F	1		3	3	4	1	1	1	14
Cascades	M		3			2				5
	Total	1	3	3	3	6	1	1	1	19
South	F		3	1					1	5
Cascades	M		1	2	2	1				6
	Total		4	3	2	1			1	11
East	F			1						1
Cascades	M				1					1
	Total			1	1					2
All Areas	F	1	3	5	3	4	1	1	2	20
	M		4	2	3	3				12
Total		1	7	7	6	7	1	1	2	32

Table 2. Mountain goat capture costs for 14 captures in the North Cascades.

	September 2003 date					
	2	3	4	5		
Operations	Setup	Mt. Baker	Mt. Baker, Church, Mamie, Whitehorse	Darrington*	Total (w/out ferry time)	Total (incl. ferry time)
Total Time		5.9	4.8	5.7		16.4
Ferry Time		1	0.5	0.7		
Capture Time		4.9	4.3	5.0	14.2	
Ferry Cost		700	346	479	1,525	
Capture Cost		3,430	3,014	3,511	9,955	11,480
Driver Pay	125	125	125	125		
Per diem Driver/Pilot	85	85	85	85		
Fuel Truck Mileage				330		
# Goats		7	5	2	14	
Goats/Hr		1.43	1.16	0.40	0.98	1.17
$$/Goat		490	603	1,756	711	820

*Three Fingers, Whitechuck, Round Lake, Falls Creek, South Cascade Glacier

For body condition, rump scores ranged from 1.5−4.0 (mean=2.58, n=21), rump fat (measured by ultrasound) ranged from 0−0.24 cm (mean=0.68, n=17), withers pinch ranged from 1/8−1 in (mean=0.32, n=21), and loin muscle depth ranged from 2.5−4.5 cm (measured by ultrasound, mean=3.17, n=17). The sample sizes are small for analysis of patterns in condition, but in general showed remarkably low levels of rump fat. In mule deer, rump fat levels typically range 0.5-2cm (W. Myers, pers. comm.). Whether this is due to differential fat deposition between mountain goats and mule deer or a consequence of a relatively dry summer is uncertain.

One hundred percent of the serum samples (*n*=21) from mountain goats captured in 2003 tested positive for 1 or more serovars of Leptospirosis. Leptospirosis affects both humans and other animals and varies in the severity of its affects, but can cause abortion in domestic animals and liver damage, kidney failure and internal bleeding in humans. In addition, 9 animals from around Mt. Baker tested positive for bovine viral diarrhea. However, the effects of these diseases on mountain goat populations may be minimal (K. Masfield pers comm. and T. Kreeger pers comm.). More detailed monitoring of population parameters will be needed to assess this.

The 4 mountain goats captured in 2002 were from isolated ridges west of the Goat Rocks Wilderness. Other captures took place in the summer and fall of 2003, so results reported here are preliminary.

For all collars, of the 41,699 attempted fixes (as of the most recent downloads), 44% achieved 3D fixes, 59% achieved 2D or 3D fixes (41% did not achieve a fix). This differed substantially among collars, range 3D fixes = 13−80%, 3D+2D fixes = 25−86%.

Movements and Habitat Use

Annual information is available for 2 of the mountain goats captured in 2002. The difference in seasonal use for one of these is illustrated in Figs. 1 and 2. During summer, 003SCF generally remained near the crest of Stonewall Ridge, predominately on the west side. During the summer, 003SCF also utilized a rocky knoll on the southern end of the ridge, an area not utilized in the winter. Winter utilization was noteworthy in the large number of locations low on the west side of the ridge near a rock outcrop above a clear cut (as low as 1,150 m). There were 3 smaller areas at low elevations on the east side of the ridge which were also visited in winter. Notably, significant utilization of the ridge top took place during winter months. Areas at low elevation used solely in winter were termed winter zones. Between 28 September 2002 and 14 August 2003, 003SCF visited winter zones on 14 occasions, many of which were not in the winter (Table 3), but most were in the winter or spring, the longest being during the second half of February through March.

