

## Case history of the Fortymile Caribou Herd, 1920–1990

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### *Abstract:*

Early this century, the Fortymile caribou herd was the largest in Alaska and one of the largest in the world. Since the 1940s the herd has remained relatively small, fluctuating between 6,000–8,000 and about 50,000. To determine possible limiting factors, we reviewed historical fluctuations in herd size and harvest, historical data on wolf numbers and summer and winter weather. The major decline in herd size from 1963 to 1973 was accompanied by high wolf numbers, some years of unfavorable winter and summer weather, and some years of high harvests. From 1974 to 1990 the Fortymile herd failed to recover as well as the adjacent Nelchina herd and provided less than one-fourth the harvest despite favorable winter conditions in both areas. Two notable differences between these herds were that (1) wolves were less strongly limited within the range of the Fortymile herd, and (2) moose as alternate prey for wolves remained more abundant within the range of the Nelchina herd.

**Key words:** caribou, Fortymile caribou herd, population dynamics, weather, wolves

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### **Introduction**

Caribou (*Rangifer tarandus granti*) herds in Alaska have undergone changes in abundance and distribution (Skoog, 1968; Davis, 1980). Causes of fluctuations are still debated despite 15 years of research using radiocollars and other modern technology (Gasaway *et al.*, 1983; Van Ballenberghe, 1985; Bergerud and Ballard, 1989). Most of the historical data on changes in caribou numbers within the range of the Fortymile herd, formerly Alaska's largest herd, has remained unpublished. Gasaway *et al.* (1992) briefly reviewed caribou and wolf (*Canis lupus*) numbers in a portion of the herd's range, and Van Ballenberghe (1985) reviewed the case history of the adjacent Nelchina caribou herd.

Our objectives are to review historical data on the Fortymile caribou herd (FCH), report new information gathered during the 1970s and 1980s, and identify some notable differences between the Nelchina and Fortymile case histories that may be helpful in interpreting the relative importance of wolf predation, hunting, and other limiting factors.

### **Range of the Fortymile caribou herd**

During its historical high in the 1920s and 1930s, movements of the FCH probably covered an area of about 220,000 km<sup>2</sup> (Murie, 1935), although in view of current knowledge some of the reported movements could have involved Nelchina or Porcupine herd caribou. Since 1968

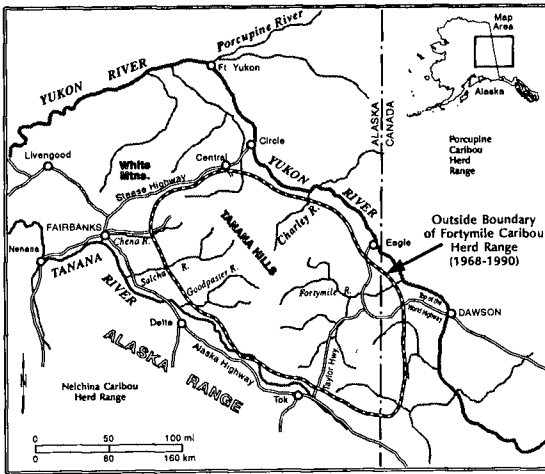


Fig. 1. Range of the Fortymile caribou herd, 1968-1990.

the herd has used a small area in east-central Alaska and the adjacent Yukon Territory (about 50,000 km<sup>2</sup>) (Fig. 1) (Valkenburg and Davis, 1986). Like most other barren-ground caribou herds, the FCH is most dispersed in winter and most concentrated in June and July. The caribou spend summer in alpine tundra and seek relief from insects at higher elevations of the Tanana Hills. In August they disperse throughout the alpine, subalpine, and forested portions of their range. They spend winter primarily in spruce forest (*Picea glauca* and *P. mariana*), on subalpine ridges, and in valleys surrounding the summer range. Curatolo (1975) provided a detailed topographic description of the area.

The climate of the area is continental with short summers and long, cold winters. Most of the area is inaccessible to ground vehicles, except along the Taylor and Steese Highways, and there are relatively few sites suitable for landing airplanes.

### Caribou numbers, 1900-1972

The FCH was the largest caribou herd in Alaska when it numbered in the hundreds of thousands during the early 1900s (Murie, 1935) (Table 1). No systematic attempt was made to census the herd between 1920 and 1953 (Skoog, 1956). Skoog (1956) estimated that the FCH declined from its peak in the late 1920s or early 1930s to 10,000-20,000 by the early 1940s, ba-

sed on modeling backward from the 1953 estimate. The timing of the population low during the 1940s and the subsequent recovery phase is not clear, but by 1953 the herd reached about 50,000 (Skoog, 1956). Olson (1959) reported the herd declined during 1956-1957 and numbered approximately 40,000 in 1958. From 1960 to 1963 all estimates of herd size were approximately 50,000 (Table 1). By 1968, however, a major decline apparently occurred because large groups of caribou could not be found on the calving areas or in the September-October migrations in 1966-1968 (L. Jennings, Alaska Department of Fish and Game, retired, pers. commun.) (Table 1). From 1969 to 1972, estimates and counts ranged from <6,000 to 20,000 (Jennings, 1971, 1973; LeResche, 1975; Davis *et al.*, 1978).

### Caribou numbers, 1973-1990

The Alaska Department of Fish and Game (ADF&G) expanded research on population dynamics in the early 1970s, when it became clear that many of Alaska's moose and caribou populations had declined precipitously. From 1973 to 1975, Davis *et al.* (1978) estimated the size of the FCH using the «Aerial Photo-Direct Count-Extrapolation» (APDCE) census technique (Davis *et al.*, 1979). These population estimates and the September-October calf:cow ratios (Table 2) led Valkenburg and Davis (1989) to conclude that the summer population size of the FCH was approximately stable at about 5,740-8,610 caribou from 1973 to 1975. After 1979, censuses were done with a modified APDCE technique (Davis *et al.*, 1979), and after 1982 from 4 to 40 radio-collared caribou were used to aid in finding caribou during censuses. Data after 1979 indicated that the FCH grew from about 5,740-8,610 caribou in summer 1975 to 22,700 in summer 1990 (Valkenburg and Davis, 1989; ADF&G files).

### Recruitment

Data were available on the percentages of calves and the calf: 100 cow ratios present in the FCH during early June, September-October, and April 1953-1963, and for late June, October, and April 1972-1990 (except 1979) (Table 2). For comparison among periods, the data on the percentage of calves in the herd composition samples in September-October are the most useful because in some years (1955-1957 and

Table 1. Estimates of the size of the Fortymile caribou herd since 1920.

