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Nutritional Status of the Southern Alaska Peninsula, Nelchina and Other Southcentral Alaska Caribou Herds

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PROGRESS REPORT (RESEARCH)

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SUMMARY

The regional caribou (*Rangifer tarandus*) biologist position was vacant for 8 months during the report period. Field activities were conducted but little in the way of data analysis was accomplished. Included as appendices to this report are: (1) a report dealing with population dynamics of the Southern Alaska Peninsula Caribou Herd; (2) a letter which summarizes comparative growth and condition data from southcentral Alaska caribou herds; and an analysis of a technique for statistically comparing calving dates of caribou herds.

Key Words: caribou, *Rangifer*, nutrition, Nelchina herd, southern Alaska Peninsula herd, growth, condition, calf recruitment, calving chronology.

CONTENTS

BACKGROUND

A number of caribou (*Rangifer tarandus*) herds in Alaska, including the Nelchina Caribou Herd (NCH) and the Southern Alaska Peninsula Caribou Herd (SAPCH) in southcentral Alaska, have undergone drastic population fluctuations in recent years. Restrictive management responses to much-reduced herd sizes caused dissatisfaction among user groups and resulted in criticism of management programs.

The NCH reached high levels during the early and mid-1960s and then declined to very low levels in the early 1970s. Human harvest, wolf predation, and severe winters all have been suggested as factors contributing to that decline (Bos 1975, Doerr 1979, Van Ballenberghe 1985, Bergerud and Ballard 1989). While undernutrition was not widely believed to be a major factor in the decline, high population density resulted in substantial deterioration of lichen flora on the Nelchina range during the 1960s (Pegau and Hemming 1972). Doerr (1979) believed that range quality deteriorated and affected either birth rates or calf survival. Measurements of mandibles from hunter-killed animals indicated that growth was reduced during the period of high caribou density (ADF&G unpublished data). Recent range studies show that even modest herd size has a substantial impact on lichen abundance (Lieb et al. 1986). Management biologists working with the NCH suspect that they may have observed reduced condition in individual animals in recent years (Lieb, pers. comm.) although no effects on calf recruitment or herd growth were noted (ADF&G unpublished data). Recent data from the SAPCH including reduced population size, small adult body size, low birth weights, late calving dates, and low calf survival suggest that undernutrition is affecting the population dynamics of that herd (Appendix I). Nutritional considerations, therefore, may be important in managing southcentral Alaskan caribou herds.

The NCH has recently grown from a low of 7,000-10,000 in the early 1970s to approximately 40,000 in 1989. Appropriate herd size is unknown and this information is needed to guide harvest levels and manage herd growth. Most other caribou herds within the state are currently growing and there are similar concerns regarding appropriate population levels for some of these herds. At the opposite extreme, the SAPCH has recently declined from >10,000 to about 4,000 animals and it is unclear what the appropriate management strategy for the herd should be because of our uncertainty as to the role of density dependent food limitation in the decline.

There is substantial evidence from studies of domestic and wild reindeer in Norway and caribou in Canada that body condition affects reproductive performance of females and survival of their calves. Lenvik (1988) found that conception date in reindeer was related to weight (and possibly energy reserves) of females during the breeding season. Pregnancy rate was closely associated with fat reserves and body weights of Peary caribou in Arctic Canada (Thomas 1982). Calves of undernourished female reindeer had reduced birth weights and reduced survival (Espmark 1980, Skogland 1984). Haukioja and Salovaara (1978) reported that larger reindeer calves had better survival. Several studies found that undernutrition of females during gestation and possibly before breeding resulted in late calving (Espmark 1980, Reimers et al. 1983, Skogland 1984). Late calving reduces the summer growth season during the first year (Klein et al. 1987) and probably reduces survival of calves into the following winter (Haukioja and Salovaara 1978). For caribou there are strong indications that nutrition, growth, condition, productivity, and survival are linked, however, our knowledge of these relationships is incomplete and additional information is needed to guide management. In addition, most Alaskan caribou herds coexist with one or more predators, most commonly wolves (*Canis lupis*) and brown bears (*Ursus arctos*), and little is known about how undernutrition interacts with predation in limiting caribou herds.

It does not appear feasible to directly calculate carrying capacity for caribou herds; even the relative importance of various dietary components are unknown. A more promising approach is the use of population and animal (physiologic) "indicators" (Franzmann 1985) which reflect the relationship of a herd with its environment, particularly the range component. This concept is based on the premise that certain biological and population parameters will change as the nutritional status of the herd changes. Both temporal and spatial comparisons can be made, e.g. comparisons of one herd over time or comparisons between herds. It appears that within southcentral Alaska there are herds under varying nutritional regimens which will allow for comparative analyses of the various potential indicator parameters. Potential indicators can be divided into two classes; individual animal indicators and population indicators. Individual animal indicators include growth, condition (body composition), rate and pattern of weight gain and loss, and blood and urine chemistry. Population indicators include calving chronology, age of sexual maturation, and birth rates. Intuitively, it seems that the individual animal indictors should be most sensitive and the first to become apparent as they are direct results of animal nutrition. Population indicators, which are responses to growth and condition (secondary responses to nutrition) may in some cases be more obtainable.

A second class of population indicators include such demographic parameters as calf recruitment, rate of herd increase, herd density, and adult survivorship. These indicators are often greatly influenced by factors other than nutrition such as predation and harvest and will not be considered in detail during this study.

Spatial (between herd) comparisons of potential nutritional indicators such as birth weight, growth, and calving chronology could conceivably be complicated by differences in genetic potential between herds, the result of selection for local environments. Skoog (1968) considered all Alaskan caribou as one population, with periodic interchange between herds, suggesting a common gene pool. Interannual variation in herd nutrition/condition resulting primarily from weather, independent of range condition, requires the collection of indicator data over several years. The utility of the indicator approach could also be compromised if nutritional stresses are detected to late for effective remedial management responses.

We propose to evaluate these potential indicators as to their utility in assessing the nutritional status of caribou herds in relation to their ranges. The availability of workable techniques to estimate these parameters will be determined. The literature will be reviewed to aid in evaluating which parameters have the most promise in determining herd-range relationships. Bioelectrical impedance measurements will be evaluated as an index to physical condition (body composition). This technique has been validated for humans (Lukaski et al. 1985) and rats (Hall et al. 1989). Validation of this technique for caribou will be accomplished through coordination with concurrent ADF&G and University of Alaska-Fairbanks investigations on body composition of moose and caribou. Data on selected indicators will be collected and compared from herds thought to be on different nutritional levels. Data collected from herds at the extremes of nutritional condition will be valuable in evaluating the utility of the proposed indicators. Data on indicator parameters will be routinely collected during survey and inventory activities for all herds. Historical data are available for some of the indicators, particularly for the NCH (Skoog 1968), which will facilitate temporal comparisons.

Data from an ongoing study of the Central Arctic Caribou Herd (Cameron et al. 1989) addressing the relationships between condition and reproductive performance will complement this project. Technique development for estimating body composition which is currently underway in that project may prove particularly valuable.

We recognize that factors other than density dependent nutritional limitation, particularly predation and human harvest, play major roles in population regulation of caribou herds. However, adequate nutrition is essential for the production and survival of animals at a high enough rate to allow herds to overcome the summation of all environmental resistance and provide for a harvestable surplus. The primary focus of this project will be on the evaluation of nutritional status of caribou herds.

GOAL

Develop a practical and economic procedure to evaluate and monitor the nutritional status of southcentral Alaskan caribou herds.

OBJECTIVES

Determine which potential animal and population indicators reflect nutritional status by characterizing indicators from herds of varying nutritional status.

Experimentally determine the effects of nutrition on calving chronology, birth weight, body composition, blood and urine chemistry, and neonatal survival.

Experimentally determine if differences between herds in calving chronology, birth weights, and growth are mediated by heredity or nutrition.

Determine if undernutrition is contributing to low calf recruitment and declining population size in the SAPCH.

Working Hypotheses:

1. Undernutrition in caribou herds will be reflected in a measurable and predictable way by selected biological and population parameters.

2. All caribou herds in southcentral Alaska comprise a single genetic population and have similar potential for growth, condition, and calving chronology.

3. The SAPCH is currently nutritionally limited to the extent that calf survivorship, growth, physical condition (including normal patterns of seasonal fattening and weight loss) and timing of calving are being negatively impacted.

METHODS

During April-May 1990, October 1990, and April-May 1991; 64, 17, and 61 caribou were live-captured, respectively, from southcentral Alaska caribou herds.

Caribou were immobilized by intramuscular injections of rompun (xylazine) then weighed and a series of body measurements taken. A subjective index was applied to each animal to evaluate body condition. Blood was collected for packed cell volume determinations. Bio-electrical impedance measurements were taken from each animal to estimate total body water, and total body fat.

Eight Nelchina herd caribou were captured in October 1990 and transported to the Moose Research Center on the Kenai Peninsula to evaluate the feasibility of conducting nutritional experiments on captive caribou at the facility.

A cooperative development between the Department, Izembek National Wildlife Refuge, and the University of Alaska, Fairbanks was developed to support a graduate study of range and activity budgets of caribou from the Southern Alaska Peninsula Caribou Herd.

RESULTS AND DISCUSSION

I was promoted, first on an acting basis and then permanently, to another position on 1 November 1990. The regional caribou biologist position has not yet been refilled although it will be in the near future. I have tried, in conjunction with my new position, to conduct important field activities for the project to remain operative. I have not had an opportunity to thoroughly tabulate or analyze data. Attached as appendices I, II, and III are an unpublished report on studies of the SAPCH, a letter summarizing comparative growth and condition indices of live-captured caribou from southcentral Alaska caribou herds, and a memorandum detailing analysis of calving chronology surveys on the NCH.

