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Status of Marine Birds of the Southeastern Beaufort Sea

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ABSTRACT. This summary and update of information on the marine birds of the southeastern Beaufort Sea is intended to support discussions on how to improve management of marine resources in the Canadian Beaufort Sea region. Perhaps the most outstanding use of the Beaufort Sea by marine birds is the staging during spring migration by hundreds of thousands of eiders and long-tailed ducks in the early open water off Cape Bathurst and Banks Island. During midsummer, tens of thousands of long-tailed ducks, scoters, scaup, and mergansers moult in the sheltered bays and behind barrier beaches and spits. Although several species of geese, ducks, loons, gulls, and terns nest on islands and in wetlands along the Beaufort Sea coast, this region has relatively few nesting seabirds compared to eastern Arctic Canada and the Bering Sea. Two possible reasons for this are a shortage of cliffs suitable for nesting and a lack of pelagic fish. The five most common sea duck species that occur in the region, long-tailed duck, king eider, common eider, surf scoter, and white-winged scoter, have all declined in numbers since the mid-1970s. Western Arctic brant populations have also declined, although their status within the Beaufort Sea region is unclear. Brant and king eider are the only marine bird species harvested there in substantial numbers. Other threats to Beaufort Sea marine bird populations include oil spills, global warming, coastal development, and contaminants. Certain threats can be managed at a local level since they are a result of local economic development, but others, such as global warming or loss of critical wintering areas, stem from environmental problems outside the region. Solving these issues will require mutual understanding and commitment on the part of numerous countries.

Key words: Beaufort Sea, sea ducks, seabirds, brant, harvest, distribution, population status, conservation

RÉSUMÉ. Cette récapitulation et mise à jour de l'information sur les oiseaux marins du sud-est de la mer de Beaufort ont été faites dans le but de fournir des arguments sur la façon d'améliorer la gestion des ressources marines dans la zone canadienne de la mer de Beaufort. L'utilisation la plus notable que font les oiseaux marins de la mer de Beaufort est peut-être en tant que halte durant la migration printanière de centaines de milliers d'eiders et de canards à longue queue dans les premières eaux libres au large du cap Bathurst et de l'île Banks. Au milieu de l'été, des dizaines de milliers de canards à longue queue, de macreuses, de fuligules milouinans et de harles muent dans les baies abritées et en arrière des flèches et cordons littoraux. Même si plusieurs espèces d'oies, de canards, de huarts, de mouettes et de sternes nichent sur les îles et dans les zones humides longeant le rivage de la mer de Beaufort, cette région voit relativement peu d'oiseaux marins qui viennent y nicher en comparaison de l'est du Canada arctique et de la mer de Béring. Il y a deux raisons possibles à cet état de choses: trop peu de falaises propices à l'établissement de nids et un manque de poissons pélagiques. Les cinq espèces de canards de mer les plus courantes dans la région, à savoir, le canard à longue queue, l'eider à tête grise, l'eider à duvet, la macreuse à front blanc et la macreuse brune, ont toutes vu leurs nombres décliner depuis le milieu des années 1970. La population de bernaches cravants de l'ouest de l'Arctique est également en déclin, bien que le statut de cet oiseau au sein de la région de la mer de Beaufort ne soit pas évident. La bernache cravant et l'eider à tête grise sont les seules espèces d'oiseaux marins prélevées en nombre important à cet endroit. Parmi les autres facteurs qui menacent les populations d'oiseaux marins de la mer de Beaufort, on compte les déversements d'hydrocarbures, le réchauffement climatique, l'aménagement du littoral et les contaminants. Certaines menaces peuvent être gérées au niveau local vu qu'elles résultent du développement économique local, mais d'autres comme le réchauffement climatique ou la perte d'aires d'hivernage critiques sont issues d'enjeux environnementaux extérieurs à la région. La résolution de ces problèmes passe obligatoirement par une compréhension et un engagement mutuels de la part de nombreux pays.

Mots clés: mer de Beaufort, canards de mer, oiseaux marins, bernache cravant, prélèvement, distribution, statut de la population, conservation

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INTRODUCTION

The marine environment is continually changing. Since the mid 1970s, the frequency of warm events has increased in the northeast Pacific (McGowan et al., 1998). These events, which are manifested in the ocean by a slight rise in temperature at the sea surface, can have a profound effect on marine ecosystems by changing ocean currents, primary productivity, distribution of prey, and ultimately affecting the survival and productivity of marine birds and mammals (Piatt and Van Pelt, 1997; McGowan et al., 1998). Global warming has also resulted in decreased sea ice coverage in the Northern Hemisphere (Vinnikov et al., 1999). Climate change is of particular concern in the Arctic, where it is predicted to have the greatest impact on ecosystems (Roots, 1989). Other changes occurring in the marine environment include the loss of coastal habitat due to industrial, urban, and recreational development, depletion of species populations due to over-harvesting, and accumulation of contaminants from industry and agriculture. Species that are commonplace today, but unable to adapt to these changes, could be a rare sighting tomorrow.

The Inuvialuit people of western Arctic Canada rely heavily on marine natural resources not only for food, but also for their cultural, social, and spiritual well-being (Day, 2002; Usher, 2002). Thus, it is appropriate that at the turn of the century, the Inuvialuit have stopped to take stock of their marine resources, searching for better ways to manage the human activity that affects them.

The following is a brief review of the status of marine bird species that regularly occupy marine waters of the southeastern Beaufort Sea. A complete review of all bird species in the region, including those that are rare visitors or occasional breeders, has been done previously (Johnson and Herter, 1989). Here, we focus on key marine bird species, presenting what is known about their seasonal distribution and habitat requirements, as well as their current population status. We then discuss the various human activities, both local and international, that potentially affect marine birds of the Beaufort Sea. The purpose is to provide a summary and update of information to support discussions on how to improve the management of the marine resources of the Inuvialuit Settlement Region.

