EVALUATION AND MANAGEMENT IMPLICATIONS OF LONG-TERM TRENDS IN COASTAL MOUNTAIN GOAT POPULATIONS IN SOUTHEAST ALASKA

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ABSTRACT

Results of aerial surveys of mountain goat (Oreamnos americanus) populations conducted since 1968 near Ketchikan, Alaska indicate that population reductions of up to 90 percent occurred during the period 1968 - 1975; mean observed rate of increase r, for three populations during this period was -.29. From 1975 to 1983 all populations monitored increased at an average r = .12, range, .03 to .21. During initial recovery, r values were as high as .38 over a 5 year period. Both declining and increasing populations provide limited evidence of correlations between density and rate of increase. Long-term weather patterns are examined as causative forces in trends. Reproductive and mortality data from radio-collared goats provide insight into demographic processes driving the unexpectedly high r values in recent years. Contrary to results of earlier studies of the "coastal" ecotype, results indicate populations can be highly productive. Nevertheless, cyclic weather severity may reverse the trend and populations will decline regardless of management strategies. The limitations of attempting to develop population models and/or harvest guidelines with only a few years' data and static demographic parameters are discussed, and application of a tracking harvest strategy is proposed.

INTRODUCTION

Mountain goat (Oreamnos americanus) populations in south coastal Alaska declined sharply in the late 1960's and early 1970's (Ballard 1977), presumably as a result of the severe winter conditions which were decimating deer (Odocoileus hemionus sitchensis) (Olson 1979) and moose (Alces alces) (Bishop and Rausch 1974) populations during those same years. Because access and, therefore, hunter harvest were limited, the declines in goat herds were not viewed with alarm nor considered cause for drastic management response. During the same period, however, Hebert and Turnbull (1977) documented demographic and behavioral differences between "coastal" and "interior" mountain goat ecotypes and hypothesized that coastal populations were generally less productive and more sensitive to harvest than populations in the intermountain region. In view of the expected low rates of increase for interior goat populations (e.g. r = .11, Youds et al. 1980) and the indication that hunting mortality is additive to other sources of mortality (Kuck 1977), Hebert and Turnbull's findings were viewed with concern by wildlife managers in Alaska.

More recent evaluation of coastal goat population dynamics by Hebert and Langin (1982) indicated that the earlier estimates of potential productivity and rate of increase were unduly conservative. However, these investigators concluded that their survey data were inadequate to allow determination of the internal dynamics of the study population or to permit development of a sound harvest regime. Hebert and Langin (1982) also implied that their surveys even were of questionable value for assessing trends, in spite of the fact that these data were obtained using relatively intensive helicopter surveys.

The lack of published information on long-term trends in coastal goat populations has, until now, prevented placing the results of work in British Columbia into perspective. The purpose of this paper is to provide such a perspective based on 15 years' aerial trend count surveys conducted near Ketchikan, Alaska and to suggest how future harvest schemes can be established when managers are faced with limited or crude census data, extensive management zones, and relatively limited hunter access. Such conditions exist over much of coastal Alaska and British Columbia where financial constraints largely prohibit detailed censuses of goat populations. I wish to emphasize that some concepts proposed herein may be inappropriate for more intensively managed goat populations.

STUDY AREA

The coastal mountains near Ketchikan consist primarily of granodiorite and quartzdiorite formations reaching elevations up to 2000 meters, heavily modified by glaciation, with sheer faces and rugged terrain extending to sea level in many areas. Bays and fjords intersect most ridge complexes; major river valleys are predominately narrow and steep sided. Vegetation below treeline (7-900 meters) is predominantly old growth western hemlock (*Tsuga heterophylla*) - Sitka spruce (*Piceasitchensis*) forest with an understory dominated by *Vaccinium* spp., ferns, and evergreen forbs(Alaback 1982). Alpine vegetation consists of heath fields and lush forbs-sedge meadows (Fox 1983, Smith 1984).

The climate is maritime with cool wet summers and relatively warm wet winters. Annual precipitation exceeds 400 centimeters per year, much of which falls as snow at higher elevations from October through March. Winter temperature patterns regulate the depth, duration and lower elevational limit of the snowpack, which is consistently of extremely high density.

METHODS

Coastal mountain blocks in the Ketchikan vicinity, divided from each other by bays, fjords or major rivers were stratified into trend count areas ranging from 50 to 280 square kilometers in size (Fig. 1). A fixed contour route, circumnavigating the ridge complexes in each mountain block, was flown in a PA-12 or PA-18 Super-Cub with a pilot and single observer. Both the pilot and the observer searched for goats. The altitude of the flight and distance from the slope were adjusted as necessary to permit a view of the entire slope from treeline to the ridge top.

In view of the variability reported by Ballard (1977) for both fixed wing and helicopter surveys in northern southeast Alaska, results of several