ACKNOWLEDGEMENTS

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CAUSES OF LOW CALF RECRUITMENT IN THE SOUTHERN ALASKA PENINSULA CARIBOU HERD AND RECENT HERD HISTORY

by

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April 1990

A report on a cooperative project between the Alaska Department of Fish and Game, Division of Wildlife Conservation and the United States Fish and Wildlife Service, Izembeck National Wildlife Refuge.

The Southern Alaska Peninsula caribou (*Rangifer tarandus*) herd (SAPCH) ranges over about 4,900 km^2 from Port Moeller to the tip of the Alaska Peninsula (Fig. 1). The area is of volcanic origin with recent, usually annual seismic and volcanic activity. Largely unvegetated habitats of glaciers, snowfields, or ash-flats dominate in elevations above 300 m. Lowlands are characterized by wet herbaceous meadows with numerous lakes and streams. Interspersed within lowlands are areas of ericaceous shrub tundra. This habitat type characterizes midland elevations from 50 to 300 m. Lowland and midland habitats comprise essentially the entire range of the SAPCH.

Climatic conditions on the SAPCH range, as measured by the National Weather Service at Cold Bay, are characterized by mild winter and summer temperatures, incessant winds, cloudy skies, and frequent but not high precipitation. The average wind speed is 16.9 mph with frequent, sustained winds in excess of 50 mph. The average annual temperature is 37.9° F. The average February temperature is 27.5° F and the August average is 51.2° F. Annual precipitation averages 35". In 1989 measurable precipitation occurred on 232 days. Although it rains or snows often, large amounts seldom fall. Appreciable amounts of snow seldom accumulate due to warm temperatures, and frequent rain and wind.

Few options for range expansion or dispersal are available to the SAPCH making it a somewhat insular situation. Areas to both the northeast and southwest (Fig. 1), the only directions the herd could move, are already inhabited by caribou.

From the mid-1970's into the early 1980's the SAPCH appeared to be a productive and increasing herd. In 1975 Irvine (1976) estimated that the herd contained 2,627 animals with 29% calves in the herd in July. An additional 3,334 caribou were counted on Unimak Island. In 1981, U.S. Fish and Wildlife Service (USF&WS) personnel from Izembeck National Wildlife Refuge began periodic surveys to monitor herd size and calf recruitment. In 1983 they obtained their highest count of 10,203 caribou. Calf recruitment was fairly low at that time as they found that calves comprised only 15% of the herd in October. Since that time the herd has declined; the 1989 herd estimate was about 4,000 caribou (Johnson in press, USF&WS unpublished data). Calf recruitment has been low as calf percentages in July averaged only 13% from 1981-89. Comparable calf percentages in the more productive Northern Alaska Peninsula caribou herd (NAPCH) have ranged between 25% and 30% in recent years (Sellers in press).

There has been suspicion that poor nutrition might be a factor in the chronically poor calf recruitment. This could be the result of low birth rates or low viability of newly born calves. Sellers (1988) noted that cows captured during

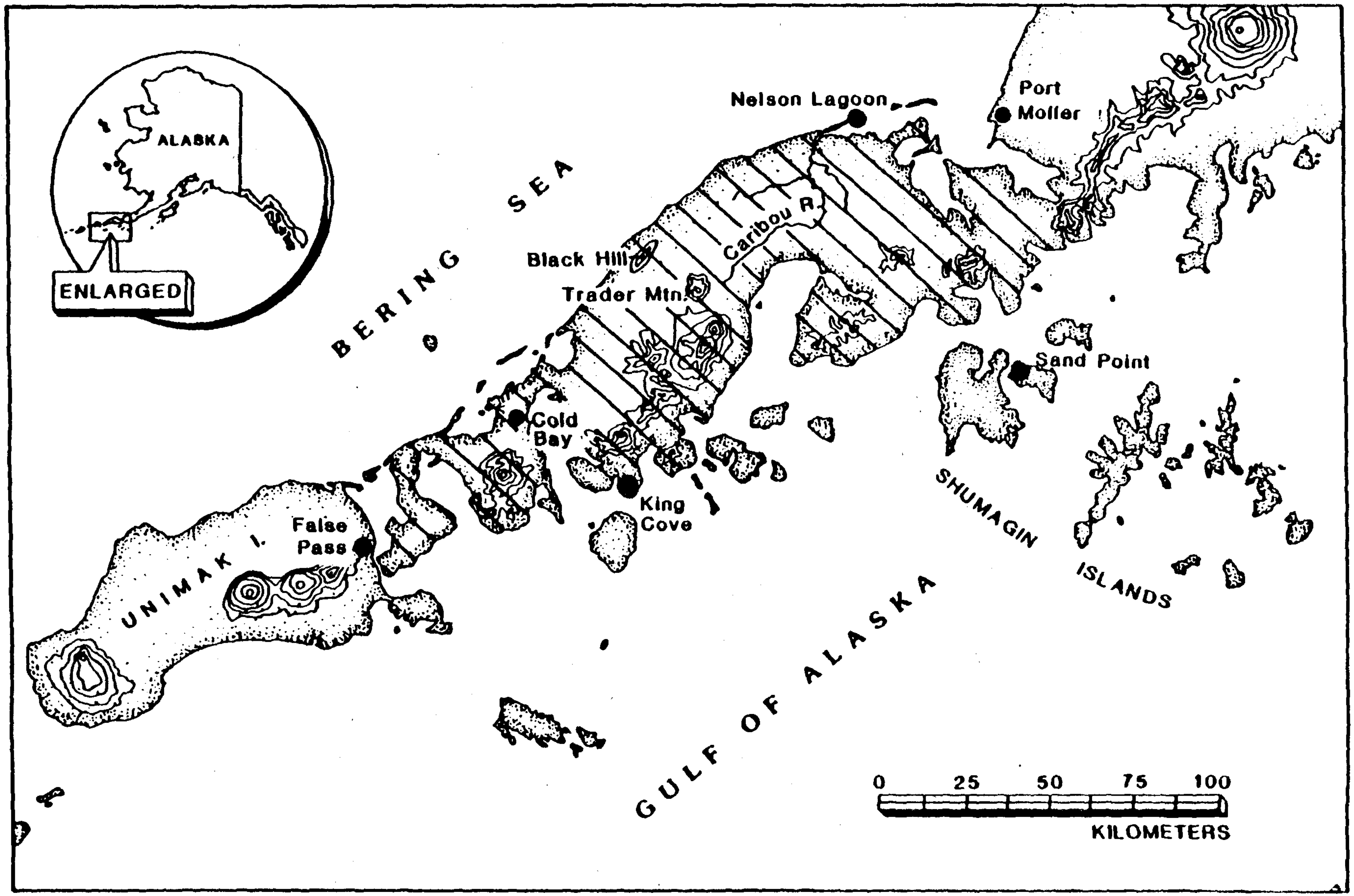
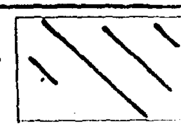


Figure 1. Range of the Southern Alaska Peninsula caribou herd. 

April appeared in poorer condition than those from the neighboring NAPCH. He also remarked that plant phenology in the spring lagged substantially behind that on the NAPCH range and speculated that this might have placed additional nutritional stress on animals that were already in poor condition after a winter on substandard range. The SAPCH range is not typical of many caribou ranges as lichen abundance is low. It is not known if low lichen abundance is the result of prolonged, high utilization by caribou or if the habitat is not suitable for extensive lichen production.

Predation, perhaps exacerbated by undernutrition, is the other likely proximate cause of low calf recruitment. Little information is available specific to the SAPCH, however both wolves (*Canis lupis*) and brown bears (*Ursus arctos*) commonly occur on the SAPCH range and both are known predators of both adult and calf caribou. Golden eagles (*Aquila chrysaetos*) are also known to prey on caribou calves but are rare on the SAPCH range. Bald eagles (*Haliaeetus leucocephalus*) are common but are not a known predator of caribou.

The purposes of this report are to review the past population dynamics of the herd and to report on recent field investigations conducted on the range of the SAPCH, including studies accomplished on the calving grounds from 29 May through 16 June 1989. This is a cooperative project between the Alaska Department of Fish and Game (ADF&G) and USF&WS. The general strategy of the field investigations was to determine if the apparent trend of poor calf recruitment was continuing and to determine the likely causes. Findings of either reduced birth rates and/or low birth weights would support the hypothesis that nutrition was a key factor in poor recruitment. Normal birth rates and birth weights in conjunction with extensive observations of predation on neonates would discount the nutritional hypothesis.

OBJECTIVES

1. To collate and critically examine recent population dynamics data for the SAPCH.

2. To obtain an estimate of the birth rate for females of the SAPCH.

3. To obtain an estimate of birth weights for calves in the SAPCH.

4. To obtain an estimate of short-term calf recruitment to the SAPCH.

5. To determine why calves are dying if the birth rate is normal and recruitment is low.

6. To evaluate growth of SAPCH animals in relation to caribou from other Alaskan herds.

7. To determine the timing of calving for the SAPCH and to compare it with calving dates for other southern Alaskan herds.

8. To obtain an estimate of the natural mortality rate for adult females in the SAPCH.

9. To obtain an estimate of the composition of the winter and spring diet of the SAPCH.

PROCEDURES

Historical herd estimates and composition data were obtained from reports produced and files maintained by USF&WS and ADF&G. Linear regression of the natural logs of annual counts by year was used to determine if trends in caribou abundance existed and to estimate r, the observed mean annual exponential rate of change (rate of increase) (Caughley 1977). Linear regression of the percentage calves in the herd by year was used to determine if trends in recruitment had occurred.

