# MITIGATION OF THE EFFECTS OF OIL FIELD DEVELOPMENT AND TRANSPORTATION CORRIDORS ON CARIBOU

Final Report to the
**Alaska Caribou Steering Committee**


**Compiled and edited by:**
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**July, 1994**

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This report concludes an agreement between the Alaska Oil and Gas Association (AOGA), U.S. Fish and Wildlife Service (FWS), Alaska Department of Fish and Game (ADF&G), and the North Slope Borough (NSB) to serve as a steering committee to oversee a study on the effectiveness of various forms of mitigation designed to lessen the effects of oil and gas development activities on caribou movements and habitat use in the North Slope oil fields. This project was funded by AOGA and performed by LGL Alaska Research Associates, Inc. The work was reviewed and guided by the steering committee comprised of representatives from AOGA, FWS, ADF&G, and the NSB.

The intent of this study is to assess the effectiveness of past caribou mitigation measures and to provide a framework for mitigation, research, and recommendations for future North Slope oil developments.

Steering Committee members as indicated below agree with the findings and conclusions of this report.

Judith Brady
Executive Director
Alaska Oil and Gas Association

Walter Stieglitz
Regional Director
U.S. Fish and Wildlife Service

Carl L. Rosier
Commissioner
Alaska Dept. of Fish and Game

Warren Matumeak
Director
Dept. of Wildlife Management
North Slope Borough

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## EXECUTIVE SUMMARY

Mitigation of the effects of oil field development on caribou has been the subject of extensive research and debate. In this report, we evaluate published and unpublished research in this field. We reviewed the historical and current status of the four Alaskan North Slope arctic caribou herds. The summer range of one of these herds (Central Arctic Herd) includes the Prudhoe Bay, Milne Point, Endicott, and Kuparuk oil fields. Oil field development has resulted in effects on individuals and groups of caribou such as displacement of cows and calves from roads and the need to cross roads and pipelines. The Central Arctic Herd has grown considerably during the period of oil field development. Lack of pre-development data and information about factors known to affect population dynamics of other Arctic herds (e.g., predation, range condition) prevent us from drawing firm conclusions about the effects of oil field development on the Central Arctic Herd.

Actual and potential effects of oil field development on caribou are described. The most important potential effects are impedance of movement through oil fields and displacement from calving areas. We considered these to be the highest priority for mitigation. Successful negotiation of barriers by perinatal and maternal cows is potentially more important to the population than crossings by other sex-age groups. Mitigation measures which have been used to allow passage of caribou through oil fields and across the Trans-Alaska Pipeline system have included gravel ramps, sagbends, buried pipes, and elevated pipes.

Studies of spatial distribution, disturbance, and crossing have been used to evaluate the response of caribou to man-made barriers. Single pipelines elevated >5 ft (1.5 m) adjacent to roads with low levels of vehicular traffic are not barriers to caribou movements under most conditions. Caribou readily cross under such elevated pipelines; and, in one study, effective crossing occurred under multiple (1–10) adjacent elevated pipelines. Elevated pipelines and adjacent roads with moderate to heavy levels of vehicle traffic impede caribou movements. Long sections of buried pipe allow free passage of caribou. Gravel ramps over pipelines (effectively short sections of buried pipe) are not necessary as caribou readily cross under pipes elevated >5 ft (1.5 m). In some cases, ramps appear to be used preferentially; but in other cases they are used very little. Problems with ramps or long sections of buried pipe may include increased cost, loss of wetlands under gravel fill, and difficulty of monitoring and maintaining pipes. Large groups (>100

individuals) of caribou may have lower crossing success rates than small groups (<100).

Roads without adjacent pipelines that experience heavy levels (>60 vehicles/hr) of vehicular traffic appear to impede caribou movement. Pipeline–road combinations have a synergistic effect on impeding caribou movements. Separation of roads from pipelines by at least 500 ft (152.4 m) appears to be an effective mitigation measure for improving caribou crossing success.

Crossing success of caribou immediately prior to and during calving has not been determined; however, cows with new calves avoid roads with relatively low levels (<100 vehicles per day) of traffic for about two weeks after parturition. During this period, cows and calves tend not to occur within 0.6 miles (1 km) of these roads and, although not statistically significant, lower densities than expected were observed out to 1.2 miles (2 km).

Caribou habituate to oil field structures. They also habituate to human and vehicular traffic, but more slowly. Habituation to human activity in areas of oil field development can be enhanced with traffic localized in space and time, constant vehicle speeds, minimal foot traffic and strict regulation or prohibition of vehicle–based hunting.

The following mitigation measures have been implemented in recent oil field development at the Kuparuk, Milne Point, and Endicott oil fields and are recommended for future developments: elevate all pipelines ≥5 ft (1.5 m), or bury pipelines where feasible from an economic and engineering standpoint; minimize the number of roads in caribou calving areas; separate roads from pipelines by at least 500 ft (152.4 m); temporally and spatially regulate vehicle, aircraft, and pedestrian traffic; and prohibit public access and hunting. These newer oil fields have technologies which have resulted in smaller areas of impact and consolidation of infrastructure compared to the original developments at Prudhoe Bay. Future oil fields may be more consolidated and impact proportionally smaller areas.