SPECIES DISTRIBUTION AND HABITAT PREFERENCES

Spring Migration

Each spring, hundreds of thousands of birds stop temporarily in leads of open water in the southeastern Beaufort Sea to rest, feed, and court (Alexander et al., 1997). The most abundant species using the leads are the common eider (*Somateria mollissima v nigra*), king eider (*Somateria spectabilis*), long-tailed duck (*Clangula hyemalis*), glaucous gull (*Larus hyperboreus*), and three species of loon. Peak movements through the Beaufort Sea occur from the last week of May until the middle of June. The open water leads at that time of year vary in size, from small patches (i.e., 1 – 10% open water) to a continuous band of open water extending from Herschel Island to Cape Bathurst to the north end of Banks Island (e.g., Alexander et al., 1997; Cormack and Macdonald, 2002). Regardless of ice conditions, open water just west of Cape Bathurst is the area used most heavily by the eiders and long-tailed ducks (Fig. 1). Another important staging area for king eiders is off the west coast of Banks Island. By contrast, most common eiders remain along the mainland coast, migrating eastward from Cape Bathurst to a second staging area in Dolphin and Union Strait (Barry, 1986; Alexander et al., 1997).

Factors that influence the distribution of sea ducks within the open water leads in spring are likely water depth, turbidity, and abundance of prey, all of which affect prey availability (Barry, 1986; Alexander et al., 1997). King and common eiders and long-tailed ducks all feed on bottom-dwelling invertebrates. However, common eiders prefer to feed in water less than 15 m deep, whereas king eiders feed in deeper water and long-tailed ducks can dive to even greater depths (Alexander et al., 1997; Bustnes and Lonne, 1997). Consequently, common eiders tend to concentrate in the shallowest open water areas: off the Tuktoyaktuk Peninsula and Cape Bathurst, where the ice edge is usually located near the 20 m bathymetric contour, and in the narrows in Dolphin and Union Strait, where the water is less than 20 m deep. King eiders, which can feed in deeper water, often stage in large concentrations in water up to 50 m deep off Banks Island (Alexander et al., 1997). Long-tailed ducks are the least restricted in their distribution because they feed on a greater variety of invertebrates, not only from the sea bottom, but also from the water column and the undersurface of the ice (e.g., isopods, amphipods; Peterson and Ellarson, 1977; Johnson, 1984). Thus, the long-tailed duck is the only sea duck found in large numbers in the deeper water off the Yukon coast (Alexander et al., 1994). Overall, sea duck concentrations are highest at Cape Bathurst, with much lower numbers present off the Mackenzie Delta. The turbid water of the Mackenzie River might hamper foraging by the ducks, as well as reduce invertebrate productivity (Parsons et al., 1988), hence contributing to the low numbers seen in this area (Alexander et al., 1997).

Nesting Season

Most sea ducks that stage in the Beaufort Sea during spring migration disperse by mid-June to nest either inland or farther east in central Arctic Canada. The king eider nests near tundra ponds and lakes, primarily on Banks and Victoria Islands (Dickson et al., 1997). The long-tailed duck also nests near freshwater, but is more common on the mainland, nesting south to the tree line (Bellrose, 1980). Common eiders nest on small, offshore islands secure from arctic foxes (*Alopex lagopus*; Barry, 1986).

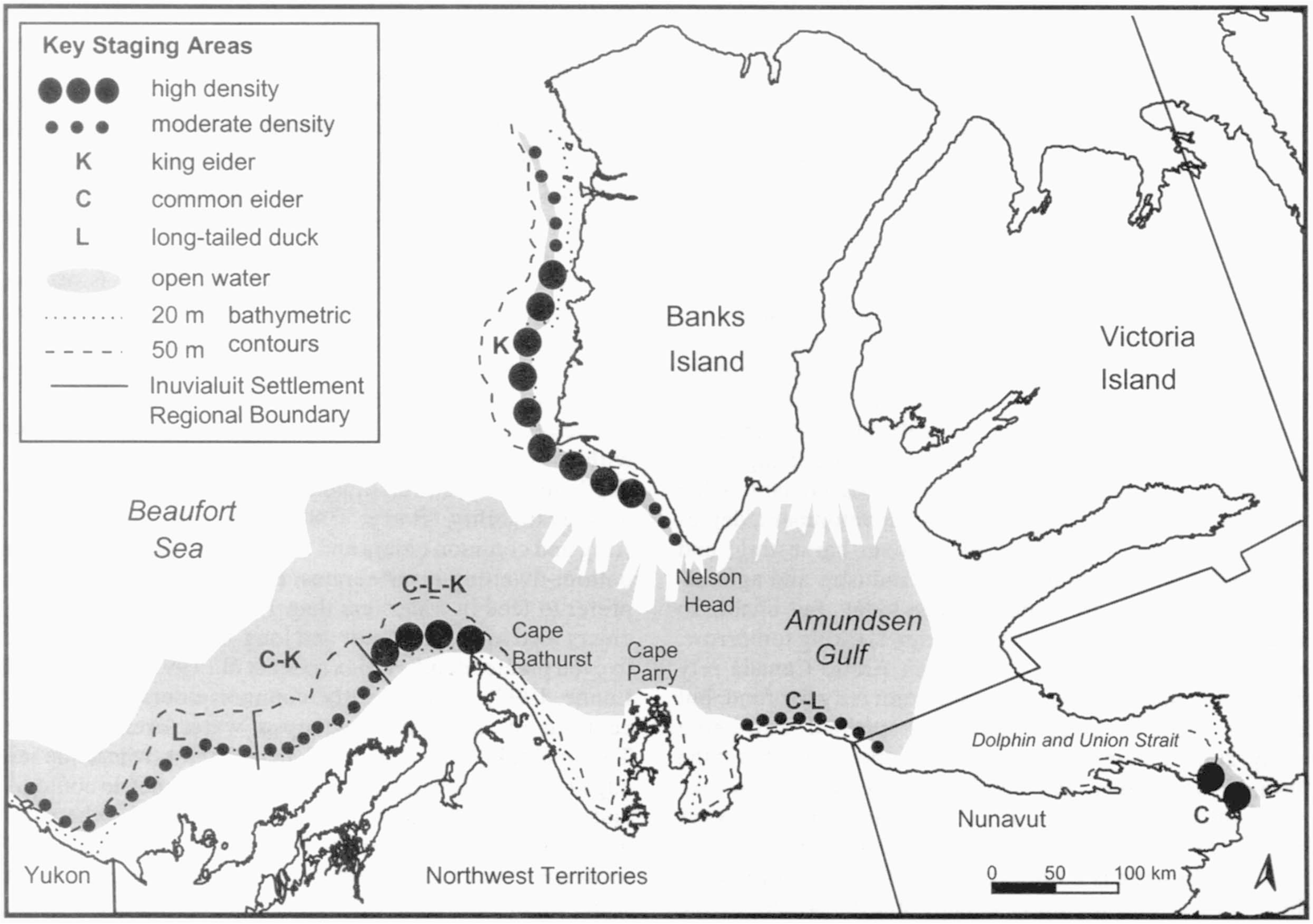

FIG. 1. Location of major staging areas for king eiders, common eiders, and long-tailed ducks in western Arctic Canada during spring migration (after Alexander et al., 1997).

