THE INFLUENCE OF WINTER SEVERITY ON DALL SHEEP PRODUCTIVITY IN SOUTHWESTERN YUKON - A PRELIMINARY ASSESSMENT

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ABSTRACT

Over the past decade 14 Dall sheep populations in southwestern Yukon were periodically assessed through aerial surveys. Lamb production averaged 28.5% (expressed as lambs per 100 nursery sheep), but large variations were documented between years as well as between populations. For variation in productivity among populations, density was found to be a contributing factor (r = -0.621). Both winter temperature as well as snow were found to have an influence on lamb production the following spring. Data from three weather stations in the area showed that temperature was the more consistent variable between stations, giving a correlation coefficient with sheep productivity of r = -0.661. Snow (total precipitation) showed considerable regional variability in this mountainous region, and its correlation with lamb production the following spring was r - -0.4555. Both weather factors were combined into an index of winter severity by expressing their deviation from the long-term mean value as percentage, positive or negative. This index of winter severity was significantly correlated with lamb production the following spring (r = -0.796), and therefore, had a higher predictive value than either temperature or snow conditions alone, if one very deviant year (1983) was excluded. A factor in this deviation may have been the failure of females to recover from the very severe winter of 1981/82.

INTRODUCTION

Dall sheep populations are known to maintain relatively stable numbers at or near the carrying capacity of their range (Nichols, 1978; Hoefs and Cowan, 1979). Long-term studies of the Sheep Mountain population in Kluane National Park, Yukon, support this statement in that between 1969 and 1981 the largest deviation from the mean population size has been only 17%. Fluctuations were due primarily to the numbers of lambs born and surviving to yearling age. Adult mortality was relatively constant (Hoefs and Bayer, 1983). However, in the immediate past, between 1981 and 1982, a 25% decline in this population was recorded, because of an unusual high winter mortality of adults followed by an extremely low lamb crop in spring of 1982. The primary cause of this decline was assumed to be the very severe winter (Burles and Hoefs, submitted to Canadian Field Naturalist). A further decline in this population was recorded for this winter 1982-1983, primarily because of a second poor lamb crop. This reproductive failure is more difficult to explain since snow fall and temperature in 1982-83 were better than average. Surveys of other Dall sheep populations in southwestern Yukon indicated that this poor productivity in recent years was fairly widespread. In this paper we therefore provide productivity data for Dall sheep populations in southwestern Yukon, as well as an analysis of data on winter weather conditions. It is generally assumed, that population levels in northern sheep populations are primarily influenced by weather factors (Nichols and Smith, 1971; Leopold and Darling, 1953, Murie, 1944) rather than by such limiting influences as diseases, parasites, predators or competition with livestock, which have been reported to impact bighorn sheep populations in southern Canada and the U.S.A.

METHODS

Annual aerial and ground surveys of the Dall sheep population at Sheep Mountain, Kluane National Park, have been carried out since 1969 to determine the size and composition of this population (Hoefs and Bayer 1983, Burles and Hoefs, submitted to Canadian Field Naturalist). The area is routinely patrolled by Park staff, and observations of interest, such as sheep mortalities and evidence of predators are generally recorded. During May 1983 a practicum student was stationed on Sheep Mountain to monitor lambing activities (Bourget, 1983). Concurrently a number of aerial surveys have been carried out by Kluane Parks staff and by the Yukon Wildlife Branch on other Dall sheep ranges in southwest Yukon since 1973. In this analysis 14 populations are included and only those have been considered for which at least four surveys have been conducted during this past decade.

In Kluane National Park three populations in addition to Sheep Mountain's have been monitored; these were those that occupy the Bighorn Range, Mt. Vulcan and the Auriol Range. In hunted areas in this vicinity the Yukon Wildlife Branch surveyed nine sheep ranges, which consisted of Gray Ridge, Mt. Skukum and Primrose Mountain on Rose Lake in Game Management Zones 7 and 9 south of Whitehorse; the Miners Range, Sifton Range and Champagne Range in Game Management Zone 5 north of Whitehorse, and four populations in the Ruby Range north of Kluane Lake in Game Management Subzones 5-28, 5-31, 5-34, and 5-36. In Fig. 1 the location of these sheep ranges are shown.

When conducting sheep inventories an attempt is being made to obtain a total count. Helicopters are used exclusively and the survey method used has been referred to as "drainage-pattern flight technique" (Nowlan et al. 1977, Hoefs, 1978). The survey area is divided into physiographic subdivisions with distinct boundaries. These subdivisions have a size that can be covered in a 2 to 3 hour flight. The most commonly employed aircraft is a Bell 206 helicopter, which can carry 3 passengers in addition to the pilot. The navigator, who is principal observer, is seated to the left of the pilot. The other observer is located in the left backseat, the right one being occupied by the recorder. An intercom system allows continuous contact between the survey

