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Effects of Arctic Alaska Oil Development on Brant and Snow Geese

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ABSTRACT. Black brant (*Branta bernicla nigricans*) and lesser snow geese (*Chen c. caerulescens*) breeding in and near arctic Alaska oil fields could be affected by oil development actions such as releases of contaminants, alteration of tundra surfaces, creation of impoundments, and human activities. These actions could affect geese directly (e.g., through oil spills) or indirectly (e.g., by altering food supplies or predator populations). Studies to date indicate no changes in the distribution, abundance, or reproduction of these geese that clearly can be attributed to development; rather, their numbers and recruitment have responded in the oil fields, as elsewhere, mainly to weather and predation. When snowmelt in spring is later than usual, the birds postpone or forego nesting, with consequent diminishment in recruitment. Predation by arctic foxes (*Alopex lagopus*), glaucous gulls (*Larus hyperboreus*), and grizzly bears (*Ursus arctos*) sometimes causes substantial losses of eggs and young, and predation by ravens (*Corvus corax*) has also been observed. Development-related changes in weather (microclimate) and loss of feeding habitat have involved small percentages of the total areas traditionally used, and populations of the birds probably have not been affected by these changes. Some studies and observations suggest that development has elevated local populations of some predators, but whether the level of predation on geese has in consequence risen above that which would have occurred in the absence of development is unknown; further investigation of this mechanism of potential impact is recommended.

Key words: Brant, *Branta bernicla*, snow goose, *Chen caerulescens*, oil development, Alaska, impact assessment, predation, nutrition

RÉSUMÉ. La bernache noire (*Branta bernicla nigricans*) et la petite oie des neiges (*Chen c. caerulescens*) nichant dans les champs pétrolifères de l'Alaska ou à proximité pourraient être affectées par des actes reliés à l'exploitation pétrolière, tels que le déversement d'agents de pollution, les modifications à la toundra de surface, la création de bassins, et par l'activité humaine. Ces interventions pourraient affecter les oies de façon directe (p. ex., par le biais de déversements de pétrole) ou indirecte (p. ex., en modifiant l'approvisionnement alimentaire ou les populations de prédateurs). Jusqu'à l'heure actuelle, les études ne montrent pas de changements dans la distribution, l'abondance ou la reproduction de ces oies, dont la cause puisse être clairement attribuée à l'exploitation; dans les champs pétrolifères, le nombre d'oies et leur augmentation ont surtout réagi, comme ailleurs, au climat et à la prédation. Quand la fonte des neiges printanière a lieu plus tard que d'habitude, les oiseaux retardent la ponte ou s'abstiennent de pondre, ce qui entraîne moins d'augmentation. La prédation par le renard arctique (*Alopex lagopus*), le goéland bourgmestre (*Larus hyperboreus*) et le grizzli (*Ursus arctos*) entraîne parfois d'importantes pertes d'oeufs et d'oisons, et on a également observé des cas de prédation par le corbeau (*Corvus corax*). Des modifications climatiques (microclimat) reliées à l'exploitation et la perte d'aires d'alimentation ne concernent qu'un faible pourcentage du total des zones utilisées traditionnellement, et les populations d'oiseaux n'ont probablement pas été affectées par ces changements. Quelques études et observations suggèrent que la mise en valeur a fait augmenter les populations locales de certains prédateurs, mais on ne sait pas si le niveau de prédation de l'oie qui en a résulté était plus élevé qu'il ne l'aurait été en l'absence de la mise en valeur; on recommande que le mécanisme de ces retombées potentielles soit étudié plus à fond.

Mots clés: bernache cravant, *Branta bernicla*, oie des neiges, *Chen caerulescens*, exploitation pétrolière, Alaska, évaluation environnementale, prédation, nutrition

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INTRODUCTION

Following discovery of oil at Prudhoe Bay in 1968, petroleum development expanded in that part of northern Alaska. Concurrently, concerns escalated about the potential impact of oil development on wildlife and wildlife habitat in the oil-field area (Walker et al., 1987), and numerous studies to assess effects on wildlife were conducted (Maki, 1992). Migratory waterbirds were the focus of many such studies because of their perceived vulnerability to development (Vermeer and Anweiler, 1975; Sargeant and Raveling, 1992).

