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A Fishery Development Strategy for the Canadian Beaufort Sea-Amundsen Gulf Area

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A FISHERY DEVELOPMENT STRATEGY FOR THE CANADIAN BEAUFORT SEA-AMUNDSEN GULF AREA

by

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This study was initiated for the Inuvialuit, by the Fisheries Joint Management Committee (FJMC), to assess opportunities for commercial fishery development in the Canadian Beaufort Sea-Amundsen Gulf area. Reviews of existing knowledge did not find invertebrate or fish stocks in the area capable of sustaining a viable commercial export fishery. They found that coastal and offshore commercial fisheries in arctic Canada are severely constrained by environmental, social, and economic factors.

Lacking a proven resource base, the FJMC has two recommended options if it plans to proceed with fishery development: 1) to conduct biological stock assessment research in hope of locating a suitable stock, and 2) to seek development opportunities in other areas such as sport fisheries. Before any commercial development proceeds, it should have local support, be sustainable, and optimize benefits to the Inuvialuit.

Given the difficulty and cost of fishery research and development in the area, it is vital that interested parties such as the FJMC, government, and others formulate an overall research and development strategy and work cooperatively towards its completion. An approach to fishery development is described, with a discussion of constraining factors and specific project recommendations.

Key words: Northwest Territories; Mackenzie Delta; Cambridge Bay; District of Keewatin; Baffin Island; Hudson Strait; Belcher Islands; fishery economics; commercial fishing; marine fish; anadromous fish; marine invertebrates; stocks; distribution; abundance; life history.

RÉSUMÉ

Stewart, D.B., R.A. Ratynski, L.M.J. Bernier, and D.J. Ramsey. 1993. A fishery development strategy for the Canadian Beaufort Sea-Amundsen Gulf area. Can. Tech. Rep. Fish. Aquat. Sci. 1910: v + 127 p.

Cette étude a été entreprise pour les Inuvialuit par le Comité mixte de gestion de la pêche (CMGP) afin d'évaluer les possibilités d'implantation de pêche commerciale dans la région canadienne de la mer de Beaufort et du golfe d'Amundsen. Selon l'examen des données actuelles, il n'existe pas dans cette région de stocks de poissons ou d'invertébrés suffisants qui permettrait de rentabiliser une pêche commerciale d'exportation. De même, il ressort que la pêche côtière et la pêche hauturière dans la région arctique canadienne sont sérieusement limitées par des facteurs environnementaux, sociaux et économiques.

Devant cette absence de ressources essentielles, le CMGP doit choisir entre deux options recommandées s'il décide de poursuivre le développement des pêches: 1) effectuer une recherche pour évaluer les stocks de poissons dans l'espoir d'en trouver qui seront exploitables; 2) rechercher des possibilités de développement dans d'autres domaines, comme, par exemple, la pêche sportive. Avant de commencer toute développement commercial, il faudra s'assurer que ce dernier est soutenu par la population locale, qu'il est durable et qu'il profite aux Inuvialuit.

Étant donné la difficulté et le coût liés au développement des pêches et de la recherche connexe dans cette région, il est essentiel que les parties concernées, à savoir le CMGP et le gouvernement, entre autres, établissent une stratégie globale de recherche et de développement et qu'elles travaillent ensemble à sa mise en oeuvre. Une démarche concernant le développement des pêches est décrite dans cette étude, ainsi qu'une discussion sur les facteurs de limitation et des recommandations sur des projets particuliers.

Mots-clés: Territoires du Nord-Ouest; delta du Mackenzie; Cambridge Bay; district de Keewatin; détroit d'Hudson; îles Belcher; économie de la pêche; pêche commerciale; poissons de mer; poissons anadromes; invertébrés de mer; stocks; distribution; abondance; évolution biologique.

INTRODUCTION

During the Fisheries Joint Management Committee's (FJMC) annual "community tour" in 1987, the Hunters and Trappers Committees (HTC) in Sachs Harbour and Holman expressed interest in developing new and existing fisheries in their areas. In response the FJMC initiated this study which was completed in 1989 (Stewart et al. 1989) and has since been updated for publication. Its purpose is to assess the potential for commercial fisheries and to consider options for fishery development in the Beaufort Sea-Amundsen Gulf area by the Inuvialuit (Fig. 1).

The study relies on existing information and its general focus is on commercially attractive invertebrates and anadromous and marine fishes which occur in the Canadian Beaufort Sea, particularly within accessible range of the communities of Sachs Harbour, Holman, Paulatuk, and Tuktoyaktuk. It is organized into three parts:

Part 1. Literature Review, which assesses the area's commercial harvest potential based on a review of existing knowledge of the fishery resource and the experience of commercial fisheries in arctic Canada;

Part 2. Strategy Development, which considers the factors involved in fishery development and recommends a general approach to fishery development; and

Part 3. A Fishery Development Strategy for the Canadian Beaufort Sea and Amundsen Gulf, which suggests rationale for fishery development by the Inuvialuit and makes specific project recommendations.

Findings and recommendations of the report are summarized briefly in the Abstract and in greater detail in the Executive Summary.

PART 1. LITERATURE REVIEW

The purpose of this literature review is to identify invertebrate and fish species in the Beaufort Sea-Amundsen Gulf study area that may offer commercial harvest potential. It describes regional fisheries research efforts, present knowledge of the fishery resource, and representative northern commercial fisheries. The commercial fishery potential of species present in the area is then assessed in light of the information available.

Information was obtained from the published literature and government files; discussions with federal and territorial government biologists, fishery managers, and economists; and from representatives of the Beaufort Sea communities and private enterprise. Emphasis was placed on the Canadian Beaufort Sea and Arctic fishery development.

RESEARCH EFFORTS

To correctly interpret biological data that are available from the Canadian Beaufort Sea one must understand the extent of the research on which those data are based. This section briefly describes the research on invertebrates and fish, including an historical overview, geographic, temporal, and spatial coverage, and sampling methods.

Historical overview

Data collection in the Canadian Beaufort Sea began with the early explorers and whalers who recorded catches and anecdotes in their diaries. Between 1896 and 1955, several biological surveys were conducted to determine what species existed in the area, including those by the Hopkins Laboratory of Leland Stanford University in 1896 (Scofield 1899), the American Museum of Natural History in 1908 (Anderson 1913), and the Canadian Arctic Expedition from 1913 to 1918 (Walters 1953a). Scientific studies of fish and invertebrates in the Canadian Beaufort Sea began in earnest in 1955.

Between 1955 and 1972, scientists from the Arctic Biological Station of the Department of Fisheries and Oceans (DFO) conducted an extensive series of baseline/distributional studies on fish and invertebrates. Using the M.V. "Salvelinus", they sampled many locations using a variety of gear types to study species biology and ecology. They were the only agency studying fish in the region from 1955 to 1972 (Ratynski et al. 1988).

In 1972, burgeoning hydrocarbon exploration in the Beaufort Sea prompted an increase in aquatic research. This led in 1974 to the Beaufort Sea Project, a joint industry-government study to assess the potential impacts of hydrocarbon exploration and related activities on the area. It included basic biological studies of species distributions, life histories, and migrations, and site specific impact assessments of seafloor dredging, artificial island construction, etc. Following the Beaufort Sea Project, industry conducted monitoring studies to satisfy licensing requirements, and DFO continued life history studies of anadromous and coastal marine fishes.

In 1985-86, low oil prices prompted cutbacks in oil exploration and development and in industry funding for biological research. Researchers from DFO Central and Arctic Region have continued their life history studies of economically important anadromous coregonids, and baseline biological and oceanographic studies to define marine water masses in the Beaufort Sea, Amundsen Gulf, and western Arctic.

Relatively little of the biological research to date has been directed toward assessing commercial fisheries potential. With few exceptions little is known about stock size, stock discreteness, or productivity--all of which affect the ability of Arctic fishes to sustain commercial harvesting. Even the stocks of Pacific herring and anadromous Arctic charr are not well known.

Because most studies have focused on baseline abundance and distribution, few invertebrate or fish species have a well understood life history. This is particularly true for the invertebrates which were often only identified to the family level, and for deep water or offshore species. The life histories of some anadromous fishes and Pacific herring, which are important to the area economy, are better documented.

Notably lacking from the literature are stock specific data on the harvest by subsistence fisheries. While the Inuvialuit Harvest Study (Fabijan 1990, 1991) details how many individuals of a species were harvested each month by community, it does not identify where the harvests took place. Coupled with the fact that several stocks of a given species may frequent the same area (Reist 1989), this makes it very difficult to determine the extent to which a particular stock is being exploited. Without this knowledge it is very difficult to determine whether a stock may also be capable of sustaining a commercial harvest. This data gap poses a serious problem for fishery development in the area.

Geographical, spatial, and temporal coverage

Sampling efforts have been concentrated about the Mackenzie Delta, mainly between Herschel Island and Cape Parry. Fewer studies have been conducted east and west of this area, and very few have examined offshore areas or the coastal waters of Banks or Victoria islands.

Most samples have been taken from coastal waters at depths less than 10 metres (Ratynski et al. 1988). Few studies have had access to a vessel that was capable of venturing into the deeper waters which in most areas are situated well off shore. There are some data from areas between the 10 and 100 m isobaths, mainly west of the Mackenzie Delta where deep water is closer to shore, and a few samples have been collected from waters deeper than 100 m near Herschel Island and in Amundsen Gulf. Waters in the study area reach depths of over 1,000 m.

Most samples have been taken during the open water season in July and August (Ratynski et al. 1988). June sampling is hindered by ice break-up and late September and October sampling by freeze-up. Cold and darkness make sampling in December through February extremely difficult so that few mid-winter samples have been taken. A few recent studies have sampled through the ice in March-May, or November, but this sampling is also made difficult by cold and thick ice.

Sampling methods

Most sampling in the study area has been conducted from small vessels that are equipped for scientific survey sampling. Most fish have been captured using handlines, gillnets, seines, or trawls and most invertebrates using benthic grabs, plankton hauls, dredges, or core samplers. Studies have lacked the powerful hydraulic winches, net sounders, and species specific harvesting equipment necessary to conduct commercial stock assessments.

Recently, researchers at DFO Central and Arctic Region have addressed the question of stock discreteness of anadromous coregonids through genetic studies. They have also used sophisticated hydroacoustic equipment to study Arctic cod on one occasion, but do not have a vessel capable of trawling deeper than 75 m to support these studies.

SPECIES DESCRIPTIONS

This section describes invertebrate and fish species that have been reported from the Canadian Beaufort Sea-Amundsen area. The purpose is to provide basic information on distribution, life history, and utilization for use by resource managers and planners. The emphases are on species with proven commercial value, and on species' life history data from the area. Marine mammals are also discussed briefly.

Bivalve molluscs (Ph. Mollusca; Cl. Bivalvia)

At least 84 species of bivalve molluscs, representing 22 families, have been reported from the Beaufort Sea and east into Amundsen Gulf (Table 1). Of these species the blue mussel, soft clam, Greenland scallop, Greenland cockle, and cockle are harvested commercially in the south and will be discussed (Table 2).

Mussels (F. Mytilidae):

BLUE MUSSEL (Mytilus edulis): The blue mussel is a boreal-subarctic species in North America, ranging from the Arctic to southern California in the Pacific, and to North Carolina in the Atlantic. It is abundant along the coasts of Hudson, James and Ungava bays, along the east coast of Baffin Island, and in coastal regions of the District of Mackenzie (Lubinsky 1980). Blue mussels are reported to be common in the "Finger Inlets" and selected areas in the outer Eskimo Lakes near Tuktoyaktuk (Hunter 1981) but are not present in great quantities in the Beaufort Sea (Wacasey et al. 1977; M.J. Lawrence, pers. comm.). They are known from coastal areas near Sachs Harbour and Holman (Sachs Harbour HTC and Holman HTC, pers. comm.). Shoreline sampling is required to elucidate the species' western Arctic distribution and abundance.

Blue mussels inhabit the intertidal zone to a depth of about 45 m but are most common at depths of 1.5 to 4 m where they adhere to rocks, gravel, shells, compact mud, and most man-made materials, often forming dense patches or beds (Heritage 1986). They tolerate a wide range of salinity and temperature, strong wave action, abrasion, and siltation, and are frequently exposed at low tides. The species can withstand freezing at -10°C (Aarset and Zachariassen 1982) and adapt to repeated exposures to air by decreasing growth rates (Heritage 1986). It is preyed upon, or parasitized, by a variety of marine organisms including seabirds, wolffish, and green sea urchin.

Blue mussels can live up to 17 years and grow to about 80 mm in length but are generally smaller in Arctic Canada than along the Atlantic coast (Lubinsky 1980). The largest mussel reported by Lubinsky (1980) from the Canadian Arctic (site unspecified) measured 83 mm. Individual mussels show seasonal variations in growth rates and, in the Trinity Bay area of Newfoundland, grow most rapidly between April and June (Thompson 1984). Gametogenesis in that population progresses rapidly from March until spawning takes place in late July. Blue mussels are dioecious and can mature in their first year with peak spawning occurring during the summer months (Scaplan 1976; Heritage 1986). Free-swimming larvae are succeeded by veliger larvae which settle when they are about 0.35 mm in length on suitable substrates (Heritage 1986). Veligers and adults are filter feeders on phytoplankton (Courtright et al. 1971; Chanley 1975; Mohlenberg and Riisgard 1978), and adults show seasonal variations in their feeding and digestive processes (Hawkins et al. 1983; Hawkins and Bayne 1984). Mussels that feed on the planktonic dinoflagellate Gonyaulax tamarensis can accumulate high concentrations of the toxin which causes paralytic shellfish poisoning (Barr and Barr 1983; Jamieson 1986). The toxin has been found in Alaskan and Atlantic blue mussels.

Blue mussels are harvested from Canadian waters for export but the fishery remains small compared to that for the sea scallop Placopecten magellanicus (FAO 1991). While most mussels are still harvested at low tide using a variety of scraping tools (Heritage 1986), they are cultured commercially in Pacific and Atlantic Canada (MacLeod 1976; Jamieson et al. 1981; Heritage 1986; Department of Fisheries and Oceans 1989b) and a culturing attempt is ongoing in the Belcher Islands of southern Hudson Bay (Giroux 1989).

Blue mussels grow quickly, have a high meat to total weight ratio, and are of high nutritional quality but they have a low market value relative to many other shellfish (Shields 1988; Crawford 1989). Care must be taken when harvesting them not to remove the byssal thread stock as this causes early mortality (Department of Fisheries and Oceans 1989b). Their shelf life is 7 to 15 d, shorter in summer than in winter. The preferred commercial size is 60 to 80 mm in shell length. In 1987, Canadian landings of blue mussel totalled 2,855 mt (tonnes) with a landed value of $4,313,000 (Department of Fisheries and Oceans 1989b).

The species is harvested and eaten by residents of the communities of Sanikiluaq (Jamieson 1986), Iqaluit, Broughton Island, and Rankin Inlet. While they are reported to be abundant in the outer Eskimo Lakes (Hunter 1981) and possibly in the Safety Channel area near Holman, blue mussels are not commonly eaten by residents of the Beaufort Sea area.

Clams (F. Myidae):

SOFT CLAM (Mya truncata): The soft clam is a boreal-panarctic bivalve with a circumpolar distribution (Foster 1946; Laursen 1966; Bernard 1979; Lubinsky 1980). It is especially common in the eastern Canadian Arctic where it occurs on top of, or burrowed into, bottom substrates in the intertidal and upper sublittoral zones (Laursen 1966; Lubinsky 1980). It is the most widespread species of Mya, and the most variable in shape (MacNeil 1965).

Mya truncata occurs in the Beaufort Sea but may be rare or unevenly distributed. It was reported offshore Cape Parry and in Darnley Bay (Lubinsky 1980; Atkinson and Wacasey 1989), in Walker Bay of Victoria Island (Atkinson and Wacasey 1989), and in the southern Beaufort Sea (Wagner 1977; Wainwright et al. 1987) but was not found by Bernard (1979) or Frost and Lowry (1983) in the western Beaufort Sea. Shells collected there by Bernard (1979) and identified as M. truncata were thought to be fossil specimens.

Mya truncata grows to a length of 90 mm, can live at least 37 years, and occurs in dwarfed form in southern Hudson and James bays (Petersen 1978; Lubinsky 1980). Growth of Mya is reported to be optimal at salinities of 25 to 35 ppt and temperatures from 6 to 14°C, but they can survive salinities of 5 ppt (Hawkins 1985). They are dioecious and mature in 2 to 3 years at lengths of about 25 mm, with peak spawning occurring in mid-July (Hawkins 1985). In Greenland, individuals do not mature until they are 20 mm long and 3 to 6 years old (Petersen 1978). In some Greenland locations they spawn primarily in summer (Laursen 1966), while in others they spawn in spring or year-round (Petersen 1978). The presence of apparently mature animals year-round suggests that individuals may not spawn annually. Veligers occur in Danish waters from October to March, with a maximum occurrence in November to January when the surface water temperature is about 5°C (Laursen 1966). Settling seems to occur mainly in summer on all sediment types (Petersen 1978).

Mya truncata are filter feeders on plankton and their siphons are often the only part of the animal visible above the substrate. In the Atlantic, closely related Mya arenaria, like Mytilus edulis, is known to concentrate the toxin causing the condition known as paralytic shellfish poisoning (Jamieson et al. 1981). Mya truncata are eaten by sea birds, foxes, walrus, fish, starfish, snails, and man (Foster 1946; Mansfield 1958; Barr and Barr 1983; Oliver et al. 1983; Hawkins 1985). In west Greenland they are parasitized by the nemertean Malacobdella grossa which reduces their commercial value (Petersen 1978). Infection rates vary with location, and the number and size of parasites within the host increase with the size and age of the host.

Mya truncata are eaten by Inuit in the central and eastern Arctic (Crawford 1989). In Iqaluit, the meats and siphons are used by residents to make clam chowder (L. Dahlke, pers. comm.). Mya truncata is not commercially exploited in the Arctic but its potential in a local fishery is being explored by DFO at Arctic Bay (H.E. Welch, pers. comm.). Mya arenaria, a closely related species, is an important commercially exploited clam species in Atlantic Canada (FAO 1991).

Scallops (F. Pectinidae):

GREENLAND SCALLOP (Delectopecten

greenlandicus): The Greenland scallop is a high-Arctic bivalve which is widely distributed and abundant in the Canadian Arctic (Lubinsky 1980). It occurs off the coasts of Greenland and Iceland and in the Atlantic south to the Gulf of St. Lawrence, but does not occur in the Bering Sea or Pacific Ocean (Bernard 1979; Lubinsky 1980). It is extremely abundant in the western Beaufort Sea (Bernard 1979; Frost and Lowry 1983) but abundance was reported to be low in the southern Beaufort Sea (Wacasey et al. 1977). The apparent low abundances in the southern Beaufort Sea may be artifacts of the grab type of sampling gear used by Wacasey et al. (1977) and the bottom trawls used by M.J. Lawrence (pers. comm.) to sample the benthos.

The Greenland scallop is small, with a maximum shell length of 30 to 35 mm (Bernard 1979; Lubinsky 1980). It is found at depths between 5 and 2,560 m, usually below 50 m. Scallops are filter feeders and inhabit various substrates, preferring firm gravel, shells, or rock (Robert 1984; Jamieson and Francis 1986). The species is not harvested in northern Canada.

Another larger scallop species, the Iceland scallop (Chlamys islandica) which grows to a shell length of 90 mm (Lubinsky 1980), is curently the target of a developing fishery in the eastern Canadian Arctic (Gillis and Allard 1988). It has been harvested traditionally by Inuit in the Belcher Islands (Jamieson 1986) and is an important by-catch in the sea scallop (Placopecten magellanicus) fishery along the Atlantic coast, especially in Newfoundland waters (Rodger and Davis 1982; Robert 1984). There are no reports of this species occurring in the Beaufort Sea.

Cockles (F. Cardiidae):

GREENLAND COCKLE (Serripes groenlandicus): The Greenland cockle is a panarctic bivalve with a circumpolar distribution which extends southward to Cape Cod, Massachusetts in the Atlantic and to northern Oregon in the Pacific (Bernard 1979; Lubinsky 1980). It occurs throughout the Canadian Arctic but is reported to be abundant only in the eastern Arctic (Lubinsky 1980; Cross et al. 1984). It is widely, but apparently sparsely distributed in the Beaufort Sea, occurring offshore Cape Bathurst in the eastern Beaufort Sea (Lubinsky 1980; Atkinson and Wacasey 1989), in Walker Bay of Victoria Island (Atkinson and Wacasey 1989), in the southern Beaufort Sea (Wagner 1977; Atkinson and Wacasey 1989), and rarely in the western Beaufort Sea (Bernard 1979).

The Greenland cockle can attain a maximum size of 100 mm but grows to only about 50 mm in high Arctic waters (Bernard 1979; Lubinsky 1980; Barr and Barr 1983). It is a species of relatively shallow water, occurring in the subtidal zone at depths of 7 to 10 m in the eastern Arctic (Shields 1988), 6 to 35 m in the southern Beaufort Sea (Wagner 1977), and from 10 to 101 m in the western Beaufort Sea (Bernard 1979). It is the target of a small subsistence fishery by residents of Resolute Bay in the high Arctic (H.E. Welch, pers. comm.), but is not harvested elsewhere in the Canadian Arctic.