Estimates of birth rates were generated by 3 independent methods. A helicopter survey was conducted late in the calving period to determine the proportion of cows with distended udders (Bergerud 1964). Shortly before giving birth, pregnant cows develop distended udders. For cows which are nursing calves, the udder remains enlarged until fall when the calf is weaned. If a calf dies the mothers' udder gradually shrinks becoming unrecognizable within about 3 weeks. Therefore the proportion of cows with distended udders late in the calving period is a close approximation of the birth rate. Whitten (1989) found that only about 90% of females that gave birth developed large udders before parturition and that some females no longer had visible udders within 2-11 days after losing their calves. Therefore the udder count technique may slightly underestimate birth rates. In 1989 19 radio-collared cows were closely monitored from fixed-wing aircraft during the calving period to determine the proportion giving birth and the calving chronology. A small sample (8) of adult female reproductive tracts were collected after the breeding season from hunter-killed animals in 1987 and were examined for the presence of fetuses and/or corpora luteau of pregnancy in order to estimate pregnancy rate.

Young calves (approximately 0-3 days old) were captured by landing a helicopter nearby and chasing them on foot. They were weighed by suspending them from a hand-held scale using a broad leather belt. Disposable surgical gloves were worn during handling and changed after each capture.

Low level surveys were conducted from a Piper Supercub (PA 18) fixed-wing aircraft both early and late in the calving period and in mid-October during which caribou were classified as calves or adults to estimate calf recruitment.

Approximately 80 hours of low-level aerial surveys were flown in a Piper Supercub and in a Hughes 500 helicopter over the calving grounds of the SAPCH during the calving period. Another 20 flight hours were spent relocating radio-collared animals through the fall and winter. Observations of dead caribou and potential predators were recorded.

Jaw length measurements were obtained from mandibles collected from hunter-killed caribou of known sex. Ages were estimated from eruption and wear of molariform teeth (Skoog 1968). Mandible length is thought to provide a good index of skeletal growth (Suttie and Mitchell 1983). Weights were obtained from adult female caribou captured for radio-collaring.

Fecal samples were analyzed for dietary components using the microhistological technique (Sparks and Malechek 1968) at the Wildlife Habitat Management Laboratory at Washington State University. A listing of vascular and non-vascular species potentially occurring in the diet of caribou on the southern Alaska Peninsula was provided to the laboratory. Two fecal pellets each from 25 individual pellet groups were collected during 3 sampling periods; 2 in December 1988 and 1 in June 1989. Results are presented as the percentage of total occurrences of taxonomic groupings encountered in each composite sample. While this technique is known to produced biased data most major foods can be identified (Dearden et al. 1975, Boertje et al. 1985).

Estimates of mean annual survival rates and associated confidence intervals were made for radio-collared animals using the software program MICROMORT (Heisey and Fuller 1985). The procedure is based on the number of mortalities experienced by radio-collared animals and the period of time the radio-collared animals were monitored.

Differences in the proportions of calves in the Caribou River flat (CRF) and Black Hill-Trader Mountain (BHTM) subgroups (areas) during late June and mid-October recruitment surveys (time) were evaluated using a logit loglinear model (Agresti 1984). Differences in weights of SAPCH animals from caribou in other Alaskan herds were tested using the Kruskal-Wallis one-way analysis of variance and Mann-Whitney U-test (Sokal and Rohlf 1969).

RESULTS AND DISCUSSION

Very few data are available regarding herd size and dynamics prior to 1975. In 1925, Murie estimated that 5,000 caribou inhabited the southern Alaska Peninsula and another 7,000 were on Unimak Island (Skoog 1968). In 1949 the USF&WS estimated the SAPCH at 500 animals with fewer on Unimak Island. In 1975 ADF&G censused the SAPCH and counted 2,267 animals with an additional 3,334 caribou on Unimak Island (Irvine 1976). Irvine found 29% calves for the SAPCH in July indicating excellent early recruitment at that time.

Since 1981 USF&WS or ADF&G have obtained yearly estimates of herd size as well as indices of calf recruitment (Table 1). The population estimates do not appear to have always been accurate as interannual variation is unrealistically large. The data do suggest an increasing population during the late 1970's and a general declining trend ($P = 0.05$) during the 1980's (Fig. 2). This assessment is also supported by calf recruitment data which suggest high recruitment in the late 1970's and low recruitment with no trend ($P = 0.98$) in the 1980's (Fig. 3).

Table 1. Summary of population statistics for Southern Alaska Peninsula caribou herd (from ADF&G) S&I reports).

YEAR	POPULATION ESTIMATE	SUMMER CALF%	BULLS /100 COWS
1975	2,627	29	
1977		27	
1981	6,000	12	
1982	7,000	13	
1983	10,203		
1984	7,500	17	
1985	4,044	6	
1986	4,543	17	32
1987	6,401	12	36
1988	4,000	16	41
1989	4,000	10	

Complicating the understanding of historical SAPCH population dynamics is the unknown magnitude of immigration of Unimak Island caribou to the SAPCH range. Skoog (1968) reported on historical movements of caribou between Unimak

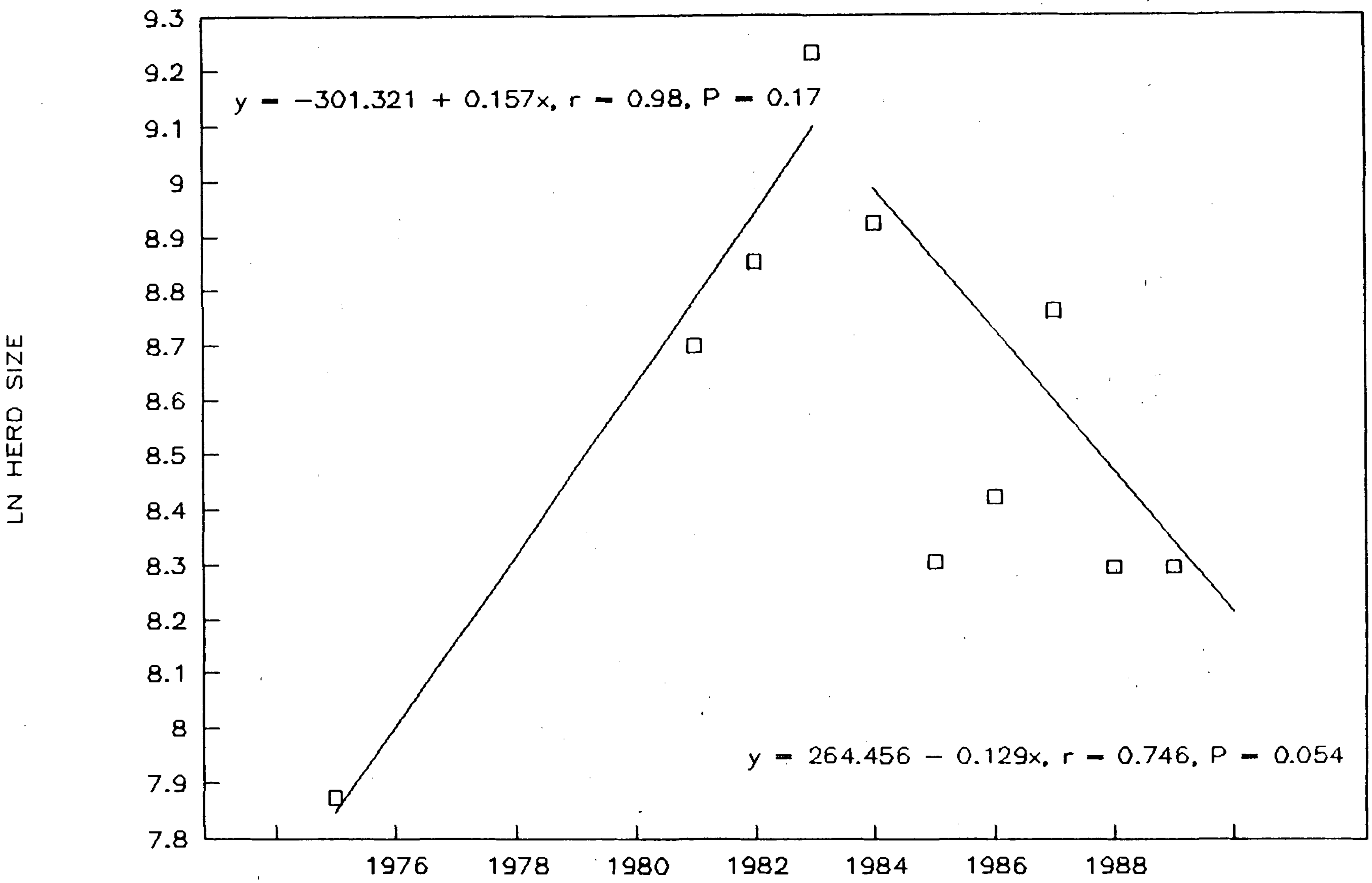


Figure 2. Linear regressions describing observed changes in numbers of the Southern Alaska Peninsula caribou herd, 1975-1989.