Some remain in western Arctic Canada, nesting primarily off the west side of Victoria Island, but most migrate farther east to nest in central Arctic Canada (L. Dickson, unpubl. data; Cornish and Dickson, 1997).

Brant (*Branta bernicla*) are uncommon in the offshore leads during spring migration (Alexander et al., 1994); they migrate along the Beaufort Sea coast, arriving on their nesting grounds in the region in late May to early June (Reed et al., 1998). On the mainland, brant nest primarily along the coast, barely above the normal tide line, on islets in river deltas and on small offshore islands and spits (Fig. 2) (Barry et al., 1981; Alexander et al., 1988). On Banks Island, however, they also nest on islands in lakes as far inland as 80 km (Cotter and Hines, 2000a.). Brant are grazers, and in summer they feed primarily on grasses and sedges (especially *Puccinellia phryganodes* and *Carex subspathacea*) on tidal flats along the mainland coast (Barry, 1967).

Red-throated loons (*Gavia stellata*) arrive in the offshore leads in late May or early June and remain there until their nesting ponds have open water, generally by mid-June (Dickson, 1993). Their young require fish to survive to fledging. Since the shallow ponds typically used for nesting freeze to the bottom, and hence support no fish, the red-throated loons must transport fish captured elsewhere. Consequently, they are restricted to nesting within about 8 km of the coast or a large lake (Douglas and Reimchen, 1988). The Pacific loon (*Gavia pacifica*) is less reliant on the ocean to feed its young, since it nests on deeper lakes that often contain enough invertebrates and fish to support the development of young. The yellow-billed loon (*Gavia adamsii*), found in the leads in spring, nests mostly on lakes on Banks and Victoria Islands (Barry et al., 1981).

Arctic terns (*Sterna paradisaea*) often nest in areas with little vegetation: on gravel ridges near lakes, on beaches, and on barrier islands. They nest either solitarily or colonially if they are near abundant food sources. During both incubation and chick rearing, they rely on amphipods and other aquatic invertebrates that they catch from both freshwater and saltwater ponds (Abraham and Ankney, 1984). Young fledge approximately 23 days after hatch, and fall migration occurs only one or two weeks after fledging in the Beaufort Sea region (Johnson and Herter, 1989).

Sabine's gulls (*Xema sabini*) typically nest on moist ground on the shores and islands of small tundra lakes. In the Beaufort Sea region, they also nest in small colonies on islands and spits (Alexander et al., 1988). The pair bond is