COCKLE (Clinocardium ciliatum): Like S. groenlandicus, this species is a panarctic bivalve with a circumpolar distribution which extends southward to Cape Cod, Massachusetts in the Atlantic and the northern Gulf of Alaska in the Pacific (Bernard 1979; Lubinsky 1980). It is abundant in the eastern Arctic but may be rare in the Arctic archipelago (Lubinsky 1980) and western Beaufort Sea (Wacasey et al. 1977; Bernard 1979). The species occurs offshore capes Bathurst and Parry and in Franklin and Darnley bays in the eastern Beaufort Sea (Lubinsky 1980; Atkinson and Wasasey 1989), and is relatively common in the southern Beaufort Sea (Wagner 1977).

Clinocardium ciliatum grows to a maximum size of about 80 mm, but does not exceed 40 mm in Hudson and James bays or 50 mm in the high Arctic (Lubinsky 1980). It prefers relatively shallow waters, and occurs at depths of 6 to 100 m in the southern Beaufort Sea (Wagner 1977). The species is not harvested in Arctic Canada, but a closely related species, Clinocardium nuttalli, is a by-catch of British Columbia clam fishery (Quayle and Bourne 1972).

Cuttlefish and octopus (Ph. Mollusca; Cl. Cephalopoda)

Two cephalopod species have been reported from the study area, Rossi molleri a small, benthic bobtailed squid (Vecchione et al. 1989), and the octopus Bathypolypus arcticus--both from Franklin and Darnley bays (Atkinson and Wacasey 1989). The Rossia were relatively common in otter trawls, occurring at depth of 15 to 129 m in temperatures ranging from -1.31 to 5.83°C and salinities of 28.63 to 32.56 ppt in August and early September. Little else is known of the species in Canadian waters except that it also occurs in Frobisher Bay (Wacasey et al. 1979). Squid beaks are found commonly, but in small numbers in the stomachs of beluga harvested in the Kugmalit Bay area (P. Weaver, pers. comm.). They have not been identified to species. Small squid have also been captured in trawls offshore Herschel Island, but were not identified (D. Chiperzak, pers. comm.).

The octopus is better known and may have commercial value.

Octopus (F. Octopodidae):

NORTH ATLANTIC OCTOPUS (Bathypolypus arcticus): This octopus occurs in the north Atlantic Ocean from the high arctic east and west of Greenland south to the North Sea in the east and the Straits of Florida in the west (Roper et al. 1984). It is widely distributed in the Canadian arctic, occurring in Frobisher Bay (Wacasey et al. 1979), Lancaster Sound (Finley and Gibb 1982), and the southern Beaufort Sea (Atkinson and Wacasey 1989). It has also been reported from near Barrow Alaska (Dall 1885 and Murdoch 1885 as cited in Stephen and Laubitz 1988).

The species is relatively small with a maximum mantle length of 10 cm and weight of 300 to 400 g (Roper et al. 1984). It is benthic in habit, ranging in depth from 14 to about 1,000 m on mud bottom, mostly of the continental shelf and upper slope. Otter trawls in Franklin and Darnley bays captured North Atlantic octopus at depths of 82 and 129 m--temperature and salinity at the former depth were 2.19°C and 32.55 ppt (Atkinson and Wacasey 1989). Breeding occurs throughout the year and individuals can live about 18 months (Roper et al. 1984). They are opportunistic feeders on brittle stars, crustaceans, polychaetes, and molluscs. North Atlantic octopus are preyed upon by Atlantic cod (Lalancette 1984), harp seal (Sergeant 1973), and narwhal (Finley and Gibb 1982).

No harvests of octopus have been reported from the Canadian arctic. However, the North Atlantic octopus is frequently taken as a by-catch in otter trawls in the north Atlantic fisheries (Roper et al. 1984). Its potential for a directed fishery has not been assessed.

Decapod crustaceans (Ph. Arthropoda; Cl. Crustacea)

At least 39 species of decapod crustaceans have been reported from the Arctic waters of North America (Table 3). They include 33 species of shrimp, 2 species of brachyuran crabs, and 4 species of anomuran crabs. Brachyurans are the true crabs (Section Brachyura) and include most commercially important species, while anomurans (Section Anomura) are crab-like crustaceans that have little commercial importance in Canada. Some anomurans, like the Alaskan king crab, have considerable commercial value.

Species discussed here are the northern or pink shrimp and the snow or queen crab. Commercially attractive anomurans have not been reported from the Canadian Beaufort Sea.

Shrimps (F. Pandalidae):

NORTHERN OR PINK SHRIMP (Pandalus borealis): The northern or pink shrimp is found in both the Atlantic and Pacific Oceans. It has a circumpolar/boreal distribution, ranging through the northeast Atlantic, including the Norwegian, Barents, and North seas, and the northwest Atlantic from western Greenland and Davis Strait southward along the Atlantic coast of North America to the Gulf of Maine. It occurs in the Beaufort, Chukchi, and Bering seas, from the Aleutian Islands in the northeastern Pacific southward to northern Oregon, and along the Asian coast from Kamchatka to Korea in the northwestern Pacific (Butler 1980; Barr and Barr 1983; Butler and Boutillier 1983; Frost and Lowry 1983; Gardner 1983; Parsons 1984; Boutillier 1986).

The pink shrimp has been reported from the Canadian Beaufort Sea (Wainwright et al. 1987) and is also recorded from near Point Barrow, Alaska (MacGinitie 1955 as cited in Frost and Lowry 1983) (Table 3). Few attempts have been made to survey and identify shrimp species in the Canadian Beaufort Sea, and recent surveys by DFO have yet to capture the pink shrimp in the southern Beaufort Sea (M. Lawrence, pers. comm.). This may be related to the fact that most stations sampled were <100 m in depth and the sampling gear was not designed specifically to capture shrimp.

Water temperature restricts the distribution of the pink shrimp. In the northwest Atlantic they are most abundant where water temperatures range from 2° to 6°C (Parsons 1984) at salinities of about 35 ppt (Shields 1988). On the Pacific coast, they occur in temperatures of 7 to 11°C at salinities of 25 to 31 ppt (Butler 1980). They are restricted by their temperature requirements to depths of 200 to 400 m in areas of the northwest Atlantic (Parsons 1984; Shields 1988), and to depths of 54 to 90 m on the Pacific coast (Butler 1980). In Alaska, larvae of pink shrimp are most abundant at depths of 10 to 40 m (Haynes 1983). The southern Beaufort Sea may be too cold for P. borealis to occur in large numbers.

Pink shrimp grow to a total length of about 16 cm, and live 3 to 5 or more years depending on latitude and water temperature (Butler 1980; Barr and Barr 1983; Gardner 1983; Parsons 1984). During the day they prefer areas with a soft, muddy bottom where they eat a variety of items including worms, small crustaceans, detritus, and marine plants; at night they migrate vertically in the water column and eat small crustacean copepods, euphasids, and mysids (Butler 1980; Barr and Barr 1983; Parsons 1984). They are prey to a variety of fishes and seals.

Pink shrimp are protandric hermophrodites, meaning that individuals function sexually first as males, undergo 4 or 5 transitional molts, and then function as females for the rest of their lives (Butler 1980; Barr and Barr 1984; Parsons 1984). Breeding occurs in late summer and fall and females carry 1,600 to 2,200 eggs until the planktonic larvae hatch in March and April. Larvae feed on small planktonic organisms in the surface waters for a few months before moving to the ocean floor where they begin to acquire their adult form. In eastern Canadian and Alaskan waters, male shrimp mature in their third year and become females by the fourth year (Davis 1982; Parsons 1984) while in Pacific waters, they mature about 1 year sooner (Butler 1980). Breeding rates for P. borealis are reduced under the influence of low water temperatures (Squires 1965).

Shrimps of the genus Pandalus are the main target species of Canada's shrimp fishery which remains small compared to that of the United States (FAO 1991). The shrimp are landed in a variety of forms, primarily fresh (Wilcox 1981a, b). In 1990, Canadian fisheries harvested 39,983 mt of shrimp with a landed value of $85,379,000 (Department of Fisheries and Oceans 1992a). The catch yielded some 18,770 mt of fresh frozen shrimp in the shell worth $86,610,000, some 4,640 mt of shucked fresh frozen shrimp worth $44,160,000 and other minor products.

Stocks of another shrimp, the yellow-leg pandalid or striped pink shrimp, P. tridens (= P. montagui tridens) were located in Hudson Strait and Ungava Bay in the 1970's, and both areas have been fished sporadically since 1980 (Parsons 1984; Crawford 1989). In 1987-88, catches in the Resolution Island area totalled 1,063 mt and in Ungava Bay 12 mt (Crawford 1989). Three Inuit corporations: the Qiqiqtaaluk Corporation, Makivik Corporation, and Labrador Inuit Association are interested in entering the fishery. To date their involvement in the offshore fishery has been limited by vessel costs and licensing. Several Inuit communities are also interested in the potential for an inshore shrimp fishery. The size of the shrimp resource remains unknown, both offshore and inshore (Crawford 1989). Depending on shrimp prices, which are volatile, vessels involved in the seasonal northern shrimp fishery generally require access to another fishery to be economically viable (Collins 1987).

Most of the product from the eastern Arctic fisheries is cooked in the shell for export to Europe with some of the shrimp being frozen raw in shell for export to Japan (S. Kerwan, pers. comm.). The northern shrimps are preferred by Europeans due to generally superior colour, texture, and flavour, however, there is growing awareness about northern shrimp in Canada resulting in growing consumer demand (Toews 1980).

Crabs (F. Majidae):

SNOW CRAB (Chionoecetes opilio): The snow crab, once commonly known as the queen or spider crab, is found in the Atlantic, Pacific, and Arctic Oceans. In the Pacific, it ranges from the Sea of Japan to Alaska, Siberia, and down the coast of British Columbia to Washington and Oregon. In the northwest Atlantic, it ranges from west Greenland down the Atlantic coast of Canada and into the Gulf of Maine

(Bailey 1981; Elner 1985). The species is absent from the northeast Atlantic (Bailey 1981).

The snow crab is known from the Beaufort Sea (Wainwright et al. 1987) and has been reported from Cape Parry (Squires 1969; Atkinson and Wacasey 1989) and Franklin Bay (Hunter 1981) in the east, and west of longitude 155° near Point Barrow, Alaska (Frost and Lowry 1983). Crab legs and claws that have washed up on the shores of Herschel Island and near the mouth of the Firth River, Yukon may be from snow crab (S. Ransom, pers. comm.). Unidentified crabs are known from Holman, Sachs Harbour, and Paulatuk (Holman HTC, Sachs Harbour HTC, and Paulatuk HTC, pers. comm.).

Male snow crabs grow to a carapace width (CW) of 15 to 16.5 cm, leg span over 90 cm, and weight of 1.35 to 2 kg while females are smaller, growing to a CW of 9.5 cm, leg span of 38 cm, and weight of 0.45 kg (Bailey 1981; Elner 1985). To achieve increases in size crabs undergo ecdysis or molting, where the old shell is discarded and the crab absorbs water and swells to its new size before the new shell hardens. Muscle and other tissues grow to replace the absorbed water. Watson (1971) found that, under laboratory conditions, crabs hardened to a commercially acceptable condition in 2 to 3 months. Donaldson et al. (1980) reported that absolute growth per molt increased with size among male tanner crab Chionoecetes bairdi and that the average increase in size for larger male and female crabs at each molt was about 21%. Male snow crabs grow in size by a similar percentage (Bailey 1981).

Snow crabs are mature at a CW of about 6 cm in males and 5 cm in females (Watson 1970a; Bailey 1981). In southern Canada they cannot be legally harvested below CW of 9.5 cm, age 5 or 6 y--effectively excluding females from the harvest (Elner and Bailey 1986). The minimum legal size is larger than the maximum size reported for males caught in the Beaufort Sea by Frost and Lowry (1983) and Squires (1969). However, unidentified crabs with estimated CW of 8 cm have been reported from Sachs Harbour and Paulatuk, and of 15 cm have been reported from Holman (Holman HTC, Sachs Harbour HTC, and Paulatuk HTC, pers. comm.).

Snow crabs are a wide-ranging species (Watson 1970b; Watson and Wells 1972), preferring mud or sand-mud bottoms at temperatures ranging from -0.5° to 4.5°C at depths of 45 to 380 m in the Atlantic (Bailey 1981). The single male found by Squires (1969) near Cape Parry, NWT occurred at a water temperature of -0.95°C.

Snow crabs eat a variety of items including shellfishes, worms, sea urchins, brittlestars, and detritus (Bailey 1981). They can escape entrapment or predation by breaking off limbs which regenerate and reach a normal size after several molts (Miller and Watson 1976).

Mating of snow crabs occurs in late winter to early spring (Bailey 1981), usually between a hard-shelled male and a soft-shelled female soon after her molt to puberty (Elner and Bailey 1986). A female can lay 20,000 to 150,000 eggs, depending on her size, and may lay more than one fertile clutch per mating because she can store spermatophores (Watson 1970a, 1972; Bailey 1981). Eggs are carried by the female until they hatch--between May and July in the Gulf of St. Lawrence (Bailey 1981). Larval crabs rise to the surface waters and are dispersed by ocean currents during their 3 to 4 month planktonic period (Elner and Bailey 1986). This type of dispersion may facilitate recruitment between snow crab grounds.

In 1987, Canadian Atlantic fisheries harvested 9,819 mt of snow crab (queen crab) with a landed value of $31,165,000 (Department of Fisheries and Oceans 1992b). Processing qaudrupled the market value of the catch (F.O.B. the fish plants), most of which was marketed fresh or frozen either in the shell or peeled. Lesser amounts were canned or processed into crab au gratin.

The snow crab is the most important commercial crab species in Canada (Elner and Bailey 1986; FAO 1991), but it is not harvested in arctic North America. It is abundant in the Gulf of St. Lawrence and off Newfoundland (Elner and Bailey 1986) but its abundance in the Beaufort Sea is unknown. Deep water research will be necessary to elucidate its distribution and abundance in the Beaufort.

Echinoderms (Ph. Echinodermata)

Starfish, sea urchins, and sea cucumbers are some familiar members of the Phylum Echinodermata. Members of the phylum occur in all of the worlds oceans from littoral waters to great depths, sometimes in large aggregations. Starfish and sea urchins are harvested for their gonads which are considered a delicacy eaten raw, while sea cucumber are usually eviscerated and dried for soup. The tests of starfish, sand dollars, and urchins are also dried for sale as souvenirs.

Very little information is available on echinoderms in Canadian Arctic waters. Two species will be discussed here, the green sea urchin and the brown sea cucumber--both of which occur in the Beaufort Sea and are harvested commercially from more southerly waters.

Sea urchins (Cl. Echinoidea; F. Strongylocentrotidae):

GREEN SEA URCHIN (Strongylocentrotus droebachiensis): The green sea urchin occurs along both coasts of North America and is common in the Canadian Arctic (Grainger 1955; Green and Steele 1975; DenBeste and McCart 1978; Dunbar and Moore 1980; Stewart and Bernier 1982, 1983, 1984; Atkinson and Wacasey 1983). It has a circumpolar distribution and inhabits the intertidal and subtidal zone to a depth of at least 130 m (Harvey 1956; Barr and Barr 1983). It is especially abundant from the low intertidal zone to about 12 m and is found on almost any surface, often in dense groups. Abundance decreases rapidly in deeper water (Jamieson and Francis 1986).

Green sea urchin occur in the Beaufort Sea (Wainwright et al. 1987), but may not be abundant or grow to a large size. Atkinson and Wacasey (1989) reported them from Franklin and Darnley bays; Cape Kellet, Banks Island; and Walker Bay, Victoria Island. They were the only echinoid found by Frost and Lowry (1983) in the western Beaufort Sea, and then only on rocky substrates in low abundance. Specimens collected from Prince Albert Sound, Victoria Island were generally small, about 30 mm in diameter (D.B. Stewart, unpublished data), as were those from Young Bay, Bathurst Island and Encampment Bay, Melville Peninsula which had mean test diameters of 37 and 31 mm respectively (D.B. Stewart and L.M.J. Bernier, unpublished data). Members of the species in the Belcher Islands of Hudson Bay are also small relative to those in the Atlantic (Jamieson 1986; Giroux 1989).

Green sea urchins grow to a test diameter of about 80 mm (Barr and Barr 1983). The mean test diameter of green sea urchins from the Pacific and Atlantic coasts of Canada are approximately twice that of their Arctic counterparts (Kramer 1980). Their growth rate and ultimate size probably depend on food availability and consumption (Ebert 1968; Kramer 1980) as both their somatic and reproductive growth are determined by their diet (Larson et al. 1980). They feed primarily on brown algae (kelp), particularly Laminaria spp. and Fucus spp., and on diatoms, coralline algae, mussels, other urchins, and dead fish (Himmelman and Steele 1971; Lawrence 1975; Vadas et al. 1986). Green sea urchins will aggregate in large groups in the presence of food (Garnick 1978; Vadas et al. 1986). They are preyed upon by sea stars, anemones, birds, fish, and marine mammals (Himmelman and Steele 1971).

Sea urchins are dioecious and spawn in spring to early summer, shedding sperm and eggs into the seawater where fertilization takes place (Barnes 1974; Barr and Barr 1983). The planktonic larvae develop a shell and sink to the bottom several months later, there they begin to feed on microscopic plants (Jamieson and Francis 1986). Spawning time varies with local conditions, a factor which is vital to commercial fishermen who harvest them for their ripe gonads.

Sea urchins of the genus Strongylocentrotus are harvested from Canadian waters for export (FAO 1988), but no stable sea urchin fishery has developed (Kramer 1980). The fresh, raw roe (male and female gonads) has a high monetary value relative to its weight and is in demand on the Japanese market. Canned and frozen roe are also sold in Japan but the markets for these products are smaller, commanding lower retail prices (Kramer 1980). Sea urchin gonads have no market value immediately after spawning, but reach marketable quality again by early fall (Jamieson and Francis 1986).

Inuit in the Belcher Islands have traditionally harvested and eaten sea urchin roe (Jamieson 1986) but urchins are not harvested in the Canadian Beaufort Sea. Studies of the commercial potential of urchins are ongoing in the Belchers, but preliminary indications are that the green sea urchins are too small and not sufficiently abundant to support more than a small commercial fishery to supply the local market (Jamieson 1986; Giroux 1989). Based on the limited information available, it seems likely that the same would apply to stocks in the Beaufort Sea.

Sea cucumbers (Cl. Holothuroidea; F. Cucumariidae):

BROWN SEA CUCUMBER (Cucumaria frondosa): Three genera of sea cucumber are known from the Beaufort Sea, Cucumeria, Psolus, and Myriotrochus (Wacasey et al. 1977; Frost and Lowry 1983; Wainwright et al. 1987). Members of the genus Cucumaria are common to North America and include the largest sea cucumber C. frondosa which grows to a length of 15 to 50 cm (Kondo et al. 1972). It occurs east of the study area in Dease Strait and Cambridge Bay (Atkinson and Wacasey 1989), offshore southern Ellesmere Island (Dunbar and Moore 1980) and near the Belcher Islands (Jamieson 1986), occupying most substrates from the tidal zone to a depth of about 350 m. Cucumaria sp. and Psolus sp. are numerous and widespread in the western Beaufort Sea (Frost and Lowry 1983). Neither genera was identified by Wacasey et al. (1977) from the southern Beaufort Sea, although they did find the wormlike sea cucumber Myriotrochus rinkii at 4 of 101 stations sampled.

Most sea cucumbers are dioecious and possess a single gonad. Sperm and eggs are shed into the seawater where fertilization takes place, and species of a genus either incubate their young or have planktonic larvae (Barr and Barr 1983; Sloan 1986a). Many cold water species incubate their eggs in special brooding pockets located on either the ventral or dorsal surface (Kondo et al. 1972; Barnes 1974). Planktonic larvae develop through several larval phases, up to 13 wks for P. californicus which spawns in early summer, before they metamorphose gradually into young sea cucumbers and settle on the bottom. P. californicus reach commercial harvest size in 4 to 5 years and live more than 8 years (Sloan 1986b). Most sea cucumbers are deposit or suspension feeders (Barnes 1974). They are eaten by crabs and other species.

Sea cucumbers are commercially harvested in Canadian waters, mainly on the Pacific coast, where the target species is the large California sea cucumber Parastichopus californicus which is harvested by divers. Sea cucumber have been harvested along the Pacific coast since 1971, and in British Columbia since 1980 (Sloan 1986a). The annual landings in British Columbia averaged 17 mt between 1980-82, and were 527 mt in 1983, and 95 mt in 1984 (Sloan 1986b). Most of the harvest took place along the east coast of Vancouver Island. While export markets are not well developed for Canadian sea cucumbers, there is a growing domestic market for the muscle strips from the inside surface of the body wall and for fresh body walls which are used as fish bait--the main product of the Canadian sea cucumber fishery (Sloan 1986a, b). The California sea cucumber is commercially harvested by divers along the southeastern coast of Alaska, mainly in the Sitka area (Woodby 1991).

In the Orient, sea cucumbers are used to make a souplike dish called trepang. It can be made from the dried body walls of about 40 different species of sea cucumbers in the Order Aspidochirota--most belonging to the genera Holothuria and Stichopus (Kondo et al. 1972). Also in demand in Japan are dried sea cucumber gonads and salted, fermented intestines which have a high monetary value relative to their weight (Callingham and Cameron 1984; Sloan 1986a).

