SNOW DEPTH AS A LIKELY FACTOR CONTRIBUTING TO THE DECLINE OF A SHEEP POPULATION IN THE CENTRAL YUKON

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Introduction

In 1983 and 1984 the licenced commercial hunting guide/outfitter operating in the Glenlyon Range of the Pelly Mountains noted thinhorn sheep (Ovis dalli) population declines, sheep absent from traditional areas, a decline in group size and poor lamb production over the preceding years. Her concerns were substantiated by an obvious decline in the average age of the sheep kill since 1982.

The only sheep demographic information available for the area was a population count carried out during an all-species survey in 1976 (Yukon Territorial Government (YTG) unpublished report), at which time sheep density was relatively high (40/100 sq. km.) and legal sheep were abundant. The occurrence of a number of exceptional trophy rams (rams with massive horns, considerably longer than full curl) in the population suggested that the kill was below that which could be sustained on an annual basis. Since 1979 sheep hunting has been restricted to full curl rams and the harvest has appeared relatively stable, averaging 8 rams per year.

An updated demographic assessment of the sheep was necessary to verify and explain the apparent population decline in the Glenlyon Range. Specifically, we intended to determine population size, composition and productivity, and incidentally, to determine general range-use patterns and identify critical components of sheep range.

Study Area

The Glenlyon Range of the Pelly Mountains (Yukon Game Management Subzones 4-16 and 4-42) lies within the Pelly River Ecoregion (Oswald and Senyk 1977), approximately 50 km west of Faro and 200 km north of Whitehorse (Figure 1). The Glenlyon range rises above the Pelly River to a height of 2100 m a.s.l. The area is rugged with extensive talus and topographic breaks. Steep south-facing slopes are dominated by grasses, ericacious shrubs and prostrate willows (*Salix spp.*).

Mean January temperatures range from -27 to -35^{o}C, while the average annual precipitation reaches as high as 500 mm at upper elevations. Snow conditions are thought to be similar to conditions in Faro.

Sheep found in the area are of the fannin or stone colour phase. Woodland caribou (*Rangifer tarandus caribou*), of the Glenlyon Herd, are also common in the Glenlyon Range. Wolves (*Canis lupus*) occur in the area but population size and distribution is unknown (Youngman 1975). Other potential sheep predators resident to the area are lynx (*Lynx lynx*), grizzly bears (*Ursus arctos*) and golden eagles (*Aquila chrysaetus*). Abundance and distribution of these animals is unknown.

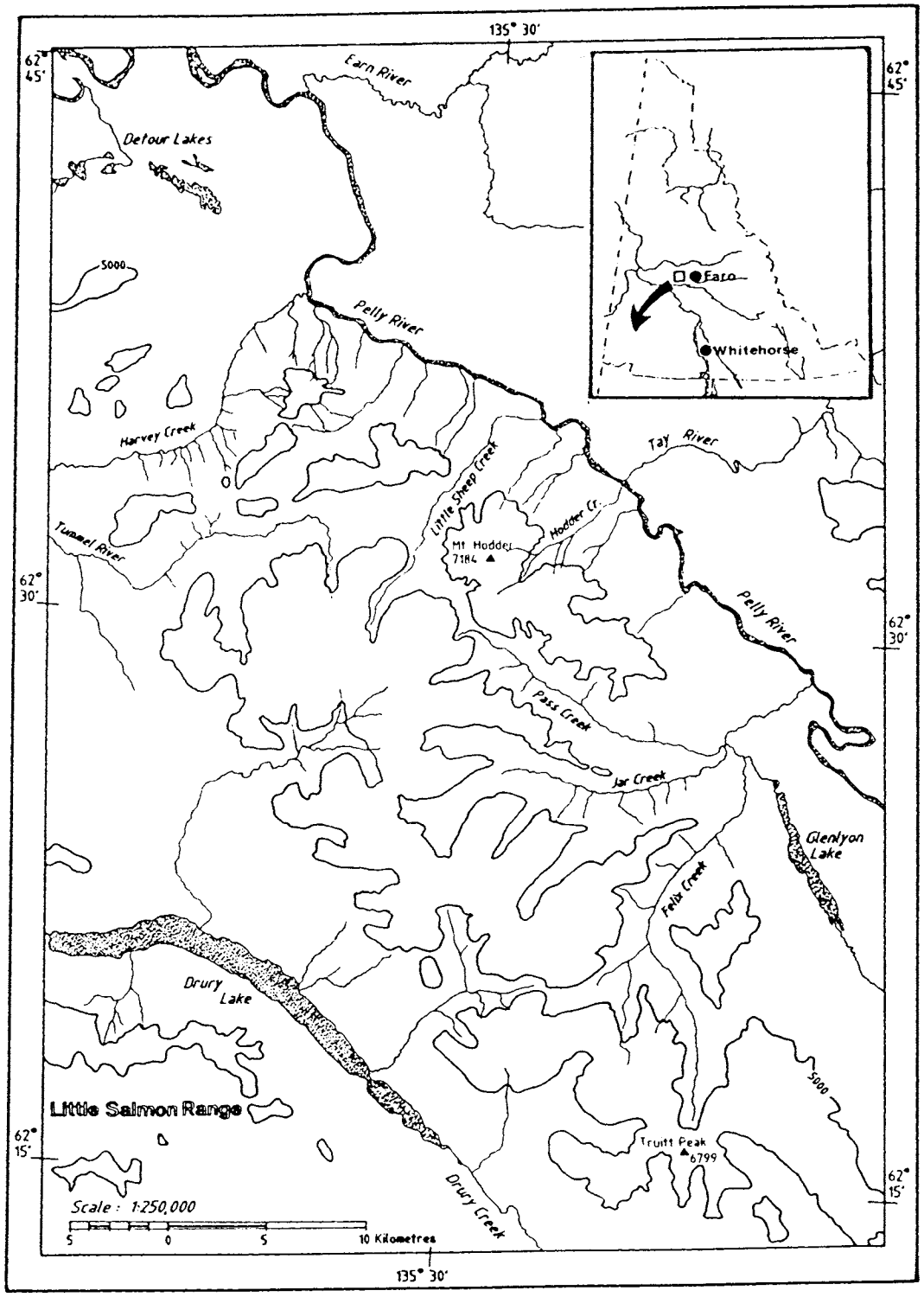

Figure 1. Study area.

Methods

Sheep were surveyed in July 1986 and March 1987, using a standard drainage survey technique (Barichello et al. 1987), which involves a complete search of all potential sheep habitat with a helicopter. The July survey was intended to provide a total population count. Thinhorn sheep are light coloured and very conspicuous during the summer when they contrast with the landscape. We assume that an insignificant number of sheep were missed, due to good observability, complete coverage and the intensity of the relatively slow speed helicopter search. The March survey was designed to provide a replication of the July survey in addition to indicating general range use. Comparative surveys of pure white Dall sheep in the northern Yukon indicated that two March censuses represented 64 and 68% of the total number of sheep counted in June of the corresponding year (Barichello et al. 1987). In the Glenlyon range where sheep generally have grey or dark markings we expected the March count to compare closely with the July results and therefore to also represent a complete population count.

Nursery groups are generally disassociated from ram groups, and include ewes, yearlings, lambs and two year old rams. We define nursery sheep as only including ewes, yearlings, and two year old rams. These nursery sheep have horns with considerably less horn mass and forming less arc than rams older than two years. Yearlings were distinguished on the basis of body and horn size

and facial characteristics (Barichello et al. 1987). Ewes were indistinguishable from 2-year old rams from aerial surveys. Rams not in association with nursery groups or with horns of arc greater than 90 degrees were classified by horn class as half, three-quarter or full curl. As horns do not grow in discrete increments according to horn class, horns falling between these broad classes were arbitrarily assigned a horn class. We assumed this assignment was unbiased. It was noted when horns had exceptionally long horn length and mass; these were considered exceptional trophy sheep.

Locations were plotted on 1:250,000 scaled maps, and winter range was delineated on the basis of the March distribution of animals and tracks.

Mid-summer lamb production was calculated as the number of lambs per 100 nursery sheep. Mortality rates of lambs, nursery sheep and rams were calculated as the change in numbers of each class from July, 1986 to March, 1987. This assumes absolute counts in July and March, and the difference as a result of mortality.

For comparison, census data from a July, 1976, sheep inventory of the study area are presented. Also, in March of 1977 sheep tracks and observations were recorded to delineate winter range use. Sheep observations in March, 1977 were incomplete so are not presented in this report. Winter range delineation in 1977, however, is compared to the March, 1987 sheep distribution.

The sheep kill was recorded through voluntary submission of ram heads by resident sport hunters from 1973-1978, and compulsory submissions by all non-resident licenced hunters since 1973 and all resident hunters since 1979. These submissions provided the ram age and horn curl. During this period there was no record of illegal sheep taken in the area. The subsistence kill was assumed to be minimal (YTG unpublished report).