Future research efforts need to stress testing of hypotheses. Additional evaluation of the following areas is necessary: determine crossing success and behavior of perinatal and calving caribou; determine effects of multiple elevated pipelines on caribou crossing success; and determine the relative costs and benefits of buried pipes, elevated pipes, and ramps for different oil field development scenarios.

## ACKNOWLEDGMENTS

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Among our colleagues at LGL Alaska Research Associates, Inc., M. Miller and M. Kircher prepared many of the figures and G. Walsh provided analyses of spatial features within the oil fields. P. Lent conducted much of the research for the project. M. Miller assisted in many ways. A. Bishop patiently and competently typed, prepared figures, and produced many draft editions of this document. M. Kircher and E. Brooks provided technical assistance.

We thank J. Monarch, Chevron Corp., for coordinating review of this report. We thank the Steering Committee members, J. Monarch, M. Joyce, P. Sousa, C. George, R. Shideler and M. Philo, for constructive review. W. Hopkins, AOGA, provided patient support and encouragement for which we are grateful.

# MITIGATION OF THE EFFECTS OF OIL FIELD DEVELOPMENT AND TRANSPORTATION CORRIDORS ON CARIBOU

## Introduction and Objectives

Oil exploration and development in the Alaskan Arctic has been underway for three decades and may occur elsewhere in this region. Development has primarily occurred within the range of the Central Arctic Caribou (*Rangifer tarandus*) herd. Future development could occur in the range of the Western Arctic, Teshekpuk, or Porcupine caribou herds. Concern has been expressed about effects of oil field development individually and cumulatively on the four herds (Cameron 1983). In 1991, the Alaska Oil and Gas Association (AOGA), the Alaska Department of Fish and Game (ADF&G), the U. S. Fish and Wildlife Service (USFWS), and the North Slope Borough (NSB) agreed to sponsor and oversee this study to evaluate and synthesize all information on the effectiveness of various forms of mitigation designed to lessen the effects of oil and gas development on caribou. The effort is intended to provide a common base of understanding with which to plan and provide for mitigation in the future.

The primary goal of this study was to evaluate the effectiveness of measures designed to mitigate effects of oil and gas development on caribou movements and habitat use in oil fields. We paid particular attention to utility and effectiveness of pipeline, ramp, and road designs intended to facilitate movement of caribou. Other mitigation measures were also considered.

This report has six principal objectives:

1. Assess the population level impacts and individual level impacts of oil field development on caribou.

2. Identify the types of mitigation measures most likely to be important for caribou in Arctic Alaska.

3. Identify mitigation measures for which effectiveness has been demonstrated.

4. Identify mitigation measures for which effectiveness has not been conclusively demonstrated, including those that have not been adequately evaluated.

5. Recommend other potential mitigation measures that warrant consideration.

6. Make recommendations for future studies relating to mitigation.

To accomplish these objectives, we focused on studies undertaken since 1972 that dealt with responses of caribou to developments and activities in the Prudhoe Bay, Endicott, Milne Point, and Kuparuk oil fields. The Prudhoe Bay oil field lies on the northern edge of Alaska's Arctic Coastal Plain and extends from the Sagavanirktok River west to just beyond the Kuparuk River. The Kuparuk oil field abuts the western border of the Prudhoe Bay oil field and extends approximately 19.3 miles (31 km) to the west. The Milne Point oil field is located north of the Kuparuk oil field and is adjacent to the western border of the Prudhoe Bay oil field. All three oil fields are bounded on the north by the Beaufort Sea. The offshore Endicott oil field is located 9.9 miles (16 km) northeast of Prudhoe Bay in front of the Sagavanirktok River delta. We have also made use of studies relating to caribou and the Trans–Alaska Pipeline System and haul road (Dalton Highway).

## Methods

We reviewed and synthesized published and unpublished reports and available unpublished data sets concerning effects of oil field development on Alaskan North Slope caribou herds. A review and discussion of the individual studies and our analyses which constitute the basis for this report are contained in Appendix A and are cited by page number for each section which addresses a particular topic. We have placed this background material in Appendix A so that interested individuals can easily grasp the conclusions and recommendations of this study without having to review individual studies.

## Population Level Effects

We reviewed available data on herd growth rates, calf:cow ratios, and summer densities for the four North Slope Caribou herds (i.e., Central Arctic Herd [CAH], Porcupine Caribou Herd [PCH], Teshekpuk Lake Herd [TCH], and Western Arctic Herd [WAH]) and compared the CAH to the other herds not exposed to oil field development (Fig. 1). We compared herd growth rates, reproductive parameters, predator densities, and annual human harvests for the four North Slope caribou herds (Table 1, Fig. 2). All estimates were obtained from published and unpublished reports. We used the aforementioned parameters to compare the CAH with the other three herds not exposed to oil field development to determine if the CAH had lower values which could be attributed to oil field development. We determined that the PCH grew significantly slower and had lower calf:cow ratios than the other herds. The CAH grew at a rate similar to the WAH, but slower than the TCH. There were no significant differences in calf:cow ratios between the WAH and the CAH, and both were higher than the PCH. Predator densities and human harvests were generally similar among herds.