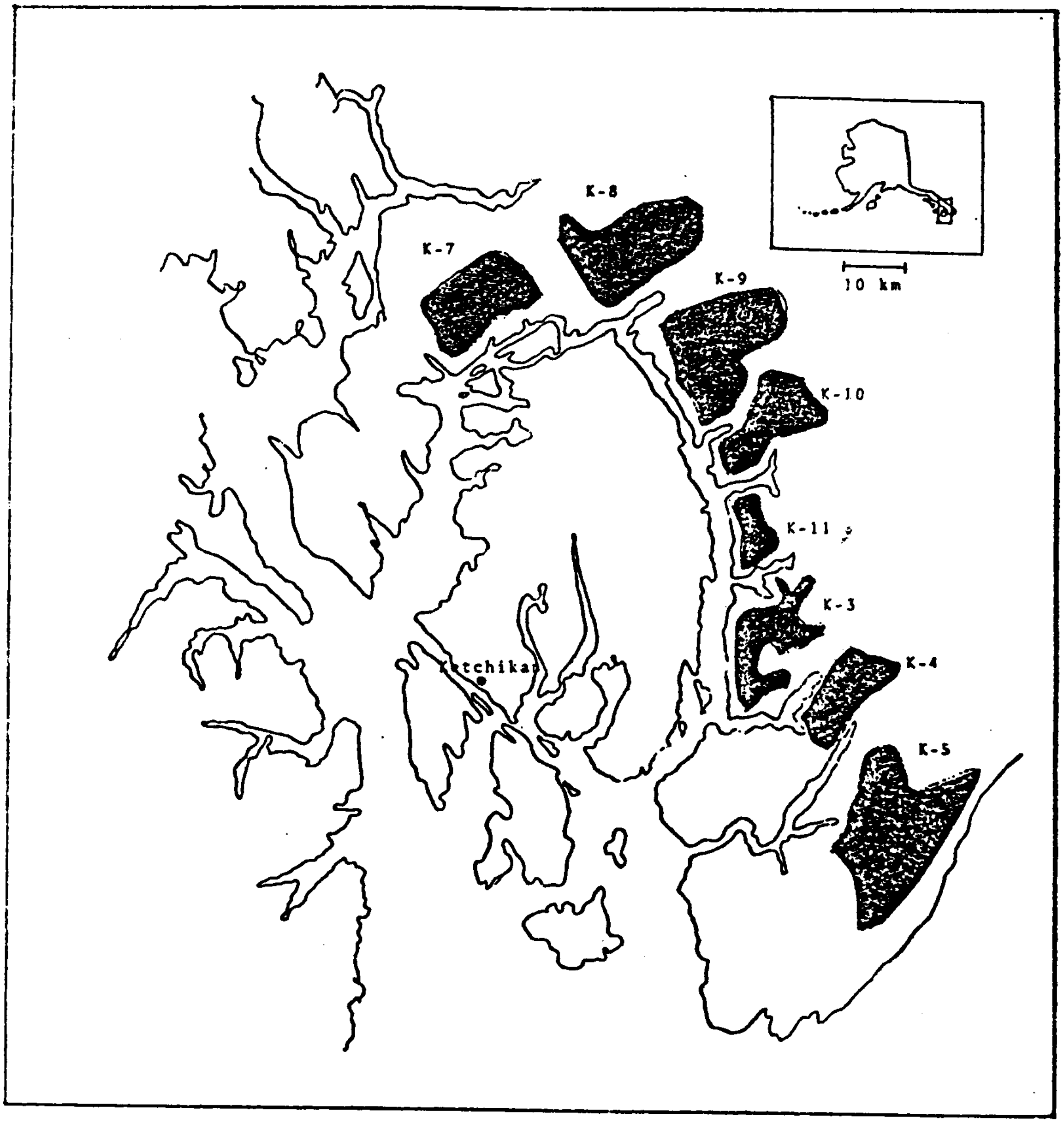

Figure 1. Mountain goat trend count areas near Ketchikan, Alaska.

replicate flights were examined for consistency. For this analysis surveys were categorized on the basis of the weather and visibility at the time of the survey. "Good" survey conditions were considered to occur in early morning or late evening hours during periods of light wind, no glare, often high scattered clouds or thin overcast and cooler temperatures. "Fair" survey conditions occurred at times with intermediate winds, occasional fog and/or warmer temperatures. "Poor" survey conditions were exemplified by limited visibility due to glare, fog or clouds, turbulent winds, high temperatures or excessive snowpack at the survey elevations. These categories parallel those used by Nichols (1980) in selecting optimal periods for goat surveys near Kenai, Alaska.

The stormy conditions typical of the north-Pacific coast prevent rigid scheduling, so survey flights were conducted from mid-August to late September as weather permitted. Recent telemetry studies have revealed that the distribution and sightability of goats is optimal and relatively constant at this time of year (Smith unpubl. data). To the extent possible, flights were timed to correspond with the goats' evening activity period (Fox 1977).

Each goat seen was classified as either a "kid" (i.e. 3-4 months old) or "adult" (any other goat). The location and composition of each observation were recorded on 1:63,360 scale topographic maps and composition was recorded on a standard data form. Following each survey the total number of goats observed, the number of goats counted per hour of survey flight time and the percentage of kids in the herd were calculated. If a survey could not be completed in a single evening due to weather, fog, darkness, etc., the ending point of the survey was noted on the topographic map. In a few cases, incomplete surveys were completed within 2 days and the data from both flights were pooled. Telemetry studies indicate that movements at this time of year are limited, so the potential for double-counting on these pooled surveys is small (Smith unpubl. data).

In trend count areas K-3 and K-8, the annual survey could not be completed in 1982. In area K-4 surveys could not be completed in 1974 and 1980 and in area K-5 the survey could not be completed in 1978. To make the results of all surveys comparable, these incomplete counts were extrapolated as follows. The proportions of adults and kids observed on completed surveys in other years in areas missed on incomplete counts were determined from maps and data sheets. The means of these proportions were used to estimate the number of goats that would have been observed in the unsurveyed portions had the aborted flights been completed. Where regression showed that significant trends in any proportion occurred over time, regression was used to calculate a more accurate estimate of the proportion and number missed than the mean. In all cases, 95 percent confidence limits were used with estimated proportions.

Population trends were determined by regression of the natural log of observed numbers on time. The slope of the regression line, r, represents the mean annual, exponential observed rate of increase (Caughley 1977 p. 109). The antilog of $\bar{r}$ is λ which can be used to calculate the percentage rate of increase by the formula, (λ-1)*100=% increase.

To test the effect of density on r in this study, density indicies were calculated by dividing the total number of goats counted on a survey by an estimate of the total area covered by the survey flight line. Because sightability of goats in coastal areas is low (Foster 1982, Smith and Bovee 1984), total survey counts represent only a portion of the population. Furthermore, the survey areas have varying amounts of subalpine and mature timber which were not surveyed, so area figures do not necessarily represent equal proportional coverage. For these reasons, data presented here are indicies only and should not be compared with actual density estimates (e.g. Smith and Bovee 1984).

Information on natality and mortality was available from records of goats captured and radiocollared for habitat use studies (Smith 1983). Natality estimates were based on observations of known females with young or lactating; mortality estimates were based on hunter returns of radiocollars or examination of remains following reception of mortality mode signals from the collars.

Additional information on mortality was provided by spring "carry-over" surveys initiated in 1982. These surveys consisted of fixed wing (PA-18-150) searches of lower elevation cliff/slide areas in April and May. Goats were classified as kids (10-11 months old) and adults. Because such habitat is sparsely distributed over several of the summer/fall trend count areas, all results were pooled to provide an estimate of percent kids in the overall herd.

Several authors have reported correlations between snowfall and goat population dynamics (Bailey and Johnson 1977, Adams and Bailey 1982). Unfortunately, no long-term snowfall records are available within the trend-count areas, and data from Ketchikan, located at sea level on the west coast of Revillagigedo Island (Fig. 1), cannot be considered comparable to conditions on mid-elevations goat winter ranges on the mainland. Thus it was necessary to rely on an indirect method of assessing winter severity on goat populations.

Given the magnitude of precipitation in the coastal region, even a relatively "dry" year has the potential for catastrophic snowfall accumulations if the winter temperatures remain low. This may explain why Merriam (1970) found an inverse correlation between mean winter temperatures at Petersburg, Alaska and over-winter deer mortality. Thus, temperature patterns have been used in this analysis to evaluate the effect of weather on goat populations.

Mean annual temperature at Ketchikan was plotted using a 5-year running mean smoothing formula to assess trends in temperature as Juday (1983) had done for the balance of Alaska. In addition, a 5-year running mean of mean winter (October-March) temperatures was used as an index to winter severity.

RESULTS

Replicate surveys were made in count areas K-4, K-5 and K-11 in 1973, 1975, 1982 and 1983 under varying conditions and with a total of 4 observers (Table 1). The pilot and type of aircraft for all except 1 of these flights were the same. The coefficient of variation (CV) for all replicate surveys flown in one area in one year ranged from 3.4 to 46.0 percent (x=24.8 percent, SE = 7.8, n=5). However, if only results of surveys conducted under "Fair" or "Good" conditions are considered, the range of CV is reduced to 3.4 to 11.1 percent (x=7.1 percent, S.E.=2.2, n=3). This indicates that the survey methodology is relatively precise (Eberhardt 1978). Furthermore, given sightability levels of 30 to 50 percent for goats on these surveys (Smith and Bovee 1984), the probability that trend lines based on results of surveys conducted under "Fair" or "Good" conditions are accurate to within ±10 percent per year is greater than 90 percent, when at least 3 years' survey results are considered (Harris 1984). Accordingly, unless otherwise noted, all r values reported herein are based on 3 or more counts obtained under "Fair" or "Good" survey conditions.

Table 1. Results of replicate aerial trend count surveys near Ketchikan, Alaska. 1973 to 1983.