Weather data was obtained from Environment Canada records for Faro, from 1978-1987. Although thermal inversions and variable wind patterns were thought to occur in the Glenlyon range, general weather patterns were assumed to be similar to that recorded at Faro, which is situated on the Pelly River about 50 km from the study area.

Results

Demography

Differences between the July 1986 and March 1987 censuses were small (Table 1). A total of 109 nursery sheep (including yearlings) and 42 rams were counted in July, in comparison to 101 nursery sheep (not including 1986 lambs) and 38 rams in March. March surveys represented 92% of the July non-lamb population count. Assuming minimal movement to and from the Glenlyon Range, it appears that either few sheep were missed during the surveys or that observability was consistent between seasons. The relatively consistent classification supports our assumption that the entire population was counted during both surveys, and that the population is discrete. Differences in the counts, then, are assumed to represent mortality losses.

From 1976 to 1986 a decline of 40 and 41% was observed in nursery sheep and ram numbers, respectively. Young rams (less than full curl) apparently declined at a rate exceeding that of full curl rams; 58% fewer young rams and 19% fewer old (full curl) rams were observed in 1986 as compared to 1976. Noteworthy is the near-complete absence of half curl rams in 1986. The composition of the ram segment of the Glenlyon population in 1986-87 was atypical of both hunted and unhunted thinhorn sheep populations in the Yukon. Census data, Yukon-wide, indicate that half curl rams generally represent about 44% of the 3+-year old rams in hunted populations (n=786), and 34% of the 3+-year old rams in

Table 1. Census and classification of thinhorn sheep in the Glenlyon Range of the Pelly Mountains, 1976 and 1986-87.

	Total (excluding lambs)		Nursery Sheep (excluding yearlings)		Yearlings	Lambs	Rams			
							Total	1/2	3/4	4/4
July 1976	253		———	182	———	29	71	-	-	31
July 1986	151	170	85	104	24	19	42	1	16	25
March 1987	139	153	———	101	———	14	38	1	12	25

unhunted populations (n=225; unpublished YTG data). In the Glenlyons half curl rams represented only 2% of the 3+-year old rams.

Mid-summer lamb production (lambs/100 nursery sheep) was 16 in 1976 and 17 in 1986. These productivity estimates are low compared to average lamb production rates of thinhorn sheep. In the southern Yukon a downward trend in lamb production (from 40 to 13 lambs per 100 nursery sheep) was observed from 1980 to 1986 (Table 2). Where lamb production estimates were available in areas within and adjacent to the Glenlyon Range from 1981 to 1986, they were similar to estimates recorded from the southern Yukon. In the south, slight variability in mid-summer lamb production has been observed between areas and within years. It is likely, then, that lamb production in the Glenlyons closely tracked rates of production in surrounding areas, and possibly was similar to a general trend in the southern Yukon. For comparison, in 1986, lamb production in the Glenlyons was 17.4/100 nursery sheep, and in the southwest Yukon was 13.1/100 nursery sheep.

From July 1986 to March 1987 26% of the lambs disappeared, while 7% of the ewes, and 10% of the rams were lost. For comparison, southern lambs, ewes and rams disappeared at average annual rates of 34, 14 and 16%, from an unhunted population, 1968-1979 (Hoefs and Cowan 1979).

Table 2. Lamb production (lambs per 100 nursery sheep) in central and southern Yukon.

Year	Southern Yukon	Central Yukon
1980	40.4	--
1981	24.3	24.9
1982	26.4	18.6
1983	19.8	--
1984	30.4	--
1985	18.5	--
1986	20.0	17.4

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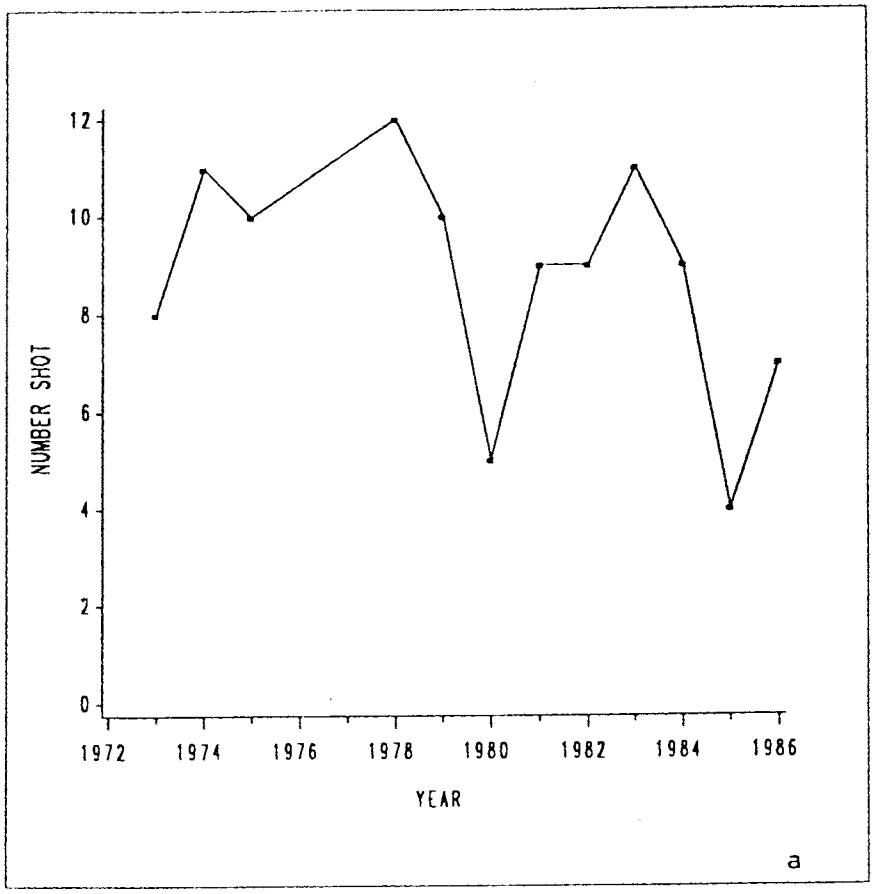
Hunter-kill

The annual sheep kill from the Glenlyons has ranged from 4 to 13 from 1973 to 1986, while the average age varied between 6.8 and 9.5 years (Figure 2). From 1982 to 1983 there was a substantial decline in the average age of the licenced sheep kill, from 9.4 to 7.3 years. Only 3 of 11 (27%) of the rams shot in 1983 were 8 years or older, compared to 6 of 9 (67%) in 1982. Since 1982 the average age has averaged less than 8.0 years annually in contrast to the previous 4 years where the annual average age was greater than 8.0 years. The average age of the kill from 1983 to 1986 was significantly less than the average age of the kill from 1979 to 1982 (7.3 versus 8.8; p 0.05).

The number of rams killed in the Glenlyons did not decline with average age from 1982 to 1983. Normally the harvest does not remove all legal rams, so a decline in the average age of the kill does not necessarily imply a decline in the number of rams killed. The loss of older aged rams may result in only a shift in the kill toward younger animals, and not a decline in the number harvested.

Weather

Average winter temperatures (November-March) did not vary significantly from 1981 to 1987 ($F=0.80$, $p=0.56$, Figure 3). Snow accumulation, however, was much more pronounced in the winter of



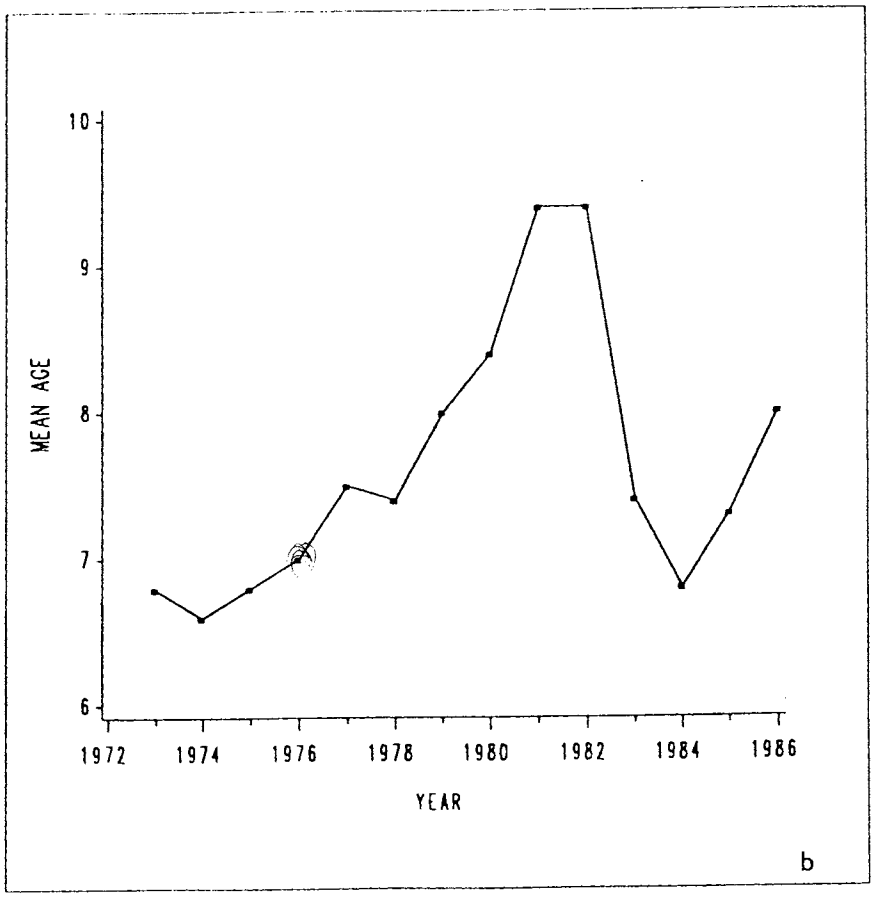


Figure 2. Number (a) and mean age (b) of rams shot in the Glenlyon Mountains 1973 - 1986.

