ALASKA DEPARTMENT OF FISH AND GAME

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FORTYMILE CARIBOU HERD STUDIES

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FINAL REPORT
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FINAL REPORT (RESEARCH)

State: Alaska

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Project Nos.: W-17-6&W-17-7 Project Title: Big Game Investigations

Job No.: 3.13R Job Title: Size, Composition and Productivity of the Fortymile Caribou Herd

Period Covered: July 1, 1973 through June 30, 1975 (limited 1976 observations included)

SUMMARY

We reviewed historical accounts of the Fortymile caribou herd. The herd apparently declined from an estimated 500,000+ animals in the 1920s. However, the decline was not continuous. The first decline began after 1928 and the maximum rate of decline occurred during the mid-1930s. Recent reported population estimates of 20,000 in 1969, less than 15,000 in 1970, and less than 15,000 caribou through 1972 appear liberal; available data suggest that the population likely did not exceed 8-10,000 animals. Since 1973, estimates of fall herd size have been 5,300 in 1973, and a minimum of 4,000 animals in 1974 and 1975, the lowest figure recorded during historical times.

The reason(s) for the decline was not documented, but the data implicate several factors. The decline was reversed during the 1940s, perhaps as late as 1947 when predator control was initiated. The population apparently increased through 1959 (except possibly from 1954-56 when predator control apparently ceased). Since 1960 the decline has been continuous. Emigration to the Porcupine herd was reported in 1957 and 1964. It appears the net loss of animals in 1957 was negligible if any. No reliable population estimates exist from 1961 to 1973; however, it appears that some net loss of animals may have resulted from the reported 1964 egress. Nevertheless, the decline from 1960 to 1975 can be explained on the basis of reported harvests, probable predation rates, and apparent yearling recruitment levels.

We summarized all sex and age composition data from surveys and jaw collections. From 1954 through 1961 the herd had an adult sex ratio of about 75 bulls:100 cows. No data are available from 1962 until 1972. Since 1972 the ratios have averaged about 30-40 bulls:100 cows; a change consistent with that experienced by several other herds in Alaska, and probably not one that would lower pregnancy rates, calving duration or patterns, or calf production. The age structure derived from teeth from over 700 jaws collected in 1972 was more similar to that of the Nelchina herd in 1970 when it was declining than during 1960 when it was increasing.

We summarized productivity and recruitment data. From 1954-1975 initial calf production has always been fairly high. However, the only years when calf survival to yearling age has been "normal" or high (i.e. over 40 percent) were in 1959 and 1960 following intensive wolf control.

Finally, we evaluated the impact of mortality factors on the herd. From the early 1950s the Fortymile herd has been an important recreational hunting resource and the annual Alaskan harvest has varied from 270 to over 2,300. From 1970 through 1972 harvest greatly exceeded the yearling recruitment rate and contributed greatly to the population decline during this period. A literature review of predation on caribou and circumstantial evidence from the Fortymile herd area strongly suggest that predation is likely the major factor responsible for the continuous caribou decline since 1960 and is likely a major factor in the decline of the moose population within the herd's range. Wolves are likely the most important single predator, but others in combination (or perhaps bears singly) may at times be as important as wolves. Windchill and poor range were discounted as major factors in the decline of the herd.

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BACKGROUND

A caribou (*Rangifer tarandus granti*) herd can be defined as a group of caribou sharing common calving ground in most years, but perhaps mingling with other herds at other times of the year (Skoog 1968). Hemming (1971) listed the Steese-Forty Mile herd as one of Alaska's six major caribou herds and Skoog (1968) listed it as the major one in eastcentral Alaska.

The Fortymile herd has been important in historical times as a source of caribou for human uses, as a major factor in the population dynamics of adjacent herds, and as the possible origin of several small herds (Skoog 1968).

The Fortymile herd has been hunted regularly since the Gold Rush of the late 1800s. Prior to the 1950s animals were taken primarily as meat for humans and food for dogs. Since then the herd has been important for recreational hunting. Through 1966 hunters killed the animals as they migrated near the Steese and Taylor Highways in August, September and October. Since then, the number of caribou crossing the Steese Highway has been too low to attract many hunters. Hunting from the Taylor Highway has increased in recent years and the harvest has varied from 500-2,500 annually depending upon timing of the migration and closing of the road by winter weather. In some years a small additional harvest occurs in Yukon Territory (LeResche 1975a).

It appears that the Delta, Mentasta, and Chisana caribou herds possibly owe their existence to the Fortymile herd (Skoog 1968). All three small herds were apparently formed at the same time and by the same circumstances (i.e. remnant groups of animals remaining after the large-scale movements of the Fortymile herd ceased about 1932). Currently, some biologists question this idea, but, as in many disagreements over interpretation of past events, the argument will likely never be resolved. Large-scale emigrations of Fortymile animals to the Porcupine herd may have occurred several times and may have added significant numbers to that herd. The Fortymile herd also "swamped" the Nelchina herd during many winters in the 1920s but the effect on Nelchina herd numbers is not known (Skoog 1968).

Recent experiences with management of the Nelchina caribou herd point out the need for maintaining an accurate annual assessment of the status of caribou populations, particularly heavily hunted herds. The minimum information necessary to maintain a working knowledge of size and status of a caribou herd is: 1) an accurate estimate of population size based on an aerial photo-direct count-extrapolation (APDCE) census or suitable substitute census for use as a baseline, 2) subsequent annual assessment of recruitment and mortality, 3) routine monitoring of gross distribution and numbers to detect egress or ingress, and 4) periodic recensusing by the APDCE technique.

The Fortymile herd was studied intensively from 1952-1955 primarily by Skoog (Skoog 1956); less intensively during 1957-1959 by Olson (LeResche 1975a); during 1960 and 1961 by Jones (Jones 1963); and by Skoog again in 1959, 1962 and 1963 (Skoog 1968). From 1963-1969 the herd was studied very little. During the late 1960s and early 1970s, several factors underscored the need for an assessment of the population and its habitat: 1) increasing recreational demand for caribou hunting, 2) apparent declining numbers of caribou, 3) imminent prospects of land ownership changes, 4) probable development within the herd's habitat, and 5) a general lack of knowledge on the overall status of the herd.

This herd is an international resource because portions of the herd often winter in Yukon Territory. Its international distribution is an important management consideration.

OBJECTIVES

To determine size, composition, and productivity of the Fortymile caribou herd.

PROCEDURES

Historical Information

We derived much of the following information pertaining to population size, composition, and productivity from Skoog (1968), Olson (1957, 1958, 1959), and Hemming (1971). We also obtained additional and more recent data from the Alaska Department of Fish and Game files (unpublished). Larry Jennings, Tok Area Biologist, collected most of these data.

Population Size

We ascertained population size primarily by use of the APDCE technique developed by Hemming (Hemming and Glenn 1968; Pegau and Hemming 1972; Bos 1973, 1974; LeResche 1975b). This technique involves four steps in the field: pre-census reconnaissance, aerial photography, classification of animals photographed, and classification of animals during rut. A final estimate of animals in the herd is calculated from this information. We carried out the four-step process as follows:

1. We conducted extensive pre-census reconnaissance flights throughout the greater range of the herd (see Fig. 4, Distribution and Movements, this report). This reconnaissance began prior to calving and continued through June in 1973 and 1974; the amount of reconnaissance done in 1975 was considerably less. We also monitored movements and distribution of caribou during the calving period and into the time of post-calving aggregation, using the following types of aircraft: C-180, C-185, PA-18-150, and HC-295.

2. We used hand-held 35 mm SLR and 3" x 5" cameras to photograph optimum aggregations. Caribou were directly enumerated from 8" x 10" or 10" x 12" color enlargements. The timing and location of photography varied. In 1973 we photographed calving aggregations

for several days preceding 6 June in the general vicinity of the headwaters of the East Fork of the Chena River, Little Windy Gulch, Williams and Gulch Creeks, and the west side of Crescent Creek. In 1974 we photographed post-calving aggregations intermittently between 4 June and 28 June. However, direct visual enumeration from aircraft on 13 and 14 June resulted in a higher count of adults than from any day of photo coverage. During 1975 we again photographed post-calving aggregations in the general vicinity of East Fork of the Chena River, Little Windy Gulch, Williams and Gulch Creeks on 5, 8, and 9 June.

3. To determine composition of the post-calving aggregation, we classified animals in the following manner: Helicopters transported one or two, 2-person crews, who used 20-60X spotting scopes to classify caribou in small groups (less than 15 animals) on the ground. Observers based age determinations on body morphology and sex determinations on external genitalia. To classify larger groups, helicopters moved the animals past observers positioned on the ground. The timing and number of caribou classified varied between years: 1,120 animals on 6 June 1973; 1,304 animals from 4-6 June 1974; and no animals in 1975.

4. We applied similar equipment and techniques to obtain fall herd composition data. Again, the timing and number of caribou classified varied: 2,700 animals (in the vicinity of Glacier Mountain) from 16-18 October 1973; 1,738 animals from 20-21 September 1974; and no animals in 1975.

Sex and Age Composition

Sex and age composition data were obtained from the helicopter counts discussed above, from hunter-killed caribou, and from ground observations throughout the summer in conjunction with Job 19.14 of this report (see Curatolo 1975). Collected tooth samples were aged from cementum annuli via the UV florescence technique (Johnson and Lucier 1975).

Productivity

Productivity was determined in conjunction with the population size and sex and age composition surveys discussed above. Past productivity was determined from literature review.

Mortality

We determined mortality rates and causes of mortality by measuring human harvest via harvest returns and check stations, by direct field observations in conjunction with other jobs in this report, and by a review of the literature.

RESULTS AND DISCUSSION

Population Size

Pre-1973

Although most of the following historical information comes from a single source (Skoog 1968:266-275), it seems appropriate to present it ir this report because of the present interest in the status and history of the Fortymile herd. The reader who desires more information is referred to Skoog.

The following is paraphrased from Skoog's review of historical information:

Few records of Fortymile caribou numbers and distribution are available prior to 1900, but from the sources available a general impression can be gained. During the 1880s and 1890s the bulk of the herd was centered and ranged much farther east and southeast than during later periods and extended as far as the Whitehorse-Skagway area. All observations during this period suggested a large caribou population from 1880-1900 and possibly earlier.

During the same period caribou were apparentl/ scarce to the west along the upper Tanana River. Natives there were reported to clothe themselves exclusively in tanned moose skins (U.S. Census Office, 1893:126). Military reconnaissance during this time also reported that caribou were scarce. However, during this period a caribou drive-fence was located on Mosquito Flats, near Ketchumstuk Village (Abercrombie 1900). The fence seemed to be in good repair and apparently had been used in recent years - a definite indication of caribou abundance and of regular, seasonal movements. Murie (1935:3) observed this fence in 1921. Based upon talks with local Indians, he estimated that it had not been used since about 1895.

By the early 1900s the distribution of caribou had shifted to the northwest from the Whitehorse-Skagway-Haines area where they were now scarce. Osgood (1909:13) stated that a large herd ranged the Tanana Hills in 1903, but that few crossed the Yukon River anymore as they had in the past. Evidentally the herd then, as in recent times, was using its main migration path, which extended southeastward along the slopes adjacent to the Sixtymile River and crossed the Yukon at various places above Dawson. Assessing the relative numbers of caribou in the herd then is difficult, but Osgood (1909:13) stated, 'Doubtless the present herds are comparatively small, but they are still large enough to be worth seeing,' implying a decrease from earlier times. However, Wickersham (1938:51) noted in October 1900, the 'great herds of caribou browsing' along the ridgetops south of Eagle, and Higginson (1926:441) stated that in the winter of 1907-08 the caribou '...ranged in droves of many thousands - some reports said hundreds of thousands - through the hills and valleys of the Stewart, Klondike and Sixtymile Rivers....'

During the 1910s caribou numbers must have been increasing rapidly, for tremendous herds were being sighted and major movements occurred in widely separated areas. Palmer (1941) stated that five large fall migrations of caribou occurred in the Fairbanks-Circle region between 1906 and 1913. In October 1909 Stuck (1914) estimated about 100,000 animals crossed Mosquito Fork and Ketchumstuk Flats. One winter, about 1912, the same man (Stuck 1917:83) observed "...the entire bed of the Charley River, from bank to bank, and even up to the first mountain benches on either side whenever they were accessible, for fifty miles, trodden hard and solid by innumerable hooves of caribou...."

By the mid-1920s the caribou in eastcentral Alaska probably had reached peak numbers. In the fall of 1920 Murie (1935:6) estimated 568,000 animals in a migration northeast of Fairbanks. Movements were widespread and in various directions. The main fall movement continued to the southeast, with the animals wintering in Canada along the hills adjacent to the Ladue, Sixtymile, Klondike, Steward, Pelly, and White Rivers. In the winter of 1924 large numbers of animals were observed as far as Whitehorse and the summits of the coast range above Skagway (Murie 1935:77) for the first time since before 1900. To the west, many caribou also crossed the Tanana River into Southcentral Alaska through Isabel and Mentasta Passes, ranging as far as Copper Center and the Lake Louise Flats. On the east, the animals were intermingling with those of northeastern Alaska at the heads of the Porcupine and Peel Rivers, and probably in the Ogilvie Mountains as well (Murie 1935:71).

During the late 1920s and early 1930s, the distribution and movement pattern of the caribou in eastcentral Alaska changed. The movements southwestward into and beyond the Isabel and Mentasta Pass areas of southcentral Alaska ceased, the last such movement occurring in 1931 (Scott et al. 1950, Alaska Game Commission 1935:80). The main northwest-southeast pattern remained, but there seemed to be an ever-increasing movement to the northeast as well. Alaska Game Commission reports noted that the Fort Yukon-Circle areas were utilized as a wintering area during 1932-1935, apparently by caribou from northeastern Alaska and eastcentral Alaska. Mertie (1932:367) stated that in 1930 large numbers of caribou still migrated through the Ogilvie Mountains each fall. In 1936 the caribou again extended far to the southeastward, wintering near Kluane Lake (Rand 1945:82). The main trend, however, seemed to be toward the northeast, and crossings of the Yukon River between Fort Yukon and Woodchopper were common until about 1935 (Alaska Game Commission 1935:34); another crossing occurred in September 1939 (1939:35). After 1939 caribou once again became scarce near Fort Yukon; the population in Region V probably had reached a low point. Alaska Game Commission reports all expressed the opinion that large numbers of caribou had moved into the arctic regions.

During the 1940s the herd seemed to increase steadily, and the southeast-northwest movement pattern was maintained. Calving took place to the northwest and wintering primarily occurred to the southeast. In June 1953 Skoog estimated the herd at 40,000 animals (Skoog 1956:65),

and the annual herd increment remained high during the next few years. It is thought that in May 1957 many animals (perhaps 30,000) went northward with the Porcupine herd (however, evidence exists that the animals later returned). Since then, the animals have remained farther to the south during the spring and early summer. In spring 1964 a large portion of the Fortymile herd once again moved northward with the Porcupine group (Skoog 1968).

The above summarization provides some basis for early population estimates. At present there remains but one calving area, and therefore but one subpopulation called the Fortymile herd. Table 1 includes these early estimates and estimates based on recent information.

Of the population estimates in Table 1 prior to 1973, the only systematic and concerted attempts to establish population size for the Fortymile herd occurred in 1920 (Murie 1935), 1953 (Skoog 1956), and 1960 (Jones 1962).

Murie (1935) conducted a census in 1920 when he witnessed a large migration headed southeastward across what is now the Steese Highway. The following quote by Murie describes how he censused the herd:

> In 1921 the author estimated the numbers in the Yukon-Tanana herd during the migration in the fall of 1920, using data obtained directly and from reports of other observers. The southeast migration of the herd covered a strip approximately 60 miles wide, 40 miles representing the part traversed by the main body and 20 miles that was covered by scattered bands. The herd took about 20 days to pass one spot. During 8 of the 20 days about 1500 animals in the main herd passed each day over a 1-mile strip and during the remaining 12 days about 100 animals a day. On this basis, the following computation was made:
>
> | | |
> |---|---|
> | 1500 a day for 8 days | 12,000 |
> | 100 a day for 12 days | 1,200 |
> | Total on 1-mile strip | 13,200 |
> | Total on 40-mile strip | 528,000 |
>
> Allowing an average of 100 a day per mile for 20 days over the 20-mile strip traversed by scatterd bands, one computes that 40,000 represents the additional number passing at the edges of the 'run.' The final estimate then is as follows:
>
> | | |
> |---|---|
> | Main herd | 528,000 |
> | Scattered bands | 40,000 |
> | Total in Yukon-Tanana herd | 568,000 |
>
> In the light of subsequent experience this figure seems conservative and it is safe to say that the herd numbered well over half a million, possibly much nearer a million.

Table 1. Estimated population size of the Fortymile herd, 1920-1975.

Year	Population Size	Source	Remarks
1920	568,000	Murie 1935	Possibly a million-see text.
1940's (early)	10,000-20,000	Skoog 1956, p. 58	Extrapolated backwards from 1953 estimate-see text.
1953	40,220 (April) 58,820 (June 16)	Skoog 1956, p. 63	Assumes 17,720 bulls missing in post-calving-actually a minimum figure.
1954	44,000-48,000 (pre-calving)	Skoog 1956, p. 59	Assumes 10%, 15%, and 20% annual increase.
1955	49,200 (pre-calving)	Skoog 1956, p. 109	Based on 1953 pop. estimate, and assumed annual increase of 7.2% for 1955 (ave.=10% for 1953-55).
1956	45,000 (June, post-calving)	Olson 1957, p. 95	Minimum estimate-includes 30,000 actually counted and 15,000 assumed no. of bulls. Using figures from June and mortality estimates. Olson uses actual est. is 37,000-40,000.
	40,000-45,000 (October est.)	Olson 1957, p. 48	
1957	No estimate		Most of herd thought to have emigrated to Porcupine herd.
1958	40,000 (fall)	Olson 1959, p. 53	"General evaluation" (i.e. no data) of fall migration.
1959	No estimate	Jones 1960, p. 246	Part of herd that emigrated to Porcupine herd returned.
1960	50,000 (mid-June)	Jones 1962, p. 99	Assumed 76M/100F not represented in post-calving, and 9,000 that calved south of Steese.
1961	50,000	Jones 1963 p. 62	
1962	50,000 (April)	Jones 1963, p. 66	
1963	51,000 (April)	Skoog 1963, p. 17	1962 estimate and yearling increment of 1000 by April 1963.
	50,000 (October)	Skoog 1964, p. 14	Estimate from ground counts and extrapolation (see explanation in this report).
1964	30,000	Lentfer 1965, p. 18	Data given in Table 6, no explanation in text.
1965	No estimate		
1966	No estimate		
1967	No estimate		
1968	30,000-40,000	Skoog 1968, p. 299	No data given.
1969	20,000 (post-calving)	ADF&G files	8,000-10,000 estimated post-calving.
1970	15,000 maximum	Jennings 1971	
1971	15,000 maximum	Unpublished files	
1972	15,000 maximum	LeResche 1975a	
1973	5,300 minimum	This report	
1974	4,000 minimum	This report	
1975	4,000 minimum	This report	

Although Murie's method of estimation can be criticized, other estimates during this period lend credence to Murie's. Various members of the Alaska Game Commission (Annual Reports, 1926-1932, a,b,c, cited in Skoog 1968) reported a huge population in this region of Alaska. During the fall of 1927, one warden estimated that over 400,000 caribou passed southward near the mouth of the Delta River during a four-day period, and that 500,000 to 700,000 animals passed during the entire two-week period of the migration.

Skoog's 1953 estimate was based on May herd composition counts conducted from the ground, along and north of the Steese Highway. He classified calves and yearlings and determined sex ratios. From 10 to 15 June the caribou crossed the Steese Highway in large groups along three miles of road above timberline. A crew of five worked day and night obtaining a total count. That count, combined with the May composition counts, provided a minimum estimate of the total herd size at that time. Skoog (1956:63-64) extrapolated as follows:

> Counts including calves totaled 19,900 animals, and those excluding calves, 10,500 - a total of 30,400. The number of calves excluded from the latter counts was computed to be 6,200, based upon calf counts taken on 9,923 animals, 3,694 or 37.2 percent, of which were calves. The total number of animals crossing the highway then reached 36,600. Composition counts indicated this portion of the herd to contain 18,660 adult cows, but only 1,440 adult bulls. Assuming a 1:1 sex ratio...the 17,220 missing bulls would bring the total population figure to 53,820 as of June 16, 1953. This figure represents a minimum one, for undoubtedly some cows, as well as calves and yearlings, were missing from the tally also.
>
> To be most useful the total population figure should apply to the herd just previous to calving, for by then annual calf mortality is evident. Thus, the elimination of 13,600 calves (37.2% of 36,600) from the above total figure leaves a minimum population before calving of about 40,000 animals.... These data provide the most complete herd statistics known to date.

Based on yearling recruitment rates, Skoog (1956) estimated the 1954 and 1955 pre-calving population as 44,800 and 49,200, respectively. Olson (1957:46-48) presented the following basis for a 1956 population estimate:

> The opportunity to ascertain total numbers of caribou in the Steese herd did not present itself at any time during the year except during the migration across the Steese Highway in June.... It is possible, however, to obtain an adjusted figure for the herd using the indicated calf mortality, which occurred during the summer months, and the hunter take. The apparent calf mortality occurring between June and October resulted in an 80 percent loss of calves. Expressing this in actual numbers would mean a loss of 7,537 calves (80% of 9,422 calves accounted for in June). The calf

loss plus the hunter take of 842 brings the June minimum estimated total down from 50,000 to 41,500. The total minimum population as of early winter 1956 is, therefore, probably somewhere between forty and forty-five thousand caribou. It must be remembered, however, that nonaccountable gains or losses of caribou can occur through emigration or immigration, particularly during the winter months when the herd is wintering in Canada. At this time, they are close enough to the Canadian herds so that the possibility of intermingling exists. If this occurs, it could very well mask the total counts arrived at earlier.

The year 1957 is of particular interest because during the winter of 1956-57 the major portion of the herd wintered in the Ogilvie Mountains north of Dawson (Skoog 1968). In May 1957, a large portion of the wintering population did not return to Alaska, and Skoog thought that many (perhaps 30,000) went northward with the Porcupine herd.

Olson (1958:43-44) commented on the population in 1957 as follows:

> During the year, there was no opportunity to determine total numbers. Highway crossings occurred under conditions which did not permit even approximate counts. The nature of the fall crossings, i.e. small size of bands, and the scattered erratic movement pattern, suggested that considerably fewer caribou crossed than in previous years.
>
> There are two possible reasons for this assumption:
>
> 1. Part of the herd may not have returned from Canada last spring; and
> 2. The reduced calf crop of the past two seasons could have contributed to a reduction of numbers.
>
> It is becoming increasingly obvious that the Steese-Fortymile herd has recently deviated significantly from its usual distribution pattern and movements. The reduced calf crop will certainly result in static or decreasing numbers in comparison to previous years. Total numbers would also change noticeably if the herd begins to break up and some segments perhaps join Canadian herds. The latter possibility is very real, since during the winter that part of the herd which crossed the Yukon could very easily have joined Canadian herds ranging in the Ogilvie Mountains.

If 30,000 animals joined the Porcupine herd in 1957 they must have later returned or a compensating ingress must have occurred, otherwise only 10,000 caribou would have been in the herd by 1958. This number is in contrast to Olson's (1959) estimate for spring 1958:

> There was no opportunity to definitely determine the total number of caribou in the Steese-Fortymile herd during the year. Post-calving counts in June at Eagle Summit showed that approximately 11,000 adults (92% cows) and 6,300 calves moved out of the

White Mountains to summer ranges south of the Steese Highway. This was only part of the herd since it was known that a segment of the herd did not cross the highway to the White Mountains calving area. The number of caribou involved in the latter is not known although it is believed that they were fewer in number than the former.

A general evaluation of the fall migration indicated that the overall size of the Steese-Fortymile herd was as large or larger than in past years. In past years the population level has been estimated at 40,000; at present, there is little reason to change this estimate. As stated previously, gains or losses incurred during the winter months in Canada by virtue of contact with Canadian herds could mask losses or gains as a result of mortality or annual increment from the calf crop.

The above suggests that no net loss occurred as a result of the 1957 movement of perhaps 30,000 caribou to the Porcupine herd.

The 1959 estimate was made by Skoog (1960:240): "No opportunity was found to ascertain the total number of caribou comprising the Steese-Fortymile herd during the year, but in past years the population has been estimated at 40,000; and at present there is little reason to change this estimate."

This estimate seems to further reflect the opinion that no substantial net loss of animals resulted from the 1957 egress to the Porcupine herd.

Jones (1962:89) used a seemingly reliable basis for a minimum population estimate in 1960 as follows:

By the middle of June, 11,174 calves had been added to the herd, of these, 60 percent survived to the yearling age or an increment of 6,690 yearlings. Other caribou mortality during the year is estimated at 2,500 animals. (This allows for predation and other natural mortality plus the 1,470 known take by hunters.) Therefore, the resulting figure for the herd increment would be approximately 4,200 animals.

During the year no opportunity to determine total numbers arose; however, from the information obtained from the calving counts, estimates can be calculated. The calving group contained 23,361 animals actually counted and a close estimation of 6,000 more that could not be counted or a total of approximately 30,000 animals. These figures indicate that 50 percent of the calving group were adult cows (two years of age or older) and less than one percent were bulls. Assuming that the Steese-Fortymile herd contains about the same ratio of cows to bulls as does the Nelchina herd, 76 bulls to 100 cows, then there are approximately 11,400 bulls in the herd. This gives a total figure for the herd of some 41,400 animals. This figure does not consider that portion of the herd which calved south of the Steese Highway; therefore, an estimation of the size of this herd is in the proximity of 50,000 animals.

By 1961 Jones (1963:62) was still estimating that the herd numbered 50,000. He reasoned as follows:

> There is no reason to believe that the size of the Steese-Fortymile caribou herd has decreased from 1960's estimate of 50,000. The calf crop of 3,500 north of the Steese Highway and an undetermined number south of the highway should have been more than sufficient to cover the loss of an estimated 2,000 hunter-killed caribou (including Canadian kill and crippling loss) and those lost to natural mortality.
>
> The size of the herd may have increased due to an influx of caribou from the Nelchina herd. Several thousand Nelchina caribou were seen traveling north through Isabel Pass, and it is possible that some of these may have eventually intermingled with the Steese-Fortymile caribou.

Skoog (1968) thought the above-mentioned caribou from the Nelchina may have stayed with the Delta herd, which would explain a rapid increase in that population.

The 1962 and 1963 population estimates are contained in the following quotation from Skoog (1963:13-17):

> Present information available concerning the Steese-Fortymile herd indicates a normal population that is increasing steadily. The productivity of the herd has fluctuated widely during the past eight years, presumably due to differences in calf survival between years; nonrepresentative aerial counts could have biased the data, however. The mortality in the animals older than calves consistently has been low, so that the herd has shown a steady increase, except for a suspected egress of several thousands of animals in 1957 to the Porcupine herd. There is no indication of a high prevalence of disease, nor of excessive wolf predation. The wintering grounds of the herd in Alaska are not considered to be in good condition, due to a general lack of lichens. The main wintering areas are located in Canada, however, and those have not been checked. There is no indication that the condition of the range is affecting the animals adversely.
>
> Last year's estimate for the population in April 1962 was 50,000 animals. In April 1963, an estimated 5,000 yearlings were added to the herd. This was offset by an estimated mortality of 4,000 adults. Thus, the herd increment in April 1963 roughly approximates 1,000 animals.

In 1963 Skoog (1964:14) again estimated the herd to number about 50,000 animals:

> The magnitude of the fall movement as viewed from the air indicated that the herd contained a large number of animals. Estimates by the writer on a flight along the migration route

between American Summit on the Taylor Highway and Eagle Summit on the Steese Highway totaled 26,000 animals. Because the animals were moving along several fronts and also through timbered regions, it seems likely that at least half the animals were not tallied. Thus, the writer estimates the herd at 50,000 animals in October 1963. In addition, the calf crop appeared to be good. The animals killed by hunters have been in excellent condition for the most part, with good fat reserves. Disease appears to be of low incidence. In view of these observations the herd apparently is healthy and probably increasing, judging from the low hunter harvests in recent years.

Later Skoog (1968:299) stated, "In April 1963, the herd was estimated to contain approximately 30,000 animals." This statement suggests that based on subsequent knowledge Skoog may have decided that the 26,000 animals he observed on his 1963 survey were closer to being the total herd rather than the 50 percent of the herd that he first estimated.

No population estimates are available from 1964-69 in Department Federal Aid Segment Reports except one in a table by Lentfer (1965:18) which indicates a population of 30,000. Lentfer (1965:14) and Skoog (1968:299) mentioned the egress to the Porcupine herd that occurred in winter 1964. Skoog (1968) documented it as follows:

> During the winter of 1963-64 the main portion of the herd wintered in the Ogilvie Mountains north of Dawson. In May 1964, during aerial reconnaissance flights, I found that most of these animals had moved northward into Region IV (the Porcupine herd's range). All that remained on the Fortymile range then were several thousand animals that had wintered to the west in the upper Goodpaster River area, plus an undetermined number to the southeast. Subsequently, it became apparent that many animals had returned to the region, and once again the herd is thought to number 30,000-40,000 animals.

Skoog's comment that the herd was thought to again number 30,000-40,000 animals was made in 1968. From 1965 to 1968 no researcher made specific estimates of herd numbers but indirect comments suggested that either substantial numbers must have remained after the 1964 egress or that the egress was of short duration. McGowan (1966:16) commented of 1965 that "...a group of 5,000 separated from the main herd...." Glenn (1967:18) mentioned "...portions of the herd (probably 5,000 to 10,000 animals)..."

Another possibility is that the above comments were based on the assumption that a sizable population of about 40,000 animals still existed. Perhaps the numbers reported comprised a sizable portion of the total population. From data available to us, the greatest number of caribou observed and reported after 1960 was 26,000 in fall 1963 (Skoog 1964). It is possible that a significant decline in numbers occurred from 1960 to 1964 when the egress to the Porcupine herd was reported. After 1964 there are no reports (or at least no specific data) indicating that large numbers were ever again observed after the

reported 1964 egress. The exception is Skoog's 1968 comment, "...the herd is thought to number 30,000-40,000 animals." However, he does not detail the basis for this estimate.

LeResche (1975a), citing unpublished Alaska Department of Fish and Game files, estimated the population to number 20,000 animals in 1969 based on 8,000-10,000 caribou observed in post-calving aggregation. Jennings (1971) in 1970 estimated that the population numbered less than 15,000 individuals and stated, "Considerable reconnaissance located less than 6,000 animals during October 1970."

In 1971 Jennings (1972) again stated, "...it is believed that the Fortymile herd does not exceed 15,000 animals." He also stated in reference to the 1971 October migration that, "An estimated 10,000-12,000 animals were involved in this migration, most of the Fortymile herd."

In 1972 Jennings (unpubl. data, cited in LeResche 1973) estimated that the herd numbered 15,000 at maximum. Jennings (1973) stated in 1972, "By October 23 the bulk of the herd, then estimated to number about 10,000 animals, had circled back and was moving west...."

Post-1972

In 1973 we derived a September population estimate of 5,312 caribou via the APDCE technique. The post-calving aggregations occurred adjacent to the calving area (see Distribution-Movements section this report) in the vicinity of the headwaters of East Fork Chena River, Little Windy Gulch, Williams and Gulch Creeks, and the west side of Crescent Creek. We photographed these aggregations on several days preceding 6 June. On 6 June, composition counts were conducted and 1,120 animals classified. The minimum estimated number of adult females in the total population on this date was extrapolated to be 3,200. This number was derived from visual estimates made concurrent to photographing the post-calving aggregations and a cursory look at the photographs. Unfortunately, the photographs were lost before they could be analyzed in detail.

We used sex and age composition counts carried out during the rut on 16-18 October 1973 to obtain representative sex and age ratios for extrapolation to a population estimate from the July cow base. The resulting ratios were 42 bulls/100 cows, 8 yearlings/100 cows and 16 calves/100 cows. Thus, the population included 25 percent bulls, 5 percent yearlings, 10 percent calves, and 60 percent cows (Table 2). Using these ratios we derived the October population estimate as follows:

Estimated base from post-calving extrapolation = 3200 cows.

3200 x .42 bulls	=	1,344 bulls
3200 x .16 calves	=	512 calves
3200 x .08 yearlings	=	256 yearlings
		3,200 cows
		5,312 Total estimate

During 1974 an APDCE census was again conducted. Direct visual enumeration of animals made on reconnaissance flights gave a higher count of adults than any day of photo coverage.

Table 2. Sex and age composition data from the Fortymile caribou herd 1953-1975.

Date	Total bulls per 100 cows	Yrlg per 100 cows	Calves per 100 cows	Yrlg % in herd	(Total yrlg)	Calf % in herd	(Total calves)	Cow % in herd	(Total cows)	Bull % in herd	(Total bulls)	Sample size
1974 (Sept)	33	8	20	5	(81)	13	(218)	62	(1078)	21	(361)	1738
1973 (Sept/Oct)	43	9	16	5	(170)	10	(318)	60	(1974)	26	(845)	3307
1972 (Oct)	30.5	16.5	21	9.8	(66)	12.5	(84)	59.5	(400)	18.2	(122)	672
1963 through 1971	No Data											
1962 (Oct/Nov)	-	-	-	-	-	11.4	(85)	-	-	-	-	743
1961 (Oct)	75	30	45	12	(133)	18	(200)	40	(444)	30	(333)	1110
1960	No Data											
1959 (Oct)	-	-	-	-	-	36	(164)	-	-	-	-	614
1958 (Aug)	-	-	-	-	-	33	(40)	-	-	-	-	127
1957 (Oct)	-	-	-	-	-	5	(26)	-	-	-	-	576
1956 (Oct)	-	-	-	-	-	5	(34)	-	-	-	-	737
1955 (Oct)	-	-	-	-	-	16	(268)	-	-	-	-	1659
1954 (late Oct?)	78	-	64	**	**	26	(50)	41	(78)**	32	(61)**	189***
1953 (Nov)	-	-	-	-	-	28.9	(66)	-	-	-	-	228

* Just after the rut.
** Yearlings were apparently classified as bulls or cows.
*** Skoog (1956:105) The counts are probably significant, although few animals were counted, because the many bands of caribou observed at that time seemed very similar in composition.

On 13 June 1974, 2,587 animals older than calves were enumerated and on 14 June 2,448 animals older than calves were enumerated. Because we did not take photos on these dates, we did not conduct composition counts. On 13 June we observed the animals closely from a Helio Courier 295 aircraft to detect whether an obvious number of bulls had joined the group since the 4-6 June composition counts. We observed only four animals with "large bull-type antlers" which suggested that the bull portion of the population was moving slowly from the east and that it had not yet joined the post-calving aggregations. Based on the 4-6 June 1974 composition data the calculated number of adult females in the 13 June count was 2,510.

Fall composition counts conducted 20-21 September 1974 yielded ratios of 33 bulls:100 cows, 8 yearlings:100 cows, and 20 calves:100 cows. Expressed as percent of herd, the proportions were 21 percent bulls, 5 percent yearlings, 13 percent calves, and 62 percent cows (Table 2). These ratios yield the following September population estimate:

Cow base from post-calving extrapolation	=	2,510
2510 x .33 bulls	=	828 bulls
2510 x .20 calves	=	502 calves
2510 x .08 yearlings	=	201 yearlings
		2,510 cows
		4,041 Total estimate

The 1974 estimate is 24 percent lower than the 1973 estimate. It is probable that a population decline occurred between the two counts as there has likely been a continuous decline since the early 1960s. However, the 1973 estimate did involve estimation of numbers whereas the 1974 estimate was based on direct enumeration. Nevertheless, it was highly probable that the 13 and 14 June counts in 1974 did not locate all of the adult females. At the time many of the animals were moving through spruce timber and dense brush so some could easily have been missed. Also, when the major area of distribution was delineated, flying an additional 20 air miles in a given direction sometimes revealed a few additional females.

In 1974 poor weather prevailed over the calving area from 6-12 June, when peak aggregations may have occurred as they did in 1973. However, based on the rate of movement by caribou from 12-14 June, we chose the period 14-16 June as the optimum time for photographing post-calving aggregations. We also chose the drainage of Crescent Creek as an optimum location because little timber and brush were present. Unfortunately, a violent storm with severe air turbulence and low clouds blanketed the area from 15-18 June, making coverage during this period impossible. When a survey was flown on 19 June we found that the animals had moved a great distance and we could only locate a fraction of them.

In 1975 we observed a maximum of 2,429 adults (animals older than calves) in any given day during the post-calving aggregation. Because of monetary constraints and a shifting research emphasis to assessment of the Western Arctic caribou herd's status, no composition data were obtained from the post-calving aggregations. However, close scrutiny

from the air (via Helio Courier 295) revealed few bulls and a minimal number of yearlings. Hence, we assumed that most of the 2,429 adults were adult females. Assuming that all adults were females, there would still be a reduction from the minimum of 2,510 cows observed in 1974. If even three percent (the percent of yearlings observed in the 1974 post-calving aggregations) of the 2,429 animals were yearlings, this would lower the adult female numbers to 2,356 or a reduction of six percent from 1974.

We were unable to obtain fall composition counts in 1975. However, by extrapolating from the 1974 and 1976 composition data, and using the estimates of the cow base and calf ratios obtained in May and July 1975, we were able to calculate a population estimate. The following assumptions were used in the extrapolations from 1974 and 1976:

1) Bull:cow ratios for 1973, 1974, and 1976 were 43:100, 33:100 and 42:100, respectively. We assumed that the fall 1975 bull:cow ratio was the average of these, or 39 bulls:100 cows;

2) From aerial counts on 27 May 1975 calf production was estimated at 64 calves/100 cows. A midsummer survey (after many bulls had joined the herd) revealed 18 calves/100 adults so the actual calf:cow ratio would have been much higher. The 1974 fall calf:cow ratio was 20 calves:100 cows. Because the 1975 cow:calf ratio was likely as high as the 1974 ratio, we assumed that the 1975 fall calf:cow ratio was 20 calves:100 cows;

3) The fall 1975 yearling:cow ratio was the average of the fall 1974 (9:100) and 1976 (11:100) yearling:cow ratios, or 10 yearlings: 100 cows.

Using these data, the fall 1975 population estimate was derived as follows:

Estimated cow base from post-calving = 2,356 cows
2356 x .39 = 919 bulls
2356 x .20 = 471 calves
2356 x .10 = 236 yearlings
= 3,982 Total population

Thus, the fall 1975 Fortymile caribou population was estimated at 3,982 animals.

Summary of Changes in Population Size

There seems little reason to doubt Skoog's (1956) impression that the population was very large throughout the 1920s, possibly peaking in the latter part of the decade. However, the estimate of 500,000 caribou during this time should probably be qualified as 500,000 ± 300,000 for a substantial range. He stated, "The decline in numbers seemed to begin after 1928 and reached its maximum rate in the mid-1930s. The population low probably occurred sometime in the early 1940s." The post-1940

period was likely one of continuous growth from the early 1940s through the mid-1950s. Skoog (1956) calculated that the population low was possibly between 10-20,000 in 1944 (based on his 1953 estimate of numbers). For this calculation he assumed that emigration and immigration were at a minimum, and that there was a constant rate of growth from 1944-1953 of 10, 15, or 20 percent yearly. As we discuss later, there is evidence to suggest that the population may not have begun to increase until 1947 so the beginning population may have been larger.