Survey area	Survey date	Survey[1] time	Survey[2] conditions	Goats observed	% Kids in herd	Observer
K-4	8-16-73	1.08(a)	Good	103	12	Wood
K-4	9-16-73	1.00(p)	Fair	88	15	Blankenbeckler
K-5	8-13-73	1.45(p)	Poor	29	25	Wood
K-5	9-11-75	1.30(p)	Good	57	30	Wood
K-4	8-13-82	1.07(p)	Poor	43	25	Wood
K-4	9-18-82	1.03(p)	Fair	87	26	Wood
K-4	9-22-82	1.25(p)	Good	99	25	Smith
K-4[3]	9-23-82	1.25(p)	Poor	71	28	Smith
K-4	9-29-82	1.30(p)	Fair	97	26	Smith
K-11	8-29-82	0.22(p)	Poor	28	29	Wood
K-11	9-12-82	0.25(p)	Good	46	31	Wood
K-4	8-17-83	1.75(p)	Fair	122	19	Bovee
K-4	9-08-83	1.40(p)	Fair	118	31	Smith
K-4	9-16-83	1.05(p)	Fair	114	23	Wood

1 Length of survey in hours, (a) = morning survey, (p) = evening survey.

2 Good = high visibility, no glare, light winds, often scattered clouds or high overcast, cooler temperatures. Fair = intermediate visibility, limited glare, moderate winds, occasional fog, warm temperatures. Poor = limited visibility due to glare, fog or clouds, turbulent winds, high temperature or excessive snowpack at survey elevations.

3 Survey conducted in Hughes 500 "D" helicopter, all others conducted in PA-12 (1973-75) or PA-18 (1982-83) with Pilot R.D. Hamlin.

In 1982, portions of trend area K-3 in the Goat Lake drainages and south of Checats Lake were not surveyed due to impending darkness. During previous years approximately 35 percent of the adults, 39 percent of the kids and 38 percent of all goats seen in K-3 were found in these areas (Table 2). It was calculated that, if the 1982 survey had been completed, 16 additional adults and 6 additional kids, or an additional total of 22 goats, would have been seen (Table 3). The precision of the estimates of adults and kids is limited by the small samples and number of surveys.

In area K-4, two years' surveys omitted the Falsegate Creek drainage. Analysis of the proportion of goats observed in this drainage on completed surveys from 1973 through 1982 (Table 4) revealed that a steadily increasing percentage of the count was found here. This trend was highly significant for kids ($p<0.03$), adults ($p<0.01$) and total goats ($p<0.01$) so regression was used to estimate the percent and number of goats that would have been seen in the Falsegate Creek drainage had the 1974 and 1980 surveys have completed (Table 5 and 6).

In area K-5, the 1978 survey omitted the north fork of the Red River drainage. Analysis of results of complete surveys in area K-5 for 1975 through 1982 (Table 7) revealed no trend in proportion of adults ($p<0.5$) or total goats ($p>0.75$), but a significant increasing ($p<0.01$) trend in the proportion of kids in this part of the survey area. Accordingly, the mean values for adults and total goats and regression value for kids were used to estimate the number of goats that would have been seen in the north fork of the Red River in 1978 had that survey been completed (Tables 8 and 9).

In count area K-8, the Grant Creek drainage was not surveyed in 1982. Results of previous surveys indicate that approximately 36 percent of the adults, 25 percent of the kids and 35 percent of all goats seen in K-8 occurred in this drainage (Table 10). Thus, had the 1982 survey been completed, an estimated 30 additional adults, 4 additional kids or 34 more total goats would have been seen (Table 11).

The extrapolated count data for areas K-3, K-4, K-5 and K-8 are presented along with results of complete surveys for these and 4 other areas in Table 12. Two different trends are evident from these results. First, from 1968 through the mid 1970's populations in the 3 areas surveyed each experienced major declines in numbers (Fig. 2). Second, since the mid 1970's, all 8 populations have increased to varying degrees (Fig. 3). These trends are evident in both the total number of goats counted and the number of goats counted per hour of survey time.

Data from trend counts were used to calculate observed rates of increase, (r), for the different count areas (Table 13). The marked declines from 1968 through 1975 or '76 are reflected in negative r values. Since the mid 1970's all the r values are positive, although most areas experienced more rapid growth in the initial 5 years of increase than over the entire period, 1975-83. In fact, following significant initial increases, populations in areas K-4, K-9, and K-10 seem to have fluctuated with no clear trend since 1980.

Table 2. Results of complete surveys of K-3, 1976 and 1980, with breakdown of goats observed in the Goat Lakes area and ridges south of Checats Lake.

Year	Goats observed	Survey time	Goat Lake/South of Checats Lake		
			% Adults	% Kids	% Total
1976	34	1.3	34.6	50.0	38.2
1980	53	1.5	40.5	27.3	37.7
x		1.4	37.6	38.7	38.0
95% C.I.			± 5.8	±22.2	± 0.5

Table 3. Estimated number of goats (and 95 percent confidence interval) that would have been counted in trend area K-3 in 1982 if the survey were completed.

Age Class	Actual count	Estimated Goats missed	Estimated Total
Adults	26	16 (12-20)	42 (38-46)
Kids	10	6 (2-16)	16 (12-26)
TOTAL	36	22 (18-27)	58 (54-63)

Table 4. Results of complete surveys of K-4, 1973-1982 with breakdown of goats observed in Falsegate Creek drainage.

Year	Goats observed	Survey time (Hr.)	Falsegate Creek Drainage had:		
			% of Adults	% of Kids	% of Total
1973	103	1.08	18.9	23.1	19.4
1975	18	0.78	26.7	0.0[1]	22.2
1976	25	0.95	27.8	14.3	33.3
1977	58	0.93	30.8	42.1	34.5
1978	84	0.85	47.7	52.6	48.8
1979	60	1.08	45.5	50.0	46.7
1981	95	0.75	51.5	44.4	49.5
1982	87	1.03	57.5	60.9	59.8
x	66	0.81	38.3	41.1	39.3
S.E.	11	0.04	4.9	6.3	5.0
n	8	8	8	7	8

1 Value deleted from calculations due to small sample size (n=3)

Table 5. Regression equations for % of adults, % of kids and % of total goats found in survey area K-4 that occurred in Falsegate Creek drainage on year for 1973 through 1982.

% of Adults = 4.44 (Year - 1900) - 306.7; r^2 = .93

n = 8; F = 76.73; significant at $p<0.01$

% of kids = 4.30 (Year - 1900) - 294.1; r^2 = .62

n = 7*; F = 5.47; significant at $p<0.03$

% of Total = 4.50 (Year - 1900) - 310-11 r^2 = .91

n = 8; F = 45.3; significant at $p<0.01$

* 1975 value excluded due to small number of kids observed (3).

Table 6. Estimated percentages and number of goats ± 95% C.I. for Falsegate Creek Drainage in 1974 and 1980.

Falsegate Drainage Estimates[1]

	% of Adults	% of Kids	% of Total	# of Adults	# of Kids	# of Total
1974	22.2	24.1	22.9	7	3	10
95% C.I.	+5.1	±16.3	± 6.1	±2	±1	± 4
1980	48.9	49.9	49.9	33	18	53[2]
95% C.I.	± 4.1	±11.6	± 4.9	± 6	± 8	±20

1 Based on regression equations in Table 3.

2 Total may not equal Adults + Kids because this value is based on a separate regression.

Table 7. Results of complete surveys of K-5, 1975-1981 with breakdown of percent of goats observed in the north fork of Red River.

Year	Goats observed	Survey time (hr)	N. Fork Red River Had: % of Adults	% of Kids	% of Total
1975	57	1.30	2.5	0.0	1.8
1976	47	1.65	10.0	0.0	8.5
1977	124	1.67	4.8	4.9	4.8
1980	151	2.08	6.0	5.7	6.0
1981	192	1.83	5.5	8.5	6.3
1982	166	1.58	5.1	6.3	6.0
1983	220	1.95	6.4	8.5	6.8
x	137	1.72	5.8	4.8	5.7
S.E.	25	0.10	0.9	1.3	0.8
n	7	7	7	7	7

Table 8. Regression equations for % of adults, % of kids and % of total goats found in north fork of the Red River portion of survey area K-5 on year for 1975-1983.