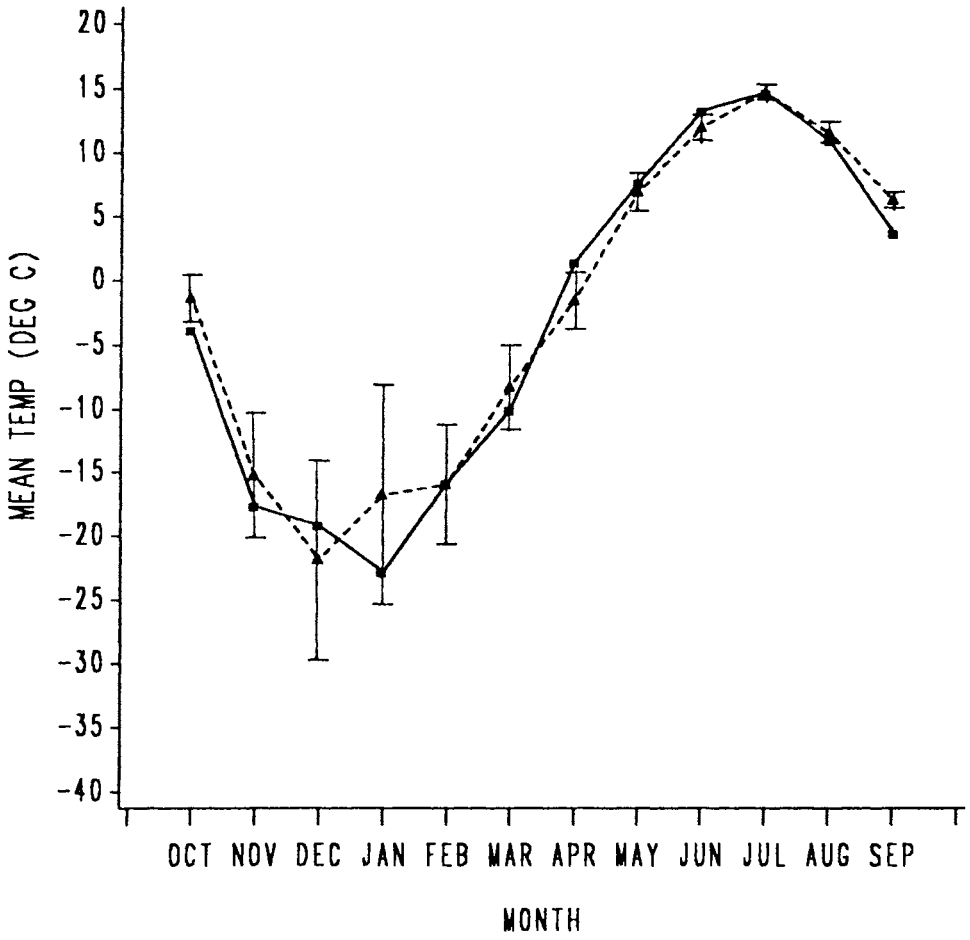


Figure 3. Mean monthly temperatures for 1982-83 (solid line) and the average mean monthly temperatures (with 95% confidence intervals) for 1981-82, 1983-84, 1985-86, 1986-87.

1982-83, as compared to all other years (Figure 4). From October to April, snow depth was significantly higher during all months in 1982-83, as compared to the average for all other winters recorded (1981-82, 1983-87; p 0.05). The average winter snow depth (November-March) was significantly higher in 1982-83, compared to all other years (F=4.82, p 0.01). Average snow depth in 1986-87 was the lowest recorded (1981-1987), however it was significantly different only in comparison to the average snow depth during the winter of 1982-83.

Sheep distribution

The summer distributions of sheep in 1976 and 1986 were similar, with two consistent centres of habitation and fairly extensive use of alpine range.

The winter distributions of sheep in 1976-77 and 1986-87 are shown in Figure 5. In 1977 sheep were concentrated between 1050 and 1200 m a.s.l., using in particular, the south slopes of creeks flowing to the northeast. In 1987 sheep were more widely dispersed, regionally and altitudinally, coinciding with low snow accumulations in that winter.

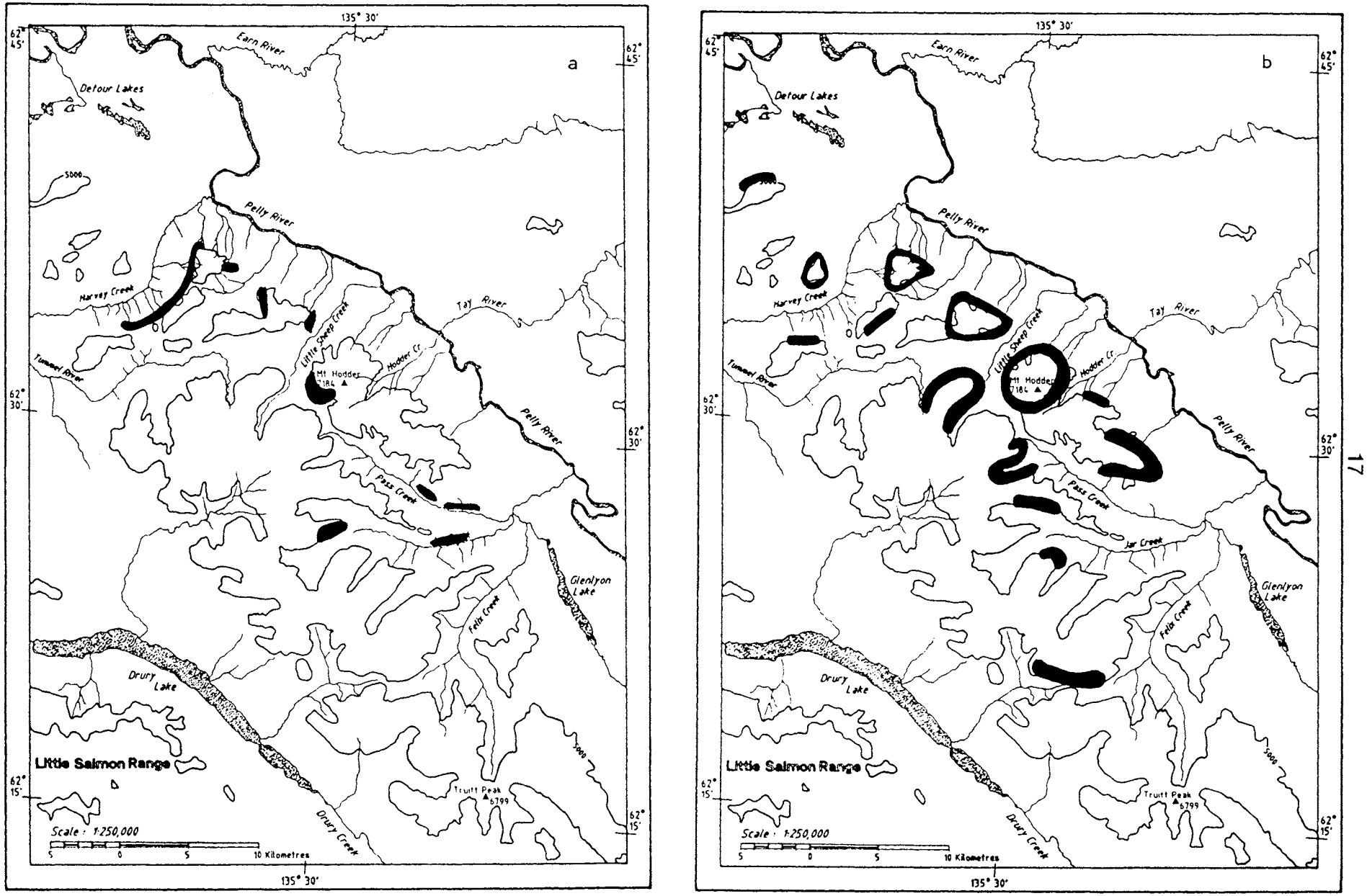


Figure 5. Winter distribution of sheep during 1976-77 (a) and 1986-87 (b).