Year	Month of survey	Number of caribou counted	Estimate of herd size	Estimated density caribou /km <sup>2</sup>	Source
1920	October	13,200	568,000	2.6	Murie 1935
1950			6,500 <sup>a</sup>		Scott <i>et al.</i> 1950
1950			20,000+ <sup>b</sup>		Skoog 1956:62
1953	June	36,600	46,000 <sup>c,d</sup>	0.5	Skoog 1956:63
1956	June	30,000	45,000 <sup>d</sup>		Olson 1957:95
1958	June		40,000		Olson 1959
1960	June		50,000 <sup>d</sup>		Jones 1962:99
1962	June		50,000 <sup>d</sup>		Jones 1963:66
1963	September	26,000	50,000		Skoog 1964:14
1969	June	8–10,000	20,000 <sup>d</sup>		LeResche 1975
1970	October	< 6,000	< 15,000 <sup>e</sup>		Jennings 1971
1971	October		10–12,000		Jennings 1973
1972	October	10,000	15,000		Jennings 1973
1973	June	3,200 <sup>f,g</sup>	5,312 <sup>d</sup>		Davis <i>et al.</i> 1978
1974	June	2,587 <sup>g</sup>	4,041 <sup>d</sup>		Davis <i>et al.</i> 1978
1975	June	2,429 <sup>g</sup>	3,982 <sup>d</sup>		Davis <i>et al.</i> 1978
1975	June		5,740–8,610 <sup>h</sup>	0.1–0.2	Valkenburg and Davis 1989
1981	June	7,914	10,093 <sup>i</sup>		Valkenburg and Davis 1989
1983	June	12,350	12,350		Valkenburg and Davis 1989
1984	June	13,402	13,402		Valkenburg and Davis 1989
1986	June	15,303	15,303		Valkenburg and Davis 1989
1988	June	19,975	19,975		Valkenburg and Davis 1989
1990	June	22,766	22,766	0.5	ADF&G files

a Based on superficial surveys.

b Based on modeling backward from the 1953 estimate.

c Skoog's original estimate was 58,820 based on an assumed 1:1 September–October sex ratio. We adjusted this estimate based on a more realistic ratio of 50 bulls: 100 cows.

d October population estimate extrapolated from June.

e No basis given for extrapolation.

f Aerial photos were lost, and the actual number of caribou counted was not recorded. The 3,200 figure represents the estimated number of adult females present in June.

g Adults only.

h June estimate based on reanalysis of 1973–1975 estimates.

i From 1981 to 1990, census estimates include only the total of caribou photographed or counted during the census. However, in 1981 there was confusion over 1 large group that was found 1 day after the census. It may or may not have been included in the 7,914 originally counted.

1959) they are the only data available and in most years until 1980 yearlings also were classified (and not included in the denominator), thus biasing calf: 100 cow ratios upward. For the period when composition data are not available (1964–1971), it was possible to determine

whether there were any severe recruitment failures by analyzing age data from 434 jaws collected along the Taylor Highway from 8 to 23 October 1972 (Table 3).

The percentage of calves in the FCH in September–October varied considerably from 1953

Table 2. Proportion of calves in the Fortymile caribou herd, 1953-1960.

Cohort birth year	Late May to early June		Mid- to late June		September-October			April	
	Calf: 100 cow ratio	n	Calf: 100 cow ratio	n	Calf: 100 cow ratio	% calves	n	Calf: 100 cow ratio	n
1953	73					29	228	21	1,359
1954	73	23,910			64	26	189	16	684
1955	65	508				16	1,659	14	1,286
1956	54	14,206				5	737	3	1,120
1957	38	1,436				5	576	3	458
1958	62	16,446				31	127	19	857
1959	58	2,061				36	450	37	652
1960	78	7,650			56	36	901	44	349
1961	74	8,178			45	18	1,110		
1962	27	1,352				19	1,462 <sup>a</sup>		
1963					20	16	n.a.		
1972					21	13	484		
1973	57				16	11	2,292		
1974	53	1,990	24	1,424		13			
1975	64		18						
1976					35	16	640		
1977			39	2,252	45	21	788		
1978			35	479	26	15	516		
1980			41	1,930	61	25	586		
1981			31	2,528	31	17	718		
1982					27	15	1,142	29	304
1983	35	2,840	38	1,020	33	18	1,404	27	960
1984	73	2,550	45	3,052				32	783
1985			48	3,388	36	19	782	40	533
1986					28	17	1,077		
1987			47	2,743	37	21	1,749		
1988			36	1,285	30	18	999		
1989					24	16	1,465		
1990					29	17	1,297		

<sup>a</sup> Excludes adult bulls.

to 1990 (Table 2). The data indicate a virtual failure in recruitment in 1956 and 1957 with most calves dying during summer rather than immediately after birth. The age structure data from the 1972 jaw collection (Table 3) show a similar failure of the 1971 cohort.

### Harvests

Market hunting of caribou was common from the late 1800s until the 1930s, and during that period large numbers of caribou were taken to feed sled dogs (Skoog, 1968; Urquart and Far-

nell, 1986), but harvests were not annually estimated until 1951. Since 1951, with the exception of 1958 and 1959, annual estimates of harvests are available (Table 4) (Davis *et al.*, 1978; Valkenburg and Davis, 1989).

Because most of the FCH range has been inaccessible, most of the caribou harvest has occurred along the area's transportation routes. Prior to the 1930s, many caribou were taken along the Yukon River, although harvest along the Steese Highway increased as the road was upgraded in the 1920s. After the 1930s, the

Steese Highway provided the main access to the herd until the early 1950s when the Taylor Highway in Alaska and the Top of the World Highway in the Yukon were completed. From the late 1950s until 1966 most harvest came from these 2 highways, with the remainder occurring along the Steese Highway (Skoog, 1968). After 1966 virtually all harvested caribou came from the vicinity of the Taylor and Top of the World Highways and from small airstrips within the Fortymile River drainage (Davis *et al.* 1978; Kelleyhouse 1986, 1992; ADF&G files).

### Wolf numbers

Until the 1960s there were relative rather than quantitative estimates of wolf numbers within the range of the FCH. Murie (1944:12) reviewed historical observations of wolf abundance and concluded that wolves were «common» until sometime after 1908, «rare» from before 1915 until after 1923, increasing until the late 1920s, and then stable until 1940. Skoog (1956) commented that wolves were «low» from 1940 until 1954. However, Kelly (1950, 1953) mentioned that wolves were «abundant» until 1949, and Kelly (1951) also mentioned that wolves

Table 3. Age distribution of 434 caribou mandibles<sup>a</sup> collected at the Taylor Highway check station, 8–22 October 1972.

