from wherever the fast ice edge is located in Lancaster Sound or Barrow Strait, and in an easterly direction from M'Clure Strait and Amundsen Gulf. Figure 7.3.1.8 presents the average date of occurrence for each event as well as the range of dates recorded over 13 years (Gorman 1988).

Break-up of the ice cover between each of the geographic locations occurs very rapidly; in the order of days (Dickins 1983; Gorman 1986). In most years, the ice sheet becomes extensively fractured and then breaks into large floes in the order of tens of kilometres (Maxwell 1980).

b) Prince of Wales Strait

Prince of Wales Strait is one of two channels to be used by the Polar 8 to access the Beaufort Sea from Parry Channel. It is a narrow channel, and concerns were raised during the Beaufort EIS over the effect of icebreaking ships on the ice regime of such channels. The ice regime of Prince of Wales Strait and possible effects of ship traffic were the subject of a discussion paper written by Dickens (1983) on behalf of the proponents of the Beaufort Sea development.

The Strait is typically covered by stable landfast ice from late October until mid to late July (Dickins 1983; Gorman 1988). Gorman (1988) reported the average date of fracture was July 15 with a range from July 5 to 28 based on 13 years of data. Dickins (1983) divided the ice regime into north and south sections of the channel, separated by the Princess Royal Islands. Break-up begins in the south section and is extremely variable with up to three weeks between first fracturing and major ice movement (Dickins 1983).

Because the channel is narrow, and there is little fetch for winds to develop except from limited directions, much of the break-up of Prince of Wales Strait results from in-situ melt. Dickins (1983) described large areas of very deteriorated ice in the Strait quickly breaking into floes almost as wide as the Strait itself in a matter of hours. He notes, "It is difficult to imagine a vessel's 50 metre wide track having a major impact on this very dynamic natural process".

c) Sverdrup Basin

With the exception of Eureka Sound, ice break-up in the channels north of Parry Channel within the Sverdrup Basin and adjacent areas, is more limited in extent, and occurs later in the summer. In most years, the fast ice in the most northerly channels opening to the Arctic Ocean, does not break at all, or only fracture and crack to a limited extent.

Figure 7.3.1.8

BREAK-UP SEQUENCE FOR THE PARRY CHANNEL 1974 - 1986

Event		Average Date of Occurrence	Range of Occurrence
1.	Development of Open Water Polynyas off Consolidated Ice Edges.	Early May	Late April - Early June
2.	a)Fracture of Northern Prince Regent Inlet.	June 29	June 17 - July 20
2.	b)c)Fracture of Lancaster Sound.	July 17	July 1 - August 3
3.	Fracture of Amundsen Gulf.	Late June	Early June - Early July
4.	Fracture of eastern Barrow Strait.	July 5	June 20 - July 27
5.	Fracture of western M'Clure Strait.	July 8	June 24 - July 22
6.	Fracture of Prince of Wales Strait.	July 15	July 6 - July 28
7.	Fracture of central Barrow Strait.	July 19	July 3 - August 9
8.	Fracture of Admiralty Inlet.	July 22	July 15 - August 4
9.	a)b)Fracture of western Barrow Strait.	July 25	July 11 - August 10
10.	a)Fracture of Wellington Channel.	July 26	July 8 - August 23
10.	b)Fracture of Peel Sound.	July 26	July 16 - August 10
10.	c)Fracture of McDougall Sound.	July 26	July 16 - August 10
11.	Fracture of central M'Clure Strait.	July 26	July 7 - August 17
12.	a)Fracture of M'Clintock Channel.	July 29	July 16 - August 22
12.	b)Fracture of eastern Viscount Melville Sound.	July 31	July 12 - August 17
13.	a)b)Fracture of eastern M'Clure Strait and western Viscount Melville Sound.	August 2	July 17 - August 17
14.	a)Fracture of southern Byam Martin Channel	August 8	July 20 - August 23
14.	b)Fracture of northern Byam Martin Channel	August 27	August 4 - Sept. 12

The ice regime of the Sverdrup Basin has been described by Markham (1981) and, more recently, using remote sensing information by Canarctic and Norland (1985). In the past four years, much of the area has been covered with airborne radar imagery collected in the winter months as part of the Canadian Arctic Marine Ice Atlas (Canarctic 1988; Canarctic 1989 (in press)).

In the Sverdrup Basin east of Loughheed and Cameron Islands, break-up of the fast ice follows a regular pattern of events, not all of which occur annually. Figure 7.3.1.9 lists the average and range of dates for significant break-up events in the Sverdrup Basin (Canarctic and Norland 1985).

Break-up is initiated from Penny Strait to the south and Belcher Channel to the east. The entire eastern half of the central Sverdrup Basin fractures within a few days to a line between Ellef Rignes and Bathurst Islands. The fracturing separates the fast ice in the Basin from adjoining channels such as Maclean Strait and Hassel Sound, leaving ice bridges across their southern exits. The fracturing results in the formation of giant floes, some of which are tens of kilometres across.

The next break-up event occurs when the western half of the Basin to a line between Lougheed and Cameron Islands fractures within days. Break-up in this area has occurred 8 out of 10 years between 1974 and 1983 (Canarctic and Norland 1985).

Break-up of the fast ice to the west and north of Lougheed Island depends on the break-up of two important ice bridges, one at the north end of Byam Martin Channel between Cameron and Melville Islands and the other in Maclean Strait between Ellef Rignes and King Christian Islands respectively. If either of these bridges breaks, the fast ice to the north in Prince Gustaf Adolf Sea will break. The resulting ice floes, most of which are multi-year ice, move south through these channels. Depending on the timing of break-up and the remaining ice concentrations, the multi-year floes can move south through Byam Martin Channel into Parry Channel.

d) Nares Strait

Nares Strait is one of two approaches to access Alert. The ice regime of Nares Strait has, until recently, been the subject of little dedicated study. Canarctic Shipping is currently preparing a report on the Eastern Parry Channel ice regime which includes a study of Nares Strait (B. Gorman, personal communication).

Figure 7.3.1.9
BREAK-UP EVENTS IN SVERDRUP BASIN
(1974 - 1983)

Event	Average Date (10 year data set)	# Of Years Event Occurs	Earliest/Latest Occurrence	Average 1980 - 1983
1. Penny Strait Bridge Break	July 31 ± 14 days	10	July 18 (1975) August 22 (1974)	July 27 ± 8 days
2. Hassel Sound Bridge Creation	August 3 ± 13 days	10	July 18 (1975) August 23 (1974)	July 28 ± 6 days
3. KCI - Helena Island Bridge Creation	August 6 ± 15 days	10	July 20 (1975) September 1 (1978)	July 28 ± 6 days
4. Maclean Strait South Bridge Creation	August 6 ± 7 days	7	July 27 (1977) August 15 (1976)	July 31 ± 7 days
5. Austin Channel Polynya/Fracture	August 3 ± 16 days	10	July 12 (1975) August 28 (1978)	July 28 ± 9 days
6. Byam Channel Polynya/Fracture	July 31 ± 10 days	10	July 15 (1975) August 18 (1974)	July 26 ± 5 days
7. Break Back to Byam Martin Channel Location	August 13 ± 16 days	9	July 28 (1977) September 17 (1978)	August 7 ± 12 days
8. Byam Martin Channel Bridge Break	August 28 ± 10 days	5	August 20 (1981) September 8 (1980)	August 27 ± 10 days*
9. Hassel Sound Bridge Break	August 16 ± 10 days	6	August 6 (1977) August 30 (1981)	August 17 ± 12 days*
10. Maclean Strait South Bridge Break	August 13 ± 10 days	8	August 3 (1981,1982) August 26 (1978)	August 11 ± 11 days
11. Maclean Strait North Bridge Break	September 9 ± 14 days	7	August 12 (1978) September 24 (1982)	September 14 ± 8 days

* 1 year out of 4 bridges did not break

Source: Canarctic and Norland, 1985

The ice regime has been described by Markham (1981), Lapp *et al.* (1986) and Gorman (1988) for limited periods of the year.

An important feature of Nares Strait is that it is a channel through which multi-year ice floes drift from the Arctic Ocean to northern Baffin Bay, ultimately reaching the eastern entrance to Lancaster Sound. The entire length of the channel becomes fast ice in winter, effectively stopping further southward ice movement until break-up in the spring. At its southern edge, the fast ice is marked by an ice bridge at the south end of Kane Basin in Smith Sound.

Break-up normally begins in the third week of July with the breaking of the ice cover in the southern part of Kennedy Channel (Markham 1981), located in the northern part of Nares Strait. The ice cover remains fast in the more southerly sections until late July to early August (Markham 1981), when the Smith Sound ice bridge fractures. On average bridge fracturing occurs on July 21, and has shown little variation in timing between 1974 and 1986 (Gorman 1988). The remaining sections of fast ice fracture soon after, but throughout the summer ice concentrations remain high, with the continued south movement of old ice from the Arctic Ocean.

7.3.2 Lower Trophic Levels

Marine plants form the basis of Arctic marine food chains that eventually lead to vertebrates that are VEC's (Valued Ecosystem Components). The small free floating plants of the phytoplankton make the largest contribution to the Arctic primary plant productivity (LGL 1983). Production by large benthic plants is relatively unimportant. Arctic primary productivity is very low compared to most of the world's oceans (Subba Rao and Platt 1984). Productivity is higher in fiords and bays than in offshore waters (Subba Rao and Platt 1984). Most plant productivity occurs in the 5 months or less of the short Arctic spring and summer. Marine plants are not valued ecosystem components in themselves. Disruption of primary productivity that affected zooplankton, fish, birds and marine mammals would be significant but unlikely.

Small herbivorous copepods usually dominate the Arctic zooplankton (Figure 7.3.2.1; Buchanan and Sekerak 1982; Longhurst *et al.* 1984; Bradstreet *et al.* 1987). Because the period of primary productivity is short, copepods have only a short period in which to store energy for the coming winter. Copepods are fed upon by larger carnivorous zooplankters. The bowhead whale, Arctic cod and some seabirds feed almost exclusively on zooplankton. For other species,

Figure 7.3.2.1
ARCTIC COPEPODS ARE THE MAIN LINK BETWEEN PRIMARY PRODUCERS AND HIGHER TROPHIC LEVELS.

Source: D. Thomson, LGL Limited

zooplankton is an intermediate step in the food chain between plants and vertebrates. Zooplankton is not a valued ecosystem component *per se* but is considered important as the basis of food chains leading to VEC's.

In spring, phytoplankton populations develop in the soft porous layer of ice on the underside of sea ice. Overall, the productivity of ice phytoplankton may be only about 3% of the total Arctic primary productivity (Subba Rao and Platt 1984). In some local areas, productivity of the ice algae could equal that of the pelagic phytoplankton (Smith *et al.* 1988). The algal layer begins to develop in April, peaks in May and then disintegrates (Cross 1987; Smith *et al.* 1988). The underice phytoplankton supports populations of invertebrates, especially amphipod crustaceans (Figure 7.3.2.2; Cross 1982; Gulliksen 1984; Cross and Martin 1987). The underice biota is not a valued ecosystem component on its own account. The ice biota of areas adjacent to springtime ice edges is a part of the ice edge community that includes birds, mammals and resource harvesting. This ice edge community is a valued ecosystem component (see Section 7.3.6).

7.3.3 Fish

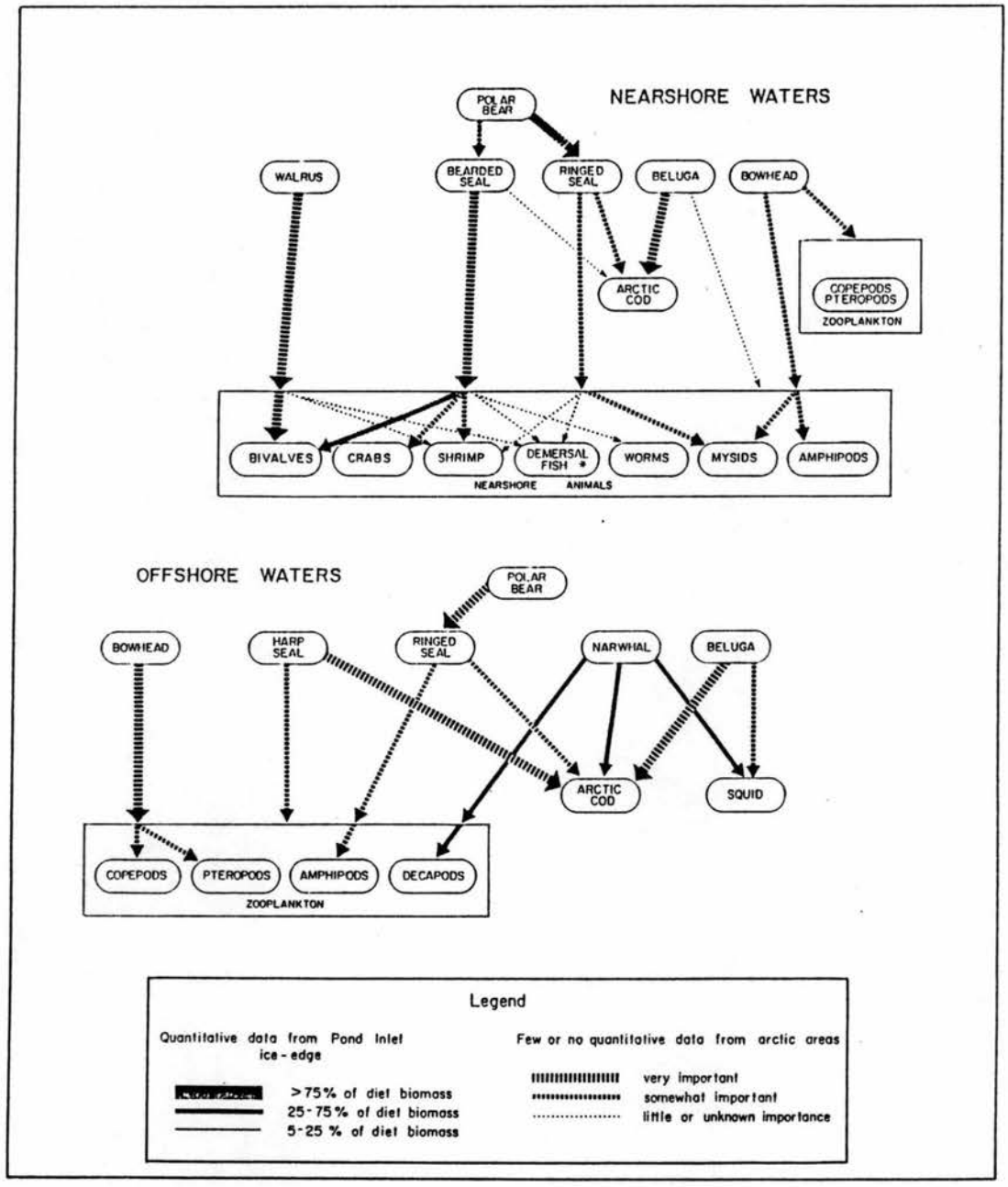
Most Arctic fish species are small, bottom dwelling, cryptic benthic forms that do not feed high in the water column. The most important pelagic species are Arctic cod, Arctic char and the ciscos and whitefish. Arctic cod are the most abundant pelagic fish and are a major vector for the transfer of energy from lower trophic levels to higher trophic levels (Figures 7.3.3.1 and 7.3.3.2; Bradstreet *et al.* 1986). Arctic cod are closely associated with ice (Cross 1982; Lonne and Gulliksen 1989). Arctic cod are a major food source for narwhal, beluga, harp seal, ringed seal, and numerous species of seabirds (Bradstreet *et al.* 1986). Because of its importance in Arctic food chains, the Arctic cod is a valued ecosystem component.

Anadromous fish such as Arctic char winter in rivers, lakes and streams, migrate to the sea in spring and summer and return to fresh water in winter. While at sea, Arctic char do not normally travel more than 150-300 km from their natal rivers and are generally restricted to shallow nearshore waters (within 100's of m of shore; Johnson 1980). At sea, the anadromous corregonids (ciscos, whitefish) remain in very shallow freshened waters within 100's of meters of shore (Craig 1984; Norton 1989). Anadromous fish are valued ecosystem components. They are harvested for subsistence and in commercial fisheries. In some areas, a tourist industry is based on fishing for Arctic char.

Figure 7.3.2.2
AMPHIPODS ON THE UNDERSURFACE OF THE ICE IN SPRING.

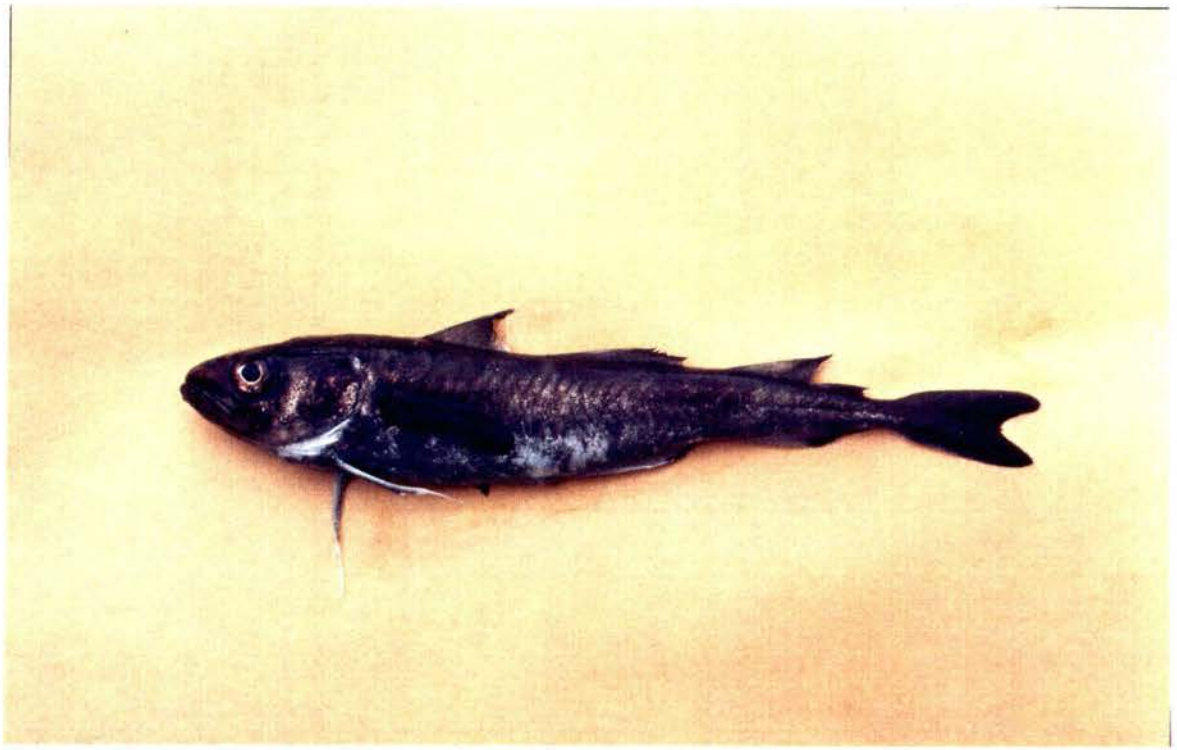
Source: W.E. Cross, LGL Limited

Figure 7.3.3.1
TROPHIC RELATIONSHIPS OF MARINE MAMMALS IN THE CANADIAN ARCTIC.



Source: Davis et al., 1980

Figure 7.3.3.2
ARCTIC COD ARE A MAJOR FOOD SOURCE FOR BIRDS AND MAINE MAMMALS



Source: D.H. Thomson, LGL Limited

7.3.4 Birds

During the open water period, sea-associated birds are abundant in many parts of the Canadian Arctic. Marine birds tend to be highly gregarious, nesting in large colonies, that often include a mixture of species. Major marine bird colonies are located on cliffs in areas where open water is accessible early in the spring. Such conditions exist primarily in the eastern Canadian Arctic and, for that reason, the major Canadian Arctic marine bird colonies are located there. Lancaster Sound, the entrance to the Northwest Passage, and Hudson Strait, the entrance to Hudson Bay, are well known for their large colonies of marine birds. During spring, marine birds concentrate in enormous numbers along floe-edges in Barrow Strait and Lancaster Sound (McLaren 1982). High densities also appear in waters surrounding colonies and in certain other coastal areas. The majority of marine birds vacate Arctic waters by early October as freezeup progresses.

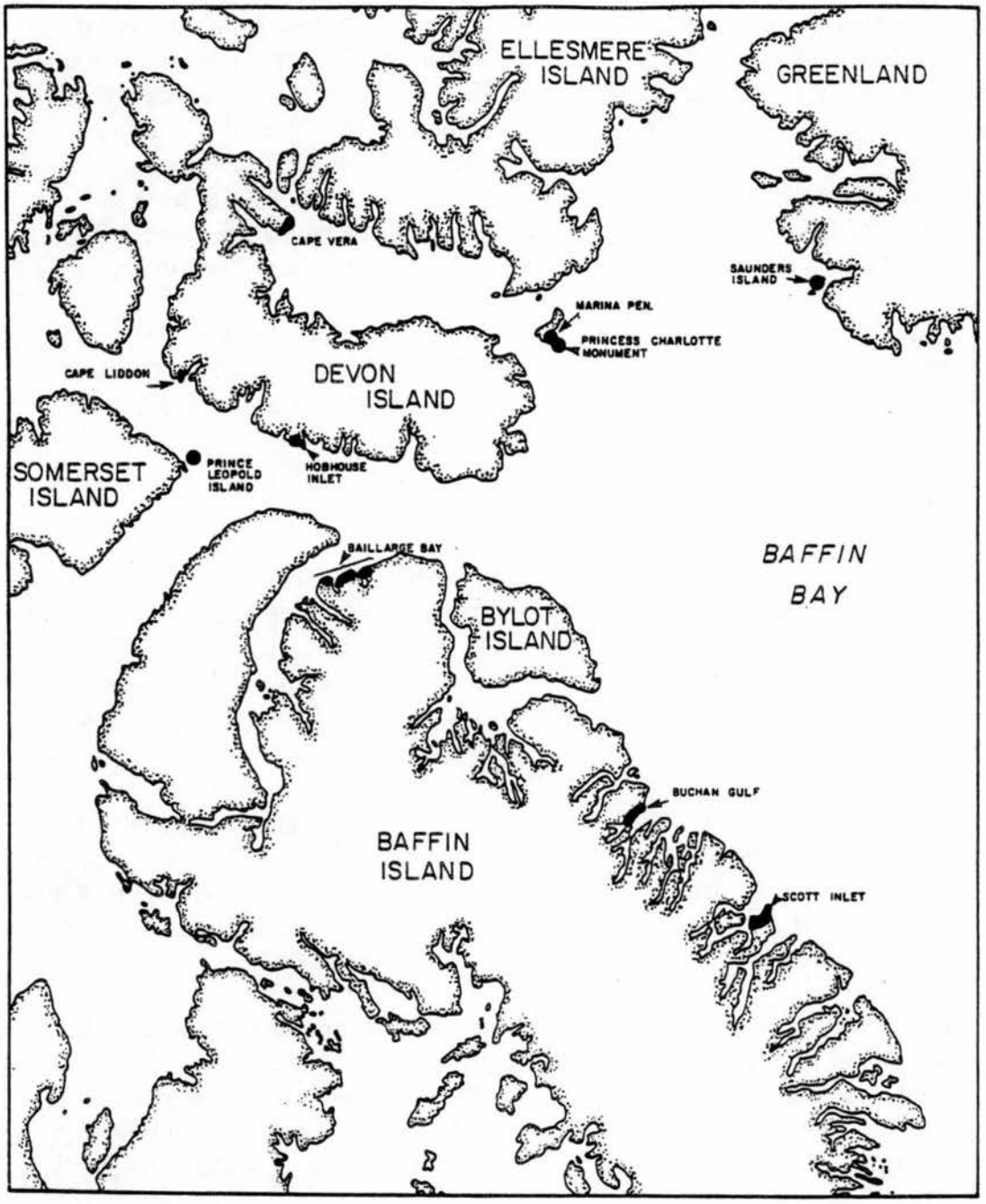
Approximately 25 species of birds regularly use the marine waters of the Northwest Passage area. However, several of these occur in small numbers and are at the peripheries of their ranges. The most important species are briefly reviewed below.

7.3.4.1 Northern Fulmar

Fulmars are present in the eastern half of the Northwest Passage by late April and remain until October. They have very long nesting cycles and are present at colonies for nearly four months. Several major fulmar colonies occur in the study area (see Figure 7.3.4.1; Nettleship 1980). Colonies at Baillarge Bay (25,000 pairs), Hobhouse Inlet (75,000 pairs), Cape Liddon (10,000 pairs) and Prince Leopold Island (62,000 pairs) in central and western Lancaster Sound contain a total of about 172,000 pairs (Nettleship 1980). Fulmars in Jones Sound (Cape Vera-25,000 pairs; Coburg Island-two colonies, 3,000 pairs) presumably also pass through the study area on migration. Two additional colonies (each with 25,000 pairs) are known on the east coast of Baffin Island within 200 km of Bylot Island. Thus, over two-thirds of the Canadian fulmar population may occur within the eastern Northwest Passage during the course of a single season.

Major concentrations of feeding fulmars occur along the coast of southeast Devon Island (Johnson *et al.* 1976a). Many tens of thousands of fulmars are concentrated in this area from mid July to mid September and birds from several colonies may be involved. It should be noted that each of the three nearest colonies (Coburg Island, Hobhouse Inlet and Baillarge Bay) is about 150 km from this important feeding area.

Figure 7.3.4.1
NORTHERN FULMAR COLONIES IN THE LANCASTER SOUND – NW BAFFIN BAY AREA.