I examined the relationship between snow, temperature, and winter zone use by comparing 003SCF's records with snow and temperature data from the Snotel (http://www.wrcc.dri.edu/snotel.html) records from Pigtail Peak, south of White Pass. This station is at the same elevation as the top of Stonewall Ridge and 22 km to the northeast. I computed snow accumulation by subtracting consecutive daily Snow Water Equivalent measures from Pigtail Peak.

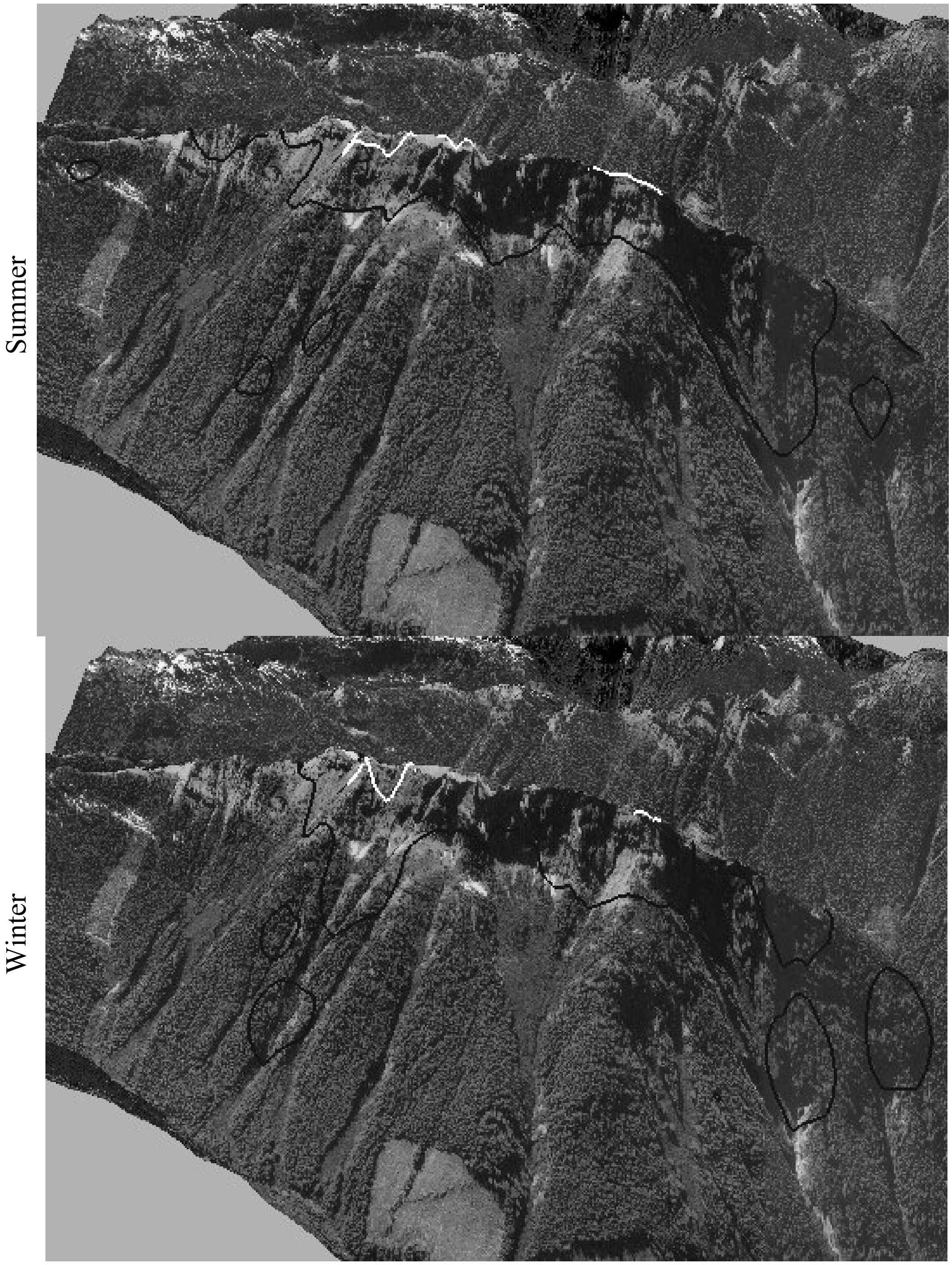

Figure 1. Fixed kernel utilization estimates for mountain goat 003SCF on Stonewall Ridge, Washington during summer (June-August 2003) and winter (December 2002-February 2003) viewed from the east. Contours shown at 0.9 (black) and 0.2 (white) of total volume of utilization. Based on 535 GPS collar locations.