% of Adults = 0.04 (Year - 1900) + 2.33; r^2 = .004

n=7; F=0.25; nonsignificant (p>0.50)

% of Kids = 1.04 (Year - 1900) - 77.12; r^2 = .83

n=7; F=22.76; significant at p<0.01

% of Total = 0.27 (Year - 1900) - 15.45; r^2 = .16

n=7; F=1.07; nonsignificant (p>0.75)

Table 9. Estimated percent and number ± 95% C.I. of adults, kids and total goats in the north fork of the Red River in Survey Area K-5 in 1978.

	N. Fork Red River Drainage Estimates					
	% of Adults[1]	% of Kids[2]	% of Total[3]	# of Adults	# of Kids	# of Total
1978	5.8	4.0	5.7	6	1	9
95% C.I.	±1.8	±1.6	±1.6	±2	±1	±2

[1] Based on mean value for 1975-1983, see Table 7.

[2] Based on regression equation for 1975-1983 data, see Table 7.

[3] Total may not equal Adults + Kids because this value is based on a separate calculation.

Table 10. Results of complete surveys of trend area K-8 in 1975 and 1976 with percentage of goats counted in Grant Creek Drainage.

Year	Goats counted	Survey time	Goats in Grant Creek		
			% of Adults	% of Kids	% of Total
1975	40	1.1	41.2	16.7	37.5
1976	51	1.3	31.1	33.3	31.4
$\bar{x}$		1.2	36.2	25.0	34.5
95% C.I.			± 10.0	± 16.3	± 6.0

Table 11. Estimated number of goats (±95% C.I.) that would have been seen in Grant Creek drainage in trend area K-8 in 1982 had the survey been completed.

Age Class	Actual count	Estimated goats missed	Estimated total
Adult	52	30 (18-45)	82 (70-97)
Kid	13	4 (1- 9)	17 (14-22)
TOTAL	65	34 (26-44)	99 (91-109)

Table 12 Results of aerial trend counts of mountain goat populations near Ketchikan, Alaska 1968-1983.

	SURVEY AREA					
	K-3			K-4		
Year	Goats counted	Goats/Hr survey	% Kids ± 95% C.I.	Goats counted	Goats/Hr survey	% Kids ± 95% C.I.
1968	79	47	21.3 ± 9.0	265	199	27.0 ± 5.4
1969	-	-	-	-	-	-
1970	-	-	-	-	-	-
1971	94	71	23.1 ± 8.5	220	189	26.5 ± 5.8
1972	-	-	-	-	-	-
1973	-	-	-	103	95	12.3 ± 6.3
1974	-	-	-	44 [a]	54 [a]	23.8 ± 12.8 [a]
1975	-	-	-	18	23	16.7 ± 17.2
1976	34	27	23.7 ± 14.3	25	26	28.1 ± 17.6
1977	-	-	-	58	62	32.9 ± 12.1
1978	-	-	-	84	99	22.5 ± 8.9
1979	-	-	-	60 [b,c]	55 [b,c]	26.5 ± 11.2 [c]
1980	53 [b]	36 [b]	20.6 ± 10.9	106 [a]	131 [a]	34.6 ± 9.1 [a]
1981	-	-	-	95	122	28.6 ± 9.1
1982	58 [d]	41 [d]	27.6 ± 11.5 [d]	87	84	26.5 ± 9.3
1983	-	-	-	114	109	23.1 ± 7.7

Table 12 continued ..

Year	K-5 Goats counted	K-5 Goats/Hr survey	K-5 % Kids ± 95% C.I.	K-7 Goats counted	K-7 Goats/Hr survey	K-7 % Kids ± 95% C.I.
	SURVEY AREA					
1968	371	194	20.0 ± 4.1	-	-	-
1969	-	-	-	-	-	-
1970	-	-	-	-	-	-
1971	168 [b]	121 [b]	20.6 ± 6.1	-	-	-
1972	-	-	-	-	-	-
1973	81	57	27.0 ± 9.7	-	-	-
1974	30 [e]	25 [e]	20.0 ± 14.3 [e]	-	-	-
1975	57	44	30.1 ± 11.9	48	26	23.1 ± 11.9
1976	47	29	15.3 ± 10.3	-	-	-
1977	124	73	32.9 ± 8.3	-	-	-
1978	140 [f]	81 [f]	25.4 ± 7.2 [f]	-	-	-
1979	-	-	-	-	-	-
1980	151 [b]	72 [b]	23.1 ± 6.7	164	91	21.0 ± 6.3
1981	192	105	24.2 ± 6.1	-	-	-
1982	166	105	29.1 ± 6.9	-	-	-
1983	220	113	21.3 ± 5.4	168	92	21.9 ± 6.3

Table 12 continued ..

	SURVEY AREA					
	K-8			K-9		
Year	Goats counted	Goats/Hr survey	% Kids ± 95% C.I.	Goats counted	Goats/Hr survey	% Kids ± 95% C.I.
1968 to 1974		NO DATA			NO DATA	
1975	40	38	15.3 ± 11.1	63	48	17.4 ± 9.4
1976	51	38	11.5 ± 8.8	93	61	21.3 ± 8.3
1977	-	-	-	148	73	29.6 ± 7.4
1978	-	-	-	158	102	23.7 ± 6.7
1979	-	-	-	122 [b,c]	75 [b,c]	18.7 ± 6.9 [b,c]
1980	-	-	-	224	122	29.6 ± 6.0
1981	-	-	-	139	75	28.1 ± 7.5
1982	99 [g]	83 [g]	17.2 ± 7.4 [g]	129	96	19.4 ± 6.8
1983	-	-	-	183	116	20.0 ± 5.8

Table 12 continued ..

	SURVEY AREA					
	K-10			K-11		
Year	Goats counted	Goats/Hr survey	% Kids ± 95% C.I.	Goats counted	Goats/Hr survey	% Kids ± 95% C.I.
1968 to 1974		NO DATA			NO DATA	
1975	105	97	29.6 ± 8.7	23	99	21.9 ± 16.9
1976	85	86	23.7 ± 9.0	21	74	23.7 ± 18.2
1977	168	117	32.9 ± 7.1	21	84	28.6 ± 19.3
1978	157	124	23.1 ± 6.6	-	-	-
1979	118 b,c	111 b,c	19.4 ± 7.1 b,c	-	-	-
1980	158	108	26.5 ± 6.9	29	102	24.2 ± 15.6
1981	152	122	21.9 ± 6.6	36	135	19.4 ± 12.9
1982	125	106	20.6 ± 7.1	46	184	30.6 ± 13.3
1983	150	130	20.0 ± 6.4	-	-	-

a. Extrapolated results from incomplete surveys, see text and Tables 4-6.
b. Poor survey conditions, goat count and goats/hr may be unreliably low.
c. Inexperienced observer, results may be unreliable.
d. Extrapolated results for incomplete surveys, see text and Table 2 & 3.
e. Different pilot and aircraft (Cessna 185) results not directly comparable.
f. Extrapolated results from incomplete surveys, see text and Tables 8-10.
g. Extrapolated results from incomplete surveys, see text and Tables 12 & 13.