Most oil development activities in northern Alaska cluster on the arctic coastal plain near the Beaufort Sea. Consequently, much research has focused on waterfowl species

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known to feed and breed in predominantly coastal areas. Two colonially nesting geese, black brant and lesser snow goose, have attracted attention from impact analysts because of their proximity to the development area during the summer breeding season.

Several hundred to a thousand or more black brant breed each year in the vicinity of northern Alaska oil fields (Johnson, 1994a; Stickney and Ritchie, 1996). Though this population represents only a small proportion of the 50 000 or so black brant nesting in Alaska (Sedinger et al., 1993), most of the population nest and feed in coastal areas vulnerable to oil development impacts (Kiera, 1984; Stickney and Ritchie, 1996). Brant numbers in Alaska have declined precipitously in recent decades (Sedinger et al., 1993), though the population in and near arctic Alaska oil fields has remained relatively stable (Stickney and Ritchie, 1996).

A snow goose nesting colony in the Sagavanirktok River delta near Prudhoe Bay contains the majority of breeders (several hundred pairs) of this species in Alaska. Families from this colony feed in coastal areas in and near oil fields (Johnson, 1994b). Though this colony is small in relation to the total snow goose population, it is of interest because it is the only North American colony of more than a few birds that nests outside Canada (Johnson, 1994b).

This paper explores the mechanisms and extent of impacts of oil development on brant and snow geese in northern Alaska. It relies heavily on the results of published and unpublished studies conducted in and near the oil fields.

POTENTIAL IMPACT MECHANISMS

Development of the Prudhoe Bay Oil Field began in 1969, and the field came into production in 1977. Since then, five additional oil fields (Kuparuk, first oil produced in 1981; Milne Pt., 1985; Endicott, 1985; Lisburne, 1986; and Pt. McIntyre, 1994, see Fig. 1) and several smaller accumulations have been brought into production in the Prudhoe Bay region. Aspects of development that could have affected geese include release of contaminants, alteration of the tundra surface, creation of impoundments, and other human activities. Both direct effects (e.g., from disturbance) and indirect effects (e.g., from alteration of food supplies or predator populations) could have resulted.

Release of Contaminants

Crude oil, chemicals, seawater, and other materials released on the tundra potentially may degrade or destroy vegetation in goose habitat. However, the magnitude of all classes of contaminants spilled in the oil-field region is small, as exemplified by data from the Prudhoe Bay Oil Field (Table 1). A spill of 48 000–95 000 L of crude oil and produced water in the Kuparuk Oil Field in late summer 1989 contaminated 0.58 ha (Jorgenson and Cater, 1992). Applying this volume-to-area ratio to Table 1 suggests that the proportion of oil-field acreage encompassed by all accidental spills has been a small fraction of 1%. Further, far less than 10% of these spills, both by number and by volume, reach the tundra; most occur on gravel roads and pads or in specially built containment areas, or on snow and ice in winter, so that they can be removed before reaching the substrate (M. Gilders and C. Herlugson, BP Exploration [Alaska] Inc., pers. comm. 1996).

In the past, muds, cuttings, and other by-products of drilling operations were released into specially constructed reserve pits at drill sites (ENSR, 1992). A few hundred such pits exist in the oil-field region—the two major operators (BP Exploration and ARCO, Alaska) report having constructed 262 reserve pits as of early 1996 (M. Gilders, BP Exploration [Alaska] Inc., pers. comm. 1996). The habitat acreage lost to reserve pits is included below in the estimated acreage lost to gravel fill. Currently, drilling by-products are injected into subsurface formations rather than deposited in surface pits.

The potential for the drilling contaminants to have affected geese directly is remote. They occur in non-toxic concentrations (ENSR, 1992), and geese have not been reported (or expected) to consume them or get appreciable amounts on their bodies.

