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FACTORS AFFECTING THE POPULATION DYNAMICS OF MOUNTAIN GOATS IN WEST-CENTRAL ALBERTA.

KIRBY G. SMITH, Alberta Fish and Wildlife Division, Bag 9000, Provincial Building, Edson, AB T0E 0P0

Abstract: Populations of mountain goats (Oreamnos americanus) in Willmore Wilderness Park of west-central Alberta were inventoried from 1973 to 1987. Hunted populations increased until 1980 - 1983, while harvest rates were held at 4.5 - 9.0%. Most populations began declining following 1980-83 as a result of poor kid production combined with below average survival of kids-to-yearling age. Harvest was reduced or eliminated after that period. The influence of additive harvest mortality on kid production and the possibility of increased predation and weather are implicated in relation to the decline.

Throughout their range, the response of mountain goat populations to regulated harvest has varied between native and introduced herds and between areas. Hunter-caused mortality was considered additive in the decline of native herds in Idaho (Kuck 1977), Montana (Chadwick 1983), and British Columbia (Hebert and Turnbull 1977); however, it was considered compensatory in introduced herds that increased in Montana (Swenson 1985, 1986). Density-dependent responses in mountain goat reproduction, kid survival (Adams and Bailey 1982) initial breeding and litter size (Houston and Stevens 1988) have been observed in introduced herds. Smith (1984) examined trends in native mountain goat populations on coastal mountain ranges in Alaska with limited hunting pressure and found a period of population reduction from 1968 - 1975 followed by a period of population increase (1976 - 1983) equal to or greater than those values reported for introduced herds in Colorado and Idaho (Hayden 1984).

Aerial surveys flown since 1973 in the Willmore Wilderness Park of west-central Alberta were used to monitor mountain goat populations under a relatively constant harvest regime. Based on data collected prior to 1979 (Hall and Bibaud 1978, Youds et al. 1980), a formal harvest strategy of 5% of the observed minimum population estimate from aerial surveys was adopted. The harvest rate was contingent upon minimum recruitment and survival rates of 57 kids:100 females (28.5 kids: 100 adults $\geq$ 2-years-old), a kid mortality rate of 40%; a yearling mortality rate of 10% and an adult mortality rate of 7%. This approach, a "tracking harvest strategy", was first proposed for ungulates (Caughley 1977:197) and later considered necessary for successful management of mountain goats (Smith 1984). Herds continued to increase under this harvest regime until a period between 1980 and 1983. Since then the populations have decreased despite a reduction in harvest.

The objective of this paper is to explore the cause(s) of the decline in mountain goat populations in west-central Alberta by examining the effects of harvest and weather on recruitment and survival of

mountain goat kids and thus the population dynamics of these herds.

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STUDY AREA

The Willmore Wilderness Park (WWP) is located directly north of Jasper National Park and along the British Columbia border in west-central Alberta (Fig. 1). The topography is dominated by several large mountain complexes and the elevation varies from 975 to 3098 m. The weather is characterized by long, cold winters and cool, wet summers with annual precipitation on the eastern edge averaging 540 mm. However, the western portion may receive as much as 1500 mm of precipitation (Alberta Wilderness Association 1973). Vegetation below treeline is dominated by white spruce (*Picea glauca*) and alpine fir (*Abies lasiocarpa*) with lodgepole pine (*Pinus contorta*) on fire-regenerated sites. Above tree line (about 1700 m), the alpine meadows are comprised of grass and sedge species as well as lichens, mosses and a variety of herbaceous species. Further descriptions can be found in Hall (1977), Hall and Bibaud (1978) and Youds et al. (1980).

This paper refers to 11 mountain goat survey areas in or near WWP that were grouped under the category Willmore study area (Fig. 1).

METHODS

Annual helicopter surveys of hunted populations of goats were conducted from 1973 to 1987 by flying mountain complexes above timberline. (Poor weather hampered survey attempts in 1978 and consequently, data are not available for that year). The navigator/principal observer was to the left of the pilot, the second observer was in the left rear seat with the recorder in the right rear seat. Beginning in 1974 mountain goats were classified as kids, yearlings and adults ($\geq$ 2-years-old). Most surveys were conducted in early July after "nursery" herds had congregated. An effort was made to fly between 0600 - 0900 and between 1700 - 2200 when goats were most active. Aerial surveys of non-hunted herds began in 1979. Aerial survey effort was reduced by 80% in 1982 and subsequent flying time allotments resulted in 2/3 of the survey areas being inventoried only on alternate years.

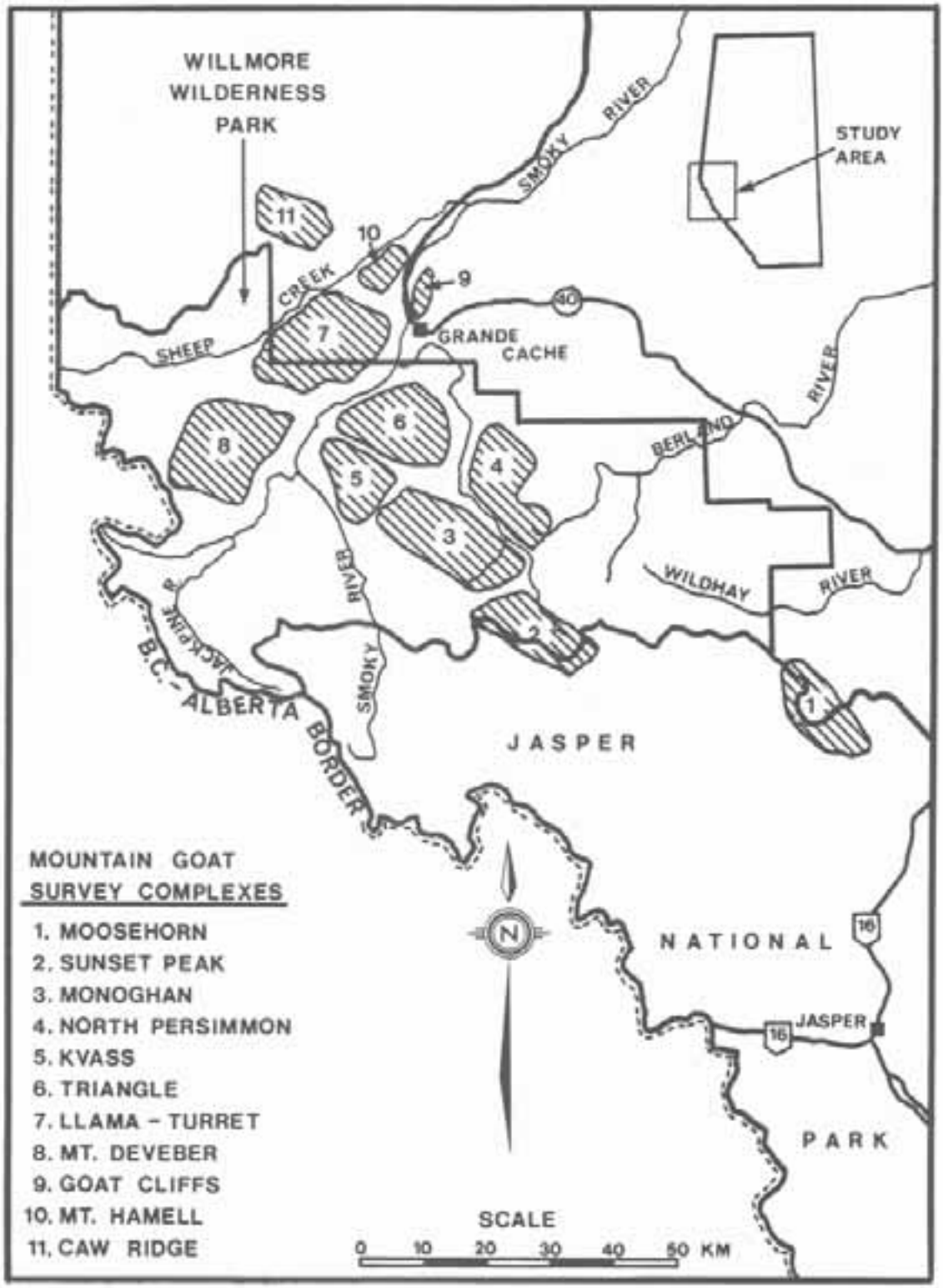

Fig. 1. Distribution of mountain goat survey complexes in the Willmore Wilderness Park study area of west-central Alberta.