The CAH has grown considerably during the period of oil field development, but lack of pre-development data makes assessment of effects of oil field development difficult. Also, our understanding of the population dynamics of the North Slope caribou herds is incomplete, and no firm conclusions about the effects of oil field development can be drawn. However, based upon our comparisons with the other herds, there have been no apparent effects of oil field development on the growth of the CAH. This does not suggest that there may not be effects in the future, nor that other herds under different ecological conditions may not be affected. Until we have a more complete understanding of the factors which limit and regulate caribou populations under natural conditions, it will be extremely difficult to test hypotheses of impacts of oil field development on caribou at the herd level.

### The Effectiveness of Existing and Potential Mitigation Measures

Our review (Appendix A) suggests that the potential effects of oil field development on caribou are impedance of movement, disturbance, and possibly increased predation. Increased predation is not, and has not been, a problem with the CAH, but could be important in future developments if caribou were displaced into areas of higher predator densities because of barriers and disturbance. Free movement of caribou through oil fields and reduction of disturbance levels could alleviate these concerns. Consequently, emphasis was placed on evaluating oil fields as barriers to movement of caribou and, where possible, mitigating those effects. A number of design changes since the original Prudhoe Bay development have allowed caribou to cross through oil fields in many situations. These design

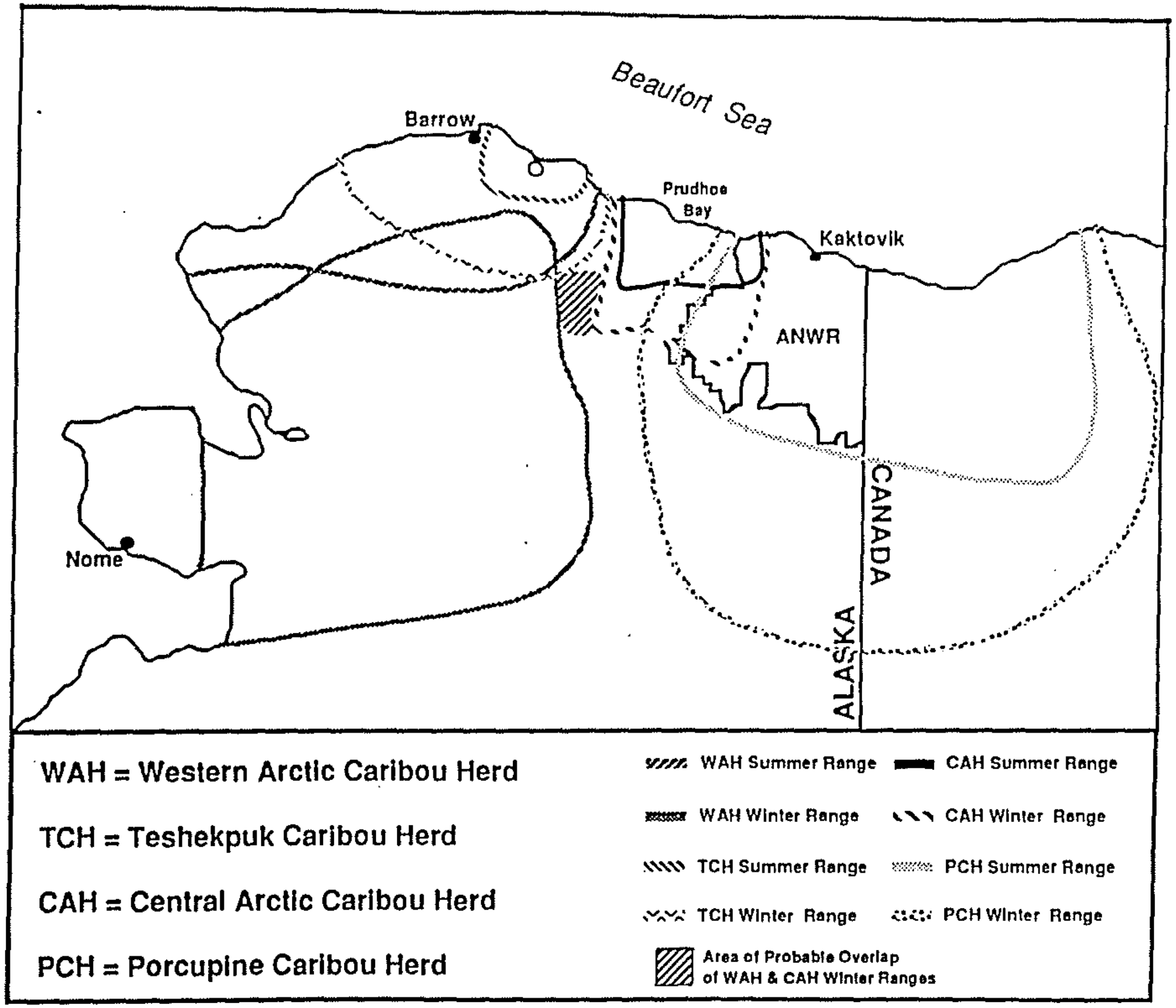


Fig. 1. Summer and winter ranges of four Alaskan arctic caribou herds (Sources: J. Dau, Alaska Dept. Fish and Game, Kotzebue, pers. comm.; G. Carroll, Alaska Dept. Fish and Game, Barrown, pers. comm.; M. Philo, North Slope Borough, Barrow, pers. comm.; D. Shideler and K. Whitten, Alaska Dept. Fish and Game, Fairbanks, pers. comm.; Lawhead 1988; Fancy et al. 1990; and Garner and Reynolds 1986).

