# REVIEW OF NORTH SLOPE ALASKA CARIBOU RESEARCH

Report to the Alaska Department of Fish and Game
*December 1991*

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December 17, 1991

Commissioner Harold Heinze
Department of Natural Resources
Mail Stop 1000
Juneau

Dear Commissioner Heinze:

In April 1991, the Alaska Department of Fish and Game requested the Wildlife Management Institute (WMI) to conduct an external evaluation of our research program on the relationship between caribou and oil exploration and development in Arctic Alaska.

The WMI assembled a team of distinguished scientists in April 1991 to conduct the review and evaluation. The team was chaired by Dr. Rollin Sparrow, President of the Wildlife Management Institute, Washington, D.C. Other team members were Dr. Ronald Skoog, former Commissioner of the Alaska Department of Fish and Game and the Michigan Department of Natural Resources, and currently a wildlife professor at the University of California-Davis; Calvin Lensink, a wildlife biologist retired from the U.S. Fish and Wildlife Service after thirty five years of experience in Alaska; Dr. Terry Bowyer, Associate Professor of Wildlife Biology, at the University of Alaska, an expert in population dynamics of ungulates; and Dr. Lyman McDonald, President of West, Inc. and an internationally recognized expert in biometrics. The team reviewed numerous scientific reports and conducted a site visit to Prudhoe Bay and the coastal plain of ANWR. They also interviewed biologists from the Division of Wildlife Conservation, U.S. Fish and Wildlife Service, University of Alaska, private consulting firms and the oil industry.

The review was completed in early December. A copy is enclosed for your information and use.

Sincerely,

Ron Somerville
Deputy Commissioner

Enclosure

## INTRODUCTION

In April 1991, the Alaska Department of Fish and Game (ADF&G) asked that the Wildlife Management Institute (WMI) assemble a Review Team (Team) of biologists and a biometrician to review published and unpublished information on North Slope caribou to answer the following primary question: "Are concerns raised and the conclusions made by Department staff in their reports and publications relative to oil development on the North Slope supported by biological data?" The subsequent review focused on data concerning the Porcupine Caribou Herd (PCH) and possible oil development in the Arctic National Wildlife Refuge (ANWR). It also included data on the Central Arctic Caribou Herd (CAH) related to effects of the Prudhoe Bay oil development. CAH data were reviewed for their utility in making predictions about future influences of development on the PCH. This report to ADF&G constitutes the results of that review.

## BACKGROUND

Oil development on Alaska's North Slope began about 1970, with drilling and intensive development in the Prudhoe Bay area starting in the mid-1970s. The ADF&G, U.S. Fish and Wildlife Service (Service) and, to a limited extent, the oil industry began conducting research during the 1970s on the CAH, which primarily uses the Prudhoe Bay area, and on the much-larger PCH, which migrates each spring from a large winter range in Canada and eastern Alaska into the coastal plain and foothills east of Prudhoe Bay, including ANWR. Work by both agencies focused on the caribou herds and on such other wildlife resources as brown bears, musk-oxen and geese. A coordinated approach to some of the work, particularly on caribou, began about 1980 between the ADF&G and Service through joint telemetry and satellite tracking. In 1988, those agencies, the Canadian Wildlife Service (CWS) and the University of Alaska

Fairbanks (University) planned and initiated a two-phase program of research of the North Slope, which emphasized studies of the primary wildlife resources, including habitat.

The Alaska National Interest Lands Conservation Act (ANILCA) of 1980 affected all of those efforts. ANILCA provided for possible development of petroleum reserves on the coastal plain of ANWR, where potentially large amounts of recoverable gas and oil are located. This part of the coastal plain is designated as the "1002" area, after the section of ANILCA pertaining to it.

A five-year baseline study was conducted by the Service from 1981 to 1986, to assess potential effects of oil and gas exploration, development and production on wildlife and their habitats within the 1002 area (Garner and Reynolds 1986). This information was incorporated in a Final Legislative Environmental Impact Statement (Clough et al. 1987) that was presented to the Congress.

During the past 30 years, the ADF&G has played a major role in research on Alaska's caribou herds in the Arctic. Since the start of major oil development in the Prudhoe Bay region, research by ADF&G biologists has concentrated on the CAH and PCH. Results of that work have increased concerns by ADF&G about whether present and future oil development in the Arctic will adversely affect the caribou. As political pressures in support of oil development have mounted, these concerns and the research itself have been criticized and challenged repeatedly.

Questions have been raised about: (1) the validity of conclusions drawn from the research; (2) research design; (3) statistical analyses; (4) sampling; (5) adjustment or errors in data; (6) assumptions; (7) lack of baseline data; and (8) objectivity of conclusions. Concerns have been expressed about using this information as a baseline for developing mitigation policies and implementing a statewide caribou policy. The Team did not have access to all documents

and past exchanges, but was informed about these issues by the ADF&G, the Service and oil industry representatives.

Congress has yet to make a decision on development within the 1002 area. Future caribou management and research are at a turning point for the ADF&G, Service, University and others interested in the future of caribou on the North Slope. Support for continuing, necessary investigations largely depends on action by the Congress. The 102nd Congress is expected to address the 1002 development issue.

## REVIEW SCOPE AND PROCESS

This review of PCH and related CAH research was requested by ADF&G to determine whether the work has been conducted in an objective manner. This is a review of research, including its design, methods, results, analysis and conclusions. It also assesses needs for additional information to manage the PCH effectively if Congress authorizes oil development on ANWR.

Much of the recent research was conducted cooperatively between the Service, ADF&G and University. Therefore, the review includes work and results from biologists outside the ADF&G. An important preliminary report edited by McCabe et al. (1991), on three years of joint research by the Service, ADF&G and University, exists in unpublished draft. Citation herein of papers from that draft are made with recognition that some may be revised.

This review is *not* an assessment of whether development should occur on ANWR. That decision will be made by Congress. Further, it is not a review of specific on-the-ground actions that might be taken if development proceeds. That is a matter to be decided by the ADF&G, Service and others.

Participants on the Team included: Rollin Sparrowe, President, Wildlife Management Institute (biologist and team leader); Lyman McDonald, President, West, Inc. (biometrician); Calvin Lensink, Anchorage, Alaska (biologist); Ronald Skoog, Wildlife Specialist, University of California-Davis (biologist); and Terry Bowyer, Associate Professor, University of Alaska-Fairbanks (biologist).

A scoping session was held with Sparrowe, Lensink and ADF&G personnel on May 28-30, 1991. Lists and copies of literature were provided to the Team in June. The Team convened in Fairbanks, Alaska, July 8-14, and interviewed ADF&G, Service and University biologists. Prudhoe Bay and ANWR were inspected from aircraft. In addition, the Prudhoe Bay oil field was visited by land vehicle. In Prudhoe Bay and ANWR, caribou and other wildlife were observed and collared caribou were located by aircraft. Additional discussions were held with ADF&G staff and other biologists during this trip. On July 15, Sparrowe and Lensink visited oil company biologists in Anchorage for their input. An extensive literature review was conducted during July and August, and a second work session convened in Fairbanks August 23-28. The Team worked on details of the report and conducted a second set of interviews with ADF&G, Service and University biologists.

The report format includes responses to specific questions posed by the ADF&G. Discussion of published evidence, and identification of strengths and weaknesses of data bases represent the primary mode of this review. Additional pertinent discussion is presented in the appendices: I. Review of Specific Papers; II. Insect Relief; and III. Overview--Ungulate Population Regulation.

## SCOPE OF WORK

WMI agreed to focus the Team's review on questions identified by ADF&G as being of primary importance in evaluating caribou research conducted in the central and eastern Arctic. The questions are:

### A. Caribou Calving Areas

1. Do traditional concentrated calving and calf rearing areas exist for the CAH and PCH?

2. Is there a survival value to caribou if they occupy a traditional concentration area that is related to:
   a. reduced predation risk?
   b. nutritional value of forage?
   c. climatic factors (insect relief)?

3. Can human disturbances displace caribou from calving areas?
   a. Local displacement?
   b. Regional displacement?

4. Does such displacement have an impact on:
   a. individual calf survival?
   b. productivity of the population?

### B. Midsummer Distribution and Movements

1. Is free passage of caribou through oil fields important in terms of habitat availability and potential impacts?
   a. Will inhibition of movement influence nutritional status?
   b. Could regional displacement affect nutritional status?