Table 1. Calculation of mountain goat kid survival rates to yearling age by 2 techniques.

Year	% Survival - Hunted		% Survival - Non-Hunted	
	Ratio[a]	Observed no.[b]	Ratio	Observed no.
1974	65%	55%		
1975	77%	71%		
1976	35%	31%		
1977	60%	72%		
1978				
1979	66%			
1980	75%	73%	68%	44%
1981				
1982				
1983	41%	50%	55%	64%
1984	53%	51%	34%	49%
1985	49%	50%	10%	9%
1986	25%	28%	53%	67%
1987	36%	35%		

[a]Survival rates calculated by comparing the yearling/adult ratio to the kid/adult ratio from the previous year in each complex.
[b]Survival rates calculated by comparing the actual number of yearlings to the number of kids from the previous year in each complex.

The number of mountain goats observed in each mountain complex was considered the minimum population. In the same mountain complex, kid/adult ratios were compared to the yearling/adult ratio for the following year in order to estimate kid survival to yearling age (13 months). A second method of calculating the kid survival rate was to compare the actual numbers of kids and yearlings observed in the same complex in subsequent years. The two methods resulted in similar survival values (Table 1) and survival rates based on ratios were used because of larger sample sizes. Confidence limits for age ratios were calculated after Bowden et al. (1984).

Annual permit allocations from 1978 - 1987 were determined by taking 5% of the minimum population estimate and dividing it by the mean hunter success rate for previous years in each individual mountain goat hunting area. Harvest data were collected by compulsory hunter registration of each goat harvested. Age was determined by sectioning the first incisor.

Weather data (mean monthly temperature, total monthly precipitation and total monthly snowfall) were obtained from the Alberta Forest Service Ranger Station at Grande Cache, which borders the eastern side of Willmore Wilderness Park at an elevation of 1310m. Regression analyses were conducted using SPSS.PC+ statistical package to investigate relationships between weather variables and the mountain goat recruitment indices. The recruitment indices were kid/adult ratios and survival to 13 months of age based on aerial survey results. Correlation analyses

were used to investigate multicollinearity (which could indicate some degree of covariation in the explanatory variables) and to investigate relationships between the number of mountain goats harvested and the % of females in the fall harvest with recruitment and kid survival the following summer. In addition, Durbin-Watson statistics were calculated to investigate autocorrelation in a time-series regression problem such as this study.

Population trends were determined by regression of the natural log of observed numbers on time. The slope of the regression line, $\bar{r}$, represents the mean annual exponential rate of increase or decrease (Caughley 1977:109).

Mean winter temperatures, considering the period October to April inclusive, were computed for each year from 1975-1987, as well as total winter snowfall for the same months. The data for each given year were then compared to the long-term mean value, and the deviation was expressed as a percentage (negative or positive). These two deviations, one for temperature and one for snow, were then combined by addition, and the sum referred to as the "annual winter severity index" (see Burles et al. 1984).

RESULTS

Hunted mountain goat herds on most of the mountain complexes increased during the period 1974 - 1980 (Fig. 2). Between 1980 and 1983, they began declining and continued to do so through 1987. Non-hunted herds increased, or declined only slightly during the same time period (Fig. 3). Mean kid/adult ratios in hunted herds were significantly lower (ANOVA, $F = 28.37$, $P = 0.0003$) during a portion of this decline (1982 - 1986) than were the observed ratios for the period of increase (1974 - 1981) (Fig. 4). Mean kid/adult ratios in non-hunted herds also declined during 1982 - 1986 (Fig. 4), but were significantly higher (ANOVA, $F = 5.79$, $P = 0.03$) than those documented for hunted herds during 1979 to 1986. Mean kid survival estimates to 13 months for hunted herds were lower, though not significantly, (ANOVA, $F = 4.09$, $P = 0.07$) from 1982 to 1986 than the estimates documented previously for the 1974 to 1981 period (Fig. 5). Non-hunted herds had lower kid survival rates after 1980 (Fig. 6), but these were not significantly different from their hunted counterparts during the period 1979 - 1986 (ANOVA, $F = 0.55$, $P = 0.48$).

The mean kid/adult ratios were not significantly correlated with harvest ($P = 0.38$), the % of females in the harvest ($P = 0.40$) or age of harvested goats ($P = 0.62$) at the overall study area level. Nor were mean kid survival rates correlated with any of these independent variables ($P = 0.43$, $P = 0.33$ and $P = 0.76$, respectively).

When the influences of monthly snowfall, monthly precipitation and mean monthly temperature were examined individually, October temperature exhibited a positive correlation ($P = 0.002$) with mean kid/adult ratios in hunted herds (Table 2). April temperature ($P = 0.036$) showed a positive correlation with mean kid/adult ratios in non-hunted herds, and October precipitation was negatively correlated ($P = 0.045$) (Table 2). Individual months of cumulative snowfall were not significantly correlated

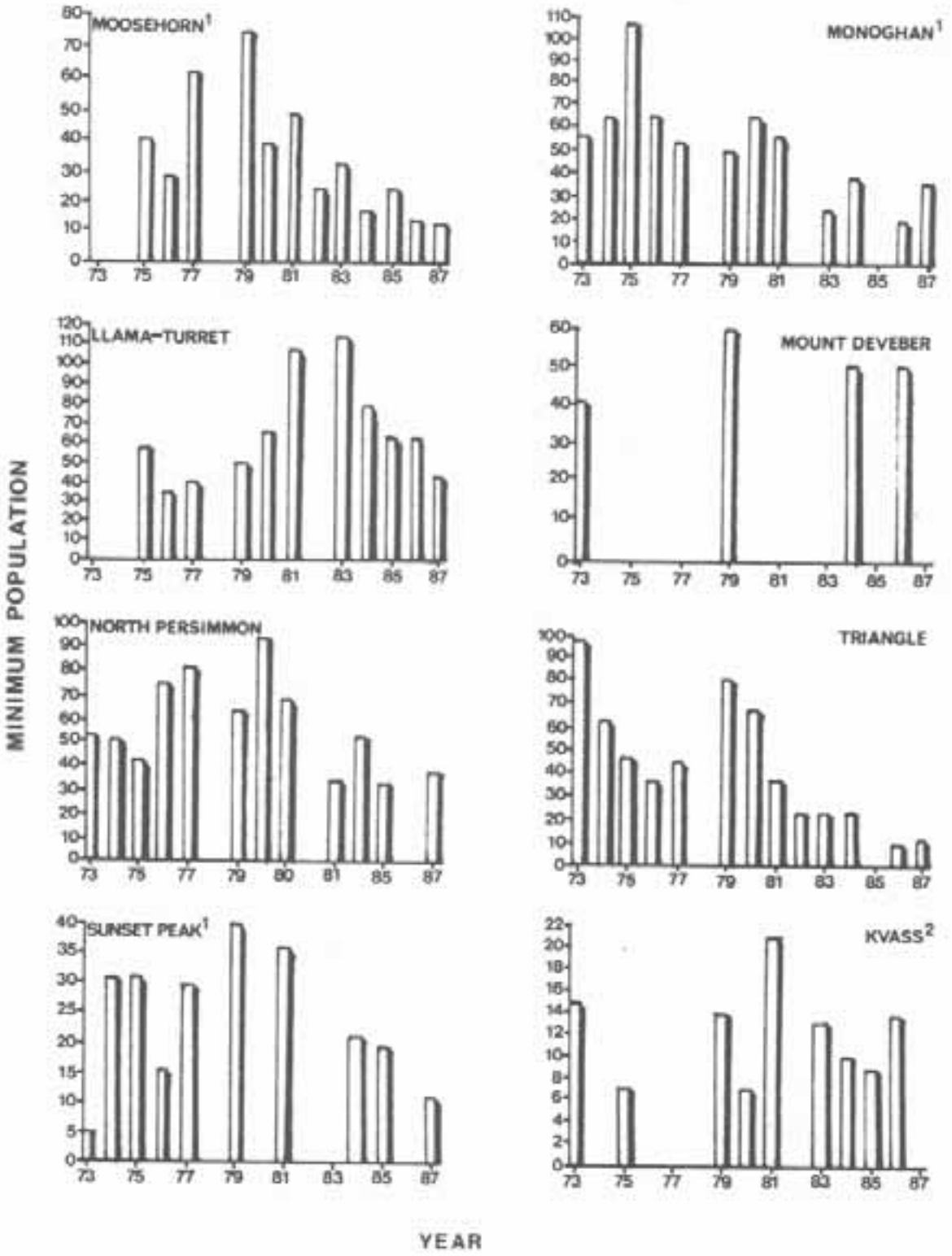

Fig. 2. Minimum mountain goat population estimates for 8 hunted herds in Willmore Wilderness Park based on aerial surveys, 1973-1987. (1=not hunted after 1986, 2=not hunted after 1984)