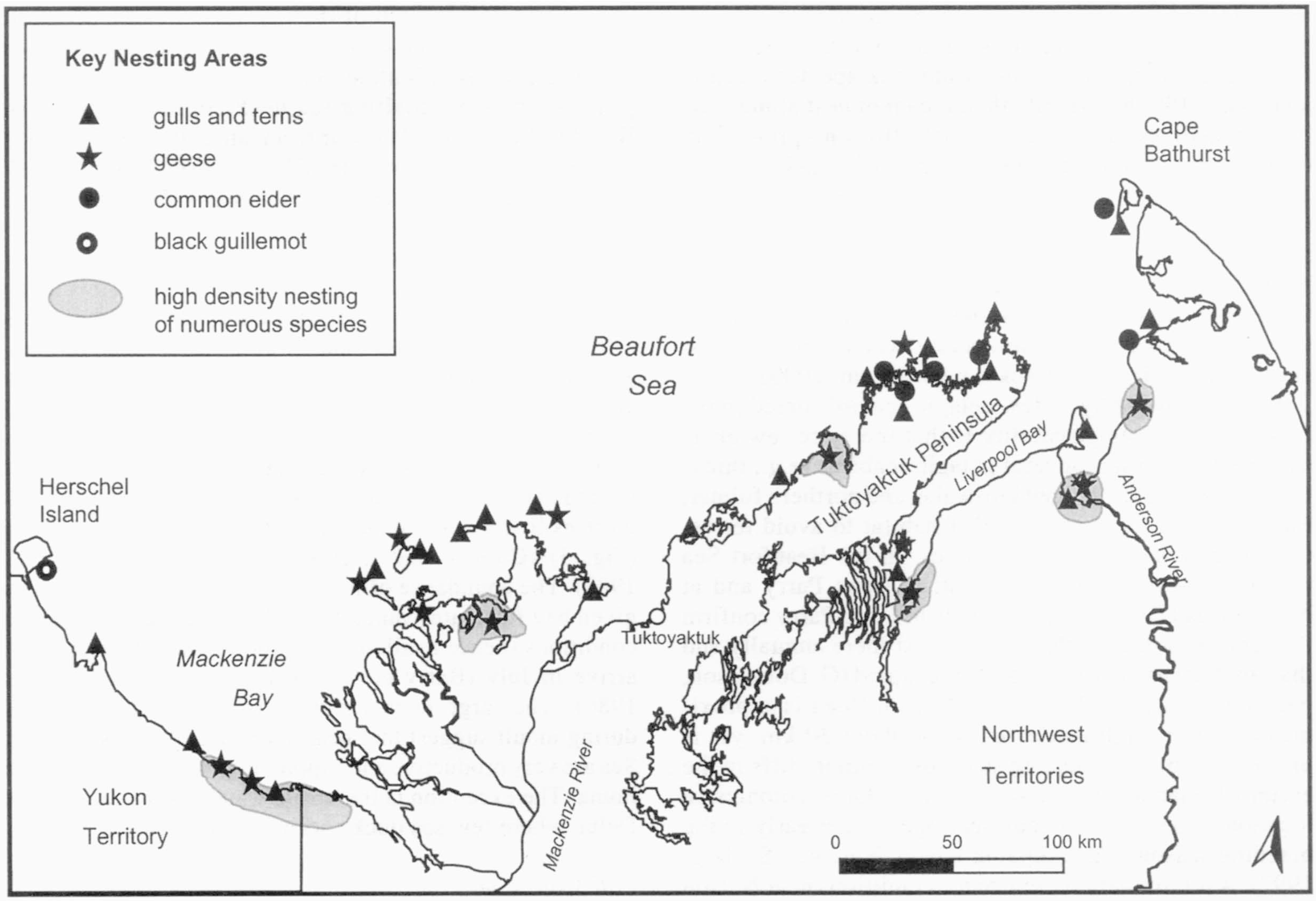

FIG. 2. Key nesting areas along the southeastern Beaufort Sea coastline (after Alexander et al., 1988).

maintained for more than one year, and pairs often return to nest within metres of previous nest sites (Stenhouse et al., 2001). Prior to laying and during incubation, Sabine's gulls feed primarily on insect invertebrates found in fresh or brackish water (Day et al., 2001). After eggs hatch, chicks and adults move to coastal areas, where chicks are provisioned and continue their development (Stenhouse et al., 2001). Sabine's gulls often nest near arctic terns, but the relationship between the two species remains unclear. Although it has been suggested that Sabine's gulls nest with arctic terns to benefit from the defensive protection they provide (Larson, 1960), the nesting association may simply reflect similar requirements for breeding habitat (Abraham, 1986; North, 1995; Stenhouse et al., 2001).

The glaucous gull is a common breeder along coasts of western Arctic Canada. In the Beaufort Sea region, it is both scavenger and predator, eating a variety of items including insects, fish, and the eggs and chicks of other birds (Barry et al., 1981; Alexander et al., 1988). It nests in colonies or in single pairs on islands, river deltas, barrier beaches, and sea cliffs, and on islands in freshwater lakes (Gilchrist, 2001). Factors that influence the spacing of nests are unknown, but may reflect interactions between the availability of nest sites free of mammalian predators and the proximity of food resources to the nest. In general, individuals that specialize on avian prey near their nests defend their feeding territories, whereas gulls foraging farther away from the nest (e.g., along coasts or out to sea) often nest colonially (Bertram and Lack, 1933; Gaston and Nettleship, 1981; Gilchrist and Gaston, 1997).

In most polar oceans, seabirds such as auks (*Alcidae*) and black-legged kittiwakes (*Rissa tridactyla*), are important components of marine ecosystems. Both the Bering Sea to the west of the Beaufort Sea and the marine waters of eastern Arctic Canada have many large seabird colonies, several supporting more than 300 000 birds (Sowls et al., 1978; Nettleship and Evans, 1985). In contrast, the southeastern Beaufort Sea has only two small seabird colonies: a colony of about 800 thick-billed murres (*Uria lomvia*) on the cliffs of Cape Parry (Johnson and Ward, 1985) and a colony of approximately 100 black guillemots (*Cepphus grylle*) nesting within rock piles and old buildings at Herschel Island (Ward and Mossop, 1986).

Black guillemots typically forage for inshore fish species in less than 30 m of water, often within 30 km of the nest site (Gaston and Jones, 1998b). They nest, either solitarily or in colonies, within crevices or in rock piles that afford them protection against predators. These nesting and foraging characteristics enable the black guillemot to nest in most Arctic regions; arguably it has one of the broadest circumpolar ranges of any auk species (Gaston and Jones, 1998b). Despite this, it cannot nest along low-lying coastlines or on beaches that afford no protection. Consequently, most of the Canadian and Alaskan coastlines of the Beaufort Sea are unsuitable nesting sites for this species. This observation is supported by two facts: the only sizable black guillemot colonies occur among human debris (Herschel Island, Ward and Mossop, 1986; Cooper Island, Alaska, G. Divoky, pers. comm. 2000), and colony size increases dramatically when artificial nest sites are provided (G. Divoky, pers. comm. 2000).

It is unknown why so few pelagic seabirds breed in the Beaufort Sea. One possibility is that there are few cliffs suitable for nesting. Several pelagic seabirds (e.g., thick-billed murre, black-legged kittiwake, and northern fulmar, *Fulmarus glacialis*) require cliff habitat to avoid terrestrial predators such as arctic foxes. In the Beaufort Sea region, only two cliff sites exist: at Cape Parry and at Nelson Head (Fig 1). Recent visits to Cape Parry confirm that only 800 thick-billed murres nest there annually and that small areas of cliff remain unoccupied (G. Donaldson, pers. comm. 2000). The cliff at Nelson Head is approximately 300 m high and extends for about 30 km, yet is unoccupied by cliff-nesting seabirds. Similar cliffs in the eastern Canadian Arctic support very large colonies in locations where cliffs occur near open water early in the breeding season (e.g., Akpatok Island, Nunavut; Stirling, 1997). A preliminary review of ice conditions near Nelson Head in late May in five years during the 1990s (1992, 1993, 1996, 1997, and 1998) indicates that open water has occurred within 30 km of the cliff each year. This suggests that ice conditions early in the nesting season do not constrain seabirds at this site.

The existence of unoccupied cliff habitat in the Beaufort Sea region suggests that other factors limit pelagic seabird populations in addition to lack of suitable nesting habitat. One possibility is that there may be low abundance of pelagic fish accessible to seabirds. Although adults often prey on invertebrates at sea (Bradstreet, 1982), their chicks require fish to grow rapidly in the short breeding season (primarily arctic cod *Boreogadus saida* in the eastern Arctic; Gaston and Nettleship, 1981). Indeed, at large colonies in the eastern Canadian Arctic, murres consume tons of arctic cod daily (Gaston and Jones, 1998a) and routinely dive to reach schools of fish at 60–80 m depth (Falk et al., 2000). The lack of pelagic seabirds nesting at Nelson Head suggests that the offshore area of the Beaufort Sea is less productive than regions at similar latitudes in both the eastern Canadian Arctic and the Bering Sea.