Skoog's 1953 estimate suggested a minimum June population of 53,280 which he revised to a pre-calving population of 40,000 by subtracting the calf portion of the herd. Based on yearling recruitment, Skoog (1956) made 1954 and 1955 pre-calving estimates of 44,800 and 49,200, respectively.

Egress to the Porcupine herd in 1957 was documented, but the net loss of animals appeared to be negligible. From the mid-1950s to 1964 it appears that the population did not increase; perhaps it even declined somewhat. No good basis for population estimates from 1961 to 1973 exists. Egress to the Porcupine herd in 1964 was documented, but the lasting effect of this egress is difficult to assess because many of the animals appeared to have subsequently returned. However, limited estimates after 1963 suggested a lowered population from one that had previously numbered 40-50,000 to one that numbered 20-30,000. In contrast to the 1957 egress, the 1964 egress may have resulted in a sustained net loss of animals.

Recent population estimates include 20,000 animals in 1969 (LeResche 1975a), less than 15,000 animals by 1970 (Jennings 1971), and less than 15,000 through 1972 (Jennings 1972, 1973). In retrospect it appears that all of these estimates were quite liberal as available data at the time suggest the largest documented minimum population to be about 8,000-10,000.

Since 1973, the estimates of fall herd size have been 5,312 animals in 1973, a minimum of 4,000 animals in 1974, and a current minimum of 4,000. An obvious substantial decrease in population size has occurred in the Fortymile caribou herd since 1964. The decline possibly began in 1960.

Sex and Age Composition

From Classification Counts

Sex and age composition data from the Fortymile herd are summarized in Table 2. The herd had a relatively high bull:cow ratio, approximately 75:100, from 1954 through 1961. From 1962 until 1972 no composition counts were conducted. The pre-1962 ratios are typical of the bull:cow ratios observed in most of Alaska's caribou herds that are unhunted or are lightly hunted for recreation (ADF&G files and Table 3). Sex and age composition data from recent years have yielded bull:cow ratios of 30.5:100 in 1972, 43:100 in 1973, and 33:100 in 1974. No composition counts were obtained in 1975. The ratios in 1972 and 1974 are not

Table 3. Bull:cow ratios in selected Alaska caribou herds after being exposed to recreational hunting pressure of various intensities for several years.

Herd	Year	Bulls/100 cows	Recreational hunting intensity level in recent years
Central Arctic	1978		light
Chisana	1977	41	medium
Delta	1969	40	medium
	1970	77	medium
	1973	28.6	heavy
Fortymile	1954	78	light
	1961	75	light
	1974	33	heavy
Mentasta	1973	40	medium
Mulchatna	1974	55	medium
Nelchina	1973	27.3	heavy
Porcupine	1977	76.1	light
Western Arctic	1977	43.2	light[1]

[1] Although "recreational" hunting is light, total human harvest is heavy.

significantly different from each other but the 1973 ratio is significantly different from both other years (Chi-Square tests; P = .05). However, it is likely that the 1973 ratios are biased by abnormal spatial separation of the sexes at the time composition counts were conducted.

Based on available data, it is difficult to state a minimum acceptable bull:cow ratio for maintaining a free-ranging barren-ground caribou population. However, there is ample circumstantial evidence to show that a ratio as low as 30 bulls (older than yearling):100 cows (older than yearling) is ample to insure breeding of most, if not all, cows during the first estrus. Alaska populations with such ratios have maintained the same calving chronology as when ratios were higher, i.e. the peak of calving and calving duration are essentially the same and calf production has not decreased.

Bergerud (1974) presented data and management recommendations for sex ratios of Newfoundland's woodland caribou (*R. t. caribou*, nomenclatures after Banfield 1961) which are likely not applicable to Alaska caribou because of basic herding and other behavioral differences between the two subspecies. However, his information is the best available for wild animals of the genus *Rangifer* in North America. Several of his conclusions follow: 1) a sex ratio of about 1:2 (male:female) seems to be a species characteristic of caribou. This ratio provides for extensive competition among males which results in the most vigorous males breeding the females. A priori we can argue that this is the optimum sex ratio for caribou and one to be sought in management programs if the quality of stock is a primary consideration; 2) when the sex ratio was one mature stag to nine does, the stag appeared tired and required approximately half a day to breed a female. If the sex ratio were 1:12 or more, it might not be possible for the mature stags (age 4-9) to breed all the females in the short 6-7 day rutting season; and 3) calves conceived during second estrus are at a survival disadvantage, since they are born only a few days before flies become bothersome. Insect harassment might reduce nursing time (and ultimately calf survival) (Bergerud 1974).

Reimers (1972) presented some relevant observations for the Eurasian tundra reindeer (*R. t. tarandus*) which is behaviorally much like Alaskan caribou. He concluded that a male:female ratio of 1:8 (older than yearling) might be a contributing factor to decreased calf production in a Norwegian herd. He qualified this conclusion by saying that poor nutrition may be a confounding influence. Reimers reviewed findings from other studies that included 1) domestic herds where 4-6 adult males:100 females was an adequate sex ratio, including examples where 1 male bred 50 or more females; and 2) the Lødingen experimental herd in which nearly all breeding males are yearlings and the male:female ratio in the herd is approximately 1:15 with satisfactory calf crops reported.

Reimers (1972) concluded that although a male:female ratio of 1:15 in a domestic herd may be satisfactory, there is evidence from wild herds that older bulls have an inhibitory effect on young males which might make such a distorted ratio unsatisfactory because the effective bull:cow ratio would be even lower.

We conclude the following about changes in the bull:cow ratio in the Fortymile herd: 1) the decreased bull:cow ratio is consistent with changes that have occurred in other populations that have been hunted fairly intensively by "recreational" hunters; and 2) the reduction has not adversely affected initial calf production (see roductivity section).

From the yearling:cow and calf:cow ratios observed over the years, we can make several inferences about the population dynamics and mortality patterns in this herd. These inferences are discussed in the Productivity section of this report.

From Jaw Collections

Jaws were collected from hunter-killed caribou intermittently from 1954 through 1972. The data are summarized in Appendix I. The small number of jaws collected in most years limits inference from the data. We did not obtain a reasonable sample size that might be large enough to represent the age structure of the harvest, i.e. 10 percent of the kill, in any single year. The 1972 sample may have come the closest to being a large enough sample. It was equal to 5.3 percent of the maximum population estimate of 15,000 animals. However, if the population numbered only 7,500 at the time, the 5.3 percent could be doubled to 10.6 percent.

It is not valid, however, to assume that the hunter kill is representative of the population. It is generally agreed that sport hunters of caribou select against calves and yearlings of both sexes, that they do not select among females two years or older, and that they select male animals older than yearlings over females older than yearlings (Skoog 1968:462).

A histogram of the 1972 structure of the female population segment reveals practically all age classes are represented in about the same proportion that occurs in a "normally" distributed population (Fig. 1 and Appendix I). A projected or predicted histogram of what the 1975 female age structure would be appears in Fig. 2. These data graphically illustrate the acute recruitment failure of yearlings into the population from 1973-1975. Further, the apparently "normal" age distribution in 1972 suggests that there had been no acute recruitment failure in at least several preceding years.

Male age structure for 1972 appears in Fig. 3. These data indicate that although there has been definite hunter selection for males over many years, hunting pressure was apparently not as intense as that on the Nelchina herd (Fig. 3).

As noted above, the 1972 jaw collection is the only collection of sufficient size to provide statistically reliable inferences about the population. However, inspection of the other years of data may be instructive, particularly if long-term trends can be noted that are further substantiated by additional data such as known calf production, yearling recruitment, and population size. The proportions of the total female population segment that the prime age classes (i.e. 2-7) comprised

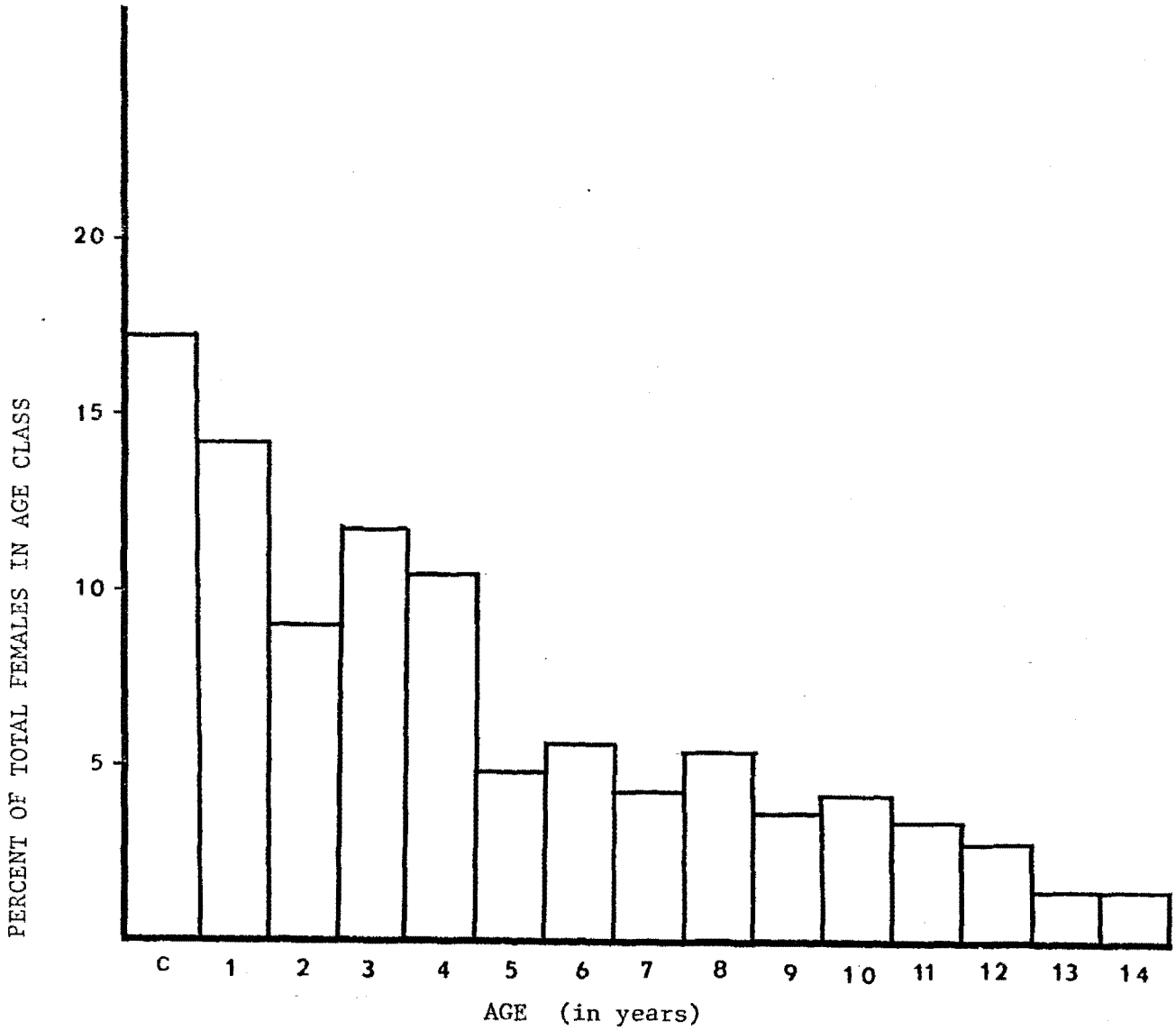

Fig. 1. Age structure of the 1972 female cohort of the Fortymile caribou herd.

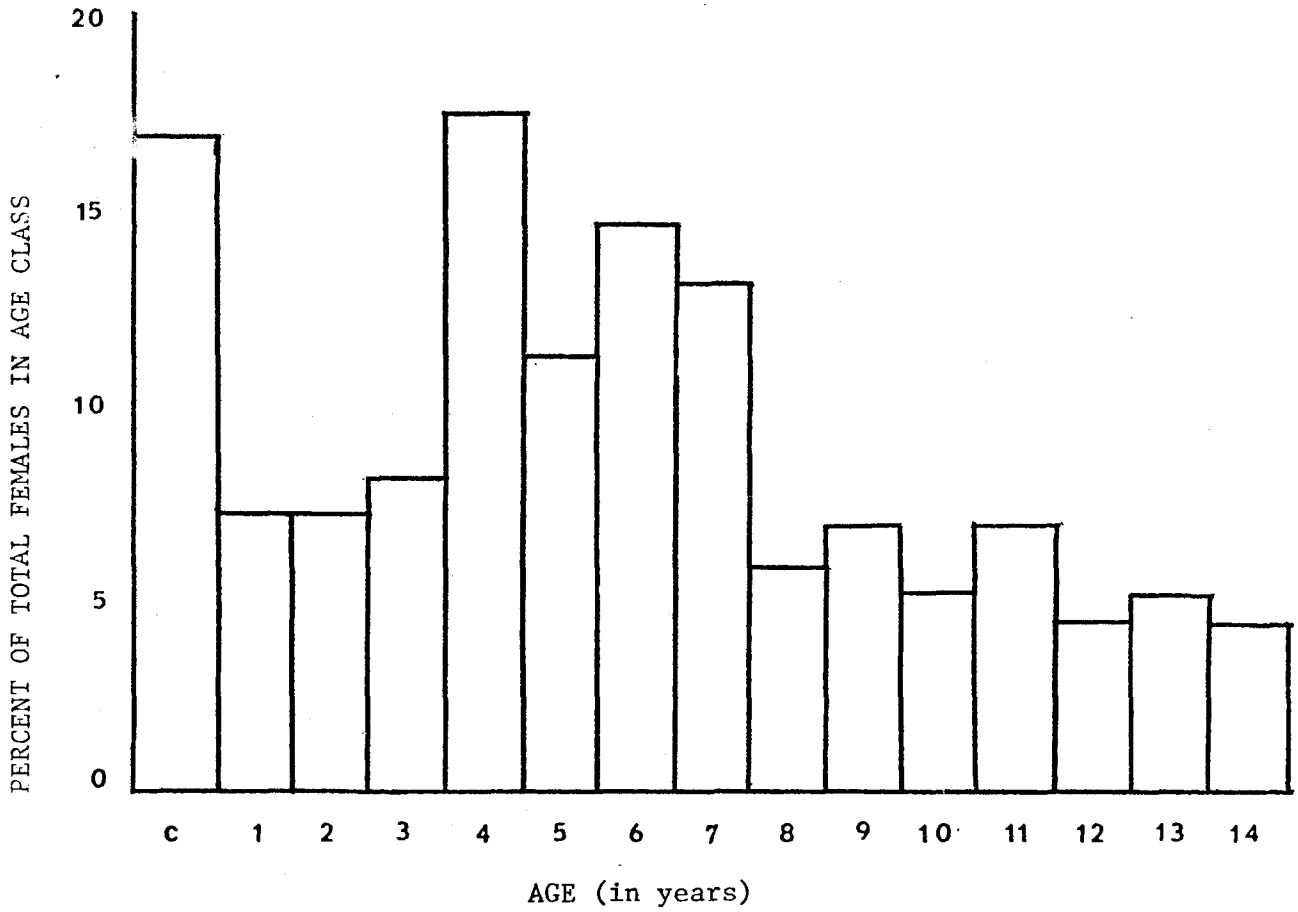

Fig 2. Age structure of the 1972 female cohort of the Fortymile caribou herd hypothetically projected to 1975.

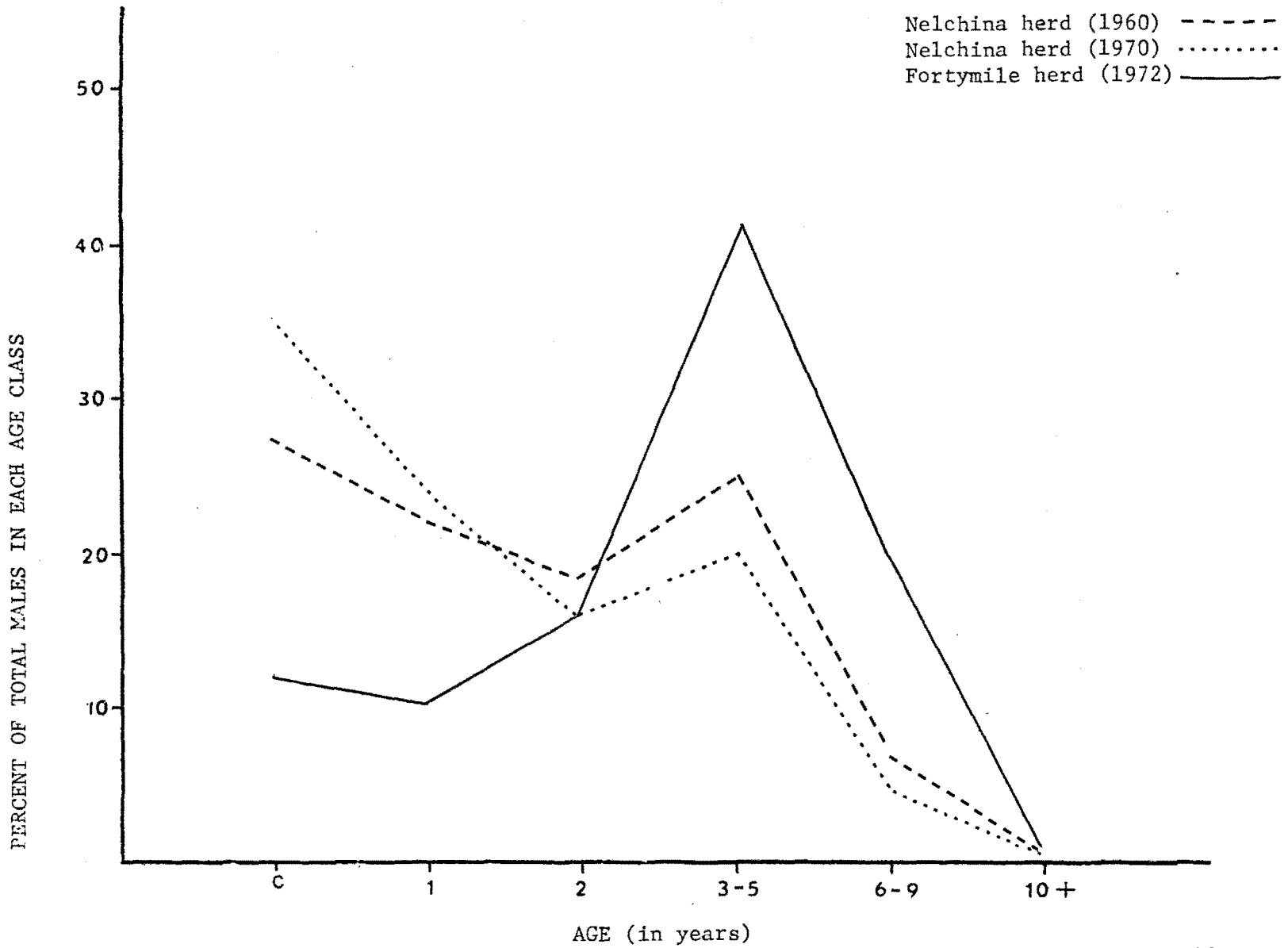

Fig. 3. Percent of total males in each age class in the Nelchina herd during rapid population increase (1960), rapid population decline (1970) and the Fortymile herd in 1972.

from 1954 through 1972 are plotted in Fig. 4. The only striking change in the data is that the percentage of animals older than 10 years increased substantially in the 1970 and 1972 samples (Fig. 5). This could reflect a true change in age structure, or be an artifact of changing techniques for aging, or both. The cementum annuli technique was used in 1970 and 1972 as opposed to the molar wear technique used in other years. However, it also appears that the population has probably experienced continuous decline since 1960. It should be noted that Bos' (1975) analysis of Nelchina herd data shows the same age structure change as the population declined. He concluded that the age structure change reflected a decreased yearling recruitment rate.

The sample of females in the age classes two years old or older provided the best information on past reproductive success because it was the least biased sex and age segment obtained from hunter-killed specimens. In addition to the obvious selection for older males, disproportionately fewer calves and yearlings of either sex are generally taken by hunters in comparison to adults.

Figs. 3 and 4 contrast the female and male age structures of the 1972 Fortymile population with those of the Nelchina herd during a period of rapid population growth (i.e. 1960) and a period of a rapid decline in numbers (i.e. 1970). The Fortymile female age structure more closely parallels that of the Nelchina herd when it was declining than when it was experiencing rapid growth. It is important to recognize that change in the size of a population cannot be predicted by inspection of the age structure unless age-specific mortality is also known. However, when hunting mortality is known, estimates of yearling recruitment will indicate whether the population has the potential to increase--depending upon additional mortality factors.

The three male age structures in Fig. 3 can be explained in terms of hunting intensity and hunter selection. The high calf and yearling bull proportions in the Nelchina harvest occurred because there were relatively few older bulls in the population and the hunters were not highly selective (i.e. they are hunting for meat, not trophies) so they are likely to take the first animal they see. The data suggest that even in 1960, the bull segment of the Nelchina herd was more heavily hunted than that of the Fortymile herd in 1972. The number of yearling and two-year-old bulls is likely proportionately high because they are as large or larger than most females and also have larger antlers than most females. In short, if hunters select for males they do so in terms of body size and antler size.

Productivity

Initial calf production and survival to yearling age in the Fortymile herd from 1953 through 1975 are summarized in Table 4. Initial calf production (as determined by spring post-calving counts) has always been fairly high. Skoog (1968) and Kelsall (1968) generalized that 60 percent of all cows, yearling age or older, produce calves in an average herd; and 80 percent of all cows two years or older produce calves. If the above-quoted figures are normal rates for initial calf production,

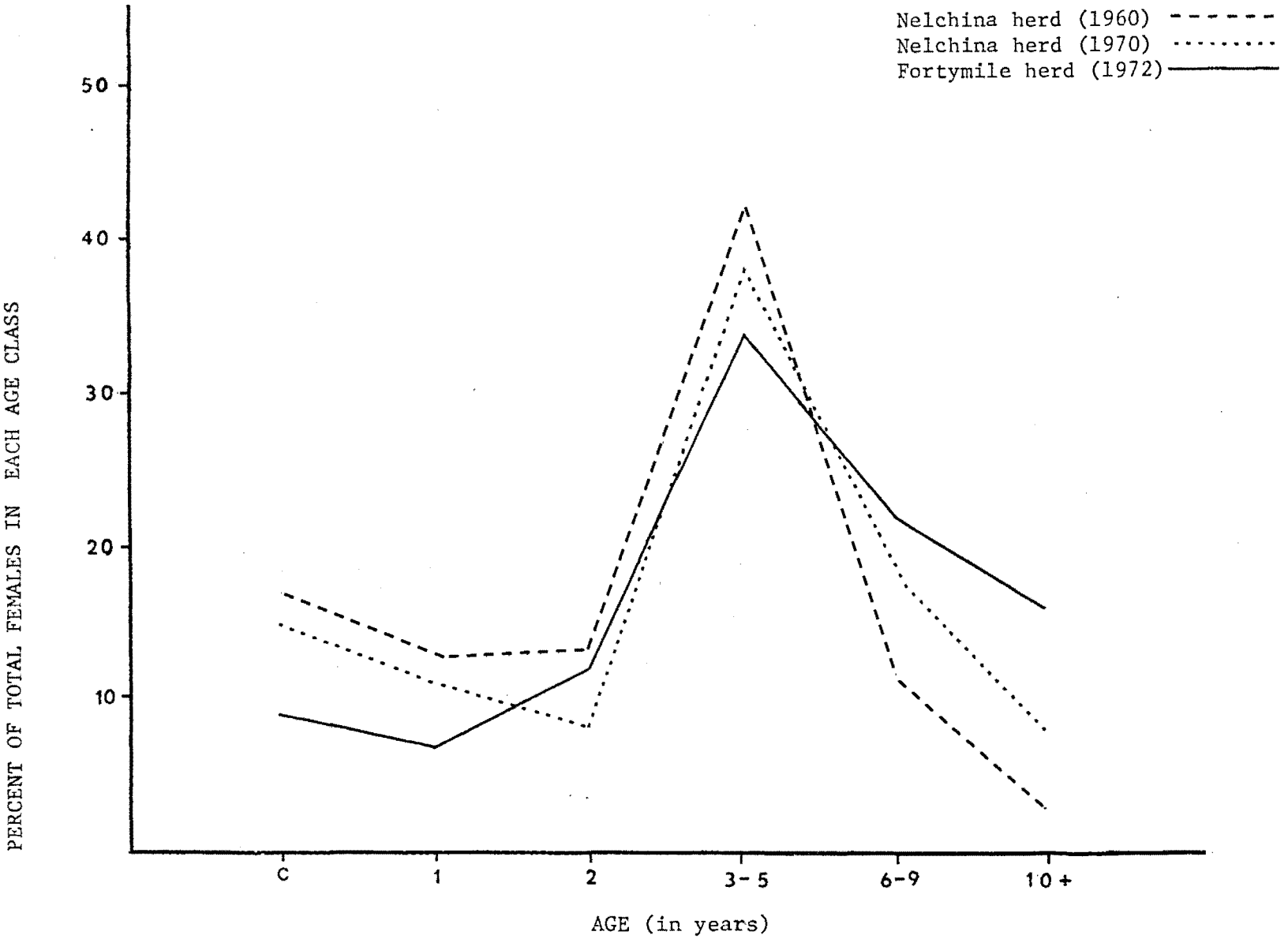

Fig. 4. Percent of total females in each age class in the Nelchina herd during rapid population increase (1960), rapid population decline (1970) and the Fortymile herd in 1972.

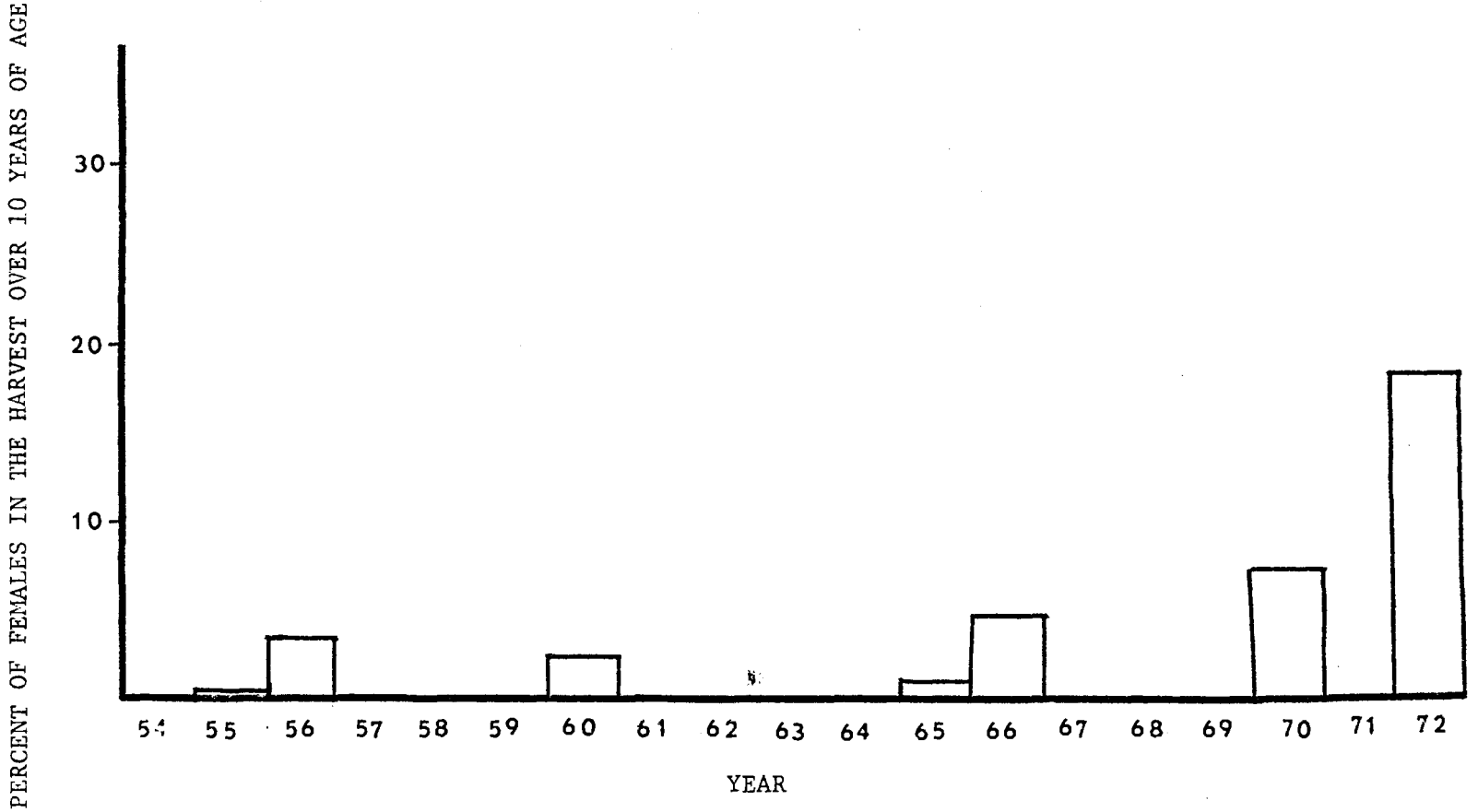

Fig. 5. Percent of females in the harvest that were over 10 years old from 1954-1972.

Table 4. Initial calf production and calf overwinter survival rates for the Fortymile caribou herd 1953-1976.

	Early Summer-postcalving			Fall		Following spring		
Date	Calves/ 100 cows	Sample Size	Calves/ 100 cows	Sample Size	Percent survival from postcalving	Short yrl/ 100 cows	Sample size	% survival from previous spring
1953	72.9	N.A.	-	-	-	20.5	231/1128	28
1954	74.9[1] 73	10,100/13,810	-	-	-	15.7	93/591	22
1955	72[1] 64.9	200/308	19.9[2]	268/1391	29	14.4	162/1124	22
1956	75[1] 54.0	4986/9220	5.0[2]	15/359	9	3[2]	36/1084	06
1957	38.0	398/1038	4.0[2]	26/576	13	3[2]	14/444ad.	8
1958	74[1] 62.0	6284/10,162	33.0	40/120	53	19[2]	136/721	31
1959	58.0	760/1301	36.4[2]	164/450ad.	63	36.9	176ad./476ad.	64
1960	78.0	3360/4290	67.9	324/577	87	43.6[2]	106/243ad.	56
1961	74.0	3477/4701	45.0	200/444	61	N.A.	-	-
1963	-	-	20.0	N.A.	-	-	-	-
1972	-	-	21.0	84/400	-	9[3]	170/1974	-
1973	57.0		16.0	318/1974	28	8[3]	81/1078	14
1974	53.0	686/1304	20.0	218/1078	38	3	(estimated)	
1975	64.0		18.0[4]		28	11.3[3]	54/476	18
1976			34.5	164/476		14[3]	75/543	

[1] For these years there are two sets of data contained in different reports.
[2] These values based on calves/100 adults and yearlings.
[3] The values calculated from yearlings/100 cows from the next fall.
[4] This was a midsummer count rather than fall; calves/100 adults.

it appears that the Fortymile herd has always realized good initial calf production (at least during the years for which data are available). Based on data from the Nelchina herd and many other herds, investigators have concluded that 40 percent survival from initial calf production to yearling age is "normal." The Fortymile herd has rarely experienced this survival rate. The only years in which more than 40 percent of the calves survived to yearling age were 1959 and 1960. The only way to determine if a population has made a net gain or loss is to know all losses and all additions; we realize that the status of a population cannot be gauged solely by an index such as a 40 percent "normal" survival of calves. Some investigators have acknowledged that poor calf production or survival has contributed to major caribou population declines (Kelsall 1968, Parker 1972, Bos 1975, Davis and Neiland 1975).

In conclusion, the Fortymile herd has generally realized good to excellent initial calf production in most years but mediocre yearling recruitment. This implies heavy calf mortality at some period in the first year of life. A discussion of possible mortality causes is presented in the Mortality section of this report.

Mortality

Hunting

LeResche (1975a:135) presented the following discussion about hunting and its impact on the Fortymile herd:

> The Fortymile Herd has been hunted regularly since gold rush days and, unlike the Porcupine Herd, may have been altered in numbers or composition by human utilization. Skoog (1956) cited an estimated (Alaska Game Commission 1934, 1935) harvest of at least 10,000 annually for dog food by trappers in the Fort Yukon district in the 1930's. Skoog concluded that a harvest of such magnitude alone could not have initiated the decline in number from more than half a million animals; however, he believed subsistence hunting might have become a 'serious factor' once the decline began.
>
> From the early 1950's until the present, the Fortymile Herd has been an important recreational hunting resource in Alaska (Table 2). Through 1966 animals were killed as they migrated near the Steese Highway in August and September. Since that time, caribou crossing the Steese have been too few to attract a significant number of hunters. Hunting on the Taylor Highway has increased in recent years and, depending upon timing of the migration and closing of the road by weather, harvest has varied from 500 to 2,500 annually. In addition, a small harvest of Fortymile Herd animals occurs some years in the Yukon Territory.
>
> Skoog (1956) calculated a minimum annual increment of 10 percent for this herd and believed it did not exceed 15 percent. His calculations were based on a spring herd size averaging 44,500

and included average hunting harvest of 1,500 over a three-year period (1953-1955). His method of calculation (1956; Table 10), which assumes calf to yearling survival of 50 percent, initial calf production of 60:100 cows (1954-1960 mean), wolf predation of 2 percent and miscellaneous mortality of 1 percent, and that 46 percent of the herd are cows; yields an annual increment of 1,080 animals before hunting to a herd presently estimated at 10,000 maximum. Thus, a harvest of 1,386 in Alaska (1970) likely exceeds the maximum allowable harvest for herd maintenance, and the 1971 harvest of 2,363 possibly doubles it. I emphasize that this calculation is based on a patchwork of data most of which are 10 years outdated, and on an estimate of total numbers that is little more than a guess at present. However, there is little current information to add optimism to the picture.

Human harvest data for the Fortymile herd are summarized in Table 5. By using estimates of population size (Table 1) and recruitment rates (Table 2), we can compare potential recruitment to harvest levels (Table 5) and determine the years in which the herd would have decreased from harvest alone (Table 6).

It is apparent that hunter harvest never exceeded probable yearling recruitment prior to 1970 and in fact rarely even approached the recruitment. However, from 1970-72 it is apparent that harvest was greatly exceeding the yearling recruitment rate and contributed greatly to the population decline during this period.

Prior to 1964 hunting probably had only a minimal impact on the herd. However, after 1964, when it is possible that substantial numbers of Fortymile herd caribou immigrated to the Porcupine herd, hunting in combination with predation and other natural mortality may have become increasingly important in the herd decline. However, as is discussed in the Predation section of this report, the loss in numbers due to hunting was likely much less than that to predation.

Predation - General Considerations

Several investigators have discussed in depth the various species that prey on caribou or are capable of preying on them (Clarke 1940, Banfield 1954, Harper 1955, Kelsall 1968, Skoog 1968, Curatolo 1975). Those occurring in the Fortymile herd's range include the coyote (*Canis latrans*), lynx (*Lynx canadensis*), black bear (*Ursus americanus*), wolverine (*Gulo gulo*), grizzly bear (*Ursus arctos*), wolf (*Canis lupus*), raven (*Corvus corax*), golden eagle (*Aquila chrysaetos*), bald eagle (*Haliailtus leucocephalus*), and red fox (*Vulpes vulpes*). Curatolo (1975) elaborated in detail on the probable impact of each on Fortymile caribou. He concluded that wolf predation on calves may be the major reason for the disappearance of over half the calf crop between June and September 1973.

Much of our thinking on the effect of predation on the Fortymile herd's population dynamics is based on circumstantial evidence and

Table 5. Summary of hunter harvest from the Fortymile caribou herd 1951-1975.

Year	Season & Limit	M killed No.(%)	F killed No.(%)	Total[1] Kill	Extrap-olated Kill	Source
1951	Sept 1-Oct 15[2] Dec 1-Dec 10 (1 caribou, either sex except fawns)	n/a	n/a	567		Olson, ibid.
1952	Sept 1-Oct 15[2] Dec 1-Dec 10 (1 bull, fork horn or larger)	n/a	n/a	164		Olson, ibid.
1953	Sept 1-30[2] Nov 20-30 (1 bull, fork horn or larger)	n/a	n/a	50		Olson, ibid.
1954	Aug 20-Sept 30[3] Nov 20-Nov 30 (1 caribou, except fawns)	462(47.5)	467(47.5)	984	1300	Olson, ibid.
1955	Aug 20-Nov 30[3] (2 caribou)	816(50.3)	747(46.0)	1631	2325	Olson, ibid.
1956	Aug 20-Dec 31[4] (2 caribou)	361(59.5)	241(39.7)	621	842	Olson, USFWS 1956-57
1957	Aug 20-Dec 31[4] (3 caribou)	257(66.8)	143(33.2)	484	648	Olson, USFWS 1958-59
1958	Aug 20-Dec 31[4] (3 caribou)	n/a	n/a	n/a	n/a	n/a
1959	Aug 20-Dec 31[4] (3 caribou)	n/a	n/a	n/a	n/a	n/a
1960	Aug 20-Dec 31[5] (3 caribou)	670(54.0)	564(46.0)		1234[6]	
1961	Aug 20-Dec 31[5] (3 caribou)	790(48.0)	854(52.0)	1685	2019	Jones, Caribou Report
1962	Aug 20-Dec 31[5] (3 caribou) Jan 18-Mar 31 (2 caribou)	170[7]	120[7]	640[8]	850[9]	Skoog, 1962-63 Caribou Report
1963	Aug 10-Mar 31[5] (3 caribou)	n/a	n/a	264	335	Skoog, 1963 Caribou Report

1964	Aug 10-Mar 31 (4 caribou)	n/a	n/a	104	270	Lentfer, 1964 Caribou Report
1965	Aug 10-Mar 31 (3 caribou)	n/a	n/a	n/a	800	McGowan, 1965 Caribou Report
1966	Aug 10-Mar 31 (3 caribou)	n/a	n/a	n/a	1900	Glenn, 1966 Caribou Report
1967	Aug 10-Mar 31 (3 caribou)	n/a	n/a	503	505	Hemming, 1967 Caribou Report
1968	Aug 10-Mar 31 (3 caribou)	191(65.4)	96(32.8)	292	579	Harvest tickets & 1970 S&I Report
1969	Aug 10-Mar 31 (3 caribou)	260(76.0)	79(23.1)	342	492	IBM & 1969 S&I report
1970	Aug 10-Mar 31 (3 caribou)	601(67.6)	275(30.9)	889	1386	IBM & 1970 S&I Report
1971	Aug 10-Mar 31 (3 caribou)	1064(53.3)	896(44.9)	1994	2360[10]	IBM & 1971 S&I Report
1972	Aug 10-Mar 31 (3 caribou)[11]	441(45.3)	508(52.2)	974	1330	IBM & 1972 S&I Report
1973	Aug 10-Sept 28 (1 caribou)	37(82.2)	8(17.7)	46		IBM Printout
1974	Aug 10-Sept 20 (1 caribou)	22(81.4)	5(8.5)	29		IBM Printout
1975	Aug 10-Sept 20 (1 caribou)	22(65)	12(35)	34		IBM Printout

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[1] Does not include animals crippled or unretrieved; includes animals whose sex was unidentifiable.
[2] Steese Highway Closed Area: Twelvemile and Eagle Summits (see Footnote 6) and area within 20 miles on the east side of the Steese between mileposts 70 and 112.
[3] Steese Highway Closed Area: Area within five miles either side of Steese between mileposts 84 and 89 on Twelvemile Summit, and mileposts 102 and 112 on Eagle Summit.
[4] Steese Highway Closed Area: Five miles either side of Steese between mileposts 102 and 112 (Eagle Summit).
[5] Steese Highway Closed Area: Area near Eagle Summit lying within 2 miles each side of Steese between Ptarmigan Creek and a point 8 miles northeast along the highway.
[6] Includes 10 percent crippling loss.
[7] Taylor Highway portion of kill only.
[8] Includes 35 on Steese, and 315 from Yukon Territory.
[9] Includes 5 percent crippling loss.
[10] Includes Yukon Territory harvest of approximately 300.
[11] Harvest quota of 1500 established, with season to close when quota reached.