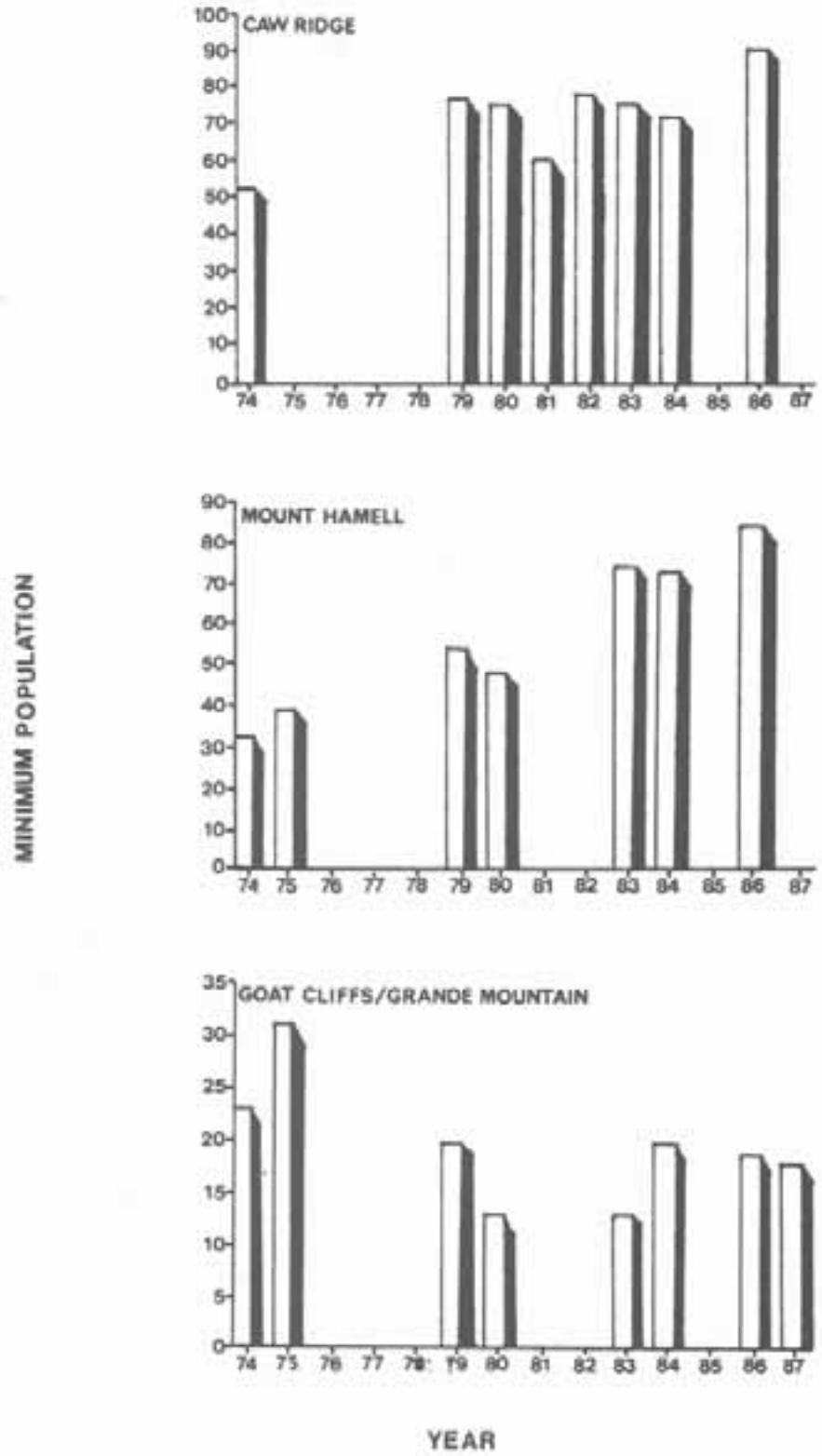

Fig. 3. Minimum mountain goat population estimates for 3 non-hunted herds in Willmore Wilderness Park based on aerial surveys, 1974-1987. Data for 1974 and 1975 are from McFetridge (1977).

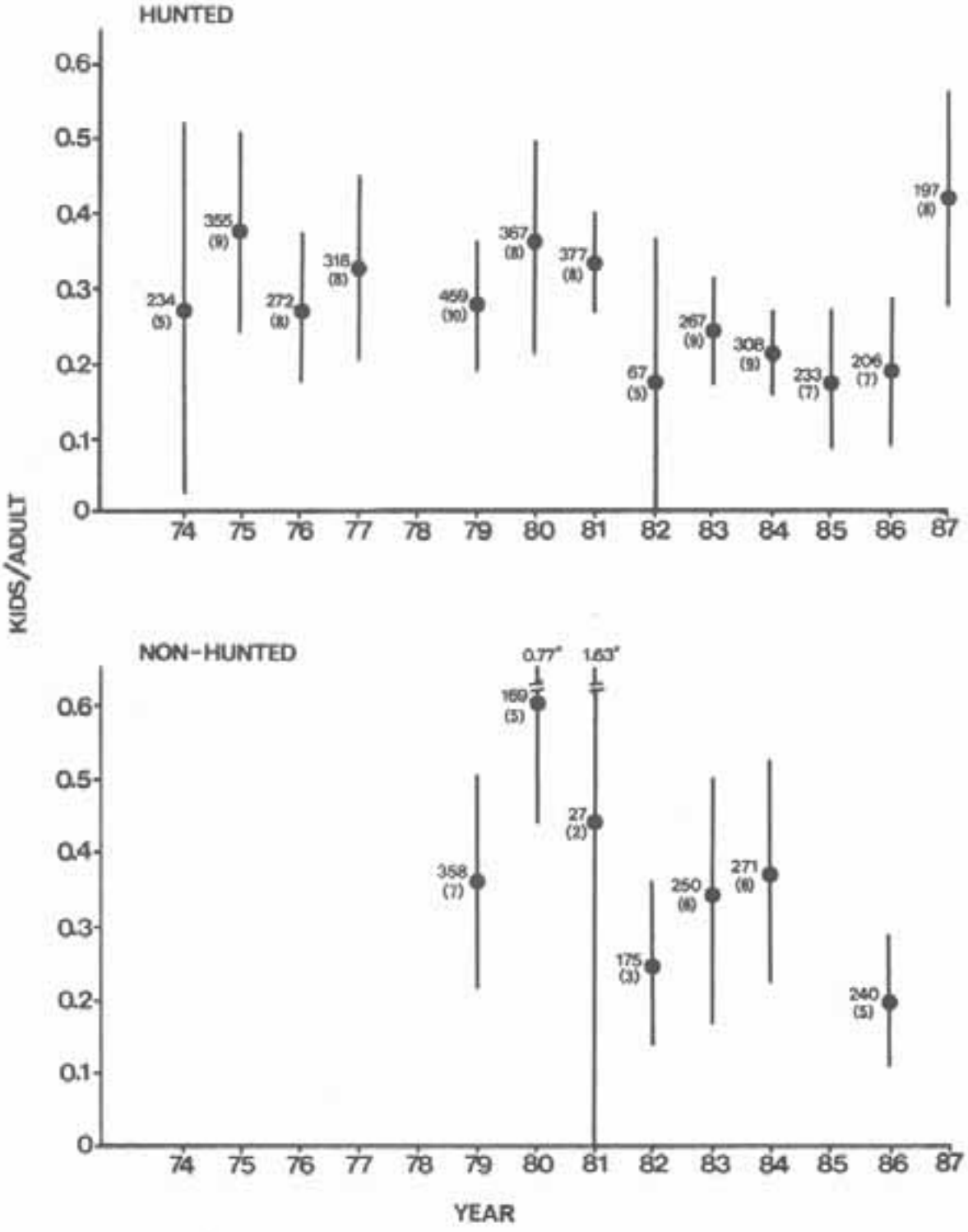

Fig. 4. Mean kid/adult ratios (●) for hunted and non-hunted mountain goat populations in Willmore Wilderness Park, 1974-1987. Vertical lines, numbers and numbers in parentheses represent 95% confidence limits, the sample size of classified animals and the number of survey areas per year, respectively. (*=upper limit of 95% confidence limits).