7.3.4.2 Waterfowl

Three species of sea-associated ducks are common in the Northwest Passage region: oldsquaw, common eider and king eider. These species are primarily coastal in distribution, but also occur along fast ice edges when these are over relatively shallow waters. At certain times of the breeding cycle (brood-rearing and moulting) these species are flightless, and hence entirely dependent on coastal marine areas (Davis *et al.* 1975; Johnson *et al.* 1976a; McLaren and Renaud 1979). The oldsquaws and eiders return to the High Arctic in May and June and most have returned south by late September.

The numbers of ducks using the study area are not known. The population of oldsquaws is thought to be typical of most eastern Arctic waters. Several tens of thousands of eiders use Lancaster Sound as a migration route (McLaren and Renaud 1979). It is probable that a significant portion of the common eiders in the Canadian Arctic use the eastern Northwest Passage during migration. Several coastal concentration areas have been documented in spring as have moulting areas in summer.

In addition to the three common species of ducks, the greater snow goose and brant goose occur in the High Arctic. These two geese nest in the High Arctic and feed and rear their young on coastal plains. On many occasions flocks of these geese use coastal marine waters, particularly in August and September.

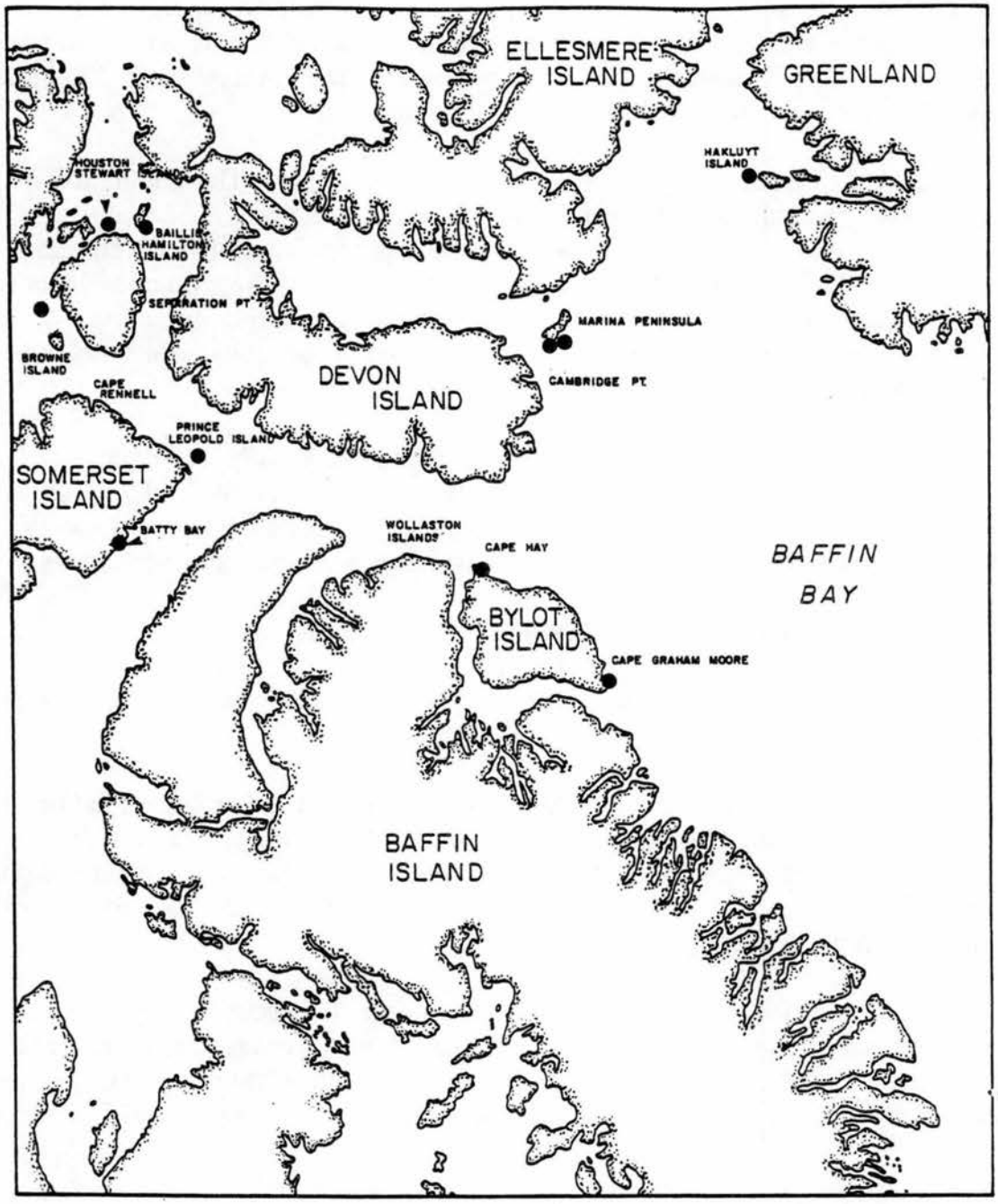
7.3.4.3 Black-legged Kittiwake

This small gull is pelagic and comes to land only to nest on cliffs at colonies of moderate size.

The largest kittiwake colonies in eastern North America are at Cape Hay on NW Bylot Island (20,000 pairs), at Prince Leopold Island in western Lancaster Sound (29,000 pairs) and at Coburg Island (30,000 pairs) in the entrance to Jones Sound (Figure 7.3.4.2). Other smaller colonies (fewer than 3,000 pairs) are found in the eastern Northwest Passage region (Nettleship 1980).

Kittiwakes concentrate in waters near colonies and also occur in large numbers with the fulmars along the coast of SE Devon Island. Throughout August and September, kittiwakes are common in both coastal and offshore waters. Migration peaks by late September and most have left the High Arctic by mid October.

Figure 7.3.4.2
BLACK-LEGGED KITTIWAKE COLONIES IN THE LANCASTER SOUND - NW BAFFIN BAY AREA.



7.3.4.4 Thick-billed Murre

The thick-billed murre is a diving species that winters off southwest Greenland and off Newfoundland. The species returns to the High Arctic in May and June when dense concentrations can be found along some ice edges (*cf.* Bradstreet 1980). The thick-billed murre feeds by diving from the water surface and during the brood-rearing phase both the adults and chicks are flightless. In fact, the first part of the autumn migration is undertaken by swimming rather than by flying.

Thick-billed murres nest in colonies on narrow ledges on precipitous cliffs (Figure 7.3.4.3). Major colonies of thick-billed murres occur at Cape Graham Moore, SE Bylot Island (about 25,000 pairs); Cape Hay, NW Bylot Island (140,000 pairs); Prince Leopold Island, W Lancaster Sound (86,000 pairs) and Coburg Island (160,000 pairs) (Nettleship 1980). In addition, there are five colonies in NW Greenland (between 76°N and 77°30'N) that contain a combined total of over 600,000 murres. There is a possibility, in autumn, that many of these Greenland birds migrate through the entrance to Lancaster Sound and then south along the west side of Baffin Bay where they would be swimming with the south-flowing current.

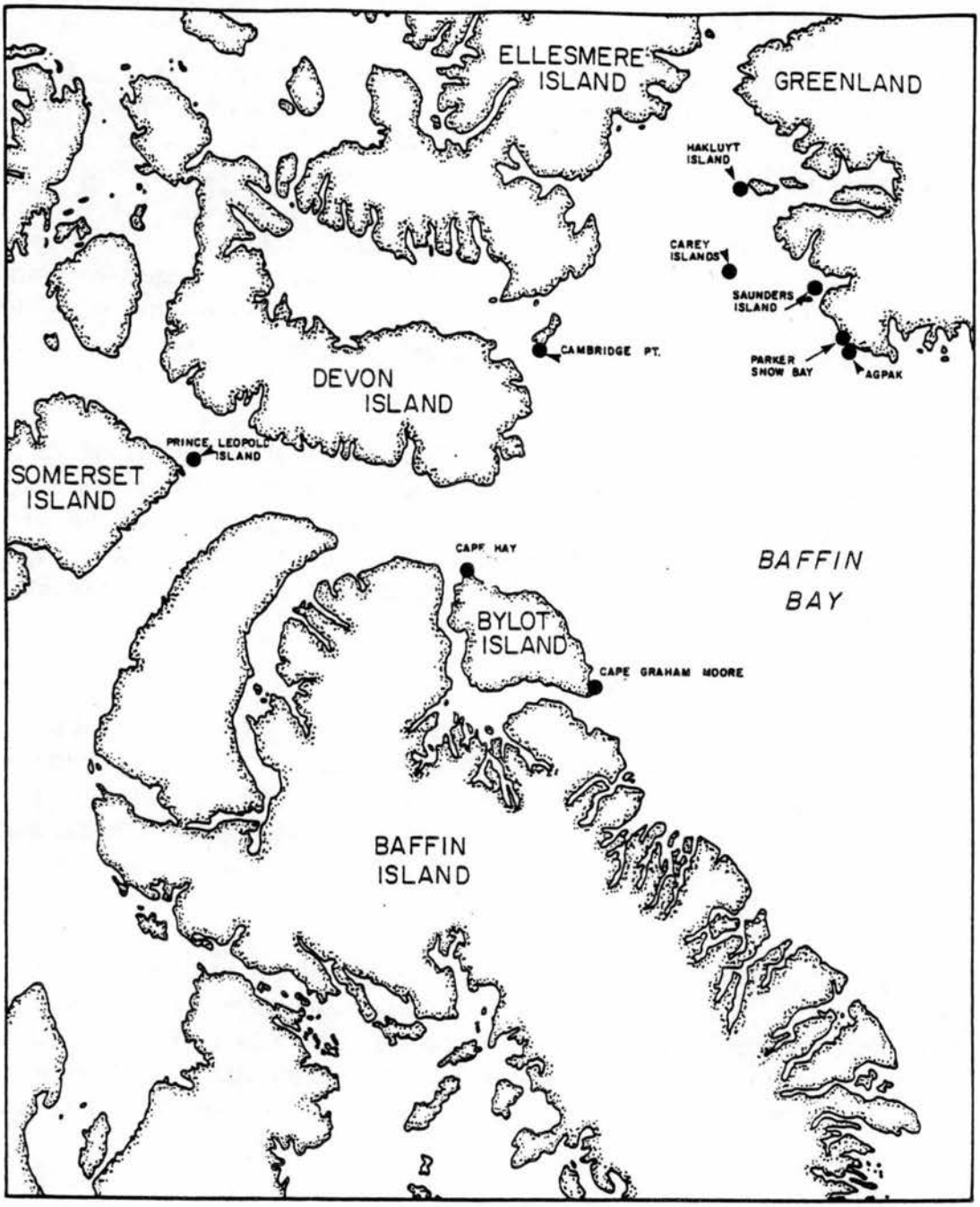
Concentrations of feeding murres have been found along fast ice edges and in waters within 50 km of major colonies. However, the species remains relatively common in other offshore areas and the factors influencing the distribution of feeding birds are not well understood. For example, in the central Arctic major feeding concentrations of murres occur in areas 150 km from nesting colonies.

7.3.4.5 Dovekie

This small auk is an extremely abundant nesting bird along the west coast of Greenland, north of 76°N. The available evidence suggests that in September and October these birds cross from Greenland to NW Baffin Bay and migrate through the eastern Northwest Passage and thence south along the east coast of Baffin Island. This pattern may be related to the affinity of this species for floating ice (APP 1982).

The spring distribution and movement patterns of dovekies are poorly known but large numbers may occur in the eastern study area. An estimated 1.5 million dovekies were present in eastern Lancaster Sound in May 1976, but these birds were only present for about two weeks (LGL Ltd., unpubl. data). In 1978, an estimated 14,000,000 dovekies were present in easternmost Lancaster Sound and northwest Baffin Bay on 14-18 May (McLaren and Renaud 1979).

Figure 7.3.4.3
THICK-BILLED MURRE COLONIES IN THE LANCASTER SOUND - NW BAFFIN BAY AREA.



7.3.4.6 Black Guillemot

This coastal species of auk nests in loose colonies and aggregations on coastal cliffs and talus slopes along Devon, Baffin and Bylot Islands. The species is present as early in the spring as April and, in fact, winters in Arctic areas in open water (Renaud and Bradstreet 1980). The major influx in spring occurs in May.

Guillemots are usually found in waters adjacent to coasts and landfast ice edges. However, aerial surveys in May reveal that guillemots are common among pack ice in offshore waters of eastern Lancaster Sound at that time (APP 1982). It is probable that most of the black guillemots from the central Arctic islands migrate through Lancaster Sound into Baffin Bay in fall.

7.3.4.7 Other Species

Several other species of birds are expected to be moderately common along coasts or in offshore waters of the Northwest Passage region. These include red-throated loon, red phalarope, pomarine jaeger, parasitic jaeger, long-tailed jaeger, glaucous gull, Thayer's gull, ivory gull and Arctic tern. Tide-flats, beaches and estuaries are used by several species of sandpipers and plovers. The most common of the above species are the glaucous gull and Thayer's gull which nest in many small coastal colonies throughout the eastern High Arctic. These colonies usually occur on cliffs and usually contain a few tens to a few hundred pairs.

7.3.5 Marine Mammals

Marine mammals are a significant component of Arctic marine ecosystems. Three main groups, seals, whales and polar bears, are represented by eight common species in Canadian Arctic waters. Only two of these, the ringed seal and polar bear, are year round inhabitants in areas of solid fast ice; the others undergo seasonal migrations in response to the advance and retreat of sea ice.

7.3.5.1 Seals and Walruses

Ringed seals are the most widespread and abundant marine mammal in Arctic waters. Because of their ability to maintain breathing holes in solid ice, they are the only seals that regularly inhabit areas of fast ice throughout the year. Densities of ringed seals are highest in fast ice in coastal areas but they also

inhabit drifting pack ice, which, because of its vast area, probably supports much larger populations overall, than areas of fast ice (Finley *et al.* 1983a,b). Ringed seals are the single most important species in the subsistence economy of the Inuit and they are also the principal prey of polar bears. Ringed seals give birth in March and April to single pups in birth lairs hollowed out of snow on the sea ice. Birth lairs are located in areas of stable ice with relief features that are sufficient to cause accumulations of drifting snow (Hammill and Smith 1988). During June and July, ringed seals haul out on the surface of the ice for long periods during their annual moult (Finley 1979). During the summer, ringed seals may undertake migrations to remain in areas where ice persists longer and to locate favourable feeding areas. In the Northwest Passage area, ringed seals are usually restricted to open water from late July until early October (Figure 7.3.5.1).

Bearded seals are large solitary seals that are distributed throughout the Arctic in relatively low densities. Because they have only a limited capability to maintain breathing holes in ice, bearded seals are excluded from areas of fast ice (e.g., many of the channels in the Arctic Archipelago) during winter. Bearded seals, therefore, undertake seasonal migrations in response to the advance and retreat of fast ice. Limited numbers of bearded seals overwinter in polynyas (Cleator *et al.* 1989). The bearded seal is a benthic feeder that is most abundant in areas where it can reach the bottom to feed and where it has access to ice pans upon which to haul out (Burns and Frost 1979, Finley and Evans 1983). Bearded seals have traditionally played a significant role in the Inuit subsistence economy, particularly valued for their thick skins which were used for many purposes, but also in some regions for their meat. The annual harvest of bearded seals is only a small portion of the ringed seal harvest (Smith 1981, Donaldson 1988).

The **harp seal** is a gregarious species that whelps in large congregations on pack ice fields off southern Labrador and in the Gulf of St. Lawrence in March. The older seals undertake long migrations to feed in Arctic waters during the summer (Sergeant 1973). Harp seals are found from late June to early October in the eastern Canadian High Arctic. Relatively small numbers of harp seals are harvested by Inuit in the Canadian Arctic (Donaldson 1988).

Walruses occupy a discontinuous circumpolar range in a number of sub-populations. The Atlantic subspecies is the only group that regularly occurs in the Canadian Arctic and it is most numerous in the northern waters of Hudson Bay, Foxe Basin and Hudson Strait (Mansfield 1973). Although walruses are widespread in the eastern Canadian Arctic waters, they are clumped in abundance in a few areas where favourable habitat occurs. Two major factors

Figure 7.3.5.1
RINGED SEAL IN THE WATER. RINGED SEALS ARE THE MOST ABUNDANT AND WIDESPREAD MARINE MAMMAL IN THE CANADIAN ARCTIC.

Source: R.A. Buchanan, LGL Limited

influencing their distribution are water depth and sea ice (Lowry 1985). Since they are benthic feeders, walruses are most abundant in shallow waters (i.e. usually < 100 m) and where they have access to ice pans on which to haul out. If sea ice is unavailable during summer, walruses use traditional terrestrial haul-out sites (Salter 1979). Walruses cannot overwinter in areas of solid ice and must make seasonal movements to areas of pack ice. Some walruses in the High Arctic overwinter in polynyas (Davis *et al.* 1978, Kiliaan and Stirling 1978). The walrus population in the Canadian High Arctic is small, 1,000-2,000 (Davis *et al.* 1978).

7.3.5.2 Polar Bear

Polar bears are distributed throughout the Arctic in a number of relatively discrete sub-populations (Stirling *et al.* 1984). The polar bear is highly dependent on ringed seals; its distribution and abundance is strongly influenced by its principal prey (the seal) and on the distribution and quality of sea ice. During winter and spring, polar bears tend to concentrate along pressure ice that parallels the coasts and in the vicinity of floe edges where they are able to hunt seals most effectively in areas of thin ice (Stirling *et al.* 1984). During the short open-water season bears are land bound (Stirling 1974). The patterns of seasonal movements vary from year to year, depending on the consistency of ice formation, dispersal and distribution.

In December, pregnant females give birth in snow dens in coastal areas. In some areas such as Hudson Bay, maternity denning areas are concentrated, but throughout the Arctic Archipelago denning habitat appears unlimited and denning occurs at low densities. In late March and early April, females with cubs return to the sea ice to hunt seals, usually concentrating in places where ringed seals are pupping (Davis *et al.* 1980).

7.3.5.3 Whales

The **white whale** or beluga (Figure 7.3.5.2) is a toothed whale that occupies a discontinuous range in the North American Arctic. The population that occupies the High Arctic numbers from 10,000-14,000 individuals (Davis and Finley 1979). These animals winter in loose pack ice along the west coast of Greenland, south of Disko Island (McLaren and Davis 1982). In spring, the whales move north along the coast of Greenland. They cross Baffin Bay and enter Lancaster Sound from the northeast in June or early July (Davis and Finley 1979). In addition, a few hundred white whales winter in the Baffin Bay North Water (Finley and Renaud 1980) and may enter Lancaster Sound in late April or early May. During

Figure 7.3.5.2
WHITE WHALES

Source: D.H. Thomson, LGL Limited

both spring and fall migrations, white whales are often found in large herds of up to several hundred animals (Koski and Davis 1979, 1980). During spring migration, white whales often encounter fast ice edges across channels where they will eventually summer. In these circumstances, large concentrations of white whales can occur along these ice edges (Finley *et al.* 1983a, 1984).

During the early open water period from late July to late August, white whales concentrate in large herds of several thousand animals in a restricted number of shallow estuaries (Finley 1976; Smith *et al.* 1985). The major estuaries regularly used in the High Arctic are Cunningham Inlet and Creswell Bay on Somerset Island. Other bays used include Batty Bay, Elwin Inlet, Garnier Bay and Radstock Bay. After leaving the estuaries in August, white whales roam the channels of the central High Arctic probably is search of large schools of Arctic cod (Finley and Johnston 1977).

The fall migration of white whales is rapid and occurs in mid to late September. The animals leave the central Arctic by swimming along the south coast of Devon Island before turning north and eventually east to retrace the spring route to west Greenland (Davis and Finley 1979; Koski and Davis 1979, 1980).

Narwhals inhabit Arctic seas bordering the North Atlantic Ocean. Like their relative, the white whale, they are seldom found far from pack ice. The narwhal winters in very heavy pack ice throughout northern Davis Strait and southern Baffin Bay (McLaren and Davis 1982). In spring, the animals move north through the loosening pack ice and enter the Northwest Passage and adjacent channels in late June and July (Koski and Davis 1979; Koski 1980). Narwhals summer in deep channels in the High Arctic with individuals and groups widely dispersed over large areas (e.g., Johnson *et al.* 1976b; Fallis *et al.* 1983).

A variety of estimates of population size have been made in recent years. Davis *et al.* (1978) estimated that the narwhal population in the Canadian High Arctic numbered 20,000-30,000 animals. Smith *et al.* (1985) covered part of the summering areas and estimated a population of 13,200-18,000 narwhals. Koski and Davis (1980) surveyed narwhals in Baffin Bay in late spring and estimated a population of about 30,000, most of which would summer in the Canadian High Arctic.

The **bowhead whale** is an ice-adapted baleen whale that is widely distributed in the Arctic. The bowhead is a large, slow-moving whale that was severely reduced by intensive commercial whaling (Ross 1979). Two stocks are relevant to the present document. The Bering Sea stock of bowheads summers in the Canadian Beaufort Sea and Amundsen Gulf (Mitchell and Reeves 1986). The Davis Strait

stock winters in the loose pack ice of Davis Strait (and possibly Hudson Strait) (McLaren and Davis 1982). These latter animals summer in the channels of the central High Arctic and in fiords along the east coast of Baffin Island (Koski and Davis 1979). The Davis Strait stock of bowheads is considered to be endangered with a present population of only a few hundred animals (Davis and Koski 1980; Finley in press). The only known, regularly-used site-specific concentration area for this population is the Isabella Bay area along the east coast of Baffin Island (Finley *et al.* 1986).

7.3.6 Ice Edges

An underice community of plants and animals is a universal feature of springtime sea ice in the Arctic and elsewhere. The underice biota is accessible to birds and mammals at ice edges. The accessibility of the underice biota to vertebrate predators can lead to very high concentrations of sea-associated birds and marine mammals along fast-ice edges in spring (Alliston *et al.* 1976; Johnson *et al.* 1976a,b; McLaren and Reneaud 1979; Bradstreet 1980). Birds concentrate along the ice edge to feed on invertebrates and Arctic cod that are associated with the underice biota (Figure 7.3.6.1; Bradstreet 1980, 1982; Bradstreet and Cross 1982; Cross 1982). The concentrations of marine mammals, primarily white whales and narwhals, that occur along ice edges represent animals waiting to migrate through the ice to summering areas. There is little marine mammal feeding that is directly associated with the ice edge (Bradstreet 1982; Finley and Gibb 1982; Finley and Evans 1983). Spring time ice edges are an important habitat for vertebrate migrants and are a valued ecosystem component.

7.3.7 Polynyas

Polynyas are areas of open water surrounded by ice. Extensive and recurring polynyas are found in the North Water in northern Baffin Bay and off Cape Bathurst in the Eastern Beaufort Sea. Other smaller polynyas may be found throughout the Arctic (see Stirling and Cleator 1981 for a review and figure 7.3.1.3). These areas of open water and adjacent thin ice remain throughout the winter. Some polynyas are important overwintering habitats for some species of marine mammals (Finley and Renaud 1980; Renaud and Bradstreet 1980; Stirling *et. al.* 1981). Polynyas and other areas of open water allow returning migrant seabirds early access to areas of open water for feeding and many seabird colonies are located near recurring polynyas (Brown and Nettleship 1981; Bradstreet 1988).

Figure 7.3.6.1
THICK-BILLED MURRES CONCENTRATE AT ICE EDGES IN SPRING.

Source: D.H. Thomson, LGL Limited

7.3.8 Inuit Resource Harvesting

Inuit resource harvesting patterns are naturally closely tied to the biology and distribution of the animals that are hunted.

7.3.8.1 Marine Mammals

The harvesting of marine mammals is the foundation of the Inuit subsistence, economy and culture, and is likely to remain so in the foreseeable future. In the past, the economic value of marine mammals was measured primarily in terms of food and raw materials, and although this is still largely the case, increased Inuit participation in a cash economy has resulted in a monetary value for some products such as ivory (narwhal and walrus) and skins (polar bear, seals).

Hunting techniques and harvesting patterns have undergone drastic changes in the past few decades due to major socio-economic changes and the acquisition of new technologies (Freeman 1976, Finley and Miller 1982). In particular, the centralization of Inuit in villages, which was completed in the mid-1960's, and the use of snowmobiles and more powerful boats have greatly affected resource harvest patterns. Although Inuit hunting territories have generally shrunk in overall area since the people became centralized in settlements, the range and efficiency of individual hunters has increased rapidly with the acquisition of powered vehicles. Local overexploitation of wildlife due to technological advances has encouraged the expansion of hunting territory and the development of "outpost camps". A brief description of modern hunting techniques and harvest patterns is necessary in order to evaluate the potential impacts of the Polar 8 on resource harvest activities.

A large proportion of Inuit hunting occurs in the marine environment and much of it is conducted from the sea ice platform (Figure 7.3.8.1). Inuit traditionally have had an intimate knowledge of the dynamics of sea ice and its role in determining the distribution and abundance of marine mammals, particularly ringed seals. Different hunting techniques are required for different species and environmental circumstances.

The ringed seal is, by far, the single most important species in the subsistence and commercial economy of the Inuit. Widespread and abundant, the ringed seal is available year round and provides a dependable source of food. About 60,000 ringed seals are harvested annually; this represents nearly 90% of the harvest of all seal species taken by Canadian Inuit (Malouf 1986). Inuit knowledge of sea ice conditions allows efficient utilization of those areas most likely to contain high

Figure 7.3.8.1
A SEAL HUNT ON THE ICE.