Moult Migration

Several species of sea duck migrate to the southeastern Beaufort Sea to moult their flight feathers. They are primarily males and failed breeders from inland nesting areas, including regions south of the tree line. Timing of moult migration varies from year to year, probably depending on the timing of nest initiation (Salomonsen, 1968). However, peak numbers of moulting sea ducks in the southeastern Beaufort Sea generally occur from late July to mid-August (Barry et al., 1981; Johnson and Richardson, 1982; Cornish and Allen, 1983). White-winged scoters (*Melanitta fusca*) are the first to arrive, staging initially in the open water lead off the Mackenzie Delta in June, then moving to the coast as the shorefast ice breaks up (Alexander et al., 1997). They are joined in July by long-tailed ducks, surf scoters (*Melanitta perspicillata*), and more white-winged scoters, as well as by some scaup (*Aythya*) and red-breasted mergansers (*Mergus serrator*) (Barry and Barry, 1982; Alexander et al., 1988; Cornish and Dickson, 1994).

Moulting sea ducks concentrate in sheltered bays and behind barrier beaches and spits, where they feed on invertebrates living both on the bottom and in the water column (Fig. 3) (Cornish and Dickson, 1986; Alexander et al., 1988). The abundance of long-tailed ducks and scoters in a given bay fluctuates annually, probably reflecting local ice conditions (hence availability of food) when the birds first arrive in July (Barry et al., 1981; Cornish and Dickson, 1986). The large concentrations of flightless sea ducks during moult suggest that near-shore areas of the Beaufort Sea are very productive and support high densities of benthic fauna. The exception is the turbid water off the Mackenzie Delta, where few sea ducks occur during moult (Fig. 3).

Fall Migration

The marine water adjacent to the barrier beaches and spits near Herschel Island is a major staging area for the red-necked phalarope (*Phalaropus lobatus*) prior to fall migration. Red phalaropes (*Phalaropus fulicaria*) also occur, but in much lower numbers. The phalaropes are present from late July to early September, but most abundant from early to mid August, when over 50 000 can be counted on a given day (Alexander et al., 1988). They forage for small invertebrates in the water column within a few metres of shore, primarily on the windward side of the beach (Alexander et al., 1988; Rubega et al., 2000).

The build-up of waterfowl along the coast during fall migration is less dramatic than the flocks of thousands of sea ducks seen in the leads in spring. Long-tailed ducks and scoters predominate in the fall, occurring in large, spread-out flocks all along the coast (Alexander et al., 1988). Few eiders are seen moving through the Beaufort Sea, both because their migration is staggered, occurring from June through to November (Barry, 1986; Suydam et al., 1997), and because they tend to migrate farther than 5 km offshore (Dickson et al., 1998). Brant in small groups move westwards along the coast in early September, stopping frequently to feed on vegetation on the tidal flats, river deltas, and lagoons (Alexander et al., 1988).

Glaucous gulls in singles, pairs, and groups of less than 15 are found on barrier beaches and sand spits. Other birds