Inuit from the Belcher Islands in Hudson Bay harvest brown sea cucumber for food and are interested in commercially harvesting the species (Jamieson 1986; Topolniski et al. 1987; Crawford 1989; Giroux 1989). While there is good local demand for sea cucumbers in Sanikiluaq and other nearby towns along eastern Hudson Bay, the stock is unlikely to support a commercial export fishery (Giroux 1989). There is no known utilization of sea cucumbers in the Canadian Beaufort Sea.

Fishes

At least 68 species of fish from 18 different taxonomic families have been reported from the Beaufort Sea. Information on their occurrence and harvest is summarized in Table 4. Small anadromous species, such as ninespine stickleback, and freshwater species which occasionally enter brackish water, such as burbot, offer little opportunity for commercial development and will not be discussed further. Information on the distribution, general biology, and utilization of the other anadromous and marine fishes, especially that pertaining to the Beaufort Sea, is reviewed below.

Lampreys (F. Petromyzontidae):

ARCTIC LAMPREY (Lampetra japonica): The Arctic lamprey has an almost circumpolar distribution, ranging from Lapland south to the Caspian Sea, eastward to Kamchatka, south to Korea, and eastward across North America to the Canadian Beaufort Sea and Mackenzie River system (Morrow 1980). In the Canadian Beaufort Sea it has been reported from Herschel Island (McAllister 1962; Kendel et al. 1975), the Yukon coast (Kendel et al. 1975), Mackenzie Bay (Slaney 1973a; 1975; 1976a), Kugmallit Bay (Slaney 1976b), Tuktoyaktuk (Riske 1960), and elsewhere along the Tuktoyaktuk Peninsula (Galbraith and Hunter 1975; Bond and Erickson 1991).

The life history of Arctic lamprey is not well known. The anadromous form spawns from late May to early July in the Mackenzie River, and migrating adults are often seen there in vast concentrations (Kendel et al. 1975). The ammocoete larvae are sedentary burrowers that eat microorganisms and mature into parasitic adults. The adults can attain lengths of 411 mm (Scott and Crossman 1973), and parasitize chinook salmon, rainbow smelt, starry flounder (McPhail and Lindsey 1970), Arctic and least cisco (Kendel et al. 1975), inconnu, lake and broad whitefish, lake trout (Riest et al. 1987), Pacific herring (Riske 1960), and probably Arctic charr (Sparling and Stewart 1986; Stewart and Sparling 1987). The incidence of attack may be more frequent than realized because lamprey often release their grip to escape when the host fish is captured in sampling gear. Lamprey scarring can reduce fishes commercial value, and Coregonus spp. appear to be the lamprey's preferred hosts (Kendel et al. 1975; Reist et al. 1987). Lamprey are eaten by Arctic charr (Kendel et al. 1975) and inconnu (Riske 1960; Kendel et al. 1975).

Arctic lamprey are not harvested from the Canadian Beaufort Sea although they were once taken in quantity by dip net from the Yukon River for food (Evermann and Goldsborough 1907). Morrow (1980) suggested that a market for smoked lampreys might be developed. In 1987, about 379 mt of lamprey were harvested world wide, mostly by the former Soviet Union (FAO 1991).

Skates (F. Rajidae):

SKATE (Raja sp.): A single skate, tentatively identified as the Arctic skate (Raja hyperborea), was collected offshore Richards Island by trawl, at a depth of 234 m, in August 1986 (Arctic Laboratories Ltd. and LGL Ltd. 1987). An embryo and two empty egg cases collected by otter trawl from Franklin Bay are the only other evidence for elasmobranchs in the Canadian Beaufort Sea (Hunter 1981). They were taken on 29 July 1977 from a depth of 335 m where water temperature was 0.30°C and salinity 34 ppt (Hunter and Leach 1983a,b). The Atlantic water layer where Raja sp. may be more common has seldom been sampled (Ratynski et al. 1988). It lies beneath the 150 to 240 m layer of Arctic surface water and extends downward to 900 m.

Two species of skate are commonly taken in the Atlantic fisheries of Canada (Wilcox 1981b). One of these, the thorny skate (R. radiata), has a range that extends into the northerly waters of West Greenland (Scott and Scott 1988) and has also been reported from Hudson Bay (Vladykov 1933). This species prefers sand and silt bottoms and temperatures above 0°C--it is rarely encountered at lower temperatures (Andriyashev 1954). Skates are sometimes processed into meal in Canada and are eaten in Europe (Scott and Scott 1988). In 1989, the Canadian fishery harvested 410 mt of skates and rays (FAO 1991).

Herrings (F. Clupeidae):

PACIFIC HERRING (Clupea harengus pallasi): The Pacific herring ranges from the northern Pacific Ocean into the Arctic Ocean. On the North American coast it is most abundant in British Columbia and southeastern and central Alaskan waters (Morrow 1980).

There are many reports of Pacific herring in the Canadian Beaufort Sea (Ratynski et al. 1988). The species is most abundant east of the Mackenzie Delta, particularly in the Tuktoyaktuk Harbour and Tuktoyaktuk Peninsula, Liverpool Bay/Husky Lakes, and Cape Bathurst areas (Slaney 1973b, 1976b; Bray 1975; Galbraith and Hunter 1975; Hunter 1975; Bond 1982; Hopky and Ratynski 1983; Gillman and Kristofferson 1984a; Lawrence et al. 1984; Shields 1985; B.W. Fallis, DFO, unpublished data, see Ratynski et al. 1988; Bond and Erickson 1991; Chiperzak et al. 1991; Dickson 1991). Hunter (1981) sighted what he believed was a large school of herring in the area between the Booth Islands and Parry Peninsula on 21 August, 1962--the concentration of fish recorded by depth sounder was 13 m deep and 2.6 km in length.

The species occurs less commonly at Herschel Island (McAllister 1962; Kendel et al. 1975), along the Yukon coast (Mann 1974; Kendel et al. 1975; Bond and Erickson 1987, 1989; and unpublished DFO studies, see Ratynski et al. 1988), and in the outer Mackenzie Delta (Slaney 1973a, 1974, 1976a, 1977a, b; Percy 1975; Lawrence et al. 1984). It may also be less common east of Cape Parry, but was common at Paulatuk (Riske 1960), and occurs in Coronation Gulf (Gillman and Kristofferson 1984b), Bathurst Inlet (Richardson 1836; J.G. Hunter, DFO, unpublished data, see Ratynski and deMarch 1988), Melville Sound (J.S. Campbell and L. Johnson, DFO, unpublished data, see Ratynski and deMarch 1988), and along coastal Victoria Island near Holman (Holman HTC, pers. comm.).

Pacific herring spawn in protected waters near shore (Taylor 1964). Mature herring have been captured under the ice of Kugmallit Bay in mid-May (Chiperzak et al. 1991). The species is known to spawn in Tuktoyaktuk Harbour (Bond 1982; Gillman and Kristofferson 1984a) and the Fingers area of Liverpool Bay (Gillman and Kristofferson 1984a; Shields 1985) about the time of ice break up--early June to mid July. Shields (1985) estimated that 8.2 mt of herring deposited about 568 x 10^6 eggs in the Fingers area of Liverpool Bay from June 12 to July 16, 1985. Planktonic larvae are common in Tuktoyaktuk Harbour from mid July to mid August, but rare in adjacent Kugmallit Bay (Ratynski 1983). Larval and juvenile Pacific herring larvae occur along the Tuktoyaktuk Peninsula from mid July into September (Hunter 1975; Jones and DenBeste 1977; Lawrence et al. 1984; D. Chiperzak, pers. comm.). They have not been captured in the Mackenzie Delta (Percy 1975) or on the Yukon coast (Kendel et al. 1975).

Pacific herring generally feed on planktonic organisms such as copepods, with adults feeding on larger items than the young--sometimes small fishes (Hart 1973; Lacho 1991). In the Beaufort Sea they also eat benthic infaunal and epibenthic organisms (Lawrence et al. 1984).

In coastal waters of British Columbia, Pacific herring typically grow to 250 mm in length and live 9 or 10 years, but can grow 330 mm in length and live 15 years (Department of Fisheries and Oceans 1983). In the Beaufort Sea herring longer than 300 mm and older than 10 years are common (Bond 1982; Hopky and Ratynski 1983; Lawrence et al. 1984; Gillman and Kristofferson 1984a).

The fecundity of Pacific herring at a particular body size generally decreases with increasing latitude (Paulson and Smith 1977; Hay 1985). This decrease is offset by an increase in mean length, resulting in an increased mean fecundity of spawners with latitude. However, the relatively slow-growing Arctic stocks are less productive and more succeptible to overharvesting. Where west coast stocks may sustain annual harvesting rates of 0.2 to 0.3 (Ware 1985) and those in the eastern Bering Sea rates of 0.2 (Fried and Wespestad 1985), those in the Beaufort Sea may only sustain annual harvesting rates of 0.1 (A.H. Kristofferson and D.V. Gillman, pers. comm.). A Beaufort Sea fishery then, might require a stock that is 2 to 3 fold larger to obtain a similar sustained roe yield.

There are small subsistence fisheries for herring by residents of Tuktoyaktuk, Inuvik, and Aklavik at coastal points near the Delta (Fabijan 1990, 1991; P.D. Sparling, pers. comm.). The fish are gutted, dressed, and pickled or fried. There is a small local market for pickled herring. Some of the herring are used for dog food. In Paulatuk and Holman herring are eaten when caught as a by-catch of charr fisheries (Holman HTC and Paulatuk HTC, pers. comm.). These herring fisheries probably developed with the advent of gillnets, since Anderson (1913) reported that herring were not utilized circa 1910. Pacific herring are not a common catch of the Alaskan Beaufort Sea subsistence fisheries except at Point Lay, where they are fished in August (Craig 1989b).

Several experimental commercial fisheries for Pacific herring have been conducted in the Canadian Beaufort Sea. The first of these took place near Baillie Island in 1963. It was prompted by DFO research in the early 1960's which indicated that sizeable stocks of Pacific herring existed between Liverpool Bay and Darnley Bay (Anonymous 1962, 1963; Hunter 1981).

The second attempt, in the 1980's, was prompted by a strong demand from Japan for herring roe (Gillman and Kristofferson 1984a). Both fisheries met with limited success and are discussed in the section on Arctic commercial fisheries.

In 1987, the British Columbia herring fishery harvested 37,615 mt of herring and 194 mt of herring roe with landed values of $96,908,000 and $10,444,000 respectively (Department of Fisheries and Oceans 1992b). The catch yielded 17,753 mt of processed products worth $173,651,000 (F.O.B. the plants), including 5,981 mt of roe worth $165,517,000; 951 mt of fish oil worth $360,000; 5,248 mt of fish meal worth $3,765,000; 804 mt of fresh or frozen bait worth $1,945,000; 578 mt of herring frozen round or dressed worth $457,000; and unknown amounts and values of fresh round or dressed and pickled and cured herring. In 1989, the Canadian fishery harvested 41,107 mt of Pacific herring (FAO 1991).

Salmons, charrs, and whitefishes (F. Salmonidae):

PINK SALMON (Oncorhynchus gorbuscha) and CHUM SALMON (O. keta): Pink and chum salmon are the only salmon that maintain viable populations in North American arctic drainages. Other salmon species, including coho (O. kisutch), sockeye (O. nerka) and chinook (O. tshawytscha), are known in arctic waters north of Point Hope, Alaska only as strays (Craig and Haldorson 1986; see also Hunter 1969).

Pink salmon occur in the lower Mackenzie River (Dymond 1940) and have been reported once from Tuktoyaktuk Harbour (Riske 1960). Chum salmon occur as far south in the Mackenzie River drainage as the mouth of the Hay River (Scott and Crossman 1973), and the Grand Canyon of the Liard River in British Columbia (58°49'N, 123°14'W; McLeod and O'Neil 1983). They have been taken in the subsistence fishery from the Mackenzie Delta, Peel River, and Arctic Red River (Corkum and McCart 1981). Residents of Aklavik catch a them in small numbers most summers (Fabijan 1990). Chum salmon also occur east of the Mackenzie Delta in Franklin and Darnley bays (Hunter 1979a) and have been captured by the Hornaday River fishery (Corkum and McCart 1981). Neither species is common or abundant in the study area.

The biology of salmon in the Canadian Beaufort Sea is poorly known. There are few, if any, coastal records of either species during numerous biological surveys conducted since the mid 1970's (Craig and Haldorson 1986; Ratynski et al. 1988). There is a small spawning population of chum salmon in the Liard River of the Mackenzie drainage (McLeod and O'Neil 1983).

To the west, there are small runs of pink salmon in seasonal streams along the north coast of Alaska between Point Hope and Barrow, and perhaps in the Colville River (Craig 1989b). Pink salmon in these drainages can grow to a fork length of 590 mm and chum salmon to 743 mm (Craig and Haldorson 1986). They grow slower and are less fecund than southern populations. Their run timing in Alaskan coastal waters usually extends from the last week of July through August, with peak numbers occurring during the first half of August (Craig 1989b). In the sea they eat Arctic cod, amphipods, and mysids (Craig and Haldorson 1986).

Salmon are the most important commercial fish species in the north Pacific Ocean, but they are too rare in the Beaufort Sea to be commercially attractive. Salmon taken in subsistence harvests are generally hung for a few days to cure and then eaten (P.D. Sparling, pers. comm.). In 1979, a single chinook salmon was captured in the subsistence fishery at Fort Liard (McLeod and O'Neil 1983). It was apparently a stray accompanying a spawning migration of chum salmon. Subsistence fisheries of Alaskan communities along the Chukchi Sea, between Point Lay and Barrow, harvest small numbers of salmon, mainly pink and chum (Craig 1989b).

ARCTIC CHARR (Salvelinus alpinus): The Arctic charr has a circumpolar distribution and populations may be anadromous or landlocked (McPhail and Lindsey 1970; Scott and Crossman 1973; Johnson 1980). The anadromous form is abundant in coastal areas of the Canadian Arctic and, except in the larger rivers, is not usually distributed far inland.

Two different, perhaps taxonomically distinct, forms of anadromous charr inhabit the southeastern Beaufort Sea. Those from rivers east of the Mackenzie

River are Arctic charr (S. alpinus) while those to the west are either a western morph of the species (McPail 1961; McCart 1980; Craig 1989a) or dolly varden (S. malma) (Morrow 1980; Reist 1989; Reist et al. 1990). Recent genetic evidence supports the latter view (Reist 1989; Reist et al. 1990). It also suggests that populations spawning in different tributaries of a river basin may be genetically different and represent distinct stocks.

The presence of genetically distinct stocks, between and within river basins, has important implications for the management and rehabilitation of anadromous charr in the study area (Reist 1989). It means that stocks may be much more succeptible to depletion through site specific harvesting than was previously thought. To prevent overharvesting managers need to know whether a fishery is harvesting fish from one or several stocks. Where a mixed stock is being fished, the level of exploitation needs to be determined for each stock and adjusted accordingly to prevent over exploitation. This will require knowledge of the life history of each stock including routes and timing of migrations, and areas utilized during different stages of the life cycle.

The primary sources of anadromous charr encountered in coastal areas to the west of the Delta are the Firth River (Glova and McCart 1974), the Babbage River (Bain 1974), and tributaries of the Mackenzie River such as the Rat and Big Fish rivers (Corkum and McCart 1981; Gillman and Sparling 1985; Sparling and Stewart 1986; MacDonell 1987), and the Peel River (Hunter 1975). Charr are present in the waters off Herschel Island (Scofield 1899; Anderson 1913; McAllister 1962; Kendel et al. 1975; Baker 1985) and are frequently encountered along the Yukon coast (Mann 1974; Griffiths et al. 1975; Kendel et al. 1975; Hunter 1981; W. Field, DFO, unpublished data, see Ratynski et al. 1988; Bond and Erickson 1987, 1989).

Charr are not known from the outer Mackenzie Delta, but have been collected from offshore artificial island sites (Envirocon 1977; Slaney 1977b). They are uncommon along the Tuktoyaktuk Peninsula (Bond and Erickson 1991), and in Tuktoyaktuk Harbour (Riske 1960).

A small stock of anadromous Arctic charr inhabits the lower Horton River (MacDonell 1989), but it is only east of Cape Bathurst that this species is found in some abundance. Arctic charr occur along the Parry Peninsula and are more abundant in the southern reaches of Franklin and Darnley bays (Hunter 1979a). The Hornaday River stock of anadromous Arctic charr has supported commercial, subsistence, and sport fisheries (MacDonell 1986, 1989; Lemieux 1990). The Brock River, which drains into southeastern Darnley Bay, also supports a small stock of anadromous Arctic charr (Sutherland and Golke 1978; MacDonell 1989).

Anadromous Arctic charr inhabit virtually every river system on Victoria Island that has suitable overwintering habitat with a passable outlet to the sea (Stewart and Bernier 1982, 1983). An important source of charr in the vicinity of Holman is the Kuujjua River, which drains into Minto Inlet. The Kagloryuak, Kuuk, Naloagyok, and Kagluk rivers which flow into Prince Albert Sound are other sources of anadromous Arctic charr in the Holman vicinity (Kristofferson and McGowan 1982; Kristofferson et al. 1984; Baker 1986; Stewart and Sparling 1987; Sparling and Stewart 1988; Lemieux and Sparling 1989; Lewis et al. 1989).

On Banks Island, anadromous Arctic charr utilize the Thomsen River (Sutherland and Gohlke 1978) and lower reaches of the Sachs and Masik rivers (Sachs Harbour HTC, pers. comm.). They may also use the Kellett River, rivers that flow into De Salis and Mercy bays, and a system which flows into Prince of Wales Strait (73°02′N, 118°15′W; Sutherland and Gohlke 1978; Baker 1987).

The anadromous charr migrate to sea during ice break-up from mid June to early July, spend the summer feeding at sea, and return upstream from mid August to mid September to overwinter in fresh water (Johnson 1980; McCart 1980; Stewart and Sparling 1987; MacDonell 1989). They have been captured in salinities of up to 32 ppt in the Beaufort Sea (Craig 1984; Bond and Erickson 1987), and range widely along the coasts in summer. They have not been reported from saline waters in winter.

Spawning occurs during late August, September, and early October, and anadromous charr west of the Mackenzie River are more likely to migrate to sea during a spawning year than are those to the east (Glova and McCart 1974; Moore 1975a,b; Johnson 1980; Stewart and Bernier 1982, 1983). Both morphs, or taxa, return to spawn in their natal lakes and streams (Glova and McCart 1974; Johnson 1980; McBride 1980). Charr prefer to spawn over a gravel bottom in an area where current is sufficient to keep the eggs detritus-free and deep enough to protect them from freezing (Moore 1975a; Johnson 1980). Eggs hatch in April or May and young pre-anadromous charr spend several years in fresh water, followed by 2 to 4 seasons of migrations to sea for feeding, before reaching sexual maturity. During the summer anadromous Arctic charr can undertake marine migrations of over 500 km and do not always return to overwinter in their natal river systems (Gyselman 1984). Maturity for both sexes is reached between ages 5 and 12 years and mature fish seldom spawn in consecutive years (Grainger 1953; Johnson 1980; McCart 1980; Stewart and Bernier 1982, 1983).

Charr in the Beaufort Sea eat predominately amphipods, isopods, mysids, and fish (McCart 1980; Stewart and Sparling 1987). Because food is more abundant at sea (Craig 1989a) they generally grow faster and larger than charr which remain in fresh water. The western form can attain a fork length of 668 mm and live 15 y (McCart 1980), and the eastern 906 mm and 23 y (Baker 1986; Stewart and Sparling 1987).

Anadromous charr are more commercially attractive than the landlocked form. The anadromous fish are available spring and fall in quantity at known locations. They grow faster and generally larger, and are almost always in better condition--having higher coefficients of condition and fewer Diphyllobothrium spp. parasites encysted in the body cavity (McCart 1980; Johnson 1980; Stewart and Bernier 1982, 1983).

There are well established Arctic commercial export fisheries for anadromous Arctic charr at Cambridge Bay and along the Keewatin coast (see section on commercial fisheries). Most Arctic communities have at least a small commercial harvest to serve local markets. However, there are no viable commercial fisheries for anadromous Arctic charr in the study area.

Anadromous Arctic charr are harvested extensively by subsistence fishermen from Sachs Harbour, Holman, Paulatuk, and Aklavik (Usher 1970, 1976; Farquharson 1976; Stewart and Bernier 1982, 1983; Sparling and Stewart 1986; Lewis et al. 1989; MacDonell 1989; Fabijan 1990, 1991) and along the Alaskan coast (Craig 1989b)--few are harvested by residents of Tuktoyaktuk or Inuvik (Fabijan 1990, 1991). Most harvesting takes place during the open water season near the communities, either along the coasts or at river mouths, or in October through the ice of overwintering lakes. Important subsistence fisheries for anadromous Arctic charr are located at the Sachs, Masik, Kuujjua, and Hornaday rivers, and in Safety Channel near Holman. Stocks in rivers that are further afield, for example the Horton River and rivers in Minto Inlet and Prince Albert Sound, are also utilized.

Few site-specific data are available for the domestic harvest, but attempts to establish commercial fisheries at systems with existing subsistence fisheries have led to overharvesting and damage to stocks in the Big Fish, Rat, and Hornaday rivers (MacDonell 1986, 1987, 1989; Sparling and Stewart 1986--see commercial fisheries section for more information). Where site specific coastal harvest data exist, it is still impossible to determine the extent to which a stock is being exploited since the degree of stock mixing at a given site is unknown. Tourist sport fisheries are not established in the study area.