Discussion

Demography

Census results are in agreement with the guide-outfitter's observations in 1983. A 40% decline in the sheep population was observed from 1976 to 1986, a rate consistent betweeen nursery and ram groups. Within the ram population the number of younger rams declined at a rate exceeding that of the older (full curl) rams. The near complete absence of half-curl rams suggests that there have been disparate losses in the younger cohorts, possibly through consecutive years' reproductive failures.

The disparity in the proportion of rams of different horn classes in the Glenlyon range in 1986-87 contrasts with findings from the Glenlyons in 1976-77 (YTG unpublished data), as well as the general demographic data from studied sheep populations in the southern and northern Yukon (Hoefs and Cowan 1979, Barichello et al. 1987). The composition of most studied sheep populations is indicative of stable populations where the young and old cohorts survive less well than middle-aged individuals (Hoefs and Cowan 1979, Simmons et al. 1984).

The idea that weather was a predisposing agent causing demographic change in the Glenlyons is consistent with census findings. Snow is perhaps the most debilitating environmental factor for Dall sheep (Seip and Bunnell 1985). Deep snow undoubtedly limits sheep foraging ability and thus predisposes

them to nutritional deficiencies and predation. The difficulty in pawing through deep snow, we expect, will lower intake rates, force sheep to extend foraging bouts and/or distance themselves from escape terrain. Nutrition and/or predator avoidance strategies are no doubt compromised as a result of deep snow, resulting in a degeneration of body condition or higher losses to predators, and consequently poor productivity and population decline.

The winter of 1982-83 was a particularily severe one, with deeper than average snows for the area (p 0.05; Fig. 5). This may have contributed substantially to the sheep decline observed, with ensuing reproductive failures in 1983 and the loss of much of the previous cohort in addition to older animals. In the southern Yukon 1983 was also a year of deep snow, resulting in a significant decline in lamb production.

Coinciding with this suspected loss of two cohorts in 1982 and 1983 in the Glenlyons was a dramatic decline in the average age (9.4 to 7.4 years) of the 1983 sheep kill in the Glenlyons. The absence of any large trophy animals observed during the 1986 survey, as compared to the 1976 survey, further corroborates the view that older-aged rams have died at higher than usual rates since 1982.

In addition to the apparent loss of two cohorts and older-aged individuals, as indicated by a decline in average age, was a 40% decline of the non-lamb population in the Glenlyons. In a stable

southwest Yukon population, the removal of two first year cohorts, in addition to sheep older than 8 years would result in a 39% decline in the population and a significant decline of the average age of the legal ram population (9.2 versus 8.0; Hoefs and Cowan 1979).

Relatively poor lamb production in 1981 and 1982, as suggested by surveys in an adjacent area, may have also contributed to the apparent decline in the Glenlyons. The severity of the 1982-83 winter may have exaggerated a modest decline due to two previously hard winters, assuming lamb production is indicative of sheep survivorship. In the southern Yukon poor productivity from 1981 to 1983 has resulted in population declines and in particular a decline in animals from the 1982 and 1983 cohorts (Barichello et al. in prep.).

Predators possibly influenced population change. However, the correlations between winter snow conditions, ram age distribution, and average age of the hunter-kill, suggest that snow conditions and not predators precipitated the sheep decline. Most likely wolves were an important mortality agent on sheep, when sheep distribution, movements and condition were compromised due to severe snow conditions. Bears and golden eagles are opportunistic predators on dall sheep, particularly lambs, but have not been found to significantly alter sheep demography (Barichello et al. in prep.).

Distribution

Population size is likely not limited by summer range. A relatively wide distribution of sheep in the two years surveyed and an apparent abundance of suitable forage and escape terrain, would suggest that high densities could be sustained on summer range.

Winter distribution of Dall sheep is likely influenced by snow conditions around adequate escape terrain. The apparent movement of sheep to south-facing slopes of creeks flowing into the Pelly River in the winter of 1976-77 and the wider dispersal of sheep in the low snow year of 1986-87 suggests that winter distribution is influenced by snow. Little snow in 1986-87 probably allowed sheep to range to higher elevations with generally more overlap with summer range.

South-facing slopes receive more solar energy and protection from cold north winds. On Sheep Mountain, in the southwest Yukon, there was a definite preference for south slopes when winds blew out of the north in the winter (Hoefs and Cowan 1979). In the Glenlyon Range the northern block of mountains probably benefits from prevailing winds along the Pelly River, and may sit in a rain shadow, protected from snow storms generated from the southwest, further facilitating snow free conditions.

Precipitation in the Glenlyons was found to be higher than in the Coastal Mountains around Whitehorse (Oswald and Senyk 1977). It

is likely that winter range is of far more importance to sheep in the Glenlyon range. Deep snow years may be relatively common, and therefore the availability of winter range may be severely limited in those years. The concentration of sheep in what was probably a normal snow year in 1976-77, emphasizes the importance of winter range.

Management Implications

Dall sheep are considered to be a "climax" species with a limited potential to increase in numbers (Hoefs 1984). Twinning is extremely rare and and ewes do not produce until age 2 to 3 (Simmons et al. 1984). Furthermore, sheep do not readily disperse and re-colonize vacant ranges (Geist 1971). Long term census data in the southwest Yukon have found population growth rates correlated to lamb production, which appears driven by the stochastic influences of weather (Burles and Hoefs 1984, unpublished YTG data). Population recovery in the Glenlyons, then, is expected to occur slowly.

The reduction of two young cohorts will eventually pass through all age classes. In the short term productivity may appear unusually high. The absence of juvenile age classes in the nursery group will presumably result in a higher ratio of lambs to nursery sheep. However, in time these missing age classes will result in poor adult ewe recruitment and consequently poor production. The same can be predicted for rams: poor recruitment to the legal category in the years ahead due to the absence of two year-classes.

The compensatory effects of higher productivity or improvement of horn growth on low density ranges, although possible, have not been reported for Dall sheep.

Population growth is probably limited by snow conditions during the winter and severe weather conditions during lambing (Hoefs 1984, Seip and Bunnell 1985). Predation is probably facilitated during deep snow years. Wolf removal in the Glenlyon Mountains would undoubtedly be expensive and politically sensitive. The benefits to the sheep populations may be evident only during hard winters where population growth is unlikely even in the absence of wolves. Therefore, we discourage this approach.

Sheep transplants could immediately increase population size and facilitate growth, however this proceedure is also expensive. Furthermore, we cannot be certain sheep would habituate to the new range. Also, if adjacent populations have experienced similar climate-induced declines, there may not be an adequate source of sheep to transplant.

Hunting restrictions will probably not produce more sheep as long as a full-curl rule is in effect. Hunting success will decline as the standing crop of legal rams declines. This is anticipated for the years ahead in light of two missing cohorts and the slow rate of recovery.

We recommend no action. The sheep population will likely recover with time. With ideal conditions this could be achieved in as few as 3 years. However, we anticipate average growth rates and poor hunting success for a period of 2-4 years in the future.