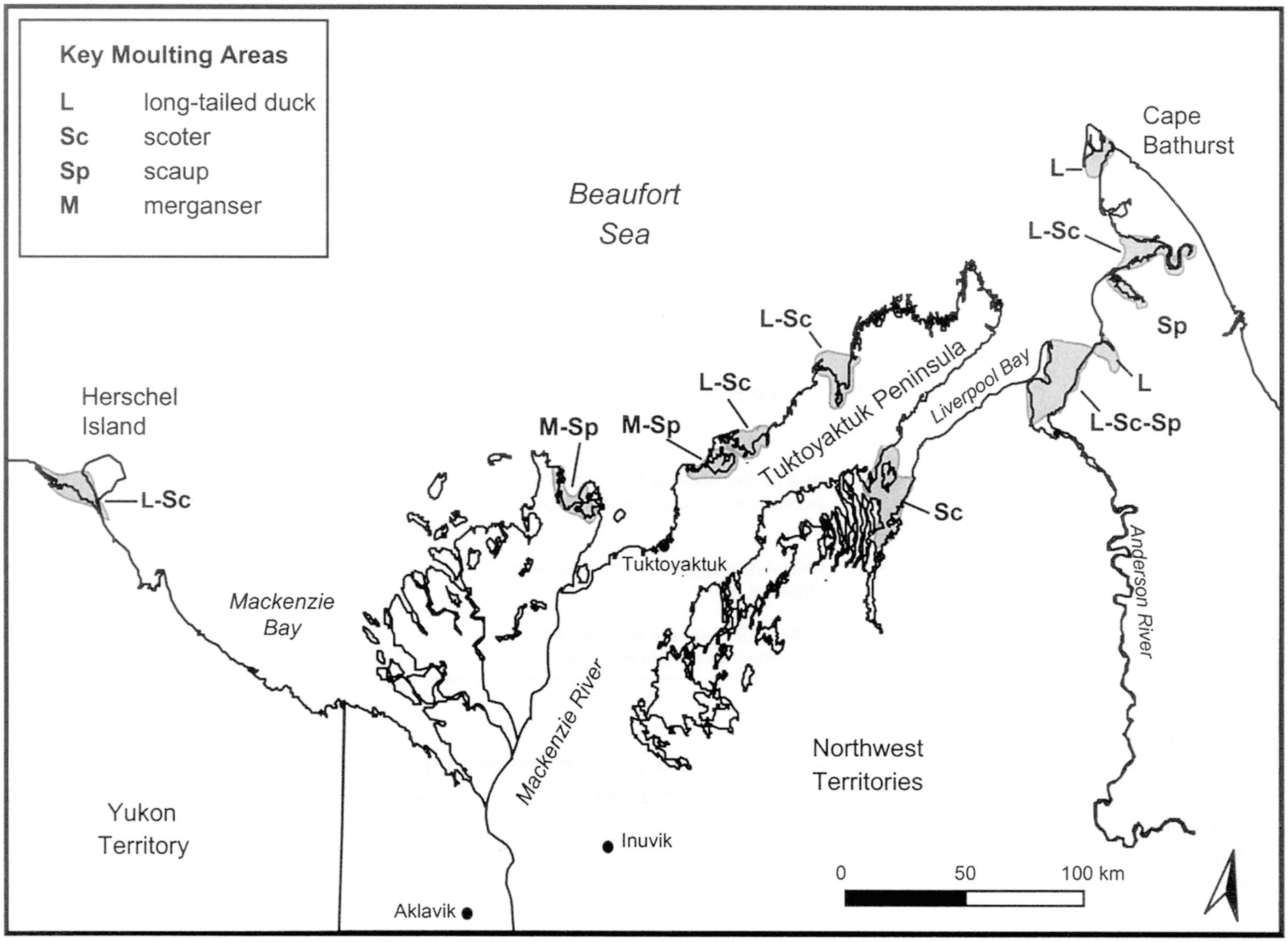

FIG. 3. Key areas for moulting sea ducks in the southeastern Beaufort Sea (after Alexander et al., 1988).

seen along the coastline in late August and September are red-breasted mergansers, scaup, Pacific loons, and red-throated loons (Alexander et al., 1988).

POPULATION SIZE AND TRENDS

Little is known about the population size and trends of marine bird species in the Beaufort Sea, particularly those that are not harvested (e.g., red-throated loon, Sabine's gull, arctic tern). Most studies of birds in the region have been either site-specific or unsystematic, so that it is impossible to extrapolate counts obtained during these studies to estimate population size. There is, however, some information on the population size and trends of bird species that are harvested (Table 1). These data have been gathered either on the nesting grounds, in the wintering area, or during migration, using systematic techniques that allow researchers to extrapolate to the population.

The most effective time to census bird species depends on a number of factors. For example, counts made during migration work reasonably well for the king and common eider, because at certain points during their journey they fly in a narrow band along the coast (Suydam et al., 1997; Byers and Dickson, 2001). The gray-bellied brant of the western High Arctic are counted on their wintering area, which is less remote and thus less expensive to survey than their nesting grounds. For most species, however, winter surveys are confounded by the fact that several breeding populations winter in the same location, and there is no way of distinguishing the different populations. In these cases, the most common method is to census birds on their nesting grounds.

The five most common species of sea duck in western Arctic Canada (long-tailed duck, king eider, common eider, surf scoter, and white-winged scoter) all declined in number by over 50% between the mid 1970s and 1996 (Table 1). This decline has been recorded not only in western Arctic Canada, but in Alaska as well (Hodges et al., 1996). Reasons for the population declines are unknown, but possible causes include over-harvest, declining food supply in shared wintering areas, oiling events, and contaminants (Suydam et al., 2000).

Two types of brant occur in western Arctic Canada: the black brant, which nests on Banks Island, Victoria Island,

TABLE 1. Population sizes and trends for harvested species of marine birds in western Arctic Canada.

Species	Estimated number in western Arctic Canada		Trend	Comments	Source
Pacific brant	Western Arctic mainland	6500	unknown		Wiebe and Hines, 2000
	Banks Island	13000	unknown		Cotter and Hines, 2000b
	Western Victoria Island	1500	unknown		Cornish and Dickson, 1996
Western High Arctic brant		11000[1]	declined since 1960s	Migrate through region to nest in High Arctic	Reed et al., 1998
King eider		356000[2]	56% decline between 1976 and 1996	Includes those that migrate through region to nest in central Arctic Canada	Larned and Balogh, 1997; Suydam et al., 2000
Common eider		70000[2]	53% decline between 1976 and 1996	Majority migrate through region to nest in central Arctic Canada	Johnson and Herter, 1989; Suydam et al., 2000
Long-tailed duck	Western Arctic mainland	45000[3]	51% decline between 1977 and 1996 in northern Yukon and northwestern NWT	Tens of thousands moult along Beaufort Sea coast	Alexander et al., 1988; CWS/USFWS, 1977–96
	Banks Island	4000	unknown		Wilbor, 1999
	Western Victoria Island	12000[4]	limited data suggest a decline between 1980 and 1992		Cornish and Dickson, 1996
Scoter[5]	western Arctic mainland	253000[3]	56% decline between 1977 and 1996 in northern Yukon and northwestern NWT	Tens of thousands moult along Beaufort Sea coast; nest only on mainland	Alexander et al., 1988; CWS/USFWS, 1977–96

[1] Based on winter survey.
[2] Based on count during spring migration at Point Barrow, Alaska, in 1996, less breeding population estimate for northern Alaska.
[3] Estimate for northern Yukon and northwestern Northwest Territories (strata 12, 13, and 14 of North American Waterfowl Breeding Population Surveys) in 1996 (CWS/USFWS, 1977–96).
[4] Applied visibility correction factor of 1.87 to estimate obtained by Cornish and Dickson (1996).
[5] Primarily white-winged scoter and surf scoter.

and mainland areas along the Beaufort Sea coast, and the gray-bellied brant, which migrates through the Beaufort Sea to nest on the High Arctic islands (Reed et al., 1998). Surveys on wintering areas indicate that both black and gray-bellied brant have declined in number since the 1960s (Reed et al., 1998). Within the Inuvialuit Settlement Region, there are population trend data for only one brant colony, the Anderson River colony, which declined from 1200 pairs in the 1960s to fewer than 500 pairs in 1996–98 (Barry, 1967; Wiebe and Hines, 2000). However, preliminary evidence suggests that the decline at Anderson River was due, at least in part, to pairs shifting to another nearby nesting area in western Liverpool Bay (Wiebe and Hines, 2000).

In contrast to sea ducks and brant, several waterfowl species that inhabit primarily freshwater in the Beaufort Sea region are not in decline. Midwinter surveys indicate that the tundra swan (*Cygnus columbianus*) population is stable and the lesser snow goose (*Chen caerulescens*) and Canada goose (*Branta canadensis*) populations are increasing (Anonymous, 1998; Kerbes et al., 1999; Hines et al., 2000). One exception is the greater white-fronted goose (*Anser albifrons*), which may have declined in the western parts of its range in recent years (J. Hines, pers. comm. 2000).