Age class	Cohort birth year	Cohort		Un-known sex	Total
		Females	Males		
Calf	1972	15	5	33	53
1	1971	7	0	1	8
2	1970	28	21	24	73
3	1969	27	19	19	65
4	1968	15	19	15	49
5	1967	18	12	7	37
6	1966	9	11	9	29
7	1965	18	6	4	28
8	1964	14	8	3	25
9	1963	11	6	4	21
10	1962	11		4	15
11	1961	9		5	14
12	1960	9		2	11
13	1959	3		0	3
14	1958	2		1	3
Total aged		196	107	131	434

<sup>a</sup> Calves and yearlings were aged by tooth eruption; all others were aged by examination of cementum annuli on the first incisor (Miller, 1974).

Table 4. Reported and estimated harvest of Fortymile caribou herd, 1951–1990.

Year	Total reported harvest	Reported % females	Total estimated harvest <sup>a</sup>	Remarks
1951	567		No estimate	
1952	164		No estimate	
1953	50		No estimate	
1954	984	48	1,300	
1955	1,631	46	2,325	
1956	621	40	842	
1957	484	33	648	
1958	No data			
1959	No data			
1960			1,234	
1961	1,685	52	2,019	
1962	640		850	Includes 325 in Yukon
1963	264		335	Taylor Highway closed early by snow
1964	104		270	Actual harvest probably much higher
1965	90		800	Actual harvest probably much higher
1966			1,900	Major road crossing at Mt. Fairplay
1967	503		505	Actual harvest probably much higher
1968	292	33	579	Light harvest, caribou not close to road

1969	342	23	492	Light harvest, caribou not close to road
1970	889	31	1,386	Check station continuously operating during road crossing
1971	1,994	45	2,360	Check station continuously operating during road crossing
1972	974	52	1,330	Check station continuously operating during road crossing
1973	46	18	75	Hunting season shortened to 10 August–20 September to avoid road crossing period; bag limit reduced to 1 caribou
1974	29	9	45	
1975	34	35	75	
1976	33	15	52	
1977	60	8	95	Season reduced to 1–15 September
1978	16	38	30	
1979	9	0 <sup>b</sup>	30	Bag limit reduced to 1 bull
1980	10	0	50	
1981	58	0	100	Hunting season lengthened to 10 August–20 September
1982	115	0	200	Bag limit increased to 2 bulls
1983	219	0	294	Chicken Trail «discovered» by off-road vehicle users
1984	245	0	450 <sup>c</sup>	Early snow and migration across road caused season to be closed by emergency order
1985	261	0	441	Bag limit reduced to 1 bull
1986	223	0	380	
1987	142	0	249	Caribou distributed away from road and trail system
1988	401	0	795	Caribou loosely distributed near roads and trails
1989	424	0	498 <sup>d</sup>	Caribou distributed away from road and trail system
1990	283	6	380	

<sup>a</sup> Harvest data during 1951–76 are from Davis *et al.* (1978). In most years prior to 1968 biologists subjectively estimated the unreported kill based on the distribution of caribou and hunters and the knowledge that check stations were not operated continuously. Estimates of crippling loss were not included except for a 10% factor used in 1960 and 5% in 1962. All known illegal (vs. unreported) kills were added to the totals. In years prior to 1973 large differences between reported and estimated harvest also reflect the addition of estimates of harvest from the Yukon. Yukon harvest was insignificant after 1973.

<sup>b</sup> From 1979 to 1989 cows could not be legally taken.

<sup>c</sup> The reporting rate of successful hunters was estimated to be 63% in 1984 (Kelleyhouse 1986) and this figure and the known illegal kill were used to estimate total harvest from 1984 to 1990.

<sup>d</sup> During 1989 and 1990 hunters in the Taylor Highway area were required to report under a stricter permit registration system with mandatory reporting.

were «plentiful» in the «Fortymile country» in 1947–1948 but that «control was achieved» by 1950 because few wolves were killed along his «getter» (cyanide gun) lines after 1949.

From 1950 to 1955, the U.S. Fish and Wildlife Service (FWS) claimed to have maintained

wolf numbers at relatively low levels, and bounty records indicated that trappers took relatively few wolves during that period (Davis *et al.*, 1978). Initially, poison («getter» lines) was used along the Steese and Taylor Highways. In 1952, a Super Cub aircraft and military game

warden-pilot became available, so aerial hunting, «getter» lines along the highways, and poison baits were used (C. Gray, former Game Warden, U.S. Army, pers. commun. 1991). Wolf control was stopped during 1955 because the wolf population was reported to be «under control».

However, the program was resumed sometime in 1956 because Olson (1958) reported a «sudden» increase in wolf numbers and a decline in the recruitment of caribou calves. A higher than average number of wolves were trapped in 1956 (Davis *et al.*, 1978). Control was suspended in spring 1959 when wolves were again reported to be «under control» (Olson, 1959).

Wolf control was terminated in 1960 and wolves increased (Gasaway *et al.*, 1992). Davis *et al.* (1978) estimated that there were 420–636 wolves within the range of the FCH during the 1960s based on the magnitude of the annual wolf harvests (they assumed that harvest was proportional to population size).

Based on reports from local residents and the harvest, Gasaway *et al.* (1992) concluded that wolves declined from 1969 to 1976 after prey became scarce. In 1981 Gasaway *et al.* (1992) estimated 125 wolves in a 15,500 km<sup>2</sup> area in September–October in the southeastern portion of the range of the FCH. In the same area, September–October wolf numbers were reduced through aerial shooting in 1982 and 1983 to 64 and 87, respectively, and then maintained at lower than precontrol numbers through 1989 (Gasaway *et al.*, 1992). In winter 1986–1987 ADF&G conducted wolf surveys throughout the 50,000 km<sup>2</sup> range of the FCH and 265 wolves were estimated to be present (Valkenburg and Davis, 1989).

## Weather

To determine if unusual winter or summer weather may have influenced natality and calf survival directly or indirectly through nutrition (Verme, 1965; Peterson, 1977, Stewart *et al.*, 1977; Helle, 1980; Dieterich and Haas, 1981; Clutton-Brock *et al.*, 1982; Huot and Beaulieu, 1985; Jonasson *et al.*, 1986; Thomas and Kiliaan, 1990; Mech *et al.*, 1991), we reviewed winter and summer weather data from the Eagle climate station from 1952 to 1990 (National Oceanic and Atmospheric Administration, Alaska, monthly summaries). We compared a snow depth index (calculated after Van Ballenberghe,

1985), mean July temperature in the preceding and current year, and July rainfall in the preceding and current year with fall calf percentage data (Table 5). In 5 years when Eagle weather data were unavailable, we used data from Circle or Central (Fig. 1). Snow index was negatively correlated and July rainfall was positively correlated with calf percentage in fall (Table 6). Snow index also was correlated with July temperature and negatively correlated with July rainfall, indicating that high snowfall winters were usually followed by relatively warm and dry conditions in July. When controlling for other weather variables, partial correlations between calf percentage and snow index, July temperature, or July rainfall were not significant.