Table 6. Comparison of yearling recruitment and hunter harvest for the Fortymile caribou herd 1920-1975.

Year	Estimated population[1]	Revised estimate	Fall %[2] yrlgs.	Number of yrlgs. recruited before mortality	Hunting harvest	Percent of yrlg. recruitment taken by hunters
1920	568,000	-	?		10,000	
early 1940s	10,000-20,000	-	?		1951=567, 1952=164	
1953	58,820	-	19.1	11,235	50	0.45
1954	48,000+	-	17.1	8,208	1,300	15.84
1955	49,200+	-	10.6	5,215	2,325	44.58
1956	45,000	-	5	2,250	842	37.42
1957	N.A.	-	5	ca.2,250	648	28.80
1958	40,000	-	21.8	8,720	N.A.	N.A.
1959	N.A.	-	23.7	ca.10,665	N.A.	N.A.
1960	50,000	-	18	9,000	1,234	13.71
1961	50,000		12[5]	6,000	2,019	33.65
1962	50,000+	-	7.5	3,750	850	22.67
1963	51,000+	-	8	4,080	335	8.21
1964	30,000	-	8	2,400	270	11.25
1965	N.A.	-	8	ca.2,400	800	33.33
1966	N.A.	-	8	ca.2,400	1,900	79.17
1967	N.A.	-	8	ca.2,400	505	21.04
1968	30-40,000	15,000 or less[3]	8	1,200	579	48.25
1969	20,000	10,000 or less[3]	8	800	492	61.50
1970	15,000 max	4-7,000 max	8	320-560	1,386	247[5] to 433
1971	15,000 max	5,300-8,000[4]	8	424-640	2,360	368[5] to 556
1972	15,000 max	4-7,000[4]	9.8[6]	392-686	1,330	193[5] to 339
1973	5,300 prob min	-	5[6]	265	46	17.36
1974	4,000 prob min	-	5[6]	200	29	14.50
1975	4,000 prob min	-	ca.5	200	34	17.00
	Total			84,774 min	19,331 min	

[1] These estimates were taken from Table 1 this report. These estimates are not directly comparable because some are spring, summer and fall estimates, respectively.

[2] All of the values in this column, unless designated otherwise, are calculated or "linearly fitted" from the calf percent of herd values in Table 2 (this report).

[3] These years estimates were reduced by 50 percent as that was approximately the amount the 1970-73 estimates were reduced by the assumption in footnote 2 above.

[4] These were recalculated on the assumption that 75 percent of the herd was located in post-calving aggregations.

[5] Harvest greater than 100 percent of yearling recruitment.

[6] Actual observed values.

inference. Therefore it seems appropriate and instructive to review the findings of other predator-caribou relationship studies for comparisons.

Studies that have focused on predators of caribou other than wolves are quite limited. The most notable study in this category is Bergerud's (1971) study of Newfoundland caribou where he concluded that 30 percent of the calves in one herd and 69 percent in another herd died from lynx predation during their first summer of life. Wolves are not present in Newfoundland.

Two other long-term life history studies of caribou, one in Alaska by Skoog (1968) and the other in northern Canada summarized in Kelsall (1968), suggested that predators other than wolves are not major mortality factors to most caribou populations. Conversely, both studies listed wolf mortality as the greatest single mortality factor in most wild populations of *Rangifer*.

The actual impact of wolves upon caribou populations is dependent upon a myriad of factors, many of which are illustrated in the various papers discussing wolf-caribou relationships that are reviewed in this report.

Selection of caribou by predators. The following discussion of food habit studies illustrates that the frequency with which wolves prey on caribou of various sex, age, and condition classes varies from situation to situation. It appears that the findings of past studies usually apply only narrowly to the particular population being studied and perhaps more narrowly to the time period at which the population was being investigated. Nevertheless, some common findings emerge. Bergerud (1971) showed lynx to be the primary predator on caribou in his area and concluded that losses of adults to predation, which could possibly be biased toward males, were so minor as to be insignificant. When 1.3 males were lost for each female that died he concluded that male calves may have been more vulnerable than females to lynx because of their tendency to wander farther from the dams. By assuming that predation was the predominant mortality cause for all calf losses from birth to six months of age, Skoog (1968) concluded that most adult animals taken by predators are killed by wolves, although occasional animals are taken by bears, wolverines, and lynx. Predation by all animals excepting the wolf (and possibly lynx) is confined mostly to calves less than 1-month old. Skoog does not explicitly generalize about wolf selection for a given "type" of caribou but does reiterate points that indicate he believes that a kill is largely a function of circumstances. For example, he states:

> It (the wolf) has little trouble killing whatever it wishes, and is able to run down healthy, adult caribou in a long chase.... It seems more probable that wolves, like most predators, obtain their prey as needed from the animals readily available; the circumstances surrounding the hunt vary as does the composition of prey (i.e. "healthy" versus "unhealthy" animals); the final selection probably results more from chance than design...handicapped animals (which

might be considered easy prey for wolves), in addition to the sick and injured, include young calves, pregnant cows in late winter, and fat bulls prior to the rut. Calves are particularly vulnerable to attack.

Kelsall (1968) had little data available upon which to base conclusions about prey selection but commented that caribou, except for incapacitated and very young animals, can normally outrun single wolves. He concluded that weakness or incapacity would make caribou more vulnerable to wolves although examination of wolf kills could not confirm this because wolves seldom left enough so that age and sex of the animal killed could be determined. Murie (1944) concluded that when calves are only a few days old wolves can kill them with little effort. Murie also stated that both young and old animals are taken but greater attention is given the calves during the calving period. He did not mention any selection by sex.

Studies designed to determine wolf food habits and selection of prey have provided more data. Several of these studies have indicated that certain age or sex classes occur in greater proportion in the wolf kill than they do in the population, indicating selection by the wolves. Using this criterion, researchers have concluded that wolves select calves (Banfield 1954, Clark 1971, Kuyt 1972, Miller in Parker 1972, Miller and Broughton 1974, Miller 1975), older animals (Banfield 1954, Kuyt 1972, Miller 1975), females (Kuyt 1972), or males (Banfield 1954). Others have concluded that wolves do not select by age (Burkholder 1959) or sex (Burkholder 1959, Miller and Broughton 1974).

Mech (1970) summarized sex and age selection by saying that, during winter, wolves prey primarily on the youngest and oldest members of most, if not all, primary prey species. In summer, several scat studies have indicated that calves and fawns also compose a high percentage of food items.

Mech summarized selection by sex as follows: "It can be said that wolf predation may exert a certain amount of selection for one sex or the other in various species and in different seasons. In most cases the year-round mortality from wolves probably occurs evenly on both sexes." He summarized selection by physical condition indirectly in his statement: "The above evidence that many of the middle-aged animals killed by wolves were injured, diseased or parasitized further supports this concept; apparently these individuals succumbed because they too were easier and safer to capture."

Contribution of caribou to wolf diet. Where caribou are present they comprise a significant portion of the diet of wolves. Stephenson (1975), in reviewing data from wolf scats, concluded that the wolf's diet is influenced by geography, season, and annual variation in prey availability. Certainly these factors affect their utilization of caribou.

This conclusion has been reached by workers making observations of the herd, examining wolf kills, or analyzing the stomach contents of wolves or wolf scats.

Kuyt (1972) concluded that wolves depend upon caribou for food to a large extent and that this dependence is greater in winter than in summer when wolves often resort to small prey. His comments referred to the wolves inhabiting the range of northern Canada's Kaminuriak caribou herd. Murie (1944) found that in Interior Alaska the main food of wolves was caribou. Kelly (1954), Banfield (1954), and Kelsall (1960) found that wolves on barren-ground caribou range preyed almost exclusively on caribou.

Burkholder (1959) found that caribou comprised 45 percent of 31 ungulates believed killed by a pack of wolves during March and April 1958 in Southcentral Alaska. Rausch (1968) noted that caribou were abundant from 1959-1967 in the same area where Burkholder's study was conducted and that caribou comprised nearly 50 percent of the carcasses located in the field that wolves had fed upon. Stephenson (1975), also working in Alaska, reported that caribou comprised 17 percent of 94 wolf-killed ungulates located between May 1975 and February 1976 in GMU 13.

Rausch (1968) also reported that caribou constituted 66.1 percent of 65 food items in 86 wolf stomachs collected in Alaska's Game Management Units (GMUs) 18, 22, 23, 24, and 26 (northwestern Alaska), and caribou comprised 19.3 percent of the food items in stomachs (42.8% empty) of wolves from GMUs 11, 12, 13, 16, 19, 20, 21, and 25 (Southcentral and Interior Alaska).

Stephenson (1975) reported that: 1) caribou appeared in 5.2 percent of 1,532 scats collected from active dens in 1975 from GMU 13, 2) caribou remains occurred in 69.5 percent of 82 scats from a wolf den on the coastal plain in northcentral Alaska, and 3) caribou and sheep (*Ovis dalli*) were the predominant food items in 59 scats collected from a den in the eastcentral Brooks Range. Clark (1971) reported that caribou remains occurred in 91.5 percent of summer scats located on Baffin Island and Kuyt (1972) reported that 47 percent of summer wolf scats from Keewatin District, N.W.T. contained caribou remains.

A complete picture of wolf food habits is presented in Mech (1970) and Stephenson (1978). Quite clearly, caribou can be a major source of food for wolves occupying caribou ranges.

Rates of wolf predation on caribou. In attempting to assess the impact that predators have upon their prey, it is necessary to know the rates of predation on that species. The literature does not contain estimates of rates of predation by any caribou predators other than wolves. Conceivably the rates of predation are dependent upon the size of prey being taken. One meaningful way of assessing rates of predation involves observing the number of kills during a given period of time and relating this observed rate to food intake requirements in terms of

pounds/day. The literature reflecting this approach yields several estimates of probable predation rates.

Mech (1970) reviewed available literature on food consumption rates. From data obtained from dogs he concluded that 3.7 pounds of meat per day could be regarded as an accurate minimum maintenance requirement for wolves in the wild, although growing wolves would need two or three times as much food per pound as adults would. Mech also pointed out the important distinction between the minimum food requirement and the amount of food actually eaten.

On Isle Royale, Mech (1966) estimated that pack members each consumed an average of 0.18 pounds of moose/pound of wolf/day in the winter of 1959, 0.13 in 1960, and 0.19 in 1961 for an average of 0.167. Pimlott (1967) and his co-workers adjusted these estimates by assigning different weights to the moose fed upon and arrived at a consumption rate of 0.14 pounds of moose/pound of wolf/day or about 10 pounds/wolf.

Kuyt (1969) determined that 3.5 pounds of meat, fat, and dog food filled the maintenance requirements of captive wolves but estimated that 7 pounds would be required for wild wolves.

Burkholder (1959) observed an actual rate of kill when a pack of Alaskan wolves killed 13 caribou and 8 moose calves during 35 days in March and April or 1.7 prey animals per wolf per month. In Alberta Cowan (1947) also reported an observed predation rate of 1.5 elk (*Cervus canadensis*) per wolf per month. Mech's (1966) observations on Isle Royale resulted in an average kill rate of 0.67 moose per wolf per month.

Other references to food consumption rates include Stephenson's (1976) conclusion that most studies show that wild wolves are successful in obtaining at least 6 pounds of meat per day during winter and up to 2-1/2 times that under ideal conditions such as excessively deep soft snow and winter concentrations of prey. Kolenosky (1972) observed wolves consuming 6.5 pounds of deer per day during a 4- month period. Mech and Frenzel (1971) observed that wolves consumed 5.6 lbs/wolf/day during a normal winter but under ideal conditions the rate was much higher.

A few investigators have estimated the number of caribou required/wolf/year, where caribou constitute the principal or only ungulate prey species. Kelsall (1968) estimated 14 caribou; Clarke (1940), 11 caribou; and Kuyt (1972) an average of 23 caribou. Skoog (1968) derived a consumption rate of 12 caribou/wolf/year for Southcentral Alaska where caribou were believed to constitute one-half of the ungulate prey of wolves present.

Use of prey by wolves. In any calculation of the impact that predators have upon prey, it is essential to determine the degree of prey utilization by the predators as well as the food requirements of the predators. Mech (1970) spoke to the question of prey utilization by wolves as follows: "Although the wolf is often accused of eating just the "best" parts of its prey and therefore wasting the rest, most

of the evidence does not bear out such a claim." Mech reported that all but 1 of the 50 moose carcasses he examined on Isle Royale were eventually completely eaten, except for one that he interfered with during summer. He summarized his feelings on the subject in his statement, "Only during long periods of unusually deep snow, when deer are especially vulnerable, have I seen where wolves have killed deer and abandoned them."

Others have reported various instances of seemingly incomplete utilization in certain situations. Kelsall (1957) found a half dozen dead, but largely uneaten, caribou on a lake in April 1950. He reported seeing similar groups of carcasses, indicating that wolves had succeeded in killing more caribou than they could eat immediately and stressed that these situations had been found only where massive groups of prey would hinder each other in escape and provide an advantage to wolves. Kelsall felt that such excess killing was not wasteful as they would eventually be cleared up by wolves in time if not first taken by scavengers. He further quoted Murie (1944) and Young and Goldman (1944) as having observed instances of wolves killing beyond the needs of the moment in the vicinity of den sites. Miller and Broughton (1972) concluded in their study that much of the wolf predation they observed exceeded the wolves' needs. Kuyt (1972) concluded that caribou killed in winter are completel/ utilized by wolves, but in summer parts of carcasses are often left to scavengers. Murie (1944) reported finding three uneaten calves that had been killed by wolves (evidence of neck bites) in a small area.

Effect of wolf predation on ungulate prey populations. That wolves depend wholly or partially on caribou in portions of their range has been well established. However, the impact that wolves have upon their prey population apparently varies greatly from one situation to another. Some studies have described the conditions under which wolves are capable of controlling the prey population. For the purpose of this report we define control as those situations in which removal of the wolves would result in a substantial population increase of the prey. In other words, they are cases in which other mortality factors cannot compensate fully for wolf predation.

Several studies of caribou populations have stated or suggested that wolf predation was controlling the study population. Miller and Broughton (1972), referring to their 1970 study of the Kaminuriak caribou herd, stated, "Pressures of wolf predation on the young of the Kaminuriak population may be a principal factor limiting the population's total growth. The importance of wolf predation on the young of caribou has not been fully realized." During this study the authors located 57 dead calves and adult females and concluded that the principal cause of calf mortality during the calving and post-calving period was predation by wolves.

Kuyt (1972) concluded in his food habits study of tundra wolves that since wolves kill many caribou calves, wolves could effectively limit caribou numbers.

Parker (1972) commented as follows:

> Pimlott et al. (1969) suggest that wolves may be capable of controlling deer populations when the ratio of wolves to deer does not exceed 1:100. If this ratio holds for white-tailed deer, then a much higher ratio would presumably fit a similar statement on the barren-ground caribou, with its much lower reproductive rate. In view of the calculated ratio of 1 wolf per 114 caribou for the Kaminuriak population in the spring, it seems quite possible that wolves may control this population.

Several other studies have suggested high calf losses to wolves (Clark 1971, Bos 1975). An instance where predators other than wolves have controlled a caribou population was reported by Bergerud (1971). He concluded:

> The 2 major mortality factors that appear to have limited population growth of caribou in Newfoundland between 1900 and 1967 are lynx predation of calves and hunting mortality of adults.... The primary limiting factor of the animals in the Interior and Avalon herds, 1957 to 1967, appeared to be lynx predation of calves in their first summer of life.

Predation - the Fortymile Caribou Herd

The present study was not designed specifically to ascertain the relationship of predation to caribou population dynamics, so much of the discussion that follows is based on circumstantial evidence. The purpose of this discussion is to assess the possible and probable impact of predators on the Fortymile herd by considering the observations from the current study and the findings of the studies discussed above.

Impact of predators other than wolves. During the course of this study golden eagles and grizzly bears were known or suspected predators observed killing caribou or feeding on recently-killed caribou. No quantitative data are available on rates of caribou take by the two species. However, some speculation is warranted. Between 1 June and 17 October 1973 Curatolo (1975) reported sightings of predator groups (he defined a predator group as one or more than one predator of the same species) as follows: 12 of brown bear, 14 different individuals; 14 of wolves, 17 different individuals; and 36 of golden eagles, an unknown number of individuals. He recorded the number of caribou/predator interactions for each of the 3 species as 4 for brown bear, 6 for wolves, and 13 for golden eagles. From these data and observations made from the air during the 1974 and 1975 summers, we conclude that golden eagles, brown bears, and wolves are relatively abundant in the summer range of the Fortymile herd. Further, golden eagles and brown bears are probably in daily contact with caribou from the initiation of calving (20 May) until fall. Observations made during this study and reports from the literature affirm that golden eagles and brown bears are probably in daily contact with caribou from the initiation of calving (20 May) until

fall. Observations made during this study and reports from the literature affirm that golden eagles and brown bears kill caribou. We propose that both species kill caribou with some degree of regularity - primarily during the first week or two after birth. Because the calving period stretches from approximately 20 May-10 June, and each newborn calf is vulnerable for a week or two, there are approximately 30 days when some calves are vulnerable to predation by these species. In addition, brown/grizzly bears are likely to encounter and kill caribou opportunistically over a much longer period. Although there is no firm basis by which to estimate the total number of brown/grizzly bears and eagles in the calving and post-calving range of the caribou herd, it is obvious that they are common. BBased on the experience gained in recent years from radio-collaring studies, it is likely that there are several times more predators in the area than were incidentally sighted while searching for caribou.

We have no data upon which to base an estimate of the rate at which either predator species kills and/or consumes caribou. During 1974 we made frequent flights during the calving period between 20 May and 4 June before caribou departed the calving area. Of five brown bear observations made during the calving period, one involved a brown bear eating a freshly-killed calf and one involved two bears feeding on a carcass which from the air could not be identified but was suspected to be a caribou calf. Of three brown bear observations during June, one involved two bears feeding on the remains of an adult bull caribou.

Of five eagles observed prior to June during 1974 one was feeding on a newborn calf.

Based on the above observations, references in the literature, and subsequent observations of bears and eagles feeding on newborn calves or unidentifiable (from the air) caribou carcasses on the calving grounds of the Porcupine and Western Arctic caribou herds, we believe that eagles and brown bears regularly feed on, and probably kill, caribou calves up to two weeks of age throughout the calving period. The most thought-provoking observation was made in June 1974 on the Porcupine herd calving ground. On one flight three brown bears were observed, each separated by about one mile, and each was feeding on a different caribou. At least two of the three were recently-killed and blood was observed on the respective bears' faces. At least one of the three was a calf, two were probably calves, and possibly all three were calves. This was two weeks after most calving had occurred. As an extensive aerial search was made over the adjacent area and no carcasses were noted, it did not seem probable that some natural calamity had killed the animals. Rather, we got the impression that perhaps when caribou are abundant at this particular time of year brown/grizzly bears could be relatively efficient as predators.

Relationship between Fortymile herd caribou and wolves

Pre-1947: The general comments by Murie (1944) and Skoog (1968) about wolves and their relationship to caribou in the Fortymile area are essentially the only information available prior to 1947 when initiation of the Federal Predator and Rodent Control (PARC) program made limited data available. Murie (1944) reviewed the available evidence concerning wolf numbers throughout Interior Alaska and concluded that wolves were abundant from at least 1880 to shortly after 1900, that they became scarce during the early 1900s and remained so to about 1925, after which they increased, and were abundant in the mid-1940s.

Skoog commented about the apparent historical relationship between statewide wolf and caribou abundance (Fig. 6). The wolf population apparently was high during the late 1800s, reached a low in the early 1910s, and increased to a high in the early 1930s. Wolf numbers then remained high as the caribou population decreased to a low in the 1940s, dropped in the early 1950s as the caribou started to increase, and increased during the mid-1960s through the early 1970s. Subsequently the caribou population has been greatly reduced again while wolves are abundant.

It is interesting to note that the trends in relative wolf and caribou abundance in the Fortymile area parallel the statewide trend (Fig. 7). These observations suggest that wolf numbers were high during periods of caribou population decrease and low during periods of caribou population increase. This suggests that periodically wolves may be an important factor in depressing caribou populations. The alternative argument is that prey abundance determines predator numbers.

1947-1959: From 1947 through 1959 the PARC program involved varying degrees of wolf control in the Fortymile herd's range. Apparently efforts were effective in substantially reducing wolf numbers, or control coincided with the natural wolf decline and precipitated it. At any rate, from Murie's comment that wolves remained abundant through the mid-1940s, we can contrast comments from the late 1940s and early 1950s and see that a substantial change must have occurred.

The PARC program was initiated in Interior Alaska in 1947 (Chuck Gray, pers. comm.). Frank Glaser was stationed in Fairbanks that year and established "getter" lines on the Steese Highway and in other areas. This level of work apparently continued until 1949 when getters and strychnine stations were deployed and aerial gunning was first used (Kelly 1949). Control of wolves was the major objective during this time and the area of caribou migration around Mt. Fairplay in the Fortymile country received priority. Joe Miner, Assistant District Agent, Fairbanks, continued operations along the Steese and Livengood Highways.

Wolves were apparently scarce by 1949-50 as Kelly (1950) stated that, "Glaser, after watching the caribou migration across the Steese

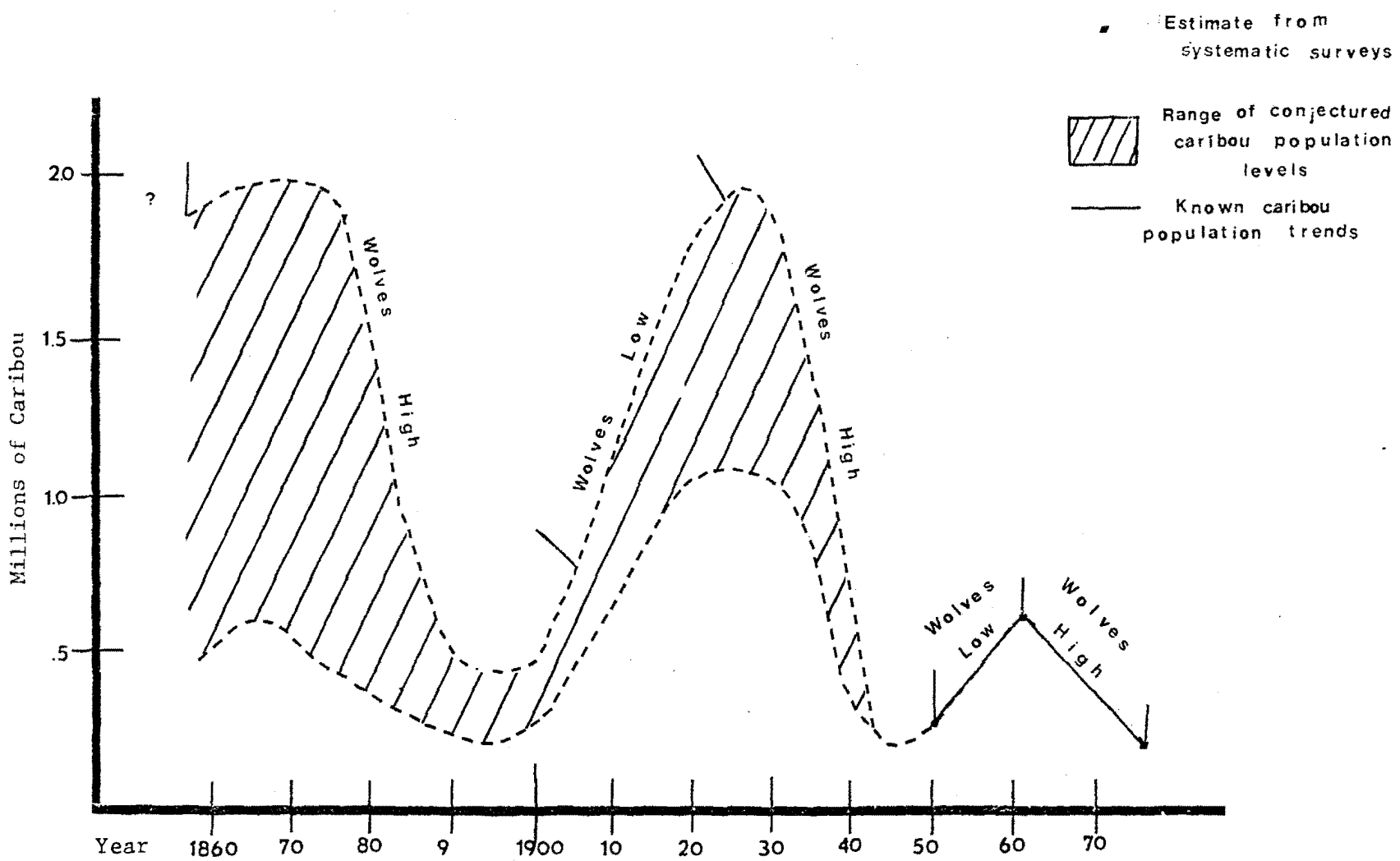

Fig. 6. Conjectured (1850-1949) and actual (1950-1977) estimates of caribou numbers and relative abundance of wolves in Alaska and adjacent Yukon Territory.

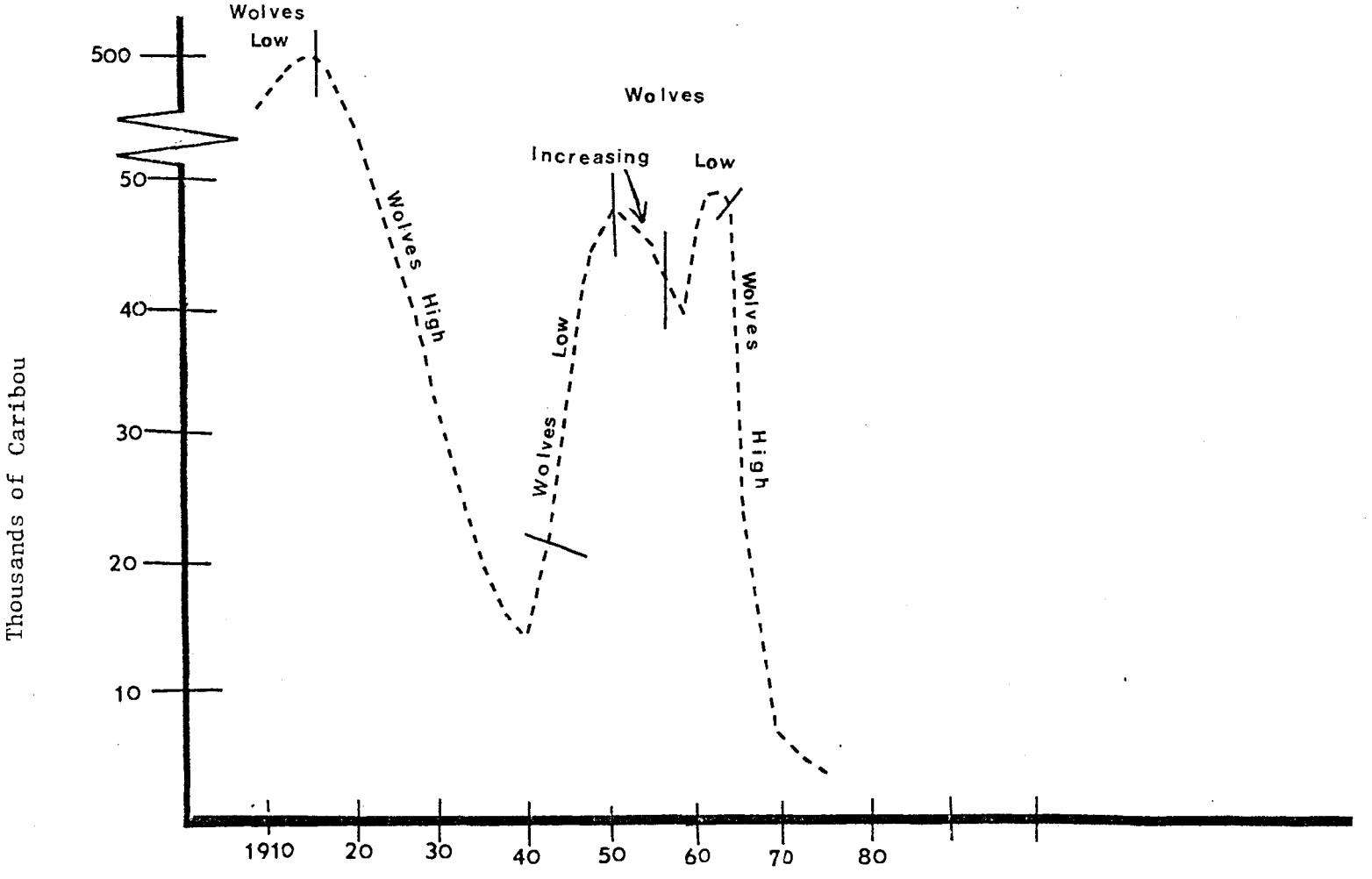

Fig. 7. Population trends of caribou and relative abundance of wolves in the Fortymile caribou herd's range.

Highway for nearly a week, reports no evidence of wolves with the herd." This view was echoed in 1950-51 as Kelly (1951) reported as follows:

> Reports from the Fairbanks District point out the change in game animal numbers in the Fortymile country where getter lines have been maintained for three years. Control has been secured in this area and the number of getters reduced from 150 to 75. Three years ago wolves were plentiful in the Fortymile and residents of this region spoke of large packs of wolves and lack of game...the caribou migrating three years ago contained few calves while last fall caribou calves showed up in good numbers.

Kelly (1952) reported that: "in 1951 getter lines were operated along the Livengood, Steese, Alaska, and Richardson Highways, and the Fortymile Road (i.e. Taylor Highway). Glaser observed that wolves and coyotes in these areas are under coutrol and he has reduced the number of getters in use."

Kelly's 1952 report contained the comments, "Moose and caribou are on the increase in this district since the local wolf packs have been destroyed" and "Getter lines have been kept in operation along the Steese Highway the last two years and during this time wolves have been scarce. Last fall during September several thousand caribou migrated from east to west over Twelvemile and Eagle Summits. During that time I had my getter lines in good shape and only one fox was destroyed."

Kelly reported in 1952-53 that Glaser took nine wolves with getters in the Fortymile country. Wolf numbers in the Fortymile and Eagle Summit areas were low. He concluded that the objective of the control program was to maintain the level of control that had been attained during the past five years.

In 1953-54 Kelly elaborated very little on the control program, although he stated control (usually getter lines) during at least one season of the year was conducted on the upper Yukon, Fortymile and Steese Highways, and Beaver Creek.

No Predator and Rodent Control reports referring to the Fortymile area exist for the period 1954 to 1957-58. Kelly (1958) commented on the situation in 1957-58 as follows:

> Additional surveys of the Steese-Fortymile herd continue to point up that a rather drastic loss has occurred in last year's calves as few yearlings are observed. It is this fact which has concentrated control in those areas the past year.... The low calf survival to yearling age in the Steese-Fortymile herd the past three years and in the increase in wolves over the same area seems more than coincidental.

Because no reports are available for the three years preceding Kelly's 1957-58 comments it is difficult to ascertain if the change in wolf numbers occurred through rapid increase through a reduced or

curtailed control program or possibly from ingress from surrounding areas. Olson's (1958) comment that, "It is interesting to note that wolves suddenly [emphasis mine] increased in the area between the White Mountains and the Taylor Highway in 1956 and 1957," suggests surprise at the increase. Stephenson (pers. comm.) believes that it is unlikely in Interior Alaska, where moose are common, that wolves would move great distances in close association with caribou. This suggests that ingress is less probable than natural increase in the above situation. Nonetheless it is interesting to note this increase in wolves coincided with the period when a large portion of the Fortymile herd wintered in the Ogilvie Mountains in Canada and a portion of the herd temporarily egressed from the Fortymile area. It is possible that their subsequent return was accompanied by some wolves.

A particularly interesting short-term correlation between calf survival and relative wolf abundance occurred from 1957-1960 (Olson 1959) and warrants thorough review. From 1953 (the first year that composition data are available) through 1955 the survival of calves from post-calving counts to the following spring ranged from 22 to 28 percent and averaged 24 percent (Table 2). Wolf control in one form or another had continued since 1947 when it was first implemented by Frank Glaser. This effort continued for three or four years until Joe Miner arrived, and the two did considerable control with the aid of aircraft. So, apparently wolf control was being carried out in the Fortymile area during this period. In 1956 and 1957 comparable caribou calf survival figures were reduced to 6 and 8 percent, respectively. The significance of these observations is clarified by Olson's (1958) comments:

> The actual causes of the high mortality rate during the first year of life for the past three years are not known or understood. There is little quantitative data providing any insight into the problem. Predation by wolves suddenly increased in the area between the White Mountains and the Taylor Highway in 1956 and 1957. Wolf densities decreased slightly in 1958 and by the spring of 1959, following three years of intensive predator control, wolves became relatively scarce. This is based on the number of wolves seen per flying hour by predator control teams operating in this area, as well as the number of wolves taken (Table 9). It should also be pointed out that as the predator control teams worked in the area they became more familiar with the terrain and distribution and activity patterns of the wolves, thus increasing their chances of encountering wolves.
>
> Calf survival was very poor in 1956-57 and 1957-58 during the periods when wolf densities were high. In 1958-59 when wolf densities apparently decreased, calf survival improved somewhat (Table 10). Whether or not the correlation between these two situations is a matter of cause and effect or merely coincidental is as yet unknown. However, the possibility exists that predation by wolves could have adversely affected calf survival and should be recognized as a potential source of early calf mortality.

In summary, the relationship between wolf and caribou numbers from 1947-1959 is an inverse one; the herd was increasing in the late 1940s and early 1950s presumably through increased calf survival which was coincident to lowered wolf numbers as a result of implementation and continuation of wolf control through 1953. Apparently control was relaxed in 1954-1956 which caused a sudden increase in wolf numbers with subsequent reduction in calf survival and a decrease in the population (see Fig. 7). It is interesting to note that once control efforts were increased again in 1957 and 1958 calf survival immediately increased as did the population.

1960-present - wolf status: In 1960 control of wolves by the PARC program formally ended in Alaska except on the Seward Peninsula reindeer range. This apparently had a substantial effect on wolf numbers in the Fortymile herd's range even though public hunting and trapping of wolves and paying bounties for wolves continued. From Table 7 we can see that the harvest under fairly intensive control efforts between 1949-54 averaged less than 28 animals per year and ranged from 10 to less than 39 per year. The PARC agents apparently relaxed control from 1954 through 1956-57; the population expanded and, under intensive control, 218 were taken the next two years. After control was terminated in 1959, the population apparently increased rapidly until by 1962 the population was large enough to sustain an average annual harvest of 84.3 from then until 1976 (1964 omitted). During this time annual harvests ranged from 51 (omitting 1964) to 134.

Although no attempts have been made to census wolves within the Fortymile range, we feel that a reasonable estimate can be obtained if we assume that: 1) the average annual harvest of 84 wolves from 1962-1976 was not reducing the annual increment to the wolf population and 2) the annual wolf harvest in the Fortymile range constituted 20 percent of the total population. These assumptions seem justified by the general opinion that hunting and trapping pressure on the GMU 20A wolf population during this same period was high and yet only 20-25 percent of the 20A wolf population was lost from fall to spring through harvest and natural mortality. Therefore we can solve the equation $.20X = 84$ wolves; $X = 420$ wolves. If we assume these wolves are distributed throughout the herd's 35,000 square mile range the average density is equal to 1 wolf/83.3 square miles. This may be a low estimate because comparable areas in adjacent Interior Alaska and Ssouthcentral Alaska with the same prey species available (i.e. moose, caribou, sheep, beavers, hares, etc.) had an average density ranging from 1 wolf per 30 to 50 square miles during the same period. Bob Stephenson (pers. comm.) has stated that 1/55 square miles is a reasonable fall density for this area and 1/75 square miles is a likely spring density. Based on these densities, we estimate that the area has a population of 420-636 wolves.

1960-present - caribou status: The Fortymile herd has gradually declined from about 40,000 to 50,000 caribou in 1960 to a minimum of 4,000 caribou in 1974. Because of discontinuous data from 1960-69, we have few population estimates or productivity figures. However, there

Table 7. Fortymile wolf harvest 1950-1974.

Year	Total Reported	PARC[3]	Other	Percent pups (of known age animals)	Source
1949-50	37[1,2]	16	21	n/a	Kelly 1950
1950-51	24[2]	10	14	n/a	Kelly 1951
1951-52	10	10	n/a	n/a	Kelly 1952
1952-53	31[2]	15	16	n/a	Kelly 1953
1953-54	39[2]	27	12	n/a	Kelly 1954
1954-56	n/a	n/a	n/a	n/a	
1956-57	140(223)	52(85)[4] 88(132)[5]	n/a	n/a	Olson 1957 Scott 1957 (memo)
1957-58	78[6]	78	n/a	n/a	Kelly 1958
1959	5[6]	3(11)	2	n/a	Olson 1959 & AGC files
1960	10[6]	n/a	10	50	Bounty Info. Forms
1961	25[6]	-[7]	25	n/a	Bounty Info. Forms
1962	59	-	59	38	Bounty Info. Forms
1963	81	-	81	13	Bounty Info. Forms
1964		-	29	n/a	Bounty Info. Forms
1965	51	-	51	28	Bounty Info. Forms
1966	70	-	70	45	Bounty Info. Forms
1967	134	-	134	33	Bounty Info. Forms
1968	84	-	84	40	Bounty Info. Forms
1969	n/a		n/a[8]	n/a	--
1970	n/a		n/a	n/a	--
1971-72	Sealing initiated - records poor				
1972-73	83			n/a - animals not aged	Sealing forms
1973-74	104				Sealing forms
1974-75	111				Sealing forms
1975-76	66			45	Sealing forms

[1] Does not include animals trapped for fur and not bountied.
[2] All of Fairbanks district.
[3] Minimal figures because many animals killed at bait stations and by M-44 (getters) were not recovered.
[4] Wolves taken and total observed (in parentheses) in Steese Highway portion of Fortymile range.
[5] Wolves taken and total observed (in parentheses) in Fortymile and Yukon (Eagle to Circle) drainages.
[6] Data incomplete.
[7] P.A.R.C. discontinued in Alaska in 1960 except for Seward Peninsula reindeer range.
[8] Bounty terminated 1969-70 regulatory year.

has been no explanation advanced to date to account for the documented substantial 1960-69 decline. Immigration to the Porcupine herd in 1964 has been suggested but this would not account for the apparent 1960-1964 decline nor the continuous post-1964 decline. Because of the seemingly consistent trend in wolf abundance and caribou numbers through 1960 (see Fig. 7) it follows that we should look critically at the correlation between increased wolf abundance after 1960 and the coincident continuous population decline. One factor that lends credibility to the correlation is the continuous upward trend in the population from the late 1940s through about 1953 or 1954 which was halted and followed by a slight decline from 1954-1958 when wolf numbers increased. In a somewhat predictable manner, after three years of intensive control ended in 1959, the calf and yearling survival greatly increased and the population again rapidly increased. Then wolf numbers began increasing and the caribou population began a continuous decline in 1960 after control ended.