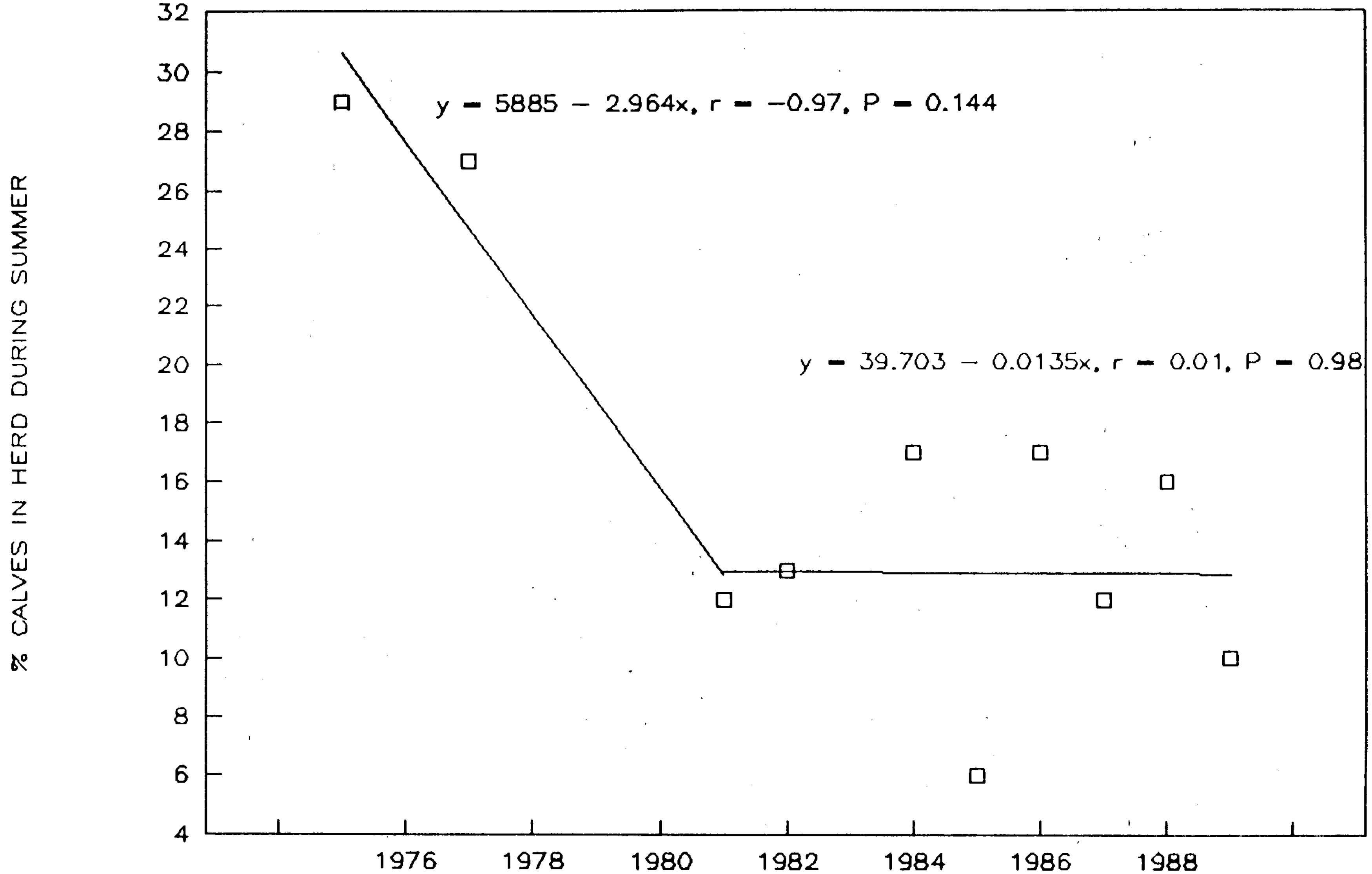


Figure 3. Linear regressions describing early calf recruitment to the Southern Alaska Peninsula caribou herd, 1975-1989.

Island and the southern Alaska Peninsula. The winter of 1975-76 was reportedly severe on Unimak and a report of 30 to 40 winter-killed caribou was received from an ADF&G fisheries biologist flying in the area. Fishermen reported seeing caribou crossing False Pass from Unimak Island to the mainland during the summer of 1976. Numbers of Unimak caribou declined from several thousand to several hundred in the mid-1970's and it is conceivable that immigration could have played a role in the increase of the SAPCH between 1975 and the early 1980's.

The overall SAPCH range comprises an area of approximately 4,875 km^2. The current density, based on an estimated herd size of 4,000 is 0.8 caribou per km^2. This is a relatively high density, now exceeded in Alaska only by the Western Arctic, Nelchina, Mulchatna, and Adak herds. The density in 1983, when the herd was estimated at 10,203, was 2.1 caribou per km^2 which is over twice as high as any current Alaskan herd. However insular Alaskan reindeer herds, in the absence of bears and wolves, have reached densities of about 18 caribou/km^2 before declining precipitously to near extinction (Scheffer 1951, Klein 1968).

Initial radio-tracking surveys flown on 29 and 30 May indicated the SAPCH was primarily located in the BHTM area, the CRF, and along the Bering Sea lowlands from Moffet Lagoon to the Cathedral River. Animals in the first 2 locations were primarily females while the latter group was composed of mostly males. Based on the proportion of radio-collared animals found in each of the areas and numbers seen during recruitment and udder counts we estimated that roughly 20-30% of the female segment of the herd was in the CRF while most of the remaining females were in the BHTM region. A few females were scattered between the 2 areas. The 2 concentrations of females were about 40 km apart.

Calving had begun by the 29th of May as 6 calves were observed during the first radio-tracking survey, including calves of 2 radio-collared females, all seen in the CRF. No calves were seen in the BHTM vicinity until 4 June at which time many calves were present on the CRF. It was apparent that calving occurred over a week earlier on the CRF than in the BHTM area. All 3 radio-collared females on the CRF had calved by 6 June (mean of 1 June) while calving by 13 radio-collared animals in the BHTM area ranged from 5 through about 14 June (mean of 10 June) (Table 2). On 4 June, 166 (18%) of a sample of 939 caribou on the CRF were calves while in the BHTM region only 7 (0.7%) of 1,070 classified were calves. Calving by caribou in southern Alaskan herds generally peaks in late May (Skoog 1968, Lieb et al. 1989) somewhat earlier than for the SAPCH, particularly the BHTM group. Late calving has been suggested as indicative of undernutrition (Espmark 1980, Skogland 1984, Reimers et al. 1983.). Calving in the Denali caribou herd, which was not thought to be nutritionally stressed (Boertje 1985), peaked on 13 May in 1987 and 1988 (Adams et al. 1989) which was nearly a month earlier than for the SAPCH. Calving in the adjoining and more productive NAPCH is thought to occur about 1 week earlier than in the SAPCH.

Table 2. Calving success of radio-collared females from the SAPCH from 29 May through 16 June 1989.

CARIBOU NO	CALVING AREA	GAVE BIRTH	LOST CALF	CALVING DATE
071	BLACK HILL	YES	YES	10 JUNE
101	BLACK HILL	NO		
170	CARIBOU R.	YES	NO	29 MAY
191	BLACK HILL	YES	NO	8 JUNE
210	BLACK HILL	NO		
221	BLACK HILL	YES	NO	11 JUNE
300	BLACK HILL	YES	YES	12 JUNE
410	CARIBOU R.	YES	NO	29 MAY
631	BLACK HILL	YES	YES	10 JUNE
661	BLACK HILL	YES	YES	15 JUNE
704	BLACK HILL	YES	YES	?
730	BLACK HILL	YES	NO	6 JUNE
749	CARIBOU R.	YES	YES	6 JUNE
130	BLACK HILL	YES	NO	5 JUNE
140	BLACK HILL	YES	YES	10 JUNE
300	BLACK HILL	YES	YES	10 JUNE
330	BLACK HILL	YES	YES	11 JUNE
370	BLACK HILL	YES	YES	8 JUNE
420	BLACK HILL	NO		

The birth rate for adult females from the SAPCH, as estimated from the sample of radio-collared females, was 84% as 16 of 19 gave birth (Table 2). During an udder survey, made about mid-way in the calving period, 73% of 332 females classified had distended udders (Table 3) indicating recently past or imminent parturition. These estimates were not strictly comparable as all radio-collared females were probably mature animals while the udder count sample contained some sexually immature animals likely accounting for the lower estimate. Seven of 8 adult females (88%) harvested after the breeding season by hunters in the Cold Bay area in 1987 were pregnant. Skoog (1968) estimated that the fertility rate for females 1 year old and older in the Nelchina herd at 72%, nearly identical to the comparable estimate of 73% from udder counts in this study. He estimated the fertility rate of females 3 years old and older at 89%, similar to the 84% estimate obtained from the sample of mature radio-collared females and the sample of hunter-killed females from the SAPCH. Bergerud (1980) reported that the mean pregnancy rate for mature females from North American caribou herds was 82% with only minor variation between herds. It appears that birth rate of mature females from the SAPCH falls within the normal range of values found for other North American caribou herds.

Table 3. Helicopter survey of the SAPCH on 9 June 1989 to estimate proportion of parturient cows.

	BLACK HILL		CARIBOU R	
	NO.	%	NO.	%
COWS W CALVES	32	13	38	48
COWS WO CALVES & W DISTENDED UDDERS	152	60	20	25
TOTAL PARTURIENT COWS	184	73	58	73
COWS WO CALVES & WO DISTENDED UDDERS (NONPARTURIENT COWS)	69	27	21	27

On 13 June, when calving was thought to be nearly completed, surveys were conducted to estimate early calf recruitment (Table 4). Recruitment appeared high on the CRF where calves comprised 33% of the sample. In the BHTM region recruitment was much lower as calves made up only 11% of the sample. Calves comprised only 2% of 129 caribou classified in the Moffet Point area, however animals in this area were primarily bulls. Overall calves comprised 20% of the total sample. The dramatic difference observed in recruitment counts between the CRF and BHTM calving areas tended to be supported by production and survival of calves by radio-collared females in the 2 areas. All 3 radio-collared females in the CRF produced calves and 2 of the 3 still had calves on 16 June when monitoring ceased. In the BHTM area 13 of 16 radio-collared females produced calves however only 4 of the 13 which produced calves still had them on 16 June.

Subsequent surveys indicated that substantial calf mortality occurred after the 13 June survey. During the ADF&G census conducted on 11 July 10% of a sample of 686 caribou were classified as calves. None of the radio-collared females were accompanied by calves as of 30 August. A recruitment survey flown on 14 October (Table 5) indicated that the percent calves in the herd had declined to 3%. The same geographical pattern of calf recruitment observed in June appeared to persist in October as the calf percentage was 13% on the CRF compared to 2% in the Black Hill to Cold Bay area. The best fitting logit loglinear model showed a significant interaction between area and time on proportion of calves ($G^2 = 58.19$, 1 df, $P = 0.99$).

Table 4. Fixed-wing survey of SAPCH calving grounds on 13 June 1989 to estimate early calf recruitment.