Source: K.J. Finley, LGL Limited

densities of seals. Ringed seals are not equally accessible under different ice conditions and hunters have learned to concentrate their efforts in certain areas such as flaw-lead zones, ice edges and tidal cracks where favourable ice conditionsprevail (Polar bears utilize similar hunting strategies). The situation of traditional Inuit habitations in coastal areas usually reflects the availability of such favourable ice conditions; many productive Inuit campsites, such as those on Baffin Island, were located near flaw-lead or floe-edge zones. These ice conditions are recurrent features dependent on coastal topography, currents and winds.

Hunting patterns and techniques for ringed seals change with the seasons as ice conditions change. During freeze-up in October and November, ringed seal hunting is restricted to the near-shore vicinity of settlements where seal breathing holes are fairly easy to locate in areas of thin ice. Seal catches decline during the winter as ice and snow cover thickens; during this period the majority of seals are taken in ice cracks and in flaw leads where ice cover is thinner and seal holes are easier to locate. As light levels increase in late winter, the Inuit hunting range tends to expand as local hunting grounds become overexploited and hunters undertake longer trips in pursuit of polar bears and other wildlife. From early April (when seal pups are born) until June, most hunting effort is directed toward young seals which are found in snow lairs that are usually located in areas of hummocky fast ice. In late May and in June, ringed seals haul out on the fast ice to moult, and hunting is especially productive as hunters can approach on snowmobiles and shoot basking seals. From 16-25% of the total annual catch of seals in Baffin Island communities is taken in May and June (Haller *et al.* 1967, Finley and Miller 1980, Donaldson 1988) but in the western Arctic this portion may be as high as 51% (Smith 1987).

The peak of Inuit harvest of ringed seals occurs in the open-water season from July to October when 37 - 49 % of the total annual catch is taken (Haller *et al.* 1967, Finley and Miller 1980, Smith 1987, Donaldson 1988). The majority of seals taken during the open water season are shot from outboard-powered boats in protected coastal waters near settlements and outpost camps (Finley and Miller 1980, Bradstreet *et al.* 1985). In many coastal settlements of the eastern Canadian Arctic, the open-water catch of ringed seals is supplemented by migrant seals abandoning offshore areas as pack ice disperses (Finley *et al.* 1983).

Polar bears naturally tend to occur in the same areas where Inuit hunt seals, so to some extent the hunting patterns for bears are similar to those for seals. However, polar bears occur in low densities, requiring hunters to range farther from the settlements. Snowmobiles are used to hunt polar bears and the majority are killed between January and May. Although wide ranging, polar bears tend to

concentrate in late winter in areas where seals are most accessible such as flaw lead zones and polynyas. The polar bear harvest is closely regulated through a community quota system and the kill distribution patterns are quite well known (Stirling *et al.* 1984). There is a limited sport hunt for polar bears .

Most of the migratory species (bearded and harp seals, walruses, narwhals and white whales) are taken during the open-water season from July to October. Spring floe-edge hunting for narwhals, white whales and walruses is an important mode of hunting for many eastern Arctic settlements (Kemp 1976, Finley *et al.* 1980, Finley and Miller 1982). As the fast ice disperses from coastal areas during July, hunters use boats to pursue marine mammals in sheltered coastal waters such as bays, fiords and amongst drifting ice. Although hunting by boat during the open water period is largely opportunistic and multi-specific, Inuit from many regions direct their efforts at certain species that are locally abundant; narwhals in northern Baffin fiords, white whales in the Mackenzie River estuary, walruses in Foxe Basin, bearded seals in Hudson Strait, harp seals in Cumberland Sound.

7.3.8.2 Sea-associated Birds

Seabirds do not constitute a major part of Inuit wildlife harvests. In some areas such as the Sanikiluaq Islands of Hudson Bay, considerable numbers of eider ducks are taken (Donaldson 1988). Inuit also collect the eggs of eiders and thick-billed murres in some areas.

7.3.8.3 Fish

Marine fish are not significant elements of the Inuit resource harvests. Arctic char is the most important fish species taken in the High Arctic and is harvested in rivers or in shallow, nearshore brackish waters.

7.3.9 Socio-Economic Environment

This section examines the socio-economic environment of the Northwest Passage Region. This environment is described by the demographic, social, cultural, and economic characteristics of the region.

7.3.9.1 Socio-cultural Setting

The socio-cultural setting of the Northwest Passage region is shaped by the populations of the nine communities in the Region and their history. From east to west, these communities are: Pond Inlet, Nanisivik, Arctic Bay, Resolute Bay, Paulatuk, Holman, Sachs Harbour, Tuktoyaktuk, and Inuvik.

One of the most striking features of the Northwest Passage region is the cultural make-up of its residents, predominantly Inuit and Inuvialuit in each community except Nanisivik and Inuvik. The ethnic distribution of the Region's people shape perspectives, lifestyles and socio-cultural values. The industrial, quasi-urbanized lifestyles of the mining community of Nanisivik and the regional government and industry centre of Inuvik are shaped by the predominantly non-aboriginal, transient population who reside there.

The aboriginal people of the Northwest Passage region are coastal people who rely on resources of the land and water to sustain them. Whales, seals and walrus are as important to these people as are polar bears, muskox and caribou. Social structures and most elements of aboriginal culture are related to the resources of the land and water.

Historically, both the Inuit and the Inuvialuit lived as semi-nomadic bands or extended family groupings. The number of camp members were small and decisions were made by a group leader. The structure of camps was guided in large part by the availability and supply of land and water resources and, the ability to harvest and provide for camp members.

The Inuit began to experience change with the coming of the whalers in the 1800's. In many ways, the changes brought about by outside influences were significantly different in the eastern and the western extremities of the Northwest Passage region. In the Beaufort, much of the Inuvialuit population was wiped out by the turn of the century by disease contacted from the whalers and food shortages resulting from commercial whaling activities. This traumatic stage of Inuvialuit history marked a turning point for local people. Many turned to the fur trade and during the 1920's prices were high and people prospered. By the 1940's the fur industry had gone flat and people began to seek new sources of cash to supplement their land based lifestyles. The movement of government and military into the region in the 1950's offered this alternative.

Even though trading posts were established at Arctic Bay and Pond Inlet in the early 1920's, the Inuit of the eastern Northwest Passage region remained virtually unaffected by the outside world until the late 1940's when government and the military became interested in sovereignty in the north. Resolute Bay was established in 1947 as a joint Canadian-American weather station and Inuit from Northern Quebec were relocated there. Similarly, northern sovereignty also inspired government relocation of Inuit from Northern Quebec and Pond Inlet to Grise Fiord.

By the 1950's the establishment of government, military and trading businesses throughout the Northwest Passage region was bringing change to the Inuvialuit and Inuit. By the 1960's, settlement or community life throughout the region became the norm rather than the exception as family groups began to stay in town year-round so that children could attend school and have access to other services. It is noteworthy that differences in the length and intensity of contact in the eastern and western extremities of the Northwest Passage region may account for the fact that today Inuktitut remains the first language of most Inuit while Inuvialuktun is now a second language of the Inuvialuit.

While the lifestyles of both Inuit and Inuvialuit have changed, family and kinship structures and cultural beliefs and expression remain firmly rooted in the land, the water and the natural resources. Family groupings continue to reaffirm this relationship with the land and water by continuing to harvest natural resources and to distribute these resources among family members. Traditional roles and responsibilities within the family unit related to harvesting and preparing resources for use are still stringently adhered to. Similarly, the value accorded to land and water resources as staples in the household diet and a necessary source of warm clothing remains as important today as a century ago. Of course with the availability of imported goods and luxury items, the technology used in contemporary harvesting practices has changed among both the Inuit and the Inuvialuit. Widespread use of modern day technology has necessitated wage employment to pay for snowmobiles, boats, motors, radios, etc.

Industrial activity in the Northwest Passage region has focused on mineral and hydrocarbon development. Few residents have been attracted to either of the two mines in the region but the Inuvialuit continue to participate in hydrocarbon developments in the Beaufort. However, regardless of participation in these industries, the Inuit and Inuvialuit continue to be concerned about the impact of industrial developments on the land, water and resources and subsequent impacts to lifestyles and cultures.

7.3.9.2 Current Issues

Many government, industrial and aboriginal initiatives underway in the Northwest Territories affect the socio-economic environment of the Northwest Passage region. Some of the major initiatives are described here.

a) Land Claims

In 1984 the first aboriginal land claim was settled in the NWT between the Inuvialuit and the Federal Government. The settlement resulted in Federal

legislation (The Inuvialuit Settlement Act) which gave the Inuvialuit control over 91,000 square kilometres of land. Five years later, the Inuvialuit have evolved a system of land and resource management structures. As well, the Inuvialuit have developed corporate structures allowing them to participate in resource development and to receive direct economic benefit from land ownership. The Federal Government continues to regulate development activities and retains ultimate authority for environmental management. The Inuvialuit control those water bodies surrounded by Inuvialuit lands but the Crown also continues to own water and manage any work related to water transportation. The Inuvialuit have established a joint Inuvialuit-government Environmental Screening and Review process which has authority to influence licensing of industrial developments which may impact upon Inuvialuit lands.

The Tungavik Federation of Nunavut (TFN) is a claims structure established by the Inuit to negotiate and settle land claims. Negotiations have been progressing and a tentative agreement has been reached. A final agreement is expected in the early 1990s. While many of the principles of the Inuvialuit Final Agreement may be mirrored in the TFN claim. To date the negotiations have produced an agreement in principle but not yet a final agreement.

b) Land Use Planning

A federally funded regional land use planning process has been in place for about five years in the Northwest Passage region. Currently, a land use plan has been proposed for the Lancaster Sound region and a draft plan is being prepared for the Beaufort region. Each plan advises on the preferred uses of land and resources in the regions and provides guidelines for land use allocation and environmental protection. Each plan is subject to approval by the Minister of the Department of Indian Affairs and Northern Development and the GNWT Minister of the Department of Renewable Resources.

The proposed Lancaster Sound Regional Land Use Plan concludes that shipping is central to the economic well-being of the region. Nevertheless, communities in the eastern extremities of the Northwest Passage are concerned about the potential effects of shipping on wildlife and resource harvesting activities.

The land use planning process in the Beaufort has identified marine transportation as a planning issue. Ocean dumping, oil spills and year-round ship traffic have been identified as concerns.

c) Industrial Development

Oil and gas exploration activity has been underway in the Beaufort Region for over two decades. The industry has achieved significant success in identifying the oil and natural gas potential of the area. Recently the National Energy Board granted approval to a consortium of companies to export natural gas from the region by 1996. The NEB approval has inspired a renewed interest in the region among gas producers, pipeline companies, governments and the Inuvialuit. For different reasons, each is anxious to see natural gas flowing from the region. Natural gas developments in the Beaufort are however contingent on proven markets which have not yet been found.

Compared to the Beaufort area, industrial development at the eastern end of the Northwest Passage region has been less dynamic. Industrial development has been mainly in the mining industry. Of the two mines, Polaris operates a fly-in/fly-out operation while Nanisivik has been established as a community. Neither is considered by local residents to have significant beneficial impact on employment, incomes or lifestyles. This is a circumstance that residents would like to see changed whether as a result of increased input into future developments or direct economic benefits.

Oil reserves have been found in the Sverdrup Basin and one field at Bent Horn has been developed. Proposals for further exploration and development are not expected until oil and gas prices increase substantially.

d) Conservation and Sustainable Development

Increasingly, northerners are echoing global concerns for the quality of the environment and the need to conserve resources for future generations. Major economic and resource development initiatives of the Government of the Northwest Territories are translating these concerns into strategies and policies. These issues are also central to aboriginal claims and regional land use plans. It can be expected that in the future northerners will employ these mechanisms as a means of intervening in those developments that are perceived to threaten the quality of resources and the northern environment.

7.3.9.3 Demographics

Settlement in the Northwest Passage region has been largely influenced by government and armed forces activities, the fur trade and hunting. Community settlement is relatively recent with communities springing up within the last 40 years. There are a handful of traditional camps in the Lancaster Sound and

Beaufort Sea areas and mining settlements at Strathcona Sound (Nanisivik) and Little Cornwallis Island (Polaris Mine).

Of the more than 6,000 (4,300 natives) people living in communities in the study area, 70 per cent live in the Beaufort Sea area, while 30 per cent live adjacent to Parry Channel. Inuvik, the only town in the region, is also the major western Arctic regional government and transportation centre. The remaining communities are small native communities with populations under 1,000.

Figure 7.3.9.1 presents population trends in the relevant communities between 1981 and 1989 and forecasts to 1995. There was a population decline between 1986 and 1989 primarily because of the downturn in oil and gas exploration in the Beaufort and the shut down of the armed forces base in Inuvik. The town of Inuvik accounts solely for the decline with a 20% population out-migration during this period.

Figure 7.3.9.1
POPULATION IN THE NORTHWEST PASSAGE REGION

		1986				
Community	1981 Final	Total	Native	Non-Native	1989 Total	1995 Total
Pond Inlet	680	795	750	45	885	1052
Arctic Bay	390	480	455	25	535	654
Nanisivik	255	315	120	195	317	362
Resolute Bay	160	185	125	60	166	189
Paulatuk	140	190	180	10	233	276
Holman Island	295	305	290	15	171	201
Sachs Harbour	150	160	145	15	171	201
Tuktoyaktuk	775	930	845	85	956	1130
Inuvik	3,105	3,385	1,405	1,980	2670	2925
Totals	5,950	6,745	4,315	2,430	6249	7191

Source: "Statistics Canada, Population and Dwelling Characteristics Northwest Territories: Part 2," catalogue 94-124, 1988 Statistics Canada, "Selected Social and Economic Characteristics, Northwest Territories," 1983 and 1989 Bureau of Statistics, GNWT.

A young but slightly aging population trend was evidenced from the first half of the 1980's throughout the Northwest Passage region. Between 1981 and 1986 about 40% of the population in eastern communities was under 15 years while in the western communities about 60% of the population reached the labour force age (15-65).

Unlike the smaller communities in the region, the town of Inuvik has a large non-native population. The populations of the smaller communities are predominantly native. It is expected that these trends will continue in the 1990's with the larger communities (Inuvik and Tuktoyaktuk) having an increasingly non-native mix as oil and gas development occurs in the Beaufort Sea.
It can be expected that more regional residents will reach labour force age in the 1990's.

7.3.9.4 The Traditional Economy

The economy of the Northwest Passage is a unique mix of the traditional and wage-based economies. Perhaps nowhere else in the NWT has there been the degree of interplay between the two economies. If it were possible to measure economic activity across the region over the past 10 years, the town of Inuvik would have demonstrated greatest dependence on a cyclical economy. The dependence on oil and gas and the large public service/government sectors have had the greatest impact on the regional economy. What would largely go unnoticed in the domestic product of the region however, would be the effects of the regional traditional economy.

The traditional economy is characterized by hunting, trapping and gathering activities. The economy depends on a readily available supply of land and sea based renewable resources. Trapping has been the major income generating activity of the traditional economy, while hunting and gathering activities supply regional families with necessary country foods and warm winter clothing.

Hunting and trapping has a relatively higher participation rate in the smaller communities, while the larger regional centre Inuvik, the Nanisivik mining community and the transportation hub Resolute Bay have a stronger mix of traditional and industrial wage-based activities.

a) Trapping

In 1988/89 at least 217 trappers, nine per cent of the territorial total, participated in the traditional economy of the Northwest Passage region. At $213,000, the value of trapping was approximately five per cent of the territorial total. There is far less impact from trapping on the local economies in the eastern Parry Channel region than in the Beaufort Sea region communities. Figure 7.3.9.2 indicates that trapping as a wage pursuit in the late 1980's was cyclical, peaking in 1987. The mid-1980 trapping decline in the Parry Channel area followed the downturn in the international fur market. The trapping returns demonstrate that per capita incomes are very low from this seasonal pursuit.

The regional fur industry has undergone significant changes during the past decade. Largely reliant on world markets, downward trends have seen the seal

Figure 7.3.9.2
PARTICIPATION IN THE FUR INDUSTRY

	1985		1986		1987		1988	
Community	#	($000)	#	($000)	#	($000)	#	($000)
Pond Inlet	38	19.2	24	20.7	22	3.7	20	17.9
Arctic Bay	14	2.3	15	3.9	16	4.9	9	9.4
Nanisivik(1)								
Resolute Bay	9	3.0	4	3.9	8	6.8	14	1.6
Paulatuk	n/a	n/a	23	20.9	19	19.2	18	11.3
Holman Island	44	16.6	87	25.0	53	61.0	45	25.3
Sachs Harbour	8	2.5	7	6.9	8	10.3	4	1.6
Tuktoyaktuk	51	53.0	71	106.4	68	120.0	38	37.9
Inuvik	143	165.0	121	220.4	92	214.9	69	108.1
Totals	307	261.6	352	408.1	248	432.2	217	213.1
NWT Total	3,250	3,900	2,922	5,652	3,000	6,136.8	2,352	4,438.6

(1) Nanisivik totals are included with Arctic Bay
= trappers.

Source: GNWT, Department of Renewable Resources Fur Returns.

market almost eliminated while Arctic fox prices are currently at a low of $35. The future of the wild fur trapping industry will depend on a number of factors including international market trends, the competitiveness of wild fur trapping with wage-based pursuits, the relative operational and capital costs of trapping, and available funds.

Of primary importance to the industry will be a continued market for wild fur such as Arctic fox, wolf, and the market development for new seal products. Today the price for farmed fox pelts is almost 5 times the value of trapped wild fur. Reports suggest that an average trapper in the NWT must make $10,000 to break even.

Hunters and trappers have received direct operating and capital assistance from government to conduct their trapping activities. However, with federal and territorial government budget constraints and the possible elimination of economic development programs, the focus of available resources for the fur trapping industry may change. Even so, trapping will continue to have seasonal importance to the traditional economy into the 1990's. But without improved markets, trapping cannot be expected to have the same economic value as in the past.

b) Subsistence Activities

While the trapping segment of the traditional economy has declined over the decade, there were still 1,884 General Hunting Licence holders in the region in 1989. This number suggests the importance of food harvesting and land/water based activities to regional residents.

Due to data constraints, it is difficult to determine an accurate value of domestic hunting and fishing. The imputed value of country foods, including fish and red meat, amounted to $46.6 million (NWT Economic Review and Outlook 1988) for a territorial population of approximately 51,000 in 1988. Based on an equivalent of $1,000 imputed value per capita and population figures for the Northwest Passage region, the approximate value of the domestic economy is $6.3 million.

7.3.9.5 The Wage Economy

a) Labour Force

The most recent survey published in 1989 demonstrates that labour force characteristics of the Northwest Passage region are very similar to the NWT as a whole. Figure 7.3.9.3 describes labour force activity in each of the communities

Figure 7.3.9.3
SIZE OF THE LABOUR FORCE IN 1989

Community	Potential Labour Force	Actual Labour Force	Part. Rate %	Employed (#)	Unempl. Rate %
Pond Inlet	498	294	59	205	30
Arctic Bay	285	170	60	130	24
Nanisivik	216	196	91	191	3
Resolute Bay	134	120	90	105	13
Paulatuk	139	64	46	56	13
Holman Island	214	126	59	110	13
Sachs Harbour	110	74	67	52	30
Tuktoyaktuk	597	350	59	229	35
Inuvik	2,119	1,732	82	1,634	6
Totals	4,312	3,126	68	2,712	13
NWT Totals	34,650	24,250	70	20,328	16

Notes:
- Potential Labour Force is all persons 15-64 years of age, excluding students.
- Actual Labour Force includes persons 15-64 working or looking for work at time of survey.
- Participation Rate is the per cent of the potential labour force that is working or looking for work.
- Employed equals the number of persons working at time of survey.
- Unemployment Rate is the percentage of actual labour force unemployed.

Source: 1989 NWT Labour Force Survey, GNWT Bureau of Statistics 1989.

and across the region. Almost 13% of the territorial labour force resides in the Northwest Passage region.

Labour activity is highest in Nanisivik, Resolute Bay and Inuvik. This is not surprising as Inuvik is a regional centre for government, a staging area for tourism and oil and gas exploration, and a transportation hub. Resolute Bay is primarily a transportation hub servicing mining and Arctic research and development in the Arctic Islands while Nanisivik is a single industry mining community.

Low participation rates in the wage economy are evident in the regional communities which depend on the traditional economy. These regional communities also have a predominantly native population. Tuktoyaktuk, however is an interesting exception. Tuktoyaktuk has been noted as a base of operations for Beaufort Sea oil and gas exploration, but in the latter part of the 1980's it has performed poorly both in participation and unemployment rates. This can be linked to the downturn in oil and gas exploration activities in the Beaufort in recent years.

b) Education

Education levels in the Northwest Passage region are similar to those of the NWT as a whole (Figure 7.3.9.4). Approximately 33% of the population over 15 has less than grade 9 education, while the remainder has a higher level of

Figure 7.3.9.4
EDUCATION LEVELS IN NORTHWEST PASSAGE COMMUNITIES

	1981		1986	
Community	<Grade 9	≥Grade 9	<Grade 9	≥Grade 9
Pond Inlet	255	115	245	200
Arctic Bay	120	90	150	105
Nanisivik	35	120	45	180
Resolute Bay	55	40	35	75
Paulatuk	60	50	70	50
Holman Island	135	45	135	70
Sachs Harbour	55	55	40	70
Tuktoyaktuk	270	230	285	295
Inuvik	400	1,785	425	2,020
Totals	1,385	2,530	1,430	3,065
NWT Total	10,635	19,030	11,580	23,350

Note: Based on total population of 15 years and over.

Source: Statistics Canada, Population and Dwelling Characteristics, Northwest Territories Part 2, Cat. 94-124, 1986.

schooling. The proportion of people with less than Grade 9 education declined from 35% in 1981 to 32% in 1986 in the Northwest Passage communities.

c) Labour Income

Figure 7.3.9.5 summarizes the average annual income in the Northwest Passage communities. It was evident from the labour force participation and unemployment rates that Nanisivik, Resolute Bay and Inuvik were considerably more involved in the wage economy than were the balance of the communities. This is confirmed by the income data. The average income figures for the region display a wide disparity between the communities depending on the traditional economy and those involved in the wage economy. The regional average income is slightly lower than the territorial income.

Figure 7.3.9.5
ESTIMATE OF AVERAGE INCOME IN SELECTED COMMUNITIES

Average Community	Income
Pond Inlet	$12,088
Arctic Bay	14,248
Nanisivik	35,811
Resolute Bay	22,550
Paulatuk	7,688
Holman Island	11,456
Sachs Harbour	17,717
Tuktoyaktuk	14,187
Inuvik	22,240
Average	$17,554
NWT Average	$18,725

Note: Average income is the total income from income tax returns divided by the number of returns.

Source: Department of Economic Development and Tourism, GNWT, 1989.

Apart from inflationary impacts, community income levels are not expected to change dramatically over the next few years. With the exception of Tuktoyaktuk, it is assumed that transfer payments and government expenditures will continue to significantly contribute to income in the small communities. With increased oil and gas exploration in the Beaufort Sea, Tuktoyaktuk may experience some improvement in income levels and greater participation and employment in the labour force. Income levels in Inuvik, Resolute Bay and Nanisivik can be expected to remain tied to private and public sector employment.

7.3.9.6 Economic Outlook

The mix of wage and domestic economic activities in the Northwest Passage region in the 1990's will be largely affected by government direction and oil and gas exploration in the Beaufort Sea.

a) Government Direction

In late 1989, the Legislative Assembly of the Northwest Territories released the report of the Special Committee On the Northern Economy. Entitled *Building Our Economic Future*, the report sets the tone for government economic policy and program direction during the next decade. The commission recognized that although the NWT economy was prospering at a rate exceeding other areas in Canada, there were some disturbing imbalances. It noted that territorial imports and attendant values are excessive and that there are vast disparities in the community economies.

The majority of the recommendations respond directly to the development needs of the underdeveloped or traditional community economies. In responding, government agencies will focus their energies on developing small community economies. They will do this through human resource development and training, policy and program development, and organizational development. Of central importance will be improved education and training, import replacement initiatives, and economic developmental programs geared to the smaller traditional style communities.

The majority of the communities in the Northwest Passage region fall into the underdeveloped category and will be the target of government programs in the 1990s.

The land use planning processes of the Northwest Passage region were completed in the Lancaster Sound region in 1989 and are now beginning in the Beaufort Sea region. The plans will provide guidelines to decision makers and should improve

and expedite the decision making capability of government regarding resource development.

b) Oil and Gas Exploration and Development

In October 1989, the National Energy Board granted licences to ESSO Resources Canada Ltd., Gulf Canada Resources Ltd., and Shell Canada Ltd. Authorizing the export of natural gas from the Mackenzie Delta. Subject to a number conditions, including domestic market priority supply and identified export contracts, the new licences will allow the three companies to export a total of 260 billion cubic metres of natural gas.

Foothills and the Polar Gas Project have made applications to the National Energy Board to construct a pipeline down the Mackenzie Valley for completion in 1996. The major issue, however, to Mackenzie Valley/Beaufort Sea gas development is the question of Alaska natural gas flowing before Mackenzie/Beaufort gas. A flow of Alaskan natural gas first would likely put off the Mackenzie/Beaufort decision into the 21st century.

Based on the recent experience of the Norman Wells/Esso Resources oil development and pipeline project, it can be expected that northerners will demand a greater share of royalties, direct employment and income benefits and business opportunities. Government is now gearing up for resource development in the 1990's in cooperation with industry through the delivery of training programs. Since the signing of the Inuvialuit Final Agreement new environmental screening and review processes for licensing have been implemented. Esso Resources was the first test. Application and approval to drill the Isserk I-15 well in the Beaufort during the 1990 winter drilling season was granted expeditiously in late 1989.

c) Tourism

Tourism is a growth industry in the Northwest Territories. In recent years Inuvik has become a summer destination community for a large number of road travellers and groups attracted by the Dempster Highway. Inuvik is also a hub for many of the outlying communities such as Tuktoyaktuk, Sachs Harbour and Holman Island. Inuvik operators have joined with the smaller communities such as Tuktoyaktuk, to package sightseeing and adventure travel opportunities. With the improved market in the Inuvik region, seasonal outfitting and hospitality/guide training opportunities are now more readily available.