Alteration of the Tundra Surface

Roads, production and processing facilities, and other support structures in northern Alaska oil fields are constructed on ribbons and "pads" of gravel fill 1–2 m thick (Walker et al., 1987), which insulate and stabilize the underlying permafrost. In the Prudhoe Bay Oil Field (Fig. 2), the oldest and most densely developed of the fields, approximately 2156 ha were covered by gravel pads, roads, or gravel excavation sites as of 1986 (Senner, 1989). This accounts for about 2.3% of the 92 876 ha oil-field unit. In the more recently developed Kuparuk Oil Field, gravel and gravel excavation sites covered approximately 1012 ha of the 130 637 ha unit near the completion of its development in 1986, or about 0.8% of the landscape (Jorgensen, 1988). The relatively small proportion of gravel coverage in the Kuparuk and other recently developed oil fields can be attributed primarily to a less redundant road network, to recent improvements in directional drilling techniques, and to recent elimination of reserve pits.

Tundra surfaces not insulated with gravel are subject to other kinds of alteration. During exploration leading to the 1968 discovery of oil, roads for cross-tundra travel were commonly constructed by mounding and grading the peaty surface soil or by blading aside the surface soil to reach the underlying permafrost. Over time such disturbances caused thermokarst, i.e., surface subsidence resulting from the thawing of ice-rich tundra soils (Mackay, 1970). Other development-related surface disruptions that have caused thermokarst include dust deposition adjacent to gravel roads (Walker and Everett, 1987) and movement of vehicles or other heavy equipment across the tundra. The latter has declined greatly since the early 1970s, when government regulations were enacted to restrict vehicular travel on the