AREA	NO. ADULTS	NO. CALVES	% CALVES
CARIBOU R.	476	237	33
BLACK HILL	1,326	151	11
MOFFET PT.	129	2	2
TOTALS	1,931	390	20

Table 5. Fixed-wing survey of SAPCH range on 14 October 1989 to estimate calf recruitment at 4 months of age.

AREA	NO. ADULTS	NO. CALVES	% CALVES
CARIBOU R.	126	18	13
BLACK H.- COLD BAY	1,528	36	2
TOTALS	1,654	54	3

It is unclear why such a large proportion of the calves died. Only 5 dead calves were observed, 4 of which were still being attended by females. Three of these calves (2 of which were examined from the ground) were intact and had been neither killed by predators nor scavenged. The other 2, which were seen only from the air, did not appear to have been killed by predators, but were damaged in the umbilical area, probably the result of scavenging by birds (2 bald eagles were perched nearby in 1 instance).

We flew approximately 80 hours of low level surveys in the vicinity of the SAPCH calving grounds between 29 May and 16 June and observed no instances of predation on calves although known caribou calf predators including brown bears, wolves, and golden eagles were seen in the area. Brown bears were relatively abundant in the area as we made a minimum of 112 sightings (not unique individuals). Each of these sightings was checked to see if it was associated with a kill. One bear was observed eating an adult caribou. Brown bears did not seem to be specifically associated with calving caribou until late in the calving period. On 16 June several bears were seen approaching groups of caribou containing calves in the BHTM area. Generally brown bears seemed more abundant in the BHTM area than on the CRF. Although we made no observations of bears killing or eating calves it was likely, based on bear abundance and distribution and caribou calf availability, that some calves were taken by bears. A wolf den, attended by a least 3 adult wolves, was located mid-way between the 2 calving areas. Again no instances were noted of predation on caribou by wolves but some likely occurred as caribou are the only large mammalian prey consistently available to wolves on the range of the SAPCH. Golden eagles were seen on 2 occasions but are considered rare in the area and are not likely significant predators of caribou calves in the SAPCH. Our impression was that although predation undoubtedly occurs on caribou calves that it is likely that other factors (undernutrition?) also played a major role in the mortality of calves. It has been brought to our attention (J. Davis, R. Boertje, W. Gasaway pers. comm.) that other biologists had come to similar conclusions, based on field observations, discounting predation as a major cause of neonatal mortality in the Delta and Denali caribou herds only to deduce from later studies that predation was the predominant cause of early calf mortality.

Survivorship of adult female caribou from the SAPCH was estimated from 36 radio-collared females monitored for varying intervals between April 1987 and June 1989. These animals were monitored for a total of 468 months and 15 natural mortalities were recorded. Mean annual survivorship for these animals was estimated at 0.62 (95% confidence interval = 0.46 to 0.77). This level of mortality is exceedingly high. Estimates of survivorship for adult females from other herds in southern Alaska were 0.91 for the Nelchina herd (Pitcher 1987) and 0.92 for the Mulchatna herd (ADF&G unpublished data). Bergerud (1980) reported annual adult mortality rates of 7 to 13% if predators are common and 5 to 6% if predators are rare. We basically have no information on causes of death for the radio-collared sample. We visited nearly all death sites on 8 and 9 June 1989; however there were few remains and none were recent. Wolf scats were seen at 3 sites and a brown bear had buried remains at another site. However whether these were scavenged animals or kills is unknown.

We made 3 observations of dead adult caribou during our surveys. We saw a bear feeding on an adult caribou on 30 May. It was not possible to tell if it was a kill or if it was being scavenged. On 3 June the skeletal remains (intact rib cage) and hair from an adult was seen near Black Hill. On 10 June a fairly fresh adult carcass with intact rib cage and spinal column was seen on the CRF calving area.

Weights were obtained from 17 young calves from the SAPCH (Table 6). Mean weight of 9 female calves was 5.4 kg ($s=1.7$). For 9 male calves mean weight was 6.7 kg ($s=2.0$). Weights for both sexes were significantly less ($P = 0.0001$) than for calves captured from the Denali caribou herd (Adams et al. 1989). Female calves from the SAPCH were smaller ($P = 0.027$) than those captured from the Porcupine caribou herd in northeastern Alaska (Whitten et al. 1985) while males were not ($P = 0.16$). Calves of undernourished females have reduced birth weights and reduced survival (Skogland 1984). Low birth weights may be correlated with low calf survival (Haukioja and Salovaara 1978). Espmark (1980) found that calves of undernourished female reindeer had low birth weights and tended to be somewhat physically retarded at birth likely reducing the calves chance of survival. He also found that undernourished females tended to be more intolerant of their calves and thought that there was increased risk of desertion. Bergerud (1980) reported that small calves which he tried to raise invariably died.

Live weights of 12 adult female caribou captured in October of 1987 and 1988 averaged 90.1 kg ($s=7.1$) (Table 6). These weights were similar to those in the Central Arctic caribou ($P = 0.90$) and Porcupine caribou herds ($P = 0.23$) but were less than for the Denali herd ($P < 0.0001$) and the adjoining NAPCH ($P = 0.0002$). Mandible lengths of 40 adult females, harvested in the Cold Bay area, averaged 263 mm ($s=8.2$). A similar sample of 34 males averaged 283 mm ($s=12.2$). These weights and measurements (Table 6) are small for caribou from southern Alaskan herds (with the exception of mandible length from the NAPCH) and are comparable in size to animals from the Western Arctic, Central Arctic, and Porcupine herds (Skoog 1968, Adams et al. 1989, Cameron et al. 1989, S. Fancy and K. Whitten pers. comm.).

Table 6. Comparative mean weights and mandible measurements for caribou from selected Alaskan caribou herds.

HERD	YEAR	FEMALE CALF WT (KG)	MALE CALF WT (KG)	FEMALE ADULT WT (KG)	FEMALE ADULT MANDIBLE LGTH (CM)
SAPCH	1987-88	5.4	6.7	90.1	263
PORCUPINE	1984-87	6.7	7.1	92.1	
C. ARCTIC	1987			89.3	
W. ARCTIC	1960'S				263
W. ARCTIC	1980's				270
NELCHINA	1989				286
MULCHATNA	1988				284
NAPCH	1988			103.0	266
DENALI	1986-87	8.3	9.5	120.9	291
ADAK	1966-86				289

There is some indication that body size may have declined in the SAPCH over the past 10 years or so. Clayton Brown, manager at the Russell Creek hatchery and longtime resident of Cold Bay, reports a substantial reduction in both body and antler size since the early 1980's. Prior to that time an adult bull provided about 52 kg of boned meat and an adult cow about 34 kg. In recent years only about 40 and 21 kg of boned meat have been obtained from mature bulls and cows, respectively. Dick Gunlogson, a registered big game guide who has hunted caribou on the SAPCH range since the 1960's, noted that antler development of bulls has declined since the late 1970's or early 1980's. John Sarvis, former Izembeck refuge manager who lived in Cold Bay between 1974 and 1988, noted a reduction in the occurrence of large antlered bulls in the early 1980's but suspected it was the result of the intensive harvest of mature males which occurred in the late 1970's and early 1980's when SAPCH caribou became available to hunters along the Cold Bay road system.

Results of fecal dietary sampling are summarized in Table 7. The winter samples were comprised of over 50% mosses, an unusually high occurrence even considering the overrepresentation of mosses which occurs using this technique (Dearden et al. 1975, Boertje et al. 1985). This high proportion of mosses, which are of low digestibility and are considered to be low quality forage, has been rivaled only by herds on Arctic Islands such as Peary Island and Svalbard Island (Thomas and Edmonds 1983, Reimers 1982).

Boertje (1984) felt that relatively high uses of evergreen shrubs and mosses probably indicated poor range condition.

Table 7. Percentage composition of plant fragments in caribou fecal samples collected on the SAPCH range during 3 sampling periods.

	(SAMPLING PERIOD)		
SPECIES/GROUP	DECEMBER 88	DECEMBER 88	JUNE 89
	PERCENTAGE OF TOTAL COMPOSITION		
MOSS (TYPE 1)	21.8	14.1	7.5
MOSS (TYPE 2)	31.3	20.9	3.4
CLUB MOSS			0.3
OTHER MOSS	4.7	17.7	2.1
TOTAL MOSS	57.8	52.7	13.3
LICHEN (ALECTORIA)	9.4	8.0	2.9
LICHEN (FRUTICOSE)	4.6	6.5	1.8
LICHEN (FOLIOSE)	1.6	4.7	1.5
TOTAL LICHEN	15.6	19.2	6.2
SEDGES	0.8	0.3	12.2
FESTUCA			5.8
CALAMAGROTIS			12.3
UNK. GRASSES	4.4	5.1	1.9
TOTAL GRASSES	4.4	5.1	20.0
SHRUBS[1]	16.4	17.4	34.3
FORBS[2]	0.6	5.0	9.8
UNK. LEAF	4.4		
HAIR		0.3	4.2

[1]Winter samples were primarily *Empetrum*, *Arctostaphylus*, *Vaccinium* and small amounts of *Salix* and *Cornus*. Spring sample mostly *Salix* and *Arctostaphylus* and small amounts of *Empetrum*, *Vaccinium*, *Rubus*, and *Equisetum*.

[2]Both winter and spring samples contained *Solidago*, *Trientalis*, and *Angelica*. The spring samples also contained *Artemisia* and *Epilobium*.

The winter samples also contained 16% lichens, which is probably an underestimate of their importance in the diet because of the high occurrence of mosses (Boertje et al. 1985). This is surprisingly high considering their apparent scarcity on the SAPCH range. Lichens comprise over 50% of the winter diet of many herds (Scotter 1967, Skoog 1968, Thompson and McCourt 1981, Boertje 1984). Most surprising was the near absence of sedges (<1%) found in the SAPCH winter samples. Sedges with green tissues are considered an important winter food of caribou (Skoog 1968, Boertje 1984) and appear to be abundant on the SAPCH range.