2. Is passage of caribou inhibited by roads, pipelines or industrial facilities?
   a. Is crossing success related to caribou group size?
   b. Can crossing success be improved by various construction techniques?
   c. Can passage be promoted by siting of production facilities?

3. Are available data adequate to predict general movement patterns of the PCH during summer?

### C. Synthesis of Information

1. Are data adequate to develop a linkage between habitat availability, disturbance, body condition and reproductive performance of the herd?

2. Are concerns raised and conclusions made by ADF&G staff in reports and publications relative to oil development on the North Slope supported by biological data?

3. Is it valid to predict, from data collected on the CAH, potential impacts on the PCH?

4. Has ADF&G's research been properly focused in the past, and where should it be focused in the future?

## RESPONSE TO SCOPE OF WORK

### A. Caribou Calving Areas

*1. Do traditional concentrated calving and calf-rearing areas exist for the CAH and PCH?*

**Answer:** Yes. Both the CAH and the PCH consistently utilize habitats on the coastal plain and in associated foothills for calving and early calf rearing. Repeated use of certain portions of the coastal plain implies value over other areas. Studies of movement indicate consistent use of these areas over time, and calving-ground surveys have documented high-density concentrations. Similar evidence is available for most other caribou herds in North America and the Soviet Union.

**Discussion:** Broad evidence indicates that portions of the coastal plain are used traditionally for caribou calving and postcalving activities. Early references on caribou (Skoog 1968, Kelsall 1968) described traditionally used calving areas for caribou herds in Alaska and elsewhere. Important Baseline Studies on the 1002 area (Garner and Reynolds 1986: 210-231) presented 16 figures and other information annually from 1972 to 1985 on repeated use of identifiable areas on the coastal plain within the 1002 area.

The early years of data were sketchy, but intensive satellite-based studies on movement later corroborated the use of these areas. Reference to both the CAH and PCH are made, with much stronger information on the PCH. The Service's computerized information system displays data on caribou movement, including six years of data since Garner and Reynolds (1986) clearly showing areas used more heavily than others by caribou during calving. From satellite- tracking imagery that revealed traditional high-density calving areas, Whitten and Fancy (1991)

summarized 1983-1990 data on movements and known calving sites. Eastland et al. (1989) used satellite imagery to examine caribou movements during calving. The authors hypothesized that caribou select zones with considerable snow cover, but with open spots that provide forage and may help in avoiding predators. These zones correspond to frequently used calving areas. Fancy and Whitten (in press) presented some of these data on satellite movements from 1983-1990.

Overall, a large body of information exists in refereed and unrefereed reports to demonstrate that large areas within the coastal plain, and specifically the 1002 area, are consistently used for calving and early calf rearing by the CAH and especially by the PCH.

2. *Is there a survival value to caribou if they occupy a traditional concentration area that is related to:*

   a. *reduced predation risk?*

**Answer:** The PCH, in general, calves in areas where predator densities are lower than in other parts of the range. Higher calf mortality occurs in years when calving activity is close to or in habitats where predators are more abundant. Consistent use of calving areas with low predator density has survival value at the individual level and presumably also at the population level.

**Discussion:** There is evidence of reduced predation risk through occupation of a traditional concentration area, specifically those areas on the coastal plain within the 1002 area used by the PCH. Whitten et al. (in press) presented results of tracking (1) collared cows with calves and (2) collared calves, and reported higher calf mortality in years when calving occurred close to foothills or in areas south of the coastal plain. These are the areas where such predators as bears, wolves and golden eagles are more abundant (Reynolds et al. 1991). Whitten et al. (in press) concluded that caribou displacement to these areas could result in increased calf mortality. Truett et al. (1989) stated that fewer predators occur in the core calving areas and, on main calving areas of other caribou herds, particularly those that use tundra habitats. Fancy and Whitten (in press)

used movement data to look at characteristics of 305 calving sites for PCH cows. They related selection of calving sites to areas with fewer predators and the presence of newly emerged (green-up) vegetation. Although the conclusion about selection of areas be cows to avoid predators may be overstated, PCH cows calve in areas with a lower number of predators. Whitten et al. (1991) consolidated the information from Fancy and Whitten (in press) and Whitten et al. (in press), bringing the data set and analysis through 1990. The former provides a stronger and clearer appraisal of the overall issue of calving site selection and mortality (Appendix I).

*b. nutritional value of forage?*

**Answer:** Probably. Poor nutrition can adversely affect survival of both a cow and its calf, especially the neonate. At calving time, greater abundance and higher quality of forage appears to occur in "concentrated" calving areas as opposed to "foothills." Nonetheless, based on current data, it is not possible to separate the effects of predators and nutrition on survival of young caribou.

**Discussion:** Parturient cow caribou have high energy demands resulting from stresses of late gestation and migration to the calving ground (Duquette and Klein 1987). That certain calving grounds are an integral and essential component of caribou ecology is demonstrated by traditional use of such areas. Moreover, calving caribou select particular areas within the broad range of calving grounds used, based in part on patterns of snowmelt that ostensibly expose high-quality forage in early phenological stages and provide concealment from predators for neonates (Eastland et al. 1989). Indeed, Fancy and Whitten (in press) documented that, relative to randomly located points, sites selected for calving were higher in *Eriophorum* (an important forage) and were displaced farther from the foothills (where predator numbers were thought to be higher). Fancy and Whitten (in press) and Whitten et al. (in press) showed that mortality of

calves was lower near the central portion of the concentrated calving area and higher near the foothills, where predators are more abundant (Young et al. 1991).

*Eriophorum* inflorescences are more abundant on the concentrated calving areas of both the Western Arctic Herd (WAH) (Kuropat 1984) and PCH (Jorgenson and Udevitz 1991) than on surrounding areas. Moreover, this sedge is more nutritious (higher nitrogen and digestibility, with lower secondary compounds) than other forage available at calving (Kuropat and Bryant 1983, Kuropat 1984).

Whitten and Cameron (1979) noted that forage, particularly forbs, were available earlier on the more southerly foothills than on the coastal plain, inferring that forage to support neonates was available there also. Nonetheless, their sampling covered too broad a period to assess forage availability at peak calving and did not include data on forage abundance, digestibility or secondary compounds.

*Eriophorum* inflorescences become senescent rapidly in quality following emergence (Kuropat 1984), and patterns of snowmelt may provide high-quality forage to caribou throughout calving on the coastal plain (Eastland et al. 1989). Thus, the notion that caribou select the coastal plain for calving *primarily* to reduce exposure to predation (Fancy and Whitten in press) is not supported strongly by existing evidence; research thus far does not allow a critical test of that hypothesis. Indeed, because poor nutrition could predispose newborns to predation, separating forage and predation into primary and secondary causes may be difficult. This criticism does not detract from data indicating that concentrated calving areas are important to caribou, or that caribou may follow plant phenology to obtain a higher quality diet (Klein 1970, Whitten and Cameron 1979).

ADF&G's concern over oil exploration and development on concentrated calving areas is justified. Even slight differences between areas in forage quality and availability can have a

profound effect on the health of individual caribou (White 1983), and presumably on the dynamics of a population. In consequence, oil development that precludes caribou use of "preferred" calving sites could have a detrimental effect on the nutritional condition of cows and the survival of their offspring and, hence, the caribou population. The notion that most of the coastal plain is equally suitable for calving in any one year can be rejected. Caribou appear to select specific sites (relative to snowmelt) that are likely to have more high-quality forage *and* reduce losses of neonates to predation. Patterns of snowmelt on the coastal plain are highly variable and influence the areas selected by calving caribou (Eastland et al. 1989). Thus, the area of calving changes from year to year, based on snowmelt, suitable forage and perhaps low predator density. To ensure that only a small "core" of the concentrated calving area is available probably is insufficient to assure consistent success in calf recruitment over time. ADF&G's concern that the PCH has access to larger sections of the 1002 area is justified.

c. *climatic factors (insect relief)?*

**Answer:** Yes. Cow and calf nutrition and insect relief are related to microclimatic conditions. PCH animals tend to select areas of mottled snow for calving. These areas provide forage in a phenologic state that is of extremely high quality (*see* A2.b). Such sites also may help conceal neonates from predators (*see* A2.a). Insect relief is important and also strongly related to local and microclimatic conditions.