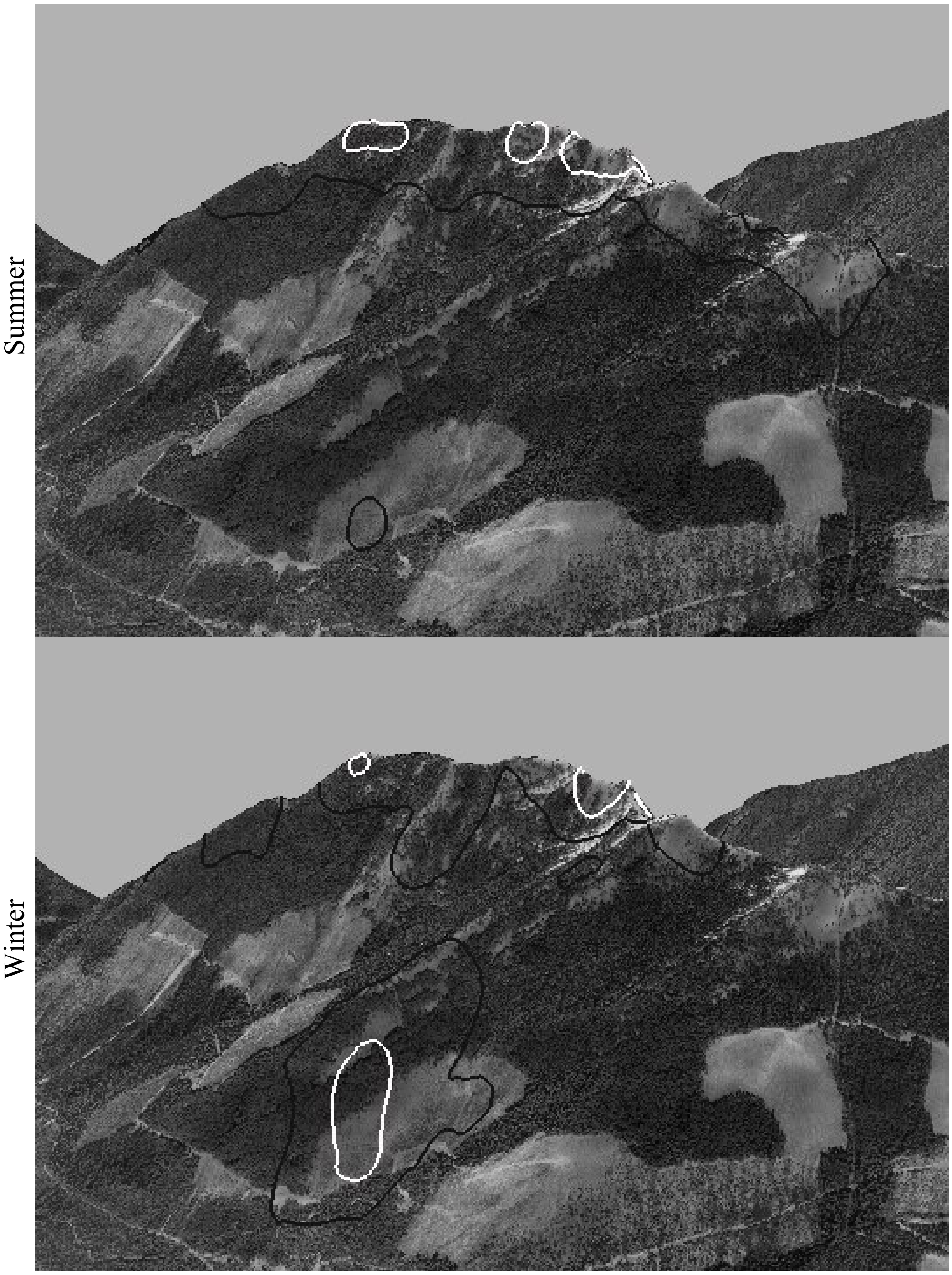

Figure 2. Fixed kernel utilization estimates for mountain goat 003SCF on Stonewall Ridge, Washington during summer (June-August 2003) and winter (December 2002-February 2003) viewed from the west. Contours shown at 0.9 (black) and 0.2 (white) of total volume of utilization. Based on 535 GPS collar locations.

Table 3. Dates of utilization of winter zones for mountain goat 003SCF on Stonewall Ridge.

First Date	Last Date	Days
10Nov2002	14Nov2002	5