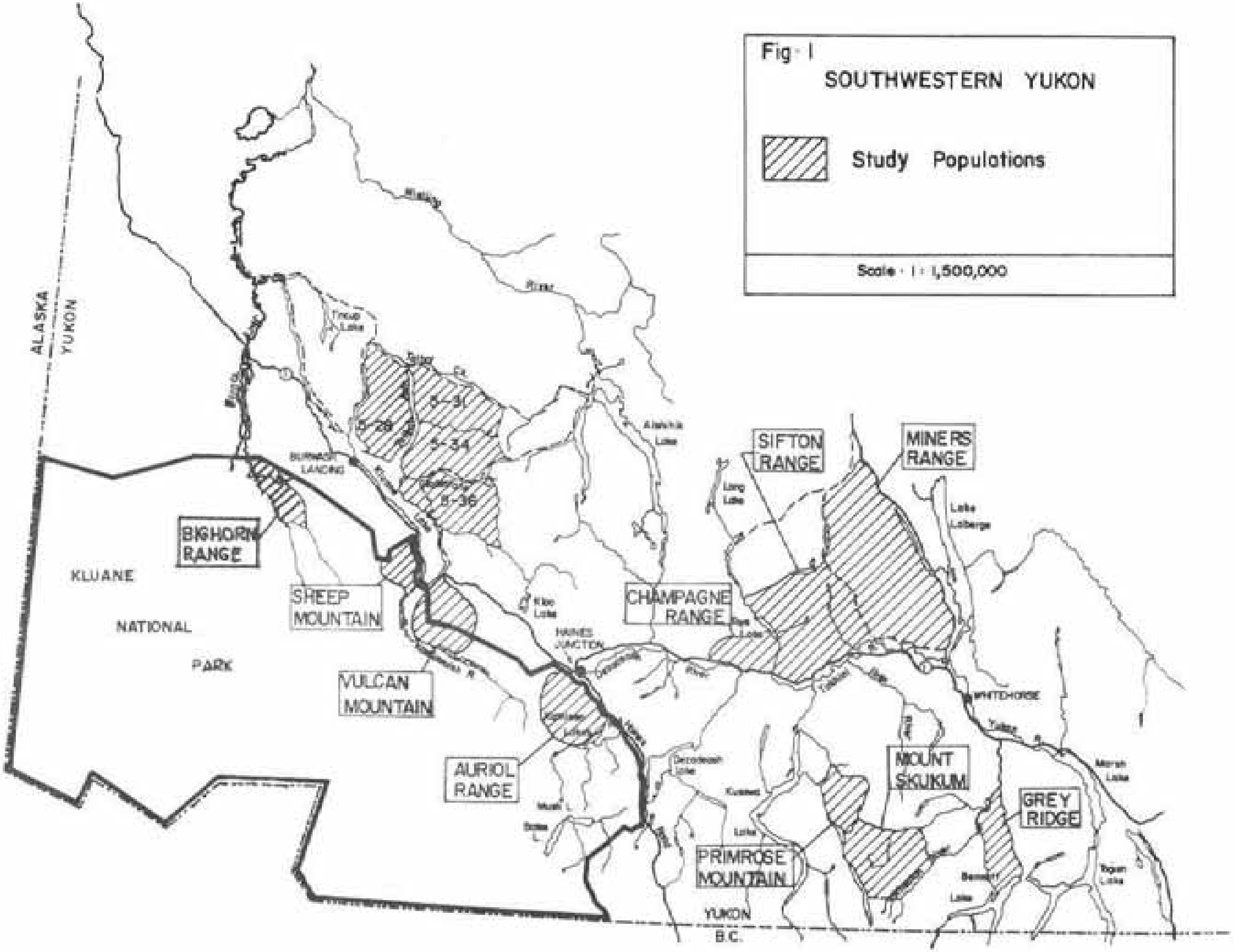


Fig. 1

SOUTHWESTERN YUKON

crew members. Each survey unit is covered by flying around it in a counter-clockwise direction at an elevation appropriate to the prevailing relief. This means that the elevation of the aircraft chosen and the distance of it from the mountains are such that the observers can keep surveillance over the slopes as well as over the ridge tops and plateaus. Wherever this is not possible with a single pass, several are made at different altitudes. The route flown and the exact locations where sheep are observed are marked on a map. All sightings are verified between the observers. If there is disagreement, another overflight is made.

The observations made are recorded on prescribed forms, which list size and composition of sheep bands, location, time of day, and other relevant information. It is known from repeated surveys made in Kluane National Park, from comparisons of ground and aerial surveys, and by using 80 marked sheep (Hoefs and Cowan 1979), that this survey technique is fairly reliable in that over 90% of the sheep can be accounted for; underestimates being influenced by terrain type and weather conditions.

While considerable variation can be expected due to terrain type, sheep density and aircraft ferry time, on the average this survey technique translates into about 100 sheep located per helicopter hour or about 120 km^2 of sheep habitat searched per helicopter hour.

In these aerial surveys, conducted in late June or July when all lambing is completed, the population composition is broken down into three components: 1) adult rams, usually three years old and older and often separated from nursery bands at that time; 2) lambs of the year and; 3) adult members of nursery bands, which include all ewes and yearlings as well as two-year old rams. In this paper "productivity" is therefore defined as the ratio of lambs to nursery sheep at that time of the year. Repeated surveys of these populations have indicated that they are relatively discrete, with the exception of that of the Bighorn Range in Kluane National Park. This population was therefore excluded from density estimations and the correlations done which use density as a variable.

Data on temperature and precipitation were obtained from three weather stations in the area: Whitehorse, Haines Junction and Burwash, the locations of which are shown on Figure 1. Mean winter temperatures, considering the period October to April inclusive, were computed for each year of the past decade, as well as total winter precipitation (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 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 "index of winter severity". It is known that other weather factors, i.e. wind, also have an influence on sheep (Hoefs, 1975). However, wind is very variable in mountainous terrain, and the weather stations are far removed from the sheep ranges. The wind data measured there have relevance only to a few sheep ranges close by and wind could therefore not be incorporated into this index of winter weather severity. Commonly applied statistical tests were used in the analyses.

RESULTS

In Table 1 the statistics on 14 Dall sheep populations monitored are listed. In Table 2 the annual productivity data are given for each of these 14 populations over the past decade. This table allows an assessment of variations among populations as well as among years. The population sizes varied from 564 on the Bighorn Range in Kluane National park to 67 on the Champagne Range northwest of Whitehorse. The greatest densities have been recorded for Primrose Mountain with 2.52 sheep per km^2, and for Sheep Mountain with 2.13 sheep per km ^{2} and the lowest densities for the Miners Range and the Sifton Range with 0.56 and 0.71 sheep per km^2, respectively. The mean productivity for all populations and all years has been 28.5 lambs per 100 nursery sheep. Among populations, the Sheep Mountain herd had the lowest productivity with only 17.8% (n=11), while the Sifton Range populations had the highest with 36.7% (n=9).

Great variation in productivity was also documented between years (Table 2). Very low lamb crops were reported for 1976, 1982 and 1983 with 16.3%, 20.3% and 17.9% respectively, and very good productivity for 1973, 1977 and 1980 with 42.0%, 36.9% and 38.1% respectively. For variation in productivity among years there was a tendency for years with low productivity having a greater variation (S) than years with high productivity (r = -0.570). There was also a tendency among populations that those with a lower productivity had a greater variation (S) in productivity among years (r = -0.553) than those with higher productivity.

Weather data and computed indices are listed in Tables 3, 4 and 5. The mean winter temperature (October to April) for all three stations was -11.0°C (Table 3). Whitehorse had the mildest weather (-9.1°) and Burwash the coldest (-12.8°C). Considerable variation was recorded among years. Mild conditions prevailed in 1976-77 with only -5.5°C, more extreme conditions were observed in 1973-74 and 1981-82 with -14.7° and -13.6°, respectively. Table 3 also shows the index of winter temperature severity. In relation to the long term mean winter temperature, this index for the three years mentioned works out to be for 1976-77: +50.0%, 1973-74: -33.6% and 1981-82: -23.6%.