ARCTIC CISCO (Coregonus autumnalis): The Arctic cisco occurs in Arctic Ocean drainages and coastal brackish waters from the White Sea eastward to Alaska and the Northwest Territories (Andriyashev 1954; Scott and Crossman 1973). In the Canadian Arctic, it occurs in mainland, coastal waters and drainages east to Rasmussen Peninsula, and on Victoria Island (Stewart and Bernier 1983).

This species is widely distributed in the southeastern Beaufort Sea. It is common and abundant in coastal Yukon waters and at Herschel Island, throughout the coastal waters of the Mackenzie Delta, at Tuktoyaktuk Harbour and other locations in Kugmallit Bay and along the Tuktoyaktuk Peninsula, in Liverpool Bay and Husky Lakes, and Franklin and Darnley bays. References for these areas include:

- **coastal Yukon waters:** Craig and Mann 1974; Griffiths et al. 1975; Kendel et al. 1975; Hunter 1981;

B. Hillaby/W. Fields, DFO, unpublished data, see Ratynski et al. 1988; Bond and Erickson 1987, 1989.
- **Herschel Island:** Scofield 1899; Anderson 1913; McAllister 1962; Kendel et al. 1975; Baker 1985.
- **coastal waters of the Mackenzie Delta:** Slaney 1973a, 1975, 1976a, 1977b; Percy 1975; Envirocon 1977; Lawrence et al. 1984.
- **Tuktoyaktuk Harbour and other locations in Kugmallit Bay and along the Tuktoyaktuk Peninsula:** Slaney 1973b, 1977b; Beak Consultants 1975; Bray 1975; Galbraith and Hunter 1975; Jones and DenBeste 1977; Byers and Kashino 1980; Bond 1982; Hopky and Ratynski 1983; Lawrence et al. 1984; Gillman and Kristofferson 1984a; B.W. Fallis, DFO, unpublished data, see Ratynski et al. 1988; Schmidt et al. 1989; Bond and Erickson 1991; Chang-Kue and Jessop 1991; Chiperzak et al. 1991; Dickson 1991.
- **Liverpool Bay and Husky Lakes:** Bray 1975; Slaney 1976b; Hunter 1981; Gillman and Kristofferson 1984a.
- **Franklin and Darnley bays:** Hunter 1979a.

Arctic cisco have been collected from offshore waters and are more tolerant of high salinity than other coregonid species (Galbraith and Hunter 1975; Reist and Bond 1988). They have been captured in water temperatures as low as -1.7°C, and salinities ranging up to 32 ppt (Craig 1984; Bond and Erickson 1987). Adult Arctic cisco tagged in Tuktoyaktuk Harbour in July were found to migrate along the coast at a rate of 7 to 17 km per day (Chang-Kue and Jessop 1991). Juvenile Arctic cisco can tolerate a wide range of simultaneous temperature (12°C to 3°C) and salinity (0 to 24 ppt) shocks (Fechhelm et al. 1989b).

Arctic cisco in the Mackenzie River system spawn in late September and early October and then migrate downstream to overwintering areas in the Delta (Stein et al. 1973; Bond 1982). They have been captured under the ice of Kugmallit Bay in mid-May (Chiperzak et al. 1991). The youngest mature fish are aged 6 years (Reist and Bond 1988). Spawning sites are located in major tributaries such as the Peel, Arctic Red, and Great Bear rivers (Stein et al. 1973), and in the Liard River upstream of Fort Simpson (McLeod and O'Neil 1983). Eggs hatch in the spring and currents transport the larvae downstream into the Delta and Beaufort Sea (Bond 1982). Genetic analyses of population variation suggest that Arctic cisco show fidelity to their natal streams for spawning but disperse in the Beaufort Sea and at overwintering sites (Bickham et al. 1989).

Young-of-the-year Arctic cisco appear to be aided in their westward dispersal by wind driven along-shore currents (Fechhelm and Fissel 1988; Griffiths and Fechhelm 1989; Moulton 1989; Schmidt et al. 1989; Fechhelm and Griffiths 1990). They arrive in the Phillips Bay, Yukon area in mid-July (Bond and Erickson 1987, 1989), and in Alaskan waters in August (Reist and Bond 1988). Gallaway et al. (1983) have hypothesized that all Arctic cisco in the brackish waters of the Canadian and Alaskan Beaufort Sea originate from spawning locations in the Mackenzie River system. Moulton (1989) has documented the westward movement of young-of-the-year along the coast between Kay Point, Yukon and the Colville River, Alaska, and the return eastward movement of tagged adults--providing further direct evidence of the exchange of this species between Prudhoe Bay, Alaska and the Mackenzie River region. Genetic data do not provide evidence for a differentiated Alaskan stock (Bickham 1989; Bickham et al. 1989).

If the proportion of the Arctic cisco population recruited into Alaskan waters is large, then the integrity of the Mackenzie River stock could depend upon the success of the Alaskan migrants (Fechhelm and Fissel 1988). When winds blow from the east, the causeway (West Bank) west of Prudhoe Bay blocks the eastward dispersal of small fish from the Colville River by modifying nearshore hydrographic conditions (Fechhelm et al. 1989a). Potential causeway developments on the Yukon coast might have similar effects (Griffiths et al. 1988). While there has been strong recruitment of Arctic cisco into Alaskan waters since causeway construction (Griffiths and Fechhelm 1989), this does raise some concerns over the effects of causeway developments on the Mackenzie River stock (Griffiths et al. 1988).

Young-of-the-year Arctic cisco also migrate eastward along the Tuktoyaktuk Peninsula (Bond 1982; Lawrence et al. 1984). However, their movements may be less influenced by wind than those of cisco entering the Alaska waters (Schmidt et al. 1989). Unlike broad and lake whitefish and least cisco, they do not utilize freshwater systems for feeding and rearing areas (Bond and Erickson 1985).

Arctic cisco in the study area eat crustaceans, molluscs, annelids, and fish (Bond 1982; Lawrence et al. 1984; Lacho 1991). Age determinations from otoliths suggest that they can live 21 years (Craig and Mann 1974). The maximum ages of 10, 11, and 13 years recorded by Lawrence et al. (1984), Bond (1982), and Hopky and Ratynski (1983) respectively, were based on scales and may be underestimates. Arctic cisco in the area can grow to a fork length of 488 mm (Jones and DenBeste 1977). East of the study area, in the Hayes River, they can live 21 years (scale age), and grow to a fork length of 498 mm (Stewart and Bernier 1983)--523 mm in the nearby Back River (MacDonald and Stewart 1980). The flesh of Arctic cisco is relatively free from parasitic infections.

Arctic cisco are harvested by subsistence and commercial fisheries of the lower Mackenzie River and Delta (Corkum and McCart 1981; Sparling and Sparling 1988; Fabijan 1990). The use of large mesh gillnets by both fisheries, and other factors, limit catches of the species to a small percentage of both harvests. Arctic cisco taken in salt water are a prized food fish (Sparling and Sparling 1988). They are boiled and eaten fresh, or dried for later use--some are used for dog food (P.D. Sparling, pers. comm.).

Because of their fat, anadromous Arctic cisco are also a favoured food fish for Inupiat subsistence fishermen along the Beaufort Sea coast of Alaska (Craig 1989b; Moulton et al. 1989). Nuiqsut fishermen catch them in fall when they gather in the Colville River to overwinter, and Kaktovik fishermen in summer as they migrate back to the Mackenzie River.

Helmerick's have operated a small commercial fishery for Arctic cisco in the Colville River Delta Alaska since 1967 (Winslow and Roguski 1970; Gallaway et al. 1983, 1989). Their annual catch of Arctic cisco has ranged from a high of 32,534 kg in 1973 to a low of 4,213 kg in 1979. Catch levels over the years suggest a marked decline in the fishery, but the catch-per-unit effort has remained relatively constant. Reasons for the lower harvests remain unclear, but the resettlement of Nuiqsut and construction of causeways may have had an effect. Arctic cisco has also been a valuable commercial species in the former Soviet Union (Andriyashev 1954).

LEAST CISCO (Coregonus sardinella): The least cisco is found in Arctic coastal waters, and in certain inland lakes and drainages, from the White Sea eastward to Alaska and the Northwest Territories (Andriyashev 1954; Scott and Crossman 1973). It also occurs in drainages of the Bering Sea (Andriyashev 1954). In the southeastern Beaufort Sea the anadromous form of the least cisco occurs at Herschel Island (McAllister 1962; Kendel et al. 1975; Baker 1985) and in Yukon coastal waters (Mann 1974; Griffiths et al. 1975; Kendel et al. 1975; Hunter 1981; B. Hillaby/W. Fields, DFO, unpublished data, see Ratynski et al. 1988). It was the third most abundant species occurring at Phillips Bay in 1985 (Bond and Erickson 1987) and in 1986 (Bond and Erickson 1989).

Anadromous least cisco are abundant in the waters of the Mackenzie Delta (Slaney 1973a, 1975, 1976a; Percy 1975; Lawrence et al. 1984) and common in Kugmallit Bay and along the Tuktoyaktuk Peninsula (Slaney 1973b, 1977b; Beak Consultants 1975; Bray 1975; Jones and DenBeste 1977; Byers and Kashino 1980; Gillman and Kristofferson 1984a; Lawrence et al. 1984; B.W. Fallis, DFO, unpublished data, see Ratynski et al. 1988; Bond and Erickson 1991; Chiperzak et al. 1991; Dickson 1991). They were the most abundantly captured fishes during 1973 to 1975 in the inshore waters in the vicinity of Tuktoyaktuk (Galbraith and Hunter 1975) and in the early 1980's from Tuktoyaktuk Harbour (Bond 1982; Hopky and Ratynski 1983).

Anadromous least cisco also occur in Liverpool Bay and the Husky Lakes (Bray 1975; Slaney 1976b; Hunter 1981; Gillman and Kristofferson 1984a), and in mainland coastal drainages of Coronation Gulf (Sutherland and Gohlke 1978; Gillman and Kristofferson 1984b), Melville Sound (J.S. Campbell and L. Johnson, DFO, unpublished data, see Ratynski and deMarch 1988), and Queen Maud Gulf (MacDonald and Stewart 1980). The species is also known from Banks, Victoria, Prince of Wales, and King William islands (McPhail and Lindsey 1970; Sutherland and Gohlke 1978; Stewart and Bernier 1983, 1984; Hunter et al. 1984) and Melville Peninsula and Southampton Island (Stewart and Bernier 1984).

The anadromous form of the least cisco probably spawns in the Mackenzie River system in late September and early October (Stein et al. 1973). The

Peel and Husky channels of the Delta, the Peel River, and the Arctic Red River are likely spawning grounds. Spent adults have been captured in early winter in inner Delta lakes and channels (Mann 1975), suggesting that they move downstream after spawning (Reist and Bond 1988). Immature and adult least cisco have been captured under the ice of Kugmallit Bay in mid-May (Chiperzak et al. 1991).

Eggs hatch in spring and, like larval broad whitefish and lake whitefish, the young are washed downstream into the Delta and estuary during spring runoff. Young-of-the-year least cisco appear at Tuktoyaktuk Harbour in mid July (Bond 1982). Most of the young probably remain in coastal areas to feed, but freshwater systems of the Tuktoyaktuk Peninsula are also important feeding and rearing areas, although to a lesser extent than for broad whitefish (Lawrence et al. 1984; Bond and Erickson 1985; Chang-Kue and Jessop 1992). During the summer of 1982, 10,599 least cisco migrated upstream into headwater lakes of a single small drainage system that flows into Tuktoyaktuk Harbour (Bond and Erickson 1985).

Least cisco are slightly less tolerant of high salinity than Arctic cisco (Reist and Bond 1988). They have been captured in water temperatures of -1.7°C, and salinities of up to 32 ppt (Craig 1984).

Least cisco eat mainly amphipod, copepod, and mysid crustaceans (Bond 1982; Lawrence et al. 1984; Lacho 1991). They also eat insects, fish, and plant material.

The least cisco is the smallest of the anadromous coregonids occurring in the southeastern Beaufort Sea. At Tuktoyaktuk Harbour, they range in fork length from 35-401 mm, with 89% less than 100 mm (Bond 1982). Hopky and Ratynski (1983) found fork lengths of 35 to 338 mm from the same area. Ages determined from scales ranged from 0 to 11 years and 0 to 10 years in the respective studies. Stein et al. (1973) reported a maximum scale age of 12 years from the Mackenzie River, and Jones and DenBeste (1977) a maximum otolith age of 12 years at Tuft Point along the Tuktoyaktuk Peninsula. A least cisco at Nunaluk Lagoon, Yukon Territory, had an otolith age of 16 years (Griffiths et al. 1975). Age estimates from scales tend to be lower than those from either fin rays or otoliths, particularly after the age of 9 years. For example, a least cisco from King William Island was found to be 15 years old when aged using scales and 23 years old using fin rays (D.B. Stewart and L.M.J. Bernier, unpublished data). Bond and Erickson (1991) recorded an otolith age of 26 years for a least cisco from Wood Bay.

Least cisco are harvested by Mackenzie Delta subsistence fisheries (Fabijan 1990). Known there as "black-tipped herring", they are smaller and less desirable than Arctic cisco (P.D. Sparling, pers. comm.). Anadromous least cisco caught in the sea are sometimes dried for food, but most are fed to dogs. There is little, if any, commercial utilization of the species in the Mackenzie Delta. However, it is an important by-catch of the commercial fishery for Arctic cisco at the Colville River, Alaska (Moulton et al. 1989), and an important harvest of the commercial fisheries in northern rivers of Siberia (Andriyashev 1954).

LAKE WHITEFISH (Coregonus clupeaformis): The lake whitefish is distributed widely in the fresh waters of North America from Alaska eastward across Canada and the northern United States to Atlantic coastal watersheds (Scott and Crossman 1973). It is common in coastal drainages of arctic North America except in the extreme northeastern District of Keewatin and on Melville Peninsula (Stewart and Bernier 1984), and occurs on Banks (Sutherland and Gohlke 1978) and Victoria islands (Stewart and Bernier 1983). It enters brackish waters in Ungava Bay, Hudson Bay, and the Beaufort Sea.

In the southeastern Beaufort Sea, the lake whitefish occurs in Yukon coastal waters (Mann 1974; Kendel et al. 1975; Hunter 1981; Bond and Erickson 1987, 1989) and in the nearshore waters of Herschel Island (Baker 1985). The species is more common and abundant in the Mackenzie Delta (Slaney 1973a, 1975, 1976a; Percy 1975; Lawrence et al. 1984) and in Tuktoyaktuk Harbour and nearshore along the Tuktoyaktuk Peninsula (Slaney 1973b; Beak Consultants Ltd. 1975; Galbraith and Hunter 1975; Bond 1982; Hopky and Ratynski 1983; Gillman and Kristofferson 1984a; Lawrence et al. 1984; B.W. Fallis, DFO, unpublished data, see Ratynski et al. 1988; Bond and Erickson 1991; Chiperzak et al. 1991; Dickson 1991) where fresh water from the Mackenzie River lowers the salinity. The lake whitefish has also been reported from Liverpool Bay and Husky Lakes (Bray 1975; Slaney 1976b; Hunter 1981; Gillman and Kristofferson 1984a).

Lake whitefish have not been reported from saline offshore waters. They have a lesser salinity tolerance than the cisco species and show a lesser degree of anadromy (Reist and Bond 1988). Individuals have been captured in water temperatures down to 0°C, and in salinities of up to 28 ppt (Craig 1984; Bond and Erickson 1987, 1989). Those caught under the ice of Kugmallit Bay in mid-May were taken from water that was relatively warm and fresh--0°C with a salinity of 0.13 ppt (Chiperzak et al. 1991).

Anadromous lake whitefish from the southeastern Beaufort Sea likely spawn in the Mackenzie River system. Spawning concentrations have been observed in October near Arctic Red River (Stein et al. 1973), but most lake whitefish in the vicinity of Tuktoyaktuk during September are non-spawning fish (Bond 1982). The youngest mature fish are aged 7 years (Stein et al. 1973; Bond and Erickson 1985, 1987), and water temperatures at spawning range from 1° to 1.5°C (Stein et al. 1973).

Newly hatched fry are likely washed into the Mackenzie Delta by spring runoff, and the delta and inner estuary may be the main nursery area for the young-of-the-year (Bond and Erickson 1985). Juvenile lake whitefish utilize freshwater drainages of the Tuktoyaktuk Peninsula for feeding, rearing, and overwintering. In 1982, 9,684 fish were counted moving upstream and 22,382 downstream in a single freshwater system draining into Tuktoyaktuk Harbour. Lake whitefish do not utilize these systems as extensively as the broad whitefish (Bond and Erickson 1985; Chang-Kue and Jessop 1992).

Adult lake whitefish are bottom feeders and consume a wide range of benthic invertebrates and small fishes (Scott and Crossman 1973). In coastal areas of the southeastern Beaufort Sea, they eat crustaceans, molluscs, annelids, insects, fish, and other items (Percy 1975; Bond 1982; Lawrence et al. 1984; Lacho 1991).

Growth of lake whitefish from the study area is slow. Bond (1982) reported that specimens from Tuktoyaktuk Harbour were among the slowest growing within the Northwest Territories, but were comparable to growth rates of other populations from similar latitudes. He reported a maximum fork length of 485 mm and a maximum scale age of 16 years. Lake dwelling lake whitefish from Richard's Island apparently grow larger and older than coastal lake whitefish from Kugmallit Bay (Lawrence et al. 1984). The former were significantly larger between ages 8 and 12. Only 12% of coastal lake whitefish were larger than 400 mm compared to 77.5% of lake dwelling samples. Lake whitefish collected in a survey of the Mackenzie Delta area domestic fishery ranged in length from 298 to 560 mm fork length and in otolith age from 4 to 18 years (Sparling and Sparling 1988).

Bond and Erickson (1991) caught several very large individuals (577, 600, and 697 mm fork length) in Wood Bay in 1989. The sex of these fish could not be determined, and the authors suggested that they might be lake whitefish x inconnu hybrids.

The lake whitefish is an important harvest of subsistence fishermen from Aklavik, Inuvik, Tuktoyaktuk, and Paulatuk but it is not harvested by residents of Holman or Sachs Harbour (Fabijan 1990). It was the most frequently encountered species in the domestic fishery harvest in the Mackenzie Delta during 1980-82 (Sparling and Sparling 1988). Most fo the lake whitefish were used for dog food, either fresh, frozen, dried, or pitted (P.D. Sparling, pers. comm.). Cysts of the tapeworm, Triaenophorus crassus, are common in the flesh of lake whitefish from this area, making it unattractive for human consumption (Bernier 1985a; Polakoff 1989). This species is one of the most valuable commercial freshwater species in Canada. In 1987, 9,034 mt of whitefish with a landed value of $12,112,000 were harvested, roughly 12% of this from the NWT (Department of Fisheries and Oceans 1992b).

BROAD WHITEFISH (Coregonus nasus): The broad whitefish is distributed in Arctic Ocean drainages and brackish waters from the Pechora River, the former Soviet Union east to the Bering and Beaufort seas, and in several river systems of the Canadian arctic mainland (McPhail and Lindsey 1970; Scott and Crossman 1973). It occurs in mainland drainages of the Coronation Gulf (Ellis 1962; Sutherland and Gohlke 1978; Gillman and Kristofferson 1984b), and Melville Sound (J.S. Campbell and L. Johnson, DFO, unpublished data, see Ratynski and deMarch 1988). The Perry River, which drains into Queen Maud Gulf, marks the eastern border of its distribution (McPhail and Lindsey 1970). The broad whitefish is known from the waters of Herschel Island (McAllister 1962), but is not recorded from any other North American island of the Arctic Ocean.

Broad whitefish are not abundant in Yukon coastal waters (Mann 1974; Kendel et al. 1975; Hunter 1981; Bond and Erickson 1987, 1989; B. Hillaby/W. Field, DFO, unpublished data, see Ratynski et al. 1988). They are most prevalent in the Mackenzie Delta and in coastal waters of the Tuktoyaktuk Peninsula that are freshened by water from the Mackenzie River, and have not been found in more saline offshore waters (Galbraith and Hunter 1975).

Broad whitefish occur from Fort Simpson northward throughout the lower Mackenzie River (Stein et al. 1973), and in the Delta (Slaney 1973a, 1975, 1976a; Percy 1975; Lawrence et al. 1984). They are common in nearshore gillnet samples from Tuktoyaktuk Harbour (Bond 1982; Hopky and Ratynski 1983), and from Tuktoyaktuk and/or nearshore waters of the Tuktoyaktuk Peninsula (Riske 1960; Slaney 1973b; Beak Consultants 1975; Bray 1975; Galbraith and Hunter 1975; Jones and DenBeste 1977; Byers and Kashino 1980; Gillman and Kristofferson 1984a; Lawrence et al. 1984; B.W. Fallis, DFO, unpublished data, see Ratynski et al. 1988; Bond and Erickson 1991; Dickson 1991).

Broad whitefish also occur in Liverpool Bay and the Husky Lakes (Bray 1975; Slaney 1976b; Hunter 1981; Gillman and Kristofferson 1984a), and in systems from Darnley Bay eastward along the mainland coast to Coronation Gulf (Sutherland and Gohlke 1978).

The species is less tolerant of high salinity than are the cisco species but more tolerant than lake whitefish and inconnu (Craig 1984; Reist and Bond 1988). It has been captured in water temperatures of 0°C, and in salinities of 30 ppt. Larvae and juveniles apparently tolerate brackish water, with larger fish having greater tolerance (de March 1989).