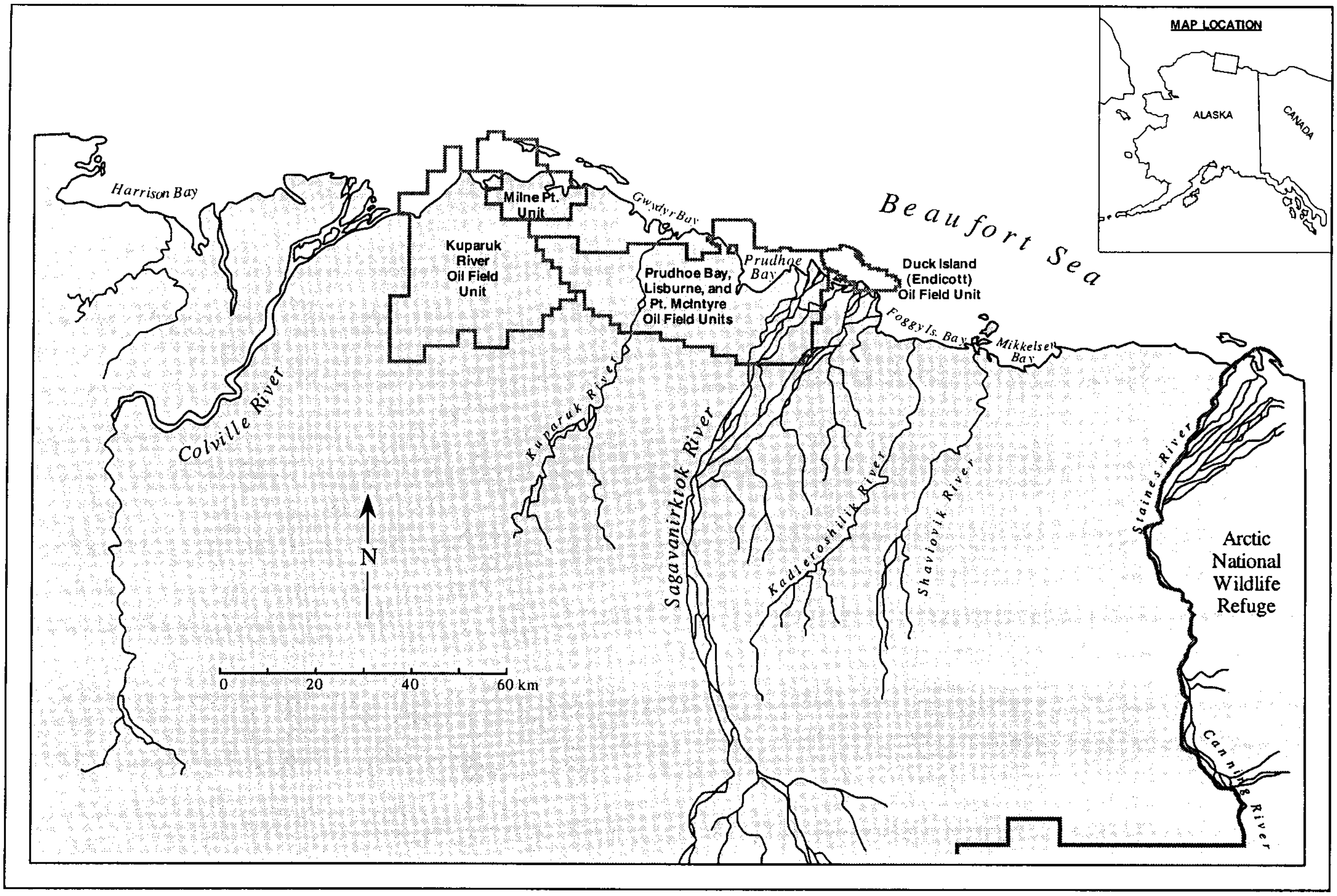

FIG. 1. Producing oil fields in northern Alaska, 1996. Adapted from a map provided by BP Exploration (Alaska) Inc., Anchorage.

tundra. As of 1983, approximately 3.6% (74 of 2088 ha) of the most intensively developed portion of the Prudhoe Bay Oil Field had been influenced by thermokarst or other non-gravel surface disturbances associated with development (Walker et al., 1986).

Creation of Impoundments

Impoundments, defined as artificial water bodies created by alteration of natural drainage patterns, have been formed in the oil fields where gravel roads and pads block surface flow of meltwater in summer. Impounded water reduces surface albedo, thereby causing thermokarst, which enlarges some impoundments until a new thermal equilibrium is attained (Lawson, 1986). Walker et al. (1986) estimated that impoundments in 1983 covered about 19.7% (411 of 2088 ha) of the landscape in an intensively developed portion of the Prudhoe Bay Oil Field. Noel et al. (1996) calculated that about 0.9% (800 of 92 876 ha) of the entire Prudhoe Bay Oil Field was covered by impounded floodwater in mid-July 1993; of this area, 75% was flooded for only a portion of the summer. Because the Prudhoe Bay Oil Field is located in an exceptionally flat and poorly drained part of the coastal plain (Walker et al., 1986), impoundments cover proportionately more of its land area than they cover in the other oil fields.

Human Activities

Human activities that could affect brant and snow geese include the construction and operation of facilities, movement of vehicles on roads and at facilities, people moving about on the tundra, and waste disposal. Movement of people and machines exerts its greatest potential influence by disturbing birds or obstructing their movements; direct mortalities are uncommon. Discarded food wastes potentially attract omnivorous scavengers that may prey on waterfowl. Food wastes generated in the oil-field region are bagged and stored temporarily in dumpsters adjacent to camp facilities, then are removed to a landfill (scheduled to close soon) located within the Prudhoe Bay Oil Field. Some wastes are incinerated to ash before being deposited in the landfill, and some are not (C. Herlugson, BP Exploration [Alaska] Inc., pers. comm. 1996).

APPARENT IMPACTS: CHANGES IN BIRD DISTRIBUTION, ABUNDANCE, AND REPRODUCTION

Brant

Brant arrive in northern Alaska in late May or early June and move quickly to nesting areas (Johnson and Herter,

TABLE 1. Number and volume of liquid contaminant (oil, other chemicals, and seawater) spills in the Prudhoe Bay Oil Field, 1990–94 (Data from M. Gilders, BP Exploration [Alaska] Inc., pers. comm. 1995).

Year	Number	Volume (liters)
1990	920	244 671
1991	930	1 695 328
1992	669	176 396
1993	657	523 993
1994	591	43 030

1989), most of which are on islands in coastal lakes and river deltas (Kiera, 1984; Stickney and Ritchie, 1996). Several hundred pairs of brant nest between the Colville and Canning Rivers; the two largest colonies are (1) on Howe and Duck Islands in the Sagavanirktok River delta near the large Endicott Development Project, and (2) in the Kuparuk River delta (Stickney et al., 1993; Johnson, 1994a; Stickney and Ritchie, 1996) (see Fig. 2). Brant numbers have varied considerably from year to year at specific nesting colonies and brood-rearing areas, but there is no evidence that these changes have been caused by oil development activities (Stickney and Ritchie, 1996). For instance, oil development in the Sagavanirktok River delta began in 1984 with commencement of the Endicott Project. The nesting population of brant in the vicinity of this development increased more than fourfold during the construction period (1984–90). The population declined during 1991–94, but for reasons not attributed to development (Johnson, 1994a, 1995).