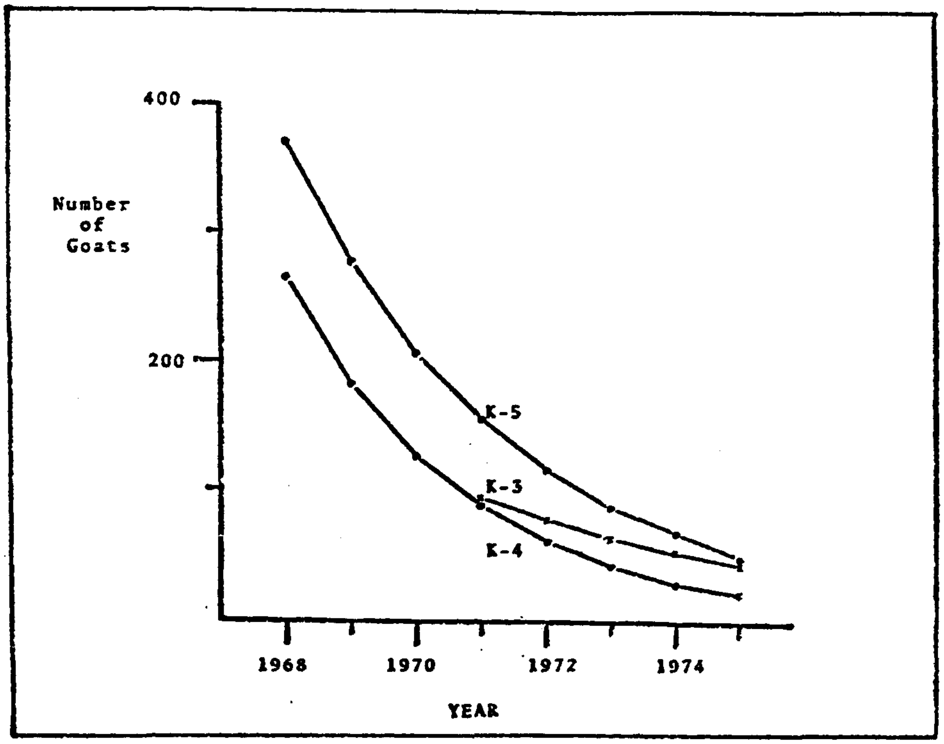

Figure 2. Trends in 3 mountain goat populations near Ketchikan, Alaska, 1968 - 1975, based on the highest pre-decline count and calculated $\bar{r}$ values.

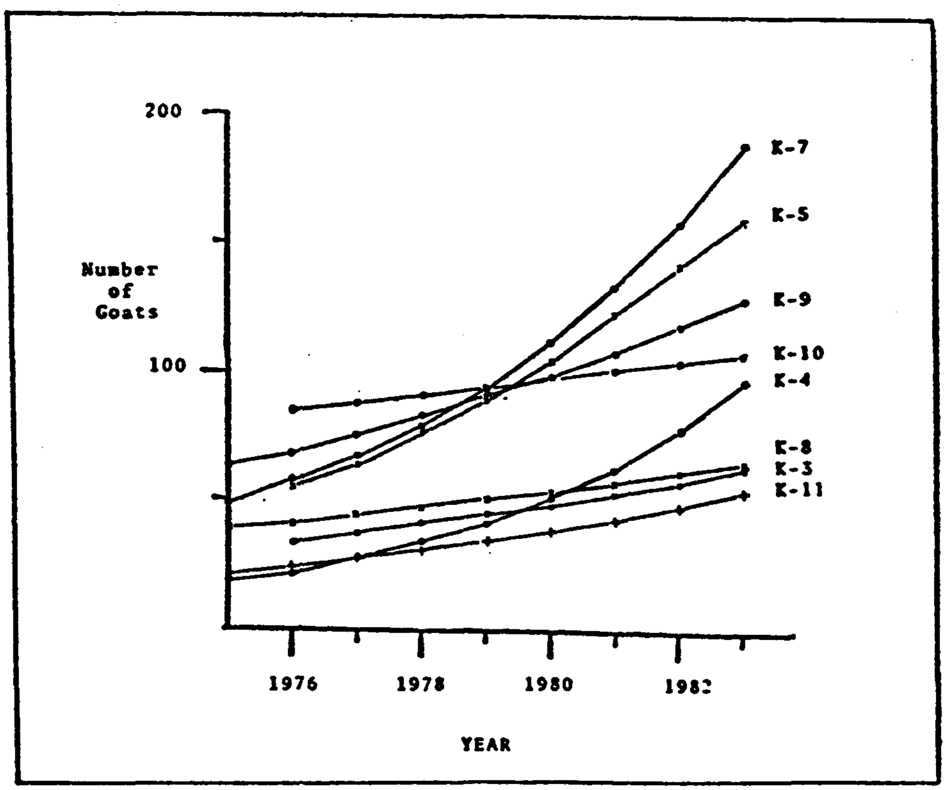

Figure 3. Trends in 8 mountain goat populations near Ketchikan, Alaska, 1975 - 1983 .

Table 13. Density index and observed rate of increase $\bar{r}$ in 8 mountain goat populations near Ketchikan, Alaska, 1968-1983.

Area	Initial Density Index	Period of decline	$\bar{r}$	Minimum Density Index	Initial		Overall		Current Density Index
					Period of Increase	$\bar{r}$	Period of Increase	$\bar{r}$	
K-3	0.99	1971-76	-.20(2) [a]	0.36	1976-80	.11(2) [b]	1976-82	.09(3) [b]	0.61
K-4	5.41	1968-75	-.37(5)	0.37	1975-80	.38(5)	1975-83	.21(8)	2.33
K-5	3.79	1968-76	-.29(5)	0.48	1976-80	.25(4) [b]	1976-83	.16(6)	2.24
K-7	-	-	-	0.45	1975-80	.25(2)	1975-83	.17(3)	1.58
K-8	-	-	-	0.49	-	-	1975-83	.06(3)	1.21
K-9	-	-	-	0.77	1975-80	.26(5)	1975-83	.09(8)	2.23
K-10	-	-	-	1.49	1976-80	.12(4)	1976-83	.03(7)	2.63
K-11	-	-	-	1.11	1975-80	.06(4)	1975-82	.12(6)	2.42

a. (x) = Number of surveys used to calculate $\bar{r}$.

b. Calculation includes results of a survey conducted under "poor" conditions; value may underestimate true $\bar{r}$.

DISCUSSION

Opinions vary as to the influence of density on the dynamics of mountain goat populations. Kuck (1977) and Hebert and Turnbull (1977) did not find the anticipated response of increased productivity in populations following reductions in density due to hunter harvest, but Stevens (1983) found that the rate of increase was inversely correlated with density in subpopulations of mountain goats introduced to Olympic National Park. Adams and Bailey (1982) also implied that r and density were inversely correlated in goats transplanted in Colorado. Results of this study lend limited support to the hypothesis that density and r are related.

Data for the declining period are too limited to permit statistical evaluation of correlation between r and density, but they are consistent with a hypothetical inverse relationship between density and rate of increase (Table 13). Data from the increasing period also indicate the potential for a density dependent relationship inasmuch as the areas with lower densities in the mid 1970's generally had higher r values during the recovery years. However, statistical tests of the significance of the correlation were inconclusive (Spearman's rank coefficient, $\bar{r}_s$=-0.53, n=8, 0.50>p>0.10).