**Discussion:** Caribou and reindeer are subjected to severe insect harassment from mosquitoes, black flies and oestrid flies in circumpolar Arctic regions, primarily during July and early August. This harassment occurs at a time when lactating cows have an especially high demand for energy and a need for quality forage. These insects can interfere with the foraging activities of cows and their ability to satisfy needs for energy and accumulation of fat reserves, the lack of which could reduce their survival and that of their calves. Animals must have access to areas that can provide

some relief from these insect attacks, (i.e., wind swept areas, coastal areas, barren ground, ridges, gravel bars, ridges, remnant snowdrifts and aufeis).

Insect relief related to microclimate is important for caribou, but present data are not adequate to quantify an adverse effect on caribou survival due to insect harassment, except under special conditions and at the individual level. Available information does suggest some adverse impacts, and the subject warrants discussion. Appendix II reviews this issue in depth.

*3. Can human disturbance displace caribou from calving areas?*

*a. Local displacement?*

**Answer**: Yes. Available data indicate a significant potential for local displacement of parturient cows from portions of calving or postcalving areas. Bulls, nonparturient cows and immature animals are less affected. Most displacement of cows and calves within the Prudhoe Bay complex has been local and caused by avoidance of roads, pipelines and other infrastructure. Such effects are cumulative, so that as roads and facilities are expanded, substantial parts of a poorly designed development area may become largely unavailable. Potential displacement from larger areas within or adjacent to an oil field, but not in the immediate vicinity of oil field facilities, can be reduced by appropriate design and siting of infrastructure to facilitate free passage of caribou through the field.

**Discussion:** Most studies related to potential displacement of caribou by petroleum development on the Arctic coastal plain have focused on impediments to movements posed by roads, pipelines and other infrastructure (Smith and Cameron 1985, Curatolo and Murphy 1986, Johnson and Lawhead 1988, Murphy 1988). Although at least partial or temporary caribou displacement is indicated by these studies, the extent or duration of actual displacement cannot be quantified by current data. Studies that considered the distribution patterns of caribou in relation to oil field infrastructure provided a more direct measure of displacement. These studies indicated lower-

than-expected numbers of cows and calves along the trans-Alaska pipeline (Cameron et al. 1979), and similar avoidance of the Milne Point Road (Dau and Cameron 1986, Cameron et al. 1991b) and other developed areas (Whitten and Cameron 1985, Cameron et al. 1991a). Jakimchuk et al. (1987) suggested an alternative explanation for fewer cows and calves along the trans-Alaska pipeline, believing that "they avoid riparian habitats which are closely associated with the pipeline." This theory, however, would not apply to indicated displacement in other areas or habitats such as the 1002 area. Unpublished work in progress--including weekly aerial surveys of caribou within the Prudhoe Bay oil field (P. Lent personal communication) and of individual caribou monitored by satellite (L. Pank personal communication)--corroborate published accounts. The latter appears to be of particular significance, and analysis and publication of these data should provide the most reliable estimates of the nature and extent of displacement.

*b. Potential for regional displacement?*

**Answer:** The Team assumes that regional displacement means "more than local," involving a broad area (e.g., an oil field) of some unspecified size, but important to caribou at the herd level. There is no evidence so far from the CAH that regional displacement *beyond the vicinity of the development area* has occurred. However, as previously mentioned, local displacement may have cumulative effects that change over time.

**Discussion:** The response of individual caribou in the PCH to development infrastructure is likely to be similar to that of caribou in the CAH. However, populations, range use, movement patterns and habitat of the PCH are sufficiently different that current predictions of displacement effects from development have a degree of uncertainty. Size of the PCH, its more extensive movements, and its high affinity to a concentrated area for calving and calf rearing within the 1002 area make this a serious question for future investigation.

4. *Does such displacement have an impact on:*

*a. individual calf survival?*

**Answer:** Displacement of PCH caribou from 1002 calving and calf-rearing zones to areas with higher predator densities outside the 1002 area likely would result in reduced calf survival.

**Discussion:** If PCH cows are displaced from their traditional calving and calf-rearing areas within the 1002 area to areas with higher predator densities, individual calf survival would be reduced. Evidence for this is presented in the answer to A2.a. There are indications that predators are more abundant in the areas south of the traditional calving areas on the 1002 area, and the published evidence seems to indicate that calf mortality would likely be higher. Displacement to areas of poor-quality forage could have a similar effect, but data are lacking to demonstrate that either the displacement or survival effect is likely (*see* A2.b). This does not answer the question of whether displacement will occur. *See* answers for A3.a and A3.b regarding local and regional displacement potentials.

*b. productivity of the population?*

**Answer:** If calving caribou are forced to use lower-quality habitat that (a) exposes calves to increased predation leading to lower calf survival and (b) restricts access to high-quality forage by cows and calves, productivity of the population may be affected. It is not possible, based on current information, to estimate the magnitude of such changes.

**Discussion:** For many wild ungulates, abundant evidence exists to show that populations are regulated by different mechanisms, depending on the nearness of the population to carrying capacity. A review of this complex topic appears as Appendix III. Basically, habitat, predation and weather may affect a population at any time; but below a threshold of population size, reproduction and survival remain high. As numbers approach carrying capacity, productivity can be expected to fall. Reduced access to forage may affect nutrition, and such density-dependent

responses as reduced conception, birth rate and calf survival may occur. Overlain with predation and weather, such changes may reduce overall productivity.

Depending on local conditions, either summer range (Skogland 1985, Messier et al. 1988, Couturier et al. 1990) or winter range (Reimers 1982, 1983a, 1983b, Adamczewski et al. 1987) may be limiting for *Rangifer*. Obviously, resources necessary for survival must be present in both seasons (Mautz 1978). Caribou in mainland Arctic North America are well-adapted to precalving winter conditions (Russell and Martell 1984), but may be limited primarily by summer range at present (Huot 1989). Much more complete understanding of habitat relationships will be necessary to deal effectively with this important issue; it is addressed herein under "Research Directions."

### B. Midsummer (July through mid-August) Distribution and Movements

*1. Is free passage of caribou through oil fields important in terms of habitat availability and potential population impacts?*

**Answer:** Yes. Caribou need free access to areas of nutritious forage and insect relief. Habitat use would be reduced in developed areas if free passage was inhibited. Cumulative effects of blocked access to adjacent areas may occur as developed areas increase.

**Discussion:** The nomadic and migratory behavior of barren ground caribou evolved over millennia and is important to the survival of this species. Such behavior provides the caribou with considerable flexibility in dealing selectively with an array of environmental factors that can affect their well-being. Freedom of movement and the ability to move long distances enable caribou herds to avoid or leave areas with adverse conditions, such as deep or ice-covered snow, floods, inadequate or poor quality forage, insect abundance, high predator densities and, to a certain extent, human development.

Situations that for a long period of time substantially inhibit or prevent "free passage" or access to or use of a given area (e.g., one of high-quality forage) would be expected to have

adverse effects on reproduction, survival and herd productivity. This would occur whether caused by a natural event or by human activity, depending on the magnitude of such interference. A large oil field might have such an impact, but no data are available to support that inference. Nevertheless, if the 1002 area is developed, ADF&G is correct in expressing opinion that caribou movements should not be restricted. It seems logical that two large oil fields, covering almost one-third of the Arctic coastal plain of Alaska, will have a cumulative impact requiring special consideration.

*a. Will inhibition of movement influence nutritional status?*

**Answer:** Yes, if caribou stay on the coastal plain. Population impacts could occur if the animals are prevented from reaching adequate forage and insect-relief habitat.

**Discussion:** During midsummer, energy demands on the lactating cows and rapidly growing calves are heavy. Growth of new hair and antlers imposes an additional energy drain. At this time, caribou also are subjected to severe insect harassment, and extensive herd movements are frequent. Access to high-quality forage at this time is important to individual animals and the herd. Also important is access to insect-relief areas, because insects can adversely affect caribou feeding behavior, including the ingestion of adequate nutrients. There is good evidence that caribou cow and calf movements are affected by oil field development, but data linking movements and nutrition are inconclusive. *See* appendicies I, II and III for further background.

b. *Could regional displacement affect nutritional status?*

**Answer:** Data are not adequate to determine whether "regional displacement" during July and August would adversely affect the nutritional status of the PCH.