CURRENT THREATS TO BEAUFORT SEA BIRDS

Most marine bird species using the Beaufort Sea are long-lived and slow to reach sexual maturity, and their annual productivity is low and variable (e.g., brant, loons, sea ducks: Barry, 1962; Dickson, 1993; Goudie et al., 1994). These species require a number of years to replace themselves within a population; consequently, their populations are vulnerable to factors that increase adult mortality.

Another factor common to many Arctic marine birds, which also makes them vulnerable, is their tendency to form large aggregations at sea. For example, most years over 20000 common eiders (or over 25% of the total Beaufort Sea population) congregate in open water leads in the ice off Cape Bathurst during spring migration (Fig. 1; Alexander et al., 1997). At this time, a single catastrophe, either natural (e.g., freeze-up; Fournier and Hines, 1994) or human-induced (e.g., oil spill), could destroy a large portion of the total common eider population.

Human activity has the potential to influence the survival of marine birds in several ways. These include 1) direct mortality from hunting, oil spills, or entanglement in fishing nets; 2) habitat degradation through release of contaminants or overexploitation of food resources such as fish, krill, and molluscs; 3) disturbance; and 4) direct loss of habitat to industrial, urban, or recreational development. Several of these factors may affect a population (often at different times during their annual cycle), so that impacts may be cumulative. Indeed, because Arctic marine birds typically migrate to seek open water during winter, it is important to consider the effect of human activity well beyond the Beaufort Sea.

Harvest

Only two marine bird species, the king eider and brant, are harvested in substantial numbers in western Arctic Canada (Anonymous, 1998). Harvest statistics for other marine bird species are low (< 200 per species annually). Thus, the influence of the harvest on all but the king eider and brant is likely negligible.

On average, an estimated 4600 king eiders are harvested annually in the Inuvialuit Settlement Region (Inuvialuit Harvest Study Data for 1988–94, in Fabijan et al., 1997). The only species more heavily harvested in the Region is the lesser snow goose. Most (98%) of the king eider harvest occurs near a single community, Holman, as the eiders fly along the nearshore ice edge during spring migration. A recent three-year study concluded that 4–7% of the king eiders that fly past Holman each spring are harvested (Byers and Dickson, 2001). Comparisons to similar species indicate that this level of harvest is likely close to the maximum sustainable (Byers and Dickson, 2001). However, more information is needed on the survival and recruitment of king eiders to determine the actual sustainable harvest level.

The king eiders that migrate through the Beaufort Sea region moult their flight feathers and winter in the Bering Sea and North Pacific (Dickson et al., 1999). Thus, when examining the effect of harvest, the take in Alaska and Russia must also be considered. The combined harvest of king and common eiders in western Arctic Canada and Alaska is an estimated 22 500 eiders (89% king eiders) (Fabijan et al., 1997). However, no harvest statistics are available for Russia. This is unfortunate, because a recent satellite telemetry study suggests that over half of the king eider stock harvested by the Inuvialuit moults off the Russian coast from August to November each year (60%, n = 16 eiders) (Dickson et al., 1999).

An estimated 500–1000 brant are taken by hunters annually in the Inuvialuit Settlement Region (Wiebe and Hines, 2000). Most of the harvest occurs at Tuktoyaktuk, although a small number of birds are taken near every community. The total annual harvest in Canada, the United States, and Mexico is thought to be less than 12% of the Pacific brant population (Reed et al., 1998). It is unknown whether the present level of harvest is sustainable.

Oil Pollution

Marine birds are vulnerable to oil spills, as evidenced by the 100 000–300 000 birds killed by the *Exxon Valdez* spill off Alaska in 1989 (Piatt et al., 1990). Oil can kill birds either through toxicological effects after ingestion or by matting their feathers, which results in hypothermia and drowning. Cold water and air temperatures heighten the hypothermic effect.

Sea ducks and seabirds are particularly vulnerable to oil spills because they tend to congregate in large flocks at sea. Consequently, even a small spill can affect a large number of birds, as happened when an oil spill of approximately 500 gallons occurred off St. Paul, Alaska in 1996, killing an estimated 2000 king eiders (Fowler and Flint, 1997).

The potential for an oil spill in the Beaufort Sea will increase if offshore oil and gas exploration resumes. Of particular concern is oil in the narrow leads of open water where tens of thousands of eiders and long-tailed ducks congregate during spring migration (Fig 1.). Arguably, it would be impossible to contain an oil spill at any time of year in the Beaufort Sea because of harsh environmental conditions and lack of infrastructure in communities to support clean-up activities. It would be equally difficult to retrieve oiled birds for rehabilitation. Furthermore, typically less than half of oiled birds captured for cleaning survive rehabilitation (Sharp, 1996). Post-release survival is also low (Anderson et al., 1996; Sharp, 1996). For example, Sharp (1996) found that most cleaned common murres (*Uria aalge*) were dead within 10 days of release. Thus, prevention of spills is the only option to protect Beaufort Sea marine birds from oil.

Chronic oil pollution poses a threat to brant on their wintering and staging areas along the west coast of North America, where they share several estuaries with industry and shipping facilities (Reed et al., 1998). However, the number of brant killed annually by chronic oil spills remains unknown.

Climate Change

The temperature in the western Arctic has warmed by about 1.5˚C over the past 100 years, and is predicted to continue to rise by nearly 5˚C over the next 100 years (Maxwell, 1997). This warming is predicted to result in earlier snowmelt, a longer open water season, a rise in sea level, and increased storm surge frequencies. The location and size of polynyas and ice edges will probably shift, as may ocean circulation patterns and primary sources of food for marine wildlife (Roots, 1989; Vinnikov et al., 1999).