Table 1. Summary of population estimates, calf:cow ratios, predator densities, and annual harvests during the late 1970's through the early 1990's for the four major caribou herds (Western Arctic Herd—WAH, Teshekpuk Caribou Herd—TCH, Central Arctic Herd—CAH, and Porcupine Caribou Herd—PCH) occurring on the North Slope of Alaska (from Ballard et al. 1990).

| PARAMETER | WAH | TCH | CAH | PCH |
|---|---|---|---|---|
| Range of Population Estimates X 1,000 (Years) | 75-415.7[1] (1976-1991) | 4-16.5[5] (1982-1989) | 6–23.4[8] (1978-1992) | 105.7–163.5[12] (1979-1989) |
| Exponential Growth Rate—r[a] (SE) | 0.112 (0.0065) | 0.178 (0.1051) | 0.086 (0.0193) | 0.033 (0.0053) |
| Average Calves/100 Cows (Range) | 71[1] (49-82) | 75[5] (0) | 75[9] (48-89) | 73[13] (43-73) |
| Range of Annual Harvest (Years) | 5900-17600[2] (1985-1989) | 808-1084[6] (1989) | 240-862[9] (1984-1989) | 1584-4764[13] (1984-1989) |
| Coastal Plain or foothills spring Wolf Densities (#/1,000km²) | 2.9-4.3[3] | 0.25–0.60[7] | 0.74-0.96[10] | 1.4-1.5[13] |
| Grizzly Bear Density (#/1,000km²) | 6.8-9.2[4] | 1.1–3.6[4] | 1.3-6.4[11] | 1.3-15.9[14] |

[a] Source: Log function of population estimates fitted by least squares regression following Netter et al. (1989).
[1] Source: Davis and Valkenburg 1978, Machida 1992, and J. Dau, Alaska Dept. Fish & Game, pers. comm.
[2] Source: Machida 1992 (Reported Annual Harvests X 4 re: Anderson and James 1986).
[3] Source: Davis et al. 1980, Ballard et al. 1990.
[4] Source: Reynolds 1976, Ballard et al. 1991.
[5] Source: Reynolds 1982.
[6] Source: Carroll 1992 ("Rough Estimate").
[7] Source: Carroll 1991.
[8] Source: Cameron and Whitten 1980; Cameron et al. 1981, 1988, 1989, 1990; Whitten and Cameron 1983; Whitten 1992; R. Cameron, Alaska Dept. Fish & Game, pers. comm.
[9] Source: Valkenburg 1992 (minimum estimates).
[10] Source: Stephenson 1991.
[11] Source: Reynolds 1976, 1979; R. Shideler, pers. comm., the 6.4/1000 km² figure may reflect high density resulting from anthropogenic food sources.
[12] Source: Whitten 1992.
[13] Source: Garner and Reynolds 1986.
[14] Source: Garner et al. 1984; Reynolds 1976, 1979.