During the past 10-20 years, hunters and trappers in Sachs Harbour and Holman Island have conducted an active sport hunt on Victoria Island and Banks Island during the late winter. Holman Island Hunters and Trappers share a polar bear quota on Melville Island with Resolute Bay Hunters and Trappers and in past years the communities have conducted sport hunting activities on and adjacent to the island.

In the eastern communities, Resolute and Pond Inlet have long been destinations for adventure travellers. Sportfishing packages at the Kuluktoo Bay sport fishing camp south of Pond Inlet are offered during the open water summer season, while floe edge and Bylot Island sightseeing adventure experiences are offered by outfitters from Pond Inlet primarily in the late spring and early summer. Outfitters from Resolute Bay take tourists on spring excursions to Grise Fiord. Resolute is also a staging area for north pole treks.

d) Small Business Sector

The small business sector is largely supported by activity in Inuvik. There is a broad range of small business activity in Inuvik compared with a very limited range in the traditional sector communities. Figure 7.3.9.6 documents business activities and employment in the Passage region. The business community is 257 strong and employs almost 1,100 people. The average size of small businesses is between 4 and 5 employees. The territorial average for small business is about 8 employees. The market for business in the region is limited, on average to one business for every 47 people.

There has seen considerable economic endeavour by the Inuvialuit in the five years since the signing of the Inuvialuit Final Agreement. Today, Inuvialuit are contributing to the economic activity and business infrastructure of the Northwest Territories through ownership interests in businesses in the real estate, oil and gas exploration and production, communication, food, and transportation sectors. The influence of Inuvialuit business activity is now felt throughout the western communities of the Northwest Passage region.

It can be expected that the eastern Arctic land claims settlement will have a similar effect on the economic development of the eastern communities in the Northwest Passage. The potential for small business in the Northwest Passage region will depend largely on expanded markets, entrepreneurial spirit, a trained labour force, and the ability of community business to get a competitive product to market.

Figure 7.3.9.6
BUSINESS ACTIVITY IN THE NORTHWEST PASSAGE REGION

Community	No. of Business	Small Bus. Market (residents)	Business Employment (full time)
Pond Inlet	13	61	54
Arctic Bay	8	60	6
Nanisivik	4	79	6
Resolute Bay	10	19	72
Paulatuk	2	95	3
Holman Island	10	31	33
Sachs Harbour	7	23	28
Tuktoyaktuk	24	39	47
Inuvik	179	19	841
Totals/Average	257	47	1,090

Note: The small business market is the population supported by each community business.

Source: GNWT, Department of Economic Development and Tourism, 1989 review of business registered in the NWT Business Directory.

7.4 INTERACTION MATRIX (LEVEL 1)

An interaction matrix for the project is presented in Figure 7.4.1. This Level 1 Matrix shows possible interactions between the project and the environment. The matrix lists possible interactions only and makes no assumptions about the possible impacts of the interactions. The construction of the Polar 8 will occur in the south and will not interact with the Arctic environment. Therefore, construction is not considered in this document.

The interactions identified in Figure 7.4.1 are evaluated in Chapter 8 (Effects of Normal Operations) and Chapter 9 (Effects of Accidents). After these evaluations, a level 2 matrix that summarizes the predicted impacts of the Polar 8 is presented Chapter 10 (Impact Summary).

Figure 7.4.1
INTERACTION (LEVEL 1) MATRIX SHOWING POSSIBLE INTERACTIONS BETWEEN THE PROJECT AND THE ENVIRONMENT.

Environmental Components	Project Activities													
	Discharges					Operations					Accidents		Infrastructure	
	Grey Water	Garbage	Oily Waste	Exhaust Fumes	Ballast Water	Open Water	Ice Breaking	Helicopter Flights	On-Ice Vehicles	Small Boats	Oil Spill	Other Spills	Empl-oyment	Purch-asing
Physical/Chemical Effects														
Integrity of the Ice Sheet							X							
Premature Breakup							X							
Lead Formation							X							
Lead Refreezing							X							
Air Quality				X										
Water Quality	X	X			X						X	X		
Ecological Effects														
Lower Trophic Levels														
Plankton	X				X		X				X	X		
Benthos											X	X		
Underice Biota	X						X				X	X		
Fish							X				X	X		
Birds														
Northern Fulmar		X	X			X	X	X	X	X	X	X		
Waterfowl			X			X	X	X		X	X	X		
Shorebirds			X			X	X	X		X	X	X		
Black-legged Kittiwake			X			X	X	X	X	X	X	X		
Other Gulls, Terns, Jaegers		X	X			X	X	X		X	X	X		
Thick-billed Murre			X			X	X	X	X	X	X	X		
Black Guillemot			X			X	X	X		X	X	X		
Dovekie			X			X	X	X		X	X	X		
Marine Mammals														
Ringed Seal						X	X	X		X	X	X		
Bearded Seal						X		X		X	X	X		
Harp Seal						X		X		X	X	X		
Walrus						X		X		X	X	X		
White Whale						X	X	X		X	X	X		
Narwhal						X	X	X		X	X	X		
Bowhead Whale						X		X		X	X	X		
Polar Bear						X	X	X	X	X	X	X		
Arctic Fox							X	X	X					
Ice Edge Communities							X	X		X	X	X		
Polynya							X	X		X	X	X		
Socio-Economic Effects														
Hunting						X	X	X	X	X	X		X	
Fishing			X								X		X	
On-ice Travel							X							
Employment											X		X	X
Communities											X		X	X

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CHAPTER 8

EFFECTS OF NORMAL OPERATIONS

This chapter considers the effects of normal ship operations on the people, communities and environment of the Arctic. Normal operations will include icebreaking, travel in open water, operations by the ship's helicopters, launches and vehicles, and will result in the discharge of exhaust fumes and purified grey water, and involve employment and resupply as indicated in figure 7.4.1.

8.1 EFFECTS OF DISCHARGES

Discharges could include exhaust fumes, purified grey water, and ballast water. Garbage will be incinerated. The Polar 8 will comply with the Arctic Waters Pollution Prevention Act and associated Arctic Water Pollution Prevention Regulations, as amended from time to time.

8.1.1 Grey and Black Water

Water will be used for cooking, cleaning and personal use and will be released as grey water. The Polar 8 is designed so that no untreated grey or black water will be discharged overboard. Grey and black water from drains and toilets will be processed through a system that includes aeration, settling and sterilization. The end products will be "potable" water to be discharged overboard and solid waste that will be incinerated. About 19,000 litres of this water will be released daily. The discharges may contain nutrients that enhance primary productivity. In summer, Arctic waters are generally poor in nutrients and an increase in nutrient levels would increase primary production. However, through wave and wind mixing, these small inputs of processed grey water would have a negligible effect on water quality and phytoplankton. There will be no effects on birds or marine mammals.

8.1.2 Garbage

Garbage will be incinerated. Residues will be transferred to a resupply ship or stored for later disposal ashore. No garbage will enter the marine system.

8.1.3 Oily Waste and Sludge

An oil and water separator will be used to separate oily waste from water. All oily wastes will be held in sludge tanks. This waste will be incinerated from time to time. The water from which the oil has been removed will be discharged over the side after meeting the necessary purity requirements. There will be no effects on marine animals from this discharge.

8.1.4 Exhaust Fumes

The main propulsion equipment for the Polar 8 has not yet been selected. The main engines will be modern, efficient and, most importantly, will burn high grade diesel fuel. Thus, emissions will be clean relative to emissions of ships that burn heavy residual fuels. As indicated in section 6.2.5.1, the exhaust gas is expected to contain nitrogen (77% by volume), oxygen (13%), carbon dioxide (5%), water vapour (5%), and negligible amounts of ash, soot, and carbon monoxide. At 85% of maximum output, the mass flow rate of the exhaust gas from the diesel engines will be about 572,468 kg/hr and that of the boiler will be about 11,900 kg/hr. The main engine will rarely be operated at 85% of maximum output. It may typically operate at about 30% of full power. Garbage, oily waste and solid waste from the sewage treatment system will be incinerated. Approximately 5,940 kg/hr of exhaust gases will be produced when the incinerator is operational.

Exhaust these emissions from the Polar 8 will meet the Canada Shipping Act regulations respecting air pollution from ships. Because these emissions will be from one modern, efficient ship that burns high grade fuel, release of exhaust fumes should have no detectable effects on water quality, marine life, resource harvesting, or air quality.

8.1.5 Ballast Water

The Polar 8 will arrive on station with nearly full oil tanks. Thus, it will have no ballast water in its tanks on arrival in the north. As oil is used, Arctic water will be taken into the ballast tanks. The possibility of contamination by water taken from the south will be negligible. In addition, the ballast tanks are self-contained and therefore the ballast water will not be contaminated with oily water or bilge water. This means that one of the most common concerns about ships discharging dirty, oily or foreign ballast water is completely avoided.

8.2 EFFECTS OF ICEBREAKING

8.2.1 Influences On The Ice Sheet

By design, an icebreaker disturbs the local ice cover. The nature of the disruption is influenced by a variety of ship-related as well as environmental factors. Considerable work has been done to evaluate the nature of ship tracks in ice and the subsequent response of the ice cover. In addition, the resultant effect on human activity has also been investigated.

When a ship passes through ice, the bow breaks ice pieces from the surrounding ice sheet. These pieces are deflected downwards and to the sides. As the ship progresses, much of the fractured ice is drawn back into the wake of the ship. The ship's track through the ice is characterized by an accumulation of various sizes of ice fragments, the size of the fragments largely determined by conditions of the ice itself. Additionally, the concentration of ice pieces is equally variable, with areas of higher and lower ice density along the ship track.

Icebreaker impacts on the ice can be generalized to a few main considerations, namely the track width, the ice conditions within the track after ship passing and the time for the track ice to reconsolidate. A final concern, which has been raised in the past, is the impact of ship traffic on ice cover stress formation.

8.2.1.1 Track Width

Whether the ice is landfast, consolidated or unconsolidated pack will have a bearing on the nature of the ship track. Under conditions of broken ice, the track may not close as the ice field itself has been displaced sideways. In regions of pack ice such as parts of the Beaufort Sea, Baffin Bay or, in late season, the Arctic Islands, this situation may be observed.

The effects of the Polar 8 on pack ice will be considerably less than on fast ice, because the ice floes are free to move and redistribute themselves through the action of wind or currents. The major effect will be breaking individual floes into two or more smaller ones as well as the formation of some brash ice. However, in a moving pack ice situation the breaking of floes will have little effect on the distribution of the ice or its movement. In lower pack ice concentrations where the Polar 8 will be breaking ice only part of the time, the effects will be even less. The ship track will disappear the first time significant winds develop after the icebreaker has passed.

Potential Polar 8 effects on polynyas, discrete features within the ice cover consisting of open water or new ice types, would be to disrupt the formation of the thin ice cover. The polynyas of primary importance to Polar 8 operations are the North Water polynya, which the icebreaker would normally travel through to access Nares Strait, and the Cape Bathurst polynya along the access route to the Beaufort Sea.

In June, 1986 level ice trials of the M.V. Arctic were conducted in Baffin Bay, Lancaster Sound and Strathcona Sound. Observations during these trials indicated that track width varied with general ice conditions and thickness (Dick and Chueng 1987). Figure 8.2.1.1 summarizes the observed variability in track width for different ice conditions. In thin ice, cusping patterns resulted in wide cusps at the shoulder of the ship and, hence a wider channel. In thick ice the cusps were narrower and located further forward along the bow, resulting in a narrower channel. In consolidated and fast ice, the greater thicknesses held the track width close to the breadth of the ship (22.9 m).

Figure 8.2.1.1
TRACK WIDTH OBSERVATIONS FROM M.V. ARCTIC ICE TRIALS JUNE, 1986

Ice Conditions	Ice Thickness (m)	Track Width (m)
Loose Pack (200 m floes)	1.0	31
Pack Ice (giant floes)	1.0	27
Consolidated (level)	1.1	25-27
Consolidated (severe ridging)	4.0	25
Landfast (small ridges)	1.7-1.9	25

Source: Dick and Chueng, 1987

Additional M.V. Arctic track width measurements in Admiralty Inlet, also in June, 1986, yield mean widths of 30.9 and 28.8 m based on numerous measurements at two separate sites (Wells *et al.* 1986). The first site was near the sheer zone separating consolidated Inlet ice from drifting ice within Lancaster Sound while the second was located deeper into Admiralty Inlet. The values are

consistent with those in Figure 8.2.1.1. This study also demonstrated that the track width was not uniform over distance. Detailed width measurements over 800 m of ship's track indicate that the width varied frequently between approximately 25 and 40 m. Figure 8.2.1.2 provides an example of the irregularity in the track edge shape. The photograph also illustrates the range of floe sizes found in the track. The presence of a person in the track provides an indication of the track crossing potential.

The results of these studies suggest that for a given ship design, the track width is largely dependent on the local ice conditions. The Polar 8 will have a breadth of 36 m and was designed to travel at 3 knots through ice 2.44 m thick. Based on these design parameters, and M.V. Arctic track observations, it seems likely that the expected the Polar 8 track width would be 36 m meters plus 5 to 10 m.

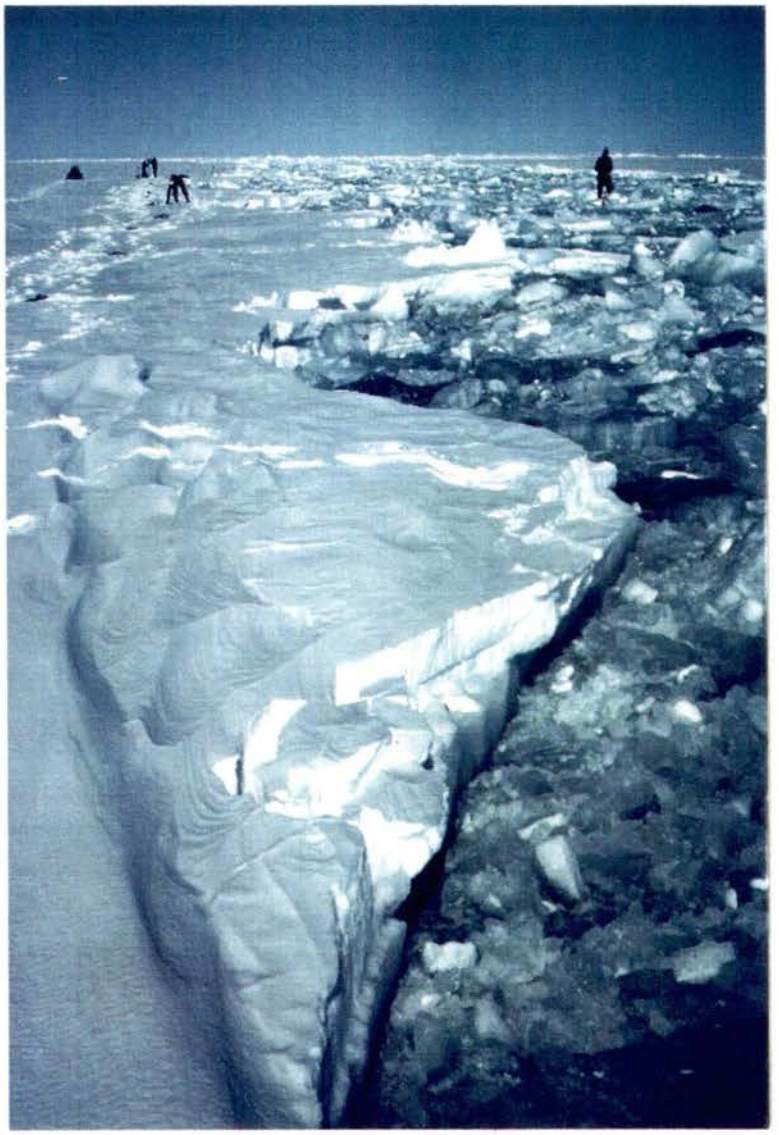
Observations made by Robson (1972) suggest that the time of year is important in influencing track width. When temperatures are high and ice is melting, with time the track will widen. Observations of M.V. Arctic track segments in late June showed that several hours after the ship had passed, the track had widened from a width close to that of the ship breadth (23 m) to approximately 39 m as ice pieces broke from the ice along the track sides.

An investigation of ship tracks created by the icebreaker Kigoriak in the Beaufort Sea also indicates that track width varied seasonally, in relation to ice conditions. In November, observed track widths were approximately 30 m while in June, when the ice was considerably decayed, the track was observed to be approximately 50 m in width (Danielewicz *et al.* 1983). Once again, similar incremental increases could be expected with the Polar 8.

8.2.1.2 Floe Size Distribution

In addition to the track width, the ice piece size distribution within the track must also be considered. This will vary as a function of hull shape and environmental conditions such as the nature of the ice itself. Danielewicz *et al.* (1983) show that Kigoriak tracks in the Beaufort Sea consisted of tightly packed ice blocks ranging in size from a few centimetres to several metres. Open water was only encountered within the first 30 metres of the ship's propeller. Other work suggests considerably longer lengths of open water when travelling through loose pack.

Figure 8.2.1.2
SHIP TRACK IN ADMIRALTY INLET - JUNE, 1986, SHOWING EDGE AND FLOE CHARACTERISTICS



Source: Wells et al., 1987

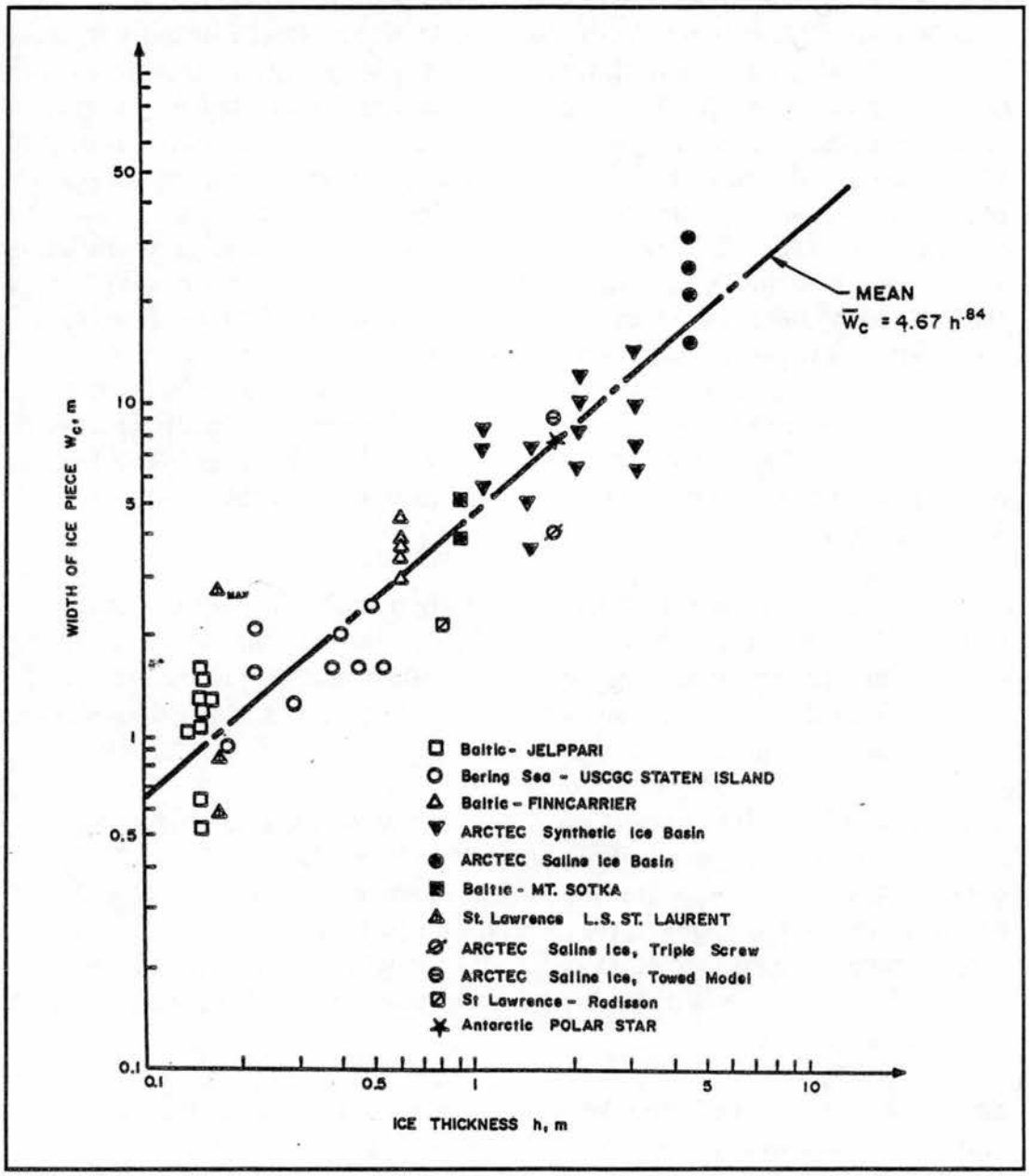
Daley and Noble (1979) evaluated floe size distributions for a variety of ships as well as for a number of model tests. The results of this part of their investigation provide an indication of the size of ice pieces as a function of ice thickness (Figure 8.2.1.3), showing an estimate of the mean measured floe width. Evaluations of M.V. Arctic ship tracks in Admiralty Inlet (Strandberg *et al.* 1985; Wells *et al.*1987) during two different years (1984 and 1986) provide an estimate of the distribution of floe sizes. Both studies were conducted in the spring with mean ice thicknesses of 1.75 m observed in 1986. Floe size distributions from the 1986 study are shown in Figure 8.2.1.4. The predominance of brash and smaller floe sizes is consistent with the mean floe size one would estimate based on the curve in Figure 8.2.1.3. Several studies have noted that the concentration of floes in the track is variable, as is the distribution of larger ice pieces (Wells *et al.*, 1987; Robson, 1982; Daley and Noble 1979). Clusters of larger floes have been noted at narrow points in the ship track. Figure 8.2.1.5 illustrates this with photographs of track segments in Admiralty Inlet. The variable track width and areas of concentrated floes are clearly evident. Even after multiple transits (Figure 8.2.1.6), highly concentrated areas remain in the track. The frequent occurrence of these concentrated regions was found to provide ample possibility for track crossing.

The 1986 data in Figure 8.2.1.4 provide further indication of the change in ice size distribution as a result of multiple transits through the track. The results of the Norland Science study suggest that the effect of multiple transits (in this case 6 transits) on the floe size distribution is greatest on the larger floes where the percentages are reduced.

The effects of multiple transits on ship tracks have been investigated at varying levels of detail (Wells *et al.* 1987; Strandberg *et al.* 1985; Robson 1982). The consensus is that multiple transits may have some effect on reducing the importance of larger floes in the overall floe size distribution. All of the noted studies have been conducted in early summer when the ice was in a state of decay. As a result, it is difficult to differentiate transit effects from those of thermal degradation.

Shear zones, ridges and multi-year floes can present barriers the Polar 8 must either cross or avoid. Where it is necessary to cross them, the composition of these features may require different navigation procedures than simply straight ahead icebreaking. Repetitive backing and ramming is a standard technique for penetrating difficult ice conditions. In cases where this action is taken, the ice cover tends to be disturbed to a greater extent than it would under normal transit. At the same time, the backing tends to break ice in the track into smaller pieces, leaving the overall floe sizes smaller than in a typical track.