Total winter precipitation (snowfall), from October through April 30 is listed in Table 4. Overall, the mean value for all years and all three stations was 123.7 mm. Burwash is the driest area with only 73.3 mm, while Haines Junction obtains the highest snowfall with 194.0 mm. Variation among years is lower than for temperature. Overall, the winters of 1972-73 and 1977-78 were relatively dry with 94.0 and 86.6 mm precipitation, respectively. On the other hand, the greatest overall snowfalls were recorded 1974-75 and 1981-82 with 160.3 and 166.6 mm. However, in contrast to temperature, the trends in snowfall between stations were not synchronized. For instance for the Whitehorse region the winter 1980-81 had the highest snowfall with 137.9 mm, while that particular winter had below average snowfall in the Burwash district (61.5 mm). On the other hand, most snow fell in Burwash in 1979/80 with 103.5 mm, while during that winter little snow fell around Whitehorse (84.4 mm). Because of this variation observed in regional snowfall the use of mean values to extrapolate weather conditions over larger areas, is much less predictive than the use of mean temperature data. Table 4 also lists the indices of winter precipitation, calculated from the deviation of the long term means. The year 1981-82 had an index of 34.6% (above the long term mean), while the year 1977-78 had one of -30.2% (less than the long term mean).

Table 1: STATISTICS ON 14 DALL SHEEP POPULATIONS IN S.W. YUKON

No. Population	Years of Survey	Sheep Number $\bar{X}$	Range Size km^2	Density Sheep/km^2	Productivity* $\bar{x}$	- s
1. Bighorn Range	5	564	?	?	31.4	12.4
2. Mt. Vulcan	6	407	352	1.17	29.0	10.3
3. Mt. Skukum	3	368	417	0.88	29.0	12.2
4. Auriol Range	6	353	354	1.00	32.3	13.8
5. GMZ 5-31	5	353	340	1.04	22.8	8.2
6. GMZ 5-28	4	331	308	1.07	27.7	8.2
7. Primrose Mtn.	6	262	104	2.52	26.4	14.8
8. GMZ 5-36	8	252	336	0.75	26.2	11.5
9. Sheep Mtn.	11	241	113	2.13	17.8	10.4
10. GMZ 5-34	5	230	341	0.67	27.2	10.2
11. Miners Range	9	149	258	0.56	31.8	10.0
12. Sifton Range	9	142	201	0.71	36.7	11.0
13. Grey Ridge	7	87	110	0.77	34.0	15.2
14. Champagne Range	8	67	40	1.67	27.0	12.3

* Lamb/100 nursery sheep in July

Table 2. Trend in productivity of 14 Dall sheep populations in southwestern Yukon, expressed as lambs per 100 nursery sheep.

Population	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	$\bar{X}$	S
Bighorn Range					33.0	30.5			53.8	21.7	18.2	31.4	12.4
Mt. Vulcan					41.1	22.0	32.5	42.4		16.2	19.9	29.0	10.3
Mt. Skukum GMZ 7-30	44.1									14.3	28.5	29.0	12.2
Auriol Range					48.0	26.6	46.5	35.2	30.9		6.7	32.3	13.8
Ruby Range GMZ 5-31		32.1					29.8	25.7		15.0	11.5	22.8	8.2
Ruby Range GMZ 5-28		28.8						37.6		29.6	14.9	27.7	8.2
Primrose Mt. GMZ 7-23	56.0						12.7	33.3	23.1	17.6	15.6	26.4	14.8
Ruby Range GMZ 5-36		42.7		11.8	36.3	35.1	24.0	31.7		8.3	19.7	26.2	11.5
Sheep Mt.	24.2	12.1	7.1	13.3	17.9	39.8	30.9	22.8	16.6	4.1	7.3	17.8	10.4
Ruby Range GMZ 5-34		20.9					35.9	41.0		25.5	12.6	27.2	10.2
Miners Range GMZ 5-50			76.7	18.1	30.3	29.3	38.2	54.2	25.5	38.7	24.8	31.8	10.0
Sifton Range GMZ 5-49			29.7	24.5	45.7	46.7	50.7	50.7	33.8	22.7	25.8	36.7	11.0
Grey Ridge GMZ 9-03	43.5		34.7			59.5	18.5	42.0	29.3	10.7		34.0	15.2
Champagne Range GMZ 5-47				13.6	43.0	11.1	30.0	40.0	12.3	39.4	26.8	27.3	12.3
$\bar{X}$	42.0	27.3	24.6	16.3	36.9	33.4	31.9	38.1	28.2	20.3	17.9		
S	11.4	10.3	10.5	4.6	9.2	13.4	10.6	8.8	11.8	9.2	6.9		

Table 3: MEAN WINTER TEMPERATURE (October to April inclusive) ^{o}C

	1972-73	73-74	74-75	75-76	76-77	77-78	78-79	79-80	80-81	81-82	82-83	$\bar{X}$
Whitehorse	-8.5	-13.2	-8.5	-11.0	-3.7	-9.9	-10.5	-7.0	-7.2	-11.5	-8.9	-9.1
Haines Jct.	-12.6	-14.6	-10.6	-13.4	-5.5	-13.7	-10.0	-8.2	-8.6	-13.8	-10.1	-11.0
Burwash	-14.6	-16.4	-12.7	-14.2	-7.3	-13.9	-13.6	-9.9	-9.8	-15.6	-13.3	-12.8
X	-11.9	-14.7	-10.6	-12.9	-5.5	-12.5	-11.4	-8.4	-8.5	-13.6	-10.8	-11.0
A Δ $\bar{X}$ (%)	-8.2%	-33.6%	3.6%	-17.3%	50.0%	-13.6%	-3.6%	23.6%	22.7%	-23.6%	1.8%	

Table 4: TOTAL WINTER PRECIPITATION (October to April) in mm

	1972-73	73-74	74-75	75-76	76-77	77-78	78-79	79-80	80-81	81-82	82-83	$\bar{X}$
Whitehorse	79.5	98.2	119.6	129.8	92.6	64.9	122.7	84.4	137.9	121.6	89.2	103.7
Haines Jct.	114.4	104.9	287.8	188.1	180.4	169.7	207.5	208.6	225.0	290.0	158.1	194.0
Burwash	88.1	93.0	73.4	98.5	56.6	25.2	61.9	103.6	61.5	88.2	56.3	73.3
$\bar{X}$	94.0	98.7	160.3	138.8	109.9	86.6	130.7	132.2	141.5	166.6	101.2	123.7
B Δ $\bar{X}$ (%)	-24.0%	-20.2%	29.5%	12.2%	-11.1%	-30.2%	5.6%	6.9%	14.5%	34.6%	-18.3%	