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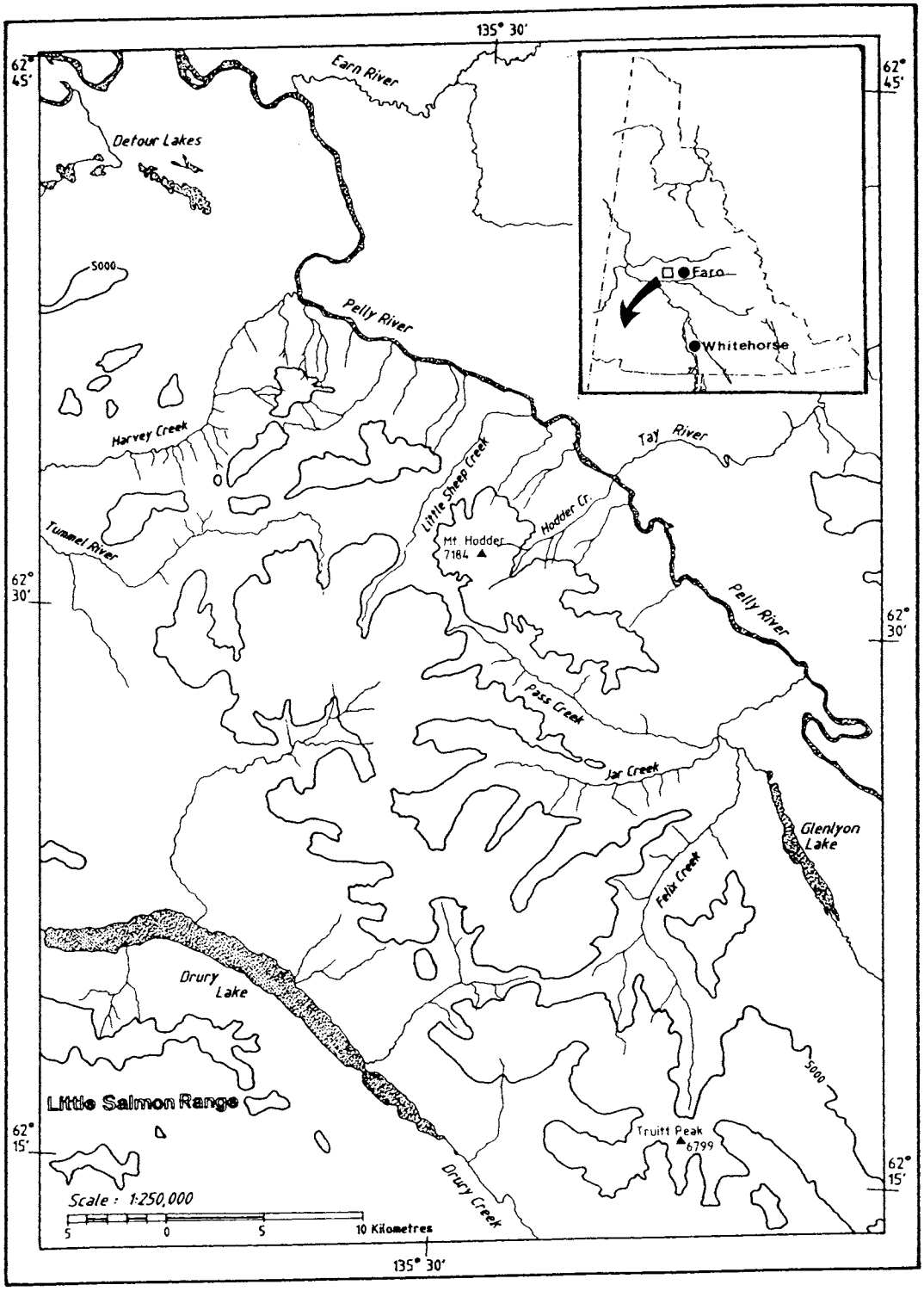

Figure 1. Study area.

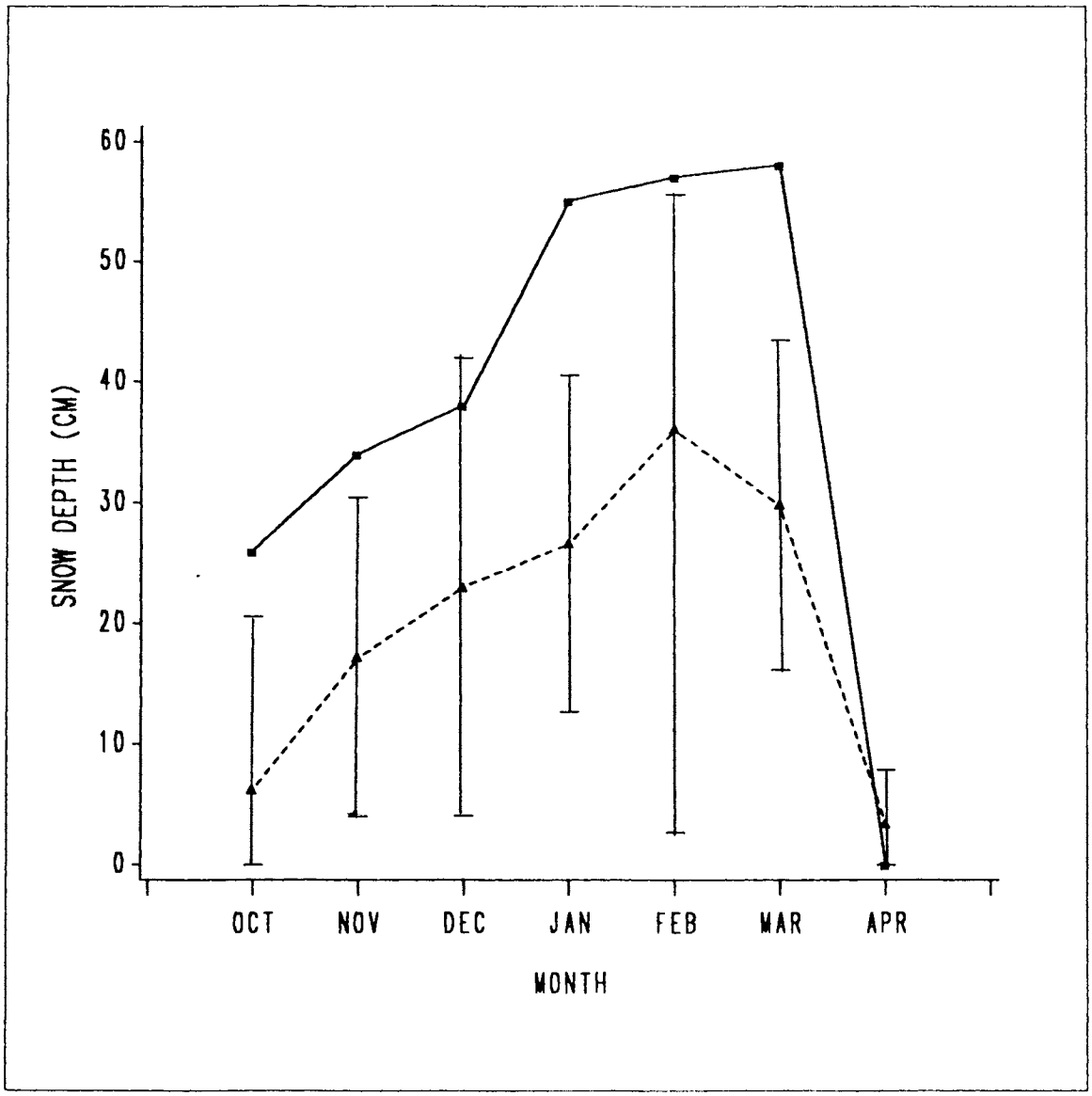

Figure 5. Snow depth during 1982-83 and the average snow depth (with 95% confidence intervals) for the surrounding 5 years.

Table 5. Ungulate:wolf and biomass:wolf ratio within respective pack territories.

		Prey:Wolf				Biomass(kg):Wolf			
Pack Name	Territory Size	Sheep	Moose	Caribou	Ungulates	Sheep	Moose	Caribou	Ungulates
BAP	412 km²	0	16	31	85	0	5638	3932	9570
TLP	350 km²	61	4	5	70	3560	1409	623	5592
CCPR	711 km²	250	14	1	265	14602	4934	122	19658
GRP	540 km²	180	3	32	227	9211	1057	2985	13253
DRP	1757 km²	359	12	1	372	20968	4228	122	25318

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Abstract

A thinhorn sheep (Ovis dalli) population was counted and classified in the Glenlyon Range of the Pelly Mountains in response to a decline in the average age of the sheep kill, and the outfitter's concerns that sheep had severely declined in the area. The population was found to have declined by about 40% of the estimated 1976 population, with the virtual absence of one-half-curl rams and large full-curl rams. Furthermore, there was a significant decline in the average age of the licenced sheep kill from 1982 to 1983 ($p<0.05$).

The winter of 1982-83 was a particularly severe one with deeper than average snow conditions during all months ($p<0.05$). The loss of the 1982 cohort and older-aged animals during this winter, compounded by the reproductive failure of the 1983 lamb crop, adequately explains the decline of the population and the average age of the kill. Relatively poor lamb production in 1981 and 1982 possibly contributed to the decline.

The concentrated distribution of sheep in March 1977, in what was possibly an average winter, in comparison to the wide distribution observed during a low-snow year in March of 1987, further suggests that winter snow conditions may play a key role in the dynamics of sheep in the area.

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Introduction

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Sheep found in the area are of the fannin or stone colour phase. Woodland caribou (Rangifer tarandus caribou), of the Glenlyon Herd, are also common in the Glenlyon Range. Wolves (Canis lupus) occur in the area but population size and distribution is unknown (Youngman 1975). Other potential sheep predators resident to the area are lynx (Lynx lynx), grizzly bears (Ursus arctos) and golden eagles (Aquila chrysaetus). Abundance and distribution of these animals is unknown.

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Sheep were surveyed in July 1986 and March 1987, using a standard drainage survey technique (Barichello et al. 1987), which involves a complete search of all potential sheep habitat with a helicopter. The July survey was intended to provide a total population count. Thinhorn sheep are light coloured and very conspicuous during the summer when they contrast with the landscape. We assume that an insignificant number of sheep were missed, due to good observability, complete coverage and the intensity of the relatively slow speed helicopter search. The March survey was designed to provide a replication of the July survey in addition to indicating general range use. Comparative surveys of pure white Dall sheep in the northern Yukon indicated that two March censuses represented 64 and 68% of the total number of sheep counted in June of the corresponding year (Barichello et al. 1987). In the Glenlyon range where sheep generally have grey or dark markings we expected the March count to compare closely with the July results and therefore to also represent a complete population count.