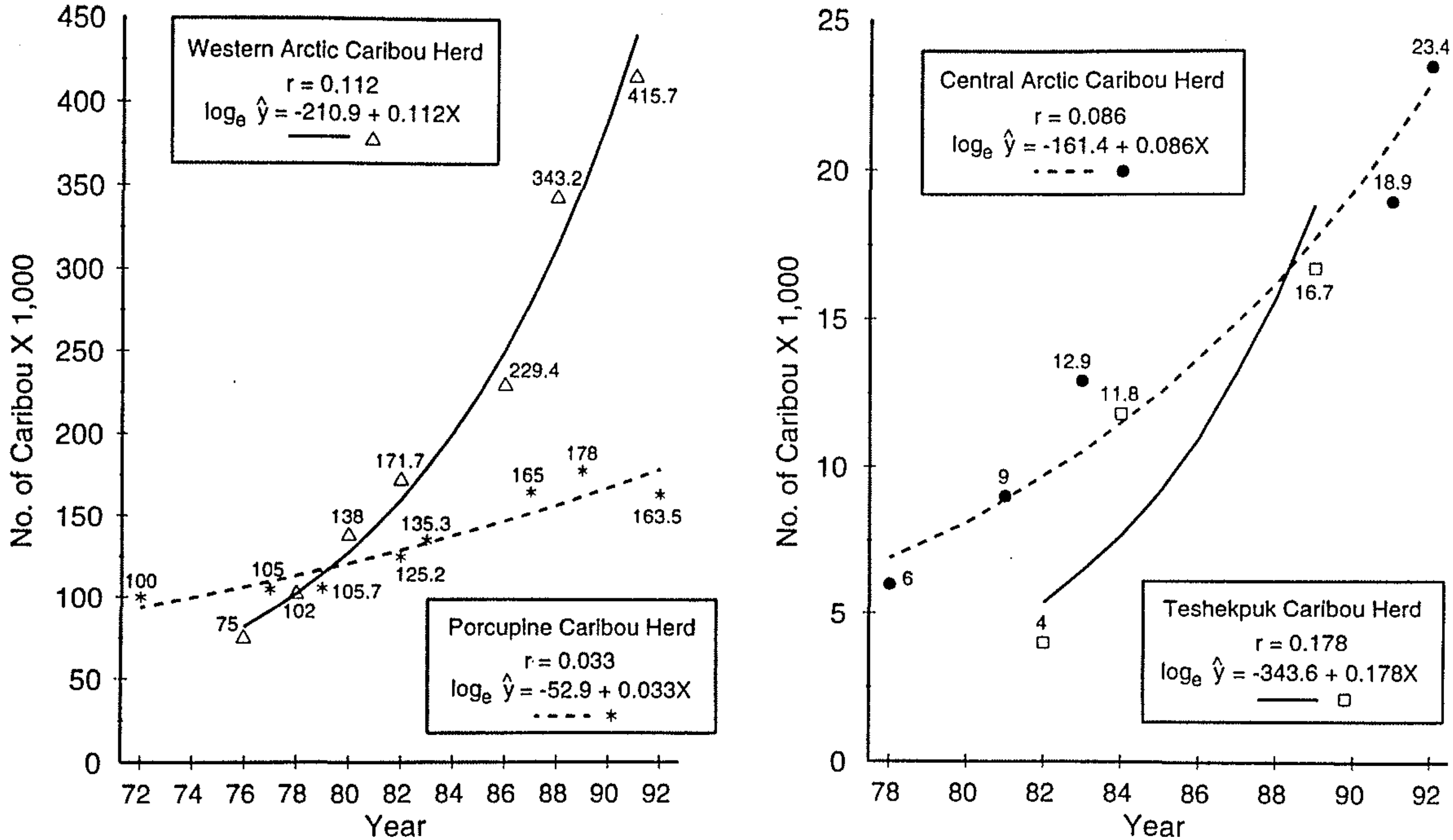


Fig. 2. Comparison of population counts and calculated exponential rates of growth on four arctic caribou herds in Alaska, 1972-1991 (from Ballard et al. 1990).

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changes, which have been incorporated in the Kuparuk, Endicott, and Milne Point oil fields, include elevated and buried pipelines, separation of roads from pipelines, construction of ramps, and regulation of vehicle and foot traffic.

Although new development within existing oil fields may increase cumulative effects, new technologies can reduce the infrastructure surface area. The use of directional drilling to maximize the number of wells at drill sites, the centralization of power plants and utility systems, and the joint use of roads, pipeline corridors, and airports all contribute to less area impacted by oil field infrastructure (Senner 1989). Smaller, less obtrusive infrastructure, along with the measures described in this report, should mitigate impacts on caribou and other wildlife in future oil fields.

Just as it is difficult to quantify the negative effects of development on caribou, it is difficult to quantify the positive effects of these phenomena as well. It is worth noting that oil field development has, to some degree, provided mitigation of natural environmental challenges faced by caribou. For example, a "dust shadow" effect has been observed whereby dust alongside roads leads to earlier snowmelt and green–up of vegetation. Lawhead and Cameron (1988) note that caribou may feed in these areas in late May before calving. This could allow foraging in calving areas earlier than would otherwise occur. Conversely, increased deposition of dust may prove harmful to vegetation. Another phenomenon frequently observed in the oil fields is congregation of caribou on gravel structures such as drilling and facility pads, and roads, and in shade created by pipelines or buildings. It has been suggested these areas are used for relief from insects, particularly from oestrid flies (Johnson and Lawhead 1989, Lawhead 1990). However, use of gravel pads as insect relief habitat may cause caribou to stop using preferred foraging areas, or it may allow caribou to remain in areas of higher quality forage, i.e., areas further inland. It has been suggested that coastal insect–relief areas have lower quality forage (Roby 1978).