Table 5: INDEX OF WINTER SEVERITY (October to April) in %

	1972-73	73-74	74-75	75-76	76-77	77-78	78-79	79-80	80-81	81-82	82-83
A ($\Delta\bar{X}$(T) %)	-8.2	-33.6	3.6	-17.3	50.0	-13.6	-3.6	23.6	22.7	-23.6	1.8
B ($\Delta\bar{X}$(P) % .(-1))	24.0	20.2	-29.5	-12.2	11.1	30.2	-5.6	-6.9	-14.5	-34.6	18.3
Index A + B	15.8	-13.4	-25.9	-29.5	61.1	16.6	-9.2	16.7	8.2	-58.2	20.1

In Table 5 the two indices, one for winter temperature and one for winter precipitation, have been combined to derive at the index of winter severity. Based on these two parameters only, it is obvious from Table 5 that the winter of 1981-82 was the most severe winter with an index of -58.2% followed by 1975-76 with -29.5%. The mildest winter was 1976-77 with an index of +61.1%.

In Tables 6, 7 and 8 the 14 Dall sheep populations have been allocated to one of these three weather station districts, based on distance from weather stations or known similarity in weather patterns. The same weather parameters as previously described for the entire survey area were computed for each of these three sub-units. The aim was to assess whether the trends observed and their correlation with productivity could be improved on.

In general the trends observed were similar in the three districts, but some differences could be documented. The three populations in the Haines Junction area, those on the Auriol Range, Mt. Vulcan and Sheep Mountain, all of which are in Kluane National Park and have a fairly high density, had a significantly lower productivity (21%) than either the Whitehorse (31.7%) or the Burwash district populations (29.3%). While temperature data show a similar trend, we have already made reference to considerable regional variation in precipitation.

The winters 1975-76 and 1981-82 were severe in all three areas, while in addition the winters 1973-74 in the Burwash area, 1974-75 in the Haines Junction area and 1978-79 in the Whitehorse district had a high index of winter severity primarily because of regionally heavy snowfall.

DISCUSSION

Many factors can influence the productivity of sheep populations, among them weather parameters, predator pressure, range conditions and population quality, diseases, parasites and various types of disturbances. For most Yukon Dall sheep populations these factors are not known, with the exception of the Sheep Mountain population, where some of these parameters have been monitored (Hoefs and Bayer, 1983; Burles and Hoefs submitted to Canadian Field Naturalist, Burles, 1984 unpublished report). For the Southwest Yukon weather parameters are the only factors whose impact can be assessed, and resulting correlations with these must be interpreted cautiously, considering the distances of the few local weather stations from sheep ranges, and the known variations of weather factors such as wind and precipitation in mountainous terrain. For "among-years" variations we have used winter temperature and winter precipitation in this analysis; we have not used wind, since the information base for individual sheep ranges was insufficient. For assessments of variation in productivity among sheep populations, density, population size, hunting pressure and accessibility of range were used. The latter parameter may be an indicator of disturbance.

Of all these parameters, which may influence differences in productivity among populations, only density appears to be relevant (Fig. 2). There is a trend of populations with a higher density having a lower productivity ($r = -0.621$). This trend was also observed during sheep surveys in the Ogilvie Mountains in the northern Yukon (Larsen, 1978). There was no correlation

Table 6. WINTER WEATHER AND PRODUCTIVITY OF DALL SHEEP POPULATIONS IN THE WHITEHORSE DISTRICT*

	1972-73	73-74	74-75	75-76	76-77	77-78	78-79	79-80	80-81	81-82	82-83	$\bar{X}$
A. Productivity(%)	47.9%	-	30.4%	18.7%	39.7%	36.7%	30.0%	44.0%	24.8%	20.8%	24.3%	31.7%
B. Mean Temp (°C)	-8.5	-13.2	-8.5	-11.0	-3.7	-9.9	-10.5	-7.0	-7.2	-11.5	-8.9	-9.1
C. Total Prec. (mm)	79.5	98.2	119.6	129.8	92.6	64.9	122.7	84.4	137.9	121.6	89.2	103.7
D. Index of winter severity	29.8	-39.8	-8.7	-46.0	70.0	28.6	-33.7	41.7	-12.0	-43.7	-17.8	

*The Whitehorse district includes populations No. 3, 7, 11, 12, 13, 14
Correlation coefficient: A-B (r = -0.543) A-C (r = -0.728) A-D (r = 0.876)

Table 7: WINTER WEATHER AND PRODUCTIVITY OF DALL SHEEP POPULATIONS IN THE HAINES JUNCTION DISTRICT*

	1972-73	73-74	74-75	75-76	76-77	77-78	78-79	79-80	80-81	81-82	82-83	$\bar{X}$
A. Productivity(%)	24.2	12.1	7.1	13.3	35.6	20.6	36.6	33.5	23.8	10.2	13.6	21.0
B. Mean Temp (°C)	-12.6	-14.6	-10.6	-13.4	-5.5	-13.7	-10.0	-8.2	-8.6	-13.8	-10.1	-11.0
C. Total Prec. (mm)	114.4	104.9	287.8	188.1	180.4	169.7	207.5	208.6	225.0	290.0	158.0	194.0
D. Index of winter severity	26.4	-27.1	-44.8	-18.8	56.8	-12.0	2.4	18.0	5.8	-75.0	-10.3	