Snow Goose

Snow geese usually arrive in the Sagavanirktok River delta in the last week of May and settle on Howe Island to nest in early June (Johnson and Herter, 1989). Some snow geese have nested on smaller islands, or on the nearby mainland, especially in years of below-average spring temperatures and years when predators have inhabited Howe Island (Johnson, 1994b). After eggs hatch in late June and early July, the geese quickly move with their broods to sedge marsh feeding areas, mainly in the Sagavanirktok delta but also at coastal locations west and east of the delta. In 1993, brood-rearing areas extended up to 20 km west, 35 km east, and 10 km inland of Howe Island (Johnson, 1994b).

Intensive studies of the Howe Island colony during nesting and brood-rearing (Johnson 1994b; 1995) disclosed no distributional changes caused by the Endicott Development Project. Geese not only nested on Howe Island both before and after the Endicott causeway passed within three km of the island, but during some post-development years, they nested even nearer to the heavily trafficked causeway corridor than they had prior to development. Pre- and post-nesting geese also continued to use sites adjacent to the development activity, and broods of young routinely crossed the Endicott road/causeway to reach traditional brood-rearing areas and to establish new ones.

The post-nesting population of Sagavanirktok delta snow geese increased tenfold during 1980–90, primarily because of consistently high annual reproductive success. Major declines in productivity occurred in 1991, 1992, and 1994 (Johnson, 1994b, 1995). During the five-year period following the initiation of the Endicott Project, the growth rate of the goose population remained about the same as it had been during the five years preceding development. The reproductive failures in 1991, 1992, and 1994 were not associated with changes in development activity.

CRYPTIC IMPACTS: THE ALTERATION OF HABITAT

Three habitat factors that could be influenced by oil development—weather, predation, and food deficiencies—have been implicated in limiting goose survival and reproduction in arctic breeding areas (Ankney et al., 1991; Sargeant and Raveling, 1992). Below we evaluate evidence that oil development in arctic Alaska may have altered weather, predator populations, or food availability so as to affect brant or snow goose populations.

Weather-related Impacts

Cold weather and the associated persistence of snow in spring on breeding grounds often causes nesting delays and reduced productivity in brant (Barry, 1962; Reeves et al., 1976; Ankney, 1984; Summers and Underhill, 1987) and snow geese (Boyd, 1982; Boyd et al., 1982; Davies and Cooke, 1983; Cooke et al., 1984). Oil development in arctic Alaska ameliorates the impact of weather locally by causing an acceleration in spring snowmelt near heavily trafficked roads. Dust from traffic settles on snow, decreases albedo, and causes snowmelt up to 100 m downwind of the road as early as 10–14 days before general melt-off (Walker and Everett, 1987).

Brant and snow geese in the oil fields sometimes preferentially occupy this early-melt dust shadow of oil-field roads prior to nesting (Burgess et al., 1990; Murphy and Anderson, 1993; Anderson and Cooper, 1994). But because roads do not pass near nesting colonies, it is unlikely that this melt-off hastens nest initiation. Even if geese find better food in the melt-off areas, potentially gaining a nutritional advantage, a small increase in the food supply is unlikely to translate into measurable improvements in recruitment, as will be discussed later.