Figure 8.2.1.3
SIZE OF ICE PIECES IN SHIP TRACKS AS A FUNCTION OF ICE THICKNESS

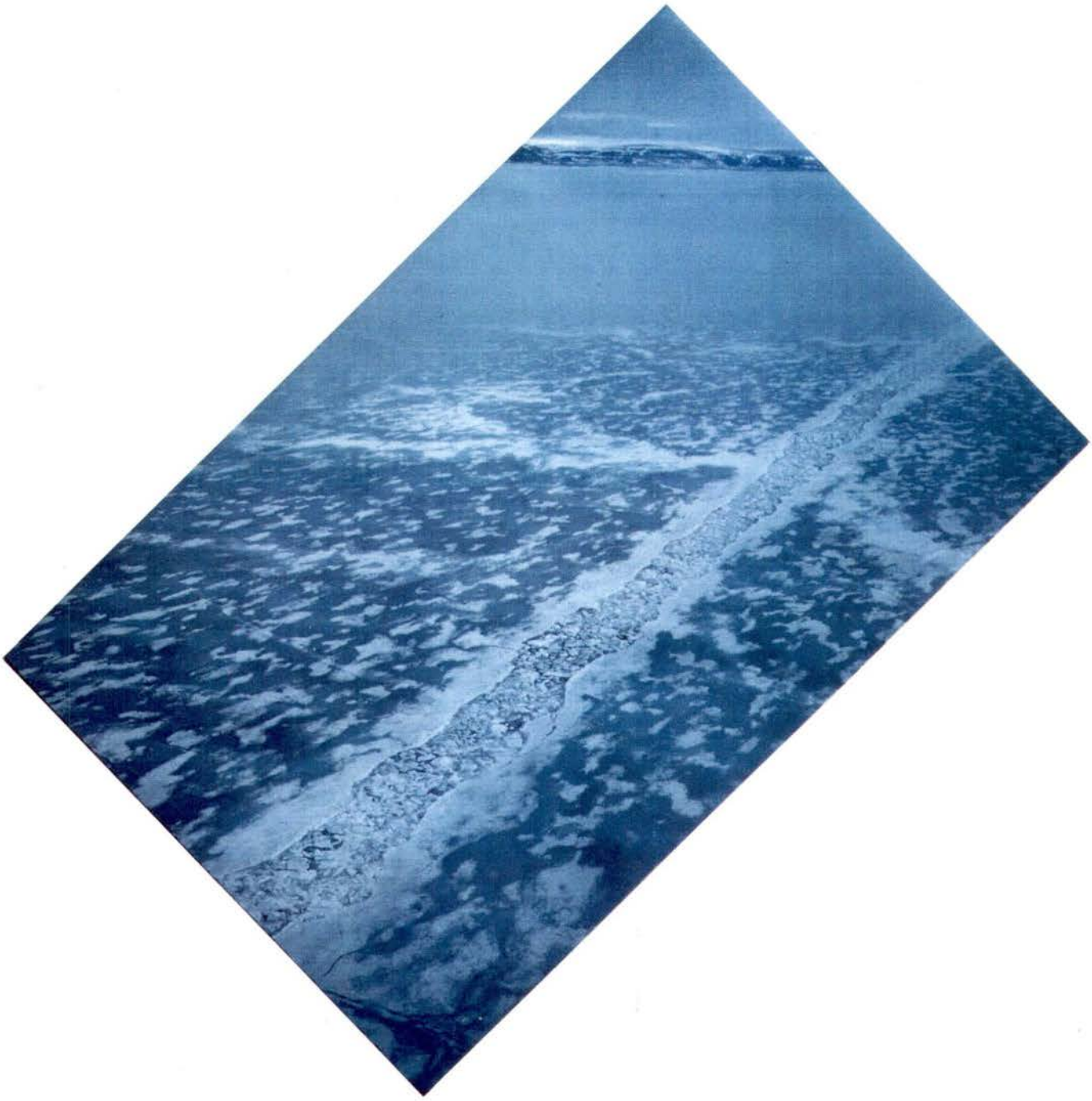


Source: Daley and Noble, 1979

Figure 8.2.1.5
SHIP TRACK SEGMENTS IN ADMIRALTY INLET SHOWING ICE CONCENTRATION VARIABILITY

Source: Wells et al., 1987

Figure 8.2.1.6
SHIP TRACK IN ADMIRALTY INLET SHOWING MULTIPLE TRANSIT EFFECT ON ICE CONCENTRATION VARIABILITY



Source: Wells et al., 1987

Figure 8.2.1.4
SUMMARY OF BROKEN ICE DISTRIBUTION DATA FOR SINGLE AND MULTIPLE SHIP TRANSITS ADMIRALTY INLET, SPRING 1986

	Site 1		Site 2	
Size Category	Single%	Multiple%	Single%	Multiple%
Open Water	4.5	11.3	4.0	14.0
Brash	51.3	18.8	31.8	35.8
2 x 1 m	16.3	24.8	16.8	17.5
4 x 2 m	13.0	27.8	14.5	17.3
7 x 4 m	9.0	17.0	24.0	12.8
15 x 10 m	6.0	0.5	9.0	2.8

Source: Strandberg et al. 1985; Wells et al. 1987

In summary, ship transit through ice produces a wide range of floe sizes in the ship track. Floe sizes can be related to ice thickness, with a mean longest dimension for level first year ice of 2.0 m thickness, being approximately 7-8 m. Multiple transits appear to have some effect on the floe size distribution in reducing the number of large floes although, based on the existing documentation, the effect is difficult to isolate from the natural effects of thermal ablation. In situations where backing and ramming become necessary, the potential exists for more wide-spread disturbance of the ice cover and for a reduction in within-track floe sizes.

8.2.1.3 Track Reconsolidation

Several studies have looked at reconsolidation of ship tracks. Danielewicz et al. (1983) found that reconsolidation as a result of gravitational compaction of the ice fragments began almost immediately after the track was created, to the extent that crossing of a 30 metre track on foot was possible within an hour of its formation in November. Even in June it was found that immediate crossing was possible although a delay of a couple hours gave time for surface water to drain. Their findings indicate that the track ice, when it consolidates, tends to be thicker than the surrounding level ice (Danielewicz *et al.*, 1983). They also found that the surface roughness of the track to be less than that of naturally occurring ice ridges although track roughness did increase through winter as the thickness of the ice being broken increased.

In looking at the potential for track bridging or crossing in Barrow Strait, Daley and Noble (1979) have calculated rates of refreezing and associated wait times for safe track crossing. Their analysis was based on the floe distribution observed behind the USCGS Polar Star which was considered representative of the proposed Arctic Pilot Project LNG (Liquified Natural Gas) carrier in terms of track characteristics.

Track reconsolidation is dependent on the time of year, which dictates ice growth rates, and the floe size within the track. In winter, reconsolidation is rapid and even in spring, when temperatures rise, refreezing between ice pieces is sufficient to permit safe crossing after a short delay. In late spring when temperatures are well above zero, refreezing will not occur and the track will remain open. When reconsolidation does occur, the refrozen track is generally thicker than the surrounding level ice. Surface roughness is largely dependent on the thickness of the ice being broken.

8.2.1.4 Stress Cracking and Leads

Stress cracks and leads occur naturally in consolidated ice both as a result of mechanical stress and temperature variation. Modelled evaluations of the effect of LNG tanker traffic through Barrow Strait suggest that ship traffic in this area might reduce cracking by a small amount although local cracking could increase. It is likely the ship track could provide stress relief, resulting in larger crack-free areas (Acres 1981).

Related to stress crack formation is the effect ship transit can have on leads (major cracks in the ice cover) as they are crossed. Some investigation has been made, once again in the Eastern Arctic (Strandberg *et al.* 1985). The limited results suggest that some stress fracturing may occur at the intersection point with large floes forming within the acutely angled regions between the lead and ship track. Wells *et al.* (1987) noted that, in some instances, the stress fracturing provided a means of bridging leads previously not possible to cross. Other aspects of lead transection by ships have been directed towards implications for ice cover break-up which is discussed in subsection 8.2.2.

8.2.2 Icebreaker Effects on Break-up

The deterioration of an ice cover through break-up is a complex process, influenced by a variety of forces. As such, it is difficult to assess the isolated contribution of one influencing factor such as that of icebreaker traffic. Concerns expressed over the potential impact of icebreaker transit on break-up pertain to the role of the ship's track in acceleration of the break-up process.

A few studies have been conducted to evaluate icebreaker effects on ice break-up and freeze-up. Most have focused on the Lancaster Sound region and, in particular, Admiralty Inlet. Although the Lancaster Sound area is of primary concern to the Polar 8, other areas will also be affected, however the results of the work done to date can serve as an important base for evaluating impacts in these regions as well.

Two studies of ship-ice interaction in Admiralty Inlet have attempted to evaluate the ship influence on ice cover break-up in this area. Norland Science (1987) investigated the relationship between break-up and early season voyages in Admiralty Inlet between 1981 and 1986. The findings of this study indicate that, in spring, when refreezing of the track does not occur, premature creation of large floes can be observed. However in none of the years studied was this sufficient to precipitate advanced clearing of the inlet. Apparently other factors such as wind speed and direction and ice conditions in Lancaster Sound were not favourable for advanced clearing.

Strandberg *et al.* (1985) compared the 1984 M.V. Arctic voyage to Nanisivik in late spring with historical break-up conditions based on satellite imagery. Their findings indicated that the ship track accelerated break-up by 1 to 2 days. They noted that it was difficult to differentiate between ship-induced effects and normal ice cover deterioration.

The complexity of the break-up process is clearly illustrated by the work of Hotzel and Noble (1979) who investigated break-up and freeze-up in Parry Channel between 1973 and 1977 using satellite imagery to document ice conditions. The formation of a consolidated ice arch in Lancaster Sound as discussed earlier, resulted in the delineation of two distinct ice regimes east and west of the ice arch. To the east, break-up and clearing was strongly influenced by the timing of ice clearing in Baffin Bay. At the same time, the east-west location of the ice arch in Lancaster Sound, dictated the amount of the channel which cleared to the east of the arch. Hotzel and Noble (1979) found evidence to indicate that the positioning of the ice arch was related to freeze-up conditions the winter before, further increasing the level of complexity. The annual positioning of this arch has been shown in Figure 7.3.1.5, providing an indication of the variability in regional ice conditions which cannot be disassociated from analyses of local break-up patterns.

The investigation by Hotzel and Noble was carried out as part of an evaluation of Arctic Pilot Project LNG traffic through Parry Channel. Taking into account the regular LNG traffic, they concluded that the impact of icebreaker traffic would

have negligible impact on break-up in Lancaster Sound in comparison to the high degree of natural variability. This would suggest that the impact of a single vessel such as the Polar 8, travelling on an irregular and flexible schedule would have even less impact.

Hotzel and Noble do suggest that the time for greatest potential impact would be in the fall during freeze-up. At this time an icebreaker could influence the formation of the ice arch as well as landfast ice, through interruption of the natural freeze-up process. In this way, the ice arch formation could be delayed or its location modified. Their evaluation concluded that, through selection of an appropriate route, it would be possible to minimize the impact on landfast ice formation and ice arch stabilization.

In response to issues raised during the Beaufort Sea Environmental Impact Statement review, Dickens (1983) looked at the effect of tanker traffic on the ice break-up in Prince of Wales Strait. Once again, normal break-up dates were found to be highly variable. Based on his investigation of historical data, Dickens determined that the passage of tankers through the Strait, even at a rate of two per day, was not likely to alter the stability of landfast ice and hence would have no influence on break-up beyond the natural variability.

It would appear that while the ship track can result in the creation of discrete floes during the spring period, the resultant break-up response is not easily predicted, being controlled by other factors such as meteorological conditions and ice
conditions in surrounding regions. The findings of previous studies suggest that potential impacts are few and would result in disturbances within the range of natural temporal variability in the break-up process.

8.2.3 Effects on Ice Edges/Bridges

A characteristic of the break-up and freeze-up of fast ice in the Canadian Arctic is the development and collapse of ice edges. In the Beaufort Sea Environmental Assessment Review, concern was expressed over the effect ship traffic might have on the stability of ice edges, particularly during break-up and freeze-up. It was felt that the resulting ship track(s) may, in the case of break-up, cause the edge/bridge to collapse earlier than normal and advance the break-up of the fast ice (with its associated impacts) in general. During freeze-up, continued transits may destroy or delay the formation of new ice edges, preventing the natural development of the fast ice cover.

For the purposes of this discussion, ice edge refers to the boundary between fast ice and open water or moving pack ice. An ice bridge consists of pack ice floes jammed together across the width of the channel.

8.2.3.1 Location of Critical Ice Edges/Bridges

The location of critical ice edges varies with the time of year. In winter, when much of the ice cover in the Arctic is consolidated, only a few ice edges or bridges are potentially significant in the sense that disruption of them could induce other changes in the regional ice regime. During the winter months the critical edges are those located in Lancaster Sound and Nares Strait. In both cases, ice conditions on one side of the edge are such that a break-up of the edge would permit a flux of ice into Baffin Bay. Ice bridges develop during the summer months when the ice is mobile. The following briefly describes what are believed to be the important ice edges and bridges in summer and fall that, if broken by a vessel such as the Polar 8, could significantly alter the resulting ice regime locally or regionally.

a) Summer Ice Edges/Bridges

Break-up of the ice edge in northern Byam Martin Channel is a significant event of the mid to late summer ice regime in the Arctic Archipelago. This edge is important because it separates the predominantly multi-year ice regime in the Prince Gustaf Adolf Sea from Parry Channel. Whether or not the edge breaks and when it occurs will largely determine how much of this multi-year ice will move into Parry Channel (with associated effects on local shipping). It is noteworthy that the edge did not break in 5 out of 10 years spanning the period from 1974 to 1983 (Canarctic and Norland, 1985) and 6 years out of 13 from 1974 to 1986 (Gorman, 1988).

An important ice edge in the Sverdrup Basin is located in Maclean Strait between King Christian Island and Ellef Rignes Island. The Maclean Strait edge does not break every year (3 years out of 10, 1974 to 1983), but when it does, large areas of mostly multi-year ice break behind it and move south into the Sverdrup Basin. The northern edge breaks around mid-September releasing the multi-year ice floes in the Prince Gustaf Adolf Sea.

The last significant ice bridge develops at the north end of Penny Strait. It develops when one or more giant multi-year floes that remain from the break-up of the Sverdrup Basin jam against the central islands in the channel. Once the bridge is in place, ice floes build up behind it. This effectively stops any further southward movement of multi-year ice from the eastern Sverdrup Basin into

Parry Channel. The bridge usually develops in September, and remains in place until break-up the following spring.

b) Fall Ice Edges/Bridges

Numerous ice edges and bridges develop in the fall during the freeze-up period. These edges are often temporary features lasting only a few days. Sometimes they mark boundaries where the developing ice cover stabilized for a time before advancing to cover the next section of channel.

The most dynamic and variable channel for ice edge and bridge formation is Parry Channel. As noted before, this channel experiences the largest variation in fast ice coverage on a year to year basis. This is due in part to the complex process of ice edge formation, collapse and reformation due to winds, currents and tides. Figure 8.2.3.1 lists the average and wide range of dates for the development of these edges which mark the progressive expansion of the fast ice cover. Freeze-up in Parry Channel is a complex array of periods of compaction and mobility and extends well into winter (Gorman 1988).

The other critical ice edge in the fall and winter months occurs at the south end of Kane Basin in Smith Sound. Once this edge/bridge develops it stops any further southward movement of old ice from Nares Strait. In two out of eleven years the Smith Sound ice edge formed early (early to mid-November) and remained stable until break-up the following year. In several other years the edge formed, broke and reformed several times throughout the winter. The remaining years showed the ice edge did not develop until mid-February.

8.2.3.2 Potential Ship Transit Effects

It is difficult to separate ice edge dynamics from overall break-up and freeze-up patterns. The potential effects of ship transit on ice edges and bridges are also closely linked to influences on break-up and freeze-up impacts. To date, limited information is available regarding the potential impacts relating to ice edge modification.

The body of work available has been compiled primarily in support of two proposed developments, the Arctic Pilot Project and Beaufort Sea offshore oil and gas development. As such, supporting documentation focuses on impacts from ship traffic along traffic corridors through the Northwest Passage. Impacts on ice edges have largely been concerned with the Lancaster Sound/Barrow Strait ice edge. The impacts on other important ice edges and bridges, identified in section 7.3.6, are, at best, incompletely documented.

Figure 8.2.3.1
FREEZE-UP AND CONSOLIDATION SEQUENCE FOR THE PARRY CHANNEL 1974-1986

Event	Average Date of Occurrence	Range of Occurrence
1. Consolidation of the narrow Channels adjoining Parry Channel.	Late October	Early October - Late November
2. Consolidation of Austin Channel.	November 7	October 8 - December 14
3. Northern Wellington Channel Ice Bridge.	November 14	October 18 - December 20
4. Compaction of Western Parry Channel.	Late November	Late October - Late December
5. Consolidation of Admiralty Inlet.	Mid-November	Mid-October - Late December
6. Consolidation of Peel Sound.	November 22	October 23 - January 9
7. Consolidation of Southern Wellington Channel.	December 4	November 4 - January 29
8. Western Barrow Strait Ice Bridge.	December 3	October 30 - December 27
9. Consolidation of Eastern M'Clure Strait and Viscount Melville Sound.	December 14	October 27 - January 20
10.Formation of Russell Island Ice Bridge.	December 14	October 10 - January 5
11.Formation of the Griffith Island Ice Bridge.	January 9	October 24 - February 28
12.Consolidation of Western M'Clure Strait.	January 24	November 19 - March 28
13.Formation of Prince Leopold Island Ice Bridge	February 2	December 11 - March 5
14.Consolidation of Lancaster Sound.	February 26	November 27 - March 23
15.Consolidation of Prince Regent Inlet.	March 5	December 3 - April 15

Source: Gorman, 1988

Lowings and Banke (1982) estimated ship transit impact on the ice edge in the context of general ice edge break-up in Lancaster Sound. On a seasonal basis, they concluded that because of the overall instability of the ice edge in spring, it was at this time that the potential impact was greatest. However, they felt that if attention were paid to minimizing ice edge entry and exit points, the impact would be well within the natural variability of ice edge deterioration. One of the few documented examples of a ship track transecting an ice edge occurred when the Louis S. St. Laurent crossed the ice edge in Lancaster Sound in May, 1977 (Hotzel and Noble 1979). The ship penetrated beyond the ice edge only 30 km but no detectable modification of the ice edge occurred despite the fact that the track remained open and Lancaster Sound was free of ice east of the ice edge, providing an open drift area for any newly formed ice pieces.

Lowings and Banke (1982) also suggested that in fall, numerous transects during freeze-up could delay edge stabilization and possibly relocate the Lancaster Sound ice edge farther west. The latter has also been suggested by Hotzel and Noble (1979) as a potential impact in considering Arctic Pilot Project LNG traffic through Lancaster Sound. In winter, no major deformation or failure would be expected in this area (Lowings and Banke 1982).

In looking at the ice edge at the southern end of Prince of Wales Strait, Dickens (1983) noted that the ice edge was extremely dynamic with regular fracturing of ice pieces into Amundsen Gulf. His conclusion was that Beaufort Sea tanker traffic was unlikely to impact this ice edge beyond its natural variability.

A potential impact that has been linked to ice edge break-up, is the subsequent release of previously confined multi-year ice. This impact is particularly important in the summer months when the ice cover is decayed and is free to move in response to winds and currents. The potential for this type of situation is of concern in the Sverdrup Basin where the ice arches across Byam Martin Channel and Penny Strait restrict the movement of ice into Parry Channel. As noted earlier, the natural break-up of the arch in Penny Strait occurs annually while the arch in Byam Martin Channel remains in place one in every four years. As such, the effect of arch deterioration is largely related to timing.

The same can be said of the ice arch in Nares Strait where break-up occurs annually although the timing may vary from year to year. In Nares Strait the presence of an ice bridge restricts the southward drift of multi-year ice into North Baffin Bay. Because of the presence of the North Water polynya, the importance of this bridge remains throughout the year. Consequently, disruption of this ice edge could affect ice regimes in other areas in winter as well as in summer.

Observation of natural ice edge deterioration, indicates that in most seasons, break-up and the subsequent freeing of confined ice floes do occur annually but that the timing of the event can vary from one year to the next. In areas where the Polar 8 transits might cross critical edges, they could be timed to minimize any potential influence the ship track might have on premature deterioration of the ice edge.

As in the case of potential impacts on regional break-up patterns, from the available information, ship traffic impact on the ice edge appears to be within the natural spatial and temporal variability. The extent of investigation is limited and warrants further attention, particularly in the case of ice edges which have not been investigated previously. Further assessment of actual ship transects of ice edges is also necessary to compliment assessments based on the evaluation of natural processes. The Polar 8 offers a means whereby this type of investigation can be conducted.

8.2.4 Lower Trophic Levels and Fish

This section is the first to deal with the biological effects. The first of these are Lower Trophic Levels and Fish.

8.2.4.1 Lower Trophic Levels

Before breakup, production of phytoplankton in the water column is low because of a lack of light and a lack of stratification of the water column. The onset of biological spring is marked by the breakup of ice (Sameoto *et al.* 1986). After breakup, the water column becomes stratified through solar heating and the freshening of surface waters. A bloom in phytoplankton production occurs after breakup. Timing of the life cycles of some zooplankton and secondary production may depend on the timing of the spring phytoplankton bloom (Sameoto *et al.* 1986; Hirche and Bohrer 1987). Biological spring and the summer cycle of copepods occur later in areas where the ice persists longer than in areas where ice breaks up early (Longhurst *et al.* 1984; Sameoto *et al.* 1986). In the unlikely event of premature breakup of a very large area of fast ice (100's of sq km) biological spring and summer would occur earlier than would have been the case if the ice had remained. However, the timing of a premature breakup would probably be within the broad range of the timing of natural breakup. Effects of premature breakup on lower trophic levels would probably be within the range of natural fluctuations in the timing of their life cycles and thus indistinguishable from them.

Icebreaking would have negligible effect on phytoplankton and zooplankton since the areas affected by the ship track are so small. The only effect could occur through the premature breakup of a large area of fast ice which is unlikely to occur. Overall, such breakup patterns would probably be marginally positive for plankton.

8.2.4.2 Fish

Most Arctic fish are bottom dwelling benthic forms. Since the Polar 8's draft will be limited to operational depths of greater than 26 m the benthic fish will be unaffected by icebreaking.

Most anadromous fish such as char do not venture beyond the 5 m contour (Johnson 1980; Craig 1989). Thus, few anadromous would be found within depths accessible to the Polar 8. In addition, most anadromous species are found in the sea only in summer when icebreaking activities will not occur. When inhabiting the undersurface of the ice in spring, a few individuals of the pelagic Arctic cod could be affected by icebreaking. This situation is discussed in the following sections.

8.2.4.3 Underice Biota

Ice breaking will disrupt the underice plants and animals within its track. The amount of disruption would likely depend on the timing of icebreaking activities and on the nature of the ice cover. The underice flora begins to develop in April, peaks in May and then declines. The areal distribution of the underice flora is patchy and some differences in ice algal biomass among areas are likely due to differences in snow cover (Cross 1982; Smith *et al.* 1988). Standing crop of ice algae is lower under ice that is covered with deep snow than under ice that is clear of snow.

There have been no studies of the effects of icebreaking on the underice flora and fauna. The following impact predictions are presented as hypotheses.

a) The track through fast ice made by the icebreaker could be up to 50 m in width. The time necessary for the track to refreeze will depend on time of year. In April and May when fast ice is increasing in thickness and the underice flora is developing, it is probable that the underice flora will develop within the new ice that reforms within the ship's track. In June, new ice formation is less likely to occur and it is unlikely that the underice plant community will reestablish itself to levels found in undisturbed areas.

However, the underice community is disintegrating at this time and effects would be minimal. In July, when the ice is rotting and the underice plant community is all but gone, new ice will not form. Therefore effects on underice flora would be "negligible".

b) The underice fauna consists largely of crustaceans. These animals live in close association with the ice and feed on the underice flora. The underice community of animals could be temporarily disrupted by icebreaking. In offshore areas, most underice amphipods are pelagic species (Cross 1982). Large natural temporal changes in the abundance of these amphipods can occur within a few weeks or less (Cross 1982). After passage of an icebreaker they can probably quickly recolonize the underice habitat of both new ice and the rubble. Amphipods that occupy benthic habitats colonize the under surface of the ice over shallow waters (Buchanan *et al.* 1977; Thomson *et al.* 1978). However, the Polar 8 will not travel in shallow water. Effects on underice fauna would be negligible.

c) Arctic cod are found throughout the Arctic. In spring, they inhabit the undersurface of the ice where they feed on the underice fauna (Bradstreet and Cross 1982). Cod can be turned up onto the ice flows during icebreaking operations (D. Thomson, LGL Ltd. personal observation). Mortality would be limited and because Arctic cod are widely distributed, recolonization could be rapid. Effects are likely to be negligible.

In summary, it is predicted that effects on the underice community within the ship's track would probably be very minor if icebreaking occurred during early spring when ice is still forming and the underice community is developing. After the time of peak development of the underice community, icebreaking would probably accelerate the decline of the community. Effects would decrease with increasing time from the period of peak development of the underice community. Effects would only occur in the April to July period and significant effects would probably occur only in June. These hypotheses are testable with experimentation conducted from the Polar 8. However, the underice biota, in itself, is not a valued ecosystem component. Effects on the underice community would only be of significance if its disruption in turn caused significant changes in the distribution or abundance of birds or marine mammals. Effects on the underice biota of fast ice are unlikely to affect the distribution of marine mammals and birds.

Ice edge communities are special situations and are dealt with in section 8.2.7.

8.2.5 Birds

Sea-associated birds occur throughout Canadian Arctic waters. However, large numbers regularly occur only during the spring, summer and early fall periods in association with areas of open water. In winter most sea-associated birds withdraw to more southerly waters associated with the edge of the winter pack ice and ice-free waters farther south. A few species such as ivory gull and black guillemot winter in polynya such as the Baffin Bay North Water.

The potential effects on birds of noise and disturbance from the Polar 8 and its associated vessels and aircraft are discussed in Section 8.3. This section is concerned only with the effects of icebreaking on birds. In general, effects are likely to be neutral to beneficial to bird populations.

Sea-associated birds are dependent upon open water for their existence. It is for this reason that all major Arctic seabird colonies are located near areas of reliably open water in spring when the birds return from their wintering areas. Since the Polar 8 may marginally increase the amount of accessible open water, there may be some incremental benefit to seabird populations.

8.2.5.1 Ice Edges

In spring and early summer, high densities of several species of sea-associated birds concentrate along fast ice edges in the Arctic (Davis *et al.* 1974; Johnson *et al.* 1976a; Bradstreet and Finley 1977; McLaren and Renaud 1979; McLaren 1980). Because of these high concentrations, ice edges are thought to be important for seabirds, concerns have been raised that any damage to an ice edge by an icebreaker would have detrimental effects on the habitat and on the birds using the edge.

It has been shown that birds concentrate along the ice edge to feed on invertebrates and Arctic cod that are associated with the underice biota (Bradstreet 1980, 1982; Bradstreet and Cross 1982; Cross 1982). The underice community is only accessible near the ice edge since birds can only feed on those animals that can be reached by diving under the ice. After a few days, the food available for birds along an ice edge may become depleted. Therefore, any agent, natural or icebreaker, that breaks off pieces of the ice edge would be beneficial in that it would expose sections of the underice biota that were previously inaccessible to birds.