## Discussion

### *The caribou population during the 1920s and 1930s*

The size of the FCH during the 1920s is relevant to its management today. Unfortunately, it is difficult to estimate the size of the FCH at its peak in the 1920s. Murie's (1935) figure and the other estimates reported by Skoog (1968) were crude, and the possibility exists that caribou from the Nelchina herd also were included in some estimates of the FCH because they were suspected to range north of the Alaska Range to Delta Junction. Nevertheless, based on the estimated size of the range during the 1920s, the FCH was undoubtedly considerably larger in the 1920s than since that time.

Although the cause of the decline during the 1930s is unknown, proposed contributing factors include destruction of the winter range by fire (Leopold and Darling, 1953) and food limitation that led to emigration (Skoog, 1956). If Murie's 1920 estimate was accurate, density would have exceeded 2.5 caribou/km<sup>2</sup>, making food limitation a possibility (Seip, 1991).

Booth Skoog (1968) and Davis *et al.* (1978) noted historical correlations between wolf numbers and caribou numbers, but neither proposed predations as a causal factor. Skoog (1956) also discounted hunting but thought that it may have become an important suppressing factor once the herd had declined to a lower level. The FCH survived the gold mining boom and the market hunting that accompanied it. The herd's decline in the 1930s occurred after mining peaked. Other caribou herds throughout

Table 5. Total July rainfall, mean July temperature, snow index (after Van Ballenberghe, 1985), and percent calves in September–October in the Fortymile caribou herd, 1952–1990.

Year	Total July rainfall (mm)	Mean July temperature (C)	Snow index <sup>a</sup>	% calves in September–October ( <u>n</u> )
1952	59	16.2	165	
1953	36	16.4	62	29 (66/228)
1954	102	15.4	62	26 (49/189)
1955	37	16.9	164	16 (265/1,659)
1956	26	16.2	168	5 (37/737)
1957	36	15.1	124	5 (29/576)
1958	74	15.9	68	31 (39/127)
1959	67	12.4	91	36 (162/450)
1960	104	14.2	90	36 (324/901)
1961	54	14.4	73	18 (200/1,110)
1962	70	15.6	115	19 (278/1,462)
1963	60	14.7	186	16 (n.a.)
1964	39	14.3	98	
1965	72	14.9	78	
1966	7	15.3	108	
1967	65	15.1	159	
1968	32	15.7	94	
1969	19	12.7	63	
1970	61	14.5	102	
1971	31	15.0	121	
1972	48	15.1	100	13 (63/484)
1973	49	15.4	117	11 (252/2,292)
1974	43	14.7	94	13 (226/1,738)
1975	50	16.6	75	
1976	47	15.9	120	18 (115/640)
1977	26	15.3	133	21 (165/788)
1978	16	16.6	156	15 (77/516)
1979	38	15.7	130	
1980	74	15.2	94	25 (147/586)
1981	123	14.2	63	17 (122/718)
1982	70	16.2	102	15 (171/1,142)
1983	92	16.6	121	18 (253/1,404)
1984	98	14.6	100	
1985	50	14.8	117	19 (149/782)
1986	53	16.3	102	17 (183/1,077)
1987	82	15.1	75	21 (367/1,749)
1988	35	15.8	124	18 (180/999)
1989	63	16.2	130	16 (234/1,465)
1990	34	17.3	155	17 (220/1,297)
39-year mean	55	15.3	110	

<sup>a</sup> Snow index is the sum of the Eagle monthly maximum snow depths for November, December, January, February, March, and April (e.g., for 1952, Nov and Dec 1951 would be combined with Jan, Feb, Mar, and Apr 1952). The 39-year median was 108.

interior Alaska also declined during the 1930s (Skoog, 1968) suggesting the influence of widespread phenomena.

*Caribou numbers, 1950s and 1960s*

Skoog (1956) provided the most rigorous estimate of population size made during the 1950s



and 1960s. From 1953 to 1957 virtually the entire calving segment of the herd crossed the Steese Highway enroute to calving areas in the White Mountains (Skoog, 1968). After 1957 calving occurred consistently southeast of the Steese Highway in more forested terrain and censusing the herd became more difficult (Jones, 1962; Skoog, 1968; Valkenburg & Davis, 1986). Based on the composition data from September–October and April (Table 2), the FCH may have grown rapidly from 1953 to 1956, unless adult mortality was extremely high. Even if the herd grew at only a moderate annual rate of about 10 % through summer 1956, it would have reached about 60,000. Olson (1959) reported that the herd declined from 1956 to 1957 because of extremely poor calf survival, and he estimated its size at 40,000 in 1958. Subsequently, both census data and the percentage of calves in the herd from 1958 to 1962 suggested that the herd increased through 1960 and then stabilized during 1961 and 1962. The reported increase during this period is surprisingly low, but could be explained by poor population estimation, higher adult mortality, or egress to other areas.

Egress was suspected in 1957 and 1964 (Lentfer, 1965). However, the population estimate of 40,000 in 1958 (Olson, 1959) does not corroborate egress in 1957, and Skoog (1968:299) rejected the idea of egress in 1964. The absence of documented cases of permanent egress in *Rangifer* worldwide and the fidelity of caribou cows to their calving ranges suggest that large-scale permanent egress of large numbers of adults is unlikely (Valkenburg *et al.*, 1983, 1988; Came-

ron *et al.*, 1986; Valkenburg and Davis; 1986; Davis *et al.*, 1991; Fancy and Whitten, 1991).

*Possible cause of the caribou decline, 1963–1973*

The cause of the decline that occurred during 1963–1973 is not clear because a combination of factors during this period was probably acting on the population including relatively high (largely unreported) harvests from 1964 or 1965 to 1967, unfavorable weather from 1966 to 1969 (Fig. 2, Table 5 and 6), and high wolf numbers. The effects of relatively heavy harvest in 1960 and 1961, when the herd was still large, could have been somewhat offset by light harvest in 1963 and 1964; however, by 1963 wolf numbers were high and a deep-snow winter occurred. Three years of relatively high harvest (1965–1967) followed during a period when wolf numbers were high and unfavorable weather occurred. Harvests in 1968 and 1969 were relatively light, but still wolf numbers were high and weather was unfavorable. Any of these factors acting alone may not have led to a decline.