These results are not intended, let alone statistically adequate, to settle the dispute over whether or not goat populations have density-dependent feed-back mechanisms. They are simply presented as indications that density may influence r. Nevertheless, I concur with Kuck (1977) and Hebert (1980) that it would be unreasonable to expect that an exploited goat population will necessarily respond by increasing it's potential r given the nature of goat social behavior and winter range habitat structure (Chadwick 1983).

While the role of density in regulating the magnitude of r may not be clearly indentified by the results of this study, it is obvious from these data that two distinct, and radically different trends have occurred in the goat populations near Ketchikan over the past 15 years.

The differences between the observed population trends are obviously the result of differing natality and/or mortality schedules operating over the years of decline versus the years of increase.

Unfortunately, the only data available from which to draw conclusions regarding these processes during the declining period are the trend survey results, and these provide few insights. Productivity, expressed as % kids in the herd in late summer, during the declining period was not measurably less than during the years of population increase (Fig.4): 1973 being lower, and 1977 higher, than the other years combined. Thus, initial productivity in this area, as measured on the trend counts, may not be as sensitive an indicator of population performance as in some other areas (Adams and Bailey 1982, Stevens 1983).

A major limitation of using kid percentages or kid:adult ratios as a measure of productivity is that changes in productivity per adult female may be masked by changes in proportions of other population segments (e.g. males, juvenile females). For this reason, direct measurement of production per female is a better approach. While no data are available for this parameter

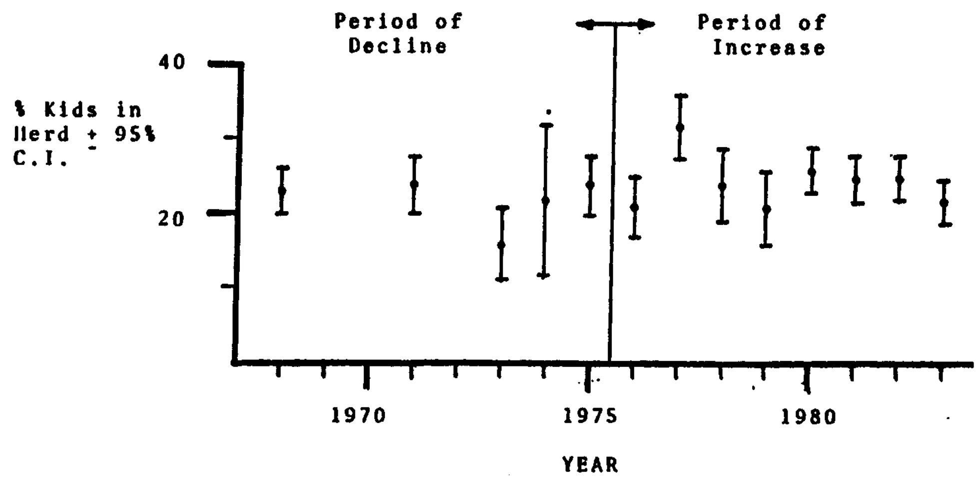

Figure 4. Percent kids in the herd ± 95 % confidence interval in late summer for combined trend count areas near Ketchikan, Alaska, 1968 - 1983.

Table 14. "Jackknife" comparison of kid percentage in the herd + 95% C.I. For individual year vs all other years using pooled data from all trend count areas.

Year	% Kids in herd in year X	% Kids in herd all other years	Deviation of % in year X from all others [1]
1968	22.9 ± 2.8	23.9 ± 1.0	0
1971	23.7 ± 3.9	23.9 ± 1.0	0
1973	17.6 ± 4.5	24.1 ± 1.0	-
1974	21.9 ± 10.1	23.9 ± 1.0	0
1975	23.8 ± 4.3	23.9 ± 1.0	0
1976	20.5 ± 4.2	24.0 ± 1.0	0
1977	31.8 ± 4.0	23.2 ± 1.0	+
1978	23.8 ± 3.6	23.9 ± 1.0	0
1979	20.7 ± 4.6	24.0 ± 1.0	0
1980	25.8 ± 2.9	23.6 ± 1.0	0
1981	24.9 ± 3.4	23.8 ± 1.0	0
1982	24.8 ± 2.8	23.7 ± 1.1	0
1983	21.8 ± 2.5	24.2 ± 1.1	0

[1] Deviation significance determined at $p<0.05$.

Table 15. Age-specific fecundity rates for female mountain goats captured near Ketchikan, Alaska 1980-1983.

Age	% Natality [1]	Sample Size
1	0	5
2	38	8
3	64 [2]	14
4	60	10
5+ [3]	100	33

[1] Based on lactative status upon capture and/or observation following radio-collaring.

[2] Includes 1 nanny captured in June determined to be pregnant by external palpation.

[3] The oldest female captured was at least 10 years old.

from the declining period, such data are available for the years 1980-83. Data representing 70 female goat-years' productivity indicate that among goats near Ketchikan, 38 percent of all 2 year old (n=8), 64 percent of all 3 year old (n=14), 60 percent of all 4 year old (n=10) and 100 percent of all 5 or more year old (n=33) nannies gave birth (Table 15).

A few reports document two-year-old females giving birth in introduced populations (Stevens 1983, Hibbs 1966), but this has not been previously reported in native herds. Thus it appears that the natality rate in goat herds near Ketchikan is currently near optimum levels. Nevertheless, general analyses of ungulate population dynamics (Caughley 1971, 1977) as well as simulation modelling of mountain goat demography (Youds et al. 1980, Adams and Bailey 1982) indicate that changes in mortality patterns are more influential than differential natality in altering r values.

Age-specific mortality data are not available for the declining period so we can only speculate as to the levels of mortality ocurring during those years. Recent spring surveys and radio-monitoring of goats provide data which indicate that mortality is presently low in these coastal goat populations.

The spring surveys which were initiated in 1982 can be compared to the previous summer's survey to provide an estimate of overwinter mortality of kids relative to other goats (Table 16). Results of the last 3 years' surveys indicate that the percent kids in the herd was not declined significantly ($p < 0.05$) over any of the past 3 winters. Thus mortality of kids must be of the same magnitude as mortality of other goats. Data on the life history of radio-collared goats in this area (Table 20) indicates that yearling mortality was approximately 33 percent (n=6) while total mortality for goats aged 2 through 7 was only 4 percent (n=93), and excluding hunter kills, mortality of these goats was nil. Total mortality for all goats over 1 year old was 12 percent (8 percent excluding hunter kills) based on 130 goat-years of radiotracking.

Given the present relatively high natality and minimal mortality in these populations it is not surprising that some have exhibited exceptional rates of increase. The question remains, however, what brought about the initial decline in goat numbers? Hunter harvest was not likely a driving force since these populations are largely inaccessible and, in any case, hunter kill, which currently ranges from 0 to 5 percent of the population in these trend count areas, has been proportionately higher during the increase than during the declining years (A.D.F. & G. unpubl. data). Disease and predation, though contributory to some population declines, have not been reported as the cause of goat declines elsewhere and, if involved in this decline, may have prevented population recovery. The most significant factor influencing these goat populations is believed to be weather.

The influence of winter weather on ungulate survival and abundance is a generally accepted feature in the ecology of high latitude species. The major natural mortality factors which affect mountain goats such as accidental falls, avalanches and starvation (Brandborg 1955, Chadwick 1983) are all exacerbated during periods of high snowfall. Thus it is logical to assume that goat populations should suffer higher mortality during cold, snowy winters. Furthermore, if goats are exposed to regular periods of severe vs

Table 16. Comparison of percent kids in the herd ± 95% C.I. in summer and the following spring for combined trend count areas K-9, K-10 and K-11, 1981 to 1984.