Nursery groups are generally disassociated from ram groups, and include ewes, yearlings, lambs and two year old rams. We define nursery sheep as only including ewes, yearlings, and two year old rams. These nursery sheep have horns with considerably less horn mass and forming less arc than rams older than two years. Yearlings were distinguished on the basis of body and horn size

and facial characteristics (Barichello et al. 1987). Ewes were indistinguishable from 2-year old rams from aerial surveys. Rams not in association with nursery groups or with horns of arc greater than 90 degrees were classified by horn class as half, three-quarter or full curl. As horns do not grow in discrete increments according to horn class, horns falling between these broad classes were arbitrarily assigned a horn class. We assumed this assignment was unbiased. It was noted when horns had exceptionally long horn length and mass; these were considered exceptional trophy sheep.

Locations were plotted on 1:250,000 scaled maps, and winter range was delineated on the basis of the March distribution of animals and tracks.

Mid-summer lamb production was calculated as the number of lambs per 100 nursery sheep. Mortality rates of lambs, nursery sheep and rams were calculated as the change in numbers of each class from July, 1986 to March, 1987. This assumes absolute counts in July and March, and the difference as a result of mortality.

For comparison, census data from a July, 1976, sheep inventory of the study area are presented. Also, in March of 1977 sheep tracks and observations were recorded to delineate winter range use. Sheep observations in March, 1977 were incomplete so are not presented in this report. Winter range delineation in 1977, however, is compared to the March, 1987 sheep distribution.

The sheep kill was recorded through voluntary submission of ram heads by resident sport hunters from 1973-1978, and compulsory submissions by all non-resident licenced hunters since 1973 and all resident hunters since 1979. These submissions provided the ram age and horn curl. During this period there was no record of illegal sheep taken in the area. The subsistence kill was assumed to be minimal (YTG unpublished report).

Weather data was obtained from Environment Canada records for Faro, from 1978-1987. Although thermal inversions and variable wind patterns were thought to occur in the Glenlyon range, general weather patterns were assumed to be similar to that recorded at Faro, which is situated on the Pelly River about 50 km from the study area.

Results

Demography

Differences between the July 1986 and March 1987 censuses were small (Table 1). A total of 109 nursery sheep (including yearlings) and 42 rams were counted in July, in comparison to 101 nursery sheep (not including 1986 lambs) and 38 rams in March. March surveys represented 92% of the July non-lamb population count. Assuming minimal movement to and from the Glenlyon Range, it appears that either few sheep were missed during the surveys or that observability was consistent between seasons. The relatively consistent classification supports our assumption that the entire population was counted during both surveys, and that the population is discrete. Differences in the counts, then, are assumed to represent mortality losses.

From 1976 to 1986 a decline of 40 and 41% was observed in nursery sheep and ram numbers, respectively. Young rams (less than full curl) apparently declined at a rate exceeding that of full curl rams; 58% fewer young rams and 19% fewer old (full curl) rams were observed in 1986 as compared to 1976. Noteworthy is the near-complete absence of half curl rams in 1986. The composition of the ram segment of the Glenlyon population in 1986-87 was atypical of both hunted and unhunted thinhorn sheep populations in the Yukon. Census data, Yukon-wide, indicate that half curl rams generally represent about 44% of the 3+-year old rams in hunted populations (n=786), and 34% of the 3+-year old rams in

Table 1. Census and classification of thinhorn sheep in the Glenlyon Range of the Pelly Mountains, 1976 and 1986-87.

	Total (excluding lambs)	Nursery Sheep (excluding yearlings)	Yearlings	Lambs	Total	Rams 1/2	Rams 3/4	Rams 4/4
July 1976	253	——— 182 ———		29	71	-	-	31
July 1986	151	85	24	19	42	1	16	25
March 1987	139	——— 101 ———		14	38	1	12	25

unhunted populations (n=225; unpublished YTG data). In the Glenlyons half curl rams represented only 2% of the 3+-year old rams.

Mid-summer lamb production (lambs/100 nursery sheep) was 16 in 1976 and 17 in 1986. These productivity estimates are low compared to average lamb production rates of thinhorn sheep. In the southern Yukon a downward trend in lamb production (from 40 to 13 lambs per 100 nursery sheep) was observed from 1980 to 1986 (Table 2). Where lamb production estimates were available in areas within and adjacent to the Glenlyon Range from 1981 to 1986, they were similar to estimates recorded from the southern Yukon. In the south, slight variability in mid-summer lamb production has been observed between areas and within years. It is likely, then, that lamb production in the Glenlyons closely tracked rates of production in surrounding areas, and possibly was similar to a general trend in the southern Yukon. For comparison, in 1986, lamb production in the Glenlyons was 17.4/100 nursery sheep, and in the southwest Yukon was 13.1/100 nursery sheep.

From July 1986 to March 1987 26% of the lambs disappeared, while 7% of the ewes, and 10% of the rams were lost. For comparison, southern lambs, ewes and rams disappeared at average annual rates of 34, 14 and 16%, from an unhunted population, 1968-1979 (Hoefs and Cowan 1979).

Table 2. Lamb production (lambs per 100 nursery sheep) in central and southern Yukon.

Year	Southern Yukon	Central Yukon
1980	40.4	--
1981	24.3	24.9
1982	26.4	18.6
1983	19.8	--
1984	30.4	--
1985	18.5	--
1986	20.0	17.4

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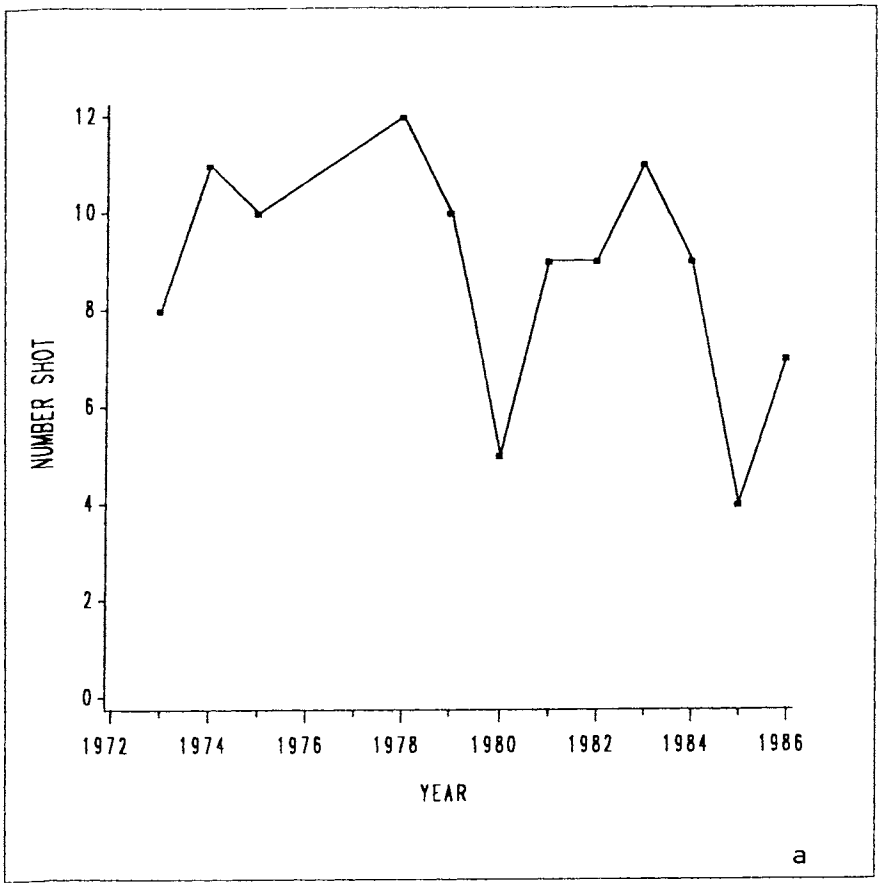
Hunter-kill

The annual sheep kill from the Glenlyons has ranged from 4 to 13 from 1973 to 1986, while the average age varied between 6.8 and 9.5 years (Figure 2). From 1982 to 1983 there was a substantial decline in the average age of the licenced sheep kill, from 9.4 to 7.3 years. Only 3 of 11 (27%) of the rams shot in 1983 were 8 years or older, compared to 6 of 9 (67%) in 1982. Since 1982 the average age has averaged less than 8.0 years annually in contrast to the previous 4 years where the annual average age was greater than 8.0 years. The average age of the kill from 1983 to 1986 was significantly less than the average age of the kill from 1979 to 1982 (7.3 versus 8.8; $p < 0.05$).

The number of rams killed in the Glenlyons did not decline with average age from 1982 to 1983. Normally the harvest does not remove all legal rams, so a decline in the average age of the kill does not necessarily imply a decline in the number of rams killed. The loss of older aged rams may result in only a shift in the kill toward younger animals, and not a decline in the number harvested.