Hunting may have been more a factor in the caribou decline than it seems from the data in Table 4 and in the analysis by Davis *et al.* (1978). Hunter check stations were operated only sporadically from 1963 to 1969 (McGowan 1966; R. James, pers. commun.), and harvest reports were not mandatory until 1968. In 1965 only 90 caribou were recorded through check stations although the estimate of total harvest was 800. In that year there were no estimates for wounding loss and no estimates for harvest in the Yukon Territory (McGowan, 1966). In 1965 and 1966 caribou were available in large

Table 6. Spearman's rank correlation coefficients between calf percentage in fall and weather variables from Table 5<sup>a</sup>.

	Previous July temp.		July temp.		Previous July rain		July rain		Snow index	
	r	(P)	r	(P)	r	(P)	r	(P)	r	(P)
Calf %	-0.03	(0.87)	-0.26	(0.20)	0.27	(0.18)	0.50	(0.01)	-0.57	(0.002)
Snow index	0.20	(0.22)	0.38	(0.02)	-0.08	(0.63)	-0.42	(0.01)		
July rain	-0.10	(0.56)	-0.27	(0.11)	0.14	(0.41)				
Previous July rain	-0.23	(0.17)	-0.09	(0.58)						
July temp.	0.24	(0.15)								

<sup>a</sup> Sample size (n) was 38 for all correlations except those involving calf percentage data for which n was 26. Methods as in Conover (1981). Bold figures indicate significant correlations (P < 0.05).

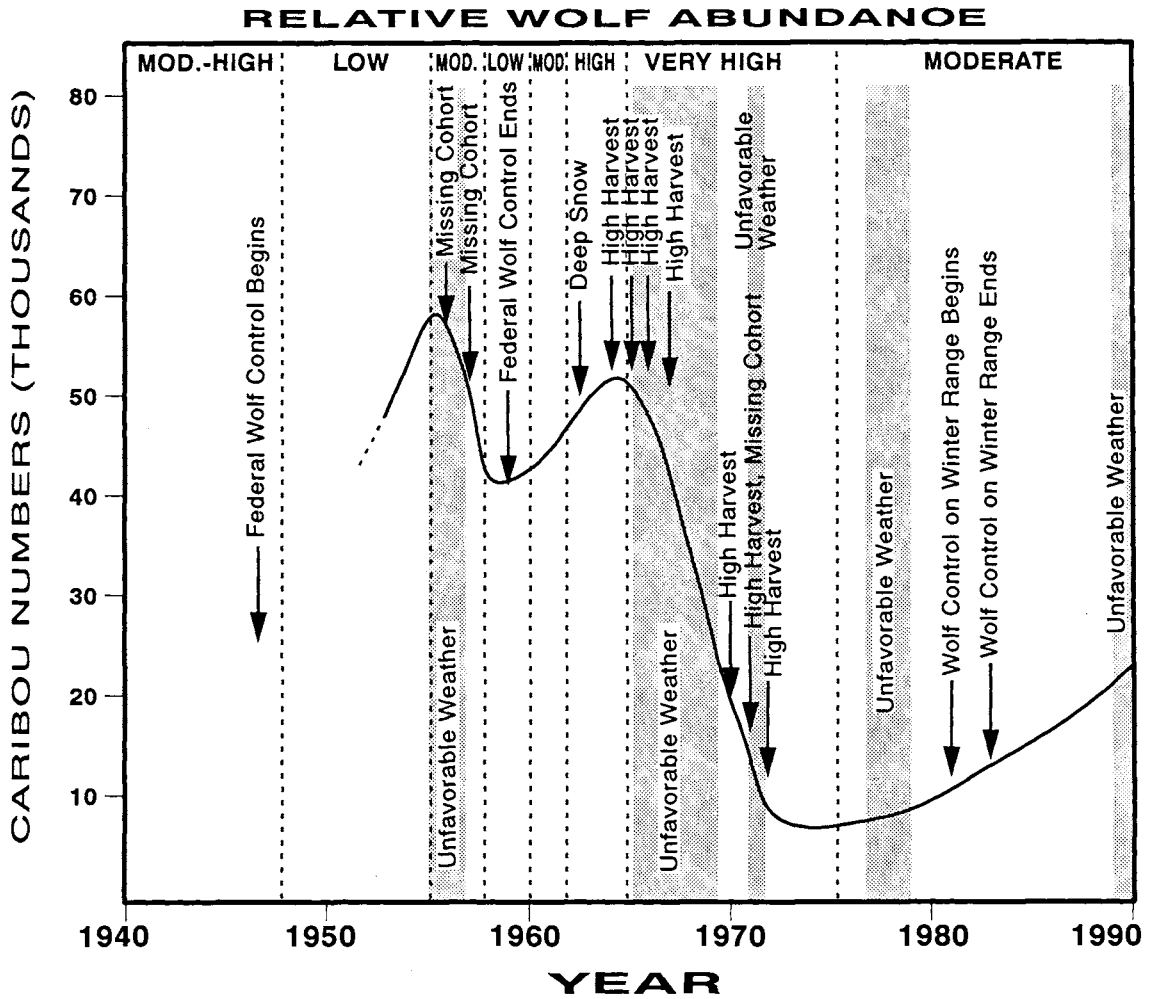


Fig. 2. Timing of caribou population fluctuations in relation to relative wolf abundance (Table 5), summer and winter weather (Table 5), and harvest (Table 4).

numbers on both the Steese and Taylor Highways and in the Yukon Territory (McGowan, 1966; Glenn, 1967). Wounding loss associated with crowded hunting conditions along highways was high and could have equalled the reported or estimated harvest in some years (Urquart and Farnell, 1986; P. Valkenburg, pers. obs.; D. Grangaard, pers. commun. 1992). Until 1973, the bag limit was 3 caribou, competition for animals was intense, and hunters were reluctant to leave the roadside to follow cripples for fear of being accidentally shot (D. Grangaard, pers. commun. 1992; P. Valkenburg, pers. obs.) In 1968, harvest reporting was required for the first time, but there was considerable resistance to the new system. According to wildlife protection officer R. James (ADF&G, retired, pers.

commun. 1992, many people did not report at all and the bag limit was flagrantly violated. In 1964 the Steese Highway Closed Area, which had protected some caribou along the roadside for many years, was eliminated. In 1968 and 1969, Burris (1970) reported that caribou were not widely available and harvest was light. From 1970 to 1972 check stations were used during the heavy harvest period in October, and crippling loss was not included in the estimates.

Deep snow may have been a factor during the FCH decline (Sep–Oct 1963 through Sep–Oct 1973). The 1963, 1966–1967, 1970–1971, and 1972–1973 winters were above the 39-year median snow index of 108 (Table 5). However, and by the 1970–1971 winter the herd had al-

ready declined greatly.