Year	% Kids in Summer	% Kids in Spring
1981-82	24.2 ± 4.6	17.9 ± 8.2
1982-83	21.7 ± 4.7	18.7 ± 5.1
1983-84 [1]	20.0 ± 6.4	17.2 ± 7.7

1. Area K-10 only.

Table 20. Age-specific mortality rates for all radio-collared goats captured near Ketchikan, Alaska, 1980-1983.

Age Class	Number tagged at age x	% Natural mortality [1]	% Overall mortality [2]
1	6	33	33
2	17	0	0
3	25	0	0
4	16	0	12
5	14	0	7
6	9	0	0
7	12	0	8
8	10	10	10
9	11	36	36
10	6	50	50
11	2	0	0
12	2	100	100

[1] % of goats at age x dying before age x+1, excluding human-induced mortality.

[2] Includes hunter kill.

moderate winters, their population should go through "boom" and "bust" cycles as Edwards (1956) demonstrated for deer (O. h. hemionus and O. virginianus), elk (Cervus canadensis) and moose in British Columbia.

Analysis of mean annual and winter temperature at Ketchikan clearly illustrate the magnitude of variation in weather patterns which could effect goat populations. Cycles in mean annual temperatures at Ketchikan appear to follow the same trends Juday (1983) charted for Juneau and Sitka (Fig. 5). The regular and distinct periods of warming and cooling reflect a pattern Juday described for most of Alaska and may occur broadly along the eastern Pacific Rim. A similar analysis of mean winter temperature in Ketchikan (Fig. 6) illustrates that winter temperature cycles parallel annual ones. During the most recent cooling period of 1965 - 1975 several cold, snowy winters occurred in Alaska. The impact of the winters of 1968 - 69, 1970 - 71 and 1971 - 72 on deer (Merriam 1970, Olson 1977) and moose (Bishop and Rausch 1974, Gasaway et al. 1983) have been documented elsewhere. Trend data presented here indicate that the goat populations near Ketchikan responded similarly to adverse winter weather.

Figure 6 presents the trend count results for area K-4 and K-5 along with the trend in mean winter temperature. The relationship between goat numbers and the temperature cycle is evident. As would be expected, initial recovery of the populations lagged behind temperature moderation by several years. Results of trend counts in the other areas reveal the same pattern shown in Fig.6. In addition, data from other studies of coastal goat populations indicate that these trends may have been widespread. Dane (1977) reported that a goat population in the upper Kleena Kleene river in coastal British Columbia declined sharply in the early 1970's during a period of severe winters. Although he attributed much of the decline to reproductive failure, it is obvious from his total count data that adult mortality was also high during the 1972 - 1976 period.

In Hebert and Turnbull's (1977) original discussion of the coastal goat ecotype, populations in the vicinity of Knight inlet were described as being of lower density and less productive than those in the interior. These conclusions were based on surveys conducted in 1974 and 1976, a period corresponding with the low point in the cycle at Ketchikan. Subsequent surveys reported Hebert and Langin (1982) documented recovery of these same populations between 1976 and 1980 at rates of increase comparable to those reported herein for populations near Ketchikan, and far exceeding those presumed possible based on population models developed using data from interior goat herds (Youds et al. 1980).

These results, along with recent re-evaluation of density in coastal goat populations (Smith and Bovee 1984) indicates that the original impressions regarding this ecotype were an artifact of studying a few areas during the "worst" time of their recent demographic history. This reinforces the value of long-term data on trends in developing an understanding of the dynamics of goat populations. Additionally, both short and long-term environmental fluctuations and variations in population parameters must be considered in mountain goat population management.

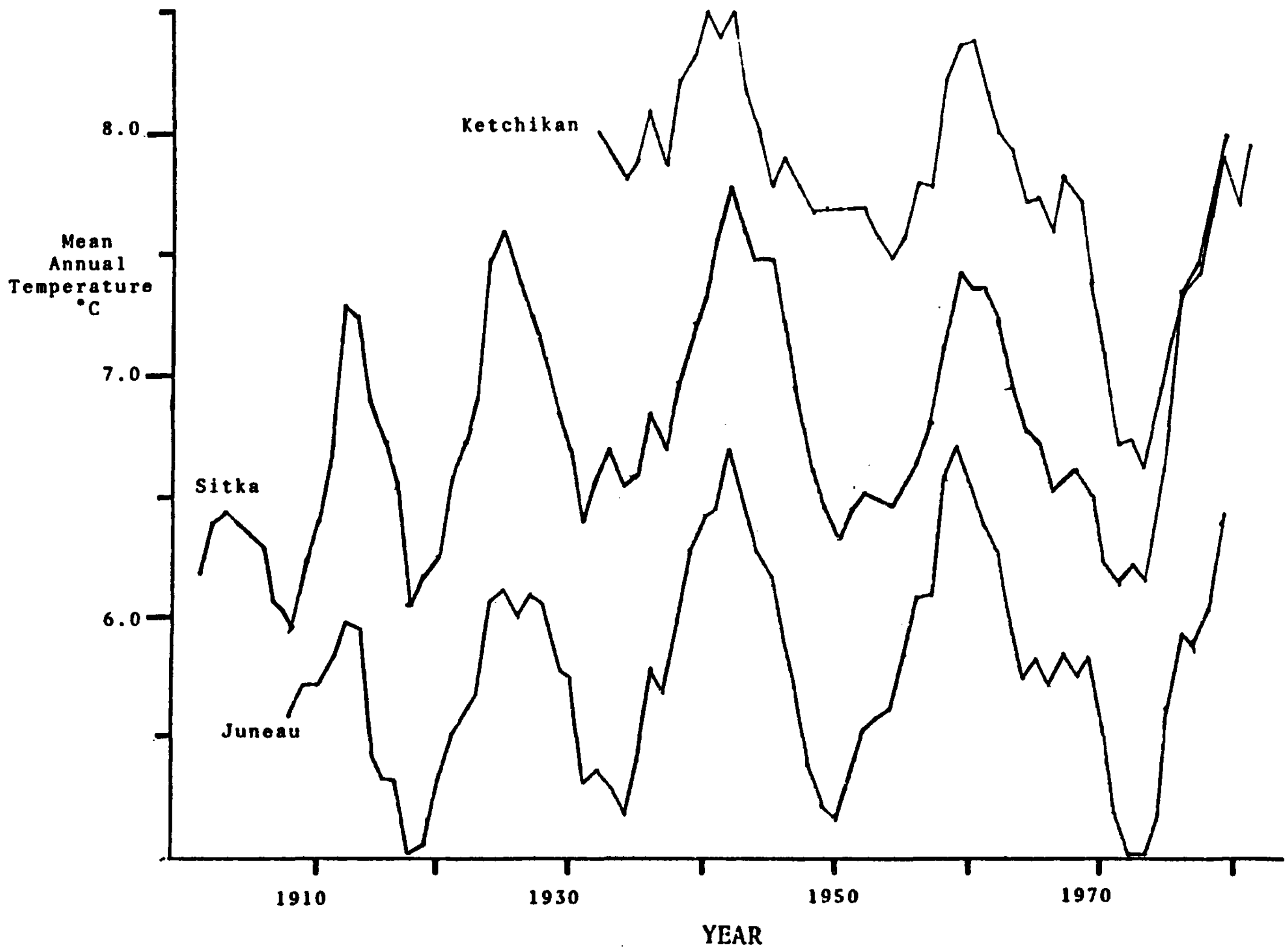

Figure 5. Trends in mean annual temperature at Juneau and Sitka since 1900 (from Juday (1982)) and Ketchikan, Alaska since 1930.