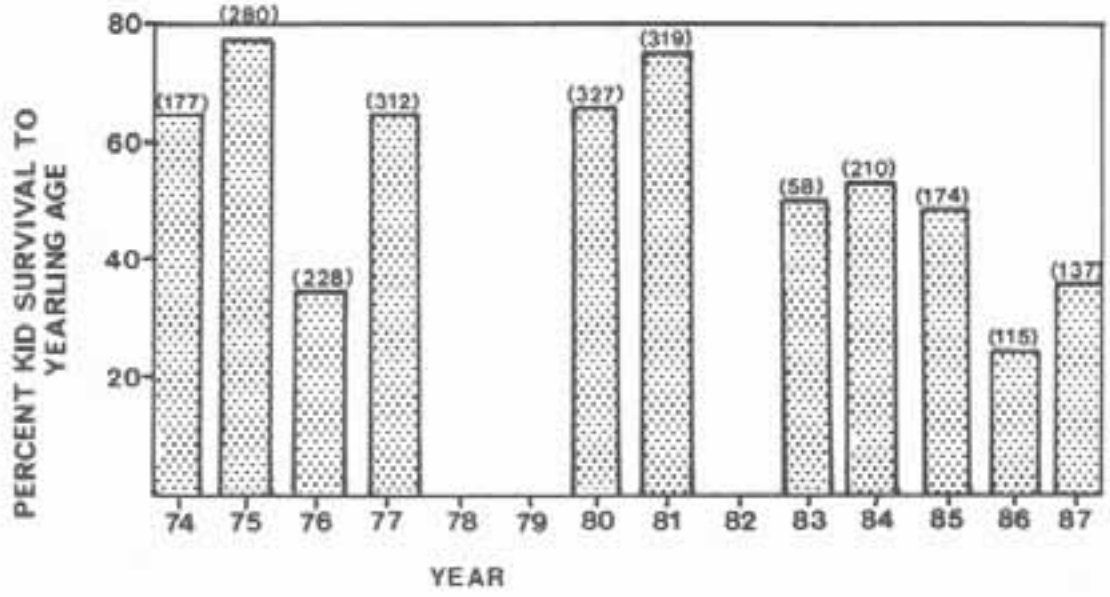

Fig. 5. Mean kid survival to yearling age for hunted mountain goat populations in Willmore Wilderness Park, 1974 - 1987. Numbers in parentheses represent the sample size of classified goats per year.

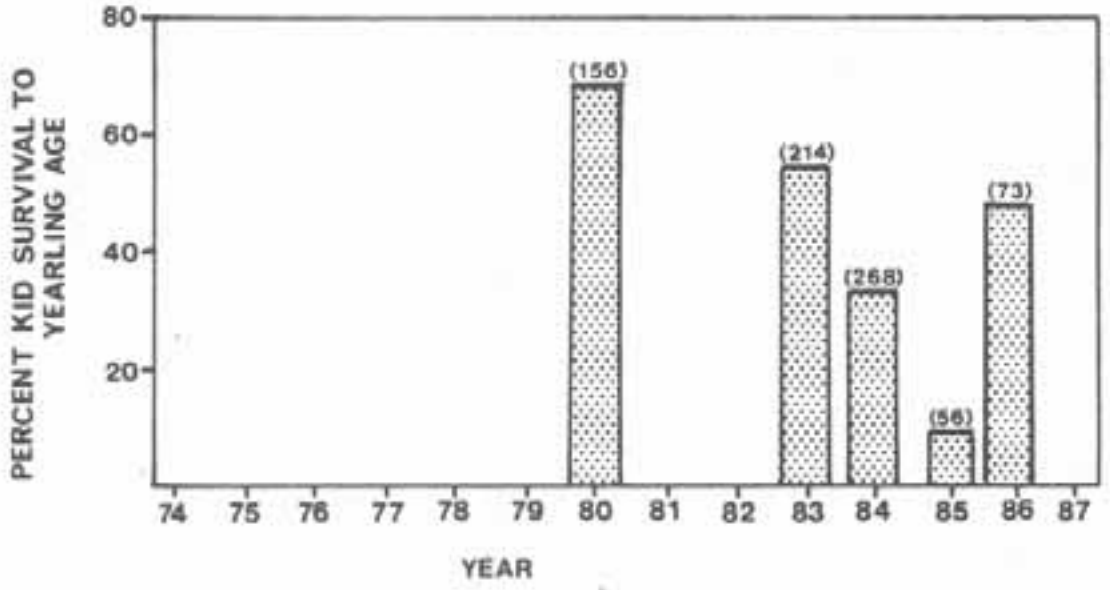

Fig. 6. Mean kid survival to yearling age for non-hunted mountain goat populations in Willmore Wilderness Park, 1980 -1986. Numbers in parentheses represent the sample size of classified goats per year.

Table 2. Significant results ($P<0.10$) of simple regressions of mountain goat recruitment and survival rates on monthly temperature (°C), precipitation (mm) and snowfall (cm), Willmore Wilderness Park, Alberta.

Dependent variable	Independent variable	Month	Regression Slope	R^2	P
Kid/adult ratio					
1974-1987 (hunted):	$\bar{x}$ Monthly Temp. (°C)	Oct.	2.45	0.62	0.0002
		Dec.	0.98	0.27	0.084
	Total Precipitation (mm)	Oct.	-0.19	0.23	0.095
	Total Snowfall (cm)	Oct.	-0.33	0.26	0.074
Kid/adult ratio 1979-1986 (non-hunted):	$\bar{x}$ Monthly Temp. (°C)	Oct.	4.49	0.39	0.097
		Apr.	6.91	0.48	0.036
	Total Precipitation (mm)	Oct.	-0.88	0.46	0.045
	Total Snowfall (cm)	Oct.	-1.28	0.34	0.097
Kid survival 1974-1987 (hunted):	$\bar{x}$ Monthly Temp. (°C)	Nov.	1.98	0.39	0.053
Kid survival 1979-1986 (non-hunted):	$\bar{x}$ Monthly Temp. (°C)	Dec.	3.23	0.73	0.065
		Jun.	24.44	0.07	0.078
	Total Snowfall (cm)	Feb.	1.46	0.71	0.077
		Jun.	-213.12	0.71	0.074

with kid recruitment nor were any weather variables for kid survival of hunted or non-hunted herds (Table 2).

DISCUSSION

The initial period of population decline (1980 - 1983) resulted in minor changes in mountain goat management strategies in the WWP study area. One problem symptomatic of goat management in many jurisdictions was the difficulty in distributing harvest pressure equitably over relatively large management zones. Consequently, zones were each divided into 2 or 3 smaller areas by 1985 and in some portions, goat hunting was eliminated. Permit allocation was re-directed into the more inaccessible units in an effort to maintain hunting opportunities, but to reduce the harvest. Permit numbers were reduced yearly (Fig. 7) and, combined with some hunting seasons (which last for 2 weeks) of extremely inclement hunting weather (which reduced harvest success), it was expected that mountain goat herds would begin to increase once more.