11Dec2002	24Dec2002	14
24Dec2002	27Dec2002	4
27Dec2002	01Jan2003	6
12Jan2003	17Jan2003	6
29Jan2003	05Feb2003	8
06Feb2003	07Feb2003	2
18Feb2003	30Mar2003	41
27Apr2003	27Apr2003	1
29Apr2003	01May2003	3
07May2003	07May2003	1
08May2003	08May2003	1
15May2003	22May2003	8
08Aug2003	09Aug2003	2

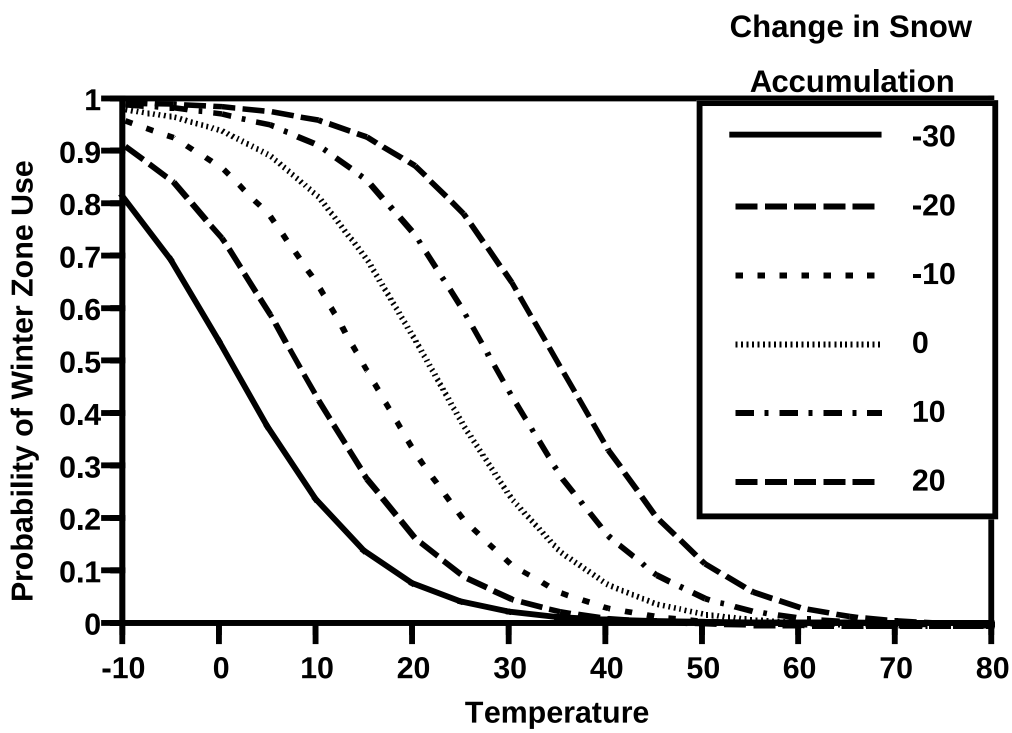

Figure 3. Relationship between probability of use of winter zones by mountain goat 003SCF according to temperature and snow accumulation during September 2002 - August 2003