Anadromous broad whitefish originating from the Mackenzie River system spawn in October and November at the mouth of the Arctic Red River (Stein et al. 1973), at Point Separation, and at the Ramparts (Chang-Kue and Jessop 1983). Reist (1987) concluded that the Mackenzie River anadromous broad whitefish are distinct from those stocks occurring in the Anderson and Hornaday rivers and in Alaskan rivers. The youngest mature broad whitefish are aged 7 years (Stein et al. 1973; Bond and Erickson 1985, 1987).

Upon hatching in the spring, larval broad whitefish from the Mackenzie River are transported to delta lakes and the estuary by spring runoff (Reist and Bond 1988). Young-of-the-year are able to migrate along freshened coastal waters of the Tuktoyaktuk Peninsula and reach Tuktoyaktuk Harbour by early July (Bond 1982). Many young broad whitefish utilize the freshwater systems of the Tuktoyaktuk Peninsula for rearing, feeding, and overwintering. Between 21 June and 12 October 1982, Bond and Erickson (1985) counted 100,178 broad whitefish moving upstream into a single freshwater system that drains into Tuktoyaktuk Harbour. Most of these 0+ to 1+ year old fish appear to remain in lakes for up to 4 years before switching to complex annual migrations between lakes and coastal waters (Chang-Kue and Jessop 1992). The older immature fish (4 to 8 y) generally forage in the lakes for 21 to 45 d before returning downstream, although some may remain in the lakes to overwinter. Sexually mature broad whitefish are infrequent in the upstream runs in these smaller creeks, but tagged individuals have been recaptured in spawning runs in the Mackenzie River drainage.

Broad whitefish eat insects crustaceans, molluscs, annelids, priapulids, and other items (Bond 1982; Lacho 1991). Feeding activity is apparently more prevalent in lakes than in rivers or coastal areas (see for example Stein et al. 1973; Bond and Erickson 1985). Broad whitefish may not be succeptible to Triaenophorus crassus infection (Bernier 1985a, b, unpublished data). Those examined from the Tuktoyaktuk Peninsula were free of the parasite which was common in least cisco from the same catches.

Most of the broad whitefish captured in gillnets along the coastal southeastern Beaufort Sea ranged in fork length from 255 to 474 mm (Bond and Erickson

1985). These are mainly immature fish that are involved in annual migrations between summer feeding areas in lakes on the Tuktoyaktuk Peninsula and overwintering locations in the Mackenzie Delta. Studies on broad whitefish in the Mackenzie River and Delta have encountered larger fish, presumably because of the congregation of mature broad whitefish. Stein et al. (1973) and Percy (1975) found that most broad whitefish in the Mackenzie Delta area were between 431 and 540 mm in length. Those taken by domestic fishermen from the Delta area in 1981, ranged in fork length of from 284 to 679 mm fork length (mean of 496 mm), and in otolith age from 3 to 17 years (mean of 9.2 years)(Sparling and Sparling 1988). Maximum reported scale and otolith ages for broad whitefish from the lower Mackenzie are 18 and 35 years, respectively (Reist and Bond 1988).

The broad whitefish is the most sought after coregonid in both the domestic and commercial fisheries of the Mackenzie Delta. It is harvested in quantity by subsistence fishermen from Aklavik, Inuvik, Tuktoyaktuk, and Paulatuk but is seldom taken by fishermen from Holman or Sachs Harbour (Fabijan 1990). Anadromous broad whitefish are available at predictable times and locations and their flesh is relatively parasite-free. Most of the catch is consumed by the fishermen and their families, either fresh, dried, frozen or pitted (Sparling and Sparling 1988). At least 35,000 to 45,000 kg of broad whitefish are harvested from the Delta annually (McCart 1980; Sparling and Sparling 1988). Commercial fisheries for this species also exist in the Colville River Delta, Alaska (Morrow 1980). Andriyashev (1954) reported that the broad whitefish was one of the most important food fishes in the rivers of Siberia.

INCONNU (Stenodus leucichthys): The inconnu is distributed in Arctic Ocean drainages and coastal brackish waters of Asia and North America from the White Sea eastwards to the Anderson River near Cape Bathurst (Andriyashev 1954; Scott and Crossman 1973). It is also found further south in drainages and coastal waters of the Bering Sea.

Inconnu are common in coastal waters of the Mackenzie Delta (Slaney 1973a, 1975, 1976a; Percy 1975; Lawrence et al. 1984) and become less common with distance from the area. In the southwestern Beaufort Sea, they are known from Herschel Island (Anderson 1913) and the coastal Yukon (Jones and Kendel 1973; Mann 1974; Griffiths et al. 1975; Kendel et al. 1975; Hunter 1981; Bond and Erickson 1987, 1989; B. Hillaby, DFO, unpublished data, see Ratynski et al. 1988).

The species is common in bays between Kittigazuit and Tuktoyaktuk Harbour (Galbraith and Hunter 1975; Lawrence et al. 1984), in Tuktoyaktuk Harbour (Slaney 1973b; Beak Consultants 1975; Byers and Kashino 1980; Bond 1982; Hopky and Ratynski 1983; Gillman and Kristofferson 1984a), and between Tuktoyaktuk and McKinley Bay (Jones and DenBeste 1977; Lawrence et al. 1984; B.W. Fallis, DFO, unpublished data, see Ratynski et al. 1988; Bond and Erickson 1991; Chiperzak et al. 1991; Dickson 1991). It occurs near shore under the ice of Kugmallit Bay in mid-May (Chiperzak et al. 1991).

Anderson (1913) and Hunter (1975) reported that inconnu were taken from the mouth of the Anderson River in Liverpool Bay, and residents of Colville Lake report that this species is present in the Anderson River (Sutherland and Golke 1978).

Inconnu are rarely caught offshore (Galbraith and Hunter 1975) and have not been reported from the Arctic Islands. They are less tolerant of high salinity than are the other anadromous coregonids (Craig 1984; Reist and Bond 1988). Inconnu have been captured in salinities of 15.3 ppt (Bond and Erickson 1987).

Inconnu that feed and overwinter along the southeastern Beaufort Sea coast originate from the lower 500 to 700 miles of the Mackenzie River system (Jessop et al. 1974; Jessop and Lilley 1975). In Alaska, summer-long upstream migrations to spawning areas begin with ice break-up (Alt 1977, 1988), and there is evidence that this pattern also exists in the southeastern Beaufort Sea (Stein et al. 1973; Percy 1975; Bond 1982; Lawrence et al. 1984). Spawning probably occurs during September and October in the upper Peel, Arctic Red, and Mackenzie rivers (Stein et al. 1973). A downstream post-spawning migration to wintering areas occurs in October (Jessop et al. 1974). Juveniles are seldom caught in coastal areas (Percy 1975; Bond 1982; Hopky and Ratynski 1983).

In Alaskan waters, the age at first maturity ranges from 4 to 9 years for males and 6 to 12 years for females (Alt 1988). Adult inconnu may not spawn every year (Alt 1969), and non-spawners and immature fish remain in coastal areas. Spawning occurs in late September to mid October at water temperatures of 0° to 4°C, in the afternoons (Alt 1988). Water depths of 1.2 to 2.3 m, current speed of 0.9 to 2.7 m s^{-1}, and a bottom composed of differently sized gravel (10 to 100 mm) are common to inconnu spawning grounds.

In the Beaufort Sea region, adult inconnu are piscivorous, preying on least cisco, Arctic cisco, inconnu, rainbow smelt, ninespine stickleback, fourhorn sculpin, Pacific herring, lamprey ammocoetes, cod, and flounder (Kendel et al. 1975; Percy 1975; Bond 1982; Lawrence et al. 1984; Lacho 1991). Invertebrates make up a small proportion of the diet of adult inconnu. However, amphipods, mysids, isopods, pelecypods, nematodes, chironomids, and plant material have all been reported from inconnu stomach contents. Young inconnu feed on invertebrates but can switch to a fish diet their first summer (Fuller 1955; Alt 1988).

Inconnu grow to a larger size than other whitefish, and a specimen captured at the mouth of the Mackenzie River reportedly weighed over 28 kg (63 lb) and measured 1.5 m (59.25") long (Dymond 1943). In the Mackenzie River delta, a fork length of 956 mm was recorded by Lawrence et al. (1984). Bond (1982) reported a maximum fork length of 933 mm for inconnu from Tuktoyaktuk Harbour, and most (72%) were between 450 to 599 mm in length. They ranged in age from 4 to 17 years with most (74%) from 5 to 8 years old (Bond 1982). On average, inconnu captured at Tuktoyaktuk were smaller and younger than those reported from the lower Mackenzie River and outer Delta by Stein et al. (1973) and Percy (1975). Rate of growth at Tuktoyaktuk was amongst the slowest reported for inconnu. Lawrence et al. (1984) also found that inconnu from the Tuktoyaktuk Peninsula coast grew slower than those from the Delta at Richards Island, and Percy (1975) found that inconnu from the outer Delta grew considerably slower than those from Great Slave Lake as reported by Fuller (1955).

Inconnu are harvested by subsistence and commercial fisheries in the Mackenzie Delta region. Fish that are alive when caught are boiled and eaten fresh or dried for later use (P.D. Sparling, pers. comm.). Further inland at Ft. Mcpherson inconnu are also smoked. Because they soften quickly in the nets, fish that die in the nets are fed to the dogs. Inconnu command similar or slightly better prices than other whitefish (Freshwater Fish Marketing Corporation 1989) but make up a relatively small portion of the total catch (Corkum and McCart 1981). They have been harvested commercially from Great Slave Lake for many years and the produce is used mainly in the smoked fish trade (Scott and Crossman 1973).

In Alaska, a small commercial fishery with a harvest limit of 11,364 kg has operated in the Kotzebue area since 1960, and there are substantial subsistence and sport harvests (Alt 1988). The economic value of the Alaskan inconnu fishery has been estimated at $20,000 US for the commercial harvest, $500,000 US for the subsistence harvest, and $250,000 US for the sport harvest. There has also been a small commercial fishery for inconnu in northern rivers of Siberia (Andriyashev 1954).

Smelts (F. Osmeridae):

CAPELIN (Mallotus villosus): The capelin has a circumpolar distribution which extends southward to Korea and Juan de Fuca Strait in the Pacific, and to Cape Cod and western Norway in the Atlantic (Scott and Scott 1988). The species occurs sporadically in the Beaufort Sea and can be very abundant locally. It has been reported from Herschel Island (Walters 1953a; McAllister 1962; Hunter 1981), the coastal Yukon (Kendel et al. 1975; Hunter 1981; Bond and Erickson 1989), Wood Bay (Bond and Erickson 1991), Liverpool Bay, Baillie Island (Hunter 1981), and Sachs Harbour (Sachs Harbour HTC, pers. comm.), further east near Coppermine (Walters 1955; Ellis 1962), and from Bathurst (Richardson 1823; Walters 1955) and Chantrey inlets (McAllister 1963a).

Many capelin spawned at Herschel Island in late July 1960, and over 700 kg were captured in eight seine tows (Hunter 1981). They were also abundant along the mainland and at Sachs Harbour in 1960, but were previously unknown to the local people. Few have since been reported. Relatively small numbers of capelin occur along the northeast Chukchi Sea coast of Alaska (Craig 1989b). They are briefly abundant in the Point Lay area during the first week of August when they spawn along shorelines.

The biology of capelin in the southeastern Beaufort Sea is poorly known. Capelin in the area spawn on beaches in late July and early August (Kendal et al. 1975; Hunter 1981). Those taken at Herschel Island were in four age classes and 50% were 4 years old (Hunter 1981). The largest individual was 163 mm long (McAllister 1963a). Capelin eat plankton, including mysids (Kendel et al. 1975; Scott and Scott 1988).

In 1987, the Canadian Atlantic fishery harvested 29,672 mt of capelin with a landed value of $7,065,000 (Department of Fisheries and Oceans 1992b). The catch yielded 16,109 mt of processed products worth $24,922,000 (F.O.B. the plants), including 254 mt of fresh round or dressed capelin worth $67,000; 15,478 mt of capelin frozen round or dressed for worth $24,308,000; 81 mt of fresh or frozen capelin for bait worth $26,000, and other minor products. In 1989, the Canadian fishery harvested about 85,947 mt of capelin (FAO 1991).

Nearly a million tonnes of capelin were harvested World-wide in 1989, making it one of the principal food species (FAO 1991). Most of the catch is processed into fish meal and oil (Scott and Scott 1988). The capelin is also an important forage species for many commercially valuable fishes, whales, and seals (Carscadden 1981). It occurs too sporadically in the Beaufort Sea for a food fishery to have developed, but in the Hudson Bay/Hudson Strait region capelin is sometimes used for human consumption or for dog food (Crawford 1989). Efforts to commercially exploit capelin in the Churchill and Port Burwell areas were short lived.

RAINBOW SMELT (Osmerus mordax): The rainbow smelt is distributed along the Arctic Ocean coast from the White Sea eastward to the southeastern Beaufort Sea and southward to Korea and Vancouver Island in the Pacific Ocean. It is also native to eastern North America from Labrador to New Jersey and has been introduced in the Great Lakes (Morrow 1980).

Rainbow smelt are widely distributed in coastal waters of the southeastern Beaufort Sea as far east as Cape Bathurst, and occur further east in Coronation Gulf and Bathurst Inlet (Hunter et al. 1984). The species has been recorded from Herschel Island (McAllister 1962; Kendel et al. 1975; Baker 1985) and the coastal Yukon (Mann 1974; Kendel et al. 1975; Bond and Erickson 1987, 1989; unpublished DFO study, see Ratynski et al. 1988).

Rainbow smelt are abundant in the Mackenzie Delta region of the study area and eastward along Tuktoyaktuk Peninsula. They have been reported in the Delta region by: Slaney (1973a; 1975; 1976a), Percy (1975), and Lawrence et al. (1984); and from Tuktoyaktuk Harbour and other locations in Kugmallit Bay and along the Tuktoyaktuk Peninsula by: Slaney (1973b; 1977b), Beak Consultants (1975), Galbraith and Hunter (1975), Jones and DenBeste (1977), Byers and Kashino (1980), Bond (1982), Hopky and Ratynski (1983), Lawrence et al. (1984), B.W. Fallis (DFO, unpublished data, see Ratynski et al. 1988), Bond and Erickson (1991), Chiperzak et al. (1990, 1991), and Dickson (1991). The species is less common in Liverpool Bay and near the Baillie Islands (Cape Bathurst) (Hunter et al. 1984; J.G. Hunter, DFO, unpublished data, see Ratynski et al. 1988), and is only occasionally taken from offshore waters (Galbraith and Hunter 1975). It is not known from the northern shores of Amundsen Gulf.

In northern areas rainbow smelt spawn during May and June (Andriyashev 1954). This activity usually occurs in freshwater streams but can also take place in the tidal zone of estuaries (Bigelow and Schroeder 1963; McKenzie 1964). Ninety-five percent of the females (n = 38) and 67% of the males (n = 26) taken under the ice of Kugmallit Bay in mid-May 1987 were mature, and the youngest mature fish of both sexes were aged 5 years (Chiperzak et al. 1991). Most spawning in the Beaufort Sea occurs in the channels of the Mackenzie River delta, and has been recorded in the vicinity of Arctic Red River (Stein et al. 1973). Newly hatched larvae drift downstream into estuarine areas. Spawning may also occur at Tuktoyaktuk Harbour and other similar coastal locations. In 1982, yolk sac larvae were far more abundant in ichthyoplankton tows taken inside Tuktoyaktuk Harbour than those taken outside the harbour in adjacent Kugmallit Bay (Ratynski 1983). A single larva was taken on the Beaufort Sea Shelf offshore Kugmallit Bay in July 1984 (Chiperzak et al. 1990). Larval rainbow smelt have also been captured west to Kay Point and in Mackenzie Bay (D. Chiperzak, unpublished data).

Mysid, amphipod, and ostracod crustaceans and small fish are important components of the diet of Beaufort Sea populations of rainbow smelt (Galbraith and Fraser 1974; Kendel et al. 1975; Percy 1975; Bond 1982; Lawrence et al. 1984; Lacho 1991).

Relative to southern populations, rainbow smelt in the southeastern Beaufort Sea are long-lived and grow slowly to a large size. Individuals older than 5 years and longer than 250 mm fork length are common (Galbraith and Hunter 1975; Percy 1975; Bond 1982; Hopky and Ratynski 1983; Lawrence et al. 1984; Bond and Erickson 1991). The maximum size reported is 350 mm fork length (Bond 1982) and the maximum age is 13 years (Galbraith and Hunter 1975; Hopky and Ratynski 1983). In southern waters rainbow smelt can live 6 years. On average it takes a female smelt in Lake Superior 6 years to attained a length of 249 mm (Bailey 1964), and a female at Tuktoyaktuk 7 years (Bond 1982).

There is a small winter subsistence fishery for rainbow smelt in the Wainwright area of the Alaskan Chukchi Sea (Craig 1989b). These smelt are harvested by jigging and are a highly regarded food. They have the distinction of being the only species of plant or animal that is regularly bought or sold in Wainwright, and are exchanged between villages.

Few rainbow smelt are harvested for food from the southeastern Beaufort Sea, or along the west coast of North America. The species does support significant sport and commercial fisheries in the Great Lakes and Maritimes. In 1987, the Canadian Atlantic fishery harvested 1,774 mt of smelt with a landed value of $1,533,000 (Department of Fisheries and Oceans 1992b). The catch yielded 816 mt of processed products worth $1,428,000 (F.O.B. the plants), including 425 mt of fresh round or dressed smelt worth $826,000, and 391 mt of smelt frozen round or dressed worth $602,000. The Great Lakes smelt fishery which is centred in Ontario, with a minor contribution from Quebec, harvested 11,580 mt of smelt with a landed value of $4,157,000 (Department of Fisheries and Oceans 1992b).

Cods (F. Gadidae):

TOOTHED COD (Arctogadus borisovi) and POLAR COD (A. glacialis): The distributions of these little known cod species are restricted to Arctic seas. The toothed cod occurs from the Kara Sea eastward along the coast of Siberia (Andriyashev 1954) through the Chukchi Sea (Nielsen and Jensen 1967) and Canadian Arctic Archipelago (Nielsen and Jensen 1967; Hunter et al. 1984) to southwest Greenland (Nielsen and Jensen 1967). The polar cod occurs in marine waters of the western Polar Basin from east and west Greenland (Nielsen and Jensen 1967), through Canadian Arctic waters (Nielsen and Jensen 1967; Hunter et al. 1984), and west to the Chukchi Sea (Walters 1961; Nielsen and Jensen 1967). Both species were encountered in the southeastern Beaufort Sea at Liverpool Bay, and near capes Bathurst and Parry during DFO surveys in the 1970's (Hunter et al. 1984; Ratynski et al. 1988). Polar cod have also been trawled from depths of 230-240 m, offshore Tuktoyaktuk in August (Arctic Laboratories Ltd. and LGL Ltd. 1987).

The toothed cod lives in coastal waters and enters the mouths of rivers (Andriyashev 1954). It may occur pelagically but is most often caught close to the bottom (Nielsen and Jensen 1967). Polar cod is a pelagic species, seldom found in brackish waters (Nielsen and Jensen 1967). Both species eat crustaceans (Walters 1961). Narwhal eat polar cod (Finley and Gibb 1982).

Arctogadus larvae were collected by DFO in ichthyoplankton tows in the offshore waters of the Beaufort Sea during the mid 1980's (D. Chiperzak, unpublished data, see Ratynski et al. 1988). They have also been reported from Lancaster Sound and Baffin Bay (Sekerak 1982).

A study of sympatric populations of toothed and polar cod at Cambridge Bay, NWT from 1964 to 1968 showed that both Arctogadus spp. grow larger and live longer than the Arctic cod (Boulva 1972, 1979). Toothed cod grew to a fork length of 518 mm and lived 11 years, polar cod to 494 mm and 11 years. Unpublished information on the biology of Arctogadus resulting from this study exists (Ratynski and deMarch 1988).

Toothed cod and polar cod are occasionally captured by jigging through ice cracks. They are gutted, split, dried, and eaten or fed to dog teams. No known commercial fishery exists, although Svetovidov (1948 In Nielsen and Jensen 1967) speculated that one based on both toothed and Arctic cod might be possible.

ARCTIC COD (Boreogadus saida): The Arctic cod is widespread in the Arctic Ocean, having been captured even near the North Pole, but is absent from the southwestern Barents Sea (Andriyashev 1954). It has been collected throughout Canada's arctic marine waters (Hunter et al. 1984). The species is also distributed southward in adjacent areas such as the Bering Sea, Gulf of Anadyr, and Norton Sound (Andriyashev 1954) and in the Labrador Sea and Gulf of St. Lawrence (Scott and Scott 1988).

In the southeastern Beaufort Sea the Arctic cod is frequently encountered but catches are dependent on locality sampled, sampling method, and the vagaries of Arctic cod movements. The species is not common in nearshore waters or in areas that are strongly influenced by fresh water from the Mackenzie River, and is more likely to be captured in trawls than gillnets. Scofield (1899), Kendel et al. (1975), and Baker (1985) all caught few Arctic cod at Herschel Island using gill nets and/or seine nets for sampling. However, McAllister (1962) described the Arctic cod as being ubiquitous in these same waters based on specimens captured by trawling (J.G. Hunter, unpublished DFO data, see Ratynski et al. 1988). Mann (1974) sampling with gillnets described it as uncommon in nearshore Yukon coastal waters.