With the exception of 1982, winter weather during the period of decline was mild (Fig. 8). Consequently, average or better kid:adult ratios were anticipated in WWP in following years. A negative correlation

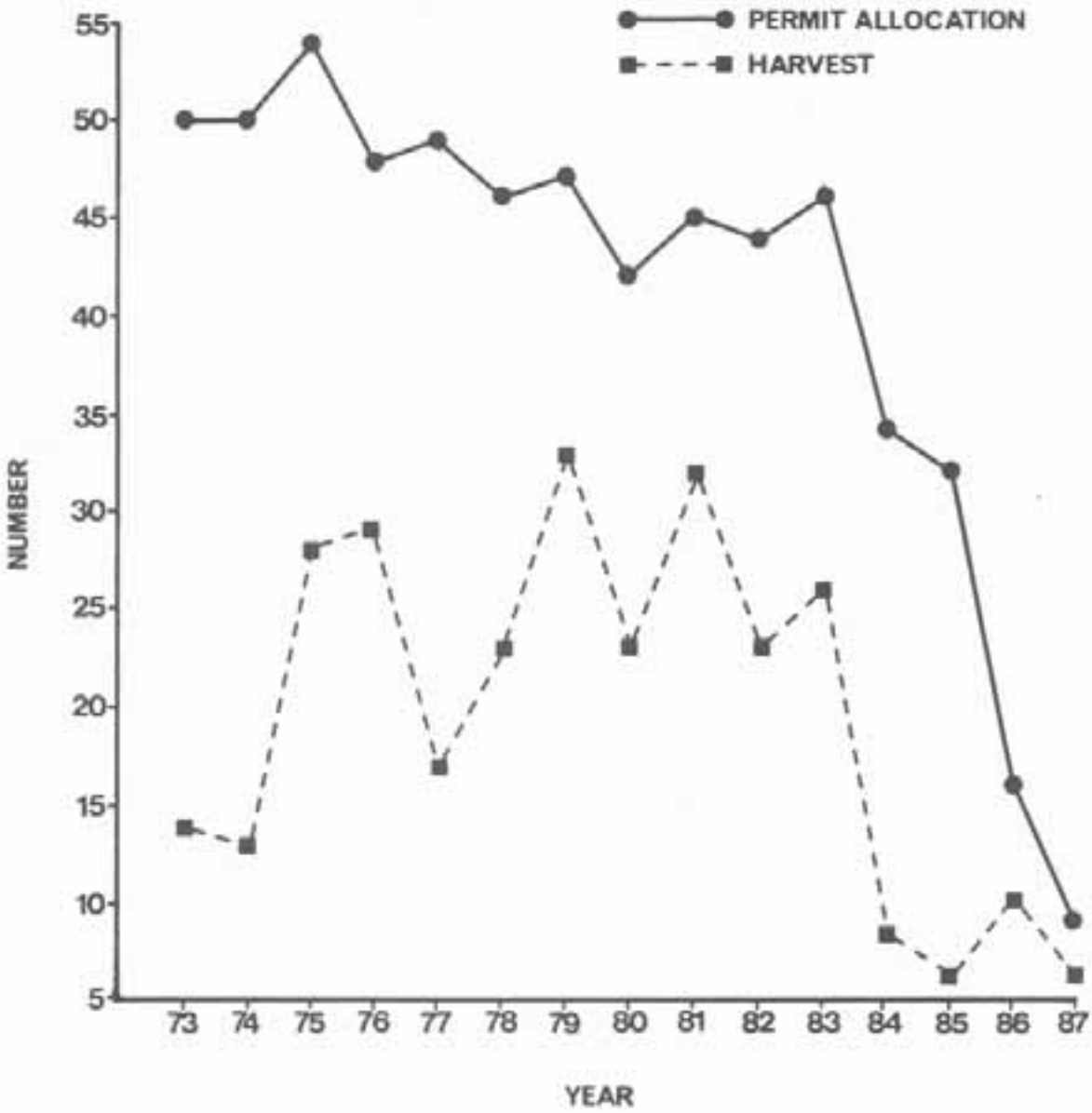

Fig. 7. The number of hunting permits allocated and the number of mountain goats harvested in Willmore Wilderness Park by year, 1973-1987.

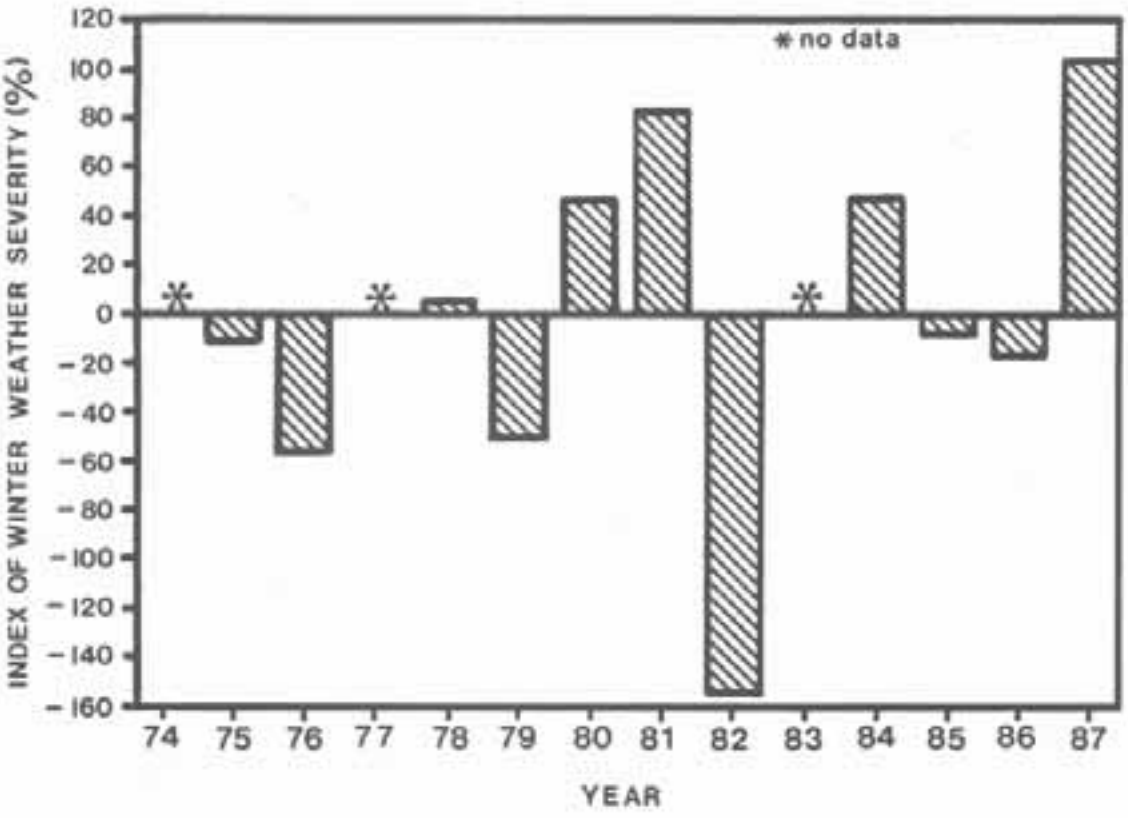

Fig. 8. Winter severity index for Grande Cache, Alberta, 1974-1987. Weather data for 1974,1977 and 1983 was incomplete and therefore not included.

Table 3. Results of multiple regression analysis of mountain goat kid/adult ratios (dependent variable) with weather (independent) variables for the Willmore study area.

	$\bar{R}^2$	b_0	Oct. temp.	Apr. temp	Oct. precip.	F Value
Hunted (1974-1987)	0.65	17.48 (0.0003)[a]	2.46) (0.0028)	-	-	16.66 (0.0028)
	0.82	14.25 (0.0006)	2.35 (0.001)	1.63 (0.028)	-	17.60 (0.0012)
Non-Hunted (1979-1986)	0.57	28.20 (0.0109)	-	7.52 (0.030)	-	7.95 (0.0304)
	0.87	54.55 (0.0016)	-	6.30 (0.011)	-0.72 (0.017)	17.44 (0.0056)

[a]Numbers in parentheses below each estimated value represent the probability associated with the coefficient being = 0(t test).

between 1 May snow depth in Colorado and kid:older animal ratios (Adams and Bailey 1982), a positive correlation with average winter (October - March) temperature in southeastern Alaska and mountain goat population size (Smith 1984), a positive correlation of reproductive rates with the total winter precipitation (November to March) 1.5 years before birth, and a similarly high correlation between reproductive rates and April snow depth 13 months before birth (Stevens 1983, in Chadwick 1983) have been described. Winter weather also has been implicated in overwinter mortality rates of mountain goat kids (Brandborg 1955, Rideout 1974, in Chadwick 1983).