**Discussion:** It is not unusual for the herd to move out of the 1002 area in early July. By late July and August, most PCH animals are off the area. Also, good forage and insect-relief areas are readily available outside of 1002. The impact of such displacement, if it occurred, might be

insignificant. Such conclusions must be tempered by the lack of definitive information on summer and winter range relationships to nutrition in the PCH.

2. *Is passage of caribou inhibited by roads, pipelines, and industrial facilities?*

**Answer:** Yes, but to varying degrees, depending on the cohort involved (e.g., adult bulls, parturient cows, etc.) and the kind of "obstruction" or "inhibiting influence" (e.g., large or small facility; low-to-ground, raised or buried pipeline; human activity of some sort; etc.).

**Discussion:** Caribou--like most ungulates and, in fact, most vertebrates--can be inhibited from pursuing normal behavioral patterns or activities at a particular time by various kinds of human influences, including those noted in this question. Whether any of the three actually restricts or prohibits passage depends on the structure itself and the human activity associated with that structure at the point of encounter. In a remote location, a gravel or dirt road across the tundra generally would have little impact. Vehicular traffic, however, could alter that situation, and perhaps considerably. A pipeline in a remote location, if raised sufficiently above the ground (e.g., five or six feet), probably would allow passage except for the most wary animals (e.g., parturient cows with young calves). On the other hand, a pipeline constructed low-to-ground would prohibit passage entirely. Individual facilities vary considerably in their size and construction, and have potential to prevent or inhibit passage. There is need for more-exacting studies on how to minimize passage inhibition and to best allow for the passage of caribou through certain portions of an oil field complex. Some work already has been done in identifying certain effects. For example, Curatolo and Murphy (1986) showed a significant effect of pipeline and road combinations on the crossing success of caribou groups. Studies of movement and distribution during midsummer and other time periods are in basic agreement with this conclusion (e.g., Smith and Cameron 1983b, Smith and Cameron 1991).

*a. Is crossing success related to caribou group size?*

**Answer:** Probably. Published data are consistent with the hypothesis that an inverse relationship exists between crossing success and group size.

**Discussion:** Using their definition that a crossing is successful if 50 percent or more of the group crosses the boundary, Curatolo and Murphy (1986) reported that there is a tendency for large groups to be less successful than small ones. These differences were not statistically significant, however, and the definition itself has been questioned. A second statistic--the proportion of the individuals in a group that are successful in crossing--is of equal importance and also should be analyzed. In these studies, the basic sampling unit usually is a "group," and the proportion of individuals successful in crossing is estimated by the ratio of random variables:

$$\frac{\Sigma i \text{ (number of successful individuals in ith group)}}{\Sigma i \text{ (number of individuals in the ith group).}}$$

Estimation of the variance of the ratio, P, of random variables should follow finite sampling theory (e.g., Cochran 1977) where the sample size is the number of groups observed.

Smith and Cameron (1983b) provided data that appear to be consistent with the hypothesis of reduced crossing success with increased group size, but no results of statistical tests were given. Smith and Cameron (1983b) recognized that their study design probably was biased toward detection of large groups which take longer to cross. This is "length-biased" sampling, and analysis requires special estimation techniques (Otis et al. 1991).

*b. Can crossing success be improved by various construction techniques?*

**Answer:** Yes. Crossing success can be improved by enlightened construction techniques.

**Discussion:** Within the CAH, caribou did not select for particular pipe heights within the range studied (152-432 cm), but did select for buried sections of pipeline, and were more likely to cross when the pipeline and road were separated by some distance (Curatolo and Murphy 1986). Smith

and Cameron (1983b) reported that crossing success was reduced or eliminated by drifted snow and pipelines that were low.

*c. Can passage be promoted by siting of production facilities?*

**Answer:** Yes. Passage via known movement corridors can be enhanced by (1) avoiding placement of dense development complexes in the corridors, (2) separating roads and pipelines, and (3) using buried pipelines. Low-to-ground pipelines, as currently exist in parts of the Prudhoe Bay complex, appear to block the passage of most caribou in those areas.

**Discussion:** The Team understands that a joint review of mitigation experience with production facilities is underway between the ADF&G, Service, and the Alaska Oil and Gas Association. This review should provide a basis for such siting.

*3. Are available data adequate to predict general movement patterns of the PCH during summer?*

**Answer:** Yes. Historical data indicate that general movement patterns of PCH caribou during summer are predictable. For example, caribou normally are present on the coastal plain from the calving period in late May and early June and through the postcalving period to late June or early July. Significant movements to seek forage or insect relief may occur in all directions during this period. During July and August, movements to seek forage or insect relief are less predictable. Specific areas of use at any given time, and timing and direction of movements within or after this period, are largely unpredictable because they are influenced by weather, insects and other variables.

**Discussion:** Movement patterns of the many caribou herds occupying taiga/tundra habitats of northern Canada and Alaska have been broadly characterized by Kelsall (1968), Hemming (1971) and Calef (1981). Although specific movements or areas of use are somewhat unpredictable, particularly in winter or summer, basic patterns of movements and range use are evident during the year (Eastland 1991). From wintering areas in taiga forest habitat, or occasionally in tundra,

Arctic caribou in Canada migrate in late winter and spring to calving grounds and summer ranges that are always on the tundra (Kelsall 1968). Movements of Arctic caribou in Alaska, including the PCH, fit this broad pattern.

As a result of extensive aerial surveys and the large number of animals monitored by conventional and satellite radio transmitters, data on use of calving and postcalving areas by the PCH may be more precise than for any other herd (Clough et al. 1987, Fancy et al. 1989, 1990, Fancy and Whitten in press). While calving areas have varied within the broad, traditional calving grounds because of annual differences in snow conditions, "concentrations of cows have used the coastal plain between the Hulahula and Aichilik rivers for calving in 17 of the past 19 years" (Fancy and Whitten in press). The extensive use of this area during the calving and postcalving period demonstrates substantial predictability of movements during this period and indicates the area's importance.

C. **Synthesis of Information**

1. *Are data adequate to develop a linkage between habitat availability, disturbance, body condition and reproductive performance of the herd?*

**Answer:** Partially. *See* A2.b, review of Cameron, et al. (1991a) in Appendix I, and Appendix III for in-depth discussions. Solid evidence exists for wild ungulates, in general, that habitat availability and quality affects body condition and, thereby, herd productivity, especially as populations approach carrying capacity.

**Discussion:** Evidence gathered in one study on the CAH and PCH (Cameron et al. 1991a) provides some potential linkage of body condition to oil development. However, differences in body condition for caribou in the east and west sides of the CAH are confounded with differences in habitat, insect relief, weather and other factors. Some changes in condition might be inferred if caribou avoid important habitat as a result of oil development. Inadequate effort has been made to link studies of herd productivity with caribou population dynamics. This line of

investigation, while logical and important, is in its infancy, and it is premature to draw conclusions from it.

2. *Are concerns raised and conclusions made by ADF&G staff in reports and publications relative to oil development on the North Slope supported by biological data?*

**Answer:** Yes. This review has focused on relatively broad questions related to concerns expressed by ADF&G biologists and collaborating Service biologists about the known and possible influences of North Slope oil development on caribou, with emphasis on the PCH. Overall, the Team finds that concerns about potential impacts are reasonable, and are based on accepted biological and analytical concepts and, in many cases, on defensible data.

**Discussion:** Some strengths and weaknesses in the information base are revealed in specific answers to the list of questions in this scope of work and the appendices. There is a gap between much of what seems logical and biologically sound and the presence of strong and definitive data sets. This problem has roots in the logistical problems of working on the North Slope, the size and complexity of the issues, and that only recently (i.e., less than 10 years) have agencies (i.e., ADF&G, Service, CWS and University) planned and executed coordinated research efforts. Those attempts to coordinate research have been limited by funds, personnel and probably policy decisions within agencies.