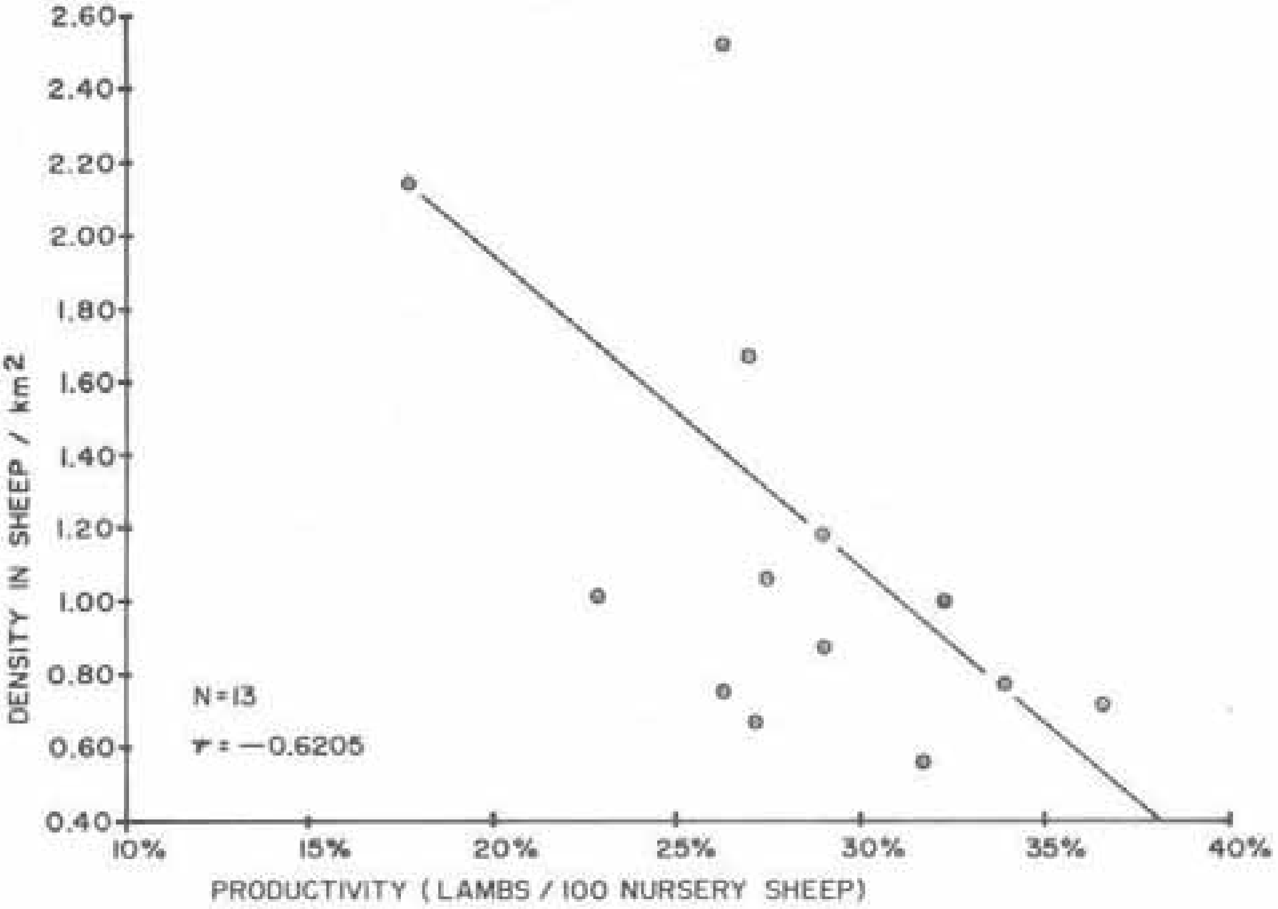
*The Haines Junction district includes populations No. 2, 4, 9
Correlation coefficient: A-B (r = -0.661) A-C (r = 0.188) A-D (r = 0.814)

Table 8: WINTER WEATHER AND PRODUCTIVITY OF DALL SHEEP POPULATIONS IN THE BURWASH DISTRICT*

	1972-73	73-74	74-75	75-76	76-77	77-78	78-79	79-80	80-81	81-82	82-83	$\bar{X}$
A. Productivity(%)	-	31.1	-	11.8	34.7	32.8	29.9	34.0	53.8	20.0	15.4	29.3
B. Mean Temp (°C)	-14.6	-16.4	-12.7	-14.2	-7.3	-13.9	-13.6	-9.9	-9.8	-15.6	-13.3	-12.8
C. Total Prec. (mm)	88.1	93.0	73.4	98.5	56.6	25.2	61.9	103.6	61.5	88.2	56.3	73.3
D. Index of winter severity	-34.4	-55.0	6.4	-45.3	65.8	57.0	9.3	-18.6	39.5	-42.2	19.3	

*The Burwash District includes populations 1, 5, 6, 8 and 10.
Correlation coefficient: A-B (r = -0.484) A-C (r = -0.231) A-D (r = 0.494)

FIG. 2. RELATIONSHIP BETWEEN DENSITY AND PRODUCTIVITY IN DALL SHEEP POPULATIONS



between population size and productivity (r = -0.072), but there were indications that in larger populations there was less fluctuation in productivity among years (r = -0.467). The correlation between density and productivity may point in certain populations to capacity-filled winter ranges and the influence on lamb production of shortage of winter forage for ewes. This has been shown for the Sheep Mountain population in years of peak population size (Hoefs, 1984). While the mean productivity over the past decade showed some relation to density, the correlation of the very low production observed during the spring of 1982 and 1983 with density, r = -0.396 and r = -0.426 are very weak. Therefore, less than 20% of the variation observed in these two years can be attributed to density-related phenomena.

Both winter temperature (Fig. 3) and total winter precipitation (Fig. 4) have an influence on productivity the following spring. The correlation coefficient between temperature and productivity, r = -0.661, is higher than that for snowfall, r = -0.455, which is understandable in light of the variable nature of the latter, as already discussed.

Both these factors are known to impact ungulates in general, as a survey of the relevant literature will reveal. Cold temperature imposes a considerable energy drain on the animals, which is particularly important to pregnant ewes. Deep snow covers winter forage of grazing animals. Time and energy must be spent in digging craters and freeing of forage, less time can be spent with actually grazing. Cold temperature and deep snow are independent events whose impacts on sheep will be additive.

We have therefore combined these two variables into the index of winter severity already described. The correlation coefficient between this index of winter severity and productivity the following spring is r = 0.796 if the 1983 data are not included (Fig. 5). Fig. 6 shows the trend in productivity and winter severity over the past decade. In general this index predicts reasonably well; good lamb crops were documented in 1973, 1977 and 1980 following winter with a positive index of winter severity. Poor productivity was documented for 1976 and 1982 following extreme winter conditions with very low negative indices of winter severity. The impact of the winter 1981/82 on the sheep population of Sheep Mountain and all its ramifications have been described in detail by Burles and Hoefs, 1984 (submitted to Canadian Field Naturalist) and need not be repeated here. Similar problems were faced by other populations during that winter as well as in 1975/76.