The possibility exists that weather also could have been a factor in low recruitment during the early 1970s. In the FCH, calf percentage in September–October was correlated with climatic factors during 1952–1990 (Fig. 2, Table 5 and 6). Biologists are only just beginning to investigate these relationships in caribou, but it seems likely that there are some periodic climatic conditions that are unfavorable for growth in caribou herds. Possible mechanisms include nutritional stress through insect harassment (Helle, 1980; Dieterich and Haas, 1981; Thomas and Kiliaan, 1990), lowered summer nutrient content of plants (Steward *et al.*, 1977; Jonasson *et al.*, 1986), and winter stress leading to increased early summer mortality of calves and increased vulnerability of caribou to predation (Verme, 1965; Peterson, 1977; Clutton-Brock *et al.*, 1982; Huot and Beaulieu, 1985; Mech *et al.*, 1991). In our analysis, it was not possible to distinguish clearly between the effects of winter versus summer weather on calf percentage in fall because of correlations between snow index, July rainfall, and July temperature. In addition, we remain unsure about which weather variables would be most appropriate to measure, and whether the climate station at Eagle is sufficiently representative of the herd's winter and summer ranges.

By 1969, the FCH had declined to approximately 10,000–20,000, and the combination of high harvests, low recruitment (especially of the 1971 cohort), and low moose and high wolf numbers suggest that a continuing decline was inevitable (Davis *et al.*, 1978; Seip, 1991).

#### *Recovery during 1976–1990 and effects of wolf control, 1981–1983*

The herd composition data (Table 2) suggest that the recovery of the FCH began with the May 1976 calving season. Recruitment remained so poor from 1972 to 1975 that even with no hunting and low adult mortality the population could not have increased appreciably. From 1976 to 1981 the mean September–October calf:100 cow ratio was 39.4 (SE=6.22 n=5), which suggests that the herd grew continuously during this period and supports the limited census data available (Table 1). From 1975 to 1990 the FCH grew at a mean annual rate of about 7–10 % to a population size of 22,700.

It is not possible to determine the effect of the 1980–1983 wolf control program on either the growth rate of the FCH or on the mortality rate of adult females because no reliable caribou census or adult mortality estimates are available for the years immediately preceding the control program. It is apparent, however, that the removal of wolves in 1981–1982 did not increase the calf:100 cow ratio in September–October during 1982–1985 (Table 2), perhaps because wolves were only removed from a portion of the caribou winter range. Wolf packs within the summer range of the caribou herd were largely unaffected by harvest or control because the FCH summer range was inaccessible and because the primary goal of wolf control was to increase moose numbers in the southeast corner of the FCH winter range.

Wolf control may have reduced adult mortality of female caribou. From 1983 to 1988, mortality rates of radio-collared females averaged 7–9 % in the FCH (Valkenburg and Davis, 1989), which was comparable with the adjacent Delta caribou herd where the mean annual mortality rate of radio-collared females from 1982 to 1985 was 6 % after intensive wolf control (Davis *et al.*, 1988). In 1982–1983 and 1983–1984, virtually the entire FCH spent the winter within the wolf control area.

#### **Management implications**

There are some notable similarities and differences between the case histories of the Forty-mile and Nelchina caribou herds. The FCH grew from between 5,740 and 8,610 caribou in 1975 to 22,700 in 1990 (7–10 % annual increase). The Nelchina herd also was recovering from a low during the same period, and grew from about 8,000 caribou in 1974 to 45,000 in 1990 (11.5 % annual increase) (Pitcher, 1987; Tobey, 1990, 1992). Winter weather was favorable in both areas during the period (Van Ballenberghe, 1985) (Table 5). Although the Nelchina herd declined to a similar level in the early 1970s and increased at only a slightly higher rate than the FCH, it provided over 4 times the harvest. From 1974 to 1990, the Nelchina herd supported a harvest of 19,311 caribou while only 4,134 were taken from the FCH (Tobey, 1992) (Table 4). Both consumptive and nonconsumptive uses of the FCH in Alaska, and especially in the Yukon Territory, have been severely reduced for over 2 decades. If har-

vest in the FCH had been curtailed in 1970 instead of 1973, the herd could probably have stabilized at 10,000–12,000 caribou (assuming harvest mortality was mostly additive) and subsequently recovered to at least 33,000 by 1990 (assuming no changes in harvest or growth rate).

Two differences between the FCH and Nelchina case histories from 1974 to 1990 were that (1) wolves were largely naturally regulated within the summer range and most of the winter range of the FCH but controlled by hunting and trapping in the entire summer range and winter range of the Nelchina herd, especially within the calving area (Van Ballenberghe, 1985; Ballard *et al.*, 1987; Gasaway *et al.*, 1992), and (2) moose as alternate prey for wolves remained more abundant within the range of the Nelchina herd (Ballard *et al.*, 1991; Gasaway *et al.*, 1992). During the mid-1980s the fall wolf:caribou:moose ratio within the range of the FCH was about 1:57:38, whereas in the range of the Nelchina herd the ratio was about 1:155:78 (Ballard *et al.*, 1987, 1991; Valkenburg and Davis, 1989; Gasaway *et al.*, 1992).

In herds where the harvest demand exceeds the supply of caribou available, harvest quotas must be annually calculated based on current estimates of population size, recruitment, adult female natural mortality, the bulhcow ratio, and management objectives. If management objectives include optimizing harvest, the influence of predators, alternate prey and unfavorable weather must be considered.