8.2.5.2 Fast Ice

As noted earlier, sea-associated birds cannot use areas of complete fast ice cover. It was also noted in Section 8.2.1 that the Polar 8 was not expected to have any significant effect on the integrity of fast ice sheets in the High Arctic channels. However, if large areas of fast ice are cleared out due to some presently unforseen set of circumstances, the effects on resident and migrant seabird populations would likely be positive. Since large amounts of previously inaccessible open water habitat could now be used by sea-associated birds. It has been demonstrated that High Arctic seabirds such as northern fulmars, black-legged kittiwakes, and thick-billed murres feed throughout open, offshore waters in low densities. In fact, a majority of the individuals in these populations feed in these areas as opposed to feeding at fast ice edges or in coastal habitats (Davis *et al.* 1974, 1975; Alliston *et al.* 1976; Johnson *et al.* 1976a).

8.2.5.3 Ship Tracks

When the Polar 8 traverses fast ice it will leave a track that is filled with ice rubble consisting of pieces of ice that were broken by the ship's passage (see Section 8.2.1; Dome *et al.* 1982a). Black-legged kittiwakes, Thayer's gulls, and glaucous gulls may eat the many fish (Arctic cod) and invertebrates that are exposed on the pieces of overturned ice in the ship's track (Andriashev 1970; MacLaren Marex 1979; W.W.H. Gunn, LGL Ltd., pers. comm.). This source of additional food is likely to be too small and unpredictable to have any effects on bird populations.

8.2.6 Marine Mammals

The potential effects on marine mammals of icebreaking activities by the Polar 8 are discussed in this section. The more wide-ranging question of the effects of underwater noise and disturbance from the Polar 8 is discussed in Section 8.3. It is recognized that the effects of icebreaking cannot be completely separated from the noise created by the icebreaking activity. This problem is considered, where appropriate, in the following discussions.

There are three major concerns associated with icebreaking activities. These are (1) the possibility of direct mortality of marine mammals through collisions with the Polar 8; (2) changes in marine mammal habitat; and (3) the possibility that whales could be trapped in leads created by the vessel.

8.2.6.1 Direct Mortality

In open water situations marine mammals have no trouble avoiding collisions with oncoming ships. Similarly, polar bears and Arctic foxes that occupy the sea ice have no trouble avoiding slow-moving icebreakers (Figure 8.2.6.1). In ice-covered waters, the situation may be somewhat different since mammals have few alternate locations where they can breath. The species of concern is the ringed seal, which occurs throughout the Canadian Arctic. The ringed seal inhabits areas of fast ice throughout the winter. Each seal maintains breathing holes in the ice. In late March and early April, pregnant females give birth to a single pup in lairs hollowed out of snow drifts on the surface of the fast ice. The snow drifts usually accumulate in the lee of pressure ridges and hummocks (Smith and Hammill 1981). The pups are usually weaned at about 6-8 weeks of age (McLaren 1958; Smith 1973). Newborn pups are unable to withstand cold temperatures when wet (Taugbol 1984 cited by Smith 1987) and thus, they are probably unable to avoid being crushed by an icebreaking ship that passes through their lairs. It is not known at what age the pups could survive immersion in the cold seawater and move out of the way of the oncoming icebreaker (LGL *et al.* 1984; ESL *et al.* 1985). The pups moult their first coats by 3-4 weeks of age (Chapskii 1938) and we have assumed that by 4 weeks of age, the newborn seal can avoid an icebreaker. Thus, there is a period of about 4 weeks in April and early May during which the Polar 8 could cause some mortality to ringed seal pups.

It is possible to calculate the extent of the possible damage by determining the proportion of the available habitat for breeding ringed seals that would be affected by the Polar 8 during the 4 week period of concern. It is premature to make such estimates for the Polar 8 since its schedule for any particular April period is not yet known. However, to put this concern in perspective it should be noted that the Polar 8 is only one ship and it physically cannot affect a significant proportion of the available habitat. The Polar 8 has a breadth of 36 m and is expected to create a track that is less than 50 m wide. Thus, if the Polar 8 traverses 20 km of landfast ice, it will actually directly affect 1 km of habitat either striking seal pups or flooding their lairs. At an average density of 1 pup/km , then one pup might be killed during April for every 20 km travelled in stable fast ice, which is the preferred pupping habitat for ringed seals (Stirling *et al.* 1977; Smith 1987). There are some possibilities for minimizing the amount of pup mortality. This can be done by avoiding known areas with high densities of breeding ringed seals in April; avoiding areas which contain prime pupping habitat in a particular year; and ensuring that return trips through an area utilize the same track as used on the inbound voyage. It should be noted that even in

Figure 8.2.6.1
POLAR BEAR ON ICE.

Source: D.H. Thomson, LGL Limited

the absence of mitigation the proportion of the ringed seal pups born in any one year in the Parry Channel region that would be affected by the Polar 8 would be small. The impact is expected to be minor.

8.2.6.2 Changes in Habitat

The Polar 8 will change some of the fast ice and heavy pack ice habitat used by ringed seals. It is possible that seals will be unable to use the ice in the track of icebreakers and/or that they will abandon the track. Studies in the Beaufort Sea (Alliston 1980) and Lake Melville, Labrador (Alliston 1981) indicate that ringed seals do not abandon fast ice areas in response to small numbers of icebreaker passages in winter. In fact, there is evidence from these studies that ringed seals may preferentially establish breathing holes in the rubble of the ship's track. Thus, it appears that effects on the fast ice habitat of ringed seals are probably best described as neutral.

Ringed seals are widely distributed in low densities on the pack ice of Baffin Bay and unconsolidated ice in Lancaster Sound. Seals in the path of the Polar 8 in this habitat will be forced to move to avoid the ship and a small amount of ice habitat will be destroyed. The loss of this habitat is expected to be trivial compared to the severe natural disruptions that regularly occur in this unstable shifting ice environment.

8.2.6.3 Entrapment in Leads

A concern about the Polar 8, and other major projects involving powerful icebreaking ships, is the possibility that the icebreaker will create open leads that could subsequently close and trap whales that had tried to follow the leads (A.P.P. 1979; Dome *et al.* 1982a, 1983). The principal species of concern are white whales and narwhals, which under natural conditions occasionally become trapped by ice and eventually succumb to starvation. Natural entrapment of white whales and narwhals has been recorded in west Greenland (Vibe 1967; Kapel 1977), in the Canadian High Arctic (Degerbøl and Freuchen 1935; Freeman 1968; Finley and Johnston 1977), and in the Beaufort Sea area (Barry 1967; M. Fabijan, Fisheries Joint Management Committee, pers. comm., Oct. 1989). The principal areas of concern for the Polar 8 are the ice edges across Lancaster Sound or Barrow Strait and adjacent channels in spring. White whales and narwhals enter and follow natural leads as soon as they form in spring (Finley *et al.* 1984). Therefore, it is possible that whales would follow artificial leads created by the Polar 8. It is also possible that the artificial leads would be unstable and prone to close and/or refreeze sometime after the ship passage thereby trapping whales.

The available evidence suggests that whales will not follow leads created by icebreakers. Icebreaker tracks through fast ice are filled with broken ice rubble and there is virtually no open water in the track. Additionally, except for very late in the spring, the rubble rapidly refreezes creating complete ice cover within a few hours (Dome *et al.* 1982a). Observations at the Admiralty Inlet ice edge in late July 1979 and in late June and early July of 1980 and 1982 demonstrated that white whales and narwhals did not follow ship tracks, although some natural leads were utilized (Hatfield 1980; Kanik *et al.* 1980; Finley *et al.* 1983). Finley *et al.* (1984) observed small numbers of narwhals and white whales using a ship track late in the break-up period in 1983, but most of these animals moved to a natural lead that formed soon after. The ship track did not contain complete ice cover and did not refreeze when the whales were using it in early July.

The available evidence indicates that white whales and narwhals take evasive action and avoid close approach by ships in spring (Fraker and Fraker 1982; Finley *et al.* 1983, 1984; Miller and Davis 1984; Finley and Davis 1984; Cosens and Dueck 1988). Thus, it is unlikely that whales would closely follow the Polar 8 which would be creating underwater noise as it breaks through fast ice. Given that whale behaviour required a few hours to return to normal after a ship passage (Finley *et al.* 1983, 1984), it is likely that the ship track would refreeze before the ship had travelled far enough for noise levels at the edge to diminish to levels that would not disturb whales that tried to enter the track. Overall, then, it is probable that the Polar 8 would not create functional artificial leads that could be used by whales.

8.2.7 Ice-edge Communities

In spring, a distinctive underice biological community develops on the under surface of the first year sea ice (see Sections 7.3 and 8.2.2.3). The underice community is widespread throughout the Arctic, but it is most important when it becomes accessible to birds and mammals at ice edges. The accessibility of the underice biota to vertebrate predators can lead to very high concentrations of sea-associated birds and marine mammals along fast-ice edges in spring (Alliston *et al.* 1976; Johnson *et al.* 1976a,b; McLaren and Renaud 1979; Bradstreet 1980). These vertebrates are the visible component of the so-called ice-edge community.

Detailed studies of the dynamics of the ice-edge community across Pond Inlet were conducted by LGL Limited in 1979 for Petro-Canada as part of the EAMES project. These studies demonstrated that the underice biota at the ice edge was similar to the community several km from the edge (Cross 1982). Thus, the underice biota was not enhanced by its proximity to the ice edge. In fact, the

underice biota near edges is heavily preyed upon by sea-associated birds that concentrate there (Bradstreet 1980, 1982, 1988; Bradstreet and Cross 1982). The concentrations of marine mammals, primarily white whales and narwhals, that occur along ice edges represent animals waiting to migrate through the ice to summering areas. There is little marine mammal feeding that is directly associated with the ice edge (Bradstreet 1982; Finley and Gibb 1982; Finley and Evans 1983).

It is clear from the studies to date that the significance of ice-edge communities is that the underice biota is accessible to feeding birds. In normal operations, the Polar 8 will have little effect on the integrity of fast-ice edges. When the icebreaker enters or leaves the fast ice, it will break the ice across an ≈50 m width of ice edge. The effects of this on the underice biota and associated seabirds would be trivial.

If the Polar 8 were to break off large pieces of ice along the edge, then another ice-edge community would be formed with a new section of the underice biota becoming available to avian predators. This could enhance seabird feeding. Thus, the Polar 8 will not have negative effects on ice-edge communities.

Overall, the effects of the Polar 8 on ice-edge communities are expected to be "negligible".

8.2.8 Polynyas

Polynyas provide overwintering habitat for some species of marine mammals and birds and open water for bird migrants that arrive early in spring (figure 7.3.1.3). In spring, the underice biota of adjacent fast ice is accessible to animals within a polynya. The effects of icebreaking on the ice edge in a polynya would be similar to those described above for ice edges. Icebreaking would not enlarge the area of the polynya because any large ice flows that were broken off during icebreaking would remain within the open water that is bounded by ice. Entrapment of marine mammals in icebreaker-created leads is not expected to be a problem (see 8.2.4.3). Overall, the effects of icebreaking on polynyas and their inhabitants are expected to be "negligible". Effects of noise and disturbance are discussed below in 8.3 and 8.4.

8.3 EFFECTS OF NOISE AND DISTURBANCE

The previous section described the physical effects of icebreaking on marine life. This section describes possible effects of noise and disturbance generated by the

ship and icebreaking activities on fish, birds and marine mammals. Potential effects of noise and disturbance caused by the ship's helicopters, auxiliary vehicles and vessels are discussed in Section 8.4.

The topics of underwater acoustics and the effects of underwater noise on marine animals are not familiar to most readers. Therefore, a brief background section is provided in an attempt to clarify some of the principles involved.

8.3.1 Background

Most treatments of the effects of underwater noise are conceptually based on the simple sonar equation:

Source : Path : Receiver

The elements of this equation are straightforward. In the present case, the noise source is the Polar 8 icebreaker which because of its powerful engines and its icebreaking role will generate large amounts of underwater noise. Noise from the ship radiates outward from the ship and travels through the water as pressure waves. Water is an efficient medium through which underwater sound can travel long distances. The receiver of these sounds is a marine animal of interest i.e., a Valued Ecosystem Component. The sounds received depend upon how much propagation loss occurred between the source and the receiver. The ability of the receiver to detect these signals depends upon the hearing capabilities of the species in question and on the amount of natural ambient or background noise in the sea around the receiver. The sea is a naturally noisy environment and this noise can drown out or mask weak signals from distant sources.

Since sound intensity, per se, cannot be measured directly, pressure is measured instead. Sound levels are reported in the logarithmic decibel scale, which measures pressures relative to a reference pressure. For underwater acoustics, the current reference pressure is 1 micro-Pascal and sound pressure levels are reported in dB re 1 μPa. Source levels are usually expressed for a standardized distance of 1 m from the source; field measurements are often extrapolated to this reference distance. Intensity measurements can be expressed as broadband, meaning the overall intensity of the sound or total sound produced over a range or band of frequencies. The intensity at a specific frequency will be lower than the broadband sound containing that frequency because the broadband sound is the sum of intensities at each frequency. Sound signatures from ships consist of measurements of noise levels at each frequency (a sound spectrum). Sound intensity can also be measured and summed over groups or bands of frequencies (e.g., octaves or third octaves).

The source : path : receiver equation will be used to illustrate the main points needed to evaluate the possible effects of the Polar 8.

8.3.1.1 Source Levels

The major portion of the radiated noise from a ship comes from the propulsion machinery. This includes the main engines, motors (if diesel-electric drive), geared reduction transmissions, and propellers. Other sources of sound include pumps, electric generators, ventilators, compressors and so on. Ship sounds may be of two types: (1) broadband sounds ("hissing" at high frequencies or "rumbling" at low frequencies) not concentrated at any particular frequencies but spread continuously over a band of frequencies, and (2) narrowband tonal sounds concentrated at particular frequencies associated with rates of events in machinery operation. Examples of tonal sources are engine cylinder firing rates, shaft rotation rates, and blade rotation rates in propeller and turbine operation. Typically, tonal components from propulsion machinery are at low frequencies, rarely exceeding 100 Hz. Auxiliary machinery tones may occur at frequencies up to a few kilohertz. These types of machinery often give rise to harmonic families of tonal components. Examples of broadband noises include the rushing sounds of fluids in pipes, and the sounds of propeller cavitation. Cavitation is a major source of sound, and it may be modulated by low frequencies associated with the shaft and blade rates (Richardson *et al.* 1989).

Information on the source noise levels of the Polar 8 is not yet available since details of the propulsion system and ship's machinery have not yet been finalized and tests of propeller design and cavitation levels have not been completed. Measurements and estimates of noise levels from a variety of icebreaking and other large vessels have been made in recent years (Ross 1976; Brown 1982b; Greene 1985, 1987; Richardson *et al.* 1989). These data are sufficient to approximate the noise levels expected from the Polar 8.

Brown (1982b), using the method of Brown (1977), calculated the estimated noise levels for six existing Canadian Coast Guard icebreakers (Louis S. St. Laurent, John A. MacDonald, Sir John Franklin, Norman Macleod Rogers, Labrador, and d'Iberville). Estimated peak spectrum source levels at 1 m ranged from 167 to 175 dB re 1 $\mu Pa^2/Hz$ for the six vessels in normal open water conditions. These figures represent broadband cavitation noises at about 50 to 60 Hz. The estimate for the Louis S. St. Laurent was compared to measurements made on a sound range; they were said to be in very good agreement, but no details were given (Brown 1982b).

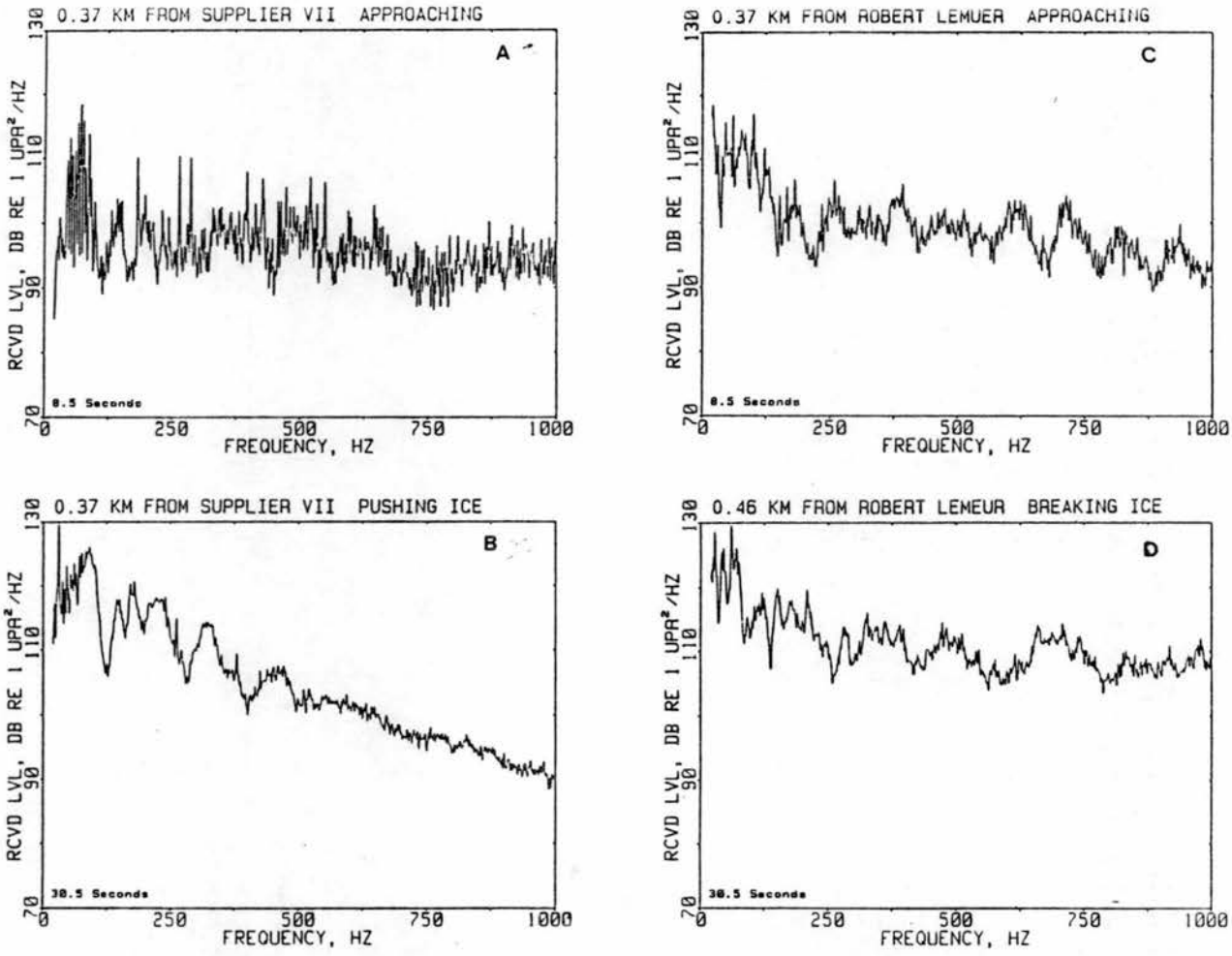
When icebreakers are underway breaking or pushing ice, they use higher power levels and create more propeller cavitation than when they are underway in open water. The effect of icebreaking on radiated ship noise is demonstrated clearly by comparing sound spectra from the same ship underway in open water vs. icebreaking at the same distance (Figure 8.3.1.1). During icebreaking, received sound levels in the 20-1000 Hz band increased by 14 dB in the case of Supplier VII and by at least 11 dB for Robert Lemeur. The differences in noise levels underway vs. icebreaking tended to decrease as distance from the ship increased (Figure 8.3.1.2). The steeper slope during icebreaking indicates more rapid attenuation of sound in the heavy ice condition. Even so, the elevated noise levels associated with icebreaking are substantial out to at least 5 km.

Icebreaking differs from normal vessel underway operations in several ways. In ice sufficiently thin for a ship to make steady progress ahead, more power is used, and more noise is generated, than for comparable operations without ice. In thicker ice, the ship must back and ram; noise levels will be higher when inreverse, when accelerating ahead, and when stopped by the ice with full power on (called the "bollard" condition). These features of icebreaking have been examined in recent studies. These studies have shown that noise levels during icebreaking are highest during the full astern phase (Figure 8.3.1.3). Levels for full astern ranged from 5 to 9 dB higher than during full ahead icebreaking. The reader is cautioned that the measurement bandwidths differ for the three ships in Figure 8.3.1.3. Therefore, it is not appropriate to compare the source levels of the three ships. The levels for the John A. MacDonald would be higher if a wider range of frequencies had been measured.

There has been speculation about whether the increased noise during icebreaking is caused by the physical crushing of ice or solely by increased propeller cavitation or engine noise. Thiele (1984) evaluated this by placing accelerometers in the bow of the icebreaker John A. MacDonald to sense icebreaking vibration and in the stern to sense to propeller vibration. Signals from the accelerometers were correlated with underwater noise received at a remote hydrophone while the ship was icebreaking and travelling in open water. There was a clear correlation between propeller cavitation and underwater noise, but little correlation between icebreaking vibration and radiated noise. Thus, the increased noise during icebreaking is primarily due to the propellers.

The largest, most powerful ships proposed for use in the Canadian Arctic were the LNG (liquified natural gas) carriers of the Arctic Pilot Project. The final design involved ships of 140,000 tonnes powered by 150 MW turbo-electric power systems driving two variable pitch propellers in Kort nozzles. A substantial

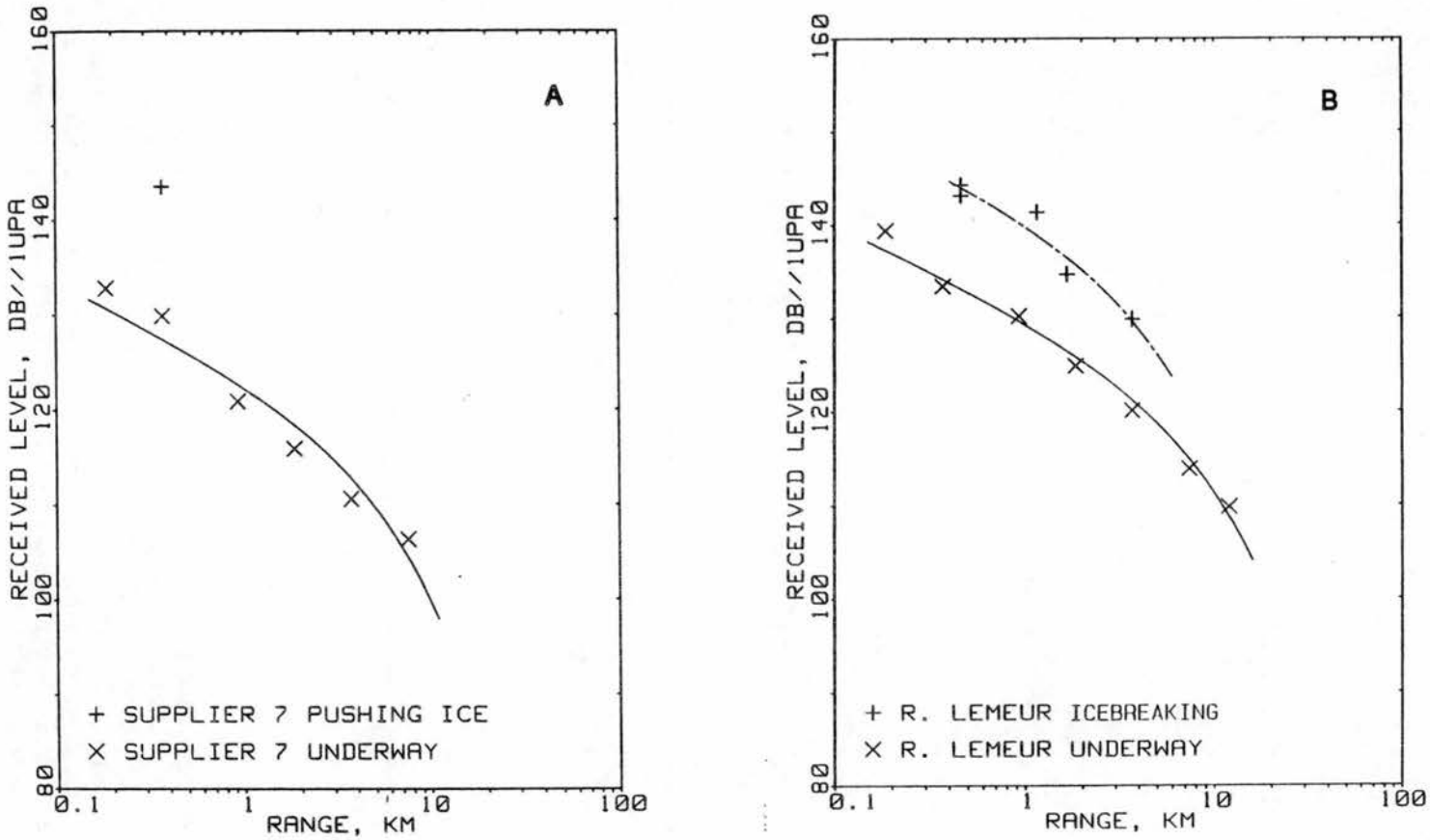
Figure 8.3.1.1
ICEBREAKER NOISE SPECTRA.



Received underwater sound pressure spectra for icebreaking supply vessels Canmar Supplier VII and Robert Lemur underway in open water (top) and icebreaking (bottom). Broadband (20-1000 Hz) received levels for Supplier VII were 130 dB in open water (A) and 144 dB while pushing ice (B). Broadband levels for *R. Lemur* were 133 dB in open water (C) and 144 dB while pushing ice (D). A-C were at range 0.37 Km whereas D was at 0.46 Km; hence levels in D should be increased by 1-2 dB to make them comparable to A-C. Analysis bandwidth was 1.7 kHz.