Weather

Average winter temperatures (November-March) did not vary significantly from 1981 to 1987 ($F=0.80$, $p=0.56$, Figure 3). Snow accumulation, however, was much more pronounced in the winter of



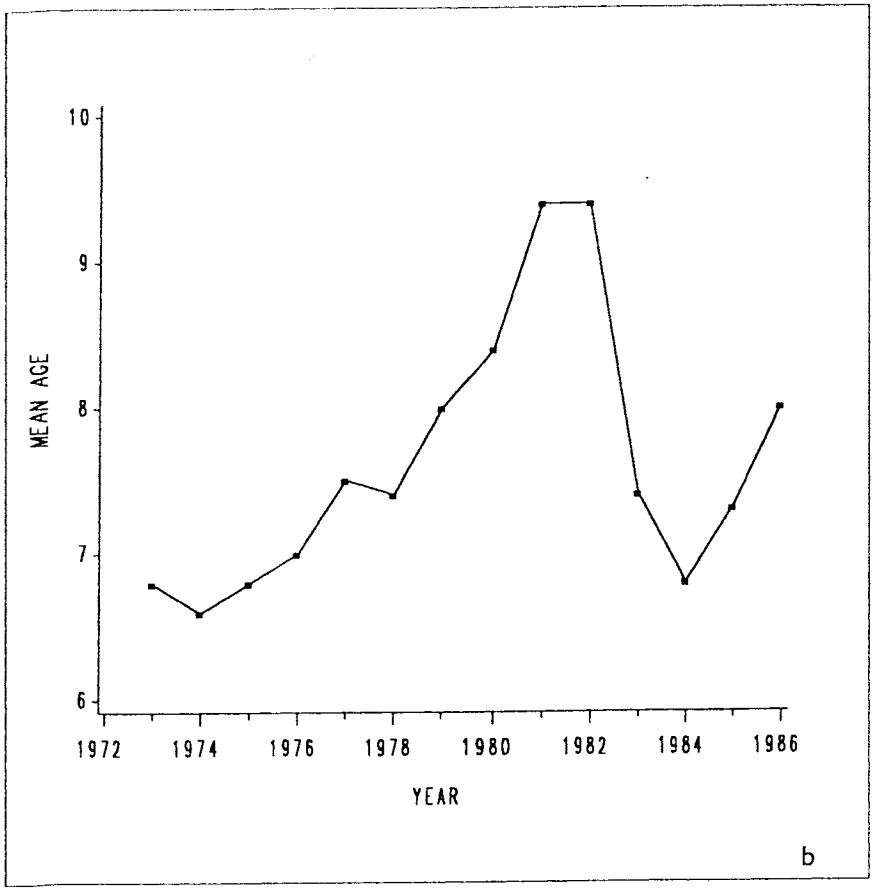


Figure 2. Number (a) and mean age (b) of rams shot in the Glenlyon Mountains 1973 - 1986.

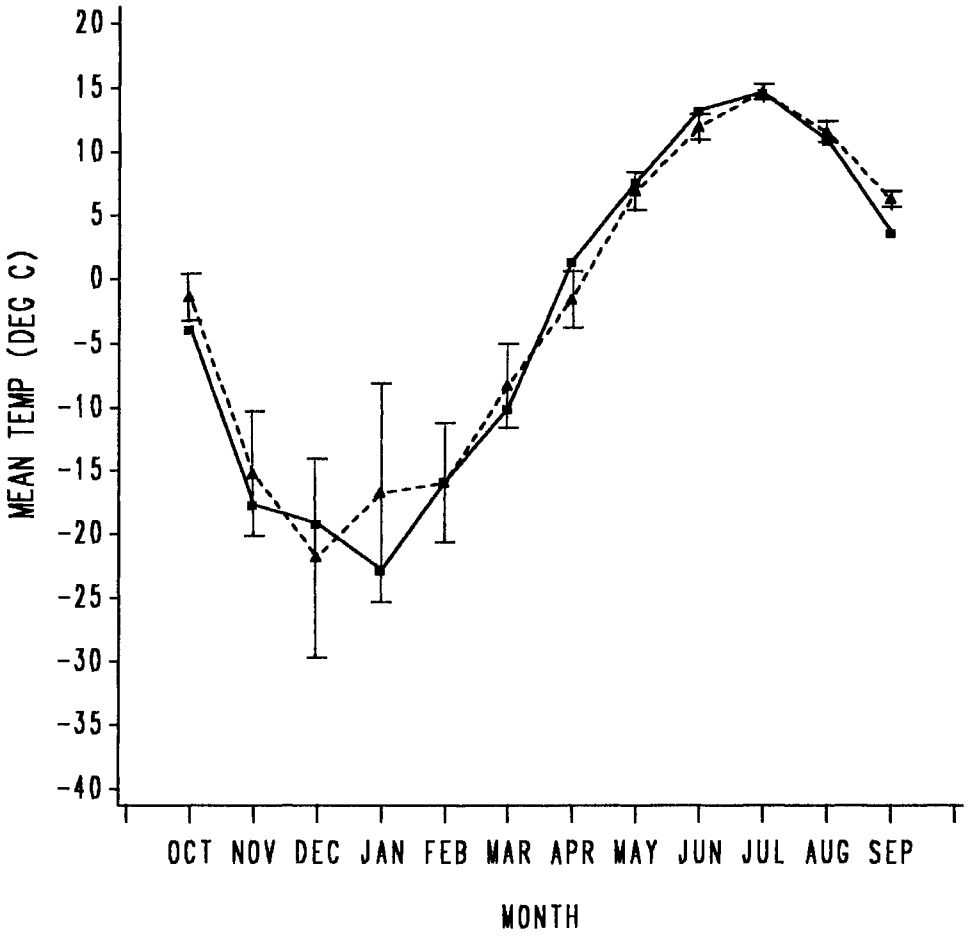


Figure 3. Mean monthly temperatures for 1982-83 (solid line) and the average mean monthly temperatures (with 95% confidence intervals) for 1981-82, 1983-84, 1985-86, 1986-87.

1982-83, as compared to all other years (Figure 4). From October to April, snow depth was significantly higher during all months in 1982-83, as compared to the average for all other winters recorded (1981-82, 1983-87; $p < 0.05$). The average winter snow depth (November-March) was significantly higher in 1982-83, compared to all other years ($F=4.82$, $p<0.01$). Average snow depth in 1986-87 was the lowest recorded (1981-1987), however it was significantly different only in comparison to the average snow depth during the winter of 1982-83.

Sheep distribution

The summer distributions of sheep in 1976 and 1986 were similar, with two consistent centres of habitation and fairly extensive use of alpine range.

The winter distributions of sheep in 1976-77 and 1986-87 are shown in Figure 5. In 1977 sheep were concentrated between 1050 and 1200 m a.s.l., using in particular, the south slopes of creeks flowing to the northeast. In 1987 sheep were more widely dispersed, regionally and altitudinally, coinciding with low snow accumulations in that winter.