SUMMARY AND CONCLUSIONS

Findings of this study corroborated earlier findings and suspicions of low calf recruitment, high adult mortality, and resultant declining herd size. The SAPCH calved primarily in 2 areas; the CRF and the BHTM vicinity and could be reasonably considered 2 herds according to traditional definition (Skoog 1968) although this remains to be clarified by additional radio-collaring and radio-tracking. Birth rates appeared to be normal in both areas. Calving for the SAPCH was late relative to other southern Alaska caribou herds. Calves were born at least 1 week earlier on the CRF than in the BHTM area. Early calf survival was much lower in the BHTM area than the CRF and this pattern appeared to persist into October. The combined findings of small adult body size, low calf birth weights, late calving dates, observations of dead calves which were not predator kills, and low quality winter diet suggested that undernutrition may be an important factor in low recruitment in the SAPCH, particularly in the BHTM vicinity. Findings of early calving and higher early calf survival on the CRF suggested differences in the condition of females utilizing the 2 calving areas. Females calving in the CRF may spend the winter and spring in different areas than those that calve in the BHTM area (John Sarvis pers. comm.) and therefore could be on different nutritional regimens. Also habitat is substantially different at the 2 calving sites. The CRF is a wet, lowland area with abundant sedge meadows. Greenup appeared earlier at this site than around BHTM which is generally higher elevation tussock and shrub tundra intersected by ridges and small drainages. Nutrition may be better near the CRF during late gestation and the calving period.

In the late 1970's much of the SAPCH began utilizing new winter range in the vicinity of Cold Bay which they continue to use. In the early 1980's low calf recruitment and possibly reduced animal growth were noted. It appears, based on radio-tracking flights and general observations, that animals utilizing the CRF also winter in that general area while animals calving in the BHTM area winter in the

Cold Bay area. These observations, combined with the differences in recruitment and calving dates between the CRF and BHTM calving areas, lead us to wonder if the Cold Bay area is particularly poor winter range and if animals utilizing it are in poorer condition than those from the CRF.

Late calving dates by the SAPCH correspond well with small body size. Late calving reduces the summer growth season during the first year (Klein et al. 1987) which likely reduces growth potential.

While it appears that undernutrition may be impacting this herd the presence of 2 known caribou predators, brown bears and wolves, cannot be discounted as mortality factors affecting the SAPCH. Brown bears are abundant throughout the range of the herd; R. Sellers, ADF&G area management biologist for the Alaska Peninsula, estimates that there are roughly 500 bears on the SAPCH range. Brown bears are known to prey on both adult and calf caribou (Whitten et al. 1985, Reynolds and Garner 1987, Boertje et al. 1988, Adams et al. 1989). We have no quantitative information on wolf abundance in the area, however, according to a longtime guide in the area, they are currently particularly abundant perhaps numbering 60 during the fall of 1989 (R. Gunlogson pers. comm.). Wolves are known to be effective predators of both calf and adult caribou (Eide and Ballard 1982, Miller et al. 1985, Ballard et al. 1987, Adams et al. 1989). Caribou are the only large mammalian prey available, on a consistent basis, to wolves in this area and therefore are likely to be highly dependent on them.

It is important to consider whether predation which occurs on the herd is compensatory rather than additive. If somehow undernutrition is predisposing either and/or both calves and adults to predation and if many of them would have died soon regardless of predators then predation is not a serious concern. However if many animals are dying as the direct result of undernutrition and then predators are killing many of the survivors then the situation is compounded. A serious concern is the possibility that when the herd declines to a size or utilizes alternative range so that nutrition is no longer limiting, then predation will either cause the herd to continue to decline or prevent it from recovering. Gasaway et al.(1983) discussed the "loose" feedback mechanism between wolf numbers and declining prey populations. It may take a number of years and very low prey populations before wolf numbers decline substantially. Brown bears, not being obligatory predators, may not decline in response to lower caribou numbers. If and when nutritional status of the SAPCH improves every effort should be made to limit human harvest and prevent the herd from declining further in order to minimize the impact of predation and the probability of long-term control of the herd by predators.

RECOMMENDATIONS

Research on the SAPCH should continue both to provide information useful in managing the herd but perhaps more importantly to obtain information on population regulation of caribou herds, particularly as undernutrition may be playing a role in the SAPCH decline. Annual estimates of herd size and indices of calf recruitment should be obtained. Future research should focus on seasonal condition, seasonal range use, and food habits of adult females utilizing both the CRF and BHTM calving areas. Consideration should be given to conducting a calf mortality study in which radio-collars would be placed on young calves which would be intensively monitored for several weeks. However the possibility exists that such a study would substantially underestimate perinatal mortality (K. Whitten, pers. comm.) from causes such as stillbirths, congenital defects, and abandonment thereby overestimating neonatal mortality resulting from predation and accidents. A proposed study of the SAPCH range by a graduate student at the University of Alaska-Fairbanks with support from USF&WS and ADF&G should be pursued. This study could include work on forage availability, forage quality, and food habits on the ranges of the CRF and BHTM subgroups. Seasonal activity budget sampling might also provide insight into nutritional status (Boertje 1985) of this herd. This would nicely supplement work planned by ADF&G and USF&WS on nutritional status and seasonal range use of these subgroups.

It is difficult to make specific management recommendations for the SAPCH without knowing if the decline is: (1) a direct result of range-wide density dependent food limitation, (2) is the result of a shift into inferior winter range, or (3) if high predator abundance and past high harvests are significant factors in the decline. However because we lack the answers to these questions and because of extremely high natural mortality of both calves and adult females we feel that hunting mortality should be reduced to the greatest extent possible, particularly for females. Unless we obtain information supporting a different approach, every effort should be made to prevent the herd from declining below 2,500 caribou, a density of about 0.5 caribou/km^2 where, normally, food limitation should not be a concern. As previously mentioned, we have concerns that predators might prevent a small, low density herd from recovering for an extended period, particularly in this case where caribou are the sole large mammalian prey. In this situation it may be difficult to manage the herd at a level between nutritional limitation and predator limitation.

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APPENDIX II

20 June 1990

Karen Gerhart
Institute of Arctic Biology
University of Alaska
Fairbanks, AK 99775

Dear Karen:

I thought I would give you a brief report on my experiences with bioelectrical impedance measurements on caribou this spring. We handled about 65 adult female caribou from 5 herds and obtained impedance measurements, weights, and length measurements from most animals. There were very noticeable differences in condition between herds and the differences appeared to be at least generally reflected by the impedance measurements.

Lacking a formula to estimate total body water, I used curve length^2/resistance (leg measurement) as an estimate of TBW. I then estimated fat free mass by multiplying that value by 1.383. Fat mass was then estimated by subtracting FFM from total mass and then expressed as percent body fat by dividing by total mass and multiplying by 100. I hoped that this would a least serve as an index with which relative body composition could be compared among herds.

Following is a table with mean growth and condition indicators summarized by herd. My impressions of condition (fatness and muscle mass) are ranked (best to worst) as follows: (1) Mulchatna herd, (2) Northern Alaska Peninsula herd, (3) Southern Alaska Peninsula herd-Caribou River, (4) Southern Alaska Peninsula herd-Black Hill, (5) Nelchina herd. Your condition index doesn't reflect this very well but I think that is because I learned as I went along and hopefully now that I have handled animals over a wide range of condition I will be more concise and consistent in the future. I actually feel that the BIA fat index reflected relative condition pretty well although the actual values are meaningless. As you can see skeletal size as well as condition varied substantially between herds. I had hoped that the weight-length ratios might make a little more sense.

11-K16LH

HERD	SAPBH	SAPCR	NAPCH	MUCH	NCH
NUMBER CARIBOU	9	9	13	13	15
MASS(KG)	83.4	95.3	100.0	113.1	107.9
CURVELNGTH(CM)	186.4	192.8	193.9	194.5	205.7
MANDLNGTH(MM)	257.3	262.2	269.8	283.5	284.7
HFLNGTH(CM)	52.5	54.3	54.3	56.0	57.3
HGIRTH(CM)	119.6	121.1	121.5	121.8	120.0
WT/CLNGTH	0.448	0.494	0.513	0.583	0.525
WT/MANDLNGTH	0.325	0.364	0.368	0.400	0.379
CONDINDEX	6.1	6.9	6.0	6.1	4.7
PACKED CELL(%)	48.9	50.3	49.6	50.2	50.2
BIA FAT INDEX(%)	9.4	9.3	13.9	22.6	7.3
FM	7.7	9.0	14.1	25.9	8.3
FFM	77.5	86.3	87.1	87.5	101.9

One thing you might be able to evaluate with your captive animals is how resistance reading are affected by a wet substrate or by wet hair. We were working in wet areas much of the time and I wondered how good an insulator wet hair was. I have the data from the live captures on a dBASE file and you are welcome to work with it if it will help on your project. I look forward to the results of your analyses of condition estimation this fall.

Sincerely,

Ken Pitcher

Ken Pitcher
Wildlife Biologist

cc: Ray Cameron
Chris Hundertmark
Bob White

MEMORANDUM

STATE OF ALASKA
DEPARTMENT OF FISH AND GAME

TO: Ken Pitcher
Caribou Biologist
Wildlife Conservation
Anchorage

THRU:

DATE: July 18, 1991

FILE NO.:

TELEPHONE: 267-2179

FROM: Earl Becker EB
Biometrician
Wildlife Conservation
Anchorage

SUBJECT: Analysis of caribou calving.

The purpose of this memorandum is to report the methods used to analyze the 1990 and 91 Nelchina caribou calving data, the results of the analysis, and recommendations for future data collection. You mentioned that only the 1990 and 91 data were collected with similar sampling schemes, therefore, only these data will be analyzed.