## Measures to Enhance Free Passage of Caribou

Use of elevated pipelines having a minimum above ground clearance of 5 ft (1.5 m) from bottom of pipe has been highly effective for facilitating the movements of caribou in the newer oil fields (Appendix A, page A–17). Although caribou appear to prefer pipelines elevated > 5 ft (1.5 m), pipelines elevated at 5 ft (1.5 m) appeared to allow free passage of caribou. Frequency of successful crossings of caribou under such elevated pipelines, where they occur alone or adjacent to roads having rates of traffic of less than approximately five vehicles per hour, was not significantly different from crossings of control areas. The efficiency of elevated pipelines was specifically demonstrated under two biologically important circumstances: when groups of caribou were moving northward toward insect relief habitat under harassment by mosquitoes and when groups of caribou were moving southward without insect harassment. Crossing success of caribou under multiple (>10) parallel elevated pipelines is unresolved because of insufficient data and confounding effects of nearby roads.

Elevation of the large diameter Trans–Alaska Pipeline ≥6.9 ft (2.1 m) above ground also has been an effective mitigation measure (Appendix A, page A–39) in taiga areas. Together with extensive buried sections, these elevated sections apparently have provided for free passage of Nelchina Herd caribou on spring and fall migrations.

Use of elevated pipelines under the conditions described above should continue to be a principal component of any future mitigation program. However, corridors comprised of such elevated pipelines with adjacent roads (usually within 82–164 ft [25–50 m]) having moderate to heavy levels of traffic (approximately 15 vehicles per hr or more) did impede the movements of caribou. Under some conditions the proportions of crossing attempts that were successful across such corridors was 50% less than on control areas. Roads without adjacent pipelines, with moderate levels of traffic (approximately 15 vehicles per hr), are not significant barriers (Appendix A, page A–43).

Studies of effects of group size on crossing success are equivocal. In some studies, large groups of caribou (>100) have less crossing success than smaller groups (<100), particularly in corridors with elevated pipelines and roads having heavy levels of traffic (Appendix A, page A–37). There appears to be a synergistic effect of roads and adjacent pipelines. In other studies, groups of 100–1000 had better crossing success than groups of 10–100. These studies were done in areas where limited numbers of gravel ramps existed within lengths of elevated pipelines. It is unknown whether the presence of these ramps altered the findings of these studies.

The fact that caribou readily cross under elevated pipelines indicates that ramps are not necessary for crossings (Appendix A, page A–27). Results of studies of ramp preference are equivocal. In some studies, groups of <100 caribou in the Prudhoe Bay oil fields used ramps more often than crossing under elevated pipelines from late June through August. In other studies during this time period, ramps were used very little. Preferences and effectiveness of ramps for groups >100 animals are not understood. Occasionally, large groups used ramps effectively for crossing of pipeline corridors. On other occasions, groups have passed by ramps or split, with some members going under elevated pipe and others using adjacent ramps. Furthermore, when ramps are used, it is not clear whether they are used opportunistically, or whether they are sought after as a means of passage.

There is no conclusive evidence that ramps facilitate direct movements of caribou across pipeline corridors or reduce time spent by caribou adjacent to corridors relative to elevated pipelines (Appendix A, page A–32). The effectiveness of ramps versus elevated pipelines in locations with adjacent roads with heavy traffic cannot be assessed at this time.

No systematic tests of effectiveness of different ramp designs have been undertaken (Appendix A, page A–35). Based on qualitative reports, it is possible that increased extension of the ramp lip away from the pipeline and use of thin, gradually sloping lips on all sides of a ramp may increase effectiveness. Length also appears to be important because shorter length ramps are likely to be missed or passed over.

Preferential use of ramps was demonstrated along the Endicott Access Road (Appendix A, page A–32). However, ramps constitute only 0.66% of the linear distance of the entire Endicott Road corridor. With this amount of coverage, it is not likely that ramps play a significant role in facilitating direct, undelayed road and pipeline crossings. Rather, the impression is that they play an important role on rare occasions in large scale post–calving movements.

No systematic study of long sections of buried pipelines has been undertaken (Appendix A, page A–32). However, observations of Nelchina Herd caribou migrating across the Trans–Alaska Pipeline System indicate that long buried sections of pipe are highly effective as crossing areas for caribou (Appendix A, page A–35). Roads with low levels of traffic and no adjacent parallel pipeline are not significant barriers to movement of caribou. It follows that burial of pipelines within an extended width road bed should be an effective mitigation measure to provide for caribou crossings. Such pipeline configurations have been used in the Milne Point area, although effectiveness has not been studied.

There are some important considerations regarding long sections of buried pipe and ramps. The cost of a ramp is generally $250,000 or more, depending on ramp width, topography, soils, and distance from the gravel mine site to the ramp site. Second, buried pipe is more difficult to monitor and maintain. Third, ramps or buried pipe will involve increased loss of wetlands because of gravel fill. The relative merit of the resources enhanced and lost must be determined. Fourth, buried pipes are sometimes not feasible from an engineering standpoint because of the thermal stability of the fill and underlying substrate. Communication between regulators, biologists, and engineers is crucial in determining the appropriateness of using buried pipelines.

The disturbance of caribou from vehicular traffic on roads, combined with the physical presence of an elevated pipeline adjacent to the road, synergistically create an effective barrier to caribou crossing (Appendix A, page A–39). That is, the success rate for both groups and individuals attempting to cross at such sites is lower than at control sites. Where the distance of separation between pipeline and road is >500 ft (152.4 m), this barrier effect is not significant.