Both snow accumulation and average daily temperature were significantly related to winter zone use ($P<0.0001$), their respective coefficients in the logistic regression being 0.089 (se 0.021) and –0.132 (se 0.013), indicating that when snow accumulated, use of winter zones increased, whereas it declined with increasing temperature (Fig. 3).

Summer and winter space utilization by mountain goat 003SCF was noteworthy in that there was considerable overlap between the seasons. However, even along the top of the ridge, there was some differentiation in the particular areas used in these 2 seasons. The physiography of the primary winter zone on the west side of Stonewall Ridge agreed with the expected in that it included rocky cliffs at low elevation surrounded by forest, and as was found in the Tolt and Mine Creek drainages in Washington, there was considerable use of a clear cut below the cliffs (Gilbert and Raedeke 1992). 003SCF provides an additional illustration of the complex interplay between slope, exposure, forest cover, forage, snow, and temperature as they affect mountain goat movements and habitat choice (Wright 1977, Reed 1983, Fox et al. 1989). Further observations in 2003 and 2004 from additional goats from isolated habitat patches and those that extensively use high-elevation areas in the summer should further our understanding of these influences.

Response to Helicopter Survey

The helicopter survey of Mt. Shuksan took place on 01 October 2003 and flew over mountain goats 008SHF and 028SHF. Neither was seen during the survey. The response of these goats to helicopter overflight is difficult to determine because the flight track of the helicopter was not available or had the segment missing in the vicinity of the mountain goat. Nevertheless, records of the mountain goat locations show no obvious movements from their center of activity at that time.

The survey of Mt. Baker took place on 22 September 2003. Mountain goats that were observed during the survey moved ¾-1½ km and climbed upwards on the morning of the survey, clearly more than they usually did on September mornings (Table 4). Notably, 015MBF did too even though she was not counted, but was close to the flight path. 011MBM, who was about 480 m from the flight path, moved less than usual. 029MBM did not move very much more than usual, (although it is hard to tell with the small sample), while he was about 1,400 feet below the helicopter.

During surveys, it is typical to closely approach mountain goats that are seen to verify total counts for groups. Hence, these animals are usually disturbed and that they moved more than usual is not surprising, although the magnitude of the movements is, perhaps, more than expected. Detailed records of movements will be of interest in further quantifying this disturbance.

Determining the extent that missed animals move is important in developing procedures for sightability modeling because if missed animals move, their location after the survey cannot be used for collecting information on covariates concerning their location when they were missed. While our sample size is low, these results might suggest that mountain goats somewhat removed from the flight path do not move, but those near to it (015MBF) may do so. This will necessitate activating collars before

Table 4. Response of mountain goats to survey. Time indicates the time frame over which movement after the survey was estimated (PST). Mean and median are for movement and elevation change measurements during September 2003 (22^{nd} excluded) from the same time frames (6-9 for Sight-9 and 6-9 and 6-12 for 6-12). Only 3D-3D GPS fixes were used for elevation measurements.