Given the parallel decrease in kid production and survival between hunted and non-hunted herds after 1980, weather was examined in detail as a significant limiting factor. However, other than pointing out the 2 extreme years of weather (Fig. 8), which correlated relatively well with kid/adult ratios (1982 had the lowest winter severity index and the second lowest kid/adult ratio of 0.18; 1987 had the highest winter severity index and the highest kid/adult ratio of 0.42), the winter severity index didn't appear to contribute significantly towards explaining the pattern of recruitment and kid survival that had been observed. Consequently, multiple regression analysis of weather variables on kid production and survival was pursued in an exploratory fashion to test the significance of a grouping of independent variables as possible limiting factors. As pointed out by Wehausen et al. (1987:89), "a lack of significance of an independent variable examined alone in a multivariate system may reflect the confounding effects of additional variables rather than a lack of correlation". Therefore, the weakly significant correlations involving weather variables where $P < 0.10$ were

included (Table 3). When October and April temperatures were included together, they explained 82% of the variance in kid/adult ratios in hunted populations. April temperature and October precipitation combined explained 87% of the variance in non-hunted kid/adult ratios. (A log transformation of October temperature reduced the significance of this variable and was an indication that a curvilinear relationship did not exist). However, three factors reduced the probability that these weather variables were biologically significant. I had no a priori hypothesis regarding the significance of temperature alone on kid/adult ratios, but rather had thought that deep snow in combination with cold temperatures should reduce the abilities of nannies to bring a fetus to term. Secondly, if these weather variables were affecting kid/adult ratios, then they should also influence kid survival rates to 13 months, which they did not ($P>0.05$). Finally, a Durbin-Watson test for autocorrelation was inconclusive, indicating that the weather variables could be autocorrelated and thereby making the statistical comparison invalid.

Based on the harvest strategy proposed by Youds et al. (1980), the significant reduction in kid production in hunted herds from a mean of 0.32 kids/adult during 1974 - 1981 to 0.20 kids/adult later on would seriously compromise the ability of mountain goats to sustain the earlier harvest level. Kid production in non-hunted herds was parallel to that of their hunted counterparts (Fig. 4).

It is generally accepted that rates of juvenile mortality are very influential on $\bar{r}$ values of ungulates (Caughley 1977:100). The rate of kid survival to yearling age declined in hunted herds from a mean of 63% (1974 - 1981) to a mean of 44% (1982 - 1986) (Fig. 5). Non-hunted herds also had lower kid survival rates from 1983 - 1986 (Fig. 6). These kid survival rates would have reduced the ability of goat herds to withstand a 5% harvest. Kid/adult ratios inconsistent with $\bar{r}$ values have been reported by others (Hebert and Langin 1982, Smith 1984). However, the mean values calculated annually for the entire study area still appear to correlate with the general population trends (kid/adult ratios were lower during the period of population decline and higher during the period of increase).

As expected, poor recruitment and kid survival after 1981 resulted in lower yearling/adult ratios in subsequent years for both hunted and non-hunted herds (Fig. 9). Although survival rates of yearlings and older goats were not available, there is a distinct possibility that the values necessary to sustain a 5% harvest in WWP were not being achieved during the period of population decline. Smith (1986) provided the first direct estimates of age-specific mortality of mountain goats. One of his most significant findings relative to WWP, is that yearlings suffered an annual mortality rate of 29% ($N = 7$) compared to the 10% used in the harvest strategy model for WWP. Furthermore, during Smith's study, the mountain goat population was increasing. His study also indicates that adult mortality was not constant, but varied from 0 - 9% for goats 2 - 8 years old. Older goats (>8 years) had annual mortality rates of 32%. Youds et al. (1980) predicted that rates of increase are very sensitive

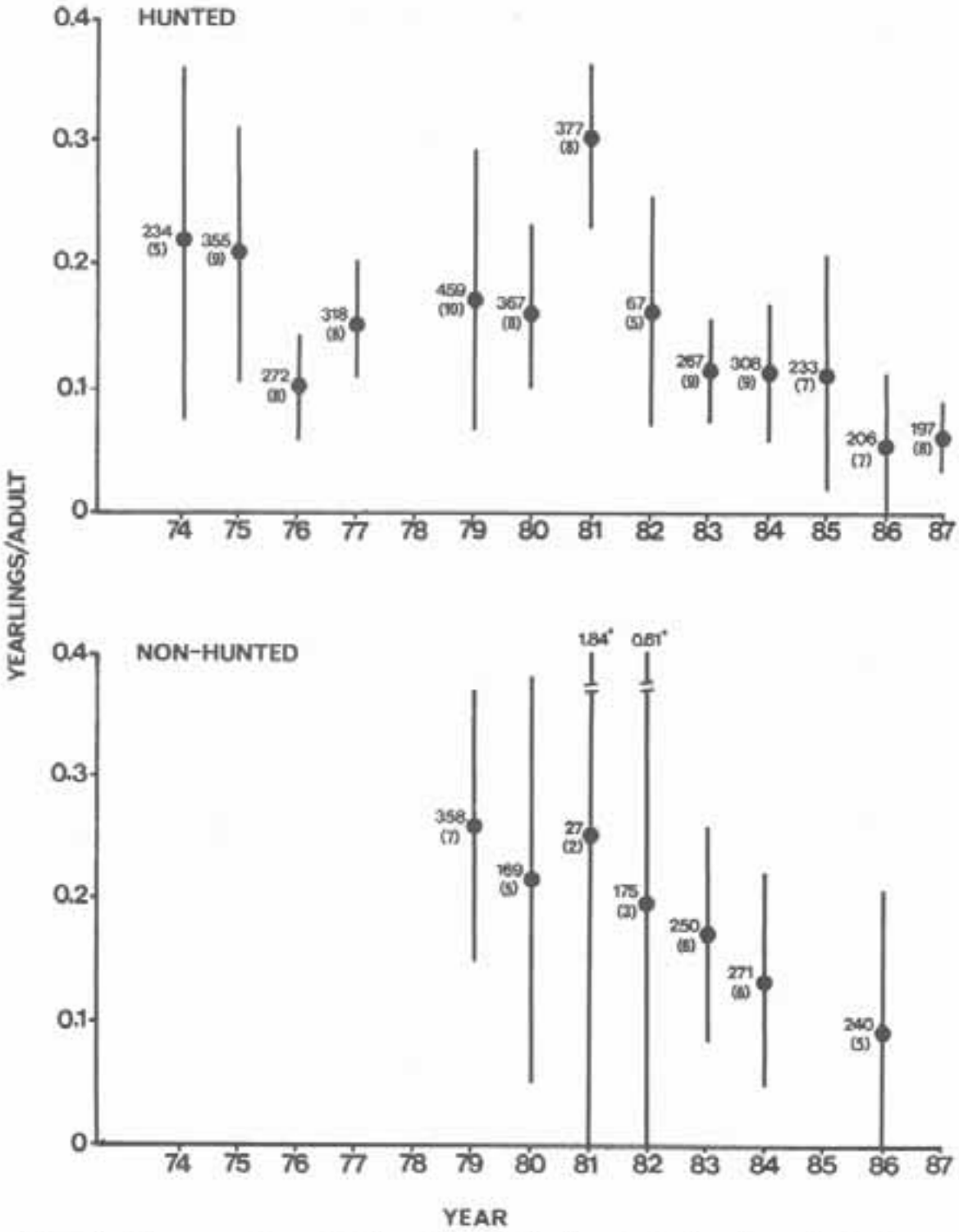

Fig. 9. Mean yearling/adult ratios (●) for hunted and non-hunted mountain goat populations in the Willmore study area, 1974-1987. Vertical lines, numbers and numbers in parentheses represent 95% confidence limits, the sample size of classified mountain goats and the number of survey areas per year, respectively.
(* = upper limits of 95% confidence limits)

Table 4. Annual mountain goat harvest results for Willmore Wilderness Park, 1974 - 1986.