The inverse correlation of Fortymile herd numbers and wolf numbers seems undeniable. A cause and effect relationship, however, can only be inferred. But we can gain further insight into this possible cause and effect relationship by employing different assumptions in making extrapolations.

Modelling the relationship between wolves and caribou

Recently Bergerud (pers. comm.) calculated natural mortality rates for North American caribou herds exposed to various rates of wolf predation. He concluded that herds exhibiting poor calf survival also lose 7-13 percent of adults (i.e. yearlings and older) to natural mortality, annually. The only data available on yearling recruitment into the Fortymile herd when wolf numbers were "high" (not controlled) are from spring counts in 1957 and 1958 and from fall counts in 1972, 1973, and 1974. Also a yearling recruitment figure can be obtained for fall 1962 through extrapolation (see Table 8). The average recruitment rate of the female cohort was 3.96 percent (4%) during years when the wolf population was high. If we contrast this 4 percent adult female recruitment rate to the 7-13 percent mortality rate proposed by Bergerud, then we should expect a net loss of 3-9 percent of adult females per year. If we take the mid-value of 6 percent and add known hunting mortality to this figure we can predict a decline from 15,000 adult females in 1960 to 2,339 adult females in 1972 (Table 9). If, in fact, mortalities and recruitments of these magnitudes were experienced by the herd, we could explain the observed decline in the herd without resorting to explanations of undocumented or unconfirmed losses through immigration or a catastrophic "die off."

Alternate extrapolations suggest that predation (including harvest by humans) could have accounted for the decline. Several of the most frequently used methods of estimating the impact of wolf predation on ungulates include: 1) determining the wolf:prey ratio at which wolves will effectively control prey numbers (i.e. the number of prey will increase if predation is reduced); 2) ascertaining the average number of prey animals consumed per wolf, over a specific time period;

Table 8. Yearling recruitment data from the Fortymile caribou herd for years data are available when wolves were not controlled/or their population was high.

Date	Wolves	Yrls/100F	Yrl F/100 F	Calf % in Herd	Sample Size
Oct 1956		-	-	5	737
Feb 1957	high	3	1.5	-	1120
Oct 1957		-	-	5	576
Feb 1958	high	3	1.5	-	458
Oct/Nov 1962		-	-	11.4	743
Oct 1972	high	16.5	8.3	12.5	672
Sep/Oct 1973	high	9	4.5	10	3307
Sep 1974	high	8	4	13	1738
			$\bar{X}$ = 3.96	$\bar{X}$ = 9.5%	

Table 9. Projection of the hypothetical number of cows in the Fortymile herd between 1960 and 1972.

Year	A Number of females harvested by humans	B Percent natural mortality	A + B	C Percent yearling recruitment	(A+B)[1] -C	Therefore, number of females in following year
Assume 15,000 females in 1960, 7% yearly loss to natural mortality, 5% yearling recruitment.						
1960	564	1050	1614	750	-864	14,136
1961	1050	990	2040	707	-1333	12,803
1962	349	896	1245	640	-605	12,198
1963	137	854	991	610	-381	11,817
1964	110	827	937	591	-346	11,471
1965	326	803	1129	574	-555	10,916
1966	775	764	1539	545	-994	9,922
1967	206	695	901	496	-405	9,517
1968	191	666	857	476	-381	9,136
1969	113	640	753	457	-296	8,840
1970	430	619	1049	442	-607	8,233
1971	1079	576	1655	412	-1243	6,990
1972	712	489	1201	350	-851.5	6,139
Assume same as above with 11% yearly loss to natural mortality.						
1960	564	1650	2214	750	-1464	13,536
1961	1050	1489	2539	677	-1862	11,674
1962	349	1287	1636	584	-1049	10,625
1963	137	1178	1315	531	-784	9,841
1964	110	1100	1210	492	-718	9,123
1965	326	1032	1358	456	-902	8,221
1966	775	946	1721	411	-1310	6,911
1967	206	817	1022	346	-676	6,235
1968	191	759	950	312	-638	5,597
1969	113	706	820	280	-540	5,057
1970	430	667	1097	253	-844	4,213
1971	1079	595	1674	211	-1463	2,750
1972	712	456	1168	138	-1030	1,720

[1] All figures in this column are negative because A and B are negative numbers (i.e. animals lost) and C is positive (i.e. animals recruited).

and 3) calculating the amount of biomass necessary to satisfy the daily food intake needs of wolves.

The control ratio index: Using the index of a control ratio, Pimlott (1967) first calculated that wolves would control white-tailed deer if the ratio exceeded 1 wolf:100 deer (assuming a 37 percent annual productivity for the deer and the other assumptions in Table 10).

Mech (1970) applied the index to other ungulates by stating that control was probable if the number of wolves/lbs of prey exceeded the ratio 1:25,000. Parker (1972) felt that other factors such as reproductive potential had to be considered and felt that because caribou are considerably less fecund than white-tailed deer perhaps 1 wolf:104 caribou would be the ratio at which the caribou were controlled. Applying this concept to the Fortymile herd, we calculated earlier that there were at least 420 wolves in the range of the Fortymile herd during the period of the early 1960s to 1976. Although good baseline population data for caribou are not available for 1960, we feel that 40,000-50,000 animals is a reasonable estimate. Thus, the wolf:caribou ratio was between 420:40,000 and 420:50,000 or 1 wolf:95-119 caribou. However, if we use the less conservative estimate of wolf density, 1/55 square miles, then the ratio would be 636:40,000 and 636:50,000, or 1 wolf:63-79 caribou. Because of the very high production rates (37%) of the prey involved in Pimlott's and Mech's wolf:prey calculations to determine "control effective" ratios, we thought it necessary to derive a comparable ratio for the Fortymile caribou herd where observed production has been considerably less. As shown in Tables 11 and 12, we calculate that given the existing sex and age composition of the herd in fall 1972 (the first year in which sufficient data were available to allow such a calculation), the average weight of animals in the herd from September to May was 230 pounds (104.54 kilograms). Also, to avoid the problem of estimating the large loss of calves in summer and probable average weight of calves (which radically alters the total number of calves calculated as eaten) we simply prorated the average year-long food requirement to the September-May period and concluded that the average wolf (as in Table 12) would require 158-165 caribou to maintain a stable wolf:caribou ratio, i.e. the controlling ratio. If we assume that only one half the wolves' ungulate diet was caribou and the other half consisted of moose, we can divide the number of caribou in half (162/2 = 81) and conclude that a wolf population greater than 494 or 617 (494/40,000 or 617/50,000) could have reduced the Fortymile caribou herd. Our estimated wolf population of 420-636 was thus capable of controlling caribou numbers. At any rate the balance of wolves and caribou was certainly a critical one. Wolves alone could have initiated a decline in the Fortymile caribou herd or small-scale emigration alone could have initiated the post-1960 population decline, even without losses from hunting.

Calculation of the average consumption rate: The second method of calculating the average number of caribou taken per year per wolf can be highly variable. Burkholder (1959) and Skoog (1968), working in areas having alternative prey species similar to those of the Fortymile herd, calculated a consumption rate of about 12 caribou/wolf/year. Four hundred twenty wolves consuming 12 caribou/year would consume 5,040

Table 10. Calculation of number of deer required to support a wolf population of one per 10 square miles (from Pimlott 1967).

Basic Assumptions	
Size of area	100 sq mi
Wolf population	10
Gross food consumption by wolves (avg. wt. 60 lbs.)	
Oct-May	8.4 lbs/day
June-Sept.	7.2 lbs/day
Wastage	20 percent
Species other than deer - winter	10 percent
summer	20 percent

Age composition and weight of deer killed

winter - fawns,	30%	80 lbs.
adults,	70%	150 lbs
summer - fawns,	80%	40 lbs.
adults,	20%	150 lbs.

Total kill of deer - winter 177
summer 190
367 deer

Density of 10 deer/sq mi, productivity of 37% is required to support 1 wolf/10 sq mi.

Table 11. Calculation of the mean weight ($\bar{X}$) of caribou in the Fortymile herd based upon 1972 fall sex and age composition; average weights for the herd obtained from Skoog (1968).

Assumptions:		Average weight:[1]
Calves	= 12.5% of herd	52.5 kilograms (115.5 lbs) sexes averaged
Yearlings	= 9.8% of herd	82.8 kilograms (182.1 lbs) sexes averaged
2 yr old males	= 3.4% of herd	117.5 kilograms (258.5 lbs) males only
2 yr old females	= 8.0% of herd	98.5 kilograms (216.7 lbs) females only
3+ yrs old females	= 51.5% of herd	103.0 kilograms (226.6 lbs) females only
3-5 yrs old males	= 9.3% of herd	152.3 kilograms (335.1 lbs) males only
6+ yrs old males	= 5.5% of herd	195.8 kilograms (430.8 lbs) males only

therefore, $\bar{X}$ for all animals at time of fall composition in 1972 Fortymile herd = 104.54 kilograms, or 229.99 lbs.

[1] Average of average fall and average post-rut weights.

Table 12. Assumptions and calculations used to determine the number of Fortymile caribou required to sustain one wolf.

Basic assumptions to calculate a wolf:caribou ratio (after Pimlott 1967)

Basic Assumptions*

Size of area	100 sq mi	
Wolf population	10	
Gross food consumption by wolves (avg. wt. 85 lbs)		
Oct-May (8 mo)	243 days	8.4 lbs/day
June-Sept (4 mo)	122 days	7.2 lbs/day
Wastage		20 percent
Species other than caribou - winter (1% or)		10 percent
- summer		10 percent

Age, composition and weight of caribou killed

winter - calves	30%	115.5 lbs
adults	70%	230.0 lbs
summer - calves	80%	64.45 lbs
adults	20%	230.0 lbs

*Assumptions of food consumption per day, wastage, and percent of diet composed of non-ungulate food recommended by ADF&G wolf biologist, Bob Stephenson.

Calculations

Oct-May = 243 days @ 8.4 lbs/day = 2041 lbs - 10% for alternate prey = 1837 = .8x x = 2296 lbs of caribou required/wolf
.3x(115) + .7x(230) = 2296
x = 11.7
.3x = 4 calves
.7x = 8 adults

June-Sept = 122 days @ 7.2 lbs/day = 878 lbs - 10% for alternate prey = 790 = .8x x = 988
.8x(64.5) + .2x(230) = 988
x = 10.3
.8x = 9 calves
.2x = 2 adults

Year-round 13 calves + 10 adults = 23 caribou/year

Loss to be compensated - 4 calves, Oct-June; 10 adults, year-round
(9 calves lost June-Sept can be included in total loss, i.e. they would likely have been lost to other natural factors)

If 100 caribou older than calves produce 14 calves by September, population could sustain itself if wolves took all 14 before the next September.

But, calves are lost to additional mortality factors.

From the observed annual loss (Sept to Sept) we can calculate the productivity necessary to sustain this loss:

Year	Calf % of herd	Yearling % in herd	Compensatory recruitment	No. Yrlgs/ 100 adults	% Survival
1971	12.5	5	14.3 -4(taken by wolves)	5.26	.51
1973	10	5	11.1 -4(taken by wolves)	5.26	.74

Thus, in 1971:
23.61 calves in September = 10 yearlings following September
Need, 21% claves in herd in September or 165 animals producing at observed rate
In 1973:
17.51 calves in September = 10 yearlings
Need, 15.8% calves in herd in September or 158 animals producing at observed rate

Therefore, 158-165 caribou/wolf/year needed to compensate loss and maintain caribou numbers

caribou per year. This approach yields variable interpretations of the impact that such a level of consumption would have on the prey population depending upon how many calves are presumed to be among the caribou eaten. One way of gaining this additional insight would be to prorate the 12 caribou/year to the 9 months of September through May and subtract the loss of calves during these three months. This simplifies calculation because if wolves select young calves the average annual consumption rate could greatly increase because of the small weight of each calf.

If the average percentage of calves in the herd from 1956-1975 was 9.5 percent in October (Table 8) it is quite probable that since 1960 the herd would have declined continuously with mortality from wolves alone. If the herd contained 40,000 animals older than calves in 1960 and had 9.5 percent calves in October there would have been a fall calf recruitment of 3,800. It is improbable that yearling recruitment would have been more than half that of the calves.

Prorating the average caribou consumption per wolf to 9 months we calculate therefore 75 (9/12) x 12 = 9 caribou/wolf/year. Four hundred twenty wolves x 9 caribou/wolf equals 3,780 caribou consumed during the 9-month period which is equal to the September calf increment. Because it is probable that the yearling increment would be considerably less than estimated and the wolf population was larger than estimated, it is likely that the herd would have suffered a continuous decline from wolf predation alone. Additional hunter-imposed mortality and other natural mortality would have guaranteed the decline.

Calculation of daily biomass intake needs: To briefly illustrate the third approach using the index of the average weight of food consumed per wolf per day to estimate the impact that wolf predation has had on the herd we calculate as follows: consumption rates are 3.5 to 7.5+ lbs/day/wolf. Therefore, 7 lbs x 365 days x 420 wolves = 1,073,100 lbs/year. Or if half the wolves' diet is caribou then 536,555 lbs of caribou/230 lbs per caribou = 3,400 caribou/year.

The wolf:caribou balance: All approaches suggest that the wolf: caribou "balance" was a precarious one in 1960. If our estimates of wolf numbers are conservative and the actual density was approximately 1 wolf/50 square miles, then 700 wolves, rather than 420, were in the area. The balance may have been such that wolf predation could have precipitated the caribou decline from 1960 regardless of human harvest. Together the two factors could easily account for the observed decline. Bergerud (pers. comm.) recently reviewed wolf predation on caribou in North America and suggested that on ranges where moose occur, wolves in a density of 1:25-100 square miles should regulate caribou to a rangewide density of 1/square mile. At densities above this both he and Haber (1977) imply or state that wolves will control the caribou population.

Our present ratio of 400-600 wolves:4000-5000 caribou yields a ratio of 1:10, or a density of wolves (if half their diet consists of caribou), that is eight times the level necessary to effectively control the number of caribou.

Effects of alternate prey: Observations in the Fortymile area suggest that wolves feed heavily upon moose as well as caribou, i.e. they are not solely dependent upon caribou. Theoretically, this must be the case because from all of the preceding calculations we can see that the existing wolf population could consume annually as many caribou as remain in the entire population. It is instructive to make calculations regarding moose similar to the above regarding caribou. No good estimates of moose numbers in the area exist. However, we do have some basis for calculating approximate moose densities. We can extrapolate from unpublished data in ADF&G files collected by William Gasaway and Larry Jennings as follows. From current studies being conducted to ascertain sightability of moose from aerial surveys, Gasaway believes that a sightability index of 0.50 is a reasonable factor for most terrain and types of aerial moose surveys conducted in this area; i.e. approximately 50 percent of the total number of moose are seen during a survey. Jennings surveyed several areas in fall 1977 and the results appear in Table 13. A third density category (poor) for moose, not included in Table 13 was designated based on subjective estimates of density differences between average and poor. It was believed that moose were substantially less than half as abundant in the poor areas as in the average density area. Considering this and rounding values from Table 13, we ascribed densities of moose to acres in the Fortymile caribou herd's range (Table 14). The proportion of the herd's range in each of the three density classifications was determined by delineating the areas contained in the known good, average and poor moose densities and estimating the percent of area falling into each category (see Table 14). As shown in the table we estimated a total of 9,285 moose in the caribou range.

The average calculated moose density in the Fortymile area of 0.27/square mile seems to be relatively high compared to what moose biologists familiar with the area think might be present based on a comparison with GMU 20A areas where moose density is well known. We feel the calculated density is liberal.

If we calculate that the "control" ratio of wolves to moose is 1:30 and of wolves to caribou is 1:162 then we can calculate how many wolves would be needed at present to control the combined prey as follows: 9,285/30 = 209.5 and 4,500/162 = 27.8; 310 + 28 = 338 wolves which is the number of wolves that could theoretically control the present number of ungulates within the Fortymile area. Thus, the number of wolves present are capable of controlling the present ungulate populations and are likely to contribute to further declines.

Another question (although academic) is that of the effect of past predation on the present moose situation. Fig. 8 graphically depicts the available data on moose recruitment. From early reports (Kelly 1949, 1950) it appeared that moose began increasing in the area in the late 1940s as did caribou when wolf control was implementd. Unfortunately, data on recruitment are available only since 1957. As shown by Fig. 8, the moose recruitment indices (i.e. calf:cow and small bull:cow ratios) have continuously declined from a peak about 1960 when predator control

Table 13. Derived moose densities in count areas within the Fortymile caribou herd range, 1977.

Subjective moose density	Area square miles	Moose seen	Observed moose/sq mi density	Sightability	True density	Observer
Average (Ladue River)	216	33	0.15	.5	0.30	Jennings
Average (Dennison Fork, Fortymile River)	504	35	0.07	.5	0.14	Jennings
Good (Ketchumstuk Flats)	252	60	0.24	.5	0.48	Jennings
Good (Mt. Fairplay area)	160	38	0.24	.5	0.48	Jennings
Good (Chena River drainage)	2,000	-	0.25	.5	0.50	Gasaway

Table 14. Estimated acreages of the Fortymile caribou herd's range containing good, average and poor moose densities.

Moose density	Miles in type	Total moose
good (0.50/sq mi)	4,300	2,150
average (0.25/sq mi)	27,100	6,775
poor (0.10/sq mi)	3,600	360
Total	35,000 sq mi	9,285 moose

$$\text{Average density} = \frac{9,285}{35,000} = 0.27 \text{ moose/sq mi}$$

ceased. Certainly weather can influence moose survival and recruitment (Coady 1976) in this area, but the long continuous decline implicates predators. Unfortunately, moose harvest data are not available for the period before 1963 when the harvest ticket program was initiated. From Table 15 we can see the total reported human harvest of moose in the caribou range. One column shows the number of wolves that could be supported by the moose actually taken by hunters, which is a relatively low number. An additional 34 wolves could have been sustained for one year during the year when the most moose were harvested by humans. Considering our range of estimates of wolf numbers, 420-636, this is a relatively small number, although even a small hunter kill could have been critical if the wolf-moose numbers were otherwise perfectly balanced.

Sheep are the only other ungulate species available but are excluded in the following discussion because Heimer (pers. comm.) estimates there are fewer than 350 animals in the present range of the Fortymile caribou herd. Limited data suggest a substantial decline in sheep numbers in the area in recent years which has paralleled declines of caribou and moose populations.

Impact of predation on calves

Portions of the preceding discussion add credence to the hypothesis that predation is the principal mortality factor accounting for the observed high rate of calf loss during the first two months post-partum. The observed chronology of calf mortality from 1973-1975 (Fig. 9) indicates that disease, parasitism, malnutrition and adverse weather are not likely major factors, because these factors would result in a massive loss of calves at birth or within the first few days post-partum. To the contrary, relatively good calf survival, 55 calves/100 cows or more, was documented over a week after most calving had occurred. Subsequent mortality appeared more as a linear decline than the abrupt decline which a natural catastrophy would produce. This pattern of mortality can be attributed to some combination of factors including intra-specific competition, accidents, and predation. Because there is no evidence of the first two occurring to any degree greater than normal, it seems improbable that they were major causes of mortality.

Determination of the actual impact of wolf predation, like that of predation by brown bears and eagles, upon the caribou population during this study depends primarily upon circumstantial evidence. Curatolo (1975) concluded that wolf predation on calves during 1973 may have been the major reason for the disappearance of over half the calf crop between June and September 1973. He provided the following estimate of wolf predation:

> The estimate was made by extrapolating the number of wolf kills observed during the post-calving period. During this 56-day post-calving period 150 hours of observation revealed two wolf kills. The number of caribou observed per hour averaged 414 from a herd of approximately 6,800 animals.
>
> The following equation extrapolates the wolf kill for the period: (56 days) x (24 hr/day) x (2 kills/150 hrs) x (68,000 caribou/414 wolves) = 294 kills.

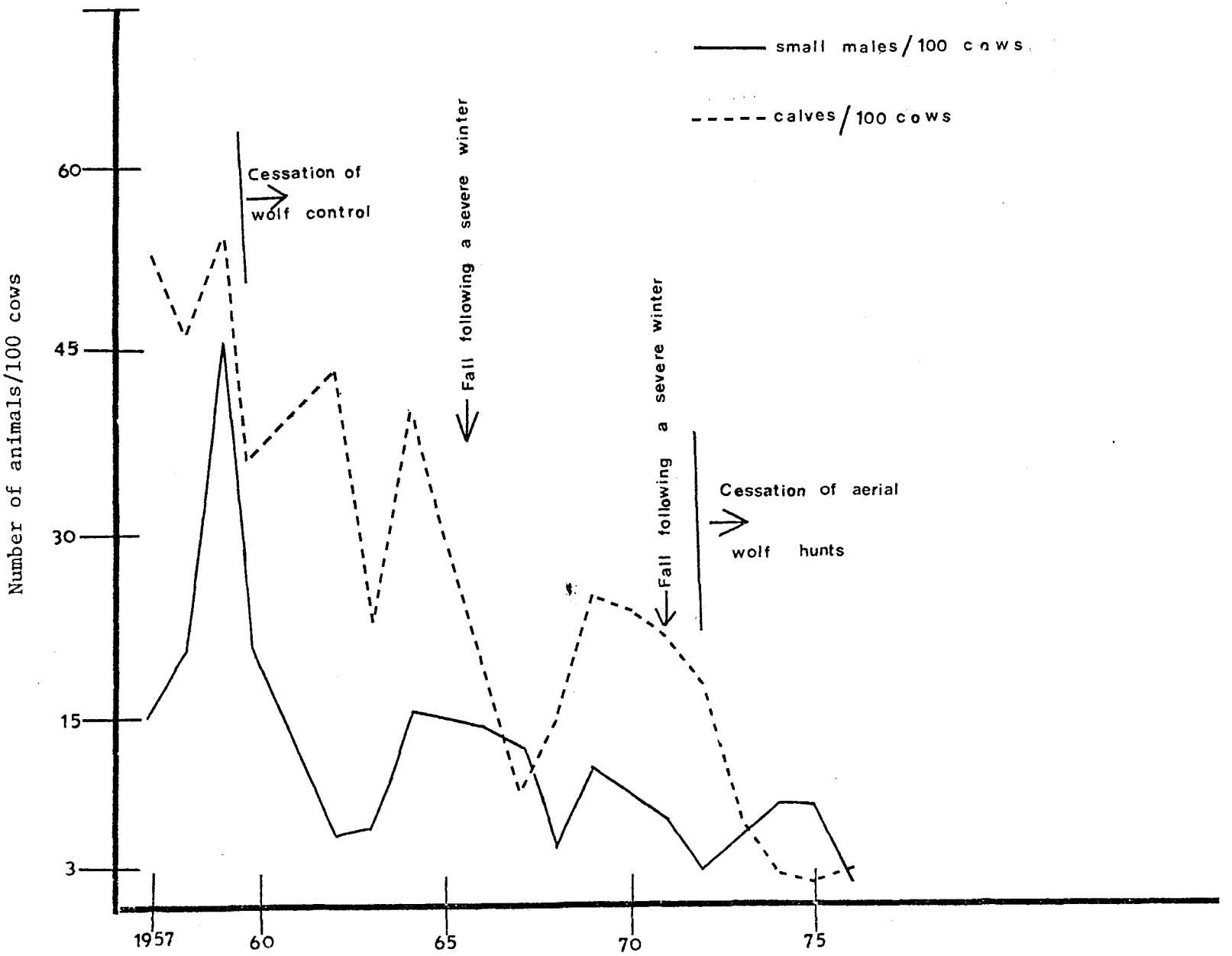

Fig. 8. Number of small males (yearlings) and calves/100 cows in the moose population within the range of the Fortymile caribou herd.

Table 15. History of moose harvest in the Fortymile caribou herd's range, i.e. one-half of GMU 20C.[1]

Year	Total reported harvest	Total reported cows	One-half reported cows	One-half reported harvest	Wolf[2] units
1963	703	39	20	352	29.3
1964	808	182	91	404	33.7
1965	714	89	45	357	29.8
1966	547	117	59	274	23
1967	533	92	46	267	22
1968	585	91	46	293	24.4
1969	692	136	68	346	28.8
1970	605	112	56	303	25.3
1971	496	79	40	248	20.7
1972	474	59	30	237	19.8
1973	665	93	27	333	27.8
1974	486	-	-	243	20.3
1975	223	0	0	112	9.3
1976	206	1	1	103	8.6
			529	3,872	

[1] It is beyond the scope of this paper to precisely determine what portion of the total 20C harvest occurred witin the range of the Fortymile caribou herd. Because 20C occupies an area approximately twice as large as the caribou range, one-half the total harvest in 20C is used.

[2] Wolf units are defined as one-half the GMU 20C moose harvest divided by the average moose/year consumption rate (12 moose/year/wolf), eg. 352/12 = 29.3.

Although this extrapolation is crude it does show that a large number of kills could take place with only a few being witnessed even under intensive observation. One must also take into account that most of the observations were made in the daytime, so the estimate may be low since wolves do most of their hunting at night (Murie 1944, Kelsall 1957).

Loss during August dispersal must also be considered, since it covers part of the time under consideration. If one assumed the same predation rate for this period as in post-calving, then approximately another 150 kills could be accounted for since August dispersal lasted half as long. Total kill, therefore, can be estimated at 294 + 150 = 444 caribou.

Fig. 9 shows the chronology of calf mortality in 1973, 1974, 1975, and 1976. It is obvious that initial production of calves is excellent --likely being over 60 calves per 100 cows during calving. Subsequent survival for at least a week or two is good (i.e. until the first week in June). Considering the chronology and extent of calf mortality, predation appears to be the major mortality factor. Nutrition, disease, parasites, and weather are not ruled out as mortality factors, but they are probably not major ones.

In most instances these factors would be most apt to cause an early death as newborn calves are weakest the first couple of days of life. Few calf carcasses were observed. However, we recovered one carcass that was being fed upon by a grizzly bear. The calf had lived for several days according to criteria established by Johnson (1951) for elk calves. The calf contained a suprising amount of mesentary fat which suggests that it was in good nutritional condition.

Wolf predation rates as calculated by Curatolo (above) combined with some natural mortality and predation by other predators can plausibly explain the observed pattern of calf mortality.

Other mortality factors

Windchill/weather. Much research has been accomplished in Canada to evaluate the impact of weather on calf mortality (Cottle 1959; McEwan 1959, 1960; deVos 1960; Kelsall 1960, 1968; Lentz and Hart 1960; Hart et al. 1961; Pruitt 1961). A general conclusion is that although weather can theoretically have an adverse impact on the calf crop, only calves less than a few days old are severely affected by weather because the animals are quite precocious. Only one case of a reduction in the calf crop as a result of adverse weather has been reported, and this occurred when conditions persisted over several days at the exact period when most calves were being born. Caribou investigators in Alaska have pointed out that conditions on Alaskan calving grounds are generally milder than those in northern Canada. Representative weather data are not available for the Fortymile herd's calving range. Curatolo (1975) did describe typical Tanana Hills weather, however, and pointed out the local precipitation patterns

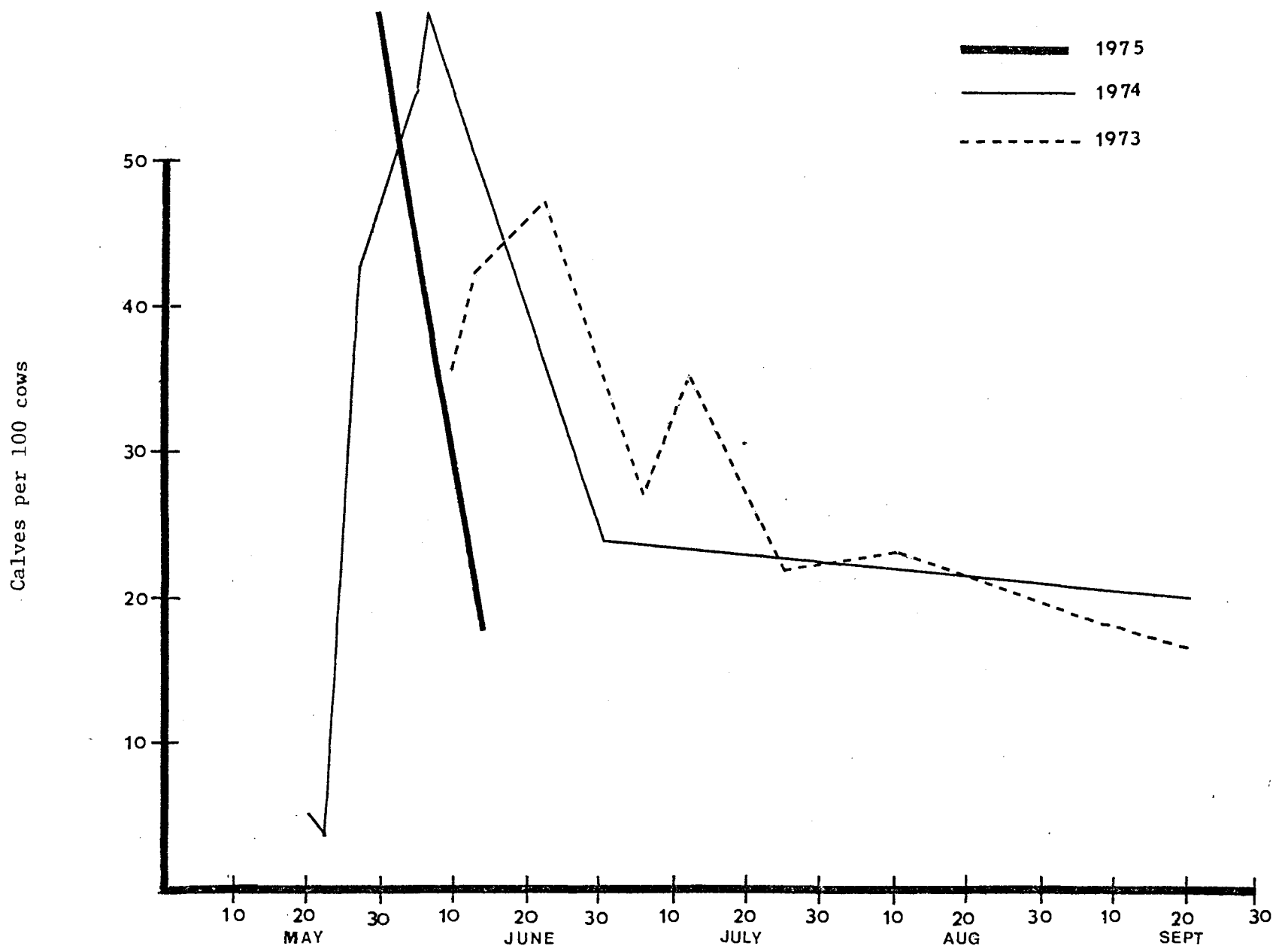

Fig. 9. Summary of cow:calf ratios observed in the Fortymile caribou herd in 1973-75 which indicate chronology of calf mortality.

characteristic of the calving season. It is interesting to note that the Delta caribou herd (the closest neighboring herd to the Fortymile) realized its highest recent initial calf production and survival during 1976. Department biologists surveyed that area because they were concerned that catastrophic calf loss might result from the low temperatures and heavy snowfall in spring 1976. We also documented highly successful calving in the Western Arctic herd in 1975 and 1976 under weather conditions that were harsher than those that occurred on the Fortymile calving grounds during this study.

We did not observe any carcasses of calves suspected to have succumbed to factors other than accidents or predation. It remains possible that these factors could predispose calves to predation or loss by accidents but we think that this was improbable.

Range

We believe that range is not the major factor limiting growth of the Fortymile herd at present or even a likely factor contributing to the decline of the herd in recent years. Range considerations are discussed more thoroughly in the Range Reconnaissance section of this report (Job 3.16R).

RECOMMENDATIONS

Available data suggest that the habitat of the Fortymile caribou herd can support many times more animals than are present and a vast amount of circumstantial evidence suggests that predation is the principal limiting factor. We therefore recommend that:

1) Professional wildlife biologists critically review the data in this report and design a program to rehabilitate the caribou herd if the public desires such action.

2) With or without the actions recommended in 1) above, a scientific study should be conducted to ascertain the factors limiting population growth (or causing the continuous decline) of the herd.

ACKNOWLEDGMENTS

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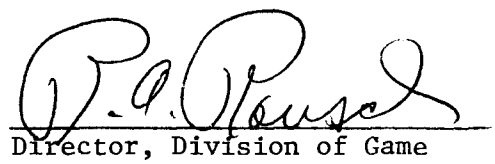

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Appendix I. Age structure of adult caribou (28 months or older) from the Fortymile herd killed by hunters in fall 1972.[1]

Age Class[2]	Females	Males	Unknown	Total
2	22	20	16	58
3	28	25	17	70
4	24	15	13	52
5	12	14	7	33
6	14	12	5	31
7	10	5	4	19
8	14	9	1	24
9	9	4	3	16
10	10	1	3	14
11	8	1	3	12
12	6	0	2	8
13	4	0	0	4
14	2	0	0	3
	165	106	75	346

[1] These 346 jaws were randomly selected from a total jaw collection containing 720 adult jaws collected from along the Taylor Highway.

[2] All teeth aged by the cementum annuli technique of ultraviolet florescence (Johnson and Lucier 1975).

FINAL REPORT (RESEARCH)

State: Alaska

Cooperators: James L. Davis, Richard Shideler and Robert E. LeResche

Project No.: W-17-6 and W-17-7 Project Title: Big Game Investigations

Job No.: 3.15R Job Title: Movements and Distribution of the Fortymile Caribou Herd

Period Covered: July 1, 1973 through June 30, 1975 (limited 1976 observations included).

SUMMARY

The Steese-Fortymile caribou herd has historically been one of Alaska's major herds. Murie (1935) estimated that the herd numbered approximately one-half million during its maximum expansion in the 1920s. The herd has since declined in numbers and its range has contracted. During the 1950s the herd numbered 50,000 and ranged from the White Mountains on the west, eastward through the Tanana Hills to the Ogilvie Mountains north of Dawson, Yukon Territory.

The current minimum population estimate is 4000. Although the herd still uses much of the same range as during the 1950s, its calving area has shifted from the White Mountains to Clums Fork (also called Coulombe's Fork) of Birch Creek in the Tanana Hills. The herd spends most of spring, summer, and fall above timberline primarily in the western two-thirds of its range. During winter most animals move to timbered areas, primarily in the Ladue and Fortymile River drainages. Pre-calving and post-calving movements occur along the alpine uplands of the Chena, Salcha, Charley and Fortymile Rivers.

Intensive monitoring of the calving area demonstrated that central and peripheral areas could be identified. Distribution and density of animals on the calving area changed as calving progressed. The western portion of the calving area, primarily Volcano and Anvil Creeks, received the earliest and heaviest use. Calving occurred from the third week of May through the first week of June.

Distribution and movements in relation to habitat are discussed, and compared with other caribou herds.

Seasonal changes in group size are discussed. Maximum mean group size occurred during late calving and in the post-calving period. Minimum mean group size occurred during dispersal in August. Environmental influences on group size are discussed. Two models of caribou social structure are presented and discussed. Criteria used in determining whether caribou form persistent social bonds are presented and discussed.

CONTENTS

BACKGROUND

The Steese-Fortymile Caribou (*Rangifer tarandus granti*) herd (Fortymile herd) has historically undergone significant population fluctuations and shifts in distribution. The primary change has been a contraction of its range as the herd declined in numbers. Aspects of abiotic (e.g. climate, slope, aspect) and biotic (e.g. vegetation, insects, predators) features of the Fortymile herd's habitat have been discussed by Skoog (1956) and Curatolo (1975).

The herd's distribution and movements are discussed in relation to three time periods: the historical past (1905 to 1969), the recent past

(1970-1972), and the present (1973-1975). Our summary of the historical past is drawn primarily from Skoog (1956, 1968) and Hemming (1971). Readers desiring more information are referred to these sources for elaboration. The recent past was discussed by LeResche (1975) who reviewed unpublished ADF&G files, primarily those of Larry Jennings, Tok Area Biologist.

Distribution and Movements

Historical Past (1905-1969)

Maximum distribution of the Fortymile herd probably occurred between 1905 and 1935, when the herd ranged over approximately 85,000 square miles (Fig. 1). Occasionally movements extended beyond the area delimited in Fig. 1. From 1923 to 1933 part of this herd moved north and south through the Nenana area, and until 1935 large numbers crossed the Yukon River near Woodchopper. From 1905-1935 there were three main wintering areas - the White Mountains/Circle area, the Ogilvie Mountains and the Fortymile/Ladue River area. Although most caribou wintered in these areas, scattered groups remained throughout the herd's range. In spring caribou which wintered in the Ogilvie Mountains migrated westward through Eagle. Animals that spent the winters in the Fortymile River drainage and adjacent areas of Canada migrated northwesterly across the Middle Fork and North Fork of the Fortymile River, usually traveling to the White Mountains before turning back to the summer range. Caribou that spent the winter in the White Mountains and the flats near Circle migrated southeastward through the Chena River highlands to summer range. Apparently the main calving area was in the White Mountains northwest of the Steese Highway; however, some calving may have occurred in other areas as well (see Skoog 1956). Caribou spent the summer in the alpine areas at the heads of the Chena, Salcha, Charley, Goodpaster, and Fortymile Rivers. Fall migration routes were essentially the same as those used in spring.

The herd decreased dramatically in the late 1930s and by the early 1940s had likely reached its lowest level (Skoog 1956). As its numbers declined, the herd's range contracted from 85,000 to 35,000 square miles (Fig. 1). The southern parts of the Fortymile River, the Sixtymile River, and the North Fork of the Ladue River became the main wintering areas, with only a remnant of the herd still wintering in the White Mountains. Since the 1930s only a few caribou have wintered in the flats between Circle and Circle Hot Springs.

A major portion of the herd spent the 1956-57 winter in the Ogilvie Mountains, and the following spring about 30,000 caribou migrated north with the Porcupine herd (Skoog 1968). However, it appears they later returned to the Fortymile herd and there was no net loss of animals (see Job 3.13R this report). From 1956-1969 this herd often wintered in the three "traditional" areas; the bulk, however, used the Fortymile-Ladue River portion. A variable number of widely dispersed groups wintered in the headwaters of the Goodpaster, Salcha, Charley, and Fortymile Rivers (Hemming 1971). During this period major spring movements occurred along summits of the Tanana Hills. Most of the herd spent the 1958-59 winter in Canada.