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## References

- Ballard, W. B., Whitman, J. S. & Gardner, C. L. 1987. Ecology of an exploited wolf population in south-central Alaska. – *Wildl. Monogr.* 98. 54 pp.
- Ballard, W. B. & Reed, D. J. 1991. Population dynamics of moose in south-central Alaska. – *Wildl. Monogr.* 114. 49 pp.
- Bergerud, A. T. 1971. The population dynamics of Newfoundland caribou. – *Wildl. Monogr.* 25. 55 pp.
- Bergerud, A. T. and Ballard, W. B. 1989. Wolf predation on the Nelchina Caribou Herd: a reply. – *J. Wildl. Manage.* 53: 251–259.
- Burris, O. E. 1970. Caribou survey-inventory progress report, 1969. Page 15 in D. E. McKnight, (ed.). *Annual Report of Survey-Inventory Activities. Part II.* Alaska Dep. Fish and Game. Fed. Aid in Wildl. Restor. Proj. W-17-2. Juneau.
- Cameron, R. D., Whitten, K. R. & Smith, W. T. 1986. Summer range fidelity of radio-collared caribou in Alaska's Central Arctic Herd. Proc. Fourth Int. Reindeer/Caribou Symp., Whitehouse, Y. T. – *Rangifer, Spec. Issue* No. 1: 51–55.
- Clutton-Brock, T. H., Guinness, F. E. & Albon, S. D. 1982. *Red deer – behavior and ecology of two sexes.* The Univ. Chicago Press, Chicago. 378 pp.
- Curatolo, J. A. 1975. *Factors influencing local movements and behavior of barren-ground caribou (Rangifer tarandus granti).* M. S. Thesis, Univ. Alaska, Fairbanks. 145 pp.
- Davis, J. L. 1980. Status of Rangifer in the U.S.A. Pages 793–797 in: E. Reimers, E. Gaare, and S. Skjennberg, (eds.). *Proc. Second Int. Reindeer/Caribou Symp., Røros, Norway.* Direktoratet for vilt og ferskvannsfisk, Trondheim.
- Davis, J. L., Schideler, R. T. & LeResche, R. E. 1978. Fortymile Caribou Herd studies. – *Alaska Dep. Fish and Game. Fed. Aid in Wildl. Restor. Final Rep. Proj. W:17-6 and W:17-7.* Juneau. 153 pp.
- Davis, J. L., Valkenburg, P. & Harbo, Jr., S. J. 1979. Refinement of the aerial photo-direct count extrapolation caribou census technique. – *Alaska Dep. Fish and Game. Fed. Aid in Wildl. Restor. Final Rep. Proj. W:17-11.* Juneau 23 pp.
- Davis, J. L., Valkenburg, P., McNay, M. E., Beasley, R. M. & Tutterow, V. L. 1991. Demography of the Delta Caribou Herd under varying rates of natural mortality and human harvest and assessment of field techniques for acquiring demographic data. – *Alaska. Dep. Fish and Game. Fed. Aid in Wildl. Restor. Final Rep. Proj. W:22-5 through W:23-3.* Juneau 112 pp.

cont. on p. 46

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## Errata

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In the paper by Valkenburg *et al.* the reference list on page 22 is incomplete (see below).

## References (cont. from p. 22)

- Davis, J. L., Valkenburg, P. & Reed, D. J. 1988. Mortality of Delta Herd caribou to 24 months of age. Proc. Third North Am. Caribou Workshop. - *Alaska Dep. Fish and Game. Juneau. Wildl. Tech. Bull.* No. 8: 38-51.
- Dieterich, R. A. & Haas, G. E. 1981. Warbles. Pages 179-182 in: R. A. Dieterich (ed.). *Alaskan Wildlife Diseases*. Inst. Arctic Biology, Univ. Alaska, Fairbanks.
- Fancy, S. G. & Whitten, K. R. 1991. Selection of calving sites by Porcupine Herd caribou. - *Can. J. Zool.* 69: 1736-1743.
- Farnell, R. & McDonald, J. In press. Demography of Yukon's Finlayson Caribou Herd. *Can. J. Zool.*
- Gasaway, W. C., Boertje, R. D., Grangaard, D. V., Kelleyhouse, D. G., Stephenson, R. O. & Larsen, D. G. 1992. The role of predation in limiting moose at low densities in Alaska and Yukon and implications for conservation. - *Wildl. Monogr. No.* 120. 59 pp.
- Gasaway, W. C., Stephenson, R. O., Davis, J. L., Shepherd, P. E. K. & Burris, O. E., 1983. Interrelationships of wolves, prey, and man in interior Alaska. - *Wildl. Monogr.* 84. 50 pp.
- Glenn, L. P. 1967. Caribou Report, 1966. - *Alaska Dep. Fish and Game. Fed. Aid in Wildl. Restor. Prog. Rep. Proj. W:15-R-1.* Juneau. pp. 18-19.
- Hayes, R. D., Baer, A. M. & Larsen, D. G. 1991. Population dynamics and prey relationships of an exploited and recovering wolf population in the southern Yukon. - *Yukon Fish and Wildlife Branch. Final Report TR-91-1.* Whitehorse, Yukon. 67 pp.
- Helle, T. 1980. Abundance of warble fly (*Oedemagena tarandi*) larvae in semi-domesticated reindeer (*Rangifer tarandus*) in Finland. - *Report from the Kevo Subarctic Research Station* 16: 1-6.
- Huot, J. & Beaulieu, M. 1985. Relationship between parasite infection levels and body fat reserves in George River caribou in spring and fall. Pages 317-327 in: *McGill Subarctic Research Paper No. 40.* McGill University, Montreal.
- Jennings, L. B. 1971. Caribou survey-inventory report, 1970. Pages 17-18 in: D. E. McKnight, ed. *Annual Report of Survey-Inventory Activities, Part II.* Alaska Dep. Fish and Game. Fed. Aid in Wildl. Restor. Proj. W:17-3. Juneau.
- Jennings, L. B. 1973. Caribou survey-inventory report, 1971. Pages 13-16 in: D. E. McKnight, (ed.). *Annual Report of Survey-Inventory Activities, Part II.* Alaska Dep. Fish and Game. Fed. Aid in Wildl. Restor. Proj. W:17-4. Juneau.
- Jonasson, S., Bryant, J. P., Chapin, F. S. & Andersson, M. 1986. Plant phenols and nutrients in relation to variations in climate and rodent grazing. - *Am. Nat.* 128: 394-408.
- Jones, F. 1962. Steese-Fortymile caribou studies: movements, distribution, and numbers. - *Alaska Dep. Fish and Game. Fed. Aid in Wildl. Restor. Prog. Rep. Proj. W:6-R-2.* Juneau pp. 91-101.
- Jones, F. 1963. Steese-Fortymile caribou studies: movements, distribution, and numbers. - *Alaska Dep. Fish and Game. Fed. Aid in Wildl. Resto. Prog. Rep. Proj. W:6-R-3.* Juneau pp. 64-79.
- Kelleyhouse, D. G. 1986. Caribou survey-inventory progress report. Pages 33-35 in: B. Townsend, (ed.). *Annual Report Survey-Inventory Activities. Part XI. Caribou.* - *Alaska Dep. Fish and Game. Fed. Aid in Wildl. Restor. Proj. W:22-4.* Juneau.
- Kelleyhouse, D. G. 1992. Fortymile caribou herd management. Pages 104-120 in *Caribou Survey-Inventory Management Report.* Edited by S. Abbott. - *Alaska Dep. Fish and Game. Fed. Aid in Wildl. Restor. Proj. W:23-3 and W:23-4.* Juneau.
- Kelly, M. W. 1950. Predator control. - *Annual report. U.S. Fish and Wildlife Service, Anchorage.*
- Kelly, M. W. 1951. Predator control. - *Annual report. U.S. Fish and Wildlife Service, Anchorage.*
- Kelly, M. W. 1953. Predator control. - *Annual report. U.S. Fish and Wildlife Service, Anchorage.*
- Lentfer, J. W. 1965. Caribou report, 1964-65. - *Alaska Dep. Proj. W:6-R-5 and 6.* Juneau. pp. 14-15.
- Leopold, A. S. & Darling, F. F. 1953. *Wildlife in Alaska.* Ronald Press Co., New York, N.Y. 129 pp.
- LeResche, R. E. 1975. The international herds: present knowledge of the Fortymile and Porcupine caribou herds. Pages 127-139 in: J. R. Luick *et al.*, (eds). *First Intl. Reindeer/Caribou Symp. Univ. Alaska, Fairbanks. Biol. Pap., Spec. Rep. No. 1.*
- McGowan, T. A. 1966. Caribou Report, 1965. - *Alaska Dep. Fish and Game. Fed. Aid in Wildl. Restor. Prog. Rep. Proj. W:6-R-6.* Juneau. 19 pp.