It is difficult to predict the positive and negative effects of global warming on marine birds in western Arctic Canada because of our poor understanding of the marine ecosystem. Several Arctic-nesting birds, including brant and red-throated loons, have poor breeding success in years when a late spring thaw delays nesting (Barry, 1962; Dickson, 1992). Should global warming result in fewer late springs, the annual average productivity of these species might increase, assuming that annual snow depth remains constant. A source of mortality for king eiders is the periodic closing of open water leads in the Beaufort Sea during spring migration due to cold temperatures and unfavourable winds (Barry, 1968; Fournier and Hines, 1994). Warmer air and sea surface temperatures could result in fewer years of heavy ice, which might benefit the king eider.

However, the presence of a greater expanse of open water could cause storm tides to occur earlier in the year. A storm tide during incubation would detrimentally affect birds nesting in low-lying areas along the coast. Similarly, the rise in sea level that is predicted (Maxwell, 1997) could increase frequency of flooding of the shallow spits, islands, and river deltas that are important nesting sites for many species. In the long term, there is no guarantee that lost coastal nesting habitat will be replaced, since nesting habitat is determined largely by surficial geology (Boyd and Diamond, 1994).

Further, early melt of sea ice could actually lower feeding opportunities for marine birds that forage on prey associated with pack ice. Among thick-billed murres nesting in northern Hudson Bay, for example, years of early ice melt are associated with a lower proportion of arctic cod and capelin (*Mallotus villosus*) delivered to chicks (Gaston and Hipfner, 1998). Floating ice concentrates prey that feed or shelter below it (Bradstreet and Cross, 1982), and cod and capelin in Hudson Bay may be most accessible to murres when fish concentrate near the surface adjacent to leads in the ice. In years of early ice melt, however, when schooling fish may be dispersed and occur at greater depths, the effort required by murres to capture fish apparently increases (Gaston and Hipfner, 1998).

Similarly, annual reproductive success of black guillemots nesting at Copper Island has declined as the offshore ice edge has retreated north since 1989. As flight distances to feeding areas at the ice edge increased for guillemots, the energetic cost of provisioning chicks increased, while the frequency of feeds to chicks declined. Lower provisioning rates apparently contributed to the slow growth of chicks and higher rates of annual reproductive failure (G. Divoky, pers. comm. 2000).

Warmer sea temperatures have also been linked to mass starvation of over 120 000 common murres (*Uria aalge*) in the Gulf of Alaska. Piatt and Van Pelt (1997) suggest that those birds starved because warmer sea temperatures either killed the forage fish directly or caused fish to move to deeper, cooler water beyond the diving capabilities of seabirds. These are dramatic examples of how small changes in sea temperatures and ice conditions can affect marine ecosystems, although the impacts of warmer sea and air temperatures on pelagic and anadromous fish, as well as those on benthic near-shore fauna in the Beaufort Sea, remain unknown.

Coastal Development

Although there has been little development along the Beaufort Sea coast to date, tourism and offshore oil and gas activity might accelerate development in the near future. Several marine coastal areas warrant protection: 1) islands, spits, and river deltas used for nesting, 2) sheltered bays and lagoons used by moulting waterfowl, and 3) tidal flats and wetlands near the coast used for brood-rearing, moulting, and staging during migration (Figs. 1, 2, and 3).

Coastal development is also a concern for black brant on their wintering and spring staging areas (Ward et al., 1997). Since the 1960s, there has been a major decrease (> 50%) in brant use of the California coastline in spring, which could be a result of increasing human activity there (Sedinger et al., 1994). Recent increased recreational activity in Mexico now threatens critical wintering lagoons used by black brant (Ward et al., 1997).

Contaminants

Pollutants are transported into western Arctic Canada from distant industrial and agricultural regions by ocean currents, air currents, and the Mackenzie River (Hansen et al., 1996). Persistent organic pollutants (e.g., polychlorinated pesticides, polychlorinated biphenyls, and polycyclic aromatic hydrocarbons) and heavy metals (e.g., cadmium, mercury, and lead) are of particular concern (Hansen et al., 1996; Hollmen et al., 1998; Olafsdottir et al., 1998). Both groups bioaccumulate and are generally more threatening to long-lived species occurring near the top of the food chain (Trust et al., 2000). Thus, birds that eat fish, such as the red-throated loon, are more vulnerable than grazers like brant. However, a small sample of red-throated loons (n = 4) and loon eggs (n = 10) was collected in the Beaufort Sea region in the mid 1980s and analyzed for organochlorine residues. Levels of all substances were low, indicating very little contamination (Dickson, 1991). Likewise, no problems have been found in brant (Reed et al., 1998).

Sea ducks are a concern because they eat benthic organisms such as mussels that are filter feeders, known to concentrate pollutants from the water column (Rainbow, 1995). Relatively high levels of mercury, cadmium, and selenium have been found in sea ducks from western Arctic Canada and Alaska (Henny et al., 1995; Trust et al., 2000; M. Wayland, pers. comm. 2000), but it is unknown whether these levels are affecting the survival or productivity of sea ducks (Henny et al., 1995; Kim et al., 1996). Thus, we do not know if recent sea duck declines are related to metals or other contaminants, nor do we know whether sea ducks are accumulating heavy metals in Arctic breeding areas, wintering areas, or both.

CHALLENGES FOR THE FUTURE

Conservation and protection of the migratory bird resource in the Inuvialuit Settlement Region will be challenged as offshore oil and gas exploration and development are resumed, the tourism industry expands, and the local human population grows. Protection of key marine areas could play an important role in maintaining the integrity of the marine ecosystem and thus preserving marine birds. Another key strategy will be for wildlife managers to work closely with resource development industries to ensure that environmental concerns are addressed as the region develops economically.

The challenge of managing the marine birds of the Beaufort Sea will go far beyond the boundaries of the Inuvialuit Settlement Region, since these birds cross several international boundaries as they travel from their nesting grounds to wintering areas. Thus, issues such as over-harvesting of a species or loss of critical habitat will sometimes have to be resolved at an international level. In addition, many of the environmental issues that threaten the future of bird populations, such as global warming and long-range transport of contaminants, are global problems. To solve these issues, numerous countries must develop a mutual understanding of the problems and be committed to take action. Given the diversity of languages and customs of the countries involved, this will be an immense challenge. The Inuvialuit, by initiating and contributing to this workshop on the Beaufort Sea, have demonstrated the interest, willingness, and level of commitment needed to meet this challenge.

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