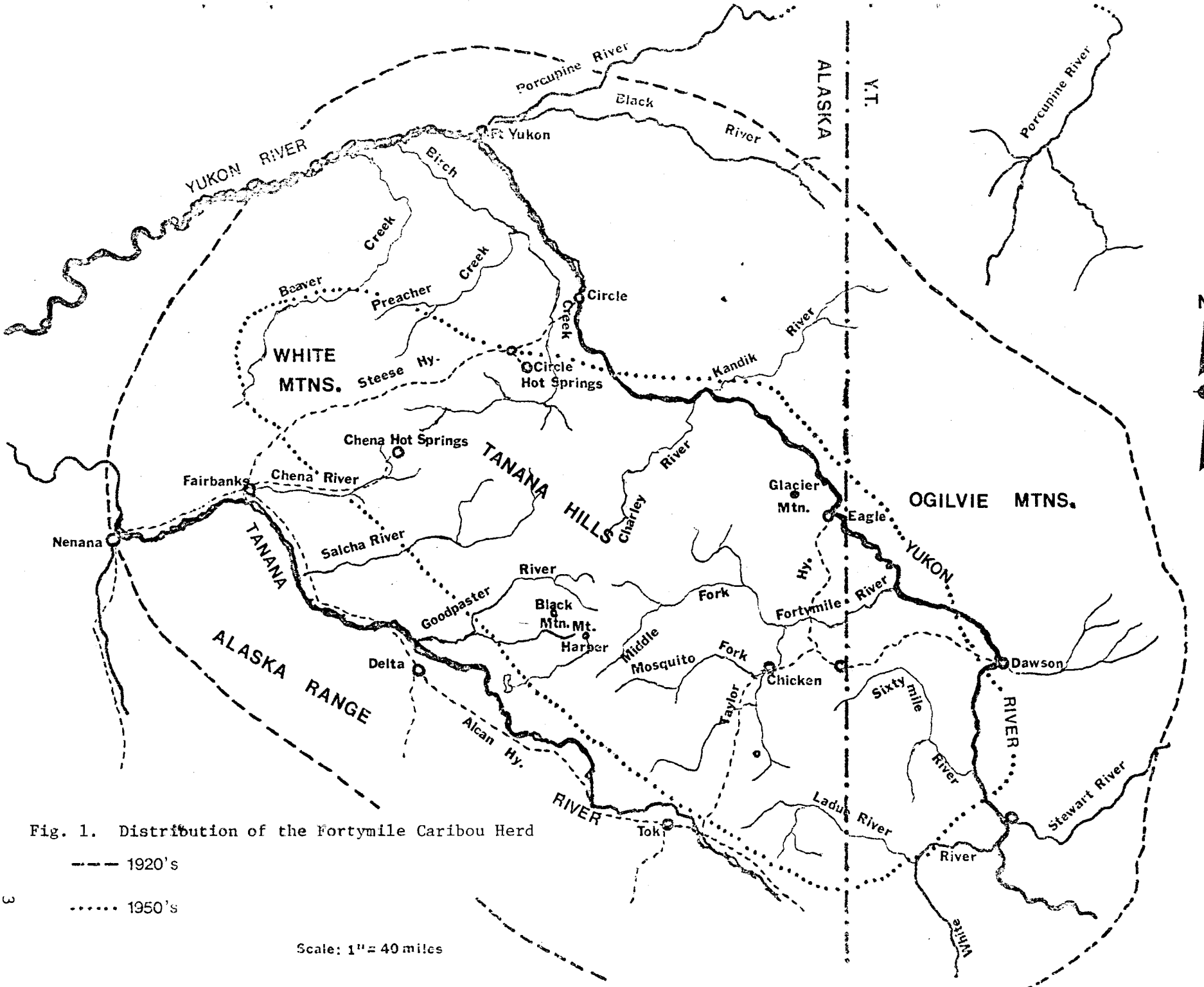

Fig. 1. Distribution of the Fortymile Caribou Herd

---- 1920's

..... 1950's

Scale: 1" = 40 miles

The most recent major spring movement across the Steese Highway was in 1960 when 30,000 caribou returned southward during post-calving migration between 2-11 June (Table 1). Between 1955 and 1960 only a few caribou were available to hunters near the Steese Highway during fall. In 1962 much of the herd moved to the White Mountains during summer, and recrossed the highway in early October. For several years afterwards caribou were available to hunters along the Steese Highway.

In 1963-64 much of the herd wintered in the Ogilvie Mountains and moved north with the Porcupine herd in spring. Most other animals spent the winter and summer in the Mt. Harper area. In fall 1964 they moved northwest almost to the Steese Highway but did not cross, and returned to the Mt. Harper area (Lentfer 1965). By mid-January 1965 a portion of this group had crossed the Taylor Highway (Table 2) to winter in the Ladue River area. The remainder of the herd wintered in the Salcha River/Goodpaster River area.

McGowan (1966) reported an unusual movement northwest of the Steese Highway in fall 1965. Several thousand animals wintered in the White Mountains that year. Some of these animals then moved to the Sawtooth Mountains southwest of Livengood, where they had not been seen for 20 years. The remainder of the herd wintered in the Fortymile/ Sixtymile River country. Specific information about the Fortymile herd is lacking from 1966-1970.

Recent Past (1970-72)

Larry Jennings, Tok Area Biologist, reported in 1970 that ca. 500 Fortymile caribou crossed the Alaska Highway and reached the foothills of the Wrangell Mountains by March.

In 1971 most of the herd wintered in the Ladue River area, with scattered groups located throughout the Fortymile River drainage and probably the entire Tanana Hills. From 18-23 June 1971 the calving segment coalesced to form a post-calving group numbering 3000-4000 near the head of the Salcha River (ADF&G files). This group apparently moved northeast through the upper Charley River/Fortymile River area, and then scattered. In early October most of the herd (an estimated 5000 caribou) moved east from Glacier Mountain and crossed the Taylor Highway at American Summit and Poly Summit. The herd then scattered over the Ladue River wintering area, and some animals drifted back to the upper Fortymile country during the winter. The "typical" northwestward drift, especially of the calving segment, occurred in March and April 1972.

The timing, location, and direction of the 1971 and 1972 post-calving movements were similar, suggesting that similar calving areas were used. Concurrent aerial surveys of the Black Mountain, Joseph Creek, and Goodpaster areas indicated that few caribou were present during late June-early July. On 20 June 1972, 600 caribou were located northwest of West Point, moving northwestward. Another 1300 caribou, either resting or moving northeastward, were located between Crescent Creek and Salcha River. In early June 3500 or more were reportedly moving northward from the upper Healy, Fortymile, and Charley Rivers

Table 1. Summary of Fortymile caribou herd crossings and harvest - Steese Highway.

Year	Crossing Dates	Estimated Harvest	Comments	Source
1954	December	850	main herd wintered on Birch Creek	Skoog (1956)
1955	None in fall Spring: calving & post-calving	150	10,000 crossed - calved at head of Preacher Creek	Skoog (1956)
1956	Few in fall May-June:	100	30,000 crossed northwestward enroute to White Mtns. calving area-returned on post-calving migration to summer range	Skoog (1956)
1957	Few in fall May 20-26 and June 7-19	50	5000 crossed to calving grounds; returned in June on post-calving migration to summer range	Olson (1958)
1958	Fall: N/A May 3-20 and June 3-18	N/A	calving and post-calving	Olson (1959)
1959	Few in fall May (?) and June 13-17	N/A	2000 crossed in calving migration (most of herd remained in Canada); returned on post-calving migration	Jones (1960)
1960	Few in fall May (?) and June 2-11	N/A	30,000 crossed in calving migration and returned on post-calving migration	Jones (1961)
1961	Few in fall June 9-13	40	caribou unavailable along Steese-remained east and south; 9300 on post-calving migration-large number calved south of Steese	Jones (1963)
1962	Early October	35	"thousands" crossed southeastward - had moved northward undetected during summer	Skoog (1963)
1963	End of September None in spring	215	main northwest movement of herd in fall reached Birch Creek and turned back-few along Steese no calving northwest of Steese Highway	Skoog (1964)
1964	October	200	caribou readily available-moved near Steese in October and remained in high country south of highway, then moved southeast	Lentfer (1965)

Table 1. Continued.

Year	Crossing Dates	Estimated Harvest	Comments	Source
1965	October-November None in spring	90	several thousand moved to the White Mtns. in fall-crossed between mile 50-100	McGowan (1966)
1966	N/A	N/A		
1967	Few in fall No spring movement	5	animals generally farther to east all year	Hemming and Glenn (1968)
1968	N/A	N/A		
1969	N/A	N/A		
1970	N/A	316		Jennings (Unpub. data)
1971	August 7-27 (most of crossing around August 20)	179	two-thirds of harvest from Steese Highway; one third from Birch/Harrison Creek	Jennings (Unpub. data)
1972	N/A	6	3 from Preacher Creek; 3 from Steese Highway	ADF&G files
1973	N/A	13	2 on Birch Creek; 11 on Steese Highway (Twelvemile Summit to Miller House)	ADF&G files
1974	N/A	3	1 on Steese Highway; 2 on Medicine Lake	ADF&G files
1975	N/A	8	6 on Steese Highway (Twelvemile Summit to Miller House); 1 on Medicine Lake; 1 on Birch Creek	ADF&G files

Table 2. Summary of fall Fortymile caribou herd crossings and harvest - Taylor Highway.

Year	Crossing Dates	Estimated Harvest	Comments	Source
1954	July 12-20 August 15-September 9 October 11-20 November 11-14	850	much of herd remained in Fortymile-Sixtymile country during summer; August-September, moved northwestward across Taylor; recrossed Taylor in October between Boundary and Chicken; in November, large segment again moved northwestward, settled for winter in Birch Creek/ Charley River area	Skoog (1956) and Olson (1957)
1955	October 12-November 1 November 10-25	2175	largely between Mile 20-110, caribou heading eastward to winter in Canada near Dawson several thousand recrossed westward to winter in Fortymile country	Olson (1955)
1956	September 25-October 10	742	heading eastward between American Summit and the Dawson turnoff (Mile 85-14)	Olson (1957)
1957	September 28-October 23 (main crossing October 1-15)	598	between Fortymile R. and Eagle (mile 105-122); small size of bands and the scattered erratic movement pattern suggested that considerably fewer caribou crossed than in previous years	Olson (1958)
1958	Late April-May 10 October 9-end of October (Main crossing October 14-20)	N/A	majority of fall movement eastward between Polly Creek Summit and Boundary	Olson (1959)
1959	First week October-end of October (majority by October 14)		main crossing eastward; Mt. Fairplay to Chicken no spring crossing	
1960	October 25	1338	eastward crossing between Mile 51-111	Jones (1962)
1961	October 5-18	1645	eastward crossing; harvest mostly Mile 90-110; some taken mile 3-160 (Mt. Fairplay area)	Jones (1963)

Table 2. Continued.

Year	Crossing Dates	Estimated Harvest	Comments	Source
1962	Late September-end of October (majority October 20-23)	425	eastward movement mostly Miles 85-102 and 121-138	Skoog (1963)
	Minor movements in November and in December		eastward movement miles 3-65	
1963	Early-late September	110	small part of herd crossed eastward at American Summit-most of remainder crossed late October-November (?)	Skoog (1964)
1964	Late October	200	only a few crossed eastward in October; majority of herd settled into Mosquito Fork, Goodpaster River, and South Fork of Fortymile River; the easternmost parts of herd crossed to Ladue River in December-January	Lentfer (1965)
	Sometime in December-January			
1965	August	200	herd of several thousand crossed eastward between Eagle and Boundary	McGowan (1966)
1966	August 5-10	1900 (for entire herd)	5,000-10,000 crossed between Mile 100-145 heading southeast; animals alone recrossed, heading west	Glenn (1967)
	Late August-early September			
	October 20-past October 25		crossed heading southeast, Miles 22-55	
1967	August-early November	500	Eastward crossing between Miles 90-146; some caribou had summered along highway; moved east during this fall period	Hemming & Glenn (1968)
1968-69	N/A			
1970	October	N/A		Jennings (Unpub. data)
1971	2nd week October-end of October	N/A	10,000-12,000 caribou crossed eastward, mostly Mile 75-105; heavy harvest, possibly excessive	Jennings (Unpub. data)
1972	October 6-23	1330	10,000 animals moved near highway near Mile 100; later moved westward away from highway	Jennings (Unpub. data)

Table 2. Continued.

Year	Crossing Dates	Estimated Harvest	Comments	Source
1973	Season: August 10 - March 31; Major crossing October 8-17	34	most of harvest along American Summit; most of crossing miles 50-100, especially mile 50-80 movement eastward	Curatolo (1975) Jennings (Unpub. data)
1974	Season: August 10 - September 20	33	harvest highest near American Summit; no information on crossing dates, although animals had moved to within 5 miles of highway on September 18	Jennings (Unpub. data)

toward Glacier Mountain. A month later a major return movement southward to the head of the Middle Fork occurred. The herd then dispersed over the Fortymile River alpine area. By late September much of the herd was near Glacier Mountain moving eastward toward the Taylor Highway. This large group neared the highway and then reversed its movement. From early September to mid-October the large group made almost a full circle from the upper Fortymile River. Apparently much of this group remained in the Fortymile drainage during winter, although a few drifted across the Taylor Highway in the Mt. Fairplay vicinity.

Between 15 and 17 November 1972 at least 700 caribou crossed the East Fork of Chena River above Van Curler's Bar and were later observed resting on the ridges between the East Fork and Clums Fork.

Location and Use of the Calving Area

Interestingly, the Fortymile herd has shifted its primary calving activity southeastward from the White Mountains to the Tanana Hills (Skoog 1956, Curatolo 1975, LeResche 1975) (Fig. 2).

Historical Past (1905-1969)

Until 1963 most of the Fortymile herd moved westward across the Steese Highway in spring, calved in the White Mountains, then recrossed the Steese Highway during post-calving migration (see Table 1). Within the principal White Mountains calving area (see Fig. 2) the upper ridges of Bear, Quartz, and Champion Creeks were most heavily used (Olson 1956). As recently as 1960, 30,000 caribou moved northwestward across the Steese Highway to calve in the White Mountains (Jones 1961). In 1961 only 9300 were observed crossing the Steese Highway (Jones 1963). From 1963 through the present no calving has been noted in the White Mountains and no significant spring movement across the Steese Highway has been observed (Table 1).

Although relocation of the calving area seems to have occurred rather abruptly, earlier records indicate that by 1955, and probably earlier, some calving occurred at the head of the Middle Fork of the Fortymile River, and along the Birch Creek/Chena River/Salcha River divide (Olson 1956, Skoog 1956). Although most calving occurred in the White Mountains in 1956, groups containing cows and newborn calves were found along the Chena River/Birch Creek/Salcha River divide on 28 May 1956, which suggests that calving occurred there also. In addition, a map of calving distribution (Olson 1956:79) indicated that the Clums Fork area was used. In 1957, following a reported emigration (see Job 3.13R) of a large part of the Fortymile herd to the Porcupine herd (Skoog 1968), Olson (1958) commented that movement to the calving area was later than usual and that a large segment of the herd calved in the area drained by the south and west forks of the upper Charley River. He reported other caribou moving toward the White Mountains, and approximately 5000 crossed the Steese Highway in the Twelvemile Summit area between 20-26 May.

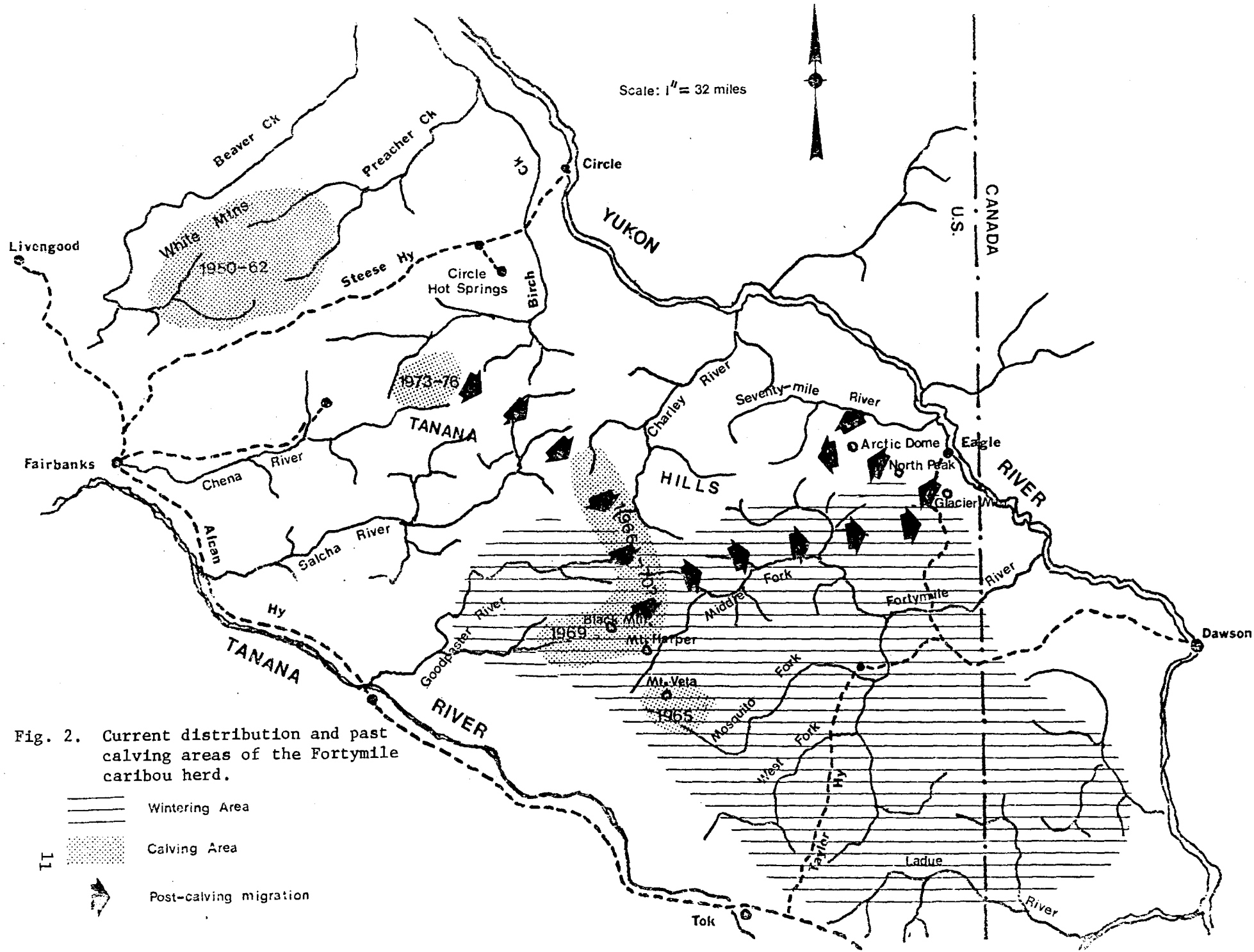

Fig. 2. Current distribution and past calving areas of the Fortymile caribou herd.

Wintering Area

Calving Area

Post-calving migration

In 1958 a considerable number of cows calved en route to the White Mountains, along the Chena River/Birch Creek divide. Animals that calved in the White Mountains in 1958 forded Birch Creek near the confluence of Clums Fork and the North Fork of Birch Creek en route to the calving area. In 1959 most of the Fortymile herd wintered and calved in Canada (Jones 1960). In 1960 most calving occurred in the White Mountains, although a "few hundred" caribou calved south of the Steese Highway (Jones 1961). In 1961 a large number of cows calved south of the Steese Highway (Jones 1963). This was the last year that a significant number of animals calved north of the Steese Highway. Skoog (1963) reported that in 1962 most of the cows calved in the mountains encompassing the upper drainages of Birch Creek and the Chena, Salcha, Charley, Goodpaster, and Fortymile Rivers.

In 1963 most calving occurred along the upper drainages of the Chena and Salcha Rivers (Skoog 1964). A large portion of the Fortymile herd emigrated to the Porcupine herd in spring 1964 (Skoog 1968). Those animals which wintered in the Mt. Harper region in 1964 apparently calved there or along the upper Charley, Salcha, and Chena River highlands (Lentfer 1965).

Records are scanty from 1965-69, but a calving area was observed in the vicinity of Mt. Veta in 1965, and the Mt. Harper vicinity from 1966-69 (Glenn 1967; Hemming and Glenn 1968; Jennings, ADF&G files). Nevertheless, it is likely that some animals continued to calve in the vicinity of Clums Fork during that period, and based on the limited surveys conducted it is not improbable that this was the primary calving area.

Recent Past (1970-1972)

Jennings (ADF&G files) observed calving in 1971 in the upper Middle Fork of the Fortymile River, near Mt. Harper and Black Mountain. Scattered calving also probably occurred throughout much of the alpine country at the heads of the Salcha, Goodpaster, Charley, and Fortymile Rivers. A group of 1000-2000 caribou was observed on 18 June 1971 moving in an easterly direction near Little Windy Gulch. This behavior suggested that some calving could have taken place along the Birch Creek/Chena River divide. From 18-23 June the calving segment coalesced to form a post-calving group of 3000-4000 near the head of the Salcha River. As stated earlier, the timing, location, and direction of the 1971 and 1972 post-calving movements were similar, which suggests that similar calving areas were used.

OBJECTIVES

To determine movements, distribution, and traditional migration routes of the Fortymile caribou herd in Alaska.

To determine movement responses to environmental factors.

PROCEDURES

ADF&G personnel conducted periodic aerial surveys to determine the herd's distribution and movements from 1973 to 1976. They used various types of fixed-wing aircraft including Cessna 180, Cessna 185, Helio Courier 250, and PA-18-150 Super Cub in these surveys and a Bell 206B helicopter to conduct post-calving and fall composition counts. Resultant locations of caribou and trails were noted on USGS topographic maps (scale 1:250,000) or sectional aeronautical charts (scale 1:500,000) filed in the Fairbanks office.

A review of available literature and notations of caribou trails during these surveys were combined to determine the historical distribution and traditional migration route of the herds.

Observers recorded habitat use and group size during these surveys and compared these to those of other caribou herds in the literature, and with ongoing research Job 19.14 (this report). "Group" was defined as any number of caribou functioning as a unit.

FINDINGS AND DISCUSSION

Distribution and Movements (1973-1976)

During the winter of 1972-73 caribou wintered in scattered small groups in the Birch Creek, Fortymile, Charley, and Goodpaster River drainages. Apparently several hundred caribou wintered in the Black Mountain vicinity. No caribou or signs of caribou were seen northwest of the Steese Highway. Although there were no specific flights over the herd's traditional winter range (Ladue River/Walker Fork area), the direction that caribou were moving in October and November suggested that the majority of the herd probably wintered there or on the Kechumstuk Flats (Jennings, ADF&G files). During March the "traditional" drift northwestward toward the calving grounds occurred.

The 1973 calving area was on the south side of Clums Fork of Birch Creek, primarily between Volcano Creek and the head of Sheep Creek (Fig. 2). Post-calving movement was eastward along the ridges separating the Chena River and Birch Creek drainages to the heads of Big Windy and Puzzle Creeks. The caribou then crossed the head of the Salcha River near Little Windy Gulch and continued south across the ridges at the heads of Williams and Gulch Creeks. Here the group split into two groups; one headed up each side of Crescent Creek to the head of Moraine Creek and continued southward along the Goodpaster River/Charley River divide. By 29 June most of the post-calving aggregation was on the ridges just west of Joseph, and by 11 July the aggregation was on the southern slopes of Glacier Mountain heading toward North Peak. Heavily-used trails on the southern slopes of North Peak indicated that this route had also been used in the past. By 22 July the aggregation reached the head of Copper Creek, and began to disperse. During August caribou were scattered in small groups throughout the upper Fortymile and Seventymile River drainages. By early September animals were beginning to aggregate in the area north of Glacier Mountain. From 11-24 September approximately

4000 caribou of all sexes and ages moved southeastward from North Peak to Glacier Mountain. The animals stalled near Comet Creek, moved westward, then started east again. On 10 October a large number of caribou crossed the Taylor Highway near Steele Creek Dome. However, more of the herd crossed along the southern portion of the highway (Mile 50-80). By late October the bulk of the herd was scattered throughout the timbered areas along the Ladue River. In December scattered small bands were located in the upper Salcha River, Charley River, and Joseph Creek areas. During February and March 1974 wintering bands were located in the upper Middle Fork of the Fortymile River, especially along Molly Creek. There was little evidence of wintering caribou in the Birch Creek/upper Chena River/Circle vicinity.

During late March 1974 only a few caribou were located in the Mt. Veta/Mt. Harper/Kechumstuk area. By mid-May small groups of cows were found in the upper Salcha/Charley Rivers moving toward the calving grounds. The cow portion of the herd moved to the Clums Fork calving area along the same routes used on the pre-calving and post-calving migrations in 1973. Heavily-used trails were especially noticeable along the divide between the East Fork of the Chena and Salcha River drainages, primarily along the heads of Gulch and Williams Creeks. No caribou could be located in the White Mountains and few were observed in the Charley River area. Bulls and yearlings were scattered along the migration route in the upper Salcha River area. Although most calving occurred in the Clums Fork area, some scattered calving occurred en route. The timing and the route of the 1974 post-calving migration were similar to those of 1973. From the calving area the animals moved up Crescent Creek, then northeastward to upper Copper/Slate Creeks. By 22 July, 2000 caribou were located on the southern slopes of Glacier Mountain. A week later the animals moved to the North Peak and Arctic Dome areas, from which point they dispersed in August. In mid-September 1500-2000 caribou moved eastward past Glacier Mountain. However, before crossing the Taylor Highway they changed direction and began moving southwestward. No information regarding the 1974 Taylor Highway crossing was obtained. Most of the Fortymile herd wintered along the South Fork of the Ladue River. As in 1973-74 few caribou wintered in the northwestern portion of the herd's range.

The Fortymile herd calved in the Clums Fork area again in 1975. Trails in the snow suggested that the same pre-calving migration routes were used as in 1973 and 1974. The 1975 post-calving migration resembled that of 1973 and 1974. On 9 June approximately 1500 animals were located in a one-half square mile area, at the confluence of Crescent and Moraine Creeks. On 11 July most of the herd was located in the alpine area between North Peak and Glacier Mountain. No observations of dispersal during the summer were made. Fall migration appeared to be later than usual. By the third week of September most animals were scattered in large groups along the Charley River and Copper Creek. No directional movement was noted, and several large groups of bulls were found, which suggested that rutting had not started. Scattered large groups were found in October west of the Taylor Highway in the Kechumstuk area, but apparently there were no major crossings until early winter (possibly November or December). On 30 December several hundred caribou

were found between Prindle Volcano to Boundary, and others were crossing the Taylor Highway from the Kechumstuk area.

Limited observations suggested that distribution and movements of the herd in 1976 were similar to those in 1973-75. Observations of migration routes to and from the Clums Fork area and use of the Clums Fork area indicated that spring and summer distributions were similar to those of preceding years. The North Peak/Glacier Mountain vicinity appeared to be a regrouping area for the fall migration. Apparently many widely scattered small groups of caribou crossed the Taylor Highway in early winter 1976.

These observations suggest that the distribution and movements of the cow/calf segment of the Fortymile herd were remarkably similar from 1973 through 1976. In all four years major migrations occurred in the North Peak area during post-calving and fall migration, and in the Little Windy Gulch, Crescent/Moraine Creek, and upper Williams/Gulch Creek areas during pre-calving and post-calving. Each year the same areas were used during summer and winter, although a more southeastern distribution probably occurred during the winter of 1974-75. Spring/summer observations of the noncalving (primarily bulls and yearlings) portion of this herd were limited in most of our study years. Generally it appeared that many yearlings and bulls drifted from wintering areas toward the calving area but at a slower rate than the cows. The eastward moving post-calving aggregation of cows and calves normally intermingled with the bulls and yearlings, which were moving westward, in the general vicinity of Crescent Creek. The herd then consolidated and moved eastward. This general pattern of pre-calving separation and post-calving intermingling was reasonably well documented for this herd in the past (Olson 1957, 1958), and for most other caribou herds (Lent 1966b, Skoog 1968, Parker 1972, Bos 1974).

Conclusions

A comparison of the movements and distribution of the Fortymile herd during the recent past (1970-72) and the present (1973-76) leads to the following conclusions:

1) Although some investigators have concluded from limited data that from 1970-72 the primary calving area was in the Mt. Harper area, other data suggest that a substantial number of cows have calved in Clums Fork since 1957.

2) There was little change in wintering areas from 1970-76. Although a few wintering animals were scattered throughout the herd's range, most animals wintered in the Ladue and Fortymile River drainages.

3) Chronology of movements related to calving, routes of migration, and distribution of caribou were nearly identical during 1973-76, and limited data suggest they may have been similar from 1970-72.

Location and Use of the Calving Area (1973-76)

Location of Calving Area

During 1973-76 the Fortymile herd calved on Clums Fork of Birch Creek, primarily between Volcano Creek and upper Grizzly Creek (Figs. 3 and 4). Scattered calving by late-arriving individuals also occurred along the Chena/Salcha/Charley River divide. The heaviest concentration of calving animals was along the higher open ridges between Volcano and Anvil Creeks. The individuals that arrived late in the season tended to calve along the upper reaches of the eastern extent of the calving area (upper MacLean, Dexter, and Anvil Creeks), as well as between Bear and Volcano Creeks. Individuals that calved early in the season tended to move back through the calving area toward the Salcha/Chena River divide. This movement initiated the post-calving migration. On 28 May 1974 about 200 adults and many calves were found just south of the divide separating Clums Fork from the East Fork of the Chena River. By 4 June 400-500 adults (plus calves) moved up Dexter Creek and into the Chena River drainage and by 12 June over 1400 cows and their calves moved along the Salcha/Charley River divide. The vanguard group was 10 miles east of Little Windy Gulch at that time.

Although the calving area and distribution and behavior of calving animals were basically the same during 1973-76, minor between-year differences occurred. Comparison of distribution of animals on 27 May 1974 to those of 27 May 1975 showed that calving animals were dispersed over a smaller area in 1975 than in 1974 (Figs. 3 and 4) and were distributed slightly more to the east. Calving appeared to be slightly earlier in 1975 than 1974, as reflected by extensive trails in snow banks in western Bear and Volcano Creeks. Regardless of these slight differences, the general pattern in all four years was remarkably similar.

We observed no caribou during a 3 June 1976 aerial survey of the Clums Fork area, but tracks in snowbanks and trails out of the calving area indicated that essentially the same areas were used in 1976 as during the preceding three years. At that time we located the calving portion of the herd moving eastward between the head of the west fork of Big Windy Creek and Gulch Creek.

Calving Chronology

In most years Fortymile herd calving begins in the third week of May, and ends during the first week of June (Table 3). Unfortunately, between 1953 and 1961, calving chronology data were obtained only for the White Mountains calving area. During several years some calving occurred in other areas and chronology may have differed between areas. Observations of small groups of parturient cows dropping out of the migration to calve en route have been common (Olson 1957, 1958, 1959; Skoog 1956; Jones 1960, 1961). If migration to calving areas is delayed, cows closest to parturition may stop short of the "intended" calving area. In 1957 many animals wintered in Canada and a larger than usual

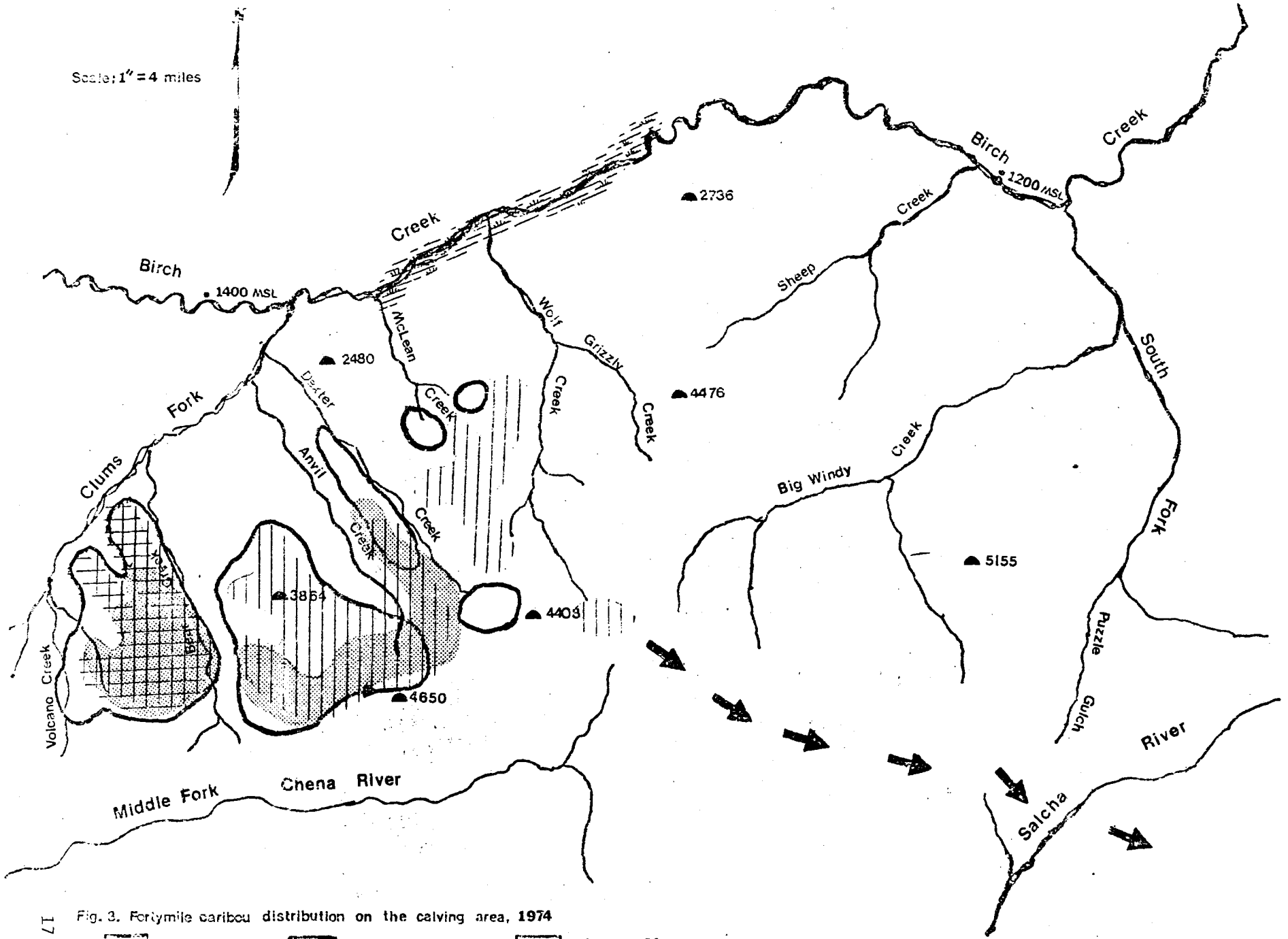

Fig. 3. Fortymile caribou distribution on the calving area, 1974

May 20 | May 21 | May 25 | May 27–30 | Post-calving movement

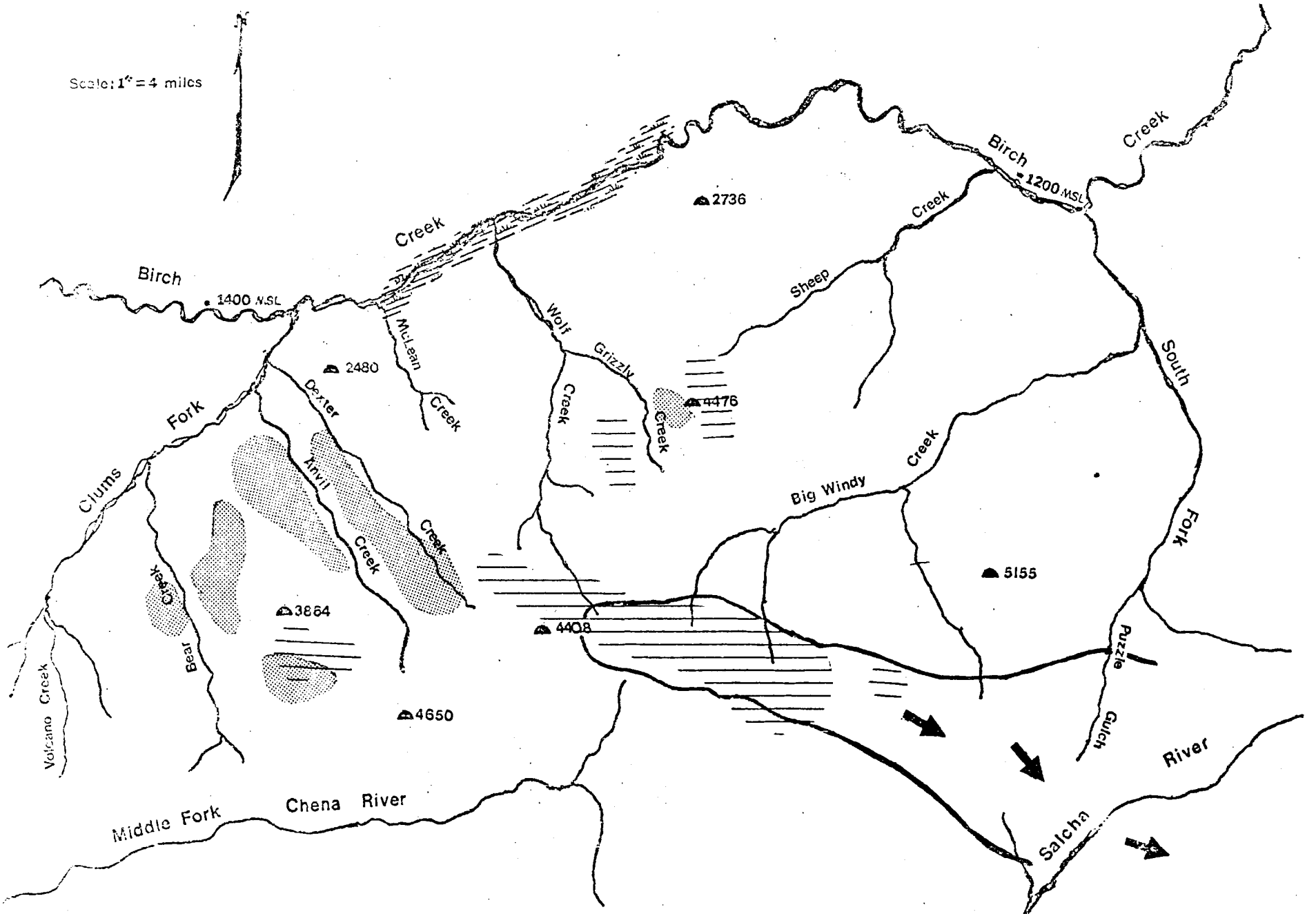

Fig. 4. Fortymile caribou distribution on the calving area, 1975

May 27 — June 5 – 8

June 2 — Post-calving movement

Table 3. Beginning, peak, and end of calving - Fortymile caribou herd.

Year	Begin	Peak[1)]	End	Area
1956	May 18	May 21-23	June 3	White Mountains
1957	May 24[2)]	May 28-29	June 6	White Mountains
1958	May 17	May 25	June 3	White Mountains[3)]
1959	N/A	N/A	June 5	White Mountains
1960	May 14-15	May 23-27	June 3	White Mountains
1961	May 14-17	N/A	June 9	White Mountains
1973	May 20	N/A	June 5	Clums Fork
1974	May 20	May 25-27	After June 4[4)]	Clums Fork
1975	N/A	N/A	June 2-5[5)]	Clums Fork
1976	N/A	N/A	Before June 3[6)]	Clums Fork

1) "Peak" defined as date when 50 percent of observed calving has occurred.
2) Migration later than usual; much of calving occurred in Fortymile country.
3) Most of Fortymile herd remained in Canada; calving included only those that had wintered in the Charley River-Fortymile country.
4) 30 percent of total cows counted were still in calving area on this date.
5) 75 percent of cows still on calving area June 2; no caribou on calving area June 5.
6) No cows on calving area, although some had been there recently.

number of caribou calved in the Fortymile River area east of the main White Mountains calving area. Because animals had farther to migrate than usual, they may have been forced to calve farther east. Nevertheless, this group, as well as other animals that migrated to the White Mountains calving area, calved a week later than normal (Olson 1958).