- Mech, L. D., Nelson, M. E. & McRoberts, R. E. 1991. Effects of maternal and grandmaternal nutrition on deer mass and vulnerability to wolf predation. - *J. Mammal.* 72: 146-151.
- Miller, F. L. 1974. Biology of the Kaminuriak population of barren-ground caribou. Part 2. Dentition as an indication of age and sex; composition and socialization of the population. - *Can. Wildl. Serv. Rep. Ser. No. 31.* 88 pp.
- Murie, A. 1944. The wolves of Mount McKinley. - *U.S. Natl. Park Serv., Fauna Natl. Parks. Ser. No. 5.* 238 pp.
- Murie, O. J. 1935. Alaska-Yukon caribou. - *U.S. Dep. Agric. North American Fauna No. 54.* 93 pp.
- Olson, S. T. 1957. Management studies of Alaska caribou - movements, distribution, and numbers. Pages 45-54 in: *Alaska Wildl. Invest. Caribou Management Studies. Fed. Aid in Wildl. Restor. Proj. W:3-R.* USFWS. Juneau.
- Olson, S. T. 1958. Management studies of Alaska caribou - movements, distribution, and numbers. Pages 41-51 in: *Alaska Wildl. Invest. Caribou Management Studies. Fed. Aid in Wildl. Restor. Proj. W:3-R.* USFWS. Juneau.
- Olson, S. T. 1959. Management studies of Alaska caribou - movements, distribution, and numbers. Pages 58-70 in: *Alaska Wildl. Invest. Caribou Management Studies. Fed. Aid in Wildl. Restor. Proj. W:3-R.* USFWS. Juneau.
- Peterson, R. O. 1977. Wolf ecology and prey relationships on Isle Royale. - *Nat. Park. Serv., Sci. Monogr. Ser.* 11: 1-210.
- Pitcher, K. W. 1987. Susitna Hydroelectric Project, Big Game Studies. Final Report. Vol. IV - Caribou. Alaska Dep. Fish and Game. Juneau. 59 pp.
- Scott, R. F., Chatelain, E. F. & Elkins, W. A. The status of the Dall sheep and caribou in Alaska. - *Trans. North Am. Wildl. Conf.* 15: 612-626.
- Seip, D. R. 1991. Predation and caribou populations. - Proc. 5th North Am. Caribou Workshop. - *Rangifer. Spec. Issue* 7: 46-52.
- Skoog, R. O. 1956. *Range, movements, population, and food habits of the Steese-Fortymile Caribou Herd.* M. S. Thesis, Univ. Alaska, Fairbanks. 145 pp.
- Skoog, R. O. 1964. Caribou report, 1963. - *Alaska Dep. Fish and Game. Fed. Aid in Wildl. Restor. Prog. Rep. Proj. W:6-R-5.* Juneau. 17 pp.
- Skoog, R. O. 1968. *Ecology of the caribou (Rangifer taruandus granti) in Alaska.* Ph. D. Thesis, Univ. California, Berkeley. 699 pp.
- Stewart, R. R., MacLennan, R. R. & Kinnear, J. D. 1977. The relationship of plant phenology to moose. - *Saskatchewan Dep. Tourism and Renew. Resour. Tech. Bull. No. 3.* 20 pp.
- Thomas, D. C. & Kiliaan, H. P. L. 1990. Warble infestations in some Canadian caribou and their significance. - *Rangifer. Spec. Issue No. 3:* 409-417.
- Tobey, R. W. 1990. Caribou survey-inventory report, Nelchina herd. Pages 66-83 in: S. Morgan, (ed). *Annual Report of Survey-Inventory Activities. Vol. XX Part XI. Alaska Dep. Fish and Game. Fed. Aid in Wildl. Restor. Proj. W:23-2.* Juneau.
- Tobey, R. W. 1992. Caribou survey-inventory management report, Mentasta herd. Pages 33vii-33xviii in: S. Abbott, (ed). *Survey-Inventory Management Report. Alaska Dep. Fish and Game. Fed. Aid in Wildl. Restor. Proj. W:23-3 and W:23-4.* Juneau.
- Urquart, D. & Farnell, R. 1986. *The Fortymile Herd - on the comeback trail to the Yukon.* Yukon Dep. Nat. Resour., Whitehorse, Yukon. 16 pp.
- Valkenburg, P. & Davis, J. L. 1986. Calving distribution of Alaska's Steese-Fortymile caribou herd: a case of infidelity? - *Rangifer, Spec. Issue No. 1:* 315-324.
- Valkenburg, P. & Davis, J. L. 1989. Status, movements, range use patterns, and limiting factors of the Fortymile Caribou Herd. *Alaska Dep. Fish and Game. Fed. Aid in Wildl. Restor. Final Rep. Proj. W: 23-1.* Juneau. 33 pp.
- Valkenburg, P., Davis, J. L. & Boertje, R. D. 1983. Social organization and seasonal range fidelity of Alaska's Western Arctic caribou - preliminary findings. - *Acta Zool. Fenn.* 175: 125-126.
- Valkenburg, P., Davis, J. L. & Reed, D. J. 1988. Distribution of radiocollared caribou from the Delta and Yanert Herds during calving. - *Proc. Third North Am. Caribou Workshop. Alaska Dep. Fish and Game. Juneau. Wildl. Tech. Bull. No. 8:* 14-25.
- Van Ballenberghe, V. 1985. Wolf predation on caribou: The Nelchina case history. - *J. Wildl. Manage.* 49: 711-720.
- Verme, L. J. 1965. Reproduction studies on penned white-tailed deer. - *J. Wildl. Manage.* 29: 74-79.

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