Arctic cod have been reported from the outer Mackenzie Delta at the Isserk (Envirocon 1977) and Issungnak (Griffiths and Buchanan 1982) artificial islands, and at Hooper Island (Lawrence et al. 1984). They have been captured in Kugmallit Bay (Galbraith and Hunter 1975; Slaney 1976a; Byers and Kashino 1980), Tuktoyaktuk Harbour (Galbraith and Hunter 1975; Hopky and Ratynski 1983), and along the Tuktoyaktuk Peninsula (Galbraith and Hunter 1975; Jones and DenBeste 1977; Lawrence et al. 1984; Bond and Erickson 1991). Arctic cod are also common in Liverpool Bay and the Husky Lakes (Gillman and Kristofferson 1984a; Hunter 1981), and present in Franklin Bay (Hunter 1979a; 1981).

Arctic cod may be very common in offshore waters of the study area. They were the most abundant species found in trawls at depths of 150 to 240 m, offshore Herschel and Richards islands in August 1986 (Arctic Laboratories Ltd. and LGL Ltd. 1987). They were also the most abundant species found in plankton tows on the Beaufort Sea Shelf between Herschel Island and Cape Bathurst in July and September 1984, making up 93.0 and 95.8% of the young-of-the-year in the respective catches (Chiperzak et al. 1990). Hunter (1979b) found young-of-the-year to be abundant in Amundsen Gulf. Planktonic young were not common in Tuktoyaktuk Harbour (Ratynski 1983).

There are no records of Arctic cod from the nearshore of northern Amundsen Gulf or between Cape Parry and Dolphin and Union Strait, but this may simply reflect a lack of sampling effort.

Arctic cod spawn from December to the end of March (Rass 1968); in the Alaskan Beaufort Sea spawning occurs between November and early February--likely both near shore and offshore (Craig et al. 1982).

The species feeds mainly on zooplankton and phytoplankton (Andriyashev 1954). Copepods, particularly calanoids, are the commonest and most abundant items found in stomachs of Arctic cod in the southeastern Beaufort Sea (Bradstreet et al. 1986; Lacho 1986; Chiperzak et al. 1990). Phytoplankton were not an important food item. Epibenthic mysids were the major summer prey of juvenile and adult Arctic cod in Simpson Lagoon--amphipods and copepods were also eaten (Craig et al. 1982).

The Arctic cod is unusual among northern fish species in that it is relatively small, short-lived, and matures at a young age (Craig et al. 1982). Published information on the age and growth of Arctic cod from the Canadian Beaufort Sea is lacking but at Simpson Lagoon, Alaska, cod ranged in fork length from 54 to 257 mm and in age from 1 to 6 years (Craig et al. 1982). Most of the fish caught were less than four years old. Arctic cod rarely reach an age of seven years or length of 300 mm (Bradstreet et al. 1986). At Liverpool Bay, Arctic cod ranged in length between 6 and 235 mm (Hunter 1981). In the northern part of Bering Sea, Arctic cod were 144 to 158 mm, 190 to

200 mm, and 220 to 230 mm in length at ages 2+, 3+, and 4+ respectively (Andriyashev 1954). At Simpson Lagoon Arctic cod appear to grow more slowly, reaching mean lengths of 128 mm, 159 mm, and 180 mm, at ages 2, 3, and 4 respectively (Craig et al. 1982).

The Arctic cod has been fished commercially by the former Soviet Union for many years, mainly for processing into animal food or oil (Andriyashev 1954; Morrow 1980). In 1989, the U.S.S.R. harvested 1,544 mt of Arctic cod from the northwest Pacific Ocean and 215 mt from the northeast Atlantic Ocean, where Greenland also harvested a further 2 mt (FAO 1991). This is a significant decline from previous years; 90,305 mt were harvested in 1983, all from the northeast Atlantic Ocean (FAO 1988). In the Canadian Arctic, this species is caught by jigging at ice leads in the spring. It is seldom eaten but sometimes fed to sled dogs.

Arctic cod are an important component of the Arctic marine food chain. They are a major food item of other fish, birds, seals, and whales that northerners depend upon for their livelihoods (Andriyashev 1954; Bradstreet et al. 1986).

SAFFRON COD (Eleginus gracilis): The saffron cod is common in coastal waters of the Pacific Ocean from the Yellow Sea north to the Sea of Japan, Sea of Okhotsk, and Bering Sea, and along the North American coast south to Sitka, Alaska (Andriyashev 1954). In the Arctic Ocean it is found as far west as the East Siberian Sea at Chaunskaya Inlet (Andriyashev 1954), and east to Coronation Gulf (Ellis 1962; Gillman and Kristofferson 1984b), Bathurst Inlet (Walters 1953a), Melville Sound (J.S. Campbell and L. Johnson, DFO, unpublished data, see Ratynski and deMarch 1988), and Queen Maud Gulf (MacDonald and Stewart 1980). Saffron cod are generally found in shallow waters, and in the northeastern Bering Sea and Norton Sound of Alaska most occurred at a depth of less than 40 m (Wolotira 1985).

In the Canadian Beaufort Sea, saffron cod have been reported from Herschel Island (McAllister 1962; Baker 1985), the Yukon coast (Kendel et al. 1975; Bond and Erickson 1987), and the Mackenzie Delta (Slaney 1973a, 1975, 1976a; Percy 1975; Lawrence et al. 1984). The species is more common along Tuktoyaktuk Peninsula (Slaney 1973b; Galbraith and Fraser 1974; Galbraith and Hunter 1975; Jones and DenBeste 1977; Byers and Kashino 1980; Bond 1982; Hopky and Ratynski 1983; Lawrence et al. 1984; Gillman and Kristofferson 1984a; B.W. Fallis, DFO, unpublished data, see Ratynski et al. 1988; Bond and Erickson 1991). It will enter brackish water and has been taken under the ice of Kugmallit Bay in mid-May in water with a salinity of 0.36-0.54 ppt (Chiperzak et al. 1991). The species is present and locally abundant in Liverpool Bay and Husky Lakes (Bray 1975; Gillman and Kristofferson 1984a; J.G. Hunter, DFO, unpublished data, see Ratynski et al. 1988).

East of Cape Bathurst saffron cod may be uncommon; several were captured at Cape Parry in 1963 and 1964 (J.G. Hunter, DFO, unpublished data, see Ratynski et al. 1988) but no other catch records are known between there and Coronation Gulf. Although the species is most commonly encountered near shore, it has been captured by offshore mid-water trawls in Mackenzie Bay and Kugmallit Bay (Galbraith and Fraser 1974). There are no records from the far offshore waters or northern coasts of Amundsen Gulf.

Saffron cod spawn in nearshore waters from February to March (Andriyashev 1954). Along the Tuktoyaktuk Peninsula, spawning probably occurs in March at Tuktoyaktuk (Bond 1982) and during March to April at Kukjuktuk Bay (B.W. Fallis, pers. comm.). However, Chiperzak et al. (1991) captured a mature adult from Kugmallit Bay in mid-May. Tuktoyaktuk Harbour is an important rearing and nursery locality; thirty seven planktonic larvae ranging from 5.6 to 8.0 mm total length were captured in the harbour during 11 July to 16 August, 1982 (Ratynski 1983), and juveniles were common during 1981 (Hopky and Ratynski 1983). A single planktonic larva was captured over the Beaufort Sea Shelf offshore Kugmallit Bay in mid-July 1984 (Chiperzak et al. 1990).

Saffron cod in the Beaufort Sea eat amphipods, isopods, mysids, polychaetes, plant material, and fish (Percy 1975; Lawrence et al. 1984; Lacho 1991). They may grow larger and live longer than saffron cod from other areas. Lawrence et al. (1984) reported that saffron cod grew very little after reaching 400 mm in fork length and age of 10 years. They found that cod older than 10 years were common and many were larger than 350 mm, the oldest was aged 19 years and the largest was 499 mm long. In the waters of western Alaska, most saffron cod are less than 5 years old, the maximum age is about 9 years, and the largest specimens encountered are about 350 mm (Wolotira 1985). In the Anadyr estuary of Siberia, the average length encountered is from 280 to 320 mm at ages 4 and 5 respectively (Andriyashev 1954).

In the Canadian Beaufort Sea, saffron cod are captured incidentally and are used as food for dogs or occasionally for human consumption (Hunter 1975; Crawford 1989; Fabijan 1991). In Alaska, they are captured in considerable numbers by subsistence fishermen jigging with hand lines through the ice (Morrow 1980). In 1989, about 27,841 mt of saffron cod were commercially harvested from the northwest Pacific Ocean (FAO 1991).

GREENLAND COD (Gadus ogac): The Greenland cod, or ogac, occurs from Point Barrow, Alaska, east along the Canadian Arctic coast to western Greenland, and south to the Gulf of St. Lawrence (Scott and Scott 1988). In the Canadian Beaufort Sea, the Greenland cod has not been reported west of Cape Dalhousie on Tuktoyaktuk Peninsula. It is rare in Liverpool Bay, but common east of Cape Bathurst (Hunter 1981). Greenland cod were common at Cape Parry during 1962 to 1964, where up to an average of 60 cod were captured per man hour of jigging on 29 June 1964 (Hunter 1981). The species has also been recorded from Franklin Bay (Hunter 1979a; Hunter et al. 1984) and from Walker Bay southwestern Victoria Island (Walters 1953a). There are other, unsubstantiated, reports of this species in the area.

There is no published information on the biology of Greenland cod in the Beaufort Sea, although there exist data collected by the Arctic Biological Station (Ratynski et al. 1988). Hunter (1981) reported that Greenland cod from near Cape Parry had mean lengths of 247 mm, 295 mm, and 335 mm in 1962, 1963, and 1964 respectively. Specimens, most of which were from the same year class, were captured by jigging, gill netting, and seining.

In Greenland waters, this species reaches a maximum age of 11 years and a maximum length of 700 mm (Jensen 1948 cited in Scott and Scott 1988). In western Hudson Bay, it grows slower, reaching a total length of about 450 mm and a maximum age of 12 years (Mikhail and Welch 1989). The Greenland cod matures at age 3 or 4 years, spawns in February and March, and eats fish, crustaceans, squid, annelids, molluscs, and echinoderms.

The species is harvested commercially by fishermen from Greenland who harvested 364 mt from west Greenland waters in 1989 (FAO 1991). There was a small commercial fishery for the species at Lake Harbour, Baffin Island in 1985 and 1986, but it suffered from poor product acceptance (R. Allan, pers. comm.). Like other cods, the species is harvested occasionally by subsistence fisheries in the Canadian arctic, generally by jigging with hand lines through ice leads in the spring, or with rod and reel in summer. It is eaten or fed to the dogs.

Eelpouts (F. Zoarcidae):

BIGEYE UNERAK (Gymnelus hemifasciatus), FISH DOCTOR (G. viridis), SHULUPAOLUK (Lycodes jugoricus), SADDLED EELPOUT (L. mucosus), PALE EELPOUT (L. pallidus), POLAR EELPOUT (L. polaris), ARCTIC EELPOUT (L. reticulatus), THREESPOT EELPOUT (L. rossi), ARCHER EELPOUT (L. saggitarius), LONGEAR EELPOUT (L. seminudus): The eelpouts are a large family of marine fishes which occur in the Arctic, Antarctic, Atlantic, and Pacific oceans (Scott and Scott 1988). The above species are found in cold Arctic waters, but some also have distributions which extend south into the north Atlantic. Hunter et al. (1984) give their distributional records for the Canadian Arctic.

Most collections of zoarcids from the southeastern Beaufort Sea are the results of bottom trawl samples made by the Arctic Biological Station from 1960 to 1977. Distributional information resulting from these collections are provided by McAllister (1962), Galbraith and Hunter (1975), McAllister et al. (1981), Hunter (1981), and Hunter et al. (1984). Hopky and Ratynski (1983) also reported on the shulupaoluk population of Tuktoyaktuk Harbour, and unpublished information resulting from recent DFO offshore surveys also exists (M.J. Lawrence, see Ratynski et al. 1988). Pale and polar eelpouts were taken in August 1986, at depths of 150 to 240 m, offshore Herschel and Richards islands (Arctic Laboratories Ltd. and LGL Ltd. 1987).

The biology of this family of fishes is not well known. Andriyashev (1954), McAllister et al. (1981), and Scott and Scott (1988) should be consulted for general species accounts. Most eelpouts are oviparous, laying a few, large-sized eggs, except for the genus Zoarces which is viviparous (Anderson 1984). Nest building with parental guardianship is probably common (Anderson 1984) and has been observed for the fish doctor (Emery 1973). Newly hatched young resemble adults and have no specialized larval pigment patterns (Anderson 1984).

The diet of eelpouts consists predominantly of bottom invertebrates. Hunter (1981) found polychaetes, copepods, cumacids, and amphipods in the stomachs of pale eelpout, isopods in the stomachs of shulupaoluk, and cumacids and amphipods in the stomachs of polar eelpout.

Most zoarcids from the southeastern Beaufort Sea are small, but Hopky and Ratynski (1983) captured shulupaoluk up to 522 mm in total length. The Arctic eelpout can grow to 750 mm in total length in southern Labrador and northern Newfoundland waters (Morosova 1982 cited in Scott and Scott 1988), and the longear eelpout to 517 mm in the waters of western Greenland (Jensen 1952 cited in McAllister et al. 1981).

None of the eelpouts found in the southeastern Beaufort Sea is commercially harvested. However, the ocean pout (Macrozoarces americanus) is taken incidentally in the Canadian Atlantic fishery and used for manufacturing meal (Scott and Scott 1988). Over 1,306 mt were harvested by the U.S. Atlantic fishery in 1989 (FAO 1991). The flesh is white, flaky, and of good quality (Scott and Scott 1988). In European waters, the eelpout (Zoarces viviparus) is the subject of a fishery which produced 53 mt in 1989 (FAO 1991). Eelpouts are considered important prey species for predaceous commercial species (Scott and Scott 1988).

Wolffishes (F. Anarhichadidae):

NORTHERN WOLFFISH (Anarhichas denticulatus), BERING WOLFFISH (A. orientalis): Wolffishes are stout-bodied, carnivorous fishes which inhabit moderately deep waters of the North Pacific and North Atlantic oceans.

The northern wolffish is distributed in the Barents and Norwegian seas, common around Iceland, and is found in the Davis Strait off Greenland (Andriyashev 1954). Its distribution extends southward to the Gulf of St. Lawrence, Grand Bank, and Sable Island Bank along the North American east coast (Scott and Scott 1988). In the Canadian Arctic, it has been reported from Mould Bay, Prince Patrick Island (Walters 1953b; Hunter et al. 1984) and tentatively from Amundsen Gulf (Smith 1977; Hunter et al. 1984).

The Bering wolffish is distributed in the northwestern Pacific Ocean, Sea of Okhotsk, Bering Sea, and Bering Strait--where it is common (Andriyashev 1954). It has not been found along the Pacific coast of North America or in the southeastern Beaufort Sea, but has been collected from Bathurst Inlet (Hunter 1981; Hunter et al. 1984).

The biology of these two species is not well known. Northern wolffish spawn from April to October, lay eggs that are 7 to 8 mm in diameter, and can live 14 years (Barsukov 1959 in Scott and Scott 1988). They generally eat bathypelagic and benthic invertebrates (Scott and Scott 1988). The specimen from Amundsen Gulf was 1,270 mm in total length and weighed 13.6 kg (Smith 1977), while that from Mould Bay was 1,160 mm long and had eaten four adult Atlantic spiny lumpsuckers (Eumicrotremus spinosus) (Walters 1953b). The Bering wolffish from Bathurst Inlet had eaten blue mussel, Mytilus edulis (Hunter 1981).

Northern wolffish are eaten by Greenlanders (Jensen 1948 cited In Scott and Scott 1988). The Bering wolffish is apparently not commercially exploited. Canadian fishermen harvested 1,994 mt of other wolffish species from the northwest Atlantic Ocean in 1989 (FAO 1991).

Pricklebacks (F. Stichaeidae):

BLACKLINE PRICKLEBACK (Acantholumpenus mackayi), STOUT EELBLENNY (Anisarchus medius), FOURLINE SNAKEBLENNY (Eumesogrammus praecisus), DAUBED SHANNY (Leptoclinus maculatus), SLENDER EELBLENNY (Lumpenus fabricii), ARCTIC SHANNY (Stichaeus punctatus): The pricklebacks are a family of marine fishes that occur in waters of the northern hemisphere (Scott and Scott 1988). The blackline prickleback has a disjunct distribution with populations centering in three regions: the Sea of Japan to the Sea of Okhotsk, the southern and eastern Bering Sea, and the Beaufort Sea (D.E. McAllister, pers. comm.). In the Beaufort Sea this species is limited in its distribution, as far as is known, to Tuktoyaktuk Harbour (Galbraith and Hunter 1975; Hunter 1981; Hopky and Ratynski 1983) and Liverpool Bay (Hunter 1981). Recently, blackline prickleback have been reported from the coastal Yukon at Phillips Bay (Bond and Erickson 1989) and from Wood Bay (Bond and Erickson 1991).

The other five species are known from the Arctic Ocean and also range southward into the Atlantic Ocean to at least the Gulf of St. Lawrence (Scott and Scott 1988), and into the north Pacific Ocean. The daubed shanny, stout eelblenny, and slender eelblenny range southward in the northwestern Pacific Ocean to the Sea of Japan and the fourline snakeblenny and Arctic shanny range south to the Sea of Okhotsk (Andriyashev 1954). Only the daubed shanny occurs in the coastal waters of British Columbia (Hart 1973). The Canadian Arctic distributions of these species are illustrated by Hunter et al. (1984). Except for the slender eelblenny which is known from Tuktoyaktuk Harbour (Galbraith and Hunter 1975; Hopky and Ratynski 1983), they are usually found in waters not under the influence of the Mackenzie River, occurring either offshore or east of Cape Dalhousie (see Hunter et al. 1984). Planktonic larvae of the stout eelblenny have been collected from the Beaufort Sea Shelf offshore Kugmallit Bay in mid-July (Chiperzak et al. 1990).

Biological accounts of these species are given by Andriyashev (1954) and Scott and Scott (1988). Blackline prickleback and slender eelblenny excepted, there is little information on the biology of stichaeids in the southeastern Beaufort Sea. Spawning generally occurs in early to mid winter. In 1981, the gonads of female slender eelblenny and blackline prickleback were approaching a ripe condition in September (R.A. Ratynski, unpublished data). Planktonic larvae are reported from Tuktoyaktuk Harbour (Ratynski 1983) and offshore waters (Anisarchus medius) (D. Chiperzak, DFO, unpublished data, see Ratynski et al. 1988) during midsummer.

Stichaeids are carnivores with varied diets. Blackline prickleback eat a variety of organisms including oligochaetes, polychaetes, nematodes, copepods, cumacids, amphipods, isopods, gastropods, pelecypods, fish eggs, and fish (Hunter 1981; Lacho 1991). In summer, the stomachs of slender eelblenny caught in Franklin Bay (Atkinson and Percy 1991) and Tuktoyaktuk Harbour (Lacho 1991) contained predominately polychaetes, amphipods, oligochaetes, and pelecypods.

Most stichaeids are small. In Greenland waters the slender eelblenny, fourline snakeblenny, daubed shenny, and stout eelblenny reach maximum lengths of 342 mm, 220 mm, 136 mm, and 141 mm respectively (Jensen 1944 cited in Scott and Scott 1988). Slender eelblenny in Tuktoyaktuk Harbour grow to 363 mm in total length and can live 17 years (Hopky and Ratynski 1983). Blackline prickleback from Tuktoyaktuk Harbour can grow to 500 mm and live 16 years (Hopky and Ratynski 1983). They grow to 700 mm in more southerly Japanese waters (D.E. McAllister, pers. comm.).

Japanese harvest blackline prickleback for the manufacture of fish cakes and paste (D.E. McAllister, pers. comm.), but elsewhere stichaeids are of little or no direct economic importance. They may be important forage for larger commercially valuable species.

Sand Lances (F. Ammodytidae):

NORTHERN SAND LANCE (Ammodytes dubius), STOUT SAND LANCE (A. hexapterus): These two species are taxonomically similar, with many overlapping characteristics. Generally, the northern sandlance is an offshore and, as its name implies, northern species. The stout sand lance is considered an inshore species (Scott 1985). Sand lances range in the northern Pacific Ocean from the Sea of Japan and California north into the Bering, Chukchi, East Siberian, and Beaufort seas. They also occur in the northwestern Atlantic from Greenland to the Scotian Shelf (Andriyashev 1954; Scott 1985; Scott and Scott 1988).

Sand lances have occasionally been collected in the southeastern Beaufort Sea from Herschel Island to Franklin Bay (Hunter et al. 1984). Specific records are from Herschel Island (McAllister 1962), the coastal Yukon (Bond and Erickson 1987, 1989), Tuktoyaktuk Peninsula (Jones and DenBeste 1977), Liverpool Bay and Franklin Bay (J.G. Hunter, DFO, unpublished data, see Ratynski et. al. 1988). They have also been recorded offshore (Galbraith and Hunter 1975), but are unknown from the northern shores of Amundsen Gulf.