We conclude that the most effective mitigation is achieved with elevated pipes, ramps, long sections of buried pipe, separation of roads and elevated pipelines by at least 500 ft (152.4 m), or by a combination of these means (Appendix A, page A–45). The relative efficiency and importance of these potential means of mitigation cannot be fully judged, but all will enhance crossing success. We also conclude that under most conditions neither elevated pipelines nor roads alone posed significant barriers to the movements of groups of caribou. Pipelines elevated at least 5 ft (1.5 m) were effective except when elevated pipelines were in proximity to roads with moderate to heavy levels of traffic (15 or more vehicles/hour). Because of lack of studies, the above conclusions are not certain where multiple numbers (>10) of elevated pipelines occur in a corridor.

Disturbance and Displacement

Caribou in oil fields encounter various types of disturbances and those caused by moving vehicles are the most frequent (Appendix A, page A–45). Under a variety of traffic levels, 95% or more of overt disturbance responses occur within 500 ft (152.4 m) of roads. Considerable reduction of the amount of time caribou spend lying down has been detected out to a distance of 1969 ft (600 m) from a road with moderate to heavy traffic during periods in summer when insects were not appreciably active. In other cases, effects on activity budgets of caribou have been demonstrated out to 984 to 1640 ft (300 to 500 m), depending upon the study conditions and methodology.

In a study in the Milne Point oil field, caribou (particularly calves) occurred at reduced densities within 0.6 to 1.2 miles (1 to 2 km) of roads with moderate to low levels of traffic for about three weeks after the peak calving period (Appendix A, page A–51). The percentage of calves or of all caribou within the 0 to 0.6 mile (0–1 km) interval was lower in the years after (1982–1987) the road was built than before (1978–1981). Cameron et al. (1992) concluded there was a significant decline in mean density of both caribou calves (P=0.05) and total caribou (P=0.04) in the 0 to 0.6 mile (0–1 km) zone in the post–construction period. Not only did the mean relative abundance of caribou decrease by two–thirds in the first 1.2 miles (2 km) away from the road, but it nearly tripled in the zones 2.5 to 3.7 miles (4 to 6 km) from the road. Although densities are reduced within the first 1.2 miles (2 km), this zone is still used by other sex and age classes of caribou. It was not clear whether this effect results from learned responses by female caribou to the long term presence of human activity associated with a road, or whether displacement was a response to stimuli occurring at the time the distributions were observed. Based on literature concerning sensitivity of maternal cows during the calving season, reduction of traffic and other activity associated with the road might significantly reduce this effect.

Caribou cows are most sensitive to human disturbance just prior to calving and when they are with neonatal calves (Appendix A, page A–56). There was no evidence regarding the effectiveness of crossing structures in providing for the movements of nursery bands (groups of cows with calves) during the calving and immediate post calving periods.

## Extrapolation of Results to other Caribou Populations

In this section, we discuss application of existing mitigation measures to other caribou populations, such as the PCH. Results of studies conducted on the CAH were already applied to the PCH in the Final Environmental Impact Statement concerning the ANWR 1002 Area (Clough et al. 1987).

Mitigation measures will differ depending upon the status of the herd in question and other ecological factors. For example, if predators are extremely abundant in areas adjacent to calving grounds, then any partial barrier effect which might alter distribution of calving groups would displace these groups into areas with higher predator densities and would presumably cause increased predation (Appendix A, page A–5).

Our emphasis here is on how aspects of population size, movement patterns, and social behavior might influence the effectiveness of mitigation measures (Appendix A, page A–58). We do not anticipate significant differences among populations in the sensory perceptions of individual animals, although, we anticipate that differences in degrees of habituation and sensitization might exist. These differences could result in different responses to oil field infrastructure and activity.

In the Alaskan Arctic there are three caribou herds in addition to the CAH. The TCH is comparable to the CAH in size (about 16,500), range (tundra areas north of the Brooks Range), and calving area (near the Beaufort Sea coast). We predict oil field development in the range of the TCH would have comparable effects to that for the CAH. Consequently, similar mitigation measures could be applied.

Recent estimates of the other two Alaskan Arctic caribou populations, the WAH and the PCH, indicate they contain approximately 417,000 and 178,000 animals, respectively. These herds also have considerably larger ranges than the CAH or TCH. Such large differences in herd and range size make extrapolation of results from the CAH questionable. Many other aspects of the annual cycle and ecology of these populations differ in ways that could affect application of effective mitigation measures.

Much attention has been given to the prospects for petroleum development within the range of the PCH and the potential effects of development. Using the development scenarios provided by Clough et al. (1987), we examine potential mitigation measures.

Group sizes of PCH caribou encountering oil field infrastructure could be significantly larger than groups of the CAH (Appendix A, page A–37). During the pre–calving period, and again immediately after calving, groups >1,000 individuals could encounter road or pipeline corridors if there were oil fields in ANWR. The equivocal results from studies of caribou crossing success relative to group size suggest there may or may not be significant problems with movement. During the post calving and insect periods, groups of up to 50,000 PCH caribou could encounter oil fields. One cannot predict the effect of oil field structures on such large groups, but existing studies suggest that caribou will cross roads and pipelines with the proper mitigation measures.