Source: Greene, 1987

Figure 8.3.1.2
ICEBREAKER NOISE *VS* RANGE: RECEIVED UNDERWATER NOISE LEVELS (20-1000 HZ) FOR (A) *CANMAR SUPPLIER VII* AND (B) *ROBERT LEMUR* WHILE (X) UNDERWAY AND (+) PUSHING AGAINST OR BREAKING ICE.



Source: Greene, 1987

Figure 8.3.1.3
ESTIMATED SOURCE LEVELS (AT 1 m) FOR ICEBREAKER NOISE

Ship/Condition	Frequencies Measured (Hz)	Source Level dB re 1 μPa
M/S Voima		
Icebreaking full ahead	20-10,000	180-185
Icebreaking full astern	20-10,000	190
M.V. Arctic		
Icebreaking ahead	10-1000	184
Icebreaking astern	10-1000	191
CCGS John A. MacDonald		
Idling	1/3 Octave*	160
Icebreaking ahead	1/3 Octave*	172
Icebreaking astern	1/3 Octave*	181

* 1/3 Octave band centred at 50 Hz.

Source: Finley et al. 1983, 1984; Thiele 1981, 1984

amount of research was generated by the Arctic Pilot Project. Noise levels of the ship were estimated by Brown (1982a,b). Source spectrum levels, in dB re 1 $(\mu Pa\text{-}m)^2/Hz$, were expected to reach 172 dB at 70 Hz at full power in open water and 165 dB at 83 Hz at half power in open water. When icebreaking at full power, source spectrum levels were expected to reach 177 dB at 55 Hz, an increase of 5 dB over the full power open water condition. The highest spectrum levels (182 dB at 40 Hz) were expected to occur in the bollard condition, where the ship was at full power but had no forward movement. This would occur only during the ramming and backing phase during breaking of very heavy ice. The overall (i.e., integrated over the 20-1000 Hz frequency band) free-field noise level under this condition was expected to be 199 dB. Blade-rate tones would have had a fundamental frequency of 5.33 Hz and noise at that frequency would have been about 191 dB re l μPa (Brown 1982a).

In the absence of more detailed research, it is appropriate to assume that noise levels from the Polar 8 will exceed those of existing Coast Guard icebreakers, but will be less than the larger, more powerful APP carriers.

8.3.1.2 Propagation Loss

Sound travels through water as pressure waves. In contrast to air, water is a good medium for sound transmission with the result that sounds can carry for very long distances in water. Low frequency sounds travel particularly well and this is of significance because most ship noise and some of the sounds produced by marine mammals, especially baleen whales, are also low frequency.

As sound travels outward from the source, its intensity decreases with distance. Under ideal conditions, propagation or transmission loss is proportional to the square of the distance from a point source in deep water and proportional to the linear distance from the source in shallow water. These ideal conditions are usually assumed when source levels are calculated. However, a number of other factors can affect rates of propagation loss, particularly in shallow water. These factors include water depth, source depth, water temperatures and salinity, surface roughness and bottom type. Received sound levels also depend on the depth of the receiver. In shallow water, less than 200 m deep, these factors can play a considerable role in increasing transmission losses. Discussing shallow water propagation, Urick (1975) states, "Because of these complexities, the transmission loss to be expected at a shallow water location may be said to be, for many purposes, unpredictable. Recourse to direct measurements is necessary.

In general, sound transmits farther in shallow, Arctic waters than in deep waters where spherical spreading loss occurs (i.e. 6 dB per doubled distance for spherical spreading loss vs. 3 dB per doubled distance for the cylindrical spreading loss that often occurs in Arctic waters (Richardson *et al.* 1983). In addition, sound absorption, which is a form of transmission loss involving conversion of acoustic energy into heat, is important in Arctic waters. Absorption is a negligible factor at low frequencies but a major factor limiting long distance propagation at high frequencies. Milne (1967) quantified this relationship for ice-covered waters as a loss rate of 0.0062f dB/km where f is the frequency of the sound in kHz. Thus, high frequency (100 kHz) echolocation sounds of white whales are absorbed at the rate of 62 dB/km whereas low frequency (100 Hz) calls of bowhead whales are absorbed at the negligible rate of 0.00006 dB/km. Since most ship noise is at low frequencies, it is expected to propagate well out to significant distances (several 10's of km in many cases).

8.3.1.3 Receiver

For an animal to hear the Polar 8, the received level of the underwater noise from the ship must be greater than the absolute hearing threshold of the animal of interest. Received sounds below this threshold are not detectable by the animal. The hearing threshold varies with frequency and the frequencies of greatest sensitivity vary among species. The underwater hearing thresholds of three common species of High Arctic marine mammals are given in Figure 8.3.1.4. Hearing thresholds have not been determined for other relevant species. Hearing threshold data are not available for any species of baleen whale, including the bowhead.

An animal's ability to detect the distant sounds of the Polar 8 will also depend on the amount of natural ambient or background noise in the waters in which it is swimming. If background noise is high, then the ship would only be detectable at relatively close ranges. The open sea is a naturally noisy environment. Typical open water ambient noise spectra are shown in Figure 8.3.1.5. Wind, thermal noise, precipitation, ship traffic, biological sources and geophysical sources are all major contributors to ambient noise. In ice covered waters, thermal stresses and cracking of fast ice, wind over granular surfaces, sounds made by floes moving against each other are major sources of ambient noise (see Richardson *et al.* 1989 for review). Underwater ambient noise associated with pressure ridges and pack ice edges is greater than that associated with fast ice.

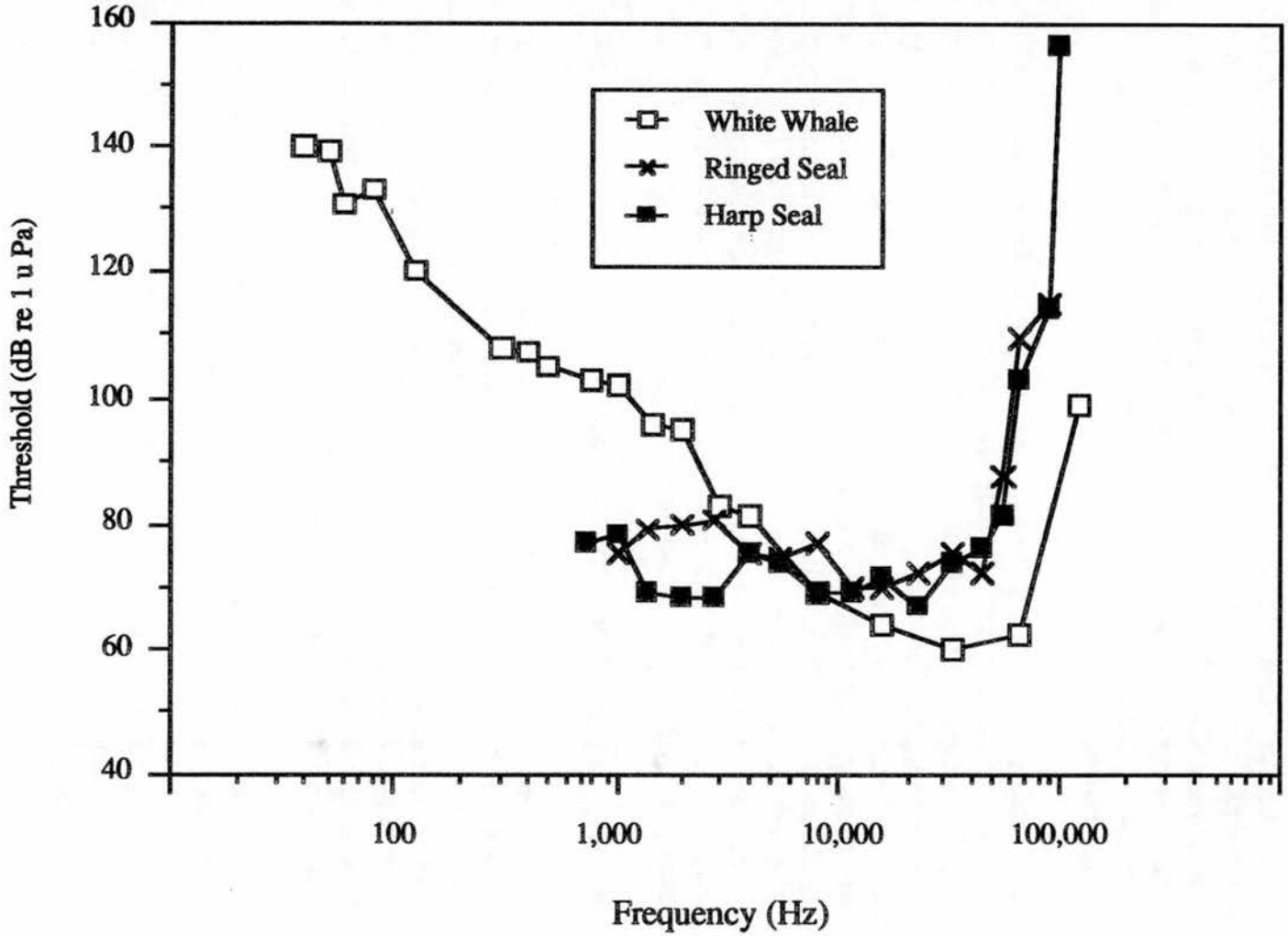
8.3.1.4 Zones of Potential Influence

Once source levels and propagation loss have been evaluated, the question becomes, "what are the effects of noise on marine animals"? This is clearly the most complicated and least understood component of the source : path : receiver model. There are many gaps in the information on hearing capabilities and on the functional significance of the communication signals. Thus, it is not yet possible to establish unequivocal criteria for determining the zone of influence or zone of effects around a noise source.

A hierarchy of criteria for establishing zones of influence can be used for discussion purposes. These criteria are based on

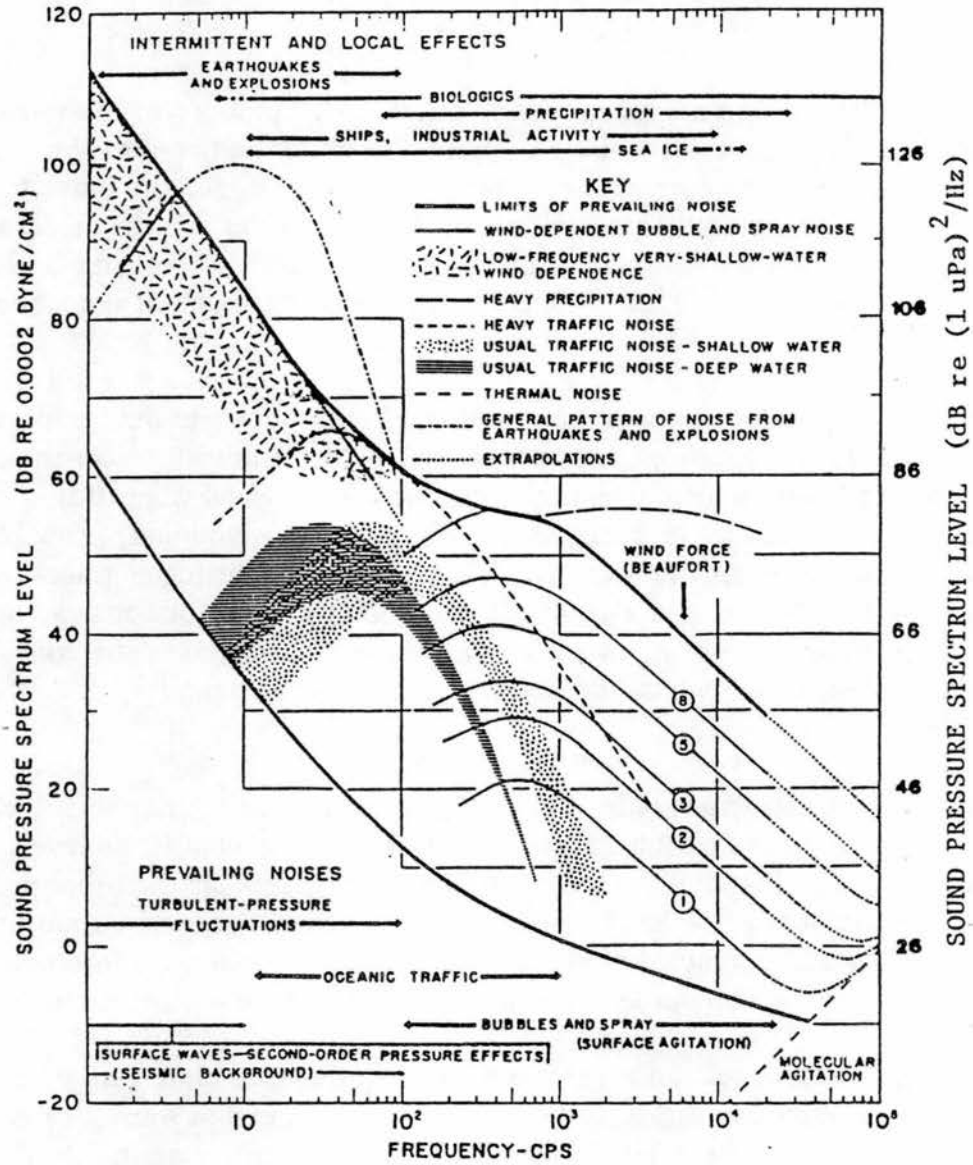
- ambient noise,
- absolute hearing thresholds,
- masking,

Figure 8.3.1.4
UNDERWATER AUDIOGRAMS SHOWING HEARING THRESHOLDS OF THREE ARCTIC MARINE MAMMALS.



Sources: Terhune and Ronald, 1972, 1975; Awbrey et al., 1988; and Johnson et al., 1989

Figure 8.3.1.5
ACOUSTIC SOURCES CONTRIBUTING TO TYPICAL OCEANIC AMBIENT NOISE SPECTRA.



Source: Wenz, 1962

- disturbance,
- hearing loss, and
- discomfort thresholds and non-auditory effects.

Based on the six criteria, one can define a series of zones of potential noise influence of generally decreasing size. The zones within which ship noise exceeds ambient levels and absolute hearing thresholds may be large. However, the zones within which there is disturbance or auditory impairment will be much smaller (see Figure 8.3.1.6).

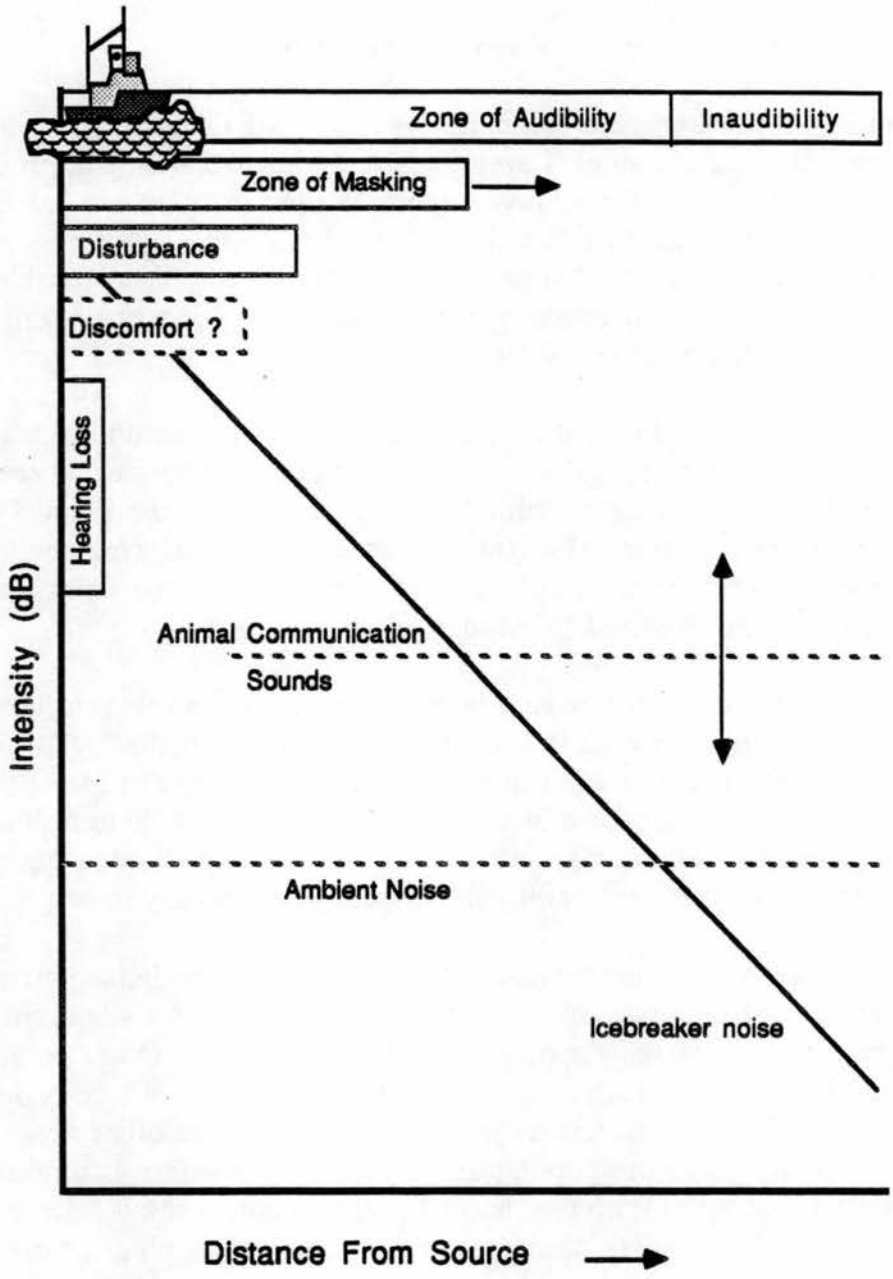
Ambient Noise - The maximum possible radius of influence of the noise from the Polar 8 is the distance at which its level falls substantially below that of the ambient noise in the corresponding frequency band. Once the noise falls substantially below ambient, marine animals will not be able to detect the presence of the noise source. Ambient noise levels vary over time and season and among geographic areas. Thus, the radius of this zone of detection is also variable.

It is not realistic to use an ambient noise criterion alone to determine a zone of influence. In some cases, the ship noise level may diminish below the animal's hearing threshold before it reaches ambient levels. Even when this is not the case, modest increases in background noise (ship plus ambient) probably do not affect marine animals significantly. It is necessary to distinguish between a zone of **potential** influence and a zone of **actual** effects. The former is a zone within which the animal might be aware of ship noise. The latter is the zone, generally much smaller, within which the animal might be detrimentally affected (see Figure 8.3.1.6).

Absolute Hearing Thresholds - At least in theory, hearing may sometimes be limited by absolute hearing thresholds rather than ambient noise levels. If so, the potential zone of audibility of ship noise would be smaller than that predicted based on ambient noise level. Again, the distinction between a zone of detectability and a zone of effect is important to remember. Mere detection of the Polar 8 is not enough to cause a negative effect on marine animals.

Masking - Noise levels above the auditory threshold can interfere with inter-animal communication and detection of echolocation sounds or other environmental cues used by marine animals, particularly mammals. Mammals require a minimum signal-to-noise ratio (= critical ratio) to detect a signal against the background noise spectrum. A larger S/N ratio is needed to process the full information content of the signal. Thus, there is a zone around a ship noise source within which the background noise level (ship plus ambient) will be

Figure 8.3.1.6
POTENTIAL ZONES OF INFLUENCE AROUND AN OCEANIC NOISE SOURCE.



Source: Adapted from Richardson et al., 1989

high enough to mask sounds with particular levels. This, in turn, may have detrimental effects on mammals.

Masking would be much more of a concern if several ships were involved and noise sources were more nearly continuous. In the present case, only a single ship is involved. The loudest noises from the Polar 8 will occur during the backing and ramming phases of icebreaking. These loud noises are intermittent with quieter periods interspersed between them.

Even in open water, received noise levels at long distances from an industrial source often are variable. Levels received from a distant ship, for example, will include periods that are relatively quiet and periods that are relatively noisy. This variability is partly a function of variable noise emission from the ship, and partly a function of variable propagation conditions. Thus, masking of marine mammal calls is not necessarily continuous at long distances from the noise source (Richardson *et al.* 1989).

In addition to the above, the Polar 8 will not be in continuous transit. Thus, the ship will be essentially quiet for significant periods of time. It seems likely, therefore, that masking of animal communications by the Polar 8 will only be localized and transitory. Longer periods of natural masking occur as the result of high winds during storms. The effects of masking by the Polar 8 are difficult to predict, but are expected to be "negligible to minor".

Disturbance - Underwater ship noise above a certain received level often disturbs marine mammals (Richardson *et al.* 1989). However, the levels, frequencies and types of noise that cause disturbance vary from species to species, and perhaps with area and season for a given species. Habituation (diminishing sensitivity during repeated exposures) and possibly sensitization (increasing sensitivity during repeated exposures) are additional sources of variability in responsiveness.

Disturbance is sometimes evident from changes in the behaviour of the animals in question. Behaviourial changes can be subtle, such as a slight change in respiration rate detectable only by statistical analysis. Other behaviourial changes can be conspicuous, such as moving out of an area to reduce exposure to noise. There may be some situations in which movements to other areas will not detrimentally affect the population. However, the safest assumption is that a population occupies optimum habitat and movement away from the habitat is likely to be detrimental, at least if the animals are displaced for more than a brief period.

The potential for the Polar 8 to disturb fish, bird and marine mammals is discussed in Sections 8.3.2, 8.3.3, and 8.3.4, respectively.

Hearing Impairment - There is no information on noise levels that would induce either temporary or permanent hearing impairment in marine mammals. Gales (1982) used the human ear as an analogy to marine mammals. In the most susceptible humans, significant hearing loss is experienced with exposures of 8 hours per day for 10 years to sounds that are 80 dB above their most sensitive absolute hearing threshold. Hearing loss is normally a cumulative process requiring a combination of high noise levels and extended periods of exposure, although brief exposure to extremely high noise levels can have permanent effects.

If the human analogy is applicable to marine mammals, then continuous exposure to noise levels of about 120 dB (80 dB above threshold at best frequency) would be required to induce hearing loss in white whales. The equivalent figure for ringed seals would be about 150 dB. Whether the human criteria realistically describe the situation in marine mammals is not known, but no relevant data are available for marine mammals.

Some marine mammals have been found to tolerate, at least over periods of a few hours, continuous sound whose received level is more than 120 dB. However, mammals often do exhibit avoidance reactions when the industrial noise level reaches 120 dB, and avoidance reactions become more common at levels above 120 dB (Richardson *et al.* 1989). It is doubtful that many marine mammals would remain in areas where received levels remain at or above 140 dB. Also, in order to be exposed to a received level of 140 dB, mammals would have to be very close (usually much less than 1 km) to the Polar 8. Given the mobility of most marine mammals and the mobility of the Polar 8, it is not conceivable that an individual marine mammal could be exposed to the amounts of continuous noise that is necessary to cause hearing loss in humans.

Discomfort Threshold and Non-auditory Effects - Sounds with very high sound pressure levels can produce discomfort and other non-auditory effects in man. Human divers exposed to intense underwater noise (e.g., 190 dB re 1 μPa) sometimes report discomfort, apparent rotation of the visual field, or dizziness (Smith 1985). Little is known about these non-auditory effects. Marine mammals are already adapted to high pressures associated with diving and, therefore, are naturally exposed to much higher pressure levels than would be produced by the Polar 8. Gales (1982) concluded that beyond a few tens of meters from even the strongest noise source, non-auditory effects on marine mammals are unlikely to

occur. Discomfort and non-auditory effects are extremely unlikely to be caused by the Polar 8.

8.3.2 Lower Trophic Levels and Fish

Underwater noise from the Polar 8 will have "negligible" effects on invertebrates.

The only fish species that regularly occurs in the deeper waters frequented by the Polar 8 and that is a Valued Ecosystem Component is the Arctic cod. The hearing capabilities and behaviour of Arctic cod are unstudied. Fish can detect underwater sounds (Wodinsky and Tavolga 1964; Buerkle 1968). Fish have hearing thresholds of about 60 to 100 dB re 1 μPa at frequencies of about 300 Hz, are most sensitive to frequencies of 300 to 800 Hz, and have an upper detection limit of about 1 to 2 kHz or higher (Wodinsky and Tavolga 1964; Schwartz and Greer 1984). At individual frequencies, Atlantic cod can detect sounds that are, on average, 25 dB above ambient in the 35-283 Hz range (Buerkle 1968). For broadband sounds, the critical ratio is about 5-6 dB.

Sounds can attract or repel fish (Moulton 1964). Moulton has described the use of sounds to attract fish. Fish respond to seismic signals and electronic signals with a rapid rise time (Anon. 1984; Schwartz and Greer 1984). Responses to seismic impulses included rapid swimming away from the stimulus, diving to the bottom and lying motionless, and diving to midwater followed by rapid changes of direction or breaking up of schools into several smaller schools. Herring swam away from the sounds of large (20 m) boats but only swam away from the sounds of smaller boats when the boat was accelerating. Herring habituated to the sound of small boats and very much less so to those of large fishing boats. Intermittent sounds of low frequency and high amplitude are likely to elicit the greatest response for fish (Chapman and Hawkins 1969).

Olsen (1969) estimated that Atlantic cod could detect ships at distances of 70-80 m. This calculation was based on a recorded auditory threshold for Atlantic cod of 113 dB re 1 μPa. If these data are relevant to Arctic cod, then it is probable that only a small proportion of the Arctic cod population will be exposed to noise from the Polar 8 on any particular passage. Overall, effects of underwater noise from the Polar 8 on Arctic cod are expected to be "negligible".