On the other hand, we have no explanations for the poor productivity observed during the spring of 1983. With a mean value of only 17.9% it was one of the lowest productivities recorded for this entire decade, in spite of the fact that both winter temperatures and snowfall were better than average, and the computed index of severity was +20.1%. Burles (1984) has speculated on possible reasons for this poor lamb production. Some of his assumptions, i.e. separation of rams and ewes during the rut because of early snow in October, high predator pressure and consequently disturbance during winter and low productivity of winter forage because of a dry growing season, may have relevance to the Sheep Mountain population but are unlikely to influence sheep productivity over the entire southwestern Yukon. On the other hand, some of his other assumptions may have relevance. The winter 1981/82 was severe over the entire area and had considerable influence on the sheep. It is likely that

FIG.3. RELATIONSHIP OF PRODUCTIVITY TO MEAN WINTER TEMPERATURE

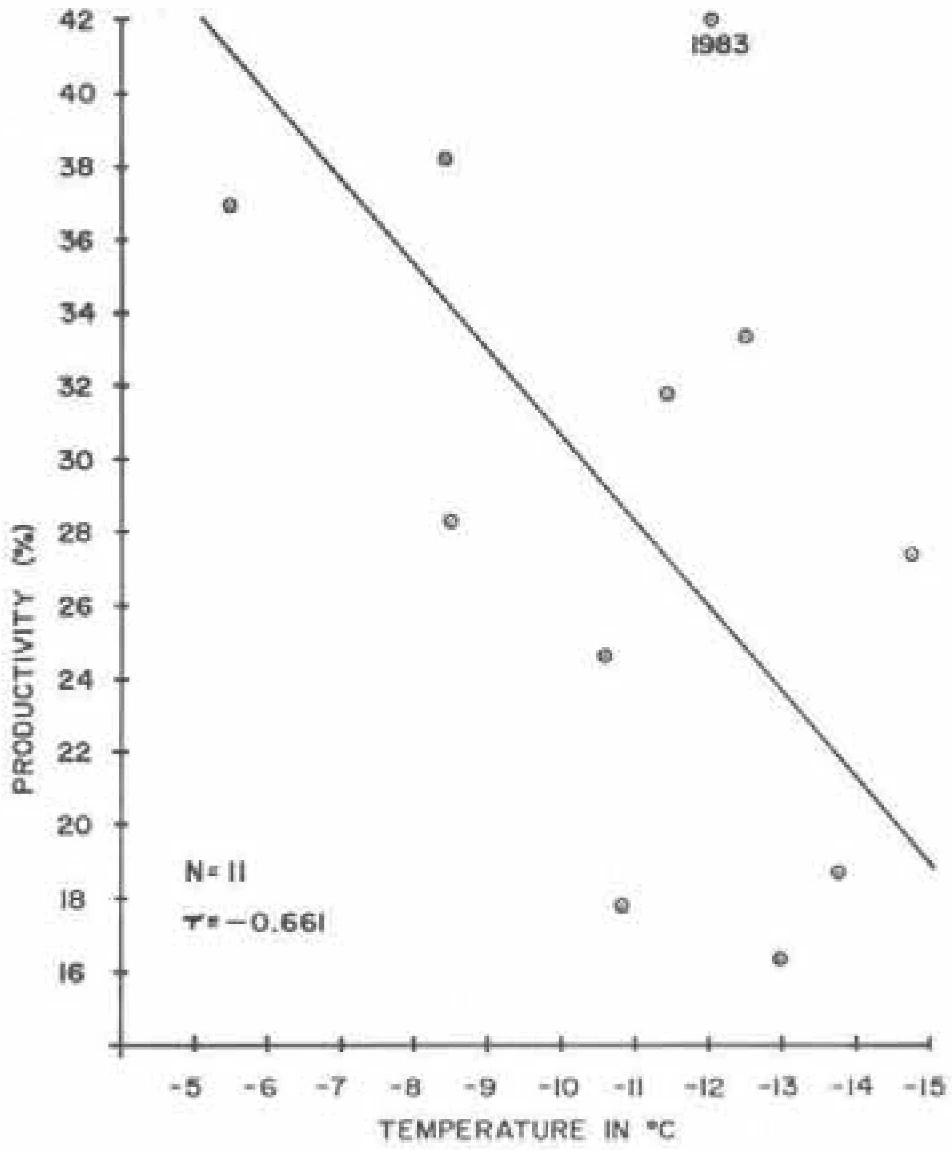


FIG. 4. RELATIONSHIP OF PRODUCTIVITY TO TOTAL WINTER PRECIPITATION

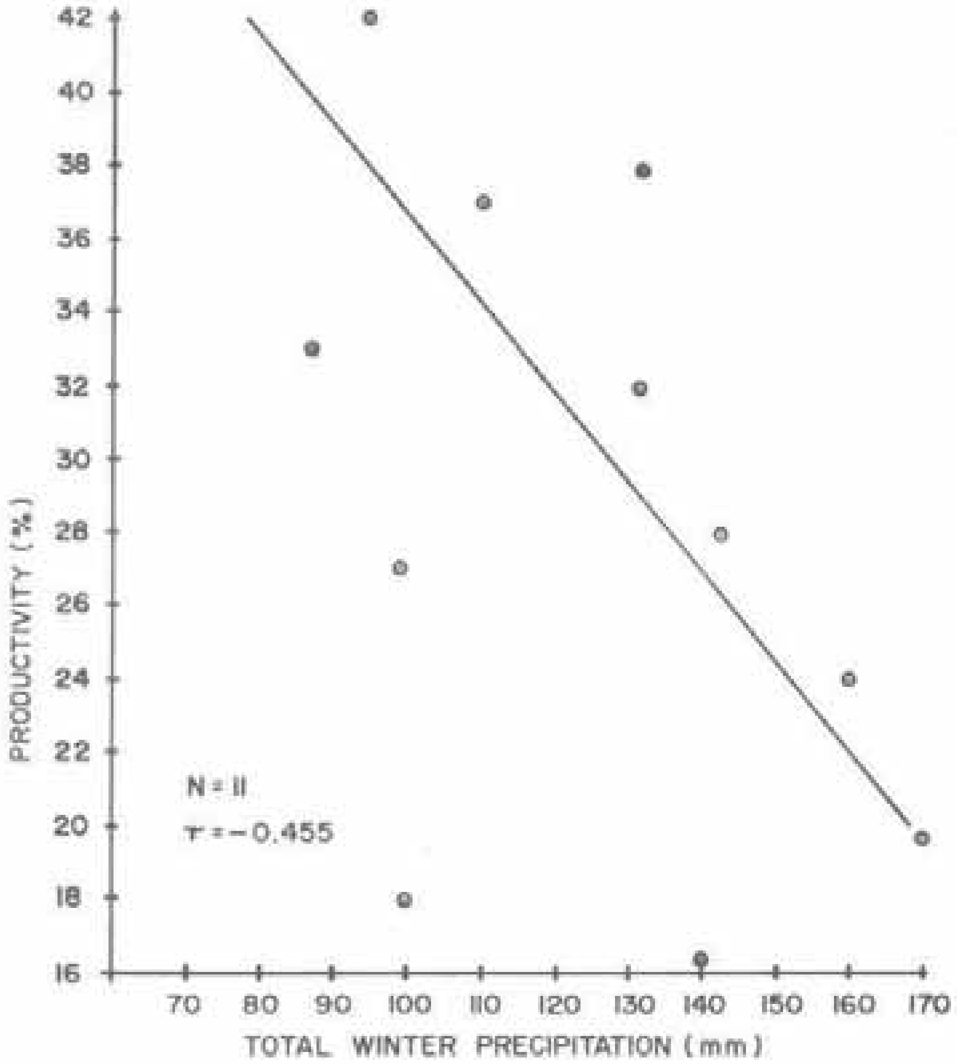


FIG.5. RELATIONSHIP OF WINTER SEVERITY AND DALL SHEEP PRODUCTIVITY THE FOLLOWING SPRING

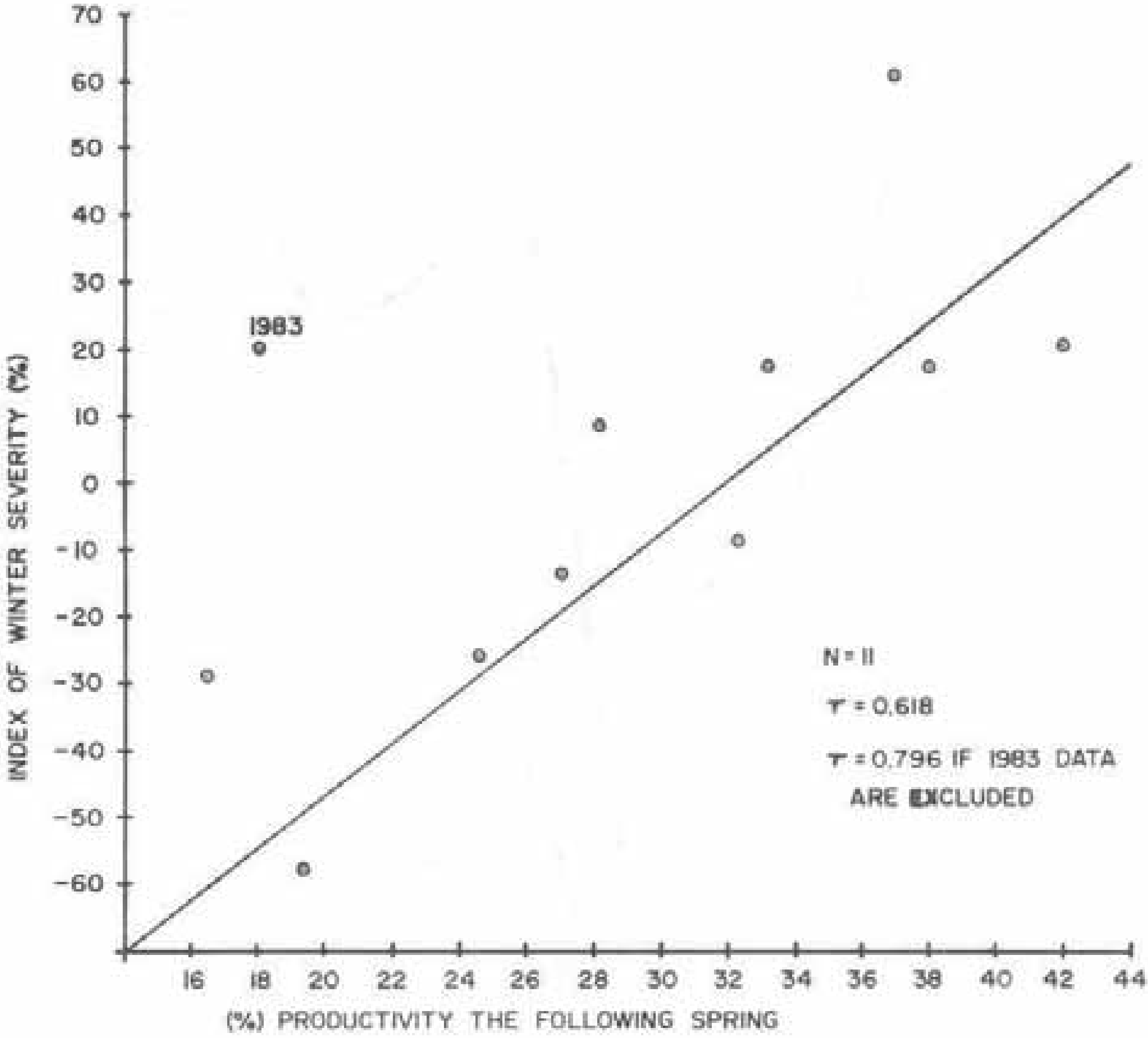
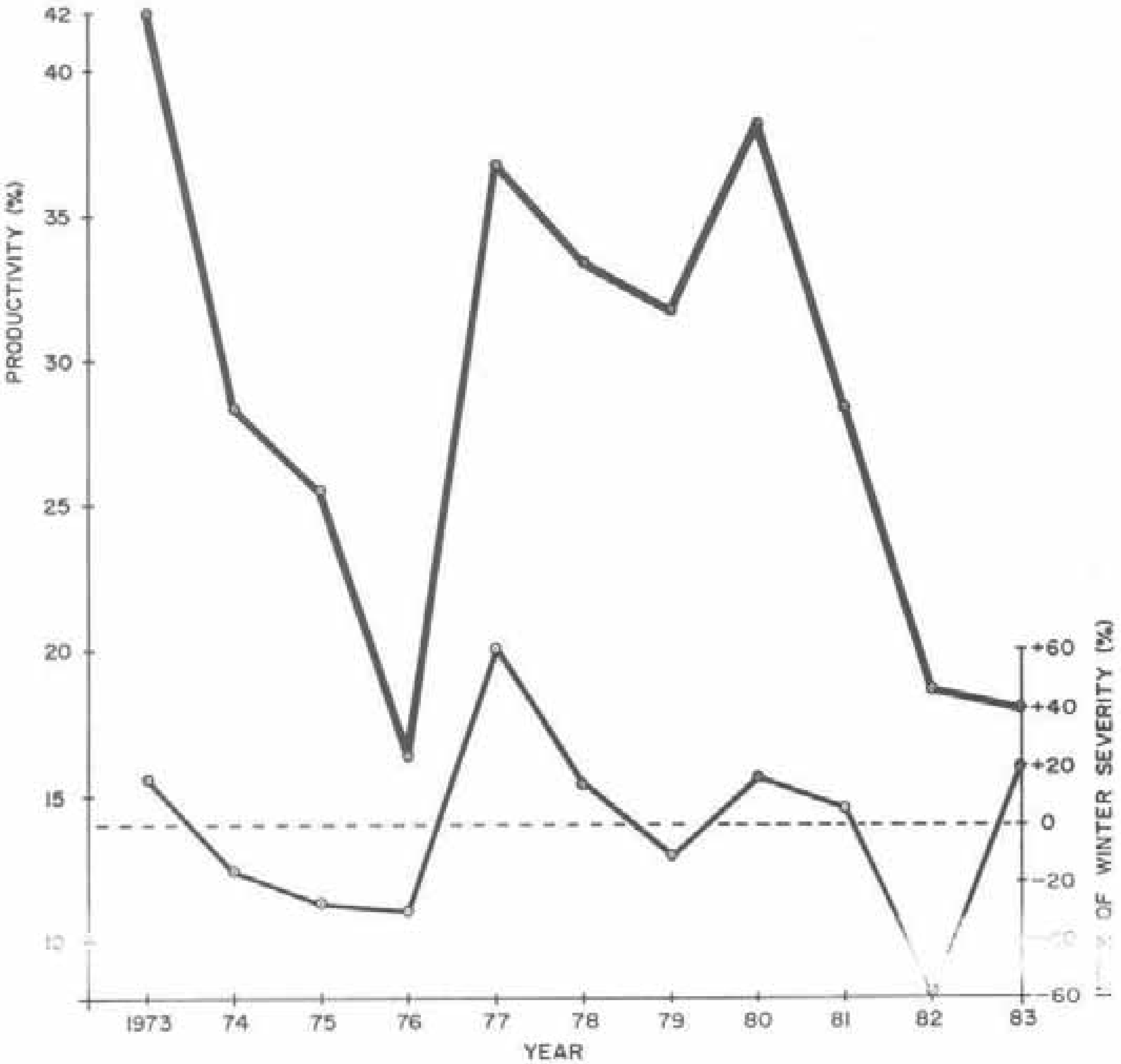