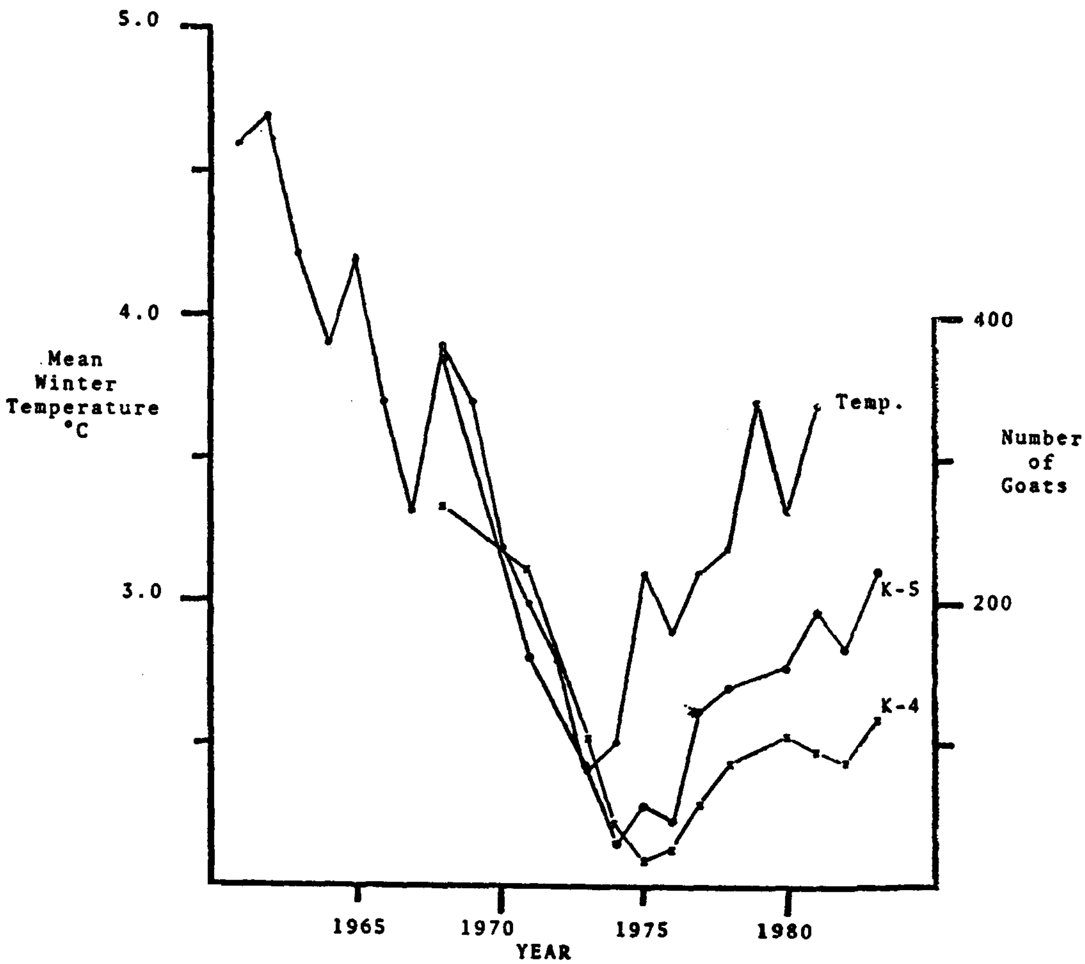

Figure 6. Trends in mean winter temperature at Ketchikan, Alaska and 2 nearby mountain goat populations, 1960 - 1983.

Management Implications

A great deal of time, effort and money has been devoted over the years to gathering detailed information on size and composition of mountain goat populations, yet biologists are still uncertain as to how to go about managing this species (Hebert and Langin 1982, Chadwick 1983). This is particularly frustrating to biologists with small budgets charged with managing large areas where sightability of goats is low and application of the intensive survey methods suggested by Nichols (1980) is not feasible.

In an effort to overcome the deficiencies of available survey results, several investigators have developed goat population models to simulate population dynamics and evaluate the potential effect of hunting on population growth (Kuck 1977, Hall and Bibaud 1978, Youds et al. 1980, Adams and Bailey 1982). As Hebert and Langin (1982) have pointed out, however, these models are non-stochastic and merely plot the trajectory of a population given an initial sex and age composition and fixed natality and mortality schedules. They invariably develop a stable age distribution and constant r. Not only are such models unrealistic, they may create either a sense of false security or unnecessary pessismism regarding goat harvest management depending upon the parameter estimates used in the simulation.

Throughout their range, mountain goat populations are influenced by highly variable biotic and abiotic factors which largely prevent development of either stable age distributions or constant rates of increase. Accordingly no single survey, or even a series of surveys is likely to provide composition data which can be entered into a non-stochastic model with the expectation of accurately predicting the future of the real goat herd. This predicament is what led Hebert and Langin (1982) to conclude that "Annual classification surveys ... produced inconsistent results which were of little value in establishing a harvest management program." They further concluded that survey methodology should be based on the objective of establishing population size, not composition. Caughley (1974) also stressed the need to measure r directly due to the ambiguity of age ratio interpretation.

The need for reliable trend information is reinforced by the fact that mountain goats apparently do not respond to management in the "traditional" way (Hebert 1980). If, as Kuck (1977) and others have concluded, hunting mortality is additive and goats do not increase productivity in response to adult losses, then the application of typical harvest strategies such as Caughley's (1977) maximum sustained yield model is inappropriate. This dilemma is complicated by the variable nature and incomplete understanding of productivity and survival in goat poulations. In short, what is needed is an entirely different philosophy toward goat harvesting; a philosophy which recognizes the fact that goat populations may not be as "resilient" as other ungulate populations, and is cognizant of the fact that there simply may be times when a population can afford additive mortality, and times when it cannot.

During periods of favorable environmental conditions, when goat populations are increasing, harvest can be permitted or increased once the population reaches a predetermined threshold, or management objective level.

When populations are declining toward the objective level, harvest should be curtailed or eliminated until conditions are again conducive to population growth. Caughley (1977) labelled this approach as "tracking harvest strategy." Caughley suggested that it is ideally suited to management of species living in environments subject to major fluctuations with long periodicity, where density and resources are seldom balanced and where little is know about the relationships between population parameters and environmental conditions. It is hard to imagine a better description of circumstances surrounding mountain goat biology and management.

Although application of a tracking harvest strategy to goat management may appear radical, it may actually produce a more stable harvest pattern than past approaches which were far too often characterized by cycles of over-overhunting, closure to allow recovery, resumed harvest based on inappropriate harvest models, etc. In addition, by coupling harvest rates to actual population trajectory relative to pre-set objectives we may be less likely to induce population declines from which herds cannot recover (Caughley 1977).

If a tracking harvest strategy were implimented the essential elements of a management program would be 1) a method of determining population trends, 2) knowledge of the distribution and magnitude of the harvest and 3) establishment of minimum population objectives. Results of this study indicate that aerial trend counts may be adequate to monitor trends. Mandatory harvest reporting can fulfill the second need. Population objectives must be based on improved knowledge of the magnitude and causes of long-term population fluctuations, distribution, amount and productivity of habitat, and the impact of changing access and hunter harvest patterns as development encroaches on currently remote goat populations. It appears appropriate for biologists in coastal regions to concentrate their efforts along these lines, rather than to continue to search for a set of variable sex and age parameters for use in simulation models which will not, in any case, provide a clearer indication of how to go about managing mountain goats in this portion of their range.

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