			Distance				Elevation Change (m)			
Mtn. Goat	Status	Time	22Sep03	Mean	Median	n	22Sep03	Mean	Median	n
010MBM	Missed (outside)	No data[1]		98	95	4		-10	-10	1
011MBM	Missed	6-12	94	461	443	23	26	74	84	22
012MBM	Sighted	Sight-9[2]	1,575	398	251	19	76	-31	-10	16
013MBF	Sighted	Sight-9[2]	1,634	301	258	17		1	-14	14
014MBF	Sighted?	No data[1]		144	122	16		27	44	12
015MBF	Missed	6-9	1,381	303	233	18	174	34	63	13
016MBF	Sighted	Sight-9[2]	1,065	358	304	15	105	40	11	3
019MBF	Sighted	6-9	934	182	32	23	312	34	10	21
029MBM	Missed (low)	6-12	284	204	204	2				0

[1] Consecutive fixes not available.
[2] From time of sighting to 0900 hrs.

each survey to collect frequent fixes, and comparing the flight path and mountain goat movements to determine the location of the mountain goat when it was missed by GPS fix rather than by its location after the survey is complete.

Sport harvest from Mt. Baker during the period covered by our model was substantial, and was often well above the 2-4% that is now considered sustainable for native mountain goat populations (Côté and Festa-Bianchet 2003). The modeled population was quite close to the population estimate at both ends of that period. While these results are preliminary, it seems likely that historic harvest levels played an important role in the decline observed on Mt. Baker. Further work is needed to incorporate uncertainty in the population parameters and incorporating other sites.

Further Research

In addition to further development of population models, there are several aspects of mountain goat ecology which can further our understanding of population regulation in this species, namely:

1. Habitat mapping – Statewide: There is a need to expand the current regional effort to delineate mountain goat seasonal habitat in the rest of the state.
2. Meteorological influences on movements and habitat use: link weather (wind, solar radiation, temperature, precipitation) with habitat/site selection. Use weather from monitoring stations and model archives with GPS locations.

3. Recreation impacts: evaluate the impacts of recreation on mountain goat habitat use. Off-road vehicles, hiking, climbing, and winter sports have the potential of affecting mountain goat populations. The recent development of back-country capable snowmobiles is an emerging issue in this area.
4. Winter habitat: while topography appears to be the dominant factor in mountain goat winter habitat (Keim 2004), but the significance of this for populations can only by understood by characterizing these areas in terms of forage and predation risk.
5. Population studies: in Washington, mountain goats populations have declined in a number of areas. In some of these locales, populations appear to be recovering but this is not evident in all of them. Assessing population parameters for healthy, recovering, and depressed populations will determine if these apparent differences in population trajectory are due to our inability to detect recovery in some areas or are underlain by differences in population processes.
6. Winter habitat and population dynamics: Numerous mountain goat publications have pointed out that the historic perception that mountain goats could be managed assuming a density dependent population response (see Côté and Festa-Bianchet 2003). Yet, a valid management and recovery paradigm has not emerged as is evidenced by Gonzalez Voyer et al.'s (2003) conclusion that all populations need to be managed (and monitored) on an individual basis. In 1971, Kuck outlined a possible mechanism for mountain goat population regulation as a consequence of mountain goat preference for terrain over forage in winter habitat use, resulting in population stagnation at low densities. However, a more thorough test of this is needed before it can be accepted as a general principle. Such a study would investigate the relationship between winter habitat availability and quality on population processes and would link forage, snowfall, population density, and winter movements, with survival and reproduction.

Conclusions

We captured mountain goats from helicopter and on the ground. Ground captures, however, are labor intensive and provide less opportunity to select where and which mountain goat will be captured. The cost of helicopter captures varies considerably with the circumstances, but are about $1,000 per mountain goat.

The proportion of fixes achieved by the GPS collars were somewhat lower than others have experienced with other species (Frair et al. 2004), which may be related to terrain shielding as our rates are comparable to those of Taylor (2002) for mountain goats in British Columbia. Certainly, a valid approach for compensating for GPS fix bias will need to be developed (Taylor 2002, Frair et al. 2004).

Initial patterns are emerging from fixes obtained to date, but detailed analysis will require observations from more mountain goats over longer time periods than we presently have.

At present, we cannot assume that mountain goats that are missed during helicopter surveys remain in the same place. Sightability model development will consequently require integration with fine-scale GPS tracking of mountain goat movements.

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