Because of annual variation in locations of PCH calving concentrations (Garner and Reynolds 1986, Clough et al. 1987), there are several possible scenarios for the arrival of caribou cows at a hypothetical oil field. They might move into or through such a field prior to the start of calving, or groups with substantial numbers of neonatal calves might arrive from the east just after the peak of calving (Garner and Reynolds 1986). In the first scenario, pregnant cows might enter or move through the oil field given appropriate use of mitigation measures shown to be effective for the CAH. The effectiveness of current mitigation measures for movement, should large numbers of cows with neonatal calves arrive in a field, is not predictable because of the uncertain or inadequate research results obtained to date for this class of animals. However, cows with new calves are more sensitive to disturbance and a barrier effect might occur. That is, cows that entered when they were pregnant might be unwilling to cross roads or pipes within three weeks after giving birth.

Movements to, and selection of, insect relief habitats are also substantially different between the CAH and the PCH. The CAH makes repeated, highly predictable, short–range movements to coastal insect relief habitat over the course of summer. In some years, caribou of the PCH make substantial use of insect relief habitats on exposed ridges and other terrain features in the adjacent foothills. In general, the movements to insect relief habitat of the PCH are likely to be large scale and less predictable with regard to location and direction than in the case of the CAH. Repeated short–distance movements of individuals back and forth across development areas might be less likely in the case of the PCH. Similar conclusions would apply with regard to interactions of caribou with any development that might occur in or around the calving grounds of the WAH. Thus, post–calving barrier effects may be less than for the CAH.

Habituation will occur by repeated exposure to human structures and activities on a regular basis in a predictable and non–threatening environment (Appendix A, page A–58). Possibilities for habituation of caribou in the PCH to structures and activities associated with oil field development may be less than in the case of the CAH. This prediction is based on differences in population size and spatial variability in calving concentrations and post–calving movements in the PCH. Large annual variability in the amount of time individuals would be exposed to these structures and activities might make habituation less likely, take longer, or both. Another factor potentially interfering with habituation of the PCH is exposure to hunting on winter ranges. Vehicular based hunting has been common along the Dempster Highway (Surrendi and DeBock 1976). PCH caribou may relate any human activity with hunters and avoid contact.

To summarize our extrapolation of knowledge of caribou mitigation, larger scale movements with larger group sizes from pre–calving through summer dispersal in the PCH may result in different effectiveness of mitigation compared to the CAH. A smaller proportion of the PCH would probably encounter developed areas on a repeated basis compared to the CAH. Also, there may be a shorter period of exposure to oil field infrastructure for any individual caribou of the PCH compared to the CAH. Habituation may be less important in altering responses to human activity. It is possible that modification of existing mitigation measures will be needed for large groups and the variation in distribution and movement patterns of different herds. As in the existing oil fields, these will need to focus on enhancing crossing of roads and pipelines and minimizing disturbance.

## Recommendations for Oil Field Design and Operations

Crossing structures and other individual mitigation measures for caribou are only part of the process of providing for the needs of these populations. Smith and Cameron (1985:44) expressed this very well:

"Increasing the effectiveness of single crossing sites and isolated sections of pipelines is but one step toward developing a strategy to maximize access of caribou to critical habitats. Although permits for pipeline construction stipulate minimum clearances and provide for some buried crossings, the placement of new roads, pipelines, and other oil-related facilities all affect the use of existing sites to some extent. To be most effective, specific crossing sites must be integrated into a regional plan to preserve intact movement corridors through single and multiple oil field complexes."

Initial oil field design and modifications have involved, and must continue to involve, biologists working with regulators and engineers. We recognize limitations of biologists' ability to develop designs and plans to minimize disturbance on caribou. Effective mitigation requires not just planning, but ongoing input and involvement in day-to-day field operations. To accomplish the above, we recommend the following measures be instituted at new oil field developments. Measures which have already been instituted in existing fields since the original Prudhoe Bay development within the CAH are noted with an asterisk(*).

1.* Continue to involve biologists in initial field design, including decisions regarding placement of facilities and routing of roads and pipelines.

2. The following design criteria have been useful for CAH caribou and should be useful for other herds as well:

   A.* Elevate all pipes at least 5 ft (1.5 m) above ground from bottom of pipe.
   B. Examine feasibility of burying pipes. Cost, maintenance requirements, suitability of substrate, and loss of wetlands must all be considered when considering burying pipes.
   C. Limit numbers of roads in caribou calving areas.
   D.* Separate elevated pipelines from roads by at least 500 ft (152.4 m).
   E.* In areas where large groups of caribou cross, use either elevated pipes with road-pipe separation, buried pipes, or ramps (design and size must be evaluated).

3. Document all criteria and information used for each decision regarding design and siting of mitigation structures. Especially for new and

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