*Data from CAH and Prudhoe Bay are largely lacking for predevelopment.* Because of this, experience by individual biologists, new data from PCH studies and the basic store of knowledge on caribou provide only limited predictive capabilities for the PCH. Further, lacking specific development plans, assessment of specific impacts is difficult. For example:

- Traditional, concentrated calving areas are important, but how much will some unspecified amount of disruption affect the PCH in the short and long terms?
- Displacement of PCH cows during calving may increase calf mortality, but what will be the effect on PCH populations now and in the future?

- Caribou populations, including the CAH and PCH, fluctuate widely, but why and how will various likely impacts of development play a role in those fluctuations?

- Caribou in the CAH have not yet shown declines in the face of development on their calving area, but how will a similar structural development on the calving ground affect the PCH--a much larger and more wide-ranging herd?

With these broad questions as a framework, none of the concerns expressed by ADF&G biologists is unreasonable.

*3. Is it valid to predict, from data collected on the CAH, impacts on the PCH?*

**Answer:** Yes, to some extent.

**Discussion:** Reactions and behavior of caribou in both herds to certain environmental factors, disturbances, structures, etc., caused by oil field development are expected to be similar. However, there definitely is a need for data obtained specifically from the PCH to document the predevelopment phase. Some of the CAH data may not be comparable at the individual or the population level due to a number of differences, including:

- the size of the area utilized by each herd and the availability of different kinds of habitats, including essential calving areas;

- the great difference in population size and, consequently, in the size of aggregations and the needs relative to forage and insect-relief areas;

- the relative extent of the coastal plain (i.e., the distance between the coast and the northern edge of the foothills);

- the extent of seasonal movements of the two herds, and potential differences in nutrition and condition related to range quality;

- the fewer predators on the coastal plains and, therefore, less impact on the CAH and the greater human utilization of the PCH; and

- perhaps other factors.

*4. Has the ADF&G's research been properly focused in the past, and where should it be focused in the future?*

## PROBLEMS ASSOCIATED WITH PAST RESEARCH

Criticisms of research design and outcomes *must be* tempered in light of available funding and the difficulty of conducting studies in an Arctic environment. Logistical difficulties, climatic extremes and the expenses of working in the North Slope are among the greatest in the world, and monies available for caribou research have been insufficient to address many critical questions. Several obvious problems exist.

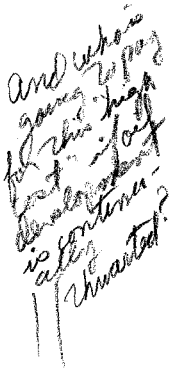
1. **Hypothesis testing.** Until recently, research designs have not addressed a critical test of ideas. Indeed, hypotheses seldom were stated and sometimes not even inferred. This has led to considerable speculation and resulted in controversies that more carefully designed studies could have avoided. There has been a strong tendency to measure *what* was happening rather than to investigate *why it* was happening. Recent studies have been more carefully designed.

2. **Multiple causation of ecological events.** Studies typically have concentrated on measuring a single variable at a time thought to affect caribou. Seldom have multiple causations been addressed adequately. No study has tried to gather integrated data on predation, forage quality and availability, condition, reproduction, and population dynamics. Studies on physical condition are just starting. Better integration of projects among agencies is needed. And a better method of reviewing project proposals is required, so that studies of the variables that affect caribou populations can be linked in a meaningful way.

3. **Failure to publish results.** Only recently have biologists begun to publish results of their research regularly in refereed journals. Too much important information is buried in progress reports. This has made much of this work unavailable to the scientific community and hampered discussions that could have improved research designs. More importantly, it has resulted in an "inbreeding" of ideas that were not regularly subjected to critical outside review.

4. **Premature publication.** Premature publication of initial results from long-term research can be misleading. The constant political pressure to produce early answers should be resisted. Completed studies produce more-useful results that can better withstand both scientific and political challenge. A strategy for publication, based on the improved design of research suggested below, should strengthen research outputs.

5. **Inadequate funding.** Adequate funding is critical to address problems associated with ANWR. Current levels are not sufficient. The high cost of this research is justified by the importance of ANWR to maintenance of the PCH and the potential profits from oil extraction. Simply providing additional monies will not solve the problems listed. There must be a fundamental change in the manner in which research is designed and conducted.



## RECOMMENDATIONS FOR IMPROVING RESEARCH AND FOR RESEARCH DIRECTIONS

1. **Research proposals.** Complete and detailed proposals should be required. Such proposals should emphasize hypothesis testing and indicate what critical tests of ideas will result from the research. Proposals should be subjected to outside reviews, and research not begun until ADF&G management is satisfied that important concerns of referees have been satisfied. Further, such proposals should be overseen by an interagency group to assure that projects are properly integrated and that multiple causes of ecological events are considered. Additional cooperation and coordination of funds and personnel among agencies and industry will be necessary to achieve this.

2. **Suggested research direction.**
   a. *Short term:*
      (1). Continued population monitoring of both the CAH and PCH, with increased emphasis on distribution and movements, calf survival to yearling age, population composition, and total numbers. The liability of not having good predevelopment data has been emphasized in problems of attempting to assess the potential effects of oil development on the CAH.

(2). Quantify on a regular basis (e.g., every three or four days) the calving area boundaries and numbers of cows in the concentrated calving areas each year for both the CAH and PCH. This information is essential for comparing forage quality and effects of predation within and outside this critical area, as well as for determining the relative importance of the different calving areas used each year.

(3). Expand studies of caribou reactions to roads, pipelines and other oil field infrastructure, especially as oil development broadens in the calving grounds of the CAH. Attempt to determine the degree of "habituation" of caribou to the oil development structures and associated activities. Test effects of roads, pipelines and infrastructure on large groups of caribou (cows and calves particularly) relative to passage obstruction, general activity patterns, foraging, physical condition and actual displacement.

(4). Design and implement studies that will integrate, evaluate and utilize knowledge obtained concerning range quality, nutrition, weather influences, movement patterns, predation and other mortality factors in determining their effects on carrying capacity and herd productivity.

b. *Long term:*

(1). Thoroughly investigate the theory of density dependence and its influences on the physical condition, reproduction and survival of caribou. This has year-round implications.

(2). More emphasis should be placed on understanding the year-round requirements of caribou. For decades, deer biologists focused on the limiting effects of winter range quality, but finally realized condition (nutrition) of animals coming off summer range was vital to winter survival and subsequent reproduction. The same may be true for caribou.

(3). Fully explore plant/herbivore relationships. The relationship of caribou nutrition and habitat and its role have received inadequate attention relative to population dynamics.

(4). Integrate models of caribou energetics with population models. Begin testing such models and making predictions about effects of oil development on changing caribou populations.

(5). Examine the value of and perhaps initiate comparative studies on the Teshekpuk Lake Herd (TLH). This herd is comparable in many ways to the CAH, but without the oil development factor. Such a study might provide good insight as to if and how such development adversely affects a caribou population.

(6). Expand predation research to include eagle and possibly wolf populations. Study of eagles as predators of PCH calves is inadequate presently, yet mortality studies of radio-tagged calves indicate that eagles may be more important predators than are bears or wolves.

Without the knowledge to be gained from the above research areas, it is not possible to ascertain whether oil development adversely affects caribou at the population level.

## CONCLUSIONS AND RECOMMENDATIONS

### Contentious Issues

The Team concluded that a number of the issues that appear to have been consistently debated during the 1980s are generally resolved. Debate should focus on important they are and how to cope with them, rather than whether a problem exists. Examples include:

1. Whether the words "core" or "concentrated" are used, some calving areas obviously are more important than others, particularly as documented by extensive movement studies for the

PCH. The question -- "Is there a concentrated area for calving?" -- should no longer be argued because evidence from many sources supports the fact that there are such areas. Rather, the question to be pursued now is--"What impact would prospective development have if it reduces or eliminates use of all or part of this area?"

2. It is illogical to suggest that existing petroleum development has had no effect on the CAH simply because the population is higher now than before development. *Caribou population dynamics work over many decades of time,* and their mechanisms are poorly known. Subtle changes probably have occurred, even if some animals have habituated and some continue to use developed areas. Work now should concentrate on investigating effects that may take long periods of time to manifest themselves, and *using the experience along the way to change significantly the implementation of oil development to benefit caribou.*

3. Insect-relief areas are important to caribou. Further, if insect harassment and other disturbances (such as from roads, pipelines and "facilities") reduce use of key forage areas and other essential habitats by caribou, there may be a nutritional impact not evident through direct mortality. The question now is how much development will affect caribou herd, in both the short- and long-term.