The biology of the sand lance from the southeastern Beaufort Sea is not well known, although unpublished data on biological characteristics exist (J.G. Hunter, DFO, unpublished data, see Ratynski et al. 1988). Sand lances in the Alaskan Bering Sea probably spawn in late fall or winter, either intertidally or at depths of 25 to 100 m in areas having strong currents (Craig 1989c). They require particular substrate compositions for burrowing and presumably for spawning. Eggs hatch in about 30 d, with the exact time depending on water temperature. After the yolk sac is absorbed the larvae become pelagic and widely distributed. The species has a wide range of tolerance to many physical factors, the most important of which in determining their distribution may be the availability of suitable sediments for burrowing and spawning.

Sand lances eat mainly copepods in summer and euphasids in winter (Craig 1989c), live to a maximum of about 9 years, and grow to a maximum length of 200 to 250 mm (Scott 1985). They can occur in large schools and are a major food item for cod, salmon, and several other commercial species. Sand lance are not harvested in the study area.

The species may be one of the major unexploited fish resources of the Northwest Atlantic (Scott 1985). Lack of a sand lance fishery on the Scotian Shelf and Newfoundland Grand Banks may be related to distance from markets, poor market demand for sand lance and fish meal, and undeveloped harvesting technology rather than to lack of resource.

There are extensive commercial fisheries for sand lances in the northwest Pacific Ocean, where Japan and the former Soviet Union harvested 77,850 mt in 1989, and in the northwest Atlantic, where the former Soviet Union and the United States harvested 195 mt (FAO 1991). Over a million tonnes of sand lances were taken in European waters.

Sculpins (F. Cottidae):

ROUGH HOOKEAR (Artediellus scaber), ARCTIC STAGHORN SCULPIN (Gymnocanthus tricuspis), TWOHORN SCULPIN (Icelus bicornis), SPATULATE SCULPIN (I. spatula), FOURHORN SCULPIN (Myoxocephalus quadricornis), ARCTIC SCULPIN (M. scorpioides), SHORTHORN SCULPIN (M. scorpius), BIGEYE SCULPIN (Triglops nybelini), RIBBED SCULPIN (T. pingeli): Nine species of marine sculpins are known to occur in the southeastern Beaufort Sea. Witht he exception of the rough hookear, they all occur in the northern Atlantic Ocean (Scott and Scott 1988). Some species, like the rough hookear, Arctic staghorn sculpin, spatulate sculpin, fourhorn sculpin, and ribbed sculpin are also distributed in the northern part of the Pacific Ocean (Andriyashev 1954). The distributions of sculpins in the Canadian Arctic are given by Hunter et al. (1984).

The fourhorn sculpin is ubiquitous in brackish and marine coastal waters of the Beaufort Sea, having been recorded in 84% of 69 sets of fisheries data described by Ratynski et al. (1988). The other sculpin species have not been collected as frequently because they occur in colder, more saline waters offshore, or in coastal areas beyond the freshening influence of the Mackenzie River where sampling efforts have not been as extensive.

With the exception of fourhorn sculpin, the biology of sculpins in the southeastern Beaufort Sea is not well known--general species accounts are given in Andriyashev (1954) and Scott and Scott (1988). Unpublished data collected by researchers from the Arctic Biological Station exist for many of the species (see Ratynski et al. 1988), and systematic information on some Beaufort Sea sculpin species was reported by McAllister (1962; 1963b).

The fourhorn sculpin spawns from mid-December to March (Morrow 1980) and in Tuktoyaktuk Harbour apparently spawns in January (Bond 1982). Planktonic larvae have been collected from the harbour in July (Khan 1971; Ratynski 1983), and from the Beaufort Sea Shelf between Herschel Island and Cape Bathurst in July and September (Chiperzak et al. 1990). More developed larvae and juveniles are commonly captured in seine hauls along the coastal Beaufort Sea (eg. Percy 1975; Bond 1982;

Bond and Erickson 1987; Dickson 1991). Larval Arctic staghorn sculpin, Icelus sp., bigeye sculpin, and ribbed sculpin have also been collected in offshore trawling and ichthyoplankton net tows (Galbraith and Hunter 1975; Chiperzak et al. 1990).

The diet of sculpins generally consists of benthic invertebrates including crustaceans, molluscs, marine worms, and occasionally small fishes (Scott and Scott 1988). Fourhorn sculpin examined from Tuktoyaktuk Harbour had eaten isopods, amphipods, mysids, ostracods, polychaetes, ascids, nematodes, hydrozoans, fish and fish eggs, small mammals, and plant material (Bond 1982). Calanoid copepods were the only organisms found in stomachs of larvae taken from the Beaufort Sea Shelf in July (Chiperzak et al. 1990). Arctic staghorn sculpin collected from Franklin Bay had eaten predominately amphipods, polychaetes, cumaceans, and pelecypods; ribbed sculpin predominately mysids and amphipods (Atkinson and Percy 1991).

Most of the sculpin species do not attain a large size, however, fourhorn sculpin larger than 300 mm total length are common in the Beaufort Sea. Bond (1982) reported a maximum length of 396 mm and age of 16 years from Tuktoyaktuk Harbour. The shorthorn sculpin also grows to a large size, and in Newfoundland waters females can grow to 506 mm and males 422 mm (Ennis 1970). They can live 15 years.

Historically, sculpin were seldom eaten in Arctic Canada except during lean years, and Inuit are often reluctant to admit having had to eat these "devil fish". Although they are jigged in the spring for sport, sculpin are seldom eaten or fed to the dogs. A few individuals, generally in the central and eastern Arctic, enjoy a periodic meal of sculpin as a change in diet. There is no developed Canadian commercial fishery for sculpin, but they are occasionally taken for domestic consumption on the Atlantic coast (R.F. Tallman, pers. comm.). In 1984, Spain harvested 99 mt of Myoxocephalus sp. from the northwest Atlantic Ocean (FAO 1988).

Poachers (F. Agonidae):

ARCTIC ALLIGATORFISH (Aspidophoroides olriki), ATLANTIC POACHER (Leptagonus decagonus): The poachers are a family of small marine fishes which inhabit northern waters of the Arctic, Pacific, and Atlantic oceans.

The Arctic alligatorfish is distributed from the Barents Sea east to western Greenland and Labrador; it is unknown from eastern Greenland, Iceland, and Spitsbergen (Andriyashev 1954). It is distributed all along Canada's Arctic coast (Hunter et al. 1984), and has been reported from Herschel Island (McAllister 1962), offshore Mackenzie Bay and Kugmallit Bay (Galbraith and Hunter 1975; Arctic Laboratories Ltd. and LGL Ltd. 1987; M.J. Lawrence, North/South Consultants Inc., Winnipeg, unpublished data, see Ratynski et al. 1988), the Baillie Islands area, and Franklin Bay (Hunter 1979a; J.G. Hunter, DFO, unpublished data, see Ratynski et al. 1988).

The Atlantic poacher also has a nearly circumpolar distribution and, although distributed in the Bering Sea and Sea of Okhotsk, may be absent from the East Siberian and Chukchi seas (Andriyashev 1954). It has been recorded from several localities in the Canadian Arctic including the Beaufort Sea (Hunter et al. 1984), but may be absent from the Alaskan Beaufort Sea (Craig 1984). The Atlantic poacher was collected by researchers from the Arctic Biological Station near Baillie Island and from Franklin Bay (Hunter et al. 1984; Ratynski et al. 1988). A planktonic larva was collected during offshore ichthyoplankton surveys in 1986 (Chiperzak et al. 1990).

The biology of these two species is not well known, but unpublished data collected by the Arctic Biological Station on age, size, and diet do exist for the southeastern Beaufort Sea (see Ratynski et al. 1988). The stomachs of 15 Arctic alligatorfish caught in Darnley Bay in summer contained mostly the pelecypod Macoma calcarea, amphipods and isopods (Atkinson and Percy 1991). The Arctic alligatorfish attains a length of 86 mm off Greenland (Jensen 1942 cited in Scott and Scott 1988) and the Atlantic poacher grow to a length of 226 mm in the Canadian Atlantic (Scott and Scott 1988).

Agonids are of no direct economic importance.

Lumpfishes and snailfishes (F. Cyclopteridae):

LEATHERFIN LUMPSUCKER (Eumicrotremus derjugini), ATLANTIC SPINY LUMPSUCKER (E. spinosus), GELATINOUS SNAILFISH (Liparis fabricii), DUSKY SNAILFISH (L. gibbus), KELP SNAILFISH (L. tunicatus): These species are mostly benthic in habit, although gelatinous snailfish also occur pelagically (Able and McAllister 1980; Scott and Scott 1988). All are northerly species, with some ranging into more southerly waters. Details of their distributions are found in Andriyashev (1954), Able and McAllister (1980) and Scott and Scott (1988); Hunter et al. (1984) give distribution records of the species for Canadian arctic waters. In the southeastern Beaufort Sea, cyclopterids avoid areas under the freshening influence of the Mackenzie River. Most collections from the area were made by the Arctic Biological Station from 1960 to 1977, with more recent offshore collections made by researchers from the Freshwater Institute (see Ratynski et al. 1988) and Arctic Laboratories Ltd. and LGL Ltd. (1987).

The biology of these fishes is not well known, especially in the Beaufort Sea. General accounts of their biology are given by Andriyashev (1954), Able and McAllister (1980), and Scott and Scott (1988). In general, they produce large eggs and the larvae are in a relatively advanced stage of development at hatching (Able et al. 1984). Parental protection of young may be provided. The planktonic young of the gelatinous snailfish and other unidentified snailfish have been collected in ichthyoplankton nets from offshore waters of the southeastern Beaufort Sea in mid summer (D. Chiperzak, DFO, unpublished data, see Ratynski et al. 1988).

Cyclopterids eat a wide variety of invertebrates, including amphipods, mysids, polychaetes, crabs, and euphasids, and the occasional fish (Andriyashev 1954; Green and Steele 1975; Able and McAllister 1980; Scott and Scott 1988). No age and growth studies are known. Atlantic spiny lumpsuckers grow to a length of 115 mm in the waters of Greenland (Jensen 1944 cited in Scott and Scott 1988). The maximum total lengths reported from the Canadian arctic for gelatinous snailfish, kelp snailfish, and dusky snailfish are 174 mm, 161 mm, and 236 mm respectively (Able and McAllister 1980). A female dusky snailfish of 524 mm total length and weighing 1.027 kg was collected from 58°N, 154°W, in Alaska (Able and McAllister 1980).

None of the cyclopterids occurring in the southeastern Beaufort Sea is commercially harvested. However, the lumpfish (Cyclopterus lumpus) has a long history of harvest in Europe and more recently in the northwest Atlantic for the production of caviar (Wilcox 1981b). The flesh is also eaten locally in both North America and Europe, sometimes smoked, and is said to have an excellent flavour (Gavaris 1985; Scott and Scott 1988). By-products from the roe fishery may have potential for use in the manufacture of lipid and glue (Paradis et al. 1975). In 1989, Greenland and St. Pierre and Miquelon harvested a total of 207 mt of lumpfish from the northwest Atlantic, and Scandinavian nations harvested 17,353 mt from the northeast Atlantic (FAO 1991). Most of the lumpfish are harvested from inshore areas during their spring shoreward spawning migration using gillnets set from small dories (Gavaris 1985).

Righteye flounders (F. Pleuronectidae):

ARCTIC FLOUNDER (Liopsetta glacialis): The Arctic flounder has an almost circumpolar distribution, being found from the White Sea eastward to the Chukchi and Bering seas, Sea of Okhotsk, and the Beaufort Sea (Andriyashev 1954). In the Canadian Arctic it has been recorded east to Queen Maud Gulf (MacDonald and Stewart 1980; Hunter et al. 1984; see also Ratynski and deMarch 1988).

In the Canadian Beaufort Sea this species has been reported from Herschel Island (Walters 1953a; McAllister 1962; Kendel et al. 1975; Baker 1985), the Yukon coast (Mann 1974; Kendel et al. 1975; Griffiths et al. 1975; Bond and Erickson 1987, 1989; and unpublished DFO studies, see Ratynski et al. 1988), and the Mackenzie Delta (Slaney 1973a, 1975, 1976a, 1977a, 1977b; Percy 1975; Lawrence et al. 1984). Like the Pacific herring, it is more abundant along the Tuktoyaktuk Peninsula and has been reported there in the shallow inshore waters by Galbraith and Hunter (1975), Byers and Kashino (1980), Jones and DenBeste (1977), Bond (1982), Hopky and Ratynski 1983), Lawrence et al. (1984), B.W. Fallis (DFO, unpublished data, see Ratynski et al. 1988), Thomas (1988), Atkinson and Percy (1991), Bond and Erickson (1991), Chiperzak et al. (1991), and Dickson (1991).

It is also common in Liverpool Bay and Husky Lakes (Hunter 1981; J.G. Hunter, DFO, unpublished data, see Ratynski et al. 1988), but uncommon east of Cape Bathurst. There are no reports of this species from offshore waters or from the northern part of Amundsen Gulf.

The spawning period of Arctic flounder runs from January to March (Andriyashev 1954), and recently spent specimens were captured on 22 March in Tuktoyaktuk Harbour (Bond 1982). At Kukjuktuk Bay on the Tuktoyaktuk Peninsula, spent individuals were found in mid March, 1978, but in 1979 Arctic flounder in ripe condition were found there in June (B.W. Fallis, pers. comm.). No planktonic young were captured during mid July to mid August, 1982 at Tuktoyaktuk Harbour (Ratynski 1983), but Jones and DenBeste (1977) collected a juvenile measuring 14 mm in length between 26 August and 3 September, 1977.

Not unexpectedly, this species preys upon benthic organisms such as pelecypods, polychaetes, ascidacians, amphipods, priapulids, and isopods (Percy 1975; Jones and DenBeste 1977; Bond 1982; Lawrence et al. 1984; Atkinson and Percy 1991; Lacho 1991).

The largest Arctic flounder recorded from the region was 452 mm in total length (Bond and Erickson 1991) and the oldest was 26 years of age (Lawrence et al. 1984). In the outer Mackenzie Delta, 5 to 7 year-olds were the most common age group (Percy 1975), but along the Tuktoyaktuk Peninsula 7 to 9 year-olds were common (Lawrence et al. 1984). Rate of growth may be similar to that reported for the Barents Sea. Females grow to 227 mm and 249 mm in the Barents Sea (Andriyashev 1954) compared to 230 mm and 246 mm in Kugmallit Bay (Lawrence et al. 1984) at ages 7 and 9 years, respectively.

Arctic flounder have been of minor commercial importance in the former Soviet Union (Andriyashev 1954). They are not harvested in the Canadian Beaufort Sea except as a by-catch, and then are used for dog food (Hunter 1975). Arctic flounder have been harvested by Alaskan coastal subsistence fisheries (Morrow 1980).

STARRY FLOUNDER (Platichthys stellatus): The starry flounder is distributed along both sides of the Pacific Ocean from Japan and Korea and northern California north to the Bering and Chukchi seas (Andriyashev 1954). It is probably the most abundant flounder in nearshore areas from northern California to the Bering Sea (Morrow 1980). It is not found on the Arctic Ocean coast of Siberia (Andriyashev 1954), but ranges along the North American coast of this ocean east to Coronation Gulf (Richardson 1836; Ellis 1962; Gillman and Kristofferson 1984b), Melville Sound (J.S. Campbell and L. Johnson, DFO, unpublished data, see Ratynski and deMarch 1988), and Bathurst Inlet (D.B. Stewart, unpublished data).

Starry flounder may be less common and widespread in the Canadian Beaufort Sea than Arctic flounder. The species has seldom been reported from Yukon coastal waters (Kendel et al. 1975) or in the outer Mackenzie Delta (Percy 1975; Lawrence et al. 1984). It is more abundant in the coastal waters of Tuktoyaktuk Peninsula (Galbraith and Hunter 1975; Jones and DenBeste 1977; Byers and Kashino 1980; Bond 1982; Hopky and Ratynski 1983; Lawrence et al. 1984; B.W. Fallis, DFO, unpublished data, see Ratynski et al. 1988; Dickson 1991), and sometimes outnumbers Arctic flounder in collections from Tuktoyaktuk Harbour (Slaney 1973b; Beak Consultants 1975; Bond 1982; Thomas 1988). The species also occurs in the Husky Lakes (Slaney 1976b; Gillman and Kristofferson 1984a), where it can be abundant relative to other areas (Hunter 1981), and in Langton Bay at the southern end of Franklin Bay (Anderson 1913). There are no reports of this species from offshore or from the northern shores of Amundsen Gulf.

Based on the occurrence of ripe fish, starry flounder spawn from June to mid July in Tuktoyaktuk Harbour (Bond 1982; G. Hopky and R.A. Ratynski, unpublished data) and other bays and inlets along the Tuktoyaktuk Peninsula coast (Lawrence et al. 1984). Planktonic eggs were collected on 14 and 15 July and larvae from 27 July to 9 August from the mid water depths of Tuktoyaktuk Harbour in 1982 (Ratynski 1983).

Like Arctic flounder, they eat benthic pelecypods, amphipods, mysids, isopods, oligochaetes, and priapulids (Bond 1982; Lawrence et al. 1984; Lacho 1991). They also eat polychaetes, chironomids, plant material, and other items.

Starry flounder in the Beaufort Sea are characterized by longevity and slow growth. The oldest reported specimen was a female aged 42 years with a total length of 365 mm (Bond 1982). In California, a typical female would exceed this size by age three (Orcutt 1950). The maximum size reported is 440 mm total length, but specimens seldom grow to this size (Byers and Kashino 1980). Along the Tuktoyaktuk Peninsula 40% of starry flounder ranged from 250 to 275 mm in total length (Lawrence et al. 1984), and at Tuktoyaktuk Harbour 68% ranged from 225 to 274 mm (Bond 1982).

Although the starry flounder is abundant and widespread on the Pacific coast of North America, it is of minor commercial importance. Morrow (1980) reported that 136 to 227 mt are taken annually in California. Moderate quantities (227 mt) are marketed annually in British Columbia (Hart 1973). In the Beaufort Sea, the starry flounder is caught incidentally in fisheries for other species and catches are fed to dogs (Hunter 1975).

Marine mammals

Beluga (Delphinapterus leucas), bowhead whale (Balaena mysticetus), ringed seal (Phoca hispida) and bearded seal (Erignathus barbatus) are the most common and abundant species of marine mammals in the Beaufort Sea-Amundsen Gulf study area. While not dealt with directly by this study, they are all potentially affected by fishery development which could compete with them for food and/or habitat. These animals are both ecologically and economically important and are the objects of important subsistence harvests (Strong 1989, 1990; Fabijan 1990; Weaver 1991). Indeed, Inuit were allowed to harvest a single bowhead in 1991 (D. Chiperzak, pers. comm.). While commercial harvest of the whales is prohibited under Canadian law, the seals have been harvested commercially for their skins and under the right conditions might offer other commercial development opportunities.

Fishery developers must keep in mind the importance of these marine mammals so as not to harm them through undue competition for food or habitat. In this regard they should refer to the "Beaufort Sea Beluga Management Plan" prepared by the Fisheries Joint Management Committee (1990) and "The Inuvialuit Sealing Economy: Prospects for Development" prepared by the Inuvialuit Regional Corporation (1990).

COASTAL AND OFFSHORE COMMERCIAL FISHERIES IN NORTHERN CANADA

This section describes representative northern commercial fisheries and some reasons for their success or failure. It includes descriptions of fisheries in the Beaufort Sea-Mackenzie Delta; the Cambridge Bay and Keewatin fisheries for anadromous Arctic charr; and marine fisheries in the Belcher Islands, Hudson Strait, and Baffin Island areas. Despite the fact that many of these fisheries are located far from the study area and harvest species not found there, they have all dealt with constraints that will face a developing fishery in the Beaufort Sea-Amundsen Gulf area. Potential developers would be well advised to learn from these often expensive lessons of their predecessors.

Beaufort Sea-Mackenzie Delta

Despite a history of commercial fishing attempts that pre-dates the 1960's, an economically viable commercial fishery has yet to be established in the Canadian Beaufort Sea-Mackenzie Delta area. Chronological descriptions of fisheries development in the area are available in Bissett (1967), Barlishen and Webber (1973a), McLeod (1973), Corkum and McCart (1981), and Davies et al. (1986). Rather than repeat these descriptions, we will elaborate on reasons why fisheries have not developed for whitefish, Arctic charr, and Pacific herring--and describe recent fishery efforts.

Whitefish: Most fisheries in the area have concentrated on the harvest of anadromous broad whitefish. These fish are gillnetted along the coasts in summer or when they enter freshwater drainages in the fall to overwinter. They are harvested in quantity by domestic and commercial fisheries, particularly in the lower Mackenzie River drainages.

Broad whitefish are attractive, readily obtained food fishes. They grow to a large size, are available in quantity at predictable locations and times, and have superior quality flesh. They remain free from

Triaenophorus crassus, a tapeworm which infests the flesh of lake whitefish, lowering their commercial value.

Failures of the broad whitefish fisheries have seldom been related to resource availability, instead they can be attributed largely to poor product quality and unfavourable economics (Barlishen and Webber 1973a; Corkum and McCart 1981; Davies et al. 1986). The problem of maintaining product quality from the time fish are caught until they are marketed caused the failure of seven of eight broad whitefish fisheries attempted in the Delta between 1960 and 1975 (Barlishen and Webber 1973a; Corkum and McCart 1981). Some of the spoilage occurred between gillnet and freezer, but most occurred as a result of inadequate freezer and storage facilities. This is still a problem, indeed, a member of the FJMC was served rancid whitefish in an Inuvik restaurant in May of 1989. Fisherman interest and conflict with domestic fisheries have also affected fisheries success; lack of the former has led to low or sporadic production, and the latter often relegates commercial fisheries to less favourable or outlying areas (Bissett 1967; Barlishen and Webber 1973a; R. Barnes, pers. comm.).