Calving in this herd has tended to occur a few days later in more recent years (Table 3) which is consistent with Bos' (1974) observations on the Nelchina caribou herd. He concluded that calving has occurred progressively later since 1957. However, data from the Fortymile are inconclusive. Although the most noteworthy aspects of calving have been its largely consistent chronology and the fact that most calves have been born during a short period, slight variations in calving chronology have occurred (Table 3).

Variations in calving chronology could theoretically be explained in several ways. Females may be able to voluntarily control the time of parturition (within a limit of several days). Such a mechanism would allow female caribou a flexible response to local environmental conditions such as deep snow, either along the migration route or on the calving ground itself. No documentation of such a mechanism for caribou is available, however. More importantly, caribou of the Fortymile herd, as well as other Alaskan herds (Lent 1966b, Skoog 1968), have calved in seemingly poor areas even though more suitable snow conditions and better vegetation were available elsewhere. Migratory caribou have calved en route to the usual calving grounds (Bergerud 1974b, Lent 1966b). These observations suggest that caribou are unable to voluntarily control the date of parturition.

Alternative explanations for slight variations in calving chronology are based on the opposing assumptions that the gestation period is either fixed or variable. Dauphine and McClure (1974) determined the age of embryos collected from female caribou of the Kaminuriak herd and found that the majority of conceptions occurred in a 5-day interval. By assuming that the gestation period is fixed, they concluded that the range of dates of the majority of calving corresponds to the range of conception dates. Bergerud (1975), on the other hand, found that although 90 percent of Newfoundland caribou (*Rangifer tarandus terranovae*) conceptions occurred in a 6 day period, 90 percent of the calves were born in a 12-day period, indicating a variation in gestation of ± 3 days. Bergerud concluded that the period of conception did not vary during the years of his study, and that the variation in calving dates he observed were due to nutrition-related changes in gestation period.

Dauphine and McClure (1974) and Bergerud (1974b) discussed several proximal factors which may influence a restricted conception period. These include social, nutritional, and demographic factors which may affect synchrony of ovulation in females. Social stimuli which include antler rubbing, body contact, and visual and olfactory stimuli may be increased during herd movement, and may result in widespread simultaneous ovulation in years in which fall migration consists of large rutting

bands. Dauphine and McClure concluded that females in good nutritional condition have a more "regular" cycle, and that females on different levels of nutrition have different estrous periods. Bergerud (1974a) found that in some groups of Newfoundland caribou, a lowered bull:cow ratio resulted in larger rutting aggregations, which may have increased the social stimuli. These proximal factors are discussed in the context of promoting a restricted conception period; however, presumably a significant lack of one or more of these factors could result in a less restricted conception period. No data exist to support either contention.

Bergerud (1975) supported his contention that the gestation period is somewhat variable by a negative correlation between snowfall during the winter of pregnancy and the mean weight of neonate calves. He assumed that neonate calf weight reflected maternal nutrition. He found that in those years in which mean birth weight of calves was smaller than average, the majority of cows calved later. McEwan and Whitehead (1972) found a shorter gestation period (216 days) and larger birth weight for captive caribou on a highly nutritious diet, than for those wild caribou presumed to be on a less nutritious diet. These data indicate that winter nutrition may affect neonate calf weights, and that there is a negative correlation between neonate calf weights and length of gestation.

Although caribou calving is characterized by relatively constant chronology and synchrony, slight variations do occur due to variations in the period of conception, period of gestation, or both.

Caribou Distribution Within the Calving Area

Most major caribou studies have shown that within the general calving area some areas receive more intense use (Olson 1957, 1958, Skoog 1958, Lent 1966, Parker 1972, Bergerud 1974b). Observations on the Clums Fork calving area in 1974 and 1975 indicated that the western portions of the area were most intensively used during the early portion of calving. Later, when post-calving aggregations were starting to form, southern and eastern portions were most heavily utilized. In 1974 the head of the calving migration moved west through the Clums Fork area to Bear and Volcano Creeks, calved, then started drifting back to the southeast. Later-arriving animals met these returning animals, intermingled and thus never proceeded farther west.

Caribou aggregations on the Clums Fork calving area were most concentrated in the "central portion" (i.e. area west of the ridge between Bear Creek and Anvil Creek) (Fig. 3 and 4). Calf:adult ratios for the central portion were compared to those from the other areas (i.e. "peripheral portions") for several days in 1974, and one day in 1975 (Table 4). In 1974 the highest proportion of calves occurred in the central western portion and the calf:adult ratio there increased steadily from 25-30 May. The lower proportion of calves in the eastern area could have resulted from: (a) an actual lower pregnancy rate of cows assembling there; (b) a greater proportion of yearlings and young males present; (c) higher neonate mortality; or (d) later calving. In

Table 4. Summary of Fortymile caribou calf:adult ratios in the central[1] and peripheral[2] portions of the calving area.

Date	Area	Adults[3] Classified	Calves Classified	Calves/ 100 Adults[3]
5/27/75	Central	168	107	64
	Peripheral	No calf counts obtained		
5/25/74	Central	314	149	47
	Peripheral	215	58	27
5/27/74	Central	366	233	64
	Peripheral	880	301	34
5/30/74	Central	255	170	67
	Peripheral	132	58	44

1) Area west of Bear Creek/Anvil Creek divide.
2) Area east of Bear Creek/Anvil Creek divide.
3) "Adults" = animals older than calves.

1975 accurate calf counts could only be obtained for the western portion of the Clums Fork area, but the high calf:adult ratio suggested a situation similar to that in 1974.

Olson (1957) found that "center" portions of the White Mountains calving area (comprising approximately 200 square miles) were occupied almost entirely by parturient cows, and that a continuous increase in the calf:adult ratio occurred until calving peaked. "Fringe" areas showed a fluctuating and lower rate of calving because of movement of nonproductive cows and yearlings to the outer areas, and gradual drift of cows with neonates back along the migration route. Skoog (1968) found "concentration" areas characterized by rapid progression of calving toward the peak, with the peak occurring a day to two earlier than in the "intermediate" zones. Calf ratios were higher (70 calves:100 adults) in concentration areas than in intermediate areas (56 calves:100 adults). Lent (1966b) found that the "central" calving group was characterized by an almost complete lack of males, by a lower percentage of noncalving females and yearlings, and by marked synchrony of birth. "Peripheral" areas were characterized by higher proportions of noncalving caribou (including males) and more variability in timing of birth. Bos (1974) found similar area-related differences in progression of calving within the Kosina Creek calving grounds of the Nelchina herd.

Caribou Densities on the Calving Ground

Skoog (1968) hypothesized that caribou populations increase to a point at which erratic movements begin, that such movements can then develop into emigration to other areas, and that this population-regulating mechanism occurs before food availability becomes an important limiting factor. An unstated assumption of this hypothesis is that caribou are able to "monitor" their population levels, possibly through interactions with their physical environment (range condition for example) or with other caribou. Presumably, if some social feedback mechanism enables caribou to monitor their numbers, it might occur on the calving ground, because the cow segment, according to Skoog, maintains the stability of the population through recurring use of the same calving area. Accordingly, we compared between-year caribou densities on the calving grounds (Table 5) to determine if calving ground densities and population levels were correlated. If such a correlation exists, it might be possible to predict a threshold density beyond which a population shift may occur.

Densities of caribou on the calving ground appear to be independent of population size. Densities for the Fortymile herd were similar in 1957, when the total population was 40,000 animals, and in 1974 and 1975, when the total population numbered only 4000-5000 (Table 4). During this period the calving area changed from 800 square miles in 1957, to 360 square miles in the late 1960s, to the current area of 150 square miles. Unfortunately, densities for the Nelchina herd cannot be compared for this same period. In 1957, the calving ground density was as high as 24 caribou/square mile in the central portion; the density for the total calving area was 18.8 caribou/square mile compared to only 10 caribou/square mile in the Fortymile herd's White Mountains calving

Table 5. Caribou densities on calving areas.

Herd	Date	Avg. Density (Caribou/mi^2)	Range (Caribou/mi^2)	Source
Fortymile[1)]	1957	10[2)]	N/A	Based on Olson (1958)
Fortymile	5/27/74 (total)	12[3)]	0-200+	Based on Davis (ADF&G Files)
	(central)	16[3)]		
	(peripheral)	7[3)]		
Fortymile	5/30/74 (total)	8.9[4)]	0-300+	Based on Davis (ADF&G Files)
	(central)	10.8[4)]		
	(peripheral)	6.6[4)]		
Fortymile	5/27/75 (central)	5[6)]	0-50+	Based on Davis (ADF&G Files)
Kaminuriak	1968	12-14	0-50	Parker (1972)
Nelchina	1957 (total)	18.8[7)]	N/A	Based on Skoog (1958)
	(central)	24[7)]	N/A	
	(peripheral)	15.6[7)]	N/A	

1) White Mountains calving area only

2) Based on following data: 5000 adults + 3300 calves (calf/adult ratio = 66/100)
= 8300 caribou
White Mountains calving area = 800 sq. mi. (Based on Olson, 1958)
8300 caribou/800 sq. mi. = 10 caribou/sq. mi.

3) Central area = 80 sq. mi. 1289 caribou/80 sq. mi. = 16 caribou/sq. mi.
Peripheral area = 70 sq. mi. 493 caribou/70 sq. mi. = 7 caribou/sq. mi.
Total area = 150 sq. mi. 1786 caribou/150 sq. mi. = 11.9 caribou/sq. mi.

4) Central: 866 caribou/80 sq. mi. = 10.8
Peripheral: 461 caribou/70 sq. mi. = 6.6
Total: 1327 caribou/150 sq. mi. = 8.9

5) Central: 418 caribou/80 sq. mi. = 5.2 caribou/sq. mi.

6) Minimum figures because not all calves were counted

7) Central areas (Tyone & Goose Creeks) = 425 sq. mi. 10,000 caribou/425 sq. mi.
= 24 caribou/sq. mi.
Peripheral area = 640 sq. mi. 10,000 caribou/640 sq. mi. = 15.6 caribou/sq. mi.
Total area = 1065 sq. mi. 20,000 caribou/1065 sq. mi. = 18.8 caribou/sq. mi.

area in 1957. No later figures from which to compute calving densities are available for the Nelchina herd, however the current calving area comprises only 300 square miles (compared to 1000 square miles in 1957). In general, it appears that caribou densities on the calving grounds are not directly related to population size, but rather the calving area contracts as the population declines in numbers.

Conclusions

1) From 1973-1975 the central calving area for the Fortymile herd was located along the high open ridges between Volcano and Anvil Creeks; the peripheral area was located east of the Bear Creek/Anvil Creek divide.

2) In most years, Fortymile herd calving began during the third week of May and ended the first week of June. With the exception of 1957, calving chronology has been fairly consistent since 1956, probably because of similar conception dates. Social, nutritional, and demographic factors contribute to a restricted conception period.

3) Minor variations in calving peaks between years are likely due to variations in environmental stimuli influencing the duration of rut and nutrition-related effects on gestation length.

4) Densities of caribou on the calving ground appear to be independent of population size.

Distribution and Movements in Relation to Habitat

Winter

During the past 10 years most of the Fortymile herd wintered in the Ladue River/Dennison Fork area. Some animals also wintered in the Fortymile and Salcha River areas. Glenn (1967) characterized the Ladue River area as "...generally hilly and low-lying with extensive lichen cover." During winter the white spruce bottomland and black spruce hillsides receive more use by caribou than during any other time of year. Current range condition of this timbered area is unknown. Skoog (1960) examined the range along the Taylor Highway and concluded that lichen condition was poor, especially compared to Nelchina winter range. He suggested that sedges as well as lichens were heavily used during winter. Effects of fire on the Fortymile herd's winter range are discussed separately in this report (see Job 3.16R).

Observations in recent years (Jennings, ADF&G files) confirm that most of the Fortymile herd continues to use the timbered areas of the Ladue/Fortymile Rivers. Nevertheless, small numbers of caribou wintered in widely scattered locations throughout the herd's range each year of this study. In 1973 animals wintered in the low hills near Circle Hot Springs. Animals were feeding in three ecotypes during this winter - 1) the timberline ecotone, 2) "brush" (primarily willow) along the Charley River, and 3) bare ridgetops along river terraces.

Snow is one obvious factor influencing seasonal caribou distribution as well as distribution within seasons. Local variations in snow density, hardness, and accumulation could account for the variability in location of foraging noted above. Effects of snow on barren-ground caribou mobility and foraging ability in the taiga have been studied by Pruitt (1960), Parker (1972), and Miller (1976). They found that: 1) snow depths of 50-60 cm were the critical limit for caribou; 2) snow in craters and trails often became so hard that animals were forced to feed in new locations; 3) craters could usually be used only twice before snow densities became too great; 4) competition for favored cratering sites occurred; and (5) only one animal utilized a crater at any time. These investigators concluded that during early and midwinter taiga ranges were a mosaic of varying snow conditions which influenced selection of foraging sites. Later in winter repeated freeze/thaw cycles prevented caribou from pawing through snow cover. The animals were then forced to rely on arboreal lichens or to utilize the exposed area at the base of conifers ("quamanig" of Pruitt 1960). During late winter and spring a general shift from taiga to tundra ranges occurred as movement became difficult in the wetter and deeper taiga snow.

In contrast to Pruitt (1960), Skoog (1968) found that Nelchina caribou distribution was more dependent on food supply than snow conditions; caribou remained in areas rich in lichens even when snow conditions were adverse. Our recent observations in the range of Alaska's Western Arctic herd parallel those of Skoog.

Fortymile herd caribou are able to migrate altitudinally, thus exploiting different habitat types and snow conditions by relatively short movements.

Spring Migration

Principal spring migration routes follow higher ridges along the divides of the Fortymile, Charley, Goodpaster, Salcha, and Chena River drainages (Fig. 2). Caribou primarily utilize *Dryas*, dwarf birch/willow, and sedge/grass communities along these ridges.

Snow depth and hardness can either facilitate or inhibit spring migration (Lent 1966b, Skoog 1968). Skoog mentioned that an early spring and consequent loss of snow usually resulted in an earlier migration to the calving area. Conversely, examples of deep snow halting or slowing migration are common. Skoog (1963) reported that in the Fortymile country: "Lingering deep snows during the spring, however, seemed to delay and retard the usual northwestward movement in April and early May to the calving grounds."

Lentfer (1965) mentioned that "spring movement was about a month late due to late accumulation of snow."

Following the unusually heavy snowfall in the winter of 1970-71, Jennings (ADF&G files) reported on 14 May 1971 that traditional calving

areas around Mt. Harper and Joseph still had three to four feet of snow and predicted that calving would occur in the timber ecotone.

During our study snow depths were not sufficiently deep to inhibit migration. During a flight on 15 May 1973 we found that 40 percent of the snow was gone above 4500' elevation and 80-90 percent was gone above 3500' elevation. On 21 May 1974 there were no areas along the migration route where snow was deep enough to impede migration.

In a related observation on 2 May 1975 we found that the Clums Fork calving area was still completely covered by snow except for a few windblown patches on the ridgetops. Furthermore, we noted three areas which had more bare ground and appeared to be better areas for calving: 1) the alpine area between the head of Eisenmenger Fork, Joseph Creek and Mt. Harper (a past calving area - see Fig. 2), 2) the alpine area at the head of the east side of upper Crescent Creek, and 3) ridges surrounding Copper Creek.

Dispersal of Caribou from Calving, Post-Calving, and Summer Areas

The Clums Fork calving area consists of a series of broad, finger-like, open ridges separating minor drainages which flow predominately north-northeast to Clums Fork. Upper portions of these ridge systems reach elevations of over 4500' near the Chena River divide, and lower portions near Clums Fork are approximately 2000' elevation. Most calving occurs in sedge meadows, *Dryas*, and dwarf birch communities. In 1974 and 1975 a considerable number of cows calved in the timber and timber-alpine ecotone along tributaries of Clums Fork and Clums Fork itself. During the entire calving period snow cover varied from widespread to patchy, depending on elevation and aspect. Wind chill has apparently not been a major factor during calving; no widespread calf mortality on the Clums Fork calving grounds has been noted during recent times and calf survival for the first week has been good. We noted that many calves were born in wet sedge-meadow areas, but even these animals were not observed to suffer ill effects from wind chill. A snowstorm on 4 June 1974 left snow above 3500' elevations on north slopes, but south and west slopes were essentially bare. However, caribou did move lower in response to this snow. The diversified habitat of the Clums Fork area apparently provides adequate forage and cover under a variety of climatic conditions.

Curatolo (1975) studied caribou post-calving and summer distribution in response to environmental factors intensively in 1973. Subsequent observations have added little to his conclusions summarized below:

1) Selected habitat ranged considerably in elevation, slope exposure and slope shape. Few obvious trends were noted except the increased use of ridgetops during August and September.

2) Caribou use of the various vegetation communities during summer was as follows: sedge-grass, 60%; dwarf birch-willow, 28%; and *Dryas*, 9%. Skoog (1956) reported above timberline plant composition to

be as follows: sedge-grass, 23%; dwarf birch-willow, 28%; and *Dryas*, = 34%.

3) During early June and August caribou preferred *Dryas* and birch-willow communities, while in July and September they preferred the sedge-grass community.

4) Weather affected caribou only indirectly through its effect on insects. Orientation and habitat selection related to wind speed and direction seemed to occur only during periods of high insect density.

Fall Migration

Fall migration usually commences when most of the herd regroups in late September or early October. In the past several years these fall aggregations have occurred in the area north of Glacier Mountain and North Peak (Fig. 2). Animals then moved southeastward, eventually crossing the Taylor Highway. Frequently-used routes have been along ridges above timberline, especially the ridge complexes near American and Poly Summits; however, lower timbered areas were also used every year and predominately in 1973. Observations of animals in or near timber were more common at this time of year than during spring migration or summer. This possibly results from loss of forage availability at higher elevations due to snow accumulation. The variability of Taylor Highway crossing dates and locations (Table 2), suggests that exogenous factors such as weather can affect timing and route of fall migration.

The role of snow in triggering fall migration is unclear. Curatolo (1975) found no evidence that snow initiated migration in fall 1973. Lent (1966b) found that fall movement of the Arctic herd south coincided with the first major snowfall. Bergerud (1974b) noted that for three years fall migration of a Newfoundland caribou herd was triggered by snowfall. Since there are no other past references to the relation of snowfall and migration by the Fortymile herd, conclusions for this herd await further study.

Conclusions

1) In winter Fortymile herd caribou primarily use spruce-timbered areas and the timber/alpine ecotone.

2) Use of alpine ridges is greatest during spring migration, the calving period, summer, and early fall.

3) Winter movements are governed by snow characteristics such as depth and hardness. Deep snow can retard spring migration.

4) More calving takes place above timberline than in timbered areas on the Clums Fork calving ground. *Dryas*, sedge-grass meadows, and dwarf birch/timber communities are the most frequently used vegetation communities for calving.

5) Fortymile caribou do not necessarily select their calving ground because it becomes snow-free earliest. During some years other alpine areas of the Tanana Hills are snow-free earlier than the Clums Fork Area. However, the Clums Fork area offers the greatest diversity of micro-habitats; i.e. aspects, slopes, vegetation communities, and elevation relief.

6) During summer, weather seems to influence caribou only indirectly through effects on insect densities.

7) Initiation of fall migration was not correlated with the first snowfall.

Seasonal Changes in Group Size

"Group" is used here as a descriptive rather than functional term. We recorded group size (see Table 6) for all caribou observations made during this study as did Curatolo (1975). Although each observer considered groups to be any number of caribou functioning as a unit, group designation was subjective and therefore there was between-observer variance. Nevertheless, seasonal changes in mean group size agree with those observed for other North American caribou herds (Lent 1966b, Skoog 1968, Parker 1972, Bergerud 1974b, Doll et al. 1974). Two periods of maximum mean group size occurred (see Table 6): post-calving (about 5 June - 1 August) and the rut (late September and early October). Group size during calving increased as calving progressed. Group size during August was the smallest.

Seasonal changes in group size result from interactions between environmental and social stimuli as discussed in the following section.

Winter

Mean winter group size during 1973 and 1974 was approximately 30 animals (see Table 6). In Newfoundland caribou Bergerud (1974b) found averages of 4.0 to 4.8 caribou/aggregation during winters ranging from mild to hard. Doll et al. (1974) found most Porcupine caribou in groups of 2-49 during winter.

Studies of other North American caribou herds revealed that winter group size was primarily determined (i.e. limited) by local environmental features such as snow depth and hardness which limited mobility and available forage (Bergerud 1974b, Miller 1976), and by competition for craters (Pruitt 1960). Social attraction and dependence on the group were also factors in the changing group sizes noted by D. Miller (1974, and see Table 7).

Calving

Group size during calving varied between 1-220 (mean = 13.7) for the early part of calving (15 May - 1 June), and 1-675 (mean = 63.3) for late calving and early post-calving (1-5 June). Bergerud (1974b) found

Table 6. Fortymile caribou group size observations, March 1973 to June 1975.

Date	Location	Total Number Observed	Number Groups	Mean Group Size	Range	Standard Deviation	Standard Error
Winter							
2/8/73	Birch Ck. - Yukon Fk. - Upper Charley R.	180	5	36	24-65	16.9	N/A
2/23/73	Fortymile drainage	N/A	N/A	50	N/A	N/A	N/A
2/7/74	Dennison Fk. - Eagle - Boundary	N/A	N/A	10-15	N/A	N/A	N/A
4/9/74	Middle Fk. - Fortymile R.	18	1	-	-	-	-
Calving							
5/15/73	West Point (Salcha R.)	31	3	10.3	2-26	13.6	4.2
6/1-5/73	Clums Fork*	891	13	69.0	2-220	56.8	15.7
5/20/74	Clums Fk. Calving Area**	356	38	8.6	1-56	12.4	2.1
5/25/74	Clums Fk. Calving Area & Surrounding Alpine**	557	60	9.3	1-60	11.8	1.4
5/27/74	Clums Fk. - Big Windy**	1269	57	22.3	1-116	21.9	2.0
5/28/74	Upper Chena - Upper Salcha**	272	11	25.1	1-200	58.7	17.7
5/29/74	Clums Fk. Area**	151	9	16.7	1-53	19.1	6.4
5/30/74	Clums Fk.	617	36	17.1	1-60	17.9	2.9
6/4/74	Clums Fk.**	861	N/A	123.0	1-450	153.7	58.1
6/4/74	Head of E. Fk. Chena R.	704	13	54.2	2-273	95.9	26.6
6/4/74	Chena - Birch Ck. Divide	765	4	191.3	41-350	127.4	63.7
5/27/75	Clums Fork Calving Area	489	59	8.29	1-55	11.47	1.5
6/5/75	Chena R. - Salcha R. Divide	2254	32	71.4	3-426	106.1	18.75
6/3/76	Clums Fork - Big Windy**	1556	38	40.9	1-675	80.8	13.1
6/3/76	Clums Fork - Big Windy***	2144	38	56.0			
Post-Calving							
6/13/73	N. Slope Mt. Harper	12	1	-	-	-	-
6/1-7/31/73	Tanana Hills*	13.611	44	330	1-2000	465.3	70.2
7/6/73	Glacier Mtn. Vicinity	ca. 3000	4	ca. 750	-	-	-
6/12/74	Little Windy Ck. (Chena - Salcha Divide)**	1351	N/A	171.1	2-600	198.1	70.1
6/19/74	Crescent - Charley R.**	703	9	74.9	1-450	144.9	45.8

Table 6. Continued.

Date	Location	Total Number Observed	Number Groups	Mean Group Size	Range	Standard Deviation	Standard Error
6/20/74	Charley R.**	1140	8	143.3	8-500	173.9	61.5
6/21/74	Upper Charley R.**	946	7	135.1	1-450	161.7	61.1
6/24/74	Charley R.**	1362	7	191.4	12-600	210.4	79.5
6/25/74	Copper Ck.**	2126	7	303.7	12-1300	451.9	170.8
6/26/74	Copper Ck. to North Peak**	2051	66	311.4	19-500	238.3	90.1
7/11/74	North Peak to Glacier Mtn.	4000-5000	N/A	N/A	30-80	-	-
7/19/74	North Peak to Glacier Mtn.**	1330	6	221.7	50-400	95.4	38.9
7/26/74	Glacier Mtn. vicinity**	1573	11	143.0	6-1000	276.2	83.3
7/29/74	Upper Copper Ck. - Slate Ck.**	203	4	40.8	1-200	89.0	39.8
6/8/75	Upper Salcha R. - Charley R. Divide	2363	13	181.8	4-776	220.9	61.2
6/9/75	Salcha R. - Charley R. - Fortymile R. Divide	764	14	54.6	4-228	65.2	17.4
August Dispersal							
8/1-31/73	Tanana Hills*	124	18	6.9	1-32	8.6	2.0
8/2/74	Mt. Sorensen to Glacier Mtn.**	378	3	126.0	100-200	137.9	79.6
8/6/74	Upper Charley R.**	245	15	16.7	7-100	27.2	7.3
8/14/74	Upper Goodpaster R. - Charley R.**	127	22	5.5	1-11	4.4	1.2
Fall Migration & Rut							
9/13/73	Copper Ck. - Glacier Mtn.	2-3000	N/A	N/A	10-75	-	-
9/1-10/3/73	Tanana Hills*	1880	24	73	4-325	92.8	4.9
9/4/74	Upper Goodpaster - Salcha R. - Mt. Harper	148	19	7.5	N/A	17.8	4.1
9/6/74	Goodpaster R. - Middle Fk. Fortymile R.**	478	18	26.5	12-55	13.3	3.1
9/12/74	Glacier Mtn. - Arctic Dome - Crescent Ck.	988	61	15.5	1-80	18.4	2.4
9/18/74	Seventymile R. to Taylor Highway	700+	N/A	N/A	25-100	-	-
9/20/74	Glacier Mtn. & vicinity	1017	21	48.4	2-223	58.76	12.8
9/21/74	Glacier Mtn. & vicinity	866	30	28.9	1-215	43.8	8.0
10/3/74	Stoney Boy Ck. - Charley Divide - Copper Ck.**	966	11	87.8	8-250	83.2	25.1
10/24/74	Charley R. - Mt. Harper - Taylor Highway	1512	17	88.9	4-1000	236.4	57.4

* Based on data from Curatolo (1975), Job 19.14R.
** Adults only; should be considered minimum figures.
*** Same observations as 6/3/76, but including calves.

Table 7. Changes in Kaminuriak caribou winter group size correlated with changing snow condition (adapted from D. Miller, 1974, p.753).

Season	Snow Condition	Movement*	Social behavior when foraging	Foraging area most used
early winter	shallow and soft, 50 cm	M	scattered in small bands, members (other than cow/calf pairs) independent	river and lake shores - open canopy
midwinter	deep and soft, 50 cm	M or S	medium-sized bands, members dependent	open conifer canopy close to treeless areas
late winter	(a) deep, sun crust	S	large bands, members dependent	open and closed conifer canopy close to treeless areas
	(b) depth diminishing, alternating crust and no crust	S	medium-sized bands, members dependent	open canopy close to treeless areas
spring	appearance of bare patches	M	scattered in small bands, members independent	open canopy on southern exposures

*M - mobile, bands migrating S - sedentary, bands not migrating

the mean aggregation size in Newfoundland caribou to be 3.4 (maximum = 57) during calving. Skoog (1968) found that average group size of the Nelchina herd to be less than 10 but increasing dramatically following the peak of calving. The Nelchina groups were comprised of cow/calf pairs and, especially in the peripheral areas, a few nonparturient cows and juveniles.

During parturition F. Miller (1974) found that cows were often alone, and may have remained alone for a brief postpartum period. Following parturition cows and calves began to move around the calving grounds and joined other cows, calves, and juveniles. Group size characteristically increases because late in the calving period smaller groups are attracted toward larger groups and coalesce (Lent 1964, Skoog 1968, F. Miller 1974).

Post-calving

Fortymile herd post-calving group sizes varied from 1-2000 (mean = 153) between 1973 and 1975. However, these data included many observations of solitary bulls and small bull bands which were scattered along the post-calving route and were not part of the post-calving aggregation and migration. Group size within the post-calving aggregation itself undoubtedly was much larger. Group size for Newfoundland caribou during post-calving aggregation reached 250 and averaged 9.8 (Bergerud 1974b). Lent (1966b) found similar masses of up to 70,000 animals in 1960 and 40,000 in 1961 in the Western Arctic herd. The actual size of "groups" within these aggregations was undoubtedly lower. For this period Doll et al. (1974) found that most Porcupine herd caribou were in groups of 1000+ in 1971 and 1972, and about equally distributed in groups of 100-499 and 1000+ in 1973. They attributed the difference in group size between 1971-72 and 1973 to a later emergence of insects in 1973.

The large post-calving aggregations are one of the more spectacular aspects of caribou biology, yet the cause(s) of these aggregations and subsequent movement remains controversial. F. Miller (1974) suggested that the primary function of post-calving aggregations is socialization - a regrouping of the winter cow/calf and bull bands and reestablishment of traditional migration routes. Lent (1964) believed that "a recombination of calving and noncalving segments of the population is the most important event of the post-calving period." Bergerud (1974b) and Curatolo (1975) shared Lent's views that aggregations result from coalescence of smaller groups. They also felt that coalescence results from inter-group social facilitation, a process by which specific individual behaviors are reinforced by the performance of these behaviors by other individuals. Skoog (1968) believed that one reason for post-calving aggregations and migrations was the high density of animals regrouping on the calving grounds, and the initial appearance of mosquitoes and later appearance of black flies. Popular literature on caribou has spread Kelsall's idea that the formation of post-calving aggregations was a defensive response to "insect" harassment. White et al. (1975), although avoiding conclusions about the cause of aggregations, reported that the peak number of Central Arctic (Prudhoe Bay) herd caribou observed

coincided with severe mosquito harassment during the post-calving period (about 7-15 July).

Skoog (1968) mentioned insects as one cause of formation of post-calving aggregations. Contrary evidence was provided by Parker (1972) who found that the Kaminuriak post-calving aggregation formed two weeks before mosquito emergence. Lent (1964) reported that post-calving aggregations fragmented following "insect" (presumably mosquito) emergence. Studies of different caribou populations have shown that phenology of mosquito emergence coincides with the period of post-calving migration, but often several weeks after the formation of the post-calving aggregations.

We believe that the controversy concerning the post-calving period is partially the result of confusion about the distinction between the formation of post-calving aggregations, and the maintenance of these aggregations during post-calving migration. White et al. (1975) found that Central Arctic (Prudhoe Bay) herd caribou aggregated in response to insects throughout the summer, far beyond the period when post-calving aggregations would have formed. Several investigators concluded that caribou aggregated on mosquito-relief terrain (e.g. wind-swept ridges and hills) (Skoog 1968, Bergerud 1974b, White et al. 1975), migrated (Parker 1972) or responded with only localized movements during extreme mosquito densities (Curatolo 1975). In all these examples group size remained large during this period. White et al. (1975) also found that on days of low insect harassment animals tended to disperse, suggesting that social factors were no longer as important in maintaining the large groups. Doll et al. (1974) found that Porcupine herd caribou did not maintain as large post-calving groups in 1973 (fewer groups were in the 1000+ class) when insect emergence was several weeks later than normal, as in 1972.

Initial formation of post-calving aggregations may occur because of social factors which prompt the calving segment to unite. These social factors may include socialization, regrouping of the calving and non-calving segments (this does not seem to be the case with the Fortymile herd), or simply social facilitation. An alternative hypothesis is that although the proximate cause(s) may be social factors, the ultimate cause is predation, primarily by the wolf (*Canis lupus*) (Bergerud 1974b). Bergerud argued that in open habitat the effects of predation by a highly mobile predator may be dampened by a brief calving season and large aggregations. By producing a large number of precocial calves during a brief period, and by forming large aggregations during and immediately after calving, the exposure of individual calves to a potential predator is decreased. Ultimate causes of post-calving aggregations may include wolf predation and/or socialization.

Virtually an identical system of calving and aggregation has been found for the wildebeest (*Connochaetes taurinus*) of Ngorongoro Crater, Tanzania (Estes 1976). Estes found that 80 percent of wildebeest calves are born in a 2-3 week period. Calf survival in large aggregations was 84 percent at the end of calving but calf survival in small aggregations was only 50 percent at the end of calving. The major mortality source

was predation by the spotted hyena (*Crocuta crocuta*). Wildebeest cows and newborn young formed large coordinated "nursery groups."

Although proximate factors influencing formation of post-calving aggregations remain obscure, maintenance of these aggregations, whether the animals migrate or move only locally, is at least partially in response to insect harassment. White et al. (1975) found that Central Arctic caribou aggregated and dispersed in response to varying mosquito densities throughout the summer. Fortymile caribou remained in large groups throughout late June and July (see Table 6), beyond the period of aggregation formation, but during the mosquito season.

August Dispersal

Fortymile group size ranged between 1-200 but the mean group size decreased to 15.1 during August 1973 and 1974. Porcupine herd caribou were observed most frequently in groups of 2-49 during the period from late July to early September (Doll et al. 1974). Kelsall (cited in Bergerud 1974b) mentioned that Canadian barren-ground caribou dispersed in August. Parker (1972) reported that the Kaminuriak herd dispersed between late July and early September, but he did not comment on the cause.

Curatolo (1975) believed that August dispersal of the Fortymile herd could have occurred because of increased oestrid (warble and nose bot) fly attacks. He observed that oestrid fly harassment caused "aberrant running" which tended to disrupt ongoing activity and disperse animals. Skoog (1968) mentioned that during this period Nelchina caribou did not remain in the fly-harassment groups seen earlier in the season, although fly annoyance could still bother the animals. Kelsall (cited in Curatolo 1975) concluded that dispersal in August by barren-ground caribou was due to cessation of insect harassment and a need to reduce competition for food. Curatolo (1975) concluded that oestrid fly harassment was probably a significant cause of dispersal in August, but that reduction of competition for forage could also be significant because forage was no longer uniformly dispersed.

Fall Migration and Rut

During September Fortymile caribou group size ranged from 1-1000 and averaged 36.7. Review of group size (see Table 6) indicates a trend from smaller groups in early September to larger groups during the rut in late September and early October. Bulls and yearlings become more mixed within the herd as the rut progresses, possibly as result of the re-aggregation of small groups which have dispersed throughout the area during August. These small groups tended to coalesce in the area north of Glacier Mountain, and began the southeastward fall movement, rutting along the way.

Bergerud (1974a) found that because Newfoundland caribou were not territorial and did not actively defend harems, groups consisted of two

types: (1) small mixed groups dominated by a single bull and (2) larger mixed groups with several large bulls which service cows as they come into estrus. Rutting group size may also be influenced by the bull:cow ratio. Bergerud (1974b) found that as the proportion of bulls in a Newfoundland herd decreased, group size increased because more cows were serviced by each bull.

Conclusions about effects of snowfall on rutting group size are speculative. If snowfall triggers fall migration, increased group size may result from large numbers of animals moving synchronously to winter range. Bergerud (1974b) found that the first snowfall coincided with the fall migration southward, but Newfoundland caribou differ from Fortymile caribou in that the former rut before migrating. Caribou in the Fortymile herd and in many other Arctic herds rut while migrating. Furthermore, Curatolo (1975) found that in fall 1973 Fortymile caribou began migrating before the first snowfall. Roseneau (cited in Curatolo 1975) found that Porcupine caribou began the fall migration following the first snowfall in 1972, but found no correlation between snowfall and fall migration in 1973. Possibly caribou will begin fall migration if the first heavy snowfall occurs early in the season, but will migrate at the "usual" time regardless of snowfall.

Conclusions

1) Seasonal changes in group size in the Fortymile herd parallel those observed in other herds. Groups are largest during the post-calving and rutting periods and smallest during August.

2) Factors that have been proposed as causes of reduced group size in August include oestrid fly harassment, movement to reduce competition for food, and a reduced insect harassment in combination with movement to reduce competition for food.

3) Fall group sizes are large because bull groups tend to join coalescing cow/calf groups during the rut. Group size may be influenced by bull:cow ratios; i.e. lower ratios may result in larger group size (Bergerud 1974b).

4) Initiation of fall migration is probably not correlated with the first snowfall. However, it is likely that a heavy, early snow could cause caribou to migrate early.

General Discussion: Subtleties and Implications of Ascertaining if Caribou Form True "Ethological Groups" or Merely Aggregations

Caribou social structure has been generally described by Lent (1965) as "temporary, tenuous association(s) of individuals," and by Bergerud (1974b) as "open social units." The generalized gregarious behavior of caribou results from the interaction of a number of factors: the individual animal's motivation, the social tolerance of the species as a whole, and social facilitation. Motivation can result from physiological processes (e.g. hormonal levels, nutrition requirements) or environmental

factors (e.g. mosquito densities), although actual separation of causes is often impossible. "Social tolerance" is a hypothetical concept, reflecting the observed tendency of caribou to form large units seasonally and to generally be considered a "social species." Although examples abound of interactions between individuals that demonstrate social intolerance, compared with other ungulates, caribou tend to be dispersed more in clumps than as solitary individuals. According to Hinde (1970), social facilitation is "...the performance of a pattern of behavior already within an individual's repertoire, as a consequence of the performance of the same behavior by other individuals." Although this definition is ambiguous, most observers agree that much synchronous behavior among caribou seems to occur merely because other individuals are performing the same behavior. Lent (1966a,b), for example, described the merging of several small caribou groups with a larger group, and the widespread reaction to disturbance among several groups even though the source of disturbance was apparent to only one group.

Lent (1965) defined a group as "...an aggregation of individuals separated by some distance from other aggregations and showing some weak coordination of activities, traveling together, or resting and feeding together." However, social ethologists, such as McBride (1971), argue that groups are "...not simple congregations of anonymous animals, but are formed and maintained by affiliative behavior."

The difference between the definitions of Lent and McBride might be purely semantic except that recent evidence suggests that caribou may be organized into groups as defined by McBride (1971). Parker (1972), Miller (1974), and Miller et al. (1975) suggested that Kaminuriak herd caribou are characterized by persistent, nonrandom associations between adult animals, which are believed to be the result of social attachment. These investigators observed radioed and visually marked caribou and found that: (1) certain animals were usually seen together the same day; (2) certain animals were usually in the same groups; and (3) animals returned to the same groups after being separated for hours or days (Miller et al. 1975). They suggested that the basic caribou social unit of usually less than 10 animals is the winter "band" (i.e. group). They believe there are two main categories of winter bands - the adult bull band (consisting of males three-years-old and older), and the cow-juvenile band (consisting primarily of cow/calf pairs, but with loosely-associated subadults) (Miller 1974). This model of caribou social structure includes social tolerance and social facilitation. These same concepts are implicit in discussions by Lent (1965) and Bergerud (1974b), but the later model also implies that social attraction (i.e. "social bonds") persists among adults. Although specific conclusions would be premature, available data suggest that caribou social structure may be more complicated than the model which Lent and Bergerud presented.

Wickler (1976) discussed social attachment (i.e. "bond") and stated that one commonly applied measure of social affinity is proximity. Proximity of individuals in pairs or groups is an essential basic part of the definitions of group proffered by Lent (1965) and McBride (1971).