4. Some displacement of caribou *has* occurred from current oil development areas. Data have clearly shown that there are some impacts, by virtue of the presence of roads, vehicular traffic, pipelines, facilities and other human activities. Again, the work needed now is to investigate the magnitude and nature of specific impacts on the short- and long-term welfare of caribou.

5. Cumulative effects on caribou can be expected if additional major oil development occurs on the North Slope, especially that proposed for the 1002 area of ANWR. These developments must be continually evaluated not solely as individual issues, but holistically. Restricted access to a major portion (one-third or more) of the coast along the North Slope can not be evaluated

merely in terms of acres covered by roadbeds and facilities. Interspersed habitat corridors, for movement, and the incremental effects of additional oil fields must be the focus.

**Recommendations**

It is logical for agencies, universities, countries and oil companies involved in projects of the magnitude of the potential development of ANWR to work together in a coordinated research program to answer basic questions regarding potential effects on wildlife and their habitats. If the energy spent assailing the quality of work done in one piece of research or the other could be rechanneled into advance planning and scientific input to the design of research to solve appropriate questions, there would likely be less conflict and better, more-constructive results. Neither the oil industry, federal government nor the State of Alaska has invested in long-term sustained efforts to understand fully the dynamics of caribou herds as they exist in the absence of development. Without that kind of background, this complex species and the changes that may occur to it through development are likely to elude all of those seeking quick answers from problem-focused studies.

It seems obvious to the Team that: (1) there are core or concentrated areas for calving needing special attention; (2) caribou need insect relief that may require movement corridors as well as protected sites; (3) increased predation is an important and likely impact if animals are displaced; (4) there has been some local displacement and could be more depending on the kind of development that occurs; and (5) nutrition and habitat quality may play a bigger role than previously thought in affecting productivity of a caribou herd over time. All of the data needed to assess these issues are not available, but considerable information does exist for an array of caribou herds and from the reindeer industry. To a certain extent, some of that knowledge can be applied to the issues in question. If long-term herd productivity and potential impacts of development are the main issues, there will have to be an ability and commitment to monitor changes through the use of baseline information (predevelopment). The lack of adequate baseline information prior to the Prudhoe Bay

development now limits predictive capabilities. *That should not happen again for the PCH.* The cooperating agencies and universities should convene with the oil companies to plan the coordinated monitoring and research program necessary to answer the basic questions that such a group can certainly pose, including those that have been identified in this report.

If such a coordinated research effort does not emerge, potential results from piecemeal planning will provide inadequate information and another decade of nonconstructive sniping at work done in response to parts of the problem. Research is not at stake; caribou are.

**APPENDIX I: Review of Specific Papers.**

1. *Reproductive performance of caribou in relation to habitat availability and quality* (Cameron et al. 1991a).

S.D. Taylor (correspondence to L. Pank, T. McCabe and W. Reglin: May 1990) suggested reasonable alternative hypotheses for the differences in cow weight gain and calf survival between western and eastern parts of the CAH. In addition, it is noted that the sample sizes are small and the differences are not significantly different. It is premature to suggest that the differences are real and due to oil development. Even with larger samples and results replicated in additional years, it will not be possible to attribute differences in female weight and calf survival to development of the oil field. Effects of the oil field development are completely confounded with any inherent differences in vegetation, insect-relief habitat, predation, etc., that exist between the eastern and western parts. Oil field effects also are confounded by an increase in size of the herd and probably by other factors, such as weather.

Nevertheless, given data on numbers, distribution and condition of caribou, and on vegetation condition, one could establish reasonable deductive judgments pertaining to the effects of oil field development. Data on predevelopment circumstances would be especially valuable in making judgments. Impacts on the PCH of development in the 1002 area will be more difficult to establish because of the larger herd size, larger migration routes and higher predation rate. The need for continuous predevelopment data on population parameters and range condition for the PCH is obvious.

Specific comments:

- The methods section is too brief for full understanding of the field and statistical procedures used.

- Repeated (potentially correlated) measurements are collected on females, and it is unclear from the methods and results sections if proper statistical analyses have been conducted in all cases. For example, it is likely that some cows are included more than once in the t-tests reported in Table 2.
- Cow age would be a valuable covariate in the statistical analysis, because some data suggest that weight and reproduction is correlated with age for cows three or more years old.
- Results section should be limited to the descriptive and inferential statistics due to this study. Discussion and theoretical arguments should be in a separate section and clearly indicated to be based in part on the deductive judgment of the researchers.

2. *Does Arctic petroleum development affect calving caribou?* (Cameron 1991b).

The abstract contains conclusions that are not direct results of statistical inference based on data reported in this study. It should be clarified that conclusions concerning the effects of predation and forage condition are partly subjective and based on the literature.

The strong conclusion in the abstract -- "Following construction of an oilfield access road through a calving concentration area, caribou density declined by two-thirds within 2 km and doubled 4-6 km from the road" -- is not based on values readily obtained from the tables or figures. This statistic is assumed to be calculated from the ratio of means from the pre- and postconstruction periods. At least, the intervals in Figure 2 and Table 2 should contain the 0-2 km and 4-6 km strips, so that calculation of decrease in the 0-2 strip and increase in the 4-6 strip are obvious. Of equal importance is the standard error of this ratio of random variables based on the assumption that data from the pre- and postconstruction periods are independent.

The statistical methods for Table 2 are reasonable and justified, but clarification should be included. It is assumed that years were considered to be independent, giving rise to sample sizes of four and six for pre- and postconstruction periods, respectively. This would be clarified if Table 2

included the degrees of freedom for each t-test. Also, two-sided tests apparently were conducted.

An alternative analysis that is similar to the t-test, but perhaps more sensitive, would be a one-factor analysis of covariance (pretreatment years versus posttreatment years) with the overall caribou density from Figure 3 as a covariate. Recommendations in Milliken and Johnson (1984) could be followed for using Levene's test for unequal variances and the resultant testing of the pair of means.

A second alternative analysis would be to estimate habitat-selection functions as recommended in the review of Cameron and Smith (1991) (this report). If distance to road is not significant for each of the years of the preconstruction period, yet is significant for each of the years of the postconstruction period, then strong inferences could be made. Even if the significance levels for each of the postconstruction years are borderline and not all "significant," Fisher's principle for combining significance levels for independent one-sided tests of the same scientific hypothesis might be used to establish overall significance (Sokal and Rohlf 1981). Fisher's principle could be applied to any set of independent yearly tests of the hypothesis that use by caribou in the 0-2 km strip close to the road is less than use by caribou in a strip at, say, 4-6 km from the road.

*3. Effects of a road system on caribou distribution during calving (*Dau and Cameron 1986).

Design, conduct and analysis of the study reported in this paper have received considerable review by agency and industry biologists. The analytic approaches used in analyses of these data are appropriate, and the basic direction of stated trends are statistically correct. These points were acknowledged in a letter from A. W. Maki (Alaska Oil and Gas Association, 505 W. Northern Lights Boulevard, Suite 219, Anchorage, AK 99503) addressed to W. Regelin (Alaska Department of Fish and Game, 333 Raspberry Road, Anchorage, AK 99502) dated March 23, 1987. Maki made several correct and relevant points concerning deductive conclusions based on this study which warrant repeating here:

- "...the data show displacement from the road corridor, the exact distance and magnitude of this displacement are somewhat more subjective."
- "This is a displacement of maternal caribou and does not translate to a total loss of habitat, i.e. there are still some animals using this area."
- "To extrapolate this as a total loss of habitat out to 2 miles as was done in the 1002 report is inappropriate."

*4. Selection of calving sites by Porcupine Herd Caribou* (Fancy and Whitten in press).

In the abstract, the statement that "Cows selected areas north of the foothills primarily to reduce exposure of calves to predators..." is a deductive conclusion that is not totally based on statistical results presented in this paper. A valid statistical inference from this study is that *for calving, PCH cows selected areas significantly related to distance from the foothills.* But there are other factors that also influence selection, and the effects of the factors are confounded. It is desirable for all papers dealing with the 1002 area to use a common boundary for the "southern edge of the coastal plain." However, even if a new boundary is selected, the variable "distance to foothills" will continue to be significant in the logistic regression if a constant is added to each measured value--i.e., if a new boundary is used which is more or less "parallel" to the one used by Fancy and Whitten (in press). Young et al. (1991) made the statistical inference that predator density decreases with increasing distance to the foothills and this gives a *deductive* conclusion that calving sites are selected in areas that have relatively fewer predators. This deductive conclusion is the responsibility of the authors. The statistical result is that cows tended to select calving sites that are farther from the foothills than are randomly located points.