Impacts on Predator Populations and Predation

Predation, often by arctic foxes and/or glaucous gulls on eggs and young, can cause major reductions in recruitment of brant (Eisenhauer, 1977; Petersen, 1982; Raveling, 1989; Anthony et al., 1991; Sedinger et al., 1993) and snow geese (MacInnes and Misra, 1972; Syroechkovskiy et al., 1991; Sargeant and Raveling, 1992). In arctic Alaska, oil development may have affected densities of some predators that are

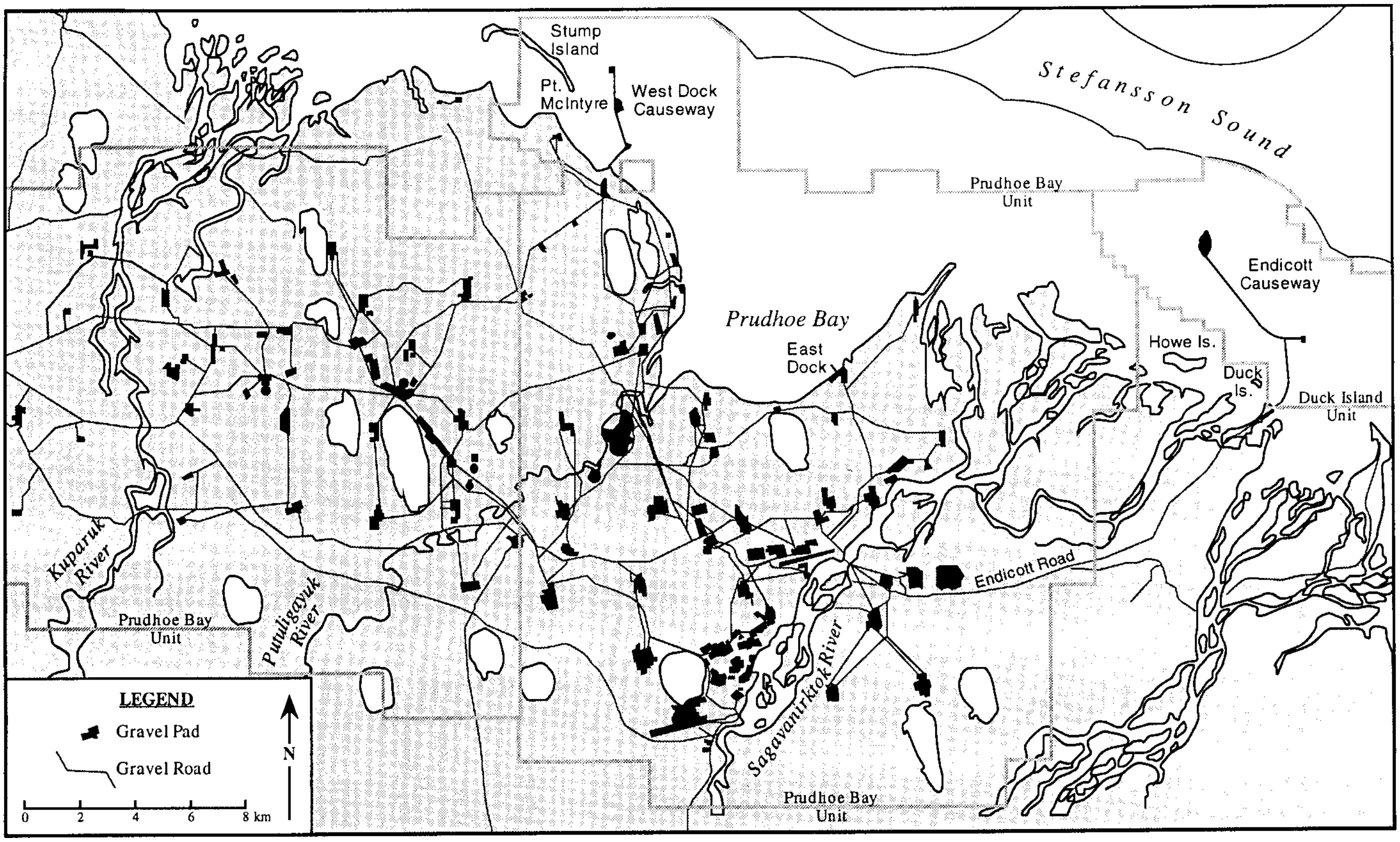

FIG. 2. The most intensively developed portion of the northern Alaska oil fields, centered on the Prudhoe Bay Unit. Adapted from a map provided by BP Exploration (Alaska) Inc., Anchorage.

known to prey on geese. Four species—arctic fox, glaucous gull, grizzly bear, and common raven—are potentially implicated.