My understanding of the sampling scheme is as follows: from approximately 35 adult female, radio-collared caribou, a random sample of 15 was selected on each day data are collected. The first 10 caribou located, in the group of 15, were sampled. Sampling a radio collared caribou consists of classifying the 100 closest caribou to the radio collared individual as either adults or calves. Sometimes more than 100 individuals were classified, and sometimes the cluster of caribou around the radio collared animal is less than 100 so less than 100 were sampled. After data collection, some of the data was deemed to be from the non-calving segment of the herd based on a location outside of the traditional core calving ground and low calving percentage compared to the data from the core calving area. This data was dropped from this analysis per your request. Barring weather problems, data collection begins by May 21 or 22, and is collected every other day until the end of May.

The objective of the data collection was to determine if the timing of calving is earlier or latter in some years versus others. In reality there are several phenomenon that one could observe. One is a shift in the timing of calving between 2 years but otherwise the slope of calving of time is similar. Another possibility is calving is initialized at the same time between the 2 years but the maximum percentage of calves is higher in 1 year versus another or the maximum percentage of calves is the same but the time to reach maximum is different, in either case the 2 years would have different slopes. The third possibility is a combination of the first 2.

Some of the important features of your data to keep in mind are: the dates on which the data are collected differ from year to year, the response variable is a percentage (% calves), the observations on the 10 groups of caribou are independent, however the observations of caribou within groups are not independent. The last point is the reason for the complexity of the analysis I used. If the data were independent, every animal observed would have the same information as 1 <u>randomly</u> observed radio collared animal. Total dependence would indicate that observations on additional caribou around the radio collared animal contains <u>no additional information</u>. Clearly the answer lies somewhere in between these 2 extremes, the difficultly is determining where in a scientifically valid manner.

If all of the observations were independent from one another, I would use a logistic regression model (Hosmer and Lemeshow, 1989) treating day, an indicator variable for year, and an interaction between these 2 variables as possible explanatory variables. The response variable would be the natural log of the odds of observing a calf versus adult on a given day and year. This statistic is called a logit. The logistic regression methodology treats <u>all</u> of the data as if they were independently from one another, since this is not the case, the variance associated with the parameters will be biased low. The likelihood ratio test (Bickel and Doksum, 1977) would normally be used to determine the best model fit, however, lack of independence will bias this methodology. A backward elimination procedure could also be used to obtain the most parsimonious model which adequately explains the data. Again, the bias will confound our ability to determine which explanatory variables are important. I used the bootstrap method (Effron 1982) to obtain unbiased estimates of the variance of the parameters, assuming normality, these variances were used to calculate a Wald statistic (Hosmer and Lemeshow, 1989) to determine the significance of the parameters and thus the best fitting model via a backward elimination process. The bootstrap method applied to the above problem is as follows:

1) using the original data, the percent calves for each group is calculated;
2) using the original data, the total number of observed caribou on a given day and year is recorded;
3) for a given date (day and year) a simple random sample, **with replacement**, of the percentages in the original data is taken and an average percent calves calculated;
4) the average percent calves is applied to the total for that date to obtain the number of calves and adults to create the bootstrap datum point for this date;

5) this process (1-5) is repeated for each date to obtain a bootstrap data set;
6) a logistic regression model is fit to the bootstrap dataset and bootstrap parameter estimates obtained;
7) the bootstrap process (steps 3-6) is repeated 1,000 times;
8) the variance of the bootstrap estimates (1,000 of them) are used as an estimate of the variance of the parameters of that logistic model, fit to the original data.

The backward elimination process started with the model:

$$\ln(n_{0ij}/n_{1ij}) = \beta_0 + \beta_1(\text{Days}) + \beta_2 I_{90} + \beta_3 I_{90}(\text{Days}) + \epsilon_{ij}; \quad \text{(eq 1)}$$

where:

Days denote days since May 20 th, which we determined to be a biologically meaningful y-intercept;

n_{0ij} denote the number of calves 'observed' on the i th day of year j;

n_{1ij} denote the number of adults 'observed' on the i th day of year j; and

I_{90} = 1 if year = 1990, 0 otherwise.

The parameter estimates were obtained by fitting the above logistic regression model to the original data, the SE estimates were obtained using the bootstrap method described above (n_b=2000), and the P values are based on an assumption of normality. The estimates are as follows:

Parameter	Variable	Est.	SE	W	P
β_0	Constant	-3.5642	0.3691	-9.7624	0.0000
β_1	Day	0.2715	0.0359	7.5606	0.0000
β_2	Yr90	0.8488	0.4296	1.9757	0.0482
β_3	DayxYr90	-0.0791	0.0462	-1.7127	0.0868

As per your request, I used an α of 0.10 to determine if a particular parameter was significantly different from 0. An examination of the above table suggests that all of the parameters in the model are significantly different from 0 and should remain in the model. To obtain a higher degree of precision on the P-value for β_3, I used 2,000 bootstrap replications instead of 1,000. A graph of the model fit and the data is given in Figure 1.

Examination of Figure 1 reveals that the 1990 data set contains a datum point after the peak of observed calf-adult ratios (or logits in this case) whereas the 1991 data set does not. In future surveys I recommend that <u>data collection be continued until a drop in the calf-adult ratio has been observed</u>. In order to determine if this discrepancy had an undue influence on the analysis I re-ran the analysis with the 30 May, 1990 datum point deleted. The data were fit to the model defined by equation 1 above, and the following estimates obtained:

Parameter	Variable	Est.	SE	W	P
β_0	Constant	-3.5642	0.3765	-9.4668	0.0000
β_1	Day	0.2715	0.0369	7.3601	0.0000
β_2	Yr90	0.3323	0.4903	0.6778	0.4979
β_3	Day×Yr90	0.0310	0.0600	0.5329	0.5941

The P-values in the above table suggest that either β_2, or β_3 could be dropped from the model. I dropped the β_3 term since it's P-value was the largest. The resulting model was fit:

$$\ln(n_{0ij}/n_{1ij}) = \beta_0 + \beta_1(\text{Days}) + \beta_2 I_{90} + \epsilon_{ij}; \qquad \text{(eq 2)}$$

and the following estimates obtained:

Parameter	Variable	Est.	SE	W	P
β_0	Constant	-3.6368	0.3134	-11.6031	0.0000
β_1	Day	0.2804	0.0293	9.5669	0.0000
β_2	Yr90	0.5399	0.1850	2.9184	0.0035

Based on the results of the above table, I concluded that the remaining parameters were significantly different from 0, and that this model (eq. 2) was the best fit of the data set. A graph of the model fit and the data is given in Figure 2. A comparison of Figures 1 & 2 clearly shows the importance of continuing the sampling until a drop in calf percentage has been observed. In the absence of such sampling, data will have to be deleted from the analysis to make the data set 'equivalent'. I recommend that the results for the last model fit (eq. 2) with the 5/30/90 datum point deleted, be used as the final model. Dividing the estimate of β_2 by the β_1 estimate yields an estimate of the difference in the timing of caribou calving between the 2 years. Calving is estimated to be 1.9255 days (0.5399/0.2804) latter in 1991 than 1990. I modified my bootstrap program to obtain an estimate of the SE of this ratio based standard deviation of 1,000 bootstrap estimates of (β_2/β_1). The SE was estimated to be: 0.5519 days, assuming normality, the 90% confidence interval would be (1.0176, 2.8334) days. A histogram of the bootstrap estimates of (β_2/β_1) (Fig. 3) suggests that the normality assumption is not badly violated .

Despite all the statistics employed in this analysis, this type of data and thus this analysis can be confounded with yearly differences in calf survival in the days following birth. From a biological perspective this may be acceptable if the survival differences are due to poor range. If the differences are due to other factors, than this type of data has the potential to be confounded and differences observed in percent calves (and thus logits) would be due, in part, to these other factors and not just differences in range. Insight into the severity of confounding might be obtainable if there is a data set which was collected in the manner outlined in this memorandum and had additional information of the fate of the calf (calves) of each radio-collared animal. We would need at least 2 years of this type of data. If you want to use percent calves as a substitute for calf timing, this type of analysis will need to be performed.

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cc: Karl Schneider
SuzAnne Miller
Craig Gardner
Jay Ver Hoeff
Dan Reed
Ken Whitten
Pat Valkenburg

GAUSS Wed Jul 17 11:03:45 1991

FIGURE 1. LOGISTIC REGRESSION OF NELCHINA CARIBOU CALVING.