The paper by Whitten et al. (in press) is essentially on the same topic. Their conclusion that "Predation was the major cause of death, and mortality increased toward higher terrain away from the coastal plain..." is a valid statistical inference and essentially agrees with the results of Fancy and

Whitten (in press). This is an important statistical conclusion, and it is unfortunate that the two papers do not reference and more clearly reinforce each other.

The paper by Whitten et al. (1991) is essentially a combination of this paper (Fancy and Whitten in press) and Whitten et al. (in press) which brings the data set and analysis up to and including 1990. Inferences in Whitten et al. (1991) are consistent, based on the combined analyses and are much stronger.

Specific comments:

- For the analysis in the section on *calving distribution* exclusively, the authors excluded 54 sites that were widely scattered in the mountains (south of the foothills boundary in Figure 1) or west of the Katakturuk. Inferences in this analysis are thus limited to distribution in an east-to-west direction along the coastal plain. This is a reasonable adjustment in the data set, given that the hypothesis is that distribution east-to-west is "random" because the $\chi^2$ analysis is particularly sensitive to the definition of "available habitat."
- The most important analysis for this paper is in the section on *calving site selection*, where all 305 calving sites were used in the analysis (except for two which calved with the CAH).
- The result of the logistic regression analysis conducted is not a standard application of the logistic model and not all diagnostic details reported by common statistical software packages are applicable. The multivariate selection function reported--$w(x_1, x_2, x_3)$--is correctly estimated and only the numerator of the common logistic model (McDonald et al. 1991).
- The authors compared distances between calving sites for the same cow, with distances between random points, and found no significance difference in the distributions. It should be pointed out that this statistical result helps justify the deductive assumption that calving sites selected are uncorrelated and to treat the 305 sites (selected by 131 cows) as independent replications in the logistic regression. Technically, one cannot "prove" that the sites are independent (i.e., one

cannot prove the null hypothesis to be correct), and the analysis involves pseudoreplication. However, in light of the test comparing distribution of distances between calving sites with distances between random points, this is a minor problem and should not change the overall statistical inferences.

5. *Caribou responses to development infrastructures and mitigation measures implemented in the central Arctic region* (Smith and Cameron 1991).

The methods seem reasonable because any visibility bias in the aerial survey should affect units in the same manner. However, the statistical analysis appears to be mainly descriptive. Statistical inferences should take the potential spatial correlation of these data into consideration.

Suggestions for further analysis:

*Spatial statistics.* Model based analysis using procedures common in geostatistics and the mining industry may be of value.

*Testing for changes in distribution.* It may be possible to test the hypothesis that spatial distribution patterns of caribou were similar between years by using the nonparametric Multi-Response Permutation Procedures (MRPP) (Mielke and Berry 1982, Mielke 1984).

*Selection function analysis.* Consider data giving rise to Figures 3 and 4. For a given survey (or collection of surveys), define a unique 4 $mi^2$ unit to be "selected" if the number of caribou sighted there is more than expected, based on percentage of the area contribution to total coverage in the survey. Define a unit to be "not selected" otherwise. Given a census of units, estimate the probability of a unit being "selected" by an ordinary logistic regression of units selected and not selected on independent predictor variables, such as distance to infrastructure, percentage snow cover, distance to the coast, etc. The inferences are "model-based," i.e., based on the analysis of residuals about the model selected for the census of units.

The definition of "selected" units could be changed to include only those units on which the

number of caribou sighted was more than expected for all years of the survey.

One could vary the size of the unit. For units that are "too small," there may not be a significant relationship between probability of use and vegetation (or other variables). As the size of the unit is increased, some relationships may become significant; if the unit is "too large," the relationships may become insignificant again. This analysis may give some hint of the size of unit to which caribou can "relate" when selecting habitat or size of unit that should be used in study of habitat selection. But, it should be viewed as exploratory data analysis because varying the size of the unit will directly influence the "sample size" going into the model-based logistic regression.

*Habitat selection by radio-tagged cows.* For relocations of radio-tagged cows in the CAH, divide the habitat into two categories, (1) within 2 km of roads, pipelines, and other infrastructure, and (2) more than 2 km from any infrastructure.

For a given radio-tagged animal identify the home range during a given period of time, e.g., calving and post calving, then analyze the habitat available in each category relative to the habitat selected. Conduct the analysis for each radio-tagged cow and determine the relative selectivity index (McDonald et al. 1991) for habitat more than 2 km from any infrastructure. Conduct a sign-test or Fisher's permutation test on the difference between the selection index and 1.0 (i.e., no selection) where the sample size is the number of radio-tagged cows.

6. *Productivity and early calf survival in the Porcupine Caribou Herd* (Whitten et al. in press).

The paper by Fancy and Whitten (in press) is essentially on the same topic. Their conclusions essentially agree with the results of this paper (Whitten et al. in press). These are important statistical conclusions, and it is unfortunate that the two papers do not reference and more clearly reinforce each other.

Specific comments:

- Statistical tests in this paper are borderline in supporting the conclusions in the abstract and discussion. Only one test statistic is reported to be significant and only at the 0.069 level (mean elevation of sites used by surviving calves vs. mean elevation of sites where collared calves died).
- The paper by Whitten et al. (1991) is essentially a combination of this paper (Whitten et al. in press) and Fancy and Whitten (in press) which bring the data set and analysis up to and including 1990. Inferences in Whitten et al. (1991) are consistent with this paper, based on the combined analyzes of the two papers and are much stronger.
- The reviewers are concerned with the possible time delay between the last sighting of a cow with calf and the first sighting of the same cow without the calf. Potentially, cows without calves could move toward the foothills. Continued analysis is recommended on subsets of these data for: locations of mortalities where only one day separated the relocations of mortalities; locations where one or two days separated the relocations; and locations where one, two or three days separated the relocations, etc.
- Taylor (S.D. Taylor's May 7, 1990, letter to L. Pank, T. McCabe and W. Reglin) suggested an alternative hypothesis to that tested in this paper, i.e., mortality risk may in fact be higher on herd peripheries even if predators were uniformly distributed.
- This is an important alternative hypothesis, and should be addressed in analysis of these data.
- One could compare the mortality rates of calves born on the interior of the annual concentrated calving area with the mortality rates of calves born on the edge. If this alternative hypothesis is true then one should see greater predation on the edge of the concentrated calving area in those years when the PCH calved in the foothills. If mortality rates on the interior of the concentrated area when the PCH calved in the foothills still are higher than the mortality rates when they calved on the coastal plain, then the hypothesis in this paper would continue to be supported.

7. *Differential impacts of predators (brown bears, wolves, golden eagles) on caribou calving in the 1002 area and potential displacement areas: An assessment of predation risks* (Young et al. 1991).

Specific comments:

- Common boundaries for the coastal plain, foothills and mountains are desirable in this paper and in Fancy and Whitten (in press) and Whitten et al. (1991). However, the only statistical test of hypothesis concerning brown bears that is influenced by the boundaries is that brown bears used the coastal plain, foothill and mountain zones in proportion to availability. Results of this test are not expected to change with minor adjustments in the boundaries. Other tests used in this paper do not appear to depend on the boundaries.
- The harmonic mean of the radio-locations is probably a better measure of the "center" of a set of dependent points than is the geometric mean. However, use of the harmonic mean in the analysis would not be expected to change the statistical inferences based on these data.