Furthermore, proximity is the only criterion used by the investigators of the Kaminuriak herd, and is the usual criterion available to biologists who must rely on aerial surveys. We also used proximity in determining Fortymile herd group size (see Table 6). Wickler (1976) found that although proximity data are the easiest to gather, they are the most difficult to interpret because the following conditions are required: (1) the individual's distribution must be measured not only against a random distribution, but also against a possible distribution due to other factors (e.g. snow hardness, food distribution, insect density); (2) a shared site attachment must be excluded; and (3) a third, fourth (or "nth") animal must not be influencing the distribution of these animals being tested.

Practical considerations limit the biologist's ability to test these other variables, but the Kaminuriak study demonstrated that caribou returned to the same group following an absence of several hours or as long as several days. These data suggest that environmental factors were not affecting the animals' distribution, but do not exclude the possibility of site (e.g. migration route) attachment. An awareness of the pitfalls involved in using proximity as a criterion for identifying a collection of caribou as a group should help field biologists determine whether or not such a collection is a group, or merely an aggregation. The more basic question of whether caribou actually form and maintain groups (after McBride) could be tested by intensive monitoring of marked free-ranging caribou for several years to determine if the apparent social attachment noted in the Kaminuriak herd study satisfied Wickler's conditions (1-3) above and actual "bonds" existed.

In other mammalian groups, particularly primates and carnivores, ethologists have been able to determine that specific behavior patterns, for example types of social grooming, occur between animals which have developed social affiliations. There is no complete "ethogram" (total behavioral repertoire) for caribou; therefore, the occurrence of such behavior patterns as social grooming is unknown. Recognition of such patterns would suggest that caribou form social bonds which are an important cohesive force in group formation.

Although identification of aggregations as either random associations or socially cohesive groups may appear to be academic, the practical significance may be considerable. It is generally recognized that other caribou comprise a major component of a caribou's environment. Thus, it follows that how caribou relate to each other is <u>the</u> important ingredient of social dynamics and may well be <u>an</u> important ingredient in population dynamics.

Several group/aggregation phenomena have been recognized in the Fortymile herd that have strong management implications and warrant study. It is well documented that, although major portions of the herd consistently calve, winter, migrate, etc. in specific locations, lesser numbers ("peripheral animals") consistently use different areas for each of these activities. What is not known is whether the peripheral animals are the same individuals each year. Management implications would be

greatly different if the peripheral animals were random members of the herd each year. For example, a small number of caribou apparently wintered in the vicinity of Circle Hot Springs each winter prior to 1974. In terms of the number of caribou present, this general area was more heavily hunted than any other portion of the herd's range. It appears that alternate explanations for the cessation of use of this winter area are: 1) animals wintering in the location had an affinity to the general area (at least during hunting season) where they were subjected to an excessive harvest; and perhaps through social facilitation the few survivors moved to alternate areas to winter with other caribou (available data suggest hunting could not account for total loss of these caribou); 2) as the entire herd declined in numbers the decline in this group was proportional and numbers became small enough that through social facilitation the few survivors followed greater numbers to alternate wintering areas; 3) the use of this area occurred primarily on a random basis; and 4) the area was used only when the herd was larger because competition on the primary wintering grounds necessitated its use.

Other phenomena, such as periodic changes of primary calving areas, possibly occur because mortality or egress is weighted toward specific discrete units of the herd. Clearly there is need to explore the mechanisms contributing to these observed phenomena because parallel situations exist in many of Alaska's caribou herds.

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FINAL REPORT (RESEARCH)

State: Alaska

Cooperators: James L. Davis, Richard Shideler and Robert E. LeResche

Project No.: W-17-6 and W-17-7 Project Title: Big Game Investigations

Job. No.: 3.16R Job Title: Range Reconnaissance-Fortymile Caribou Herd

Period Covered: July 1, 1973 through June 30, 1975

SUMMARY

The generalization that fire has been the cause of widespread North American caribou declines in the late 1800s and early 1900s is not tenable. Evidence from Alaska and Canada suggests that fire has never been the major limiting factor to most caribou populations. The role of fire in caribou declines can only be evaluated on a case-by-case basis. Destruction of lichens has been hypothesized as the primary detrimental effect of fires. However, several studies have shown that caribou and reindeer are not dependent on lichens. Furthermore, there is evidence that lichen forage can in fact increase following fire, and that forage species from seral stages which are dependent on fire are heavily utilized by caribou. Indirect effects of fire on caribou, such as adverse snow accumulation, increase in predator numbers, and exposure to disease transmitted by animals dependent on seral stages, may be as important in explaining population declines as the hypothesized destruction of lichens.

Extermination of caribou from the Kenai Peninsula is the most frequently cited Alaskan situation in which fire has been assumed to be the cause. This speculation is too simplistic - it is probable that other factors such as overhunting and adverse weather were possible primary causes.

Although fires may have reduced the winter carrying capacity of the Fortymile herd's range during this century, the number of animals present at any time has been well below the calculated carrying capacity. The most conservative estimate of carrying capacity was 70,000-90,000 in 1956, when the population was only 50,000 animals. The present carrying capacity is conservatively estimated at 61,000 animals, while the population is 4000-6000. Furthermore, at no time since 1956 has the population level even approached the carrying capacity estimates.

CONTENTS

BACKGROUND

The recent decline of the Fortymile caribou (*Rangifer tarandus granti*) herd renewed interest in assessing the herd's habitat, because several biologists have speculated that habitat deterioration may have contributed to this decline. In the first intensive investigation of this herd, Skoog (1956) assessed and described its habitat. His was essentially the only habitat study conducted on the Fortymile herd's range.

The objectives and procedures for this job changed considerably from the time it was proposed until it was completed. Factors contributing to the changes included a review of feasibility, a change in research emphasis from the Fortymile herd to the Western Arctic herd, changes in project personnel, and a proposal by the Bureau of Land Management to initiate a comprehensive habitat inventory of the "Fortymile area" using ERTS-A multispectral photography.

Originally, we planned to characterize habitat by delineating range units and determining distribution and extent of plant communities within these range units. We also planned to determine proportions of plant communities present by autumn aerial transects (after Skoog), and assess successional changes by comparing our data with those of Skoog. Briefly, Skoog's (1956) procedure is stated as follows:

> An accurate range analysis of the plant distribution would require the use of random flight lines over the range. A lack of time and money, however, prevented the flying of such lines. Instead, a flight made to locate the caribou herd provided the only means for accomplishing the task. During such a flight a tendency exists to traverse mainly the areas above timberline, where one can see the animals more easily. As a result, the data obtained do not provide a true picture of the actual plant distribution. The flight took place on September 21, 1953...

The only way to obtain data comparable to Skoog's would have been to duplicate the original flight line and procedure. However, we were unable to obtain the original flight information in time to do this.

We intended to prepare a general range unit map using information gathered during aerial and ground surveys and from ERTS-A multispectral photography. The two types of data were to be correlated to provide "ground-truth" information necessary for interpreting ERTS data.

However, plans for mapping the range utilizing ERTS-A multispectral photography were delayed because the technology for interpreting ERTS photos did not advance as rapidly as was anticipated. As a consequence, for the scope of this project, it was prohibitively expensive to obtain adequate ground truth data (LaPerriere 1976).

Since we were unable to prepare the general range unit map we decided to investigate the influence that forest fires may have had on the Fortymile herd decline.

OBJECTIVES

Original: To delineate, characterize and map habitat used by the Fortymile caribou herd.

Amended: To delineate habitat used by the Fortymile herd and assess the effects of wildfire on the herd and its habitat and to review the relationship between wildfire and caribou in Alaska and Canada.

PROCEDURES

We delineated habitat in conjunction with Jobs 3.13 and 3.15 by periodic aerial reconnaissance (see Procedures, Jobs 3.13 and 3.15 this report).

Data concerning location and timing of fires and acreages burned in the herd's range existed in fire control files provided by the U. S. Bureau of Land Management. We were then able to assess the probable impact of the fires by synthesizing data in the existing literature on fire ecology and by carrying out aerial reconnaissance of vegetation recovery in burned areas of known history.

FINDINGS AND DISCUSSION

Habitat Delineation

Habitat delineation resulted from records of seasonal movements and distribution of the herd obtained from periodic aerial surveys and from reports by individuals (see Job 3.15R).

Effects of Wildfire on Caribou and Their Habitat

General Effects of Fire on Caribou

Many observers and biologists have discussed the effects of wildfire on caribou populations. Wildfires, both natural and those caused by man, have commonly occurred for hundreds of years throughout most of the area inhabited by caribou in North America. Vierick (1973) summarized the occurrence of fire as follows: "Fire has always been a part of the Alaska taiga ecosystem; if it is totally excluded from the environment, some major ecological changes will result." Scotter (1964) stated that "Comments on forest fires in the journals of early explorers, and the presence of charcoal in soil profiles indicate that the relationship between forest fires and caribou is not a recent one." Scotter (1967, 1971a,b) reiterated that opinion and other authors (Lutz 1956, Skoog 1968) reached similar conclusions.

Many observers believe that caribou populations in North America began a general decline in numbers in the late 1800s and continued to decline through this century. Most early writers (Hind 1863, Pike 1892, Hornby 1934, Anderson 1938, Allen 1942, Manning 1946, deVos 1948, Rousseau 1951, Leopold and Darling 1953, Banfield 1954, Edwards 1954, Moisan 1955, Lutz 1956, Cringan 1957, Kelsall 1957, Banfield and Tener 1958, Pruitt 1959, Scotter 1964, 1967, 1971a,b) expressed the opinion that fire was detrimental to caribou. Many biologists and explorers have observed a strong direct correlation between increased forest fires (on a local scale) and declining caribou populations. Bergerud (1974) has recently discussed this viewpoint as follows:

> The majority of northern biologists believe that man's destruction of caribou habitat was the primary cause of the Nearctic decline concurrent with settlement. For instance, Peterson (1966:334) in referring to caribou in eastern Canada stated, '...it seems obvious that the deterioration of habitat by fire and human activity has been the most important fact in their decline.' Leopold and Darling (1953:67), 'Caribou have been...very much reduced in central and southern Alaska by burning over the winter range.' Again Scotter (1967:257) refers to the decline of barren-ground caribou in Canada: '...there can be little doubt that forest fires have been one of the principal causes of the decline.'

Bergerud (1974) argued that wildfire was not the major factor responsible for the decline of caribou in Canada following settlement.

He believed that caribou declined due to increased mortality from hunting augmented by increased predation and possibly disease. Bergerud (1974) stated the following:

> Recently, three long-term life history studies of caribou in North America have been completed. Two of those studies at opposite ends of the continent (Alaska and Newfoundland) concluded that caribou do not require lichens, and that range destruction was not a factor in the decline of caribou (Skoog 1968; Bergerud 1971a, b, 1972). In the third study in the Northwest Territories, Banfield (1954) and later Kelsall (1968) emphasized hunting mortality as the cause of the decline.

Three assumptions are involved in the theory that increased wildfires reduced the absolute abundance of lichens which caused the caribou population declines. The first assumption is that fires increased following settlement. The second is that quality and/or quantity of caribou range were reduced because of wildfire. The third is that lichen requirements of caribou are sufficiently high that reduction in absolute abundance can cause a major reduction in the caribou population.

Frequency of Fires in the Canadian North and Alaska

Investigators in Canada do not agree fire increased following settlement in the North. Kelsall et al. (1977) presented an excellent review of the history of fire in northern Canada.

In Alaska, however, records indicate that burning of wildlands increased during periods of early white settlement and mining activities (Lutz 1956, Skoog 1968). Lutz (1956) stated:

> The tempo of forest destruction in Alaska was substantially increased after gold was discovered in the Klondike in 1896. The fabulous stampede that followed brought thousands of people to Yukon and to Alaska.... With the advent of white man in the Territory near the end of the 19th century, fires became even more widespread than previously. Particularly affected were those districts where gold placer deposits were discovered. A map of the Fortymile Quadrangle prepared by Barnard (9) shows that at that time (1900) only 3.6 percent (54 of 1,481 square miles) of the forest land had been burned over. Barnard wrote, 'The entire area of this quadrangle is fairly well timbered to an altitude of 3,000 feet, save some areas which have been burned over....' Since then most of the region has been burned.

Lutz (1956) also stated that 1915 was one of the worst fire years recorded. Viereck (1973) mentioned, "With the appearance of contemporary man in the northern areas, fire activity increased, especially during the Gold Rush at the turn of the century."

The second and third assumptions are related; reduction of range quality by removal of the climax species of lichens is based on the assumption that lichens are important to caribou. These assumptions are an essential part of the theory that fire has a detrimental effect on caribou populations. Leopold and Darling (1953) wrote: "To ignore range limitation for caribou is to ignore the crux of the problem. One fire could undo the work of decades in protecting a local caribou population from men and wolves." They further state that "...fire has played so dominant a part in destroying the lichen range that we feel quite safe in attaching to that one factor the major blame for caribou decrease." Scotter (1967) concluded, "More prevention and control of forest fires would seem desirable in light of the small caribou population and the long-term destruction of winter range by fire." Edwards (1954) concluded:

> It appears that fire is the major cause of caribou decline in Wells Gray Park. The northward march of the decline through the province is suggestive of the same cause, since the trend of first human influence upon wilderness lands in British Columbia had progressed generally from south to north. In Alaska (Murie 1951, p. 278), western Ontario (deVos 1948) and other areas where caribou declines or exterminations were followed by increases in deer or moose there is ample evidence to suspect fire.

The general rule that survival of caribou depends on the abundance of lichens is not valid (Bonner 1958, Skoog 1968, Bergerud 1974, Klein 1974). Feeding studies have shown that caribou almost invariably lose weight on an ad libitum diet of only lichen (Courtright 1959, Kelsall 1968, Bergerud 1974, Cameron et al. 1976). In fact there is some evidence that some *Rangifers* may fare better on a reduced lichen diet. Klein (1974) described a situation in Siberia as follows:

> One study involved the comparison of feeding behavior of the Hargin reindeer from the Chukotsk region (Chukchi Peninsula) and the Evenki reindeer typical of the region. The Hargin deer are well known for their thriftiness in existing on ranges with little or no lichens present. In the study, carried out in winter, groups of Hargin and Evenki deer were kept in adjacent large enclosures with similar forage available to each group. The Evenki deer used 70 percent lichens and 30 percent nonlichens and gave a meat yield of 50 kg per 100 kg of live weight. The Hargin deer used 30 percent lichens and 70 percent nonlichens and were able to obtain their forage needs on a smaller area per animal than the Evenki deer. Meat yield from the Hargin deer averaged 65 kg per 100 kg live weight.

In many areas lichens form only a minor portion of the diet or are completely lacking (for food habits see Murie 1935, Cringan 1956, Bonner 1958, Courtwright 1959, Kelsall 1968, Klein 1968, Skoog 1968,

Bergerud 1972). Skoog (1968:352) stated: "...all who have discussed caribou-range relationships have implied that lichens are required by caribou and that the relative abundance of these plants sets the carrying capacity of the range. There seems to be adequate information available to dispute this idea." Furthermore, investigators have shown that certain lichens are highly digestible, high in carbohydrates, but low in nitrogen (Cameron et al. 1976, Pegau et al. 1973, Miller 1976).

Fire may in fact improve the quality of caribou range. Ahti and Hepburn (1967) and Rowe and Scotter (1973) concluded that because fire destroys thick carpets of bryophytes in the southern part of barren-ground caribou range in Canada it makes the forest more productive of lichens and other forage plants.

Courtwright (1959) believed that small fires would be beneficial to the range by returning nutrients to the soil. Similarly, Bergerud (1971) concluded "...forest fires in the past have increased the extent of winter range by altering closed-canopy forests to lichen woodlands or shrub-barrens, and prostrate subalpine spruce-fir thickets to lichen shrub barrens."

Effects of Fires other than Reducing Lichens

Although no cause-and-effect relationship between increased wildfires and caribou population declines has been demonstrated, the correlation between these two events suggests that wildfire may have direct or indirect effects other than destroying lichens. Because caribou are mobile and can avoid a wildfire, and because they are usually in tundra habitat during the taiga fire season, they would rarely be killed by the fire itself.

Indirect adverse effects of fire have been postulated by several authors but most conclusions are speculative. Banfield (1954) and Scotter (1971a) speculated that fire could create physical barriers (e.g. downed timber) and Banfield (1954) observed caribou avoiding recent burns during migrations. Kelsall (1957) and Scotter (1967) found that caribou avoid areas in young successional stages and frequented more open forest of spruce or jack pine. They also observed that snow conditions, low forage production and windfallen trees made recent burns unattractive to caribou.

Bergerud (1974) has discussed extensively the increases in predator populations and exposure of caribou to parasites which occurred following increases in fires resulting in seral habitat. Seral habitat allowed increases in different "buffer species" of prey, which in turn allowed predator populations to increase. He discussed Edwards' (1954) data from Wells Gray Park, and concluded that increased predation rather than a shortage of lichen habitat was responsible for the caribou population decline noted there. Bergerud reviewed observations from other Canadian studies, and reached similar conclusions for these populations. Seral habitat may have resulted in faunal changes which subjected caribou to a wider array of diseases and parasites. Bergerud (1974) presents circumstantial evidence that range extension by white-tailed deer (*Odocoileus virginianus*)

into caribou habitat possibly resulted in a decline in caribou populations due to infection with meningeal worm (*Parelaphostrongylus tenuis*) transmitted by the deer.

Conclusions

1) Wildfires in Alaska increased following white settlement. However, evidence obtained in northern Canada is contradictory.

2) Although the period of caribou population declines correlates well with periods of increased occurrence of wildfire, especially in Alaska, no evidence supports a causal relationship. Destruction of caribou range by wildfire does not appear to be entirely responsible for the declines because caribou do not appear to be dependent on lichens, and effects of wildfire on lichen range are not necessarily harmful.

3) Other direct or indirect effects of wildfire may have contributed to the caribou population declines. Seral stages resulting from wildfire may enhance faunal changes such as increased predator density or influx of disease and parasite vectors.

4) Decimating or regulatory factors involved in the caribou population decline likely included overhunting (Elton 1942, Banfield 1954, Sonnenfield 1960, Bergerud 1974), increased natural predation (Bergerud 1974), or some combination of these, possibly in conjunction with increased fires.

Effects of Fire on Alaska Caribou Herds

Statewide Effects of Fire on Caribou

The relationship between past fluctuations in Alaskan caribou abundance and acreage burned per year may reflect the role of fire as a factor in caribou population dynamics even though a confounding time lag may be involved. Alaskan caribou literature was reviewed by Skoog (1968) and, although historical fire records are scanty, Lutz (1956) summarized the occurrence of large fires in Alaska from 1893-1950. Statewide occurrence of fire and abundance of caribou may be masked by regional differences, therefore we compared the regional historical caribou population profile with the acreage of burns (summarized in Table 1).

Skoog (1968) interpreted the historical data on statewide caribou abundance as follows:

> There is sufficient evidence to suppose a population high in the 1860's and the 1920's, and a low in the 1890's and 1940's.... Considerable fluctuations have occurred, of course, in the numbers within any one region. In Alaska as a whole, however, it is difficult to say how much the total population actually changed during the so-called "highs" and "lows." The extent of such changes could have been obscured by the population shifts.

Table 1. Summary of major shifts in distribution of Alaska caribou and occurrence of wildfires during the past 100 years. (Adapted from Skoog 1968.)

REGION*	HERD/AREA	PERIOD	SHIFTS IN DISTRIBUTION NOTED	YEAR and (acreage of major fires)
I	Alaska Peninsula	Late 1870's	Movements to SW of Port Moller stopped; center of abundance in NE	
		1880's	Movements across Kvichak River stopped; emigration of animals N into Region II	
		ca.1900	Center of abundance shifted to SW	
		Early 1940's	Center of abundance shifted to NE	
II	Lower Kuskokwim River	1870's	Movements of Norton Sound herd (Region III) N-S across lower Yukon & Kuskokwim Rivers stopped; many probably remained in II; center of abundance in south half of Region II	
	Kuskokwim Mountains	1880's	Probable emigration N across Yukon River into Region III from Kuskokwim Mountains	
	Mulchatna herd	1880's	Movements to Alaska Peninsula across Kvichak River stopped; most of herd probably remained in upper Mulchatna River area (Region II)	
	Whole region	ca. 1900	Center of abundance shifted to NE	
	McKinley herd	1906	Large movement across Yukon River at Tanana	1924 (200,000) (150,000)
		1925-31	Extensive annual movements E into Region VI; return each spring	
		1927	Emigration N into Region III	
		1932	Eastward movements stopped; winter range now to W	1935 (640,000) (1,900,000)
		Early 1930's	Further emigrations N into Region III; center shifted S toward Rainy Pass	
		Late 1930's	Center shifted back to NE	1940 (1,250,000) (750,000)

*Skoog's six main caribou regions (see Skoog 1968).

Table 1. Continued.

REGION	HERD/AREA	PERIOD	SHIFTS IN DISTRIBUTION NOTED	YEAR and (acreage of major fires)
III	Arctic herd	1837	Abundant on arctic coast year round	
		After 1837	Probable shift away from arctic coast	
	Norton Sound herd	1860's	Abundance in Norton Sound area and along lower Yukon and Kuskokwim Rivers	
		Early 1870's	Movements N-S across lower Yukon and Kuskokwim Rivers stopped; herd left area; probably emigrated E into Region II and/or N into Arctic	
	Arctic herd	1883	Animals returned to arctic coast	
		Late 1890's	Shift away from arctic coast, S and perhaps E; center of abundance along upper Colville River	
		Late 1910's	Shift E to central Brooks Range; probably formed separate herd, embracing portions of both Region III and IV; reduced herd remained in DeLong Mts. and along upper Colville River	
	Central Brooks Range	Late 1910's	Immigration from Region IV	1920 (115,200)
		1927	Immigration from Region II	
		Early 1930's	Further immigrations from II and IV, and possibly from V	
		1940's	Shift to W; herd no longer separate	
	Arctic herd	1940's	Began to winter on south slopes of Brooks Range and along Kobuk River; began to appear along Bering Sea coast N of Kotzebue	1940 (450,000) 1941 (202,000)** (112,000)** (1,000,000) (500,000) 1947 (192,000)
		1960's	Extensive movements to all portions of region, except Seward Peninsula	

**these were on the boundary of Regions II and III.

Table 1. Continued.

REGION	HERD/AREA	PERIOD	SHIFTS IN DISTRIBUTION NOTED	YEAR and (acreage of major fires)
IV	Porcupine herd	Early 1900's	Shift inland from arctic coast; movements extended far to S; possible emigration into Region V	
		Late 1910's	Shift of animals W into Central Brooks Range	
		1920's	Intermingling with Fortymile herd of Region V; split occurred, with one portion comprising the Central Brooks Range herd, together with animals from Region III	1922 (448,000) 1930 (134,000)
		1930's	Immigration from Region V	1930 (134,000) 1936 (288,000) 1937 (312,320) 1940 (192,000) 1941 (268,800) (128,000) (256,000) 1943 (224,000) (179,200)
		Late 1940's	Large emigration either E into NW Territories of Canada or W into Region III, or both	1950 (1,800,000)
		1957; 1964	Immigration from Region V	
V	Fortymile herd	Late 1800's	Shift in wintering grounds to W from Whitehorse area	
		Early 1900's	Probable immigrations from Region IV	
		1920's	Huge population; widespread, erratic movements; seasonal movements into Region VI, return each spring; intermingling with animals of Region IV	1922 (921,600) 1926 (100,000) 1927 (5,000)

Table 1. Continued.

REGION	HERD/AREA	PERIOD	SHIFTS IN DISTRIBUTION NOTED	YEAR and (acreage of major fires)
		Early 1930's	Shift in winter distribution to N and NE; movements to Region VI stopped	
		1930's	Emigration N into Region IV	
		Late 1930's	Main wintering grounds again to SE	1940 (192,000) (640,000) 1941 (216,320) (211,200) 1944 (96,000) 1947 (187,000) 1945-55 (2,560,000)
		1957; 1964	Emigration N into Region IV	
VI	Nelchina herd	1870's	Decline in numbers from previous high; possible emigration NW into Region II	1893 (135,000) 1896 (34,000) 1915 (384,000) (64,000)
		1918-31	Received seasonal influx of animals from Region II and V; left each spring; some may have remained; movements stopped in 1932	1927 (128,000) 1941 (252,000) 1942 (250,000) 1947 (421,000) (125,000)
		1960's	Large population; widespread, erratic movements; winter movements extending into Region II and to border of Region V	

In the past, few biologists have estimated caribou abundance. Murie (1935) believed there were between one and two million caribou in Alaska and Yukon Territory. Skoog (1968) commented as follows:

> In view of the discussion thus far, I think it is unlikely that Alaska's total population ever has exceeded a density of 5 animals/sq. mi. If the figure of 400,000 square miles represents a valid estimate of the potential habitat that has been available to caribou, then it would appear the total numbers have not exceeded 2 million. It seems more likely that the population has remained far below that figure, and that the total habitat never has been fully occupied. Indeed, it is almost axiomatic to say that no animal ever has occupied fully its natural habitat. Disruptive distributions and density fluctuations characterize all species. The population 'forces' of reproduction, mortality and movements provide the flexibility needed to achieve in time the environmental balance necessary for a population's continued existence. It is my opinion the present estimate of 600,000 for caribou numbers in Alaska probably is not far removed from what might be considered a near normal population size--both past and present.

Because no fire records for the period are available, the reported population high in the 1860s and the extent of habitat burned cannot be compared. The population low in the 1890s was a decade earlier than the first period of reported extensive burning. The 1920 high in caribou abundance possibly occurred during the peak period of extensive burning. Skoog (1968) stated, "In fact, considering the great amount of activity in the region prior to 1920, it seems likely that fires were common then." Data for the 1940s are ambiguous because although there was a low caribou population throughout the decade, and 1940 and 1941 were years of high fire activity, the occurrence of wildfire from 1942-1945 is among the lowest recorded.

This attempt to correlate statewide caribou abundance with the occurrence of wildfire has obvious shortcomings. We felt more insight into the relationship could be gained by reviewing available data on a regional basis.

Skoog (1968) divided Alaska into six regions, and assessed caribou abundance from historical times to 1968 in each region. By comparing his caribou data to the extent of wildfire in each particular region as reported by Lutz (1956), we felt we could infer much about the probable impact of fires (Table 1). A review by region follows:

Region I (Southwest Alaska and Alaska Peninsula - inhabited by the Alaska Peninsula Herd). Skoog (1968) reported that:

> The Alaska Peninsula (Region I) has not been affected much by fire because the forested areas are limited mostly to north of the Naknek River system. The caribou herd has

> remained south of this line since prior to 1900. Practically the entire forested area along the Kvichak River, and much along Lake Iliamna, was destroyed by fire in 1935 (Heintzleman 1936:592, Lutz 1956:16). In 1960 I noted that the effects of fire were still quite evident and lichens were particularly scarce. At the same time, however, lush stands of lichens were present along the highlands south of Lake Iliamna to Naknek Lake, which are not being utilized by caribou. The Alaska Peninsula herd winters mostly in the Lake Becharof area to the south, where lichens are rather scarce; the diet is mostly sedge. Farther south, forage lichens are extremely scarce and the diet is almost exclusively sedges and grasses. The burned area along the Kvichak River and the shores of Lake Iliamna very definitely constitute a barrier of sorts to caribou movement between the mainland and the Alaska Peninsula, because of the general lack of forage there. There is no indication, however, that caribou ever have "tested" this barrier.

According to Lutz (1956), no major fires were recorded for this area between 1893-1950. Fire probably has not influenced caribou population dynamics in this area. Skoog (1968) added:

> In summary, the caribou population of Region I has fluctuated considerably during the past 100 years, both in distribution and in numbers.... This shift might have been influenced in part by the extensive hunting of caribou during the period 1880-1910.... Three severe winters (1930-31; 1933-34; and 1938-39) resulted in heavy mortality, and a low point in the population probably was reached during the 1940's.... In numbers, it seems doubtful that the total population has exceeded 20,000 animals since the 1890's. The fluctuations in distribution and numbers that have occurred since then can be attributed probably to weather and perhaps, in part, to volcanic activity, both as influences upon food supply and/or availability and therefore upon movements and survival.... I consider most of the Alaska Peninsula to be rather marginal habitat for a sustained large caribou population, because of the severe icing conditions that occur periodically.

During 1975 ADF&G conducted a photocensus during the post-calving period and composition counts during fall migration. Although the population was estimated at approximately 11,000 animals, the investigator felt that there were likely 15-20,000 animals present (Irvine 1976).

Region II (Western Alaska - inhabited by the McKinley, Mulchatna, Beaver, and Kuskokwim Mountains herds). Skoog summarized the role of fire in Western Alaska as follows:

> In western Alaska (Region II) spruce forest comprises the major vegetation type over much of the area. As one might suppose, fires have been widespread, although mostly

limited since the 1940's to the areas surrounding the relatively few towns and mining operations remaining. Black-spruce bogs are rather common and some of these support good lichen stands, especially in the Lake Minchumina area where the McKinley herd frequently winters. Burned sections extend throughout the Kuskokwim Mountains, however, and these may have inhibited a buildup of caribou there. Alpine areas there are limited, and caribou must utilize the spruce forests for part of their subsistence, as the Beaver herd does today. On the other hand, the extensive spruce forests would indicate rather marginal habitat for a sustained, year-round population, and therefore the effect of fire probably is secondary. If the population to the east (center of habitation) were to reach high densities, however, it would require these spruce forests for winter range. At present that potential utilization has been severely restricted because of fire damage. The abundant lichen and sedge stands present along the Alaska Range are more than adequate for the population now.

A comparison of data in Table 1 to Skoog's (1968) summary of population distribution and dynamics in this region shows no obvious correlations between reduced numbers of caribou or increased movements and the incidence of fires.

During the past several years the Mulchatna herd has become the largest herd in this region. The herd numbered about 15,000 when censused in 1974 and had grown rapidly since the mid-1960s. The Rainy Pass, McKinley, and Beaver herds in this region have remained small, numbering from 1000-3000 each.

Region III (Northwest Alaska - Western Arctic herd):

Again, a comparison of data from Table 1 with Skoog's (1968) summary of caribou population dynamics and movements in this region suggests no obvious correlations.

Skoog (1968) summarized the effects of wildfire in this region as follows:

> Northwestern Alaska (Region III) has not been affected much by fire except in the southeastern quadrant. This burned area extends northward from the Yukon River to encompass much of the Koyukuk River valley as far as Bettles. There, extensive fires have occurred periodically during the past 50 years, and the lichen cover generally is poor, as viewed from the air. In spite of that caribou have wintered there several times during the 1960's; presumably the black-spruce bogs and the alpine areas supplied the forage, which must have been mostly sedges in this case. Extensive stands of lichen are present in the spruce along both sides of the Kobuk River, however, and the herd has been utilizing these since the late 1940's. Fire has been

uncommon along the Kobuk. Prior to the 1940's the herd wintered exclusively to the north, frequently on the arctic coastal plain; the animals must have subsisted mostly on sedges, because forage lichens are quite scarce north of the Baird and Endicott Mountains.

The Western Arctic caribou herd declined dramatically between 1970 and 1976. Several intensive studies of the population are presently being conducted. However, to date it does not appear that wildfires played a significant role in that decline.

Region IV (Northeast Alaska - Porcupine herd):

As indicated in Table 1, Region IV was the most extensively burned area between 1893-1950. Concurrent with extensive burning in the late 1930s and early 1940s, large emigrations occurred either east into the Northwest Territories or west into the Western Arctic (Region III). The correlation is apparent, but a causal relationship can probably never be established. Skoog's discussion of population dynamics follows:

> Prior to 1900 the subpopulation of Region IV seemed to be rather large. Caribou also were abundant to the east of the Mackenzie Delta and there may have been a periodic exchange of animals across the Mackenzie River. During the early 1900's the herd remained large at the center of habitation, but had shifted away from the coast, and segments also were shifting toward the Endicott Mountains on the west. In the 1920's and 1930's there were essentially two herds in Region IV: one ranging the center of habitation in the northeast, and the other occupying the central Brooks Range, i.e. the upper drainages of the Koyukuk and Chandalar Rivers northward to the arctic slope. There was an influx of animals into the arctic from Regions II and V during and after the late 1920's, and there may have been an interchange between Regions III and IV as well. By the mid-1940's the subpopulation in Region IV was quite large, but by the early 1950's had dwindled considerably. It seems likely that a shift in numbers to the east or to the west had occurred. Since about 1953 or earlier there has been a steady buildup in numbers, and evidence exists for further immigrations from Region V on the south. The central Brooks Range "herd" disappeared as a separate group during the 1950's presumably joining those to the westward, and by 1964 the Alaskan arctic contained but two subpopulations: the Arctic herd of Region III and the Porcupine herd of Region IV, each utilizing a separate, distinct calving area. No other calving areas were evident in those regions.

Skoog (1968) summarized the impact of fire in this region as follows:

> Northeastern Alaska (Region IV) has been burned extensively from the Yukon River-Black River-Porcupine River flats northward

onto the south slopes of the eastern Brooks Range (southwest quadrant). Fortunately, this section has not been utilized much by caribou in historical times, although once again the potential utilization value has been reduced. Sedge areas remain abundant, however, in the lake-pond-bog terrain. In the Yukon, fires have burned portions of the Old Crow Flats, an important wintering area for these caribou. Perhaps this loss has caused the animals to move into the alpine areas farther south, although these appear to have been utilized frequently in the past anyway. Abundant alpine vegetation remains in this region, and the loss of winter forage by fire thus seems insignificant relative to the population present.

Region V (Eastcentral Alaska - Fortymile herd):

A detailed discussion of recent and historical effects of fire on Fortymile caribou abundance appears in a later subsection: Effects of Fire on the Fortymile Herd.

Region VI (Southcentral Alaska - Nelchina, Mentasta, and Kenai herds):

Skoog (1968) summarized the impact of fire in this region as follows:

> Fires in southcentral Alaska (Region VI) have been limited mostly to the terrain adjacent to the Tanana, Copper, and Susitna Rivers. These areas have not supported permanent caribou populations in historical times, although periodically caribou have passed through them. Large fires on the Kenai Peninsula were thought to have been the principal factor in the loss of caribou there (Palmer 1941). This opinion seems valid, because the limited alpine areas suitable for caribou winter grazing would force the animal to rely heavily upon the spruce forests. On the other hand, as discussed earlier, I consider the Kenai to be a marginal habitat for a sustained caribou population, so perhaps the fires merely hastened what might be considered an inevitable decline. The Lake Louise Flats, extending eastward and southeastward to and beyond the Copper River, has been subjected to widespread fires periodically since before the white man arrived. Glenn stated (Glenn and Abercrombie, 1899:59) as he approached the Lake Louise Flat in 1898, 'We entered what we called the "burned district," which seemed to extend as far as the country is visible toward the Copper River, and to the northward almost to the Alaska Range...none of the Indians we encountered remembered it as being in any other condition than it is at the present time.' He noted, however, the lichen cover and growth were quite good throughout the Flat. Several fires since that time, plus numerous winters of grazing by caribou, have left the lichen cover in rather poor condition; yet there is still abundant forage and the caribou still utilize the Flat

for early winter feeding. Elsewhere in the region winter forage is abundant, and excellent lichen stands occur both in the dwarf birch zone and in other alpine areas. A large proportion of this region lies near or above timberline, and hence fires have not significantly damaged the caribou range.

In this region there are no obvious correlations between changes in caribou abundance and extent of fires. In fact, most major fires occurred during the 1940s (Table 1), yet during the late 1940s through the 1960s the population expanded considerably.

Effects of Fire on the Kenai Peninsula

The relationship between fire and caribou on the Kenai Peninsula merits extensive discussion because this situation is frequently cited as a classic situation in which the disappearance of caribou and the appearance of moose in an area were due to fire-initiated succession. We do not believe the actual sequence of events there is obvious.

Several authors (Leopold and Darling 1953, Palmer 1941) have cited the extirpation of the Kenai caribou herd in the early 1900s as an example of a species (caribou) dependent on climax vegetation being outcompeted by a species (moose) that thrives on seral vegetation. The basis for this conclusion is the observation by Dufresne (1946, cited in Lutz 1956) that Kenai caribou disappeared following the fire of 1883. Also, Murie (1951:278) contributed to this view with his statement that where caribou population declines or exterminations were followed by increases in deer or moose there is ample evidence to suspect fire as being the cause of the decline in caribou numbers.

Another explanation for the Kenai caribou decline is that overhunting by both Natives and Whites occurred during the late 1800s (Lutz 1956). Lutz (1956) cited observations by Stone, Elliott, and Lee of overhunting during the late 1800s.

A third explanation of the Kenai caribou decline was presented by Murie (1935) and Skoog (1968). Skoog (1968) commented as follows:

> The presence of caribou on the Kenai Peninsula during this early period also might have been an indicator of a former high population farther to the north. This area, as well as the Chugach Mountains on the north through which the animals would have had to pass in order to reach the Kenai, can be considered as marginal habitat for caribou, because of the precipitous terrain, deep snows in the mountains, and rather limited suitable areas above timberline (i.e., extensive sedge-meadow and/or heath-lichen stands). There is no record indicating that caribou were ever particularly abundant on the Kenai. Petrov (1881:38) mentioned the natives there hunted caribou in the interior, but from his comments it would appear that moose

and fish provided most of the protein food. At any rate, by 1900 the animals had become quite scarce and A. J. Stone stated they "...will doubtless soon be exterminated," (Osgood, 1901:61). Neither Osgood (1901) nor J. A. Allen (1904) were successful in locating caribou in 1900 and 1903, respectively, although both noted recent evidence of the animals' presence, as did Radclyffe (1904) in 1903 also. Lutz (1956:85) stated the last known record of a caribou being sighted on the Kenai was in 1912. Palmer (1941) suggested that the widespread fires on the Kenai in the late 1800's (1871, 1883, 1891) were in large measure responsible for the disappearance of caribou. To a certain extent this opinion might be true, for certainly the fires destroyed a large portion of the winter range, which in this area was located mostly in the spruce forests. I concur more with O. J. Murie's (1935:77) statement, however, that, "the Kenai Peninsula seems to be simply an overflow area that probably often received an influx of caribou from unusual migratory movements of interior herds." In this respect, then, the Kenai Peninsula, like the Chitina River Valley mentioned earlier, would be utilized only as a result of high population pressures at the center of habitation.

These diverse interpretations demonstrate that the disappearance of caribou from the Kenai Peninsula during the early twentieth century cannot be solely attributed to habitat destruction by fire.

Caribou from the Nelchina herd were transplanted to the Kenai Peninsula in 1965 and 1966 and are presently well established (Burris and McKnight 1973). There are two distinct groups and both utilize winter range that was not affected by fires in the past. We interpret this fact as suggesting that this habitat was also present at the time that caribou were eliminated, supposedly due to habitat destruction. A herd of 300 animals (maintained at that number by hunting) presently inhabits an alpine area in the Kenai Mountains, south of Hope. These animals attain large body and antler size, and the herd as a whole has excellent initial production. The herd uses an alpine area that has presumably been little affected by fire throughout the years.

A smaller herd (65-80 animals in 1976) occupies a black spruce muskeg habitat in the Kenai lowlands on the Moose River Flats. This area is inside the perimeter of the 1947 burn but was likely little affected by that fire. The animals appear to feed mainly in sedge areas, but they may also be feeding on lichen growth in the sparse black spruce ecotype. Stands of climax white spruce forest are located to the east and to the north of this ecotype, but they apparently receive no caribou use, suggesting that habitat loss because of fire likely was not the sole reason for extinction of the Kenai caribou.

Apparently there is suitable caribou habitat in at least two other locations: the alpine benchland country between Tustumena and Skilak Lakes, and a more marginal area in the Caribou Hills. These areas of potential caribou habitat were probably never greatly affected by fire.