Year	Male	Female	Total
1974	7	5	12
1975	10	18	28
1976	17	12	29
1977	5	11	16
1978	12	10	22
1979	28	5	33
1980	7	16	23
1981	21	11	32
1982	14	9	23
1983	15	11	26
1984	5	3	8
1985	6	0	6
Total	153	115	268
(% of harvest)	(57)	(43)	(100)

to changes in adult mortality based on constant mortality values in a population simulation model of WWP; however, Smith (1986) argues that, since adult mortality is not constant, models that use constant death rates for adult goats may produce unrealistic results by prematurely reducing prime-age cohorts.

Because mortality of goats aged 2 - 8 years was almost exclusively due to hunting in Smith's (1986) study, he concluded that this source of mortality is additive in native populations. This fact supports the conclusions of Hebert and Turnbull (1977), Kuck (1977) and Chadwick (1983). Minimum population estimates from aerial surveys of 8 hunted herds (C.V. = 37%) were not significantly more variable (Mann-Whitney U Test, $P < 0.05$) than were estimates for 3 non-hunted herds in WWP (C.V. = 24%). However, these data are consistent with the hyothesis that hunting is impacting herd dynamics in WWP and perhaps the collection of more data will allow statistical significance to be achieved.

Mean kid/adult ratios were significantly lower for hunted herds in WWP when compared to non-hunted herds from 1982 to 1986 ($P < 0.05$). Kuck (1977) found no increase in the kid/adult female ratio as the population size decreased and Hebert and Turnbull (1977) also found significantly lower kid proportions in heavily hunted populations compared to those that were lightly hunted or not hunted. However, kid survival to yearling age in WWP was not significantly different from 1982 to 1986 suggesting that variables other than hunting were relatively consistent in the study area. The mechanism responsible for the difference in kid production may be explained by adult female mortality.

Females made up an average of 43% of the WWP harvest between 1974 and 1986 (Table 4). In addition, the mean age of goats harvested per

Table 5. Mean age of mountain goats harvested in Willmore Wilderness Park year 1977 - 1986.

Year	Male			Female		
	Mean age (years)	Range	n	Mean age	Range	n
1977	6.3	3.5 - 8.5	5	4.6	1.5 - 8.5	8
1978[a]						
1979	4.8	1.5 - 9.5	27	6.3	2.5 - 9.5	5
1980	6.5	3.5 - 12.5	7	5.3	2.5 - 7.5	13
1981	5.1	1.5 - 13.5	19	5.7	1.5 - 10.5	10
1982	4.7	2.5 - 9.5	10	7.0	4.5 - 12.5	6
1983	5.7	1.5 - 13.5	11	5.1	1.5 - 13.5	5
1984	4.0	2.5 - 4.5	4	6.2	3.5 - 9.5	3
1985[a]						
1986	5.5	3.5 - 7.5	4	8.5	8.5	3

[a]No sex specific data.

year was centered in the prime age category for breeders (Table 5). Hunters who were unsuccessful in finding a billy probably took a lead nanny with the largest horns. Among social mammals in general, dominant females often show superior breeding success (Clutton - Brock and Albon 1985, in Houston and Stevens 1988). Consequently, productivity of hunted herds would probably be affected in a negative manner. However, orphaning may not make a significant difference in kid survival (Foster and Rahs 1982).

Observed rates of increase were compared relative to harvest rates during the period of increase and decline in goat populations in WWP (Table 6). Harvest rates were reduced by as much as 58% during the period of decline (Fig. 7), but herds continued to decline. The numbers of goats harvested constituted 0 - 80% of the observed decline in numbers, but the hunter-caused mortality appeared additive nonetheless and contributed significantly to the decline; both directly (through removal of goats) and indirectly (by reducing productivity). Goat populations declined dramatically in Olympic National Park when cropped at levels approaching the production of young (Houston and Stevens 1988). Conversely, non-hunted herds in WWP had positive rates of increase or declined only slightly during the same time period (1974 - 1987).

Unfortunately, predation, which could be significant in affecting mountain goat population dynamics, was not measured in this study. The major predators of mountain goats include mountain lion (Felis concolor), golden eagle (Aquila chrysaetos), bobcat (Lynx rufus), coyote (Canis latrans), black bear (Ursus americanus) and grizzly bear (Ursus arctos) (Rideout 1978). With the exception of bobcat, all are found in WWP. Repeated sightings of a mountain lion harassing mountain goats on Mt. Hammel (Alberta Forest Service, Grande Cache, Alberta) during 1987

Table 6. Observed rate of increase $\bar{r}$ in 9 mountain goat populations in the Willmore study area, 1973-1987.

Complex (Zone)[a]	Period of Increase	$\bar{r}$	Mean Harvest	Period of Decline	$\bar{r}$	Mean Harvest(%)
HUNTED						
Moosehorn (A)	1975-1979	0.20(4)[b]	7.4	1979-1986	-0.20(8)	5.1
Persimmons(B)	1974-1980	0.05(6)	9.0	1980-1984	-0.10(3)	7.5
Monoghan/Sunset/ Rockslide (C)	1974-1980	0.01(6)	6.0	1980-1984	-0.19(5)	5.4
Triangle/Kvass(D)	1974-1979	0.08(5)	4.9	1979-1984	-0.23(6)	5.1
Llama/Turret(E)	1975-1983	0.13(7)	5.4	1983-1987	-0.21(5)	2.3
Mt. Deveber(F)	1973-1979	0.06(2)	4.4	1979-1986	-0.03(2)	3.5
NON-HUNTED						
Caw Ridge	1974-1986	0.04(8)				
Mount Hamell	1974-1986	0.08(7)				
Goat Cliffs				1974-1987	-0.03(8)	

[a]Mountain goat hunting zone designation up to and including 1984.
[b](x) = Number of surveys used to calculate $\bar{r}$.

substantiate this factor. In addition, wolves (Canis lupus) are plentiful in the area and wolf scats collected from Caw Ridge contained mountain goat hair. Wolf predation was the most significant factor limiting the recovery of woodland caribou (Rangifer tarandus) in west-central Alberta (Edmonds 1988). Wolf populations in WWP are considered to have increased since control measures were relaxed in the early 1960's (Edmonds 1988) and other prey species such as woodland caribou and moose (Alces alces), have declined. "Prey switching" by wolves could potentially place more predator pressure on alpine ungulates and increase the chances of mountain goat populations declining while hunting continued. A decline in bighorn sheep (Ovis canadesis) populations for 3 of the mountain complexes where mountain goats were inventoried, paralled that of mountain goats despite a relatively consistent harvest regime throughout the entire period 1975 - 1987 (Fig. 10). Three separate incidences of wolves chasing bighorn sheep were documented in WWP and vicinity during 30 hours of winter helicopter sheep surveys in 1988 compared to none recorded for any of the previous sheep surveys. Increasing wolf predation may be influencing these results. Moreover, Smith (1986) found that of the 13 goats where cause of death could be determined in his study in southeastern Alaska, the mortality was relatively equally distributed among hunting, predation and factors other than hunting. Of the 4 killed by predators, 3 were taken by wolves and 1 by a bear (Ursus spp.).