**APPENDIX II: Insect Relief**

During the summer (approximately mid-June to mid-August primarily), caribou and reindeer in the circumpolar Arctic are subjected to severe insect harassment from certain blood-sucking and parasitic flies of the insect order Diptera. These include various species of mosquitoes (Culicidae), black flies (Simuliidae) and bot flies (Oestridae). This phenomenon is well-known to reindeer herders in the Arctic and subarctic regions of the northern hemisphere and to those who have studied wild *Rangifer* populations. Although these insects are seldom a problem during the parturition period of the PCH, the mosquitoes become active shortly thereafter and continue with increasing intensity through the latter half of June and into July when other flies also become active. Oestrid flies remain active well-into August. During this time, animals must have access to areas that can provide some relief from these attacks, e.g., wind-swept areas (the Arctic coast, barren ground, ridges, river sand/gravel bars, etc.) and remnant snowdrifts and aufeis (an extensive area of ice formed on many stream beds due to "overflows" throughout the winter). Shaposhnikov (1955) stated that the low air temperature immediately above the snow inhibits the attack of flies.

Many workers have commented on the severe attacks of these flies on caribou and reindeer and the adverse effects on movements, foraging, behavior, body growth and fat build-up (Hadwen and Palmer 1922, Turi 1931, Flerov 1952, Alaruikka 1959). In their studies of growth in reindeer calves, Krebs and Cowan (1962) recorded instances of the actual stoppage of growth during summer as a result of mosquito harassment. Some indication of this harassment can be gained from the following description by Banfield (1954:37) of flies on the tundra of northern Canada:

> The torment they inflict upon all warm-blooded creatures is difficult to describe. Lemmings, ground squirrels, nesting birds, and caribou are surrounded by clouds of these insects during calm days. These insects attack the caribou where the fur is thin....Summer specimens examined had the ears swollen with numerous small blood scabs and the eyes and lips ringed with hundreds of mosquitoes and black flies. In the fur were thousands of flies.

During some years, the blood-sucking flies are particularly numerous and apparently can cause a certain amount of mortality. During June through August when the caribou are molting, they become quite vulnerable to fly attack anywhere that the hair is thin--lips, muzzle, eyes, ears-- and places where the hair has been shed or rubbed off. These attacks can become quite serious. Kelsall (1957:39) cited an instance where Eskimos found numerous dead caribou during summer 1949 in coastal marshes of the Bathurst Inlet region; death was attributed to insect attack. Kelsall stated, however, that during this investigation, "...no deaths wholly or partially attributed to insects were noted, but caribou were seen so plagued by flies that the possibility of death resulting seemed real."

These observations pertain mostly to the flat, extensive tundra areas of Canada's arctic coast, but similar situations exist for those caribou of Arctic Alaska that continue to remain on the coastal plain from June through August. Many of the animals in the PCH, however, move southward into the foothills and mountains during the fly season, where they can find ready relief on windswept areas. Fly-relief terrain is not readily available on the coastal plain, except in certain areas along the coast and the "Jago Uplands," which are used commonly by PCH caribou during and after calving.

The fly season occurs when a major portion of the herd remains on or near the calving ground, at a time when lactating cows have especially high energy demands and need quality forage, and when then young calves are growing rapidly The insects can interfere with the cows' foraging and calves' nursing activities, and have the potential of adversely affecting the survival of both.

The impact of the fly season on the herd in any one year, however, depends on a number of factors--weather (temperature, wind), magnitude of the fly hatch, availability of fly-relief areas and distribution of the caribou. Some years are worse than others. Nevertheless, well-being of the animals requires insect relief *every year.* To protect themselves adequately from the flies, the caribou must have access to fly-relief areas and freedom of movement across any area they occupy at this

time. Presumably, the "traditional calving grounds" of the PCH along the Arctic slope of Alaska and Canada do provide these needs, as do the various "core areas" that have been identified.

Quantitative data documenting the impact of insects and the value of insect-relief areas on caribou survival are not now available. Recent research on the PCH by Service personnel of the Alaska Fish and Wildlife Research Center and the ANWR has provided good information, however, on the areas and vegetation types used by these caribou during midsummer (Walsch and Fancy 1991). Continued research will fill in more of the knowledge gaps that remain regarding this important facet of caribou ecology.

## APPENDIX III: Overview--Ungulate Population Regulation

Ungulates are large-bodied, long-lived mammals that delay reproduction, have comparatively few offspring per litter, and provide maternal care for young; such animals are referred to as "K-selected." Density-dependent mechanisms would be expected to play an important role in the population regulation of these species as K (carrying capacity) is approached (Fowler 1987). Indeed, the population characteristics of large mammals are substantially different than that of their smaller-bodied counterparts (Caughley and Krebs 1983, Miller and Zammuto 1983). Not all ungulates will exhibit the same response in life-history characteristics to changes in population size (Fowler 1987), but density limitations for such large mammals are the rule (Smith and Fowler 1981). As McCullough (1979) noted, if weather and predation do not regulate ungulate populations, then density-dependent mechanisms will. Social regulation of such populations is unlikely because this often requires group selection (Bowyer et al. 1986); where behavioral limitations can be demonstrated, they tend to be inconsequential (Berger 1986). Caribou (*Rangifer tarandus) h*ave many unique adaptations to northern latitudes (Kelsall 1968, Skoog 1968), including migration, that may help prolong the time to onset of density-related effects. However, recent evidence from the George River Herd (Messier et al. 1988) indicates that such limitations ultimately are inescapable.

In theory, as an ungulate population approaches carrying capacity (K), intraspecific competition for limited resources intensifies, and productivity of the population declines. Numerous studies point to quantity and quality of food as the principal factors regulating population growth (e.g., Leopold et al. 1951, Robinette et al. 1977, Clutton-Brock et al. 1982, Skogland 1983, McCullough 1984, Godkin 1986, Leader-Williams 1988). This relationship is not dependent solely on population size, density of animals, or forage quality and quantity; the number of animals in relation to the carrying capacity of the environment is the critical factor.

Populations at carrying capacity are limited by a number of variables related to the physical condition of females. Ovulation and embryo rates are inversely correlated with population size (McCullough 1979, Teer et al. 1965). Females in extremely poor physical condition may abort fetuses (Tyler 1987, Robinette et al. 1977), although this is not thought to occur commonly. Nonetheless, poor physical condition in the last third of gestation may affect the growth rate of the fetus adversely (Adamczewski et al. 1987, Thomas 1982, Thorne et al. 1978). Some females may delay age at first reproduction. Malnourished females that succeed in bringing a pregnancy to term may give birth to still-borne or underweight neonates that suffer high rates of mortality (Julander et al. 1961, Robinette et al. 1977, Skogland 1984, Clutton-Brock et al. 1987, Rogomo et al. 1983).

Females on a low plane of nutrition may fail to give adequate maternal care to young (Langenau and Lerg 1976), and such neonates may be more susceptible to predators (Smith 1987). Populations at K also may harbor more parasites (Eve and Kellogg 1977). Limited forage availability may lower rates of fetal growth and lengthen the gestation period or cause females to ovulate and conceive later (McCullough 1979, Kiltie 1982, Ozoga and Verme 1982), causing mean date of birth to be later for populations near K. Likewise, females may delay age at first reproduction when stressed nutritionally (McCullough 1979, Reimers 1983b). Because competition for resources at K is intense, deterioration of range condition should be expected, especially where overshoots of carrying capacity occur (Leopold 1943, Klein 1968, McCullough 1979, Leader-Williams et al. 1987).

When populations are backed away from K, an antithetic set of circumstances holds. Intraspecific competition is lax because food is abundant and of high quality. Females are in good condition, and conception rates and survivorship of young are high. Overgrazing or trampling of preferred forages is rare--range condition is excellent. Thus, the underlying mechanism of population regulation that will be modified by climactic factors and predation is density dependence.

Depending on local conditions, either summer range (Skogland 1985), Messier et al. 1988, Couturier et al. 1990) or winter range (Reimers 1982, 1983a, 1983b, 1983c, Adamczewski et al. 1987) may be limiting for *Rangifer.* Obviously, resources necessary for survival must be present in both seasons (Mautz 1978), but caribou in mainland Arctic North America are well-adapted to precalving winter conditions (Russell and Martell 1984), and may to be limited primarily by summer range under some conditions (Huot 1989).

Much debate has been focused on the regulation of caribou populations via predation. The recent increase of the George River Herd, while wolf (*Canis lupus)* populations also increased (Couturier et al. 1990), make it unlikely that predation is the sole factor (*see* Bergerud 1983) regulating caribou. When caribou populations are low, however, predation might slow rates of recovery, or it may interact with other density-dependent factors to affect caribou populations.

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