8.3.3 Birds

The normal offshore activities of the Polar 8 are likely to have inconsequential effects on sea-associated birds. Direct effects are unlikely since seabirds are highly mobile and can easily avoid the ship by flight or by diving. Energy

expended in these infrequent evasive movements would be trivial and have no effect on the individual's daily energy budget. It is conceivable that the Polar 8 could cause some mortality to individual thick-billed murres during their swimming migration in the early fall. The young-of-the-year and adult murres are flightless at this time. Given the moderate cruising speed of the Polar 8, the infrequency of passages through the murre migration routes, the shortness of the murre migration periods (≈3 weeks), the unlikelihood of actually striking a murre, and the large size of the murre population, it is safe to conclude that direct mortality from the Polar 8 will have a negligible effect on the murre population.

Noise and disturbance from the ship itself are unlikely to affect birds in the area. Birds have adapted to ship traffic throughout the world. Some species, such as northern fulmar and gulls, are actually attracted to ships and often follow them for extended periods (Wahl and Heinemann 1979; Brown 1986). Thus, noise and disturbance from normal offshore operations of the Polar 8 will not affect sea-associated birds.

There is a concern that the ship could disturb seabird colonies if it passed nearby or operated its aircraft or accessory vessels in the vicinity of colonies. Some High Arctic colonies contain tens of thousands of pairs of cliff-nesting species that are vulnerable to panic responses caused by man-induced activities. Temporary abandonment of colonies can also lead to increased predation on eggs and young by glaucous gulls and common ravens. Helicopter traffic is the main concern (see also Section 8.4), but the ship itself could cause problems during the open water season when the colony is occupied. The Coast Guard is committed to monitoring the Polar 8's effect on major resources such as colonial seabirds. To this end, an Environmental Pilot that identifies important environmental areas will be prepared.

8.3.4 Marine Mammals

The review in Section 8.3.1 indicated that the potential disturbance of marine mammals was the main concern about underwater noise from the Polar 8. The documented reactions of Arctic marine mammals to ship noise are reviewed in this section. The probable responses to noise from the Polar 8 are also assessed. The response of mammals to helicopters, on-ice vehicles and small boats associated with the Polar 8 are discussed in Section 8.4.

8.3.4.1 Seals and Walrus

Few authors have described responses of pinnipeds to boats or ships. Most of the information that has been published is anecdotal in nature.

In the case of walruses, Salter (1979) observed no detectable response of animals on a terrestrial haul-out site when outboard-powered inflatable boats approached to distances of 1.8-7.7 km (n = 6). Similarly, Brooks (cited in Fay 1981) said that walruses appeared not to be disturbed by the sound of outboard engines on small boats at distances >400 m. On the other hand, Fay *et al.* (1986) stated that high-frequency noise from outboard engines appears to cause more disturbance than low-frequency noise from diesel engines. Kapel (1975) indicated that many hunters in Greenland oppose the use of outboard motors because they think that these frighten seals away. However, seals may associate the boat noise with being hunted, and thus, they may be reacting to the threat of being hunted rather than the noise *per se*.

Walruses hauled out on ice react at greater distances when a ship approaches downwind than upwind (Fay and Kelly 1982; Fay *et al.* 1986). The reaction distance also depended on ship speed, and seemed to be influenced by the sight and possibly the smell of the ship as well as its sound. Walruses sometimes did not react until the ship was considerably closer than the distance at which the vessel first became audible to man. Reactions of walruses on ice-pans included waking up, head-raises, and entering the water. Groups of females with young seemed more wary than adult male walruses. Walruses in open water seemed much less sensitive than those hauled out on ice pans; those in water "usually showed little concern about an approaching vessel, unless the ship was about to run over them" (Fay *et al.* 1986). These authors suggested that vessel disturbance can lead to increased calf abandonment. They also observed that calves were often the last walruses to leave ice pans as a ship approached. On one occasion a walrus calf was killed by a polar bear as the walruses were leaving the ice. Fay *et al.* speculated that ship disturbance might result in increased predation, although this seems much less likely in the central High Arctic where walrus herds are much smaller than those studied by Fay.

In general, scientific evidence about reactions of seals to vessels is too meagre to allow firm conclusions. However, the limited available information, together with data on reactions of seals to most other forms of disturbance, suggests that seals will normally show considerable tolerance of boats and ships (Richardson *et al.* 1989).

The Environmental Pilot will document terrestrial haulout sites used by walruses and the Polar 8 will not approach within 2 km of them during the mid July to mid September haulout period. This protection measure will reduce a possible "minor" impact to a "negligible" one. Apart from avoidance responses by animals near the vessel's track, it seems unlikely that swimming seals and walruses will be

affected by underwater noise and disturbance from the Polar 8. The short range reactions would have negligible effects on populations.

8.3.4.2 Toothed Whales

Two species of odontocete or toothed whales regularly occur in the Canadian High Arctic. These are the white whale or beluga that occurs throughout the North American Arctic and the narwhal (Figure 8.3.4.1) which is restricted to the eastern Arctic. The reactions of white whales to vessels have been observed in much more detail than have the reactions of narwhals. The sensitivity of white whales to vessel disturbance seems to vary considerably over time depending on habitat, type of boat, activities of the whales, and the previous experience of the whales.

White whale populations that have been hunted from power boats in traditional estuarine concentration areas continue to return to those areas each summer even though hunting often causes short-term displacement (e.g., Fraker 1980; Brodie 1981a,b; Reeves and Mitchell 1981; Seaman and Burns 1981; Caron and Smith 1985). The annual return to traditional concentration points occurs even where the population has been seriously reduced by overharvesting (e.g., Finley 1982; Finley *et al.* 1982). Sergeant (1981) argued that the West Hudson Bay population of white whales, some of which occur in the port of Churchill in summer, has not declined despite an average of 59 ship arrivals over a 3 month shipping season and a 20 year commercial hunt that took about 500 whales per year. Although white whales return annually to the general areas where they are subject to hunting from motorboats, small-scale changes in distribution may occur due to disturbance and hunting (Burns and Seaman 1985).

White whales feeding on salmon in Bristol Bay, Alaska, are not easily disturbed even when purposefully harassed by motorboats (Fish and Vania 1971). White whales move back and forth amidst hundreds of salmon fishing vessels in inner Bristol Bay (L. Lowry, *in* Davis and Thomson 1984). However, Stewart *et al.* (1982) found that white whales in a river adjacent to Bristol Bay interrupted their feeding and swam downriver in response to noise from motorboats. Avoidance was evident even when the received noise level was quite low. However, the thresholds of responsiveness to motorboats, in terms of noise level and distance, were not determined.

Stewart *et al.* (1982) found that white whales were more sensitive to outboard-powered motorboats than to other vessels. Besides the fact that white whales are often hunted from outboard motorboats, the higher frequency content

Figure 8.3.4.1.
NARWHAL IN A LEAD.

Source: G.W. Miller, LGL Limited

of the noise from outboard engines is probably a factor, given that toothed whales are more sensitive to moderate and high frequencies than to low frequencies. Stewart *et al.* attempted to test reactions to playbacks of recorded supply ship noise, but the results were inconclusive because of small sample size and confounding by motorboat disturbance. In Cook Inlet, Alaska, white whales occur commonly in areas of considerable ship and small boat traffic (Burns and Seaman 1985). Similarly, white whales in the St. Lawrence estuary of eastern Canada are reasonably tolerant of ferry boats and other slow moving vessels travelling in consistent directions (Macfarlane 1981; Pippard 1985; Sergeant 1986). However, the whales tend to flee from fast and erratically moving small boats.

Reactions of white whales in shallow water to oil industry vessels *per se* have been studied in the Mackenzie Estuary of the eastern Beaufort Sea. White whales sometimes turn and swim rapidly away from approaching tugboats or other vessels when the vessels are as much as 2.4 km away (e.g., Fraker 1977a, 1978). Sometimes a group of white whales disperses or separates into two subgroups when a vessel approaches. On other occasions, however, white whales have been seen within 200 m of moving tugboats and/or barges (Fraker 1977b). In one case when two tugs pushing three barges approached to within 2.4 km of a group of white whales, the group split into two subgroups and the vessels passed between the subgroups. The subgroups remained separate for at least 3 h but <30 h (Fraker 1977a). Short-term avoidance reactions of these types were observed often over a several year period, but white whales continued to use shallow areas where vessel traffic was common (Norton Fraker 1983).

Observations of white whales in leads suggest that the animals are more sensitive to vessels when ice is present (Norton Fraker and Fraker 1982; Burns and Seaman 1985). Although white whales are usually quite insensitive to stationary vessels, a group of whales that came within 1 km of a stationary, inactive drillship while they were swimming along a lead changed course to avoid the ship (Norton Fraker and Fraker 1982). White whales in leads consistently swam away from supply boats that were in motion at distances of one to several kilometres.

Reactions of white whales and narwhals to shipping in areas with much ice has been studied recently in deep channels of the Canadian high arctic (LGL and Greeneridge 1986; Barber and Hochheim 1986; Cosens and Dueck 1988). In 1982, white whales along an ice edge moved away at unusually high speed when an approaching ship was 35-40 km away (Finley *et al.* 1983). Ship noise was first detectable by spectral analysis when the vessel was 105 km away, and white whales began to emit "alarm" calls at about that time. Ship noise was clearly audible to humans listening to hydrophone signals before the whales moved away. Narwhal behaviour also changed in response to the approaching ship, but "freeze"

behaviour rather than fleeing was the most evident effect on narwhals. Both species returned to the ice edge and resumed normal activities about 48 h after the ship had passed (Finley *et al.* 1983; Finley and Davis 1984).

In view of these surprising 1982 results, extensive follow-up work has been conducted. Similar results were obtained in 1983 and 1984, including alarm calls and fleeing responses by white whales when the approaching ship was still several tens of kilometres away, and "freezing" behaviour by narwhals (LGL and Greeneridge 1986). White whales and narwhals were displaced by as much as 49 km and 18 km, respectively. White whales reacted to each of several onsets of ship noise over a one-week period, but narwhals seemed less sensitive to repeated noise onsets. Some parts of this 1982-84 work were replicated in 1986 by Barber and Hochheim (1986) and Cosens and Dueck (1988). They also observed the "fleeing" and "freezing" reactions of white whales and narwhals, respectively, and found that white whales began to react when ships were 45-60 km away.

The evidence of strong and consistent behaviourial reactions at such long ranges from industrial operations is unique in the marine mammal literature. LGL and Greeneridge (1986) suggested three possible reasons for the great sensitivity of the whales and the large radii of influence around the ships: the partial confinement of the whales by heavy ice cover, the novelty of ship traffic in the High Arctic in spring, and the good sound propagation conditions in deep water.

The wide variety of responses to ship traffic shown by various populations of white whales make it difficult to predict the responses of white whales and narwhals to noise and disturbance from the Polar 8. The expected responses will probably vary with season, habitat and ice conditions. The effects of ship noise and disturbance on whales in open water conditions are likely to be "negligible to minor". Effects on concentrations of whales in leads or along ice edges in spring could range from "minor to moderate". Effects on white whales in estuarine concentration areas could range from "minor to major". However, measures will be taken to mitigate effects in the latter two situations.

All major estuaries used by white whales in July and August are known and will be listed in the Environmental Pilot. The Polar 8 cannot enter these shallow areas and will not conduct operations near the entrances to estuaries that are occupied by whales. Spring-time concentrations of white whales and narwhals are known or can be predicted based on ice conditions. The Polar 8 will attempt to avoid such areas, but the long distance responses by whales noted in previous studies suggest that some residual responses will still occur. Therefore, predicted effects after mitigation could be reduced to "negligible" for white whales in the estuaries and to "negligible to minor" for concentrations along ice edges. It

should be stressed that these assessments are based on insufficient amounts of data particularly relating to possible habituation or lack thereof.

8.3.4.3 Bowhead Whale

The bowhead is the only baleen whale to regularly occur in the Canadian High Arctic and Beaufort Sea. The Eastern Arctic population is considered to be endangered and numbers only a few hundred individuals (Davis and Koski 1980). Reactions of bowhead whales to vessel traffic associated with offshore oil exploration have been studied in the Canadian Beaufort Sea in summer and the Alaskan Beaufort Sea in early autumn.

In the Canadian Beaufort Sea, oil industry personnel have reported bowheads within a few hundred meters of various vessels; sometimes the whales dove, possibly in response to the vessel (Fraker 1978; Fraker and Fraker 1979, 1981). More detailed information about reactions to ships and boats operating in open water was obtained by Richardson *et al.* (1985a,b), who observed seven such incidents from an aircraft circling high above. Obvious avoidance responses usually began when a vessel approached to within 1-4 km. However, a few whales may have begun reacting when the vessel was as much as 5-7 km away and, in contrast, a few others did not appear to react until the vessel was <1 km away. The initial reaction was usually to try to outswim the vessel. When an overtaking vessel approached within a few hundred meters, the whales often changed course and moved perpendicularly away from the boat's track. The whales ceased fleeing after the vessels were a few kilometres past.

The levels of underwater noise that apparently elicited these flight reactions were not very high. In one disturbance test, received noise levels 4 and 1½ km from the approaching vessel were only about 84 and 91 dB re 1 μPa in the 1/3-octave band of strongest noise. These values were only about 6 and 13 dB above the background noise in that band (Miles *et al.* 1987).

Fleeing bowheads typically swam faster than observed at other times, and exhibited shorter surface times, fewer respirations per surfacing, and reduced dive durations. Although the flight reaction was most conspicuous when a vessel headed directly toward bowheads, reduced surface times and fewer respirations per surfacing were evident when a crew boat's engines began idling 3-4 km away after a quiet period (Richardson *et al.* 1985a,b).

Similar observations have been obtained in the Eastern Alaskan Beaufort Sea during early autumn (Koski and Johnson 1987; Thomson and Richardson 1987). In one case, bowheads that were initially 1-2 km to the side of the track of an

approaching oil industry supply vessel swam rapidly away to points about 4-6 km from the vessel's track (Koski and Johnson 1987). On another occasion, a mother and calf located between two approaching ships exhibited several of the above-mentioned types of reactions even though neither ship approached closer than about 15 km. That is the largest radius of apparent vessel response that has been noted for bowheads. Photoidentification data showed that at least some bowheads returned to feeding locations after being displaced by boats (Koski and Johnson 1987; Thomson and Richardson 1987). Whether they would continue to return after repeated boat disturbance was not determined.

In the Eastern Canadian Arctic, bowheads have been reported to be very sensitive to motorboats (Degerbøl and Freuchen 1935). The track and speed of a bowhead fleeing from an outboard-powered boat were determined by theodolite (Finley *et al.* 1986). The animal moved very rapidly (for a bowhead) as the boat approached: 7.7 km/h during one dive and 10.3 km/h during the next; during the latter dive the whale travelled 1.8 km underwater. This strong reaction occurred even though eastern arctic bowheads are not hunted.

In general, bowheads react strongly and rather consistently to approaching vessels of a wide variety of types and sizes. Bowheads interrupt their normal behaviour and swim rapidly away. Surfacing, respiration and diving cycles are affected during this time. The flight response often subsides by the time the vessel has moved a few kilometres away. Following single disturbance incidents, at least some bowheads return to their original locations.

The only regularly occupied concentration area for bowheads in the Eastern Arctic is Isabella Bay along the east coast of Baffin Island. The Polar 8 will not be near this area during the mid August to early October period when the whales are present. In the rest of the Eastern High Arctic it is likely that the Polar 8 will encounter a few bowheads in open water and loose pack-ice conditions. In some cases, these encounters may cause "short-term, local minor" effects to bowheads. The welfare of the individuals affected is not likely to be compromised.

8.4 EFFECTS OF ASSOCIATED AIRCRAFT, VEHICLES AND LAUNCHES

The Polar 8 will use a variety of aircraft, vehicles and small vessels to accomplish its various roles. These are described in Chapter 3 (vehicles and vessels) and Chapter 4 (aircraft). All of these craft will extend the range of the Polar 8 and its potential impacts on wildlife resources.

8.4.1 Aircraft

The ship will carry three helicopters. Two will be multi-engined helicopters equipped to operate under Instrument Flight Rules (IFR) and to operate year-round in all weather conditions. These machines will be quite large (up to 30 passengers) and they will be present onboard year-round. The third helicopter will be a small, twin-engined utility helicopter that will supply close support services during daylight, Visual Flight Rules (VFR) conditions. This machine will probably be a five passenger BO-105 since the Coast Guard already operates 16 of these helicopters. The Polar 8's helicopters will cover a fairly large range to accomplish their mission of personnel transfer and resupply, pollution detection and response, SAR, scientific research, sovereignty and various reconnaissance operations.

8.4.1.1 Birds

It is well known that most sea-associated birds flush or dive, in response to low-flying aircraft (e.g., Polar Gas Project 1977; LGL Ltd., unpubl. data). The significance of these disturbances is probably low if the flights are infrequent. In one of the few systematic studies of aircraft disturbance, Ward and Sharp (1974) found that moulting sea ducks in the Beaufort Sea showed no detectable reaction to helicopter overflights at 300 m (1,000 ft) above sea level. Overflights at 100 m (330 ft) had no apparent influence on feeding activity or population size, although the ducks did show a short-term avoidance reaction.

Studies of other species in other situations have shown a variety of responses to overflying aircraft (Davis and Wisely 1974; Gollop *et al.* 1974a,b; Schweinsburg 1974; Koski 1975, 1977; Barry and Spencer 1976; Fyfe and Oldenorff 1976; Platt and Tull 1977; Fletcher and Busnel 1978; Webb 1980). In general, these studies support the contention that birds respond most to low level flights and the effects of these responses are generally transitory. Nonetheless, the operations of the helicopters of the Polar 8 will be conducted to minimize even these responses.

The helicopters will fly at minimum altitudes of 300 m (1,000 ft) whenever possible and pilots will be instructed to avoid repeated overflights of concentrations of birds and/or important bird habitats such as ice edges. The Environmental Pilot will identify important bird concentration areas and habitat types. Overflights of these areas will be avoided at key times of the year.

Of most concern are the large colonies of seabirds and nesting concentrations of coastal waterfowl (Figure 8.4.1.1; Evans and Nettleship 1985). The major seabird

Figure 8.4.1.1
BLACK-LEGGED KITTIWAKES NESTING AT A COLONY.

Source: M.S. W. Bradstreet, LGL Limited

colonies involve cliff-nesting species such northern fulmar, black-legged kittiwake, and thick-billed murre (see Section 7.3.4). In addition, there are many smaller colonies of black guillemots, glaucous gulls and Thayer's gulls. The Environmental Pilot will document known locations of these colonies and contain instructions for avoiding disturbing the birds at the colonies. The guidelines for avoiding major seabird colonies will be based on Nettleship (1980). These are Canadian Wildlife Service guidelines that recommend that aircraft not approach closer than 8 km seaward and 3 km landward of a seabird colony from 1 April to 1 November.

8.4.1.2 Marine Mammals

The literature on the effects of helicopter and fixed-wing aircraft overflights of marine mammals is scattered and diffuse. The available information has recently been summarized by Richardson *et al.* (1989). The information pertaining to species relevant to this IEE is reviewed here.

Ringed and **bearded seals** hauled out on the ice may dive when approached by a low-flying aircraft or helicopter (e.g., Burns and Harbo 1972; Alliston 1981; Burns and Frost 1983), although they do not always do so (e.g., Burns *et al.* 1982). Specific details on range and altitude effects for seals exposed on the ice are lacking. However, Finley (1976) studied ringed seals hauled out along a 10.8 km long aerial survey transect in Barrow Strait near Resolute. The transect was overflown 31 times at an altitude 91 m (300 ft) from 4 June to 8 July 1975. Finley was unable to detect any decline in seal numbers that could be attributed to the aircraft disturbance.

Kelly *et al.* (1986) found via radio telemetry that reactions of ringed seals concealed in their subnivean lairs (below snow on ice) to helicopter noise varied with aircraft altitude and lateral distance:

> "Seals did not leave their haul-out sites in response to helicopter flights at or above an altitude of 457 m. Departures were observed in 8 of 15 (53%) instances when helicopters were at altitudes of 305 m or less. Seals departed in 6 of 9 (67%) instances at that altitude when helicopters were within 2 km (lateral distance) of the haul-out site. At distances greater than 2 km, helicopters at or below 305 m caused 2 of 6 (33%) seals to depart...".

The noise received by a seal in a subnivean lair is probably less than that received from a corresponding overflight when the seal is exposed on the ice. Cummings and Holliday (1983) reported that snow over simulated ringed seal lairs caused considerable attenuation of airborne noise, especially at high frequencies (e.g., 10.5 kHz).

Burns and Frost (1983) stated that Bearded seals usually react mildly to an airplane, even at close range. They almost always raise their heads, frequently look up at the plane and usually remain on the ice unless the plane passes directly over them. On a warm calm spring day when they are basking they often show little concern for a low-flying aircraft. Burns and Frost noted that helicopters are particularly disturbing to bearded seals and suggest that flight altitudes be at least 2000 feet (≈600 m) over bearded seal habitat. Bearded seals are widely dispersed and only occur in low densities in the Canadian High Arctic. Therefore, few individuals would be exposed to disturbance by helicopter flights below 600 m asl.

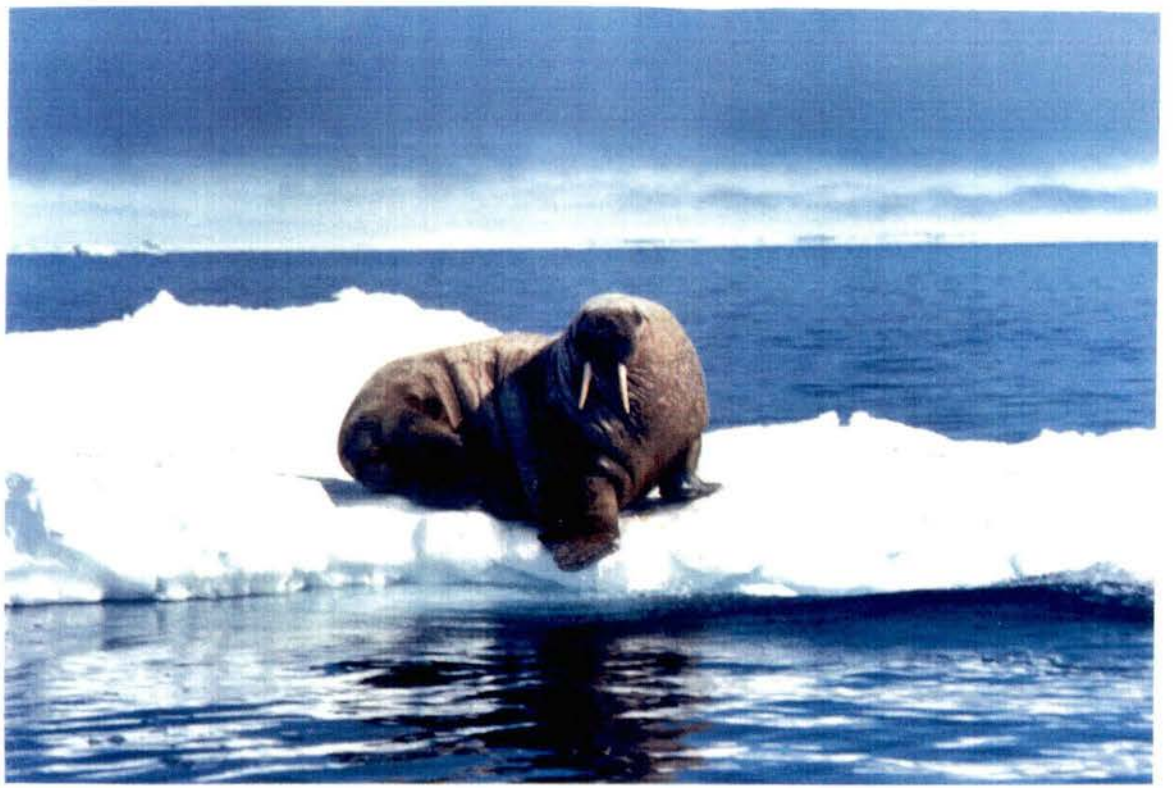
The reactions of swimming ringed and bearded seals to aircraft overflights have not been documented. Swimming seals are generally considered to be less susceptible to airborne disturbance than are seals that are hauled out (Richardson *et al.* 1989).

The available evidence suggests that the effects of helicopter overflights above the nominal minimums will have "negligible" effects on ringed and bearded seals.

Walruses (Figure 8.4.1.2) use several relatively small terrestrial haulout sites in the central Canadian High Arctic (Davis *et al.* 1978). Responses of walruses to aircraft disturbance at terrestrial haul-out sites vary with range, aircraft type, flight pattern, age-sex class of the animals, and group size. Brooks (1954 cited by Fay 1981) noted that walruses on shore were disturbed by an aircraft at 300 m. In a more extensive study on Bathurst Island, Salter (1978, 1979) found that, at horizontal distances beyond 2.5 km, the only response elicited by aircraft was raising of the head by some of the hauled out animals. A Bell 206 helicopter 1.3 km from a haul-out site and flying at an altitude of less than 150 m prompted orientation toward the water by 31 of 47 animals. When the helicopter veered suddenly causing an abrupt change in pitch of the noise, 26 of 47 walruses rushed into the water (Salter 1979). Another flight by a Bell 206 helicopter at the same altitude but at a range less than 1 km elicited head raising and orientation toward the water by some animals but no escape reactions--presumably because there were no sudden changes in the flight pattern or noise. DeHavilland Otter aircraft, which have a single piston engine, caused escape reactions by walruses at horizontal ranges less than 1 km during overflights at altitudes of 1,000 and 1,500 m (Salter 1979).

Disturbances observed by Salter never caused escape reactions in all the walruses at the haul-out site; adult females, calves and immatures were more likely than adult males to enter the water during disturbance. However, severe disturbance may cause stampedes into the water by all the walruses at a haul-out site.

Figure 8.4.1.2
WALRUS HAULED OUT ON ICE.



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