During the 1960's and 1970's late freezer start-up, inadequate freezer capacity, and freezer breakdown limited the quantities of fish that could be harvested and led to the spoilage of over 20 mt of whitefish (Bissett 1967; Barlishen and Webber 1973a; Corkum and McCart 1981). Pre-season planning to ensure the early arrival and testing of freezer facilities, adequate supplies of spare parts, and the availability of trained maintenance personnel might have eliminated these problems.

On the economic side, there were limited local markets for whitefish and high production and transportation costs. Many people in the area were reluctant to purchase fish from a company when they could catch their own fish or eliminate the middleman by purchasing from the fisherman (Barlishen and Webber 1973a). The costs of producing marketable whitefish and transporting them to southern markets were also high relative to more southerly fisheries (Bissett 1967; McLeod 1973; Corkum and McCart 1981).

Commercial fisheries for broad whitefish operated on a small, local scale between 1981 and 1988. The total estimated commercial harvest of coregonids in the Delta, including broad and lake whitefish and inconnu, was 8,500 kg in 1987-8 (W. Bond, pers. comm.). Most of these fish were taken during subsistence fisheries by fishermen with commercial licences, and were sold locally to subsidize subsistence fishing efforts. The Mackenzie Delta catch generally represents less than 1% of the annual whitefish harvest in the territories (W. Bond, pers. comm.) and is much smaller than the subsistence harvest. Indeed, subsistence fisheries harvested 83% of fish caught in the area in 1979 and 79% in 1980 (Corkum and McCart 1981)--commercial harvests in both years were large relative to recent years.

During the 1980's fish were still harvested with gillnets from small boats. Most fish were marketed locally, often through Ulu Foods of Inuvik which sometimes marketed them in southern Canada. In October 1988, Ulu Foods closed temporarily while awaiting a restructuring of the operation by the Government of the Northwest Territories (GNWT)(C. Gour, pers. comm.). Unfortunately, the portable fish plant trailers had been bartered away for services, the processing equipment has been sitting unused for the past 2 years, and the freezer compressors were missing.

In 1988, a private entrepreneur from Whitehorse, Yukon, purchased 1,582 kg (3,480 lb) of fish, mainly whitefish, from the Arctic Red River and Peel River areas (R. Barnes, pers. comm.). The fish were packed in ice, trucked to Inuvik, and flown on backhaul to Whitehorse. To take advantage of cheaper backhaul rates negotiated with the air carrier, daily catches of 223 kg (500 lbs) were required--they were seldom met. Despite the fish costing $5.69/kg to produce, and problems obtaining equipment and attracting fishermen, the entrepreneur was enthusiastic about the quality of fish and hoped to continue the operation.

In 1989, after the Freshwater Fish Marketing Corporation (FFMC) expressed interest in obtaining fresh whitefish from the Mackenzie Delta area for test marketing purposes, GNWT Economic Development and Tourism (EDT) coordinated a test fishery (Polakoff 1989). A test fishery licence was granted to EDT for the harvest of 16,000 kg of whitefish and 6,000 kg combined of northern pike and inconnu. The fishery was conducted between 30 August and 9 September in the east channels of the Mackenzie near Inuvik using the "Northwind", a square-fronted vessel with bow-mounted net spools (bowpicker) which had been used successfully in the past to harvest broad whitefish from the Delta. The total catch was 12,496 kg (dressed weight), including: 5,028.5 kg of broad whitefish, 5,611 kg of lake whitefish, 1,444.5 kg of northern pike, and 412 kg of inconnu. Fish were iced on site, transported by boat to Inuvik, and delivered by truck to the newly renovated and upgraded fish plant. After sorting, weighing, and re-icing they were transported by refrigerator truck to the FFMC processing plant in LaRonge, Saskatchewan. They arrived there in good condition to be graded, processed, and sent to market.

The harsh realities of previous fishery attempts went unheeded by this renewed effort. Vital equipment such as the "Northwind" and the gillnets were not properly tested and failed during the fishery (Polakoff 1989). That, and poor weather, prevented fishermen for harvesting their full quota. Lake whitefish were found to contain high levels of the parasite Triaenophorus crassus (>80 cysts per 100 kg) which reduced their value to cutter grade ($0.40 per kg) and broad whitefish, while export grade, were less abundant than had been hoped. However, relatively high prices were paid for the northern pike--which were in demand in France, and the inconnu. Revenue from fish sold to the FFMC, including agency fees, was $16,320.77 while the cost of the fishery, including capital purchases but not biological research costs, was $141,477.27--operating costs alone amounted to $49,471.42 (G. Fricke, pers. comm.).

The fishery was repeated in 1990 with marginally improved catches and economics (Fricke 1991). The total catch was 18,545 kg (dressed weight), including: 11,392 kg of broad whitefish, 6,247 kg of northern pike, and 906 kg of inconnu. Revenue from fish sold to the FFMC, including agency fees, was $26,929.83 while the cost of the fishery, including capital purchases but not biological research costs, was $139,070.54. Again, the "Northwind" and the gillnets were not properly tested and failed during the fishery. It also took 4 to 5 days to transport the catch to the FFMC in Edmonton, where it did not command top prices because the fish were beginning to soften and had to be frozen.

Arctic charr: Arctic charr stocks in this area are harvested largely by subsistence fisheries. Indeed, subsistence harvest levels preclude the establishment of commercial fisheries at most rivers near the communities. Two areas with histories of commercial charr fishing are the Hornaday River (MacDonell 1986, 1989), near Paulatuk, and Area 1 of the Mackenzie River Delta which includes the Big Fish and Rat Rivers (Sparling and Stewart 1986; MacDonell 1987). Charr stocks in all three rivers were depleted by the combined efforts of subsistence and commercial fisheries. In 1987, the Hornaday and Rat rivers were closed to commercial fishing and the Big Fish River was closed to all fishing to enable stocks to recover (Kristofferson et al. 1989). A small commercial fishery, with an annual harvest quota of 600 kg round weight, has operated in conjunction with the important subsistence fishery at the Kuujjua River on Victoria Island since 1979 (Lewis et al. 1989). Its purpose is to provide fish for local consumption and sale to tourists.

Recent interest in locating commercially exploitable stocks has prompted test fisheries at rivers on Banks (Baker 1987; Esau et al. 1989) and Victoria islands (Baker 1986; Stewart and Sparling 1987; Sparling and Stewart 1988; Lemieux and Sparling 1989), and near Paulatuk (MacDonell 1986, 1989; Lemieux 1990). Stocks with the potential to support a viable commercial fishery have yet to be found and weir ennumerations are continuing. Many of the rivers tested must be serviced by plane because of their distance from a community and/or local weather conditions. In the cases of Sachs Harbour, Holman Island, and Paulatuk planes have to be chartered from Inuvik or Cambridge Bay. These costs alone make small fisheries in the area uneconomical.

Weir harvests have the advantage of optomizing the utilization and quality of the anadromous Arctic charr harvested, while facilitating fishery management. The fish are less apt to spoil or to be damaged than in a gillnet fishery where weather can prevent daily tending of the nets, netted fish can be scavenged by piscivorous birds and benthic invertebrates, and many of the fish show unsightly net marks which reduce their market value.

Pacific herring: The first attempt to commercially harvest herring in the area was in 1963 at Baillie Island (Bissett 1967). The fishery failed for both logistic and economic reasons. It was inaccessible to regular supply and pick-up, tide and wind conditions made inshore fishing hazardous, and fresh water had to be obtained from the mainland. The product, 8,200 kg of marketable pickled herring, could not compete successfully with Scandinavian herring in the Edmonton market due to high costs of production and transportation.

The success of Canada's west coast herring roe fishery renewed interest in the commercial harvest of Beaufort Sea herring. Salt-cured herring roe has a high dollar value relative to its weight, minimizing the impact of transportation costs from the Northwest Territories to major Japanese markets. In 1981, responding to a request from the Inuvialuit Development Corporation, DFO initiated a feasibility study into the development of a herring roe fishery (Gillman and Kristofferson 1984a). Studies between 1981 and 1983 determined that the herring spawn in the spring under the ice of Tuktoyaktuk Harbour and Liverpool Bay. Hazardous ice conditions suggested that Tuktoyaktuk Harbour was not a suitable harvesting location and work in 1983 was confined to the Fingers area of Liverpool Bay.

In June 1983, 4,581 kg of male and female herring were processed at the Ulu Foods fish plant (D. Iredale, pers. comm.). The 2,472 kg of female herring yielded 398 kg of processed roe. Two methods of roe extraction were tested, brine-aging with and without pre-freezing. The extracted roe was bleached, cured, and packed for shipment in saturated brine solution. The availability of refrigerated holding space and a blast freezer period of 5 to 6 hours limited the volume of herring that could be handled. Most roe was extracted using the pre-freezing method due to the limited refrigerated holding space.

The processed roe was sent for quality and marketability assessment to the Prince Rupert Fisherman's Cooperative Federation, a B.C. herring roe processor, and to Marubeni Canada Ltd., a Japanese company which trades in herring roe (D. Iredale, pers. comm.). The product was of less than optimal quality but was considered marketable, ranging in grade from #1 (Quality) to #6 (Fragments). Inexperienced handling and processing and the presence of immature eggs (23.7%) were to blame for the poorer quality roe. The problem of how best to utilize male herring and the carcasses of female herring was not addressed--male herring were processed and frozen for use by the Ulu Foods fish plant and female carcasses were wasted.

In 1985, DFO and the Economic Development Agreement (EDA) funded studies to estimate the spawning stock biomass of Pacific herring in the Fingers area of Liverpool Bay. Once stock biomass was established, a sustainable yield was to be determined which would provide the basis for a future economic assessment of the potential for establishing a commercial herring roe fishery at this location (A.H. Kristofferson and D.V. Gillman, pers. comm.). The estimated spawning stock biomass was 8.2±5.6 mt (Shields 1985), too little to sustain a viable commercial fishery. This result, when compared with the 1983 harvest suggests that spawning intensity in the Fingers may vary considerably from year to year.

Kristofferson and Gillman (pers. comm.) suggested that a spawning stock biomass of 500 to 1,000 mt might be required to support a viable roe fishery on a sustained annual basis in the Fingers area. They estimated that an annual exploitation rate of 0.10 could be sustained, significantly less than the rate of 0.2 to 0.3 predicted for faster-growing Pacific herring on Canada's west coast (Fried and Wespestad 1985; Ware 1985). At an exploitation rate of 0.10, a 1,000 mt spawning stock might sustain an annual harvest of 100 mt. Based on an 8.7% roe recovery (ie. 398 kg roe/4,581 kg herring) 100 mt of herring might produce 8.7 mt of roe which at $25/kg (Department of Fisheries and Oceans 1989a) for #1 roe would have a B.C. landed value of $217,500. However, aerial surveys of the area in 1986 were unsuccessful in locating herring in Liverpool Bay (McElderry 1986), and to date no stock of this magnitude has been located in the Beaufort Sea.

Cambridge Bay

Established in an area with a tradition of good subsistence fishing (Abrahamson et al. 1964; Farquharson 1976; Stewart and Bernier 1983), the Cambridge Bay fishery has grown into the largest and most successful commercial fishery for anadromous Arctic charr in the NWT (Carder and Stewart 1989).

It will be described in detail as it is the only proven example of a biologically sustainable, financially viable, commercial fishery which exports fish from the Canadian Arctic.

The fishery began in 1960 when the federal Department of Northern Affairs and National Resources (DNANR) conducted a test fishery to determine the feasibility of commercial fishing in the Cambridge Bay area (Barlishen and Webber 1973b; Kristofferson and Carder 1980). Local fishermen were hired and their catch was sold in Cambridge Bay and Yellowknife. Good catches and local demand for the Arctic charr prompted formation of the Ekaloktotiak Eskimo Co-operative under the auspices of DNANR to undertake the export and sale of frozen Arctic charr, and resulted in the granting of a commercial harvesting quota for the area by DFO. Since then, the fishery has experienced and solved many of the problems that a developing arctic fishery will encounter.

Fishing takes place at river mouths in the spring and fall (Kristofferson and Carder 1980; Carder 1981, 1983, 1988, 1991; Carder and Low 1985; Carder and Stewart 1989). Boats and equipment are transported to the fishing sites by snowmobile and sled before spring ice break-up, and fishermen follow later by float-equipped aircraft. Spring fishing begins at break-up when charr migrate seaward to feed, and the fall fishery when they return upstream to overwinter. The Paliryuak, Halovik, and Lauchlan rivers are usually fished in the spring, mid-July to early August; while the Ellice, Ekalluk, and Jayco rivers are usually fished in the fall, mid-August to the end of the first week in September--other areas are fished occasionally. The number of fishermen and length of time spent camped at each site depend on the quota allocation and duration of the run. Poor ice and weather conditions preclude fall fisheries in some areas.

Most charr are netted in or near river mouths. The nets are generally 45 or 90 m in length with 139 mm mesh and 20 to 30 meshes deep. They are set on the bottom and lifted twice daily. A weir has also been used very successfully to harvest charr at the Jayco River.

The catch is dressed on-site (gills and viscera removed), packed in ice, and flown daily to the freezer plant in Cambridge Bay by float plane. At the plant the fish are washed, fast frozen, sorted by size, and packed for shipment by scheduled air carrier to the FFMC in Edmonton or Winnipeg for distribution. Some charr are kept for local sale.

Government cooperation has been instrumental in the success of the Cambridge Bay fishery. Fishery managers and inspectors have worked closely with the Co-op to see that fish stocks and product quality are maintained. Where once the fishermen remonstrated against the quotas and fish handling procedures, they now recognize the benefits of compliance.

Organization and infrastructure: The Cambridge Bay fishing operation is now owned and operated by the community's Ikaluktutiak Co-operative Limited. It is financially viable and very successful. As part of the larger co-operative the fishery has significant advantages over most of its northern competitors in the areas of cash flow, infrastructure costs, and participation (J. MacMillan, pers. comm.). For example, the retail store operation provides working capital for the fishery during the spring set-up period--money which would otherwise have to be held back from the fishermen. Infrastructure costs are relatively low because the manager participates in several small businesses, and there is little or no theft because the Co-operative is owned by the participants. There is also strong peer pressure for hard work and good management.

The Cambridge Bay fishery normally employs about 50 persons on a seasonal basis (J. MacMillan, pers. comm.). This includes 18 to 35 fishermen who are paid for the fish they catch, fish plant employees who are paid casual wages ($6.00/h in 1988), a supervisor ($15.00/h in 1988), and a Plant Manager who is paid on contract. Meetings are held in May or June (planning) and in the fall (recap) to discuss the fishery. There is strong competition for the work. In 1989 there were over 100 applicants for work in the fishery. Fishermen are chosen on the basis of past support, performance, and socio-economic criteria. Older fishermen are encouraged to train younger members to replace them when they retire.

The Cambridge Bay fish plant is spartan but functional. It was built by the Government of the Northwest Territories (GNWT) and leased to the Co-op until 1980 when the Co-op purchased it on a 5 year repayment plan, and it underwent a $40,000 retrofit in 1988 (J. MacMillan, pers. comm.). The plant has unused capacity and several years ago offered to process charr from Coppermine, but transportation costs between Coppermine and Cambridge Bay were prohibitive. If the Co-op decided to build a fish plant they would likely have it designed by the FFMC. A new plant would be small and simple, like the existing facility.

Finances: The discussion that follows is based on the 1988 fishing season.

In 1988, 18 Cambridge Bay fishermen harvested 46,408 kg (dressed weight; or 58,010 kg round weight) of anadromous Arctic charr from the six rivers that are fished regularly during the open water season (Carder and Stewart 1989). The only winter commercial fishing was at Toassie Lake where 839 kg (round weight) of whitefish and cisco, 82 kg of lake trout, and 14 kg of charr were caught (G. Low, pers. comm.).

The year's fish sales were about $400,000 of which $170,000 was used as a first payment to the fishermen, $130,000 as the second payment to the fishermen, and $100,000 was used to cover operating and maintenance costs (J. MacMillan, pers. comm.). Surplus income from the fishery is distributed among the fishermen.

Fishermen normally receive four payments annually from the Co-op (J. MacMillan, pers. comm.). The first payment is conservative to ensure that fishermen do not have to refund money and that they have the continuity of several modest payments through the year. It is paid in August or September, after the first fish are delivered to the FFMC (ie. spring or fall fishery), to cover the grubstake and provide a modest income. The second payment is based on the FFMC's profits on charr purchased (excluding culls) the previous year. It is divided among fishermen on the basis of their portion of the total catch (including culls). It is usually paid in December. The third payment is made in April or May and based on surplus from the fishery after operating and marketing expenses have been paid. The fourth payment, in June, is based on patronage of the Co-op retail store where fishermen buy much of their equipment and supplies.

In 1988 the payments were (Fig. 2): first $1.76/kg (dressed; $0.80/lb), second $2.97/kg ($1.35/lb; based on 1987 season), and third $3.08/kg ($1.40/lb; J. MacMillan, pers. comm.). The fourth payment will be a dividend of $0.20 to $0.30 on each dollar an individual fishermen spent at the Co-op. The initial payment from the FFMC, which included the government freight subsidy, was $7.70/kg ($3.50/lb). All of the charr sold to FFMC in 1988 were frozen (B. Popko, pers. comm.). FFMC payments for frozen charr were $6.61/kg ($3.00/lb) compared with $8.81/kg ($4.00/lb) for fresh charr. Of this amount $4.84/kg ($2.20/lb) covered the Co-op's first and third payments to fishermen, and the remaining $2.86/kg ($1.30/lb) covered all operating and capital costs associated with the fishery. In 1988, the average fisherman harvested 2,578 kg (5,671 lb; Carder and Stewart 1989) and, assuming they harvested the same amount in 1987, would have grossed over $20,000.

The Co-op pays the costs of transporting fishermen, ice, supplies, and fish between the rivers and fish plant (J. MacMillan, pers. comm.). Fishermen are "grub staked" at the beginning of each season. They generally have to buy their own nets, but in the past have obtained boats and motors through a special Arctic Resource Development Agreement (ARDA) grant, with the Co-op paying the 10% normally paid by the fishermen. The Co-op pays for the fishermen's licences.

The GNWT pays 50% of transportation costs for shipments of fish from the Cambridge fish plant and the FFMC in Winnipeg or Edmonton (J. MacMillan, pers. comm.). In 1988, the cost to the Co-op of these shipments was $0.45/kg to Edmonton plus $0.054/kg for trucking frozen charr or $0.112/kg for flying fresh charr to the FFMC in Winnipeg. These rates had remained stable for several years and increases were anticipated. Charr are packed fresh or frozen in Cambridge Bay and flown via Canadian Airlines to Edmonton. Fish destined for western markets are checked at the FFMC in Edmonton and distributed from there, fish destined for eastern markets are flown fresh or trucked frozen via Canadian Airlines to the FFMC in Winnipeg. Favourable backhaul rates have been negotiated with the airlines and trucking companies. Fresh fish arrive in Winnipeg on the same day they are caught and are distributed as far south as California.

To maximize return on charr sales the FFMC manager marketing the fish follows the international market trends to take advantage of short-term market fluctuations (B. Popko, pers. comm.). For example, if cod are being "dumped" on the east coast and distributors are tying up their money in cod, there may be little demand for a specialty fish like charr and consequently a low price. A few weeks can make a significant difference in the return to the producer.

The Co-op stresses expense control (J. MacMillan, pers. comm.). Operating costs are reduced by prompt freezer shutdowns to save expensive electricity, and by trucking their own water. Fish are shipped promptly and freezers are emptied quickly. The freezers are turned off when empty or once temperatures drop sufficiently to keep fish well frozen. In 1988, it cost $800-900/month to operate the blast freezer. Water was hauled in a tank mounted on a trailer behind the 3/4 ton truck. It cost $0.015/gal compared to $0.018/gal from the town truck and represented a substantial saving. The Hunters and Trappers Association (HTA) is encouraged to purchase fish for local sale so that fish plant freezers are empty and can be shut down. The last fish are generally sold by the HTA in April or May.

Operation: The Co-op tries to keep equipment and fishery operations simple to facilitate maintenance and repairs, and to smooth the way for new managers (J. MacMillan, pers. comm.). Written records of the operations that detail the work to be done and the solutions to problems that have been encountered are kept. For example, to ensure that equipment is in good operating order during the short fishing season the Co-op follows a schedule of maintenance activities (eg. May 15th--truck maintenance, May 28th--plant start-up and testing, June 30th--DFO plant inspection...). There is about a month of start-up, followed by 3-4 weeks of spring fishery, 3-4 weeks shutdown and overhaul, 3-4 weeks of fall fishery, and 3-4 weeks of shutdown and overhaul. The plant is thoroughly overhauled every 3 years at a cost of about $25,000.

To avoid costly shut-downs they keep spare parts for most machinery on hand. It takes several days for parts to arrive from the south and the cost of a major failure would be very high.

Logistics are coordinated by radio. There is a base radio at the Co-op and a radio at each camp. By linking fishermen, float planes, fish plant, and airlines the Co-op is able to minimize the effects of adverse weather and nearly eliminate fish spoilage.

In dealing successfully with many of the problems that face developing fisheries in the Canadian Arctic, the Co-op has examined a variety of methods for harvesting, storing, and transporting fish.

Weir