Development probably has benefitted arctic foxes by providing food subsidies (garbage) and denning sites (Burgess et al., 1993). Eberhardt et al. (1983) found the density of arctic fox dens in the Prudhoe Bay oil-field area to be about three times that in the undeveloped Colville River delta west of the oil fields. The oil-field fox population also was more dense and underwent less dramatic fluctuations than that in the Colville delta (Eberhardt et al., 1982). Likewise, Burgess et al. (1993) found a greater density of fox dens and breeding foxes in developed than in undeveloped portions of the Prudhoe Bay region; they found pup survival to be highest in areas of high-density development. (The absence of temporal controls in these studies weakens the inference that oil development always caused the observed differences between developed and undeveloped areas.)

Some studies elsewhere show a direct relationship between arctic fox density and losses of waterfowl eggs. MacInnes and Misra (1972) reported that near Hudson Bay, the losses of Canada goose (*Branta canadensis*) nests to arctic foxes increased with fox density. Petersen (1982) noted the increased predation loss of Canada goose and black brant nests at Kokechik Bay, Alaska, with increases in arctic fox density. Sargeant and Raveling (1992) attributed increased losses of goose nests (several species) on the Yukon-Kuskokwim delta, Alaska, at least partly to increases in the arctic fox population.

Fox predation is known to influence substantially brant and snow goose nesting success in arctic Alaska oil fields. Stickney et al. (1993) attributed reduced nesting success by brant in the oil-field region in some years mainly to foxes. Johnson (1994a) identified foxes as the primary cause of brant nest failure in the Sagavanirktok River delta in 1991–93, and Johnson (1994b) blamed primarily foxes for major snow goose nest failures on Howe Island in 1991 and 1992. The main factor leading to these losses appeared to be easier-than-usual access by arctic foxes to the nesting islands (usually caused by late thaw) rather than development-related changes in the fox population.

Glaucous gulls also take eggs and young of geese in the oil fields and, in comparison with foxes, have easier access to island-nesting birds. Murphy et al. (1986) documented the total loss of eggs in a brant nesting colony near Prudhoe Bay, apparently to glaucous gulls. Johnson (1994b), who observed glaucous gulls preying on snow goose goslings leaving the Howe Island colony in 1993, suspected that gull predation killed a substantial percentage of the young geese that year. It is generally believed that oil development in northern Alaska has led to a local increase in glaucous gulls. Gulls commonly congregate to feed at municipal dumps and other sites of human activity where waste food sources exist (Johnson and Herter, 1989). Murphy and Anderson (1993) reported that glaucous gull numbers were much higher within 20 km of the North Slope Borough landfill near Prudhoe Bay (the only landfill in the oil-field area) than they were 20–40 km away from the landfill.

Increases in gull densities may exacerbate predation losses in waterfowl. Dwernychuk and Boag (1972) correlated mortality levels in Alberta ducklings (several species) with ring-billed gull (*Larus delawarensis*) and California gull (*L. californicus*) densities; duckling survival declined to zero at maximum gull densities. Milne and Reed (1974) attributed most losses of common eider (*Somateria mollissima*) eggs in St. Lawrence estuary nesting colonies to herring gulls (*L. argentatus*) and great black-backed gulls (*L. marinus*); losses increased with gull density. Choate (1967) found common eider nesting success in Penobscot Bay, Maine, to be inversely correlated with the density of herring and black-backed gulls. Whether increases in glaucous gull abundance in the oil fields of northern Alaska have resulted in increased losses of brant or snow geese eggs or young is unknown.

Grizzly bear populations have increased in the oil fields since development began, but also have increased elsewhere in arctic coastal Alaska during the same period. Bears in and near oil fields show evidence of better nutrition—greater adult weights and larger litter sizes—and perhaps a greater density than those elsewhere in arctic Alaska, presumably because they are subsidized by development-generated refuse (R. Shideler, Alaska Dept. Fish and Game, pers. comm. 1996). Several investigators have reported bears preying on goose nests (and other waterfowl nests) in the oil fields (Johnson, 1995; Stickney and Ritchie, 1996; R. Shideler, Alaska Dept. Fish and Game, pers. comm. 1996). Whether bear predation on brant and snow geese has increased because of oil development has not been quantitatively assessed.