FIG.6. 10 YEAR TREND IN PRODUCTIVITY AND WINTER SEVERITY



many ewes did not recover sufficiently by the next rutting season to come into estrus. Both Nichols (1978) and Heimer (1978) have described for Alaska sheep, that ewes in poor physical shape, particularly those leading a lamb, may give birth only every second year. Another possibility is the mummification of fetuses in females in poor physical shape, that will prevent their becoming pregnant the following year. This has so far not been documented for sheep, but has been described for pronghorn antelope, deer and moose (Barrett, 1982). These data for 1983 do not follow the general trend observed over the past decade, and if included into our analyses lower the predictability of the index of winter severity from about 64% to 38%.

Attempts to improve this predictive potential of this index by assigning populations to one of the three weather station regions have met with limited success (Tables 6, 7, 8). In general temperature is a more reliable indicator than precipitation and correlations of productivity with temperature are better. In all cases is the index of winter severity a better method in predicting lamb production the following spring, than either of the weather parameters alone. The correlation of this index with productivity including the 1983 data, was as follows for the three regions:

Whitehorse: r = 0.876 (Table 6);
Haines Junction: r = 0.814 (Table 7); and
Burwash: r = 0.494 (Table 8).

The discrepancy observed in the 1983 data, is primarily due to observations made in the Burwash district.

We hope to improve on this index of winter severity by including wind, which has negative as well as positive aspects to it. A strong wind may expose foraging areas and therefore counteract the effects of deep snow. However, a strong wind may also combine with a reasonable temperature to give a wind chill index, not tolerable to sheep (Hoefs, 1975). Here the impact of wind is negative and additive. We also know that favorable temperatures early in the growing season and precipitation during the growing season will influence forage production of winter ranges which in turn will influence the productivity of dense populations (Hoefs, 1984).

Considering that these two important variables could so far not be included for lack of information, the index of winter severity derived predicts perhaps as well as we can hope for.

LITERATURE CITED

Barrett, M. W. 1982. Distribution, behaviour, and mortality of pronghorns during a severe winter in Alberta. J. Wildl. Manage. 46(4):991-1002.

Bourget, R. 1983. The Demography of Dall Sheep on Sheep Mountain, Parks Canada. Unpublished Report. 9pp.

Burles, D. W. 1984. Reproductive failure in Yukon Dall sheep. Parks Canada, Unpublished Report. 5pp.

Burles, D. W. and M. Hoefs. 1984. Winter mortality of Dall sheep in Kluane National Park, submitted to Canadian Field Naturalist.

Heimer, W. 1978. Interior sheep studies. Alaska Department of Fish and Game, Fairbanks, AK, Project W-17-10.

Hoefs, M. 1975. Ecological investigation of Dall sheep and their habitat. Ph.D. Thesis, University of British Columbia. 495pp

Hoefs, M. 1984. Productivity and carrying capacity of a subarctic sheep winter range. ARCTIC 37(2):141-147.

Hoefs, M. and I. McT. Cowan. 1979. Ecological investigation of a population of Dall sheep. Syesis 12 (supp.1): 1-81.

Hoefs, M. and M. Bayer, 1983. Demography of an unhunted Dall sheep (Ovi dalli dalli) population in southwest Yukon, Canada. Can. J. Zool. 61(6):1346-1357.

Larsen, D. G. 1978. Wildlife inventories in Game Management Zone 2; Yukon Territory; Unpublished report.

Leopold, A. S. and F. F. Darling. 1953. Wildlife in Alaska. The Ronald Press Company, New York. 128pp.

Murie, A. 1944. The wolves of Mount McKinley. U. S. Dept. of Interior, Parks Services. Fauna Series 5, 238pp.

Nichols, L. 1978. Dall sheep IN Big Game of North America. Schmidt, T. L. and D. L. Gilbert (eds). Stockpole Books. 494pp.

Nichols, L. and A. Smith. 1971. Sheep report. Alaska Dept. of Fish and Game. Project No. W-17-2 & 3.

Nolan, J. W. and J. P. Kelsall. 1977. Dall sheep and their habitat in relation to pipeline proposals in Northwestern Canada. Canadian Wildlife Service Special publication. 64pp.