In summary, populations of mountain goats in WWP appear to have suffered from a combination of factors resulting in a decrease in the mid 1980's. A severe winter in 1982 may have significantly reduced populations in general,

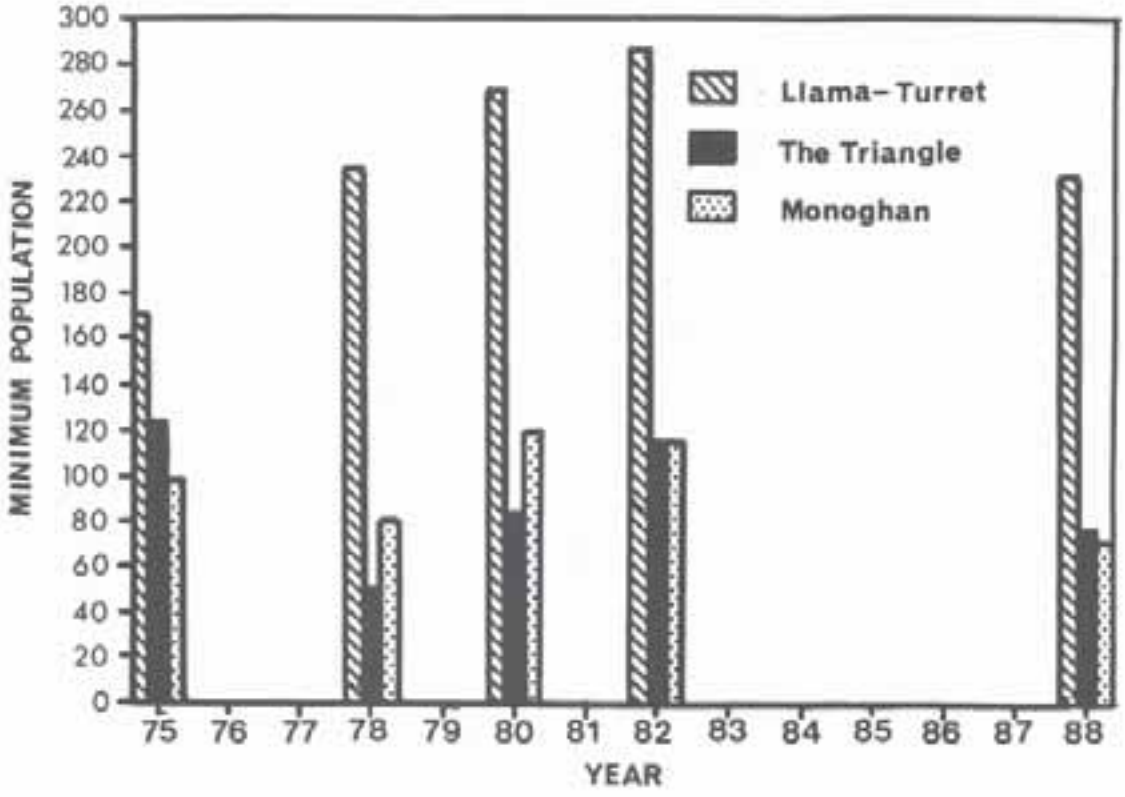

Fig. 10. Minimum mountain sheep population estimates for 3 mountain complexes in Willmore Wilderness Park based on aerial surveys, 1975-1988.

which in turn was not documented sufficiently due to an 80% reduction in helicopter survey time that year. Subsequent inventories resulted in 2/3 of the mountain complexes being inventoried only in alternate years, thereby reducing confidence in predicting trends. Data suggests that hunting mortality was additive and exceeded the rate of increase as kid recruitment and survival continued to decline. The failure of the 1982 year classes continued to affect productivity in subsequent years. Relatively mild winter weather following the severe winter of 1982, resulted in higher expectations for population recovery than were realized. These problems may have been exacerbated by increasing wolf predation, in conjunction with other predators. Non-hunted herds were able to either increase or decrease only slightly during the same time period. Consequently, the mountain goat hunting season in WWP will be closed until populations recover. If population recovery is sufficient to allow hunting, the harvest should remain below 3% (Hebert and Langin 1982) and be restricted to billies only. Annual inventories, with the objective of obtaining total counts, should be required for all hunted populations.

LITERATURE CITED

Adams, L. G., and J. A. Bailey. 1982. Population dynamics of mountain goats in the Sawatch Range, Colorado. J. Wildl. Manage. 46:1003-1009.

Alberta Wilderness Association. 1973. The Willmore Wilderness Park. Unpubl. Rept. The Alberta Wilderness Association. Lynnprint Publishers, Calgary, Alberta. 42 pp.

Bowden, D. C., A. E. Anderson and D. E. Medin. 1984. Sampling plans for mule deer sex and age ratios. J.Wildl. Manage. 48:500-509.

Brandborg, S. M. 1955. Life history and management of the mountain goat in Idaho. Idaho Dep. Fish and Game, Wildl. Bull. 2. 142 pp.

Burles, D., M. Hoefs and N. Barichello. 1984. The influence of winter severity on Dall sheep productivity in southwestern Yukon - a preliminary assessment. Bienn. Symp. North. Wild Sheep and Goat Counc. 4:67-84.

Caughley, G. 1977. Analysis of vertebrate populations. John Wiley and Sons. New York, N.Y. 234 pp.

Chadwick, D. H. 1983. A beast the color of winter. Sierra Club Books. San Francisco, Ca. 208 pp.

Edmonds, E. J. 1988. Population status, distribution and movements of woodland caribou in west-central Alberta. Can. J. Zool. 66:817-826.

Foster, B. R. and E. Y. Rahs. 1982. Implications of maternal separation on overwinter survival of mountain goat kids. Bienn. Symp. North. Wild Sheep and Goat Counc. 3:351-362.

Hall, W. K. 1977. Status and management of the Rocky Mountain goat, (Oreamnos americanus), in the Province of Alberta. Pp. 8-14 in W. M. Samuel and W. G. MacGregor, (Eds.) Proc. First Internat. Mountain Goat Symp., Kalispell, MT. 243 pp.

_____ and J. A. Bibaud. 1978. Goats and their management in Alberta. Bienn. Symp. North. Wild Sheep and Goat Counc. 1:142-164.

Hayden, J.A. 1984. Introduced mountain goats in the Snake River Range, Idaho: characteristics of vigorous population growth. Proc. Bienn. Symp. North. Wild Sheep and Goat Counc. 4:94-119.

Hebert, D. M. and G. W. Turnbull. 1977. A description of southern interior and coastal mountain goat ecotypes in British Columbia pp. 126 - 146 in W. M. Samuel and W. G. MacGregor (Eds.), Proc. First Internat. Mountain Goat Symp., Kalispell, MT. 243 pp.

_____. and H. D. Langin. 1982. Mountain goat inventory and harvest strategies: a re-evaluation. Proc. Bienn. Symp. North. Wild Sheep and Goat Counc. 3:339-350.

Houston, D. B. and V. Stevens. 1988. Resource limitation in mountain goats: a test by experimental cropping. Can J. Zool. 66:228-238.

Kuck, L. 1977. The impact of hunting on Idaho's Pahsimeroi mountain goat herd. Pp. 114-125 in W. M. Samuel and W. G. MacGregor (Eds.), Proc. First Internat. Mountain Goat Symp., Kalispell, MT. 243 pp.

McFetridge, R. J. 1977. Strategy of resource use by mountain goats in Alberta. M. S. thesis, Univ. of Alberta, Edmonton, Alberta. 148 pp.

Rideout, C. B. 1978. Mountain goat. Pp. 149-159 in J. L. Schmidt and D. L. Gilbert (Eds.), Big game of North America. Stackpole Books, Harrisburg, PA. 494 pp.

Smith, C. A. 1984. Evaluation and management implication of long-term trend in coastal mountain goat populations in southeast Alaska. Bienn. Symp. North. Wild Sheep and Goat Counc. 4:395-424.

_____. 1986. Rates and causes of mortality in mountain goats in southeast Alaska. J. Wildl. Manage. 50:743-746.

Swenson, J. E. 1985. Compensatory reproduction in an introduced mountain goat population in the Absoroka Mountains, Montana. J. Wildl. Manage. 49:837-843.

_____. 1986. Reproductive response of the Absoroka mountain goat population to an experimental reduction. Bienn. Symp. North. Wild Sheep and Goat Counc. 5:71-75.

Wehausen, J. D., V. C. Bleich, B. Blong and T. L. Russi. 1987. Recruitment dynamics in a southern California mountain sheep population. J. Wildl. Manage. 51:86-98.

Youds, J. A., D. M. Hebert, W. K. Hall, and R. A. Demarchi. 1980. Preliminary data on mountain goat population growth. Bienn. Symp. North. Wild Sheep and Goat Counc. 2:482-519.