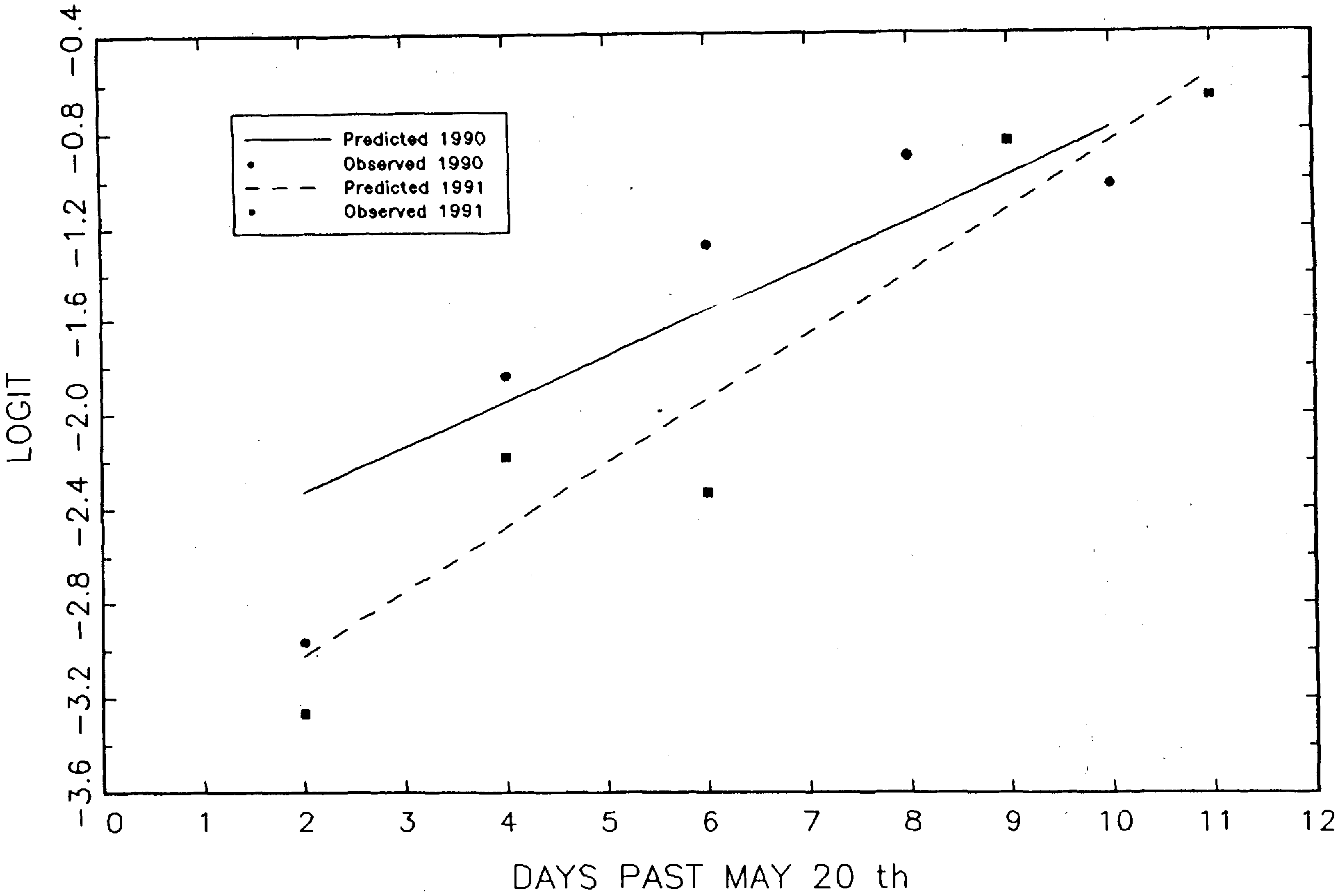

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FIGURE 2. LOGISTIC REGRESSION OF CARIBOU CALVING, w/o 5/30/90

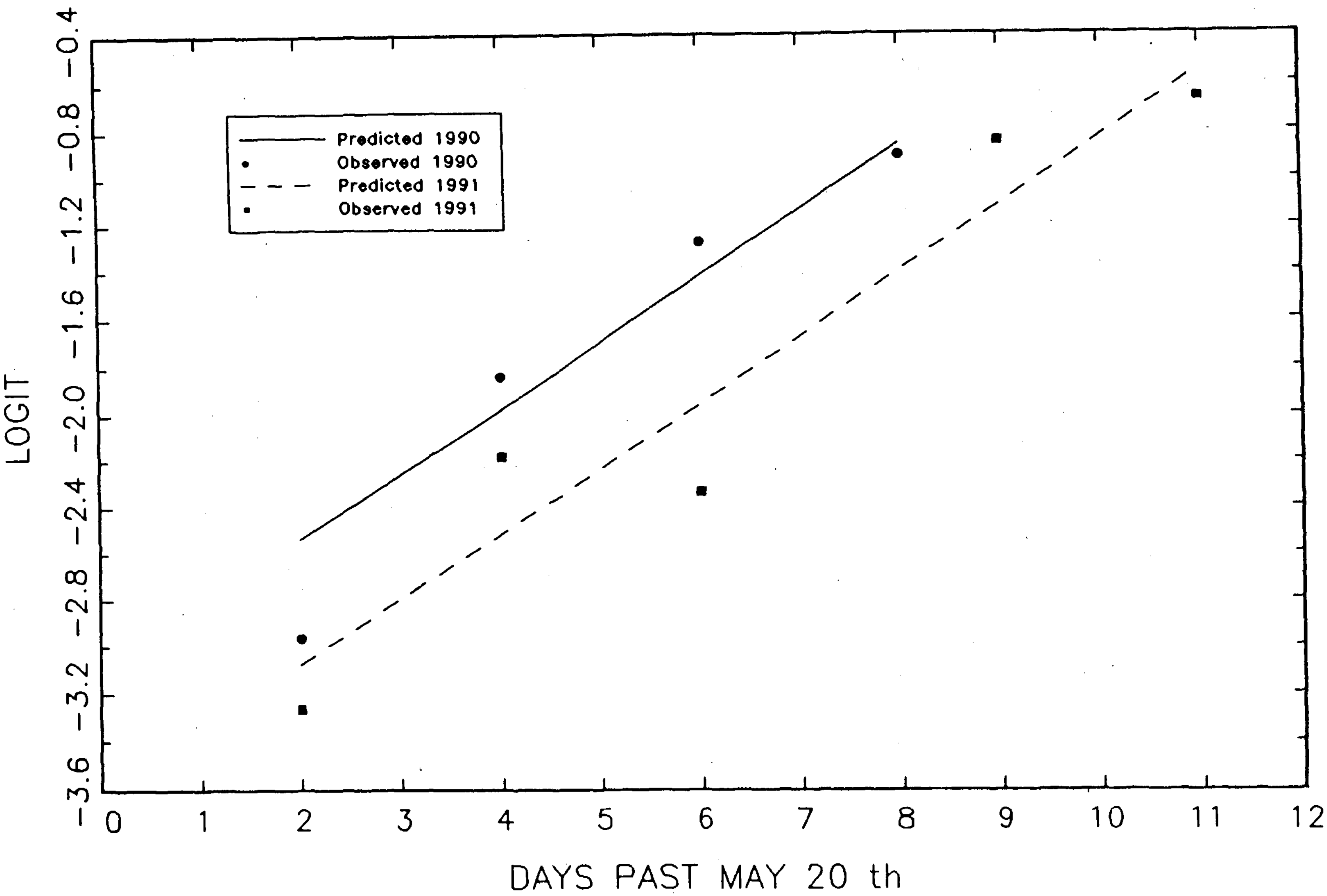

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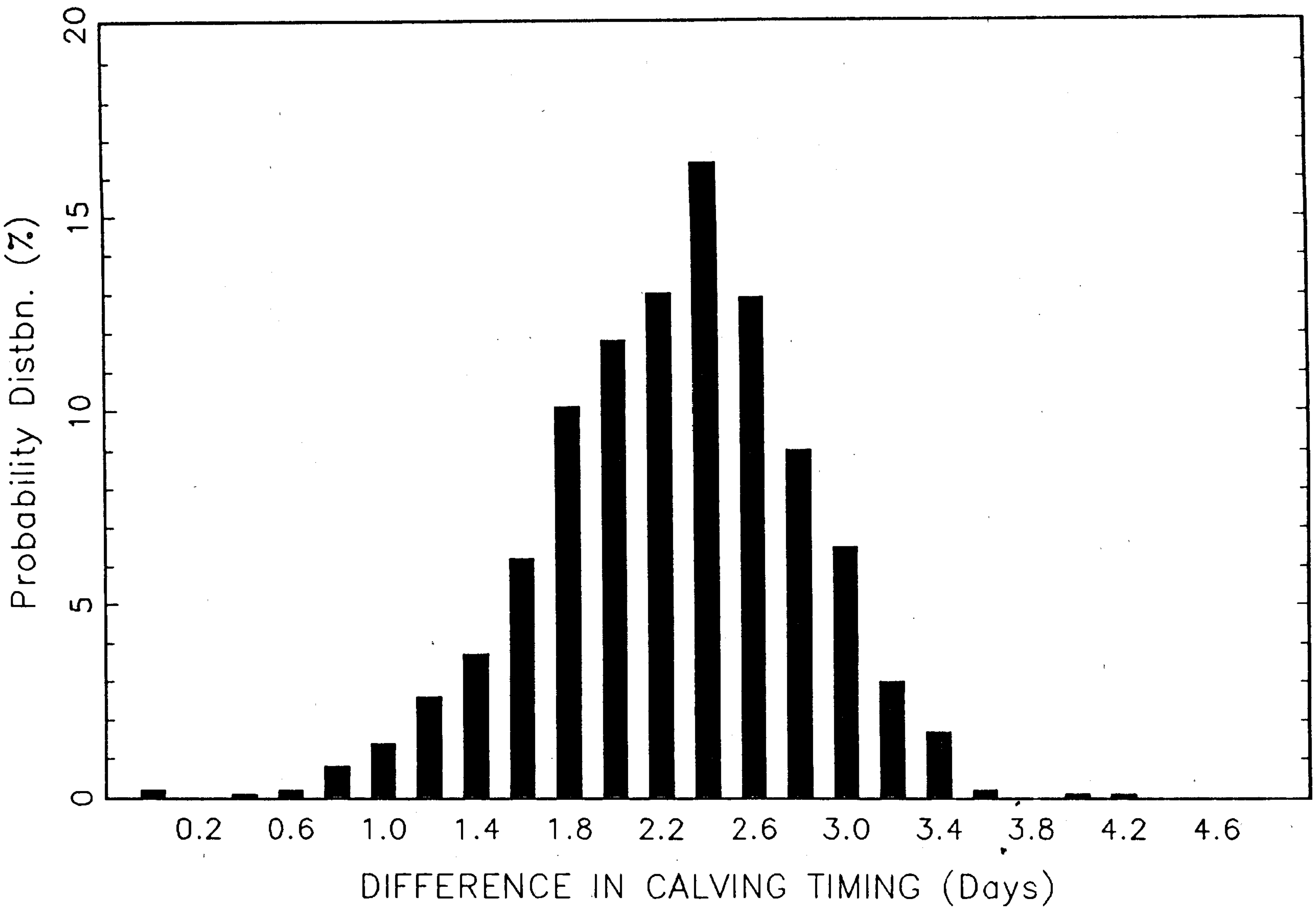
FIGURE 3. DIFFERENCE IN CALVING TIMES, 1990 vs 91



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