Skoog (1968) and Murie (1935) may be correct in assuming that the Kenai has been an "overflow area," enough suitable habitat has remained to support a remnant caribou population in spite of the widespread occurrence of fire. It is likely that factors other than wildfire were responsible for the decline of Kenai caribou during the early twentieth century.

Effects of Fire on the Fortymile Herd

Food habits and carrying capacity

No food habits studies have been conducted on the Fortymile herd since Skoog's (1956) study. Curatolo (1975) noted vegetation types utilized, but did not analyze food habits. Because the topography, climate and vegetation of the Nelchina area are similar to those of the Fortymile area, we feel that the findings of Nelchina range studies by Pegau (1972) can be extrapolated (at least in part) to the Fortymile area.

Fortymile caribou utilized areas above timberline (approximately 3000' MSL) from spring to late fall (Skoog 1956, Curatolo 1975, see "Distribution and Movements in Relation to Habitat," Job 3.15R, this report). During early to late winter, the animals moved to timbered areas and remained there until snow conditions in late winter caused them to seek snow-free areas on higher ridges.

The extent of utilization of lichens varied seasonally from 1-15 percent by volume in summer (Skoog 1956) to over 50 percent by volume during early winter. During all seasons sedges and leaves of woody plants (*Salix* spp. and *Betula glandulosa*) were also important food items.

Skoog (1956) collected rumen samples during August and September 1954 and November 1952. He analyzed the samples volumetrically (Table 2). During fall, when the *Dryas* and dwarf birch communities were extensively used, lichens (primarily *Cladonia*) increased in importance from 15 percent occurrence in the diet in August to 48 percent in late September. By November, when the animals moved to timbered areas, lichens comprised 55 percent of the diet. During winter the lichen genera *Stereocaulon* and *Cetraria* were utilized as well as *Cladonia*. On two occasions Skoog (1956) also observed caribou feeding on arboreal lichens. During winter range reconnaissance Skoog (1956) found numerous places where animals had cratered and eaten lichens on the bare *Dryas*, sedge-grass, and dwarf birch-willow ridgetops. Pegau (1972) felt that lichens were most important to Nelchina caribou during early winter.

By late winter and early spring Fortymile herd caribou frequented timberline habitat, especially snow-free areas. They increased their utilization of emerging green vegetation, especially young leaves of willow and dwarf birch, sedges, and grasses, although they still ate lichens. Snow conditions determined the movements of caribou and the locations in which they fed.

Table 2. Food items contained in rumens[1] of Fortymile caribou during fall and winter (after Skoog 1956).

Food Item	Fall				Winter	
	August 20-31, 1954		September 12-24, 1954		November, 1952	
	Mean(%)	Range(%) (n=19)	Mean(%)	Range(%)	Mean(%)	Range(%) (n=70)
Lichen[2]	15.1	0.5-37.4	47.8	5.8-71.2	55	25-80
Sedge-grass	0.7	0.0-3.4	10.2	0.5-21.0	25	10-60
Woody (esp. Birch-Willow)	36.0	9.6-75.2	12.4	2.6-40.0	15	5-35
Total	41.8		70.4		95	

[1] Rumen contents were macroscopically analyzed and recorded as percent of species occurring by volume (complete description of technique in Skoog 1956, p. 126)

[2] Primarily Cladonia during winter; entirely Cladonia during fall.

Thus, caribou ate lichens during the entire year, but lichens were the most important food source only during winter, especially early winter. Other vegetation, especially sedges and shrubs, was also used during the entire year. An accurate appraisal of the importance of lichens to the Fortymile caribou herd, and the consequences of wildfire to lichen abundance in the Fortymile herd's range, must be related to this seasonality of forage use.

Although there is no information on the lichen biomass of the Fortymile area, in his 1972 report Pegau examined the range of the Nelchina herd, and re-evaluated range sites which had been studied by Hanson in 1957 and Skoog from 1960-1966. Pegau recalculated some of the biomass figures from earlier investigators, and reported the following estimates of total fruticose lichen air-dry weight in several vegetation types:

Heath type (lowland): 5000 lb/acre (mostly *Cladonia*)
Bog type (poor drainage): 644 lb/acre
Shrub birch (old burn): 2560 lb/acre
Shrub birch (overgrazed): 695 lb/acre
Shrub birch (good condition): 2290-4930 lb/acre (mean = 3610 lb/acre)
Open spruce (30-year-old burn): 329 lb/acre
Open spruce (unburned): 2730 lb/acre

These biomass estimates were admittedly crude extrapolations from clipped meter-square quadrats in areas which had received varied intensities of grazing, and were not divided into important forage lichen species. Nevertheless they do reflect major differences in forage availability among vegetation types.

The vegetation types in the Fortymile area which are usually affected by fire are the black spruce, white birch-white spruce and dwarf birch-willow types. However, all fires do not reach the dwarf birch type. According to Pegau (1972), unburned open spruce stands and the dwarf birch vegetation type (in good condition) usually contain the greatest abundance of preferred forage lichens in the Nelchina area. Therefore, we selected these two vegetation types for calculations involving carrying capacity and habitat loss to wildfire.

In the following discussion we acknowledge that many of our assumptions are based on findings of studies in other locations and that extrapolations from them to the Fortymile herd may not be valid. Although we recognize the utility of acquiring comparable data for the Fortymile herd, we maintain that other data needs have higher priority. The concept of forage carrying capacity is difficult to articulate, and factors other than relative forage abundance can determine the actual carrying capacity. However, in the following discussion we define carrying capacity in the manner of Stoddart and Smith (1955) as: "the maximum animal numbers which can graze each year on a given area of range, for a specific number of days, without inducing a downward trend in forage production, forage quality, or soil."

Knowing the amount of lichen habitat burned by wildfire is useful for deriving estimates of forage carrying capacity, which in turn are useful in assessing the role of range condition in the decline of the Fortymile herd. A very simplistic estimate of forage carrying capacity can be obtained by dividing caribou winter forage ingestion rates into estimates of net annual lichen production for different vegetation types. This method produces very conservative estimates as lichens are assumed to be the only forage available.

For our calculations of carrying capacity, we made the following assumptions:

1) Annual productivity of lichens is 10 percent of the standing crop.
2) Lichen forage ingestion rates = 22 lb/day (air-dry weight).
3) Trampling, cratering, trailing and other conditions did not make more than 90 percent of the standing crop of lichen unavailable. Thus, the entire 10 percent annual productivity is available for ingestion each year.
4) Due to the occurrence of fire, at any given time the average production of the entire lichen area was only 50 percent of its potential.
5) Lichen production for a given vegetation type is the same in the Fortymile area as Pegau (1972) found in the Nelchina.
6) Fortymile caribou are dependent upon lichens for 6 months of the year.

The basis for these assumptions follows:

Because carrying capacity estimates are determined on a sustained yield basis, estimates must reflect annual lichen production rates rather than standing crop. Andreev (1954) calculated that under conditions of moderate grazing, the average annual production of *Cladonia* lichens was from 7-10 percent of the standing crop. We used 10 percent annual production as our estimate.

Only a few estimates of lichen ingestion rates could be found in the literature. Hanson et al. (1975) estimated that a free-ranging caribou near Anaktuvuk Pass ate an average of 11 pounds/day (oven-dry weight) of lichens between January and April, which is approximately 22 pounds/day (air-dry weight). These investigators summarized other estimates of lichen ingestion rate, and concluded that their own estimate more closely approximated the true ingestion rate. We used 22 pounds/day (air-dry weight) as our estimate of ingestion rate.

Andreev (1954), Pegau (1968, 1970, 1972), and Miller (1976) discussed the incidental effects of feeding activities on lichens. Andreev (1954) mentioned that pawing and trampling associated with reindeer feeding activities could mechanically damage lichens, and that recovery rates varied from two years to several decades, depending on the amount removed. Pegau (1970) found that on a heavily-used western Alaska reindeer site

where lichens composed over 30 percent of the available forage, at least 15 percent of the total lichens became unavailable due to trampling. Pegau (1972) examined an area of the Nelchina range which had been heavily used for three months each year during three consecutive winters. He found that 9 percent of the lichen cover had been destroyed by trampling, and 19 percent had been lightly grazed. Miller (1976) found little mechanical damage to lichen areas grazed by caribou of the Kaminuriak herd during winter, but observed noticeable damage to lichen areas grazed during the snow-free period. Miller also found that in areas utilized by caribou during mid winter and late winter, the snow cover mitigated the effects of trampling, although pawing action during cratering did dislodge some lichens. We assumed that the amount of lichens damaged by trampling equals the amount ingested. We further assumed that deep snow during midwinter and late winter lessens the effects of trampling, and that trampling is critical for only 90 days per year.

Snow compaction, which results from cratering, reduces the amount of lichen available during the same winter. Bunnell et al. (1975) estimated that the amount made unavailable following cratering was 10-20 times the amount eaten, but presented no data to support the figure. Thing (1977) found that each Western Arctic caribou dug an average of 116 craters per day over the six-month winter period, and that the area of each crater averaged 0.25 m^2. Therefore the total area cratered was 29 m^2 per day. Hanson et al. (1975) estimated that a caribou at Anaktuvuk Pass required 10 m^2 per day of lichens to satisfy its daily forage requirements. Assuming that lichen biomass was similar in both areas, cratering activity made twice as much lichen unavailable as was ingested. Thing (1977) found that snow compaction due to trails and tracks reduced available forage by twice the amount reduced by cratering, or four times the area grazed. Because trampling and snow compaction do not reduce forage availability by more than 90 percent during that year, we assumed that the entire 10 percent annual production is available for caribou forage.

Palmer (quoted in Skoog 1956) stated that at least 75 percent of the Fortymile range had burned at least once since 1900. Lutz (1956) believed that most of the Fortymile area had burned since 1900. We assumed that all of the available lichen areas had burned since 1855. We further assumed that the period required for full regeneration of lichens is 100 years, a conservative estimate because the average lichen regeneration time is approximately 40-60 years (Table 3). Therefore the average annual loss of lichen habitat is one percent. We assume therefore that only 50 percent of the lichen range is available at one time because at that time, the <u>average</u> production of the entire range is only 50 percent, e.g. for each acre that is 10 percent productive there is another acre that has regenerated to 90 percent productivity, etc.

Pegau (1970) calculated that the two Nelchina vegetation communities which supplied most of the caribou's lichen forage were the "unburned open spruce" and the "shrub birch (good condition)." Applying Pegau's (1972) biomass estimates, we derived the following formula for determining

Table 3. Time required for regeneration of lichens following fire.

Lichen Type	Habitat Type	Regeneration Time	Source
Unspecified	"Woodland" (Alaska)	"...A full recovery in lichen composition comprising chiefly short growth forms takes place in about 50 years...the original cover of tall growth lichens... requires considerably more than 100 years..."	Palmer 1941 (in Lutz 1956)
Unspecified	Unspecified	"...up to 50 or even 100 years being required for them to reach preburn production"	Leopold and Darling 1953
Cladonia alpestris	Reindeer range (Norway)	Estimated minimum of 20-50 years recovery; after 50 years some areas had not equalled former production.	Lynge (in Lutz 1956)
Unspecified	Unspecified	"...a conservative estimate of the usual length of time would appear to be 40 to 50 years..."	Lutz 1956
Cladonia alpestris and C. rangiferina	"Lichen ranges" (northern Saskatchewan)	"...complete recovery of two 'reindeer lichens' may require 90 to 120 years..."	Scotter 1964
Cladonia	Lichen woodland (Newfoundland)	over 25 years, increasing rapidly 30-40 years	Bergerud 1971
Cladonia	Forest (Newfoundland)	"...fires improved shrub and lichen supplies in the interval 15-35 years after the burn."	Bergerud 1971
Cladonia	Taiga (northern Canada)	"Major forage lichens usually take from 70 to more than 100 years to recover their former abundance."	Scotter 1971
Cladonia rangiferina and C. arbuscula	Open spruce (3-14' tall) (Nelchina)	Early seral stages (C. gracilis and funnel-form Cladonia) 6-15 years after fire; preferred (C. rangiferina and arbuscula) 30-40 years if sufficient organic substrate and no grazing/trampling.	Pegau 1972
Unspecified	Unspecified	"...often requiring more than 100 years."	Viereck 1973

Table 3. Continued.

Lichen Type	Habitat Type	Regeneration Time	Source
Unspecified	Unspecified	"...no significant recovery of the lichen cover 9 years after a fire"	Cody (in Viereck 1973)
Cladonia arbuscula and C. rangiferina	Heath/sedge (Nelchina)	"...recovery by Cladonia arbuscula and C. rangiferina usually occurred 30 to 40 years following the fire."	Pegau 1975
Cladonia alpestris and rangiferina	Taiga	40 years or more	Miller 1976
Cladonia mitis	Taiga	Less than 40 years	Miller 1976

the stocking rate for each of these two vegetation types for the Fortymile range considering that lichens dictate the carrying capacity:

$$R = \frac{(S)(P)(.50)}{(I) \times 180 \text{ day/yr}}$$

where:
- R = stocking rate (caribou/acre)
- S = standing crop of lichens (lb/acre)
- P = annual production = 10 percent
- .50 = 50 percent of lichen production level because of lowered production to fire
- I = lichen forage ingestion rate (22 lb/day)(air-dry)
- 180 day/yr = days in which caribou utilize lichens at a rate of 100 percent

Solving this equation for the two vegetation types above, we calculated:

$$R_{spruce} = \frac{(2730 \text{ lb/acre})(.10)(.50)}{(22 \text{ lb/day})(180 \text{ day/yr})} = \frac{136.5 \text{ lb/acre}}{3960 \text{ lb/yr}} =$$

0.0344 caribou/acre/yr = 29.06 acre/caribou

$$R_{\text{dwarf birch}} = \frac{(3610 \text{ lb/acre})(.10)(.50)}{3960 \text{ lb/yr}} = \frac{180.5 \text{ lb/acre}}{3960 \text{ lb/yr}} =$$

0.0455 caribou/acre/yr = 21.97 acre/caribou

Skoog (1956) calculated that these two types comprise 50 percent and 15 percent of the entire 35,000 mi^2 range, or 11.2 million and 3.36 million acres, respectively. Carrying capacity estimates for each vegetation type are:

(spruce) - 11.2 million acres ÷ 29.06 caribou/acre = 385,409 caribou
(birch) - 3.36 million acres ÷ 21.97 caribou/acre = 152,936 caribou
Total = 538,345 caribou

This estimate is likely conservative because it is based on (a) conservative estimates of lichen regeneration time and fire coverage, and (b) 100 percent selection of lichen by caribou. Skoog (1956) felt that caribou consumed a diet of only 50 percent lichens even during winter months.

Skoog (1956) extrapolated from data supplied by Palmer (1941) for western Alaska reindeer range in good condition. According to Palmer's (1941) data, each Fortymile caribou required 40-60 acres per year if: (a) 50 percent of the winter diet were composed of lichens, and (b) the range were in good-to-excellent condition. From Skoog's calculation that the bulk of the animals' food came from plant communities comprising 13.4-16.7 million acres, we calculated that the 1956 theoretical carrying capacity for the Fortymile range was 223,300-417,500 caribou.

These two carrying capacity estimates, one derived from approximations of annual lichen production and the other from extrapolations from reindeer range, reflect the theoretical population which the Fortymile range could support.

Fire History and Effects on the Population

Skoog (1968) summarized the impact of fire between the late 1800s and 1965 as follows:

> Eastcentral Alaska (Region V) was more or less the center for the gold mining industry during the late 1800's and the first 20 years of this century. Fires have been a common phenomenon since prior to 1890. Earlier I had computed (Skoog, 1956:28) the extent of fire damage to the main portion (34,000 square miles) of the Fortymile herd's range; between 1920 and 1955 approximately 20 percent of this area had burned. In addition, of course, much had burned previous to that time as well. In fact, considering the great amount of activity in the region prior to 1920, it seems likely that fires were more common then. In 1959 a range reconnaissance by the author revealed that many of these old burns were reforested, and in some the forage lichens had returned to rather fair growth (20-50% cover; 1"-2" height).
>
> Alpine areas are abundant, but in the Alaska portion of this region lichens are not particularly abundant except in the dwarf birch zone; alpine sedge meadows, however, are numerous. Limited flights over the mountains of adjacent Yukon seemed to indicate a similar vegetation distribution. The rapid increase of this caribou population prior to 1930 during the midst of intense mining activity suggests that fires, hunting, and the other disturbances accompanying this industry development had little effect on numbers or distribution. The northward shift of this population during the 1930's occurred after these disturbances had been reduced considerably. The loss in winter forage due to fires could have been a factor in this shift, although the high population density seems a more likely cause.

Skoog suggested that the extensive wildfires in the 1920s were not an important factor in the major range shifts noted in the 1930s, however there could have been a lag between the period of burning and the time at which the effects were felt by the animals. It is impossible to determine if such a delayed effect occurred, however, because adequate fire records and documentation of human population changes are lacking.

There is an apparent discrepancy between the statement of Skoog (above) that 20 percent of the Fortymile range burned between 1920 and 1955, and that of Palmer (1941, in Skoog 1956, p. 25) that 75 percent of the area had been burned since 1900. Skoog (1956) admitted that he probably underestimated the occurrence of fire because: (a) his own estimate was based on incomplete fire records, and (b) Palmer's estimate

included 1900-1920, a period of rapid settlement and development in the area during which fires likely were more common than in later years.

Following range deterioration at the original stocking rates, Palmer (in Skoog 1956) revised his stocking rate estimate for Western Alaska ranges from 40-60 acres per reindeer to 100 acres per reindeer. Skoog extrapolated from Palmer's revised estimate and assumed that fire and grazing had increased the forage requirements for Fortymile caribou to 185 acres per animal (Skoog 1956:25). Skoog concluded that in 1955 the carrying capacity of the Fortymile range was 70,000-90,000 caribou. This carrying capacity estimate is very conservative because it does not account for: (a) lichen regeneration since 1900, and (b) benefits of wildfire such as increased dwarf birch and willow production. Nevertheless, Skoog's estimate exceeds the 1955 caribou population level of 40,000-50,000 (Fig. 1).

Since 1956 more accurate fire records are available for the Fortymile area. From these fire records we can estimate the lichen habitat burned. By dividing the estimated lichen habitat burned by Skoog's conservative estimate of stocking rate (195 acres/caribou), we can determine a theoretical decrease in the carrying capacity. We can then compare this decrease with the population decrease over the same period.

Records of individual fires in the Fortymile range are unavailable for the period 1956-65. However, Barney (1969) summarized the acreage burned for the Delta and Fairbanks BLM administrative areas between 1956 and 1965 (Table 4). During that period, the Fortymile range consisted of most of the Delta administrative area and approximately one-quarter of the Fairbanks administrative area. Therefore the total acreages in Table 4 are overestimates. An estimate of lichen habitat burned by these fires was calculated based on the following assumptions: (a) 75 percent of all vegetated areas below 3000' MSL was lichen habitat (see Skoog 1956), (b) all assumed lichen habitat was also caribou winter range, (c) all areas above 3000' were not burned and (d) severity of burn was 100 percent. Thus the "lichen habitat burned" column represents 75 percent of the total acreage burned.

From 1956-1965 a total of 964,880 acres burned in the combined Delta-Fairbanks administrative areas (Table 4). Of this total, an estimated 723,660 acres were possibly lichen habitat. No carrying capacity estimates for this period are available, but, using Skoog's (1956) estimated annual requirement of 185 acres/caribou to calculate the lichen forage destroyed, one can determine that the area burned would have supported a total of 3,912 caribou during this 10-year period. This would have represented an average loss to the population of only 391 caribou/year. During this same period the population increased from approximately 40-45,000 animals in 1956 to 50,000 from 1960-63, then possibly declined again to 30,000 in 1964. Documentation of the decline in numbers is scanty (see Table 1, Job 13.3R, this report), but it is possible that a portion of the herd emigrated to the Porcupine herd (see discussion in Job 3.13R, this report).

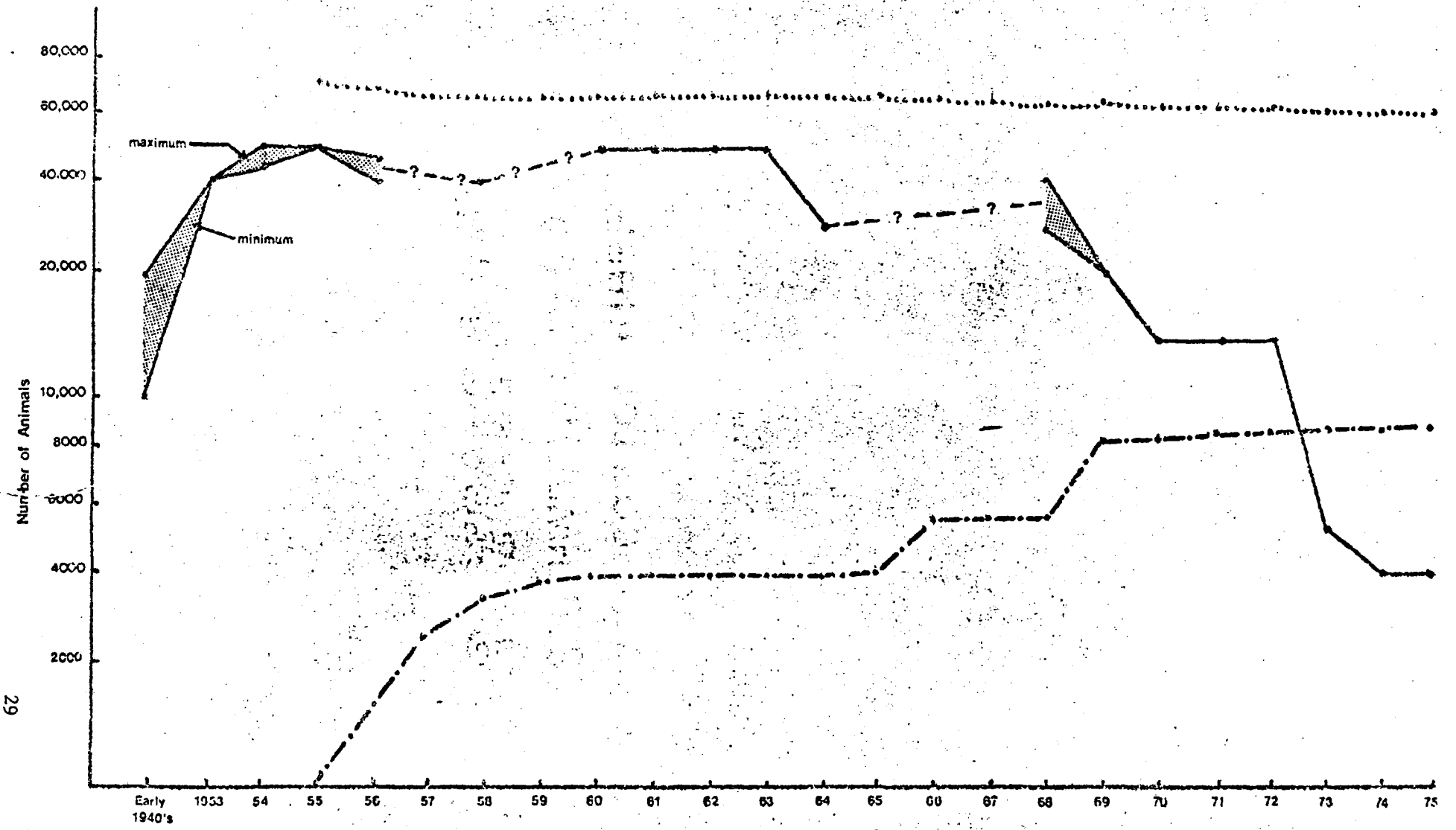

Fig.1. Population size and changes in carrying capacity

Population size

Cumulative decline carrying capacity

Carrying capacity

Table 4. Total acreage and estimated lichen habitat burned in the Delta and Fairbanks BLM administrative areas, 1956-65 (after Barney 1969).

Year	Acres burned		Total	Estimated lichen habitat burned[1]
	Delta	Fairbanks		
1956	31	14,118	14,149	10,612
1957	21,065	537,894	558,959	419,219
1958	43,451	216,609	260,060	195,045
1959	1,378	109,611	110,989	83,242
1960	627	14,096	14,723	11,042
1961	146	225	371	278
1962	201	626	827	620
1963	711	875	1,586	1,190
1964	127	117	244	183
1965	2,872	100	2,972	2,229
Total	70,609	894,271	964,880	723,660

[1] Assumes that 75 percent of total acreage burned = lichen habitat

The BLM fire records since 1965 are more complete than earlier records. Unfortunately the records still do not indicate the severity of burn, e.g. 100 percent of the area, 75 percent, etc., or the habitat type. Therefore the same assumptions were used in Table 5 as in Table 4 to calculate the amount of lichen habitat destroyed.

Between 1966-76 wildfires destroyed 761,577 acres of lichen habitat (Table 6 and Fig. 2). This burned acreage resulted in a decrease in the available forage sufficient to maintain a total of 4,711 caribou during that 11-year period. During the same period the population declined from 30,000-40,000 in 1968 (Skoog 1968) to 4000 in 1976. The estimated minimum carrying capacity in 1965 was 66,089, or almost double the population level. By 1976, although the population had declined to 4000 animals, the carrying capacity had decreased to only 61,373.

The large discrepancy between the carrying capacity and population level throughout the period 1955-1976 strongly suggests that at no time has the herd exceeded, or even approached, the actual carrying capacity (see Fig. 1). The timing of declines in the population could be construed to be a result of decreases in carrying capacity caused by fire, e.g. the 1967-1970 period. However, the magnitude of the population decline (from ca. 30,000 to 15,000) between 1967-70 exceeds the total calculated carrying capacity decrease from 1955-76.

The carrying capacity estimates can be justifiably criticized as being too simplistic; however, in all cases, we attempted to use conservative estimates for carrying capacity calculations, and liberal estimates for population levels. The effects of grazing on reduction of carrying capacity were included in Skoog's (1956) original range requirement figure of 185 acres/animal-year. Likewise, the possible increases in available forage due to forest fire have not been included. Fires may increase the production of dwarf birch and willows; both species are important forage plants utilized during early summer. Additionally, potential lichen production in some areas may have been increased by fires due to the reduction of competition with mosses and the opening of thick timber stands. Calculations involving these beneficial aspects of wildfire have not been included in the estimates of carrying capacity. Thus, the assumptions used in our calculations should result in an overestimation of the decrease in actual carrying capacity caused by wildfire.

CONCLUSIONS

There is ample direct and indirect evidence to suggest that during the period around the turn of the century there was an increase in the number of wildfires in Alaska. During the same period there was a decline in several caribou populations, which was initially attributed to the destruction of lichen range by fire. The conclusion that destruction of lichen range was responsible for caribou declines became common in both the scientific and popular literature. Unfortunately, the assumptions upon which this conclusion had been based have not withstood the scrutiny of further research. There is ample evidence to suggest that lichens

Table 5. Cumulative decrease in carrying capacity, Fortymile area, 1956-1975.

Year	Total acres burned	Estimated habitat loss(acres)[1]	Annual decrease in carrying capacity[2] (no. of animals)	Cumulative decrease in carrying capacity[2] (no. of animals)	Carrying capacity[3] (no. of animals)
1956	14,149	10,612	57	57	69,943
1957	558,959	419,219	2266	2323	67,677
1958	260,060	195,045	1054	3377	66,623
1959	110,989	83,242	450	3827	66,173
1960	14,723	11,042	60	3887	66,113
1961	371	278	1.5	3888	66,111
1962	827	620	3.5	3892	66,108
1963	1,586	1,190	6	3898	66,102
1964	244	183	1	3899	66,101
1965	2,972	2,229	12	3911	66,089
1966	745,000	294,450	1592	5503	64,497
1967	53,130	35,250	191	5694	64,306
1968	0	0	0	5694	64,306
1969	764,420	522,060	2822	8516	61,484
1970	0	0	0	8516	61,484
1971	20,000	14,250	77	8593	61,407
1972	6,400	4,800	26	8619	61,381
1973	79	59	0	8619	61,381
1974	75	56	0	8619	61,381
1975	233	175	1	8620	61,380
1976	636	477	2.5	8622	61,373
Total	2,550,263	1,595,237	8622.5		

[1] Assumes 75 percent of total acreage burned = lichen habitat

[2] Assumes each caribou requires 185 acres/year

[3] Lower limit, based on 1955 carrying capacity estimate of 70-90,000 (Skoog 1956)

Table 6. Total acreage and estimated lichen habitat burned in the Fortymile area, 1966-76.

Identification code[1]	Date/ Year	Total area burned (acres)	Estimated lichen habitat burned[2] (acres)	Comments
	1966			
Y33	7/23	26,000	13,650	Ladue River flats
Y34	7/23	203,000	121,800	West Fork Fortymile River flats
Z61	8/8	16,000	9,000	Upper Salcha River
Y46	8/19	500,000	150,000	Includes 250,000 acres burned on Canadian side
	Total 1966	745,000	294,450	
	1967			
Y43	6/14	6,000	4,500	Mosquito Flats
Y61	6/16	10,000	7,500	North of Yukon River
Y70	6/17	9,020	4,500	
Y72	6/17	9,410	5,250	
Y76	6/18	7,200	5,250	
Y78	6/18	11,500	8,250	Woodchopper Creek
	Total 1967	53,130	35,250	
	1968			
	No fires			
	1969			
9430	6/10	525,000	381,940	
9446	6/15	94,000	57,300	Ladue River
9492	6/22	3,650	2,625	
9495	6/22	28,800	16,500	Along Yukon River, north of Eagle
9502	6/23	4,000	3,000	Lower Preacher Creek (past wintering area)
9509	6/23	46,080	27,675	North of Yukon River
9518	6/24	35,000	22,310	Mt. Harper area
9589	7/12	20,400	10,710	
	Total 1969	764,420	522,060	
	1970			
	No fires			
	1971			
8593	6/21	20,000	14,250	
	Total 1971	20,000	14,250	

Table 6. Continued.

Identification code[1]	Date/ Year	Total area burned (acres)	Estimated lichen habitat burned[2] (acres)	Comments
8774	1972 7/13	6,400	4,800	Beaver Creek flats
	Total 1972	6,400	4,800	
	Total 1973	79	59	
	Total 1974	75	56	
	Total 1975	233	175	
	Total 1976	636	477	
	Total 1966-76	1,585,383	871,577	

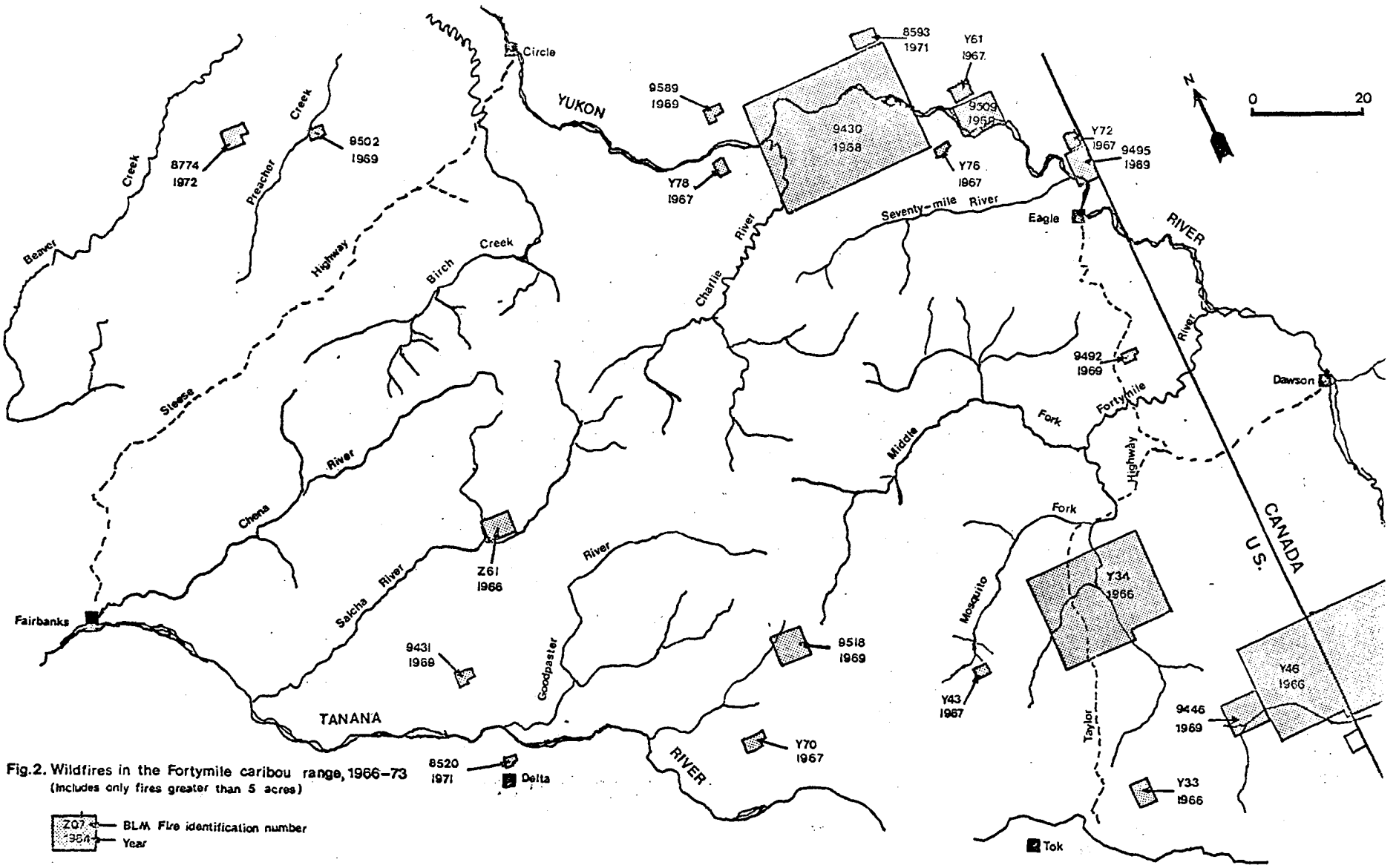

Fig.2. Wildfires in the Fortymile caribou range, 1966–73
(Includes only fires greater than 5 acres)

Z07 — BLM Fire identification number
1964 — Year

are not necessary for caribou survival (Klein 1974, Courtwright 1959, Skoog 1968, Bergerud 1971) and some evidence to suggest that wildfire may in fact benefit lichen regrowth in certain cases (Bergerud 1971, Rowe and Scotter 1973, Courtwright 1959).

Indirect effects of wildfire which may have detrimentally influenced caribou populations have not received adequate research. Such factors are: (1) shift in succession to earlier (and presumably, undesirable) seral stages (e.g. Scotter 1967), (2) adverse snow accumulation (Pruitt 1959, or (3) change of habitat allowing increased predator density (e.g. Bergerud 1974) may have been at least partially responsible for some caribou population declines. No negative effects have been conclusively demonstrated, however. Others researchers (e.g. Bergerud 1974) have concluded that, especially with regard to Canadian herds, overhunting or increased predation or a combination thereof, were more likely causes for the population declines observed.

Evidence from Alaska caribou herds is contradictory. Skoog's (1968) extensive summary of population changes of most Alaska herds is compared to the known extent of fire within each herd's range (Table 1). Only one population shift, that of the Porcupine herd in northeast Alaska, appears concurrent with an increase in the area burned; and even this correlation is obscured because there had been frequent interchange reported between this herd and Interior and Arctic herds in the past. Skoog (1968) and others (e.g. Leopold and Darling 1953) felt that the decline in the small Kenai caribou herd could have been a direct result of destruction of forest-lichen habitat by wildfire. However, we feel that there is adequate evidence to suggest that other factors such as overhunting could have been equally as important. Skoog found no correlation between declining populations and incidence of fire in several other Alaskan herds. He found that the Nelchina herd actually increased coincident with an increase in wildfires during the 1950s and 1960s. Comparison of the Alaskan caribou population changes to incidence of wildfire suggests that fire has not been an important factor in the population changes over the past century.

The Fortymile herd is particularly interesting in this regard. During the early 1900s the influx of miners and associated activities by white settlers resulted in a large increase in the amount of burning. Between this period and the 1950s the population level rose and fell dramatically, then increased again (Fig. 1). Using biomass calculations derived from Pegau (1972) for the Nelchina herd, we estimated that the theoretical 1956 carrying capacity of the Fortymile range exceeded 500,000 animals. Extrapolating from stocking rates on western Alaska reindeer range, Skoog (1956) estimated the Fortymile range carrying capacity at 70,000-90,000. The population numbered only 50,000 animals (Fig. 1).

Since 1955 an estimated total of 1.6 million acres of potential lichen habitat have burned (Table 6). This estimate is a liberal one, and does not account for lichen regeneration during the same period, or for the possible beneficial aspects of wildfire to caribou range. This lost habitat would have supported a total of 8,622 animals during the same

20-year period. During this period the herd declined from 50,000 in 1955 to 4000 in 1975. Furthermore, the timing of fires and declines in the population were not correlated until the early 1970s when the population was far below the actual carrying capacity of 61,484 (Table 6).

Although our calculations are admittedly crude and our assumptions equivocal, we feel that probable error is biased toward a conservative estimate of carrying capacity and a liberal estimate of habitat loss. The actual effects of wildfire to the Fortymile herd have likely been even less damaging than presented here. Therefore, we feel that the population decline of the Fortymile herd has not been the result of habitat destruction, and that the limiting factor at present is not range.

The evidence from caribou populations in Alaska and Canada suggests that fire has not been the major limiting factor to most caribou populations including the Fortymile herd, and that the proper evaluation of its role in caribou declines must be analyzed on a case-by-case basis. The textbook ecology conclusion that fire has been the cause of widespread North American caribou declines in the twentieth century does not seem tenable. It can be argued that fires can temporarily reduce the absolute abundance of forage available, but in most instances it does not appear that the amount of forage available at any given time is low enough to be considered the limiting factor for most caribou herds.

RECOMMENDATIONS

We recommend the following:

1. That land management agencies which are responsible for managing the habitat of the Fortymile herd study the relationship between fires and vegetation changes. One preferable result of this study would be a detailed vegetation type map of the area including the extent and frequency of fires, and successional patterns of caribou forage species, especially lichens.

2. That the Alaska Department of Fish and Game encourage land management agencies responsible for the management of the habitat of the Fortymile herd to pursue habitat studies. The Department should direct its emphasis toward herd rehabilitation and demographic studies.

3. That a fire control policy for the Fortymile herd's range be implemented based upon the following:

a. An overwhelming amount of evidence exists to support the conclusion that fire is the most important single factor influencing ecology of the taiga ecosystem. The mosaic of forest habitat types resulting from fires are natural features of the taiga, to which plants and animals have adapted. From the standpoint of caribou management it appears that lichen recovery within 50 years after a fire is sufficient to allow caribou use. This suggests that a 50-year fire "rotation period" would not result in a reduced caribou carrying capacity. Therefore,

if an average of less than two percent of the herd's habitat is burned annually, the caribou carrying capacity would not be reduced. Conversely, near elimination of fires could ultimately reduce the carrying capacity by eliminating optimal fire-successional stages; evidence suggests that lichen production peaks at some interval following burning.

b. Naturally-caused fires should be allowed to burn unless developed areas, personal property, or critical habitat for another species are threatened. Fire suppression should be considered and perhaps initiated only after the total of human-caused and naturally-caused fires over a period of years exceeds an average of two percent per year of the herd's range.

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