Common ravens currently nest and forage in the oil-field region, but never nested and were seldom present in the area prior to oil development (Johnson and Herter, 1989; S.R. Johnson, LGL Ltd. Environmental Research Associates, pers. comm. 1996). Three pairs of ravens nesting on development structures in the Endicott Oil Field in the Sagavanirktok River delta in 1995 fed their young daily on goose and other waterfowl eggs and on garbage from oil-field dumpsters (S.R. Johnson, LGL Ltd. Environmental Research Associates, pers. comm. 1996). Given the reasonable assumption that these birds would not have nested in the oil fields in the absence of the structures, this predation loss is attributable to development. The level of its effect on brant and snow goose nest success is unknown.

Impacts on Food Availability

Inadequate nutrition of brant prior to and during egg-laying (Ankney, 1984) and of snow geese prior to egg-laying (Ankney and MacInnes, 1978) can curtail their reproductive output, and inadequate nutrition of brant (Sedinger and Flint, 1991) and snow goose (Cooke et al., 1995) broods may reduce gosling growth and thus long-term recruitment. Whether oil development in arctic Alaska has diminished the quality or quantity of the food resource sufficiently to adversely affect brant or snow goose productivity and recruitment depends on (1) the predevelopment adequacy of the forage with respect to needs of the goose populations and (2) the proportion of the food base lost to development.

Much evidence suggests that food may be superabundant in the oil-field region with respect to nutritional needs of the brant and snow goose populations. Weights of given-age brant goslings in the oil-field region are greater than those reported elsewhere, indicating superior nutrition (J.S. Sedinger, Institute of Arctic Biology, unpubl. data). Snow goose densities on the brood-rearing areas of the Howe Island colony are at least an order of magnitude lower than densities in brood-rearing areas of some snow goose colonies in Canada (Johnson et al., 1985), but food production and quality in the Alaskan and Canadian areas probably are roughly comparable (Harwood, 1977).

With respect to snow geese, grazing in the densely populated Canadian colonies has severely damaged the vegetation (Kerbes et al., 1990; Cooke et al., 1995; Ankney, 1996), but even so the reproductive rates have been little affected (Kerbes et al., 1990; Cooke et al., 1995). Similarly severe habitat impacts have not been reported for brood-rearing areas in northern Alaska; thus, food shortages caused by habitat loss seem unlikely. Finally, evidence of large fluctuations in snow goose recruitment in response to weather and predation (presented earlier) suggests that food scarcity per se is secondary to these factors in affecting oil-field populations of these birds.

Not only has the proportion of the goose food base in the oil fields affected by development been small, but food quality and/or quantity in some affected areas may have been improved over their original condition. McKendrick (1986) observed grasses that were planted on gravel fill on the National Petroleum Reserve in northern Alaska being selectively grazed by geese 1–3 years after seeding. Truett and Kertell (1992) concluded that mechanical disruptions of the tundra surface often have led to improvements of rather than declines in the net productivity of plants commonly eaten by geese.

CONCLUSIONS AND RECOMMENDATION

Oil development in arctic Alaska has caused no apparent changes in the distribution, abundance, or productivity of black brant or snow geese. Since development began, annual distributional shifts within populations of both species, and increases in the abundance of snow geese, have been documented, but none of these changes bear a clear relationship to development.

Weather, predation, and food availability may affect arctic-nesting geese; among these, predation alone has the potential to be altered substantially in its effect by oil development in arctic Alaska. Three known predators of brant and snow geese—arctic foxes, glaucous gulls, and grizzly bears—may have increased in abundance because of development. A fourth—the common raven—has recently established a small nesting population, apparently because of development, and birds from this population have preyed on goose eggs. Studies elsewhere have shown that increases in predator populations sometimes cause increases in losses of waterfowl eggs and young. Whether oil development has exacerbated annual predation losses in black brant and snow goose populations in arctic Alaska oil fields is currently unknown.

We recommend that biologists and impact analysts studying brant and snow geese in the oil-field region focus more attention on development-related changes in predator populations and the impacts of these changes on recruitment of young into the goose populations.

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