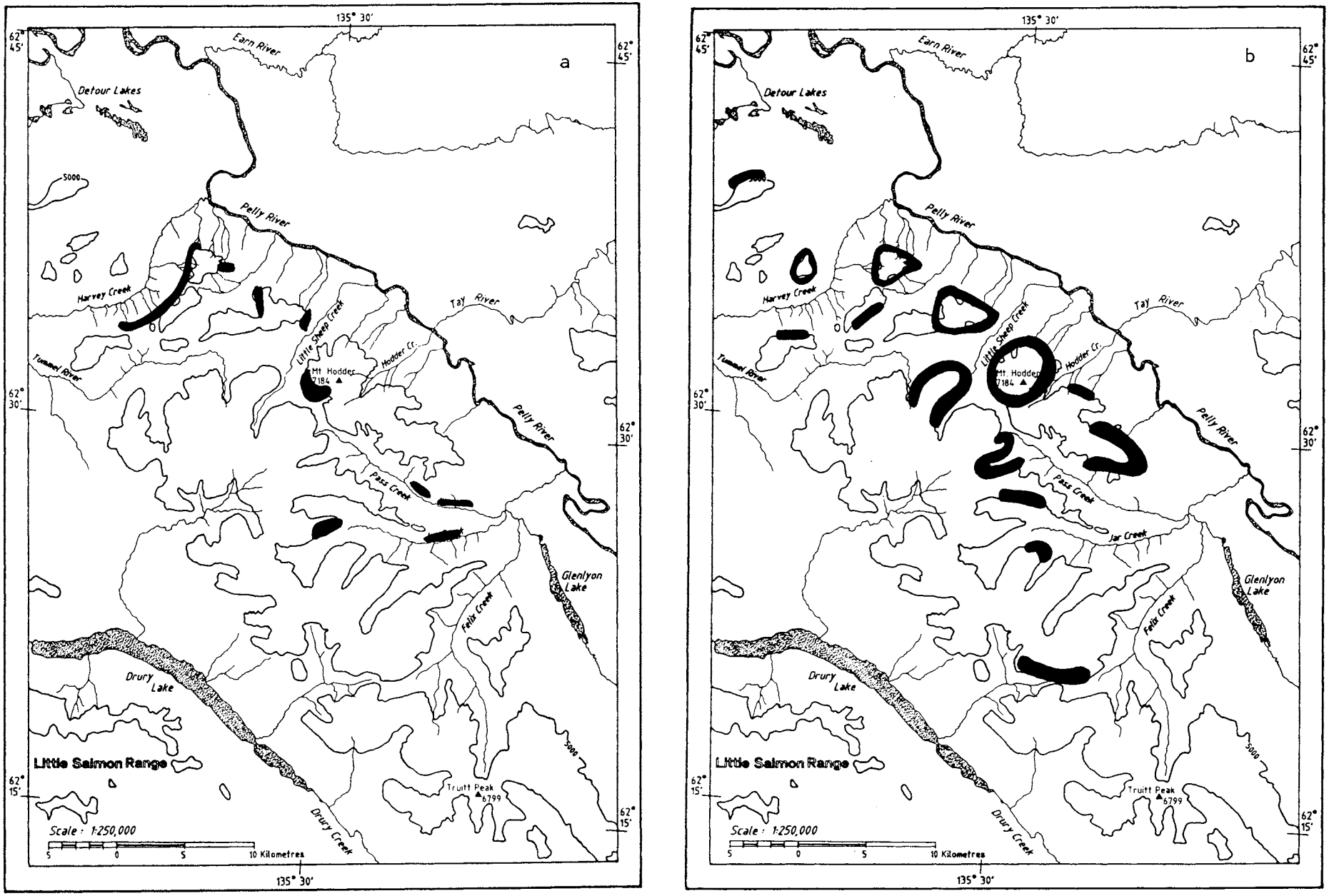


Figure 5. Winter distribution of sheep during 1976-77 (a) and 1986-87 (b).

Discussion

Demography

Census results are in agreement with the guide-outfitter's observations in 1983. A 40% decline in the sheep population was observed from 1976 to 1986, a rate consistent betweeen nursery and ram groups. Within the ram population the number of younger rams declined at a rate exceeding that of the older (full curl) rams. The near complete absence of half-curl rams suggests that there have been disparate losses in the younger cohorts, possibly through consecutive years' reproductive failures.

The disparity in the proportion of rams of different horn classes in the Glenlyon range in 1986-87 contrasts with findings from the Glenlyons in 1976-77 (YTG unpublished data), as well as the general demographic data from studied sheep populations in the southern and northern Yukon (Hoefs and Cowan 1979, Barichello et al. 1987). The composition of most studied sheep populations is indicative of stable populations where the young and old cohorts survive less well than middle-aged individuals (Hoefs and Cowan 1979, Simmons et al. 1984).

The idea that weather was a predisposing agent causing demographic change in the Glenlyons is consistent with census findings. Snow is perhaps the most debilitating environmental factor for Dall sheep (Seip and Bunnell 1985). Deep snow undoubtedly limits sheep foraging ability and thus predisposes

them to nutritional deficiencies and predation. The difficulty in pawing through deep snow, we expect, will lower intake rates, force sheep to extend foraging bouts and/or distance themselves from escape terrain. Nutrition and/or predator avoidance strategies are no doubt compromised as a result of deep snow, resulting in a degeneration of body condition or higher losses to predators, and consequently poor productivity and population decline.

The winter of 1982-83 was a particularily severe one, with deeper than average snows for the area ($p<0.05$; Fig. 5). This may have contributed substantially to the sheep decline observed, with ensuing reproductive failures in 1983 and the loss of much of the previous cohort in addition to older animals. In the southern Yukon 1983 was also a year of deep snow, resulting in a significant decline in lamb production.

Coinciding with this suspected loss of two cohorts in 1982 and 1983 in the Glenlyons was a dramatic decline in the average age (9.4 to 7.4 years) of the 1983 sheep kill in the Glenlyons. The absence of any large trophy animals observed during the 1986 survey, as compared to the 1976 survey, further corroborates the view that older-aged rams have died at higher than usual rates since 1982.

In addition to the apparent loss of two cohorts and older-aged individuals, as indicated by a decline in average age, was a 40% decline of the non-lamb population in the Glenlyons. In a stable

southwest Yukon population, the removal of two first year cohorts, in addition to sheep older than 8 years would result in a 39% decline in the population and a significant decline of the average age of the legal ram population (9.2 versus 8.0; Hoefs and Cowan 1979).

Relatively poor lamb production in 1981 and 1982, as suggested by surveys in an adjacent area, may have also contributed to the apparent decline in the Glenlyons. The severity of the 1982-83 winter may have exaggerated a modest decline due to two previously hard winters, assuming lamb production is indicative of sheep survivorship. In the southern Yukon poor productivity from 1981 to 1983 has resulted in population declines and in particular a decline in animals from the 1982 and 1983 cohorts (Barichello et al. in prep.).

Predators possibly influenced population change. However, the correlations between winter snow conditions, ram age distribution, and average age of the hunter-kill, suggest that snow conditions and not predators precipitated the sheep decline. Most likely wolves were an important mortality agent on sheep, when sheep distribution, movements and condition were compromised due to severe snow conditions. Bears and golden eagles are opportunistic predators on dall sheep, particularly lambs, but have not been found to significantly alter sheep demography (Barichello et al. in prep.).

Distribution

Population size is likely not limited by summer range. A relatively wide distribution of sheep in the two years surveyed and an apparent abundance of suitable forage and escape terrain, would suggest that high densities could be sustained on summer range.

Winter distribution of Dall sheep is likely influenced by snow conditions around adequate escape terrain. The apparent movement of sheep to south-facing slopes of creeks flowing into the Pelly River in the winter of 1976-77 and the wider dispersal of sheep in the low snow year of 1986-87 suggests that winter distribution is influenced by snow. Little snow in 1986-87 probably allowed sheep to range to higher elevations with generally more overlap with summer range.

South-facing slopes receive more solar energy and protection from cold north winds. On Sheep Mountain, in the southwest Yukon, there was a definite preference for south slopes when winds blew out of the north in the winter (Hoefs and Cowan 1979). In the Glenlyon Range the northern block of mountains probably benefits from prevailing winds along the Pelly River, and may sit in a rain shadow, protected from snow storms generated from the southwest, further facilitating snow free conditions.

Precipitation in the Glenlyons was found to be higher than in the Coastal Mountains around Whitehorse (Oswald and Senyk 1977). It

is likely that winter range is of far more importance to shee
the Glenlyon range. Deep snow years may be relatively com
and therefore the availability of winter range may be sever
limited in those years. The concentration of sheep in what
probably a normal snow year in 1976-77, emphasizes the importa
of winter range.

Management Implications

Dall sheep are considered to be a "climax" species with a limited potential to increase in numbers (Hoefs 1984). Twinning is extremely rare and and ewes do not produce until age 2 to 3 (Simmons et al. 1984). Furthermore, sheep do not readily disperse and re-colonize vacant ranges (Geist 1971). Long term census data in the southwest Yukon have found population growth rates correlated to lamb production, which appears driven by the stochastic influences of weather (Burles and Hoefs 1984, unpublished YTG data). Population recovery in the Glenlyons, then, is expected to occur slowly.

The reduction of two young cohorts will eventually pass through all age classes. In the short term productivity may appear unusually high. The absence of juvenile age classes in the nursery group will presumably result in a higher ratio of lambs to nursery sheep. However, in time these missing age classes will result in poor adult ewe recruitment and consequently poor production. The same can be predicted for rams: poor recruitment to the legal category in the years ahead due to the absence of two year-classes.

The compensatory effects of higher productivity or improvement of horn growth on low density ranges, although possible, have not been reported for Dall sheep.

Population growth is probably limited by snow conditions during the winter and severe weather conditions during lambing (Hoefs 1984, Seip and Bunnell 1985). Predation is probably facilitated during deep snow years. Wolf removal in the Glenlyon Mountains would undoubtedly be expensive and politically sensitive. The benefits to the sheep populations may be evident only during hard winters where population growth is unlikely even in the absence of wolves. Therefore, we discourage this approach.

Sheep transplants could immediately increase population size and facilitate growth, however this proceedure is also expensive. Furthermore, we cannot be certain sheep would habituate to the new range. Also, if adjacent populations have experienced similar climate-induced declines, there may not be an adequate source of sheep to transplant.

Hunting restrictions will probably not produce more sheep as long as a full-curl rule is in effect. Hunting success will decline as the standing crop of legal rams declines. This is anticipated for the years ahead in light of two missing cohorts and the slow rate of recovery.

We recommend no action. The sheep population will likely recover with time. With ideal conditions this could be achieved in as few as 3 years. However, we anticipate average growth rates and poor hunting success for a period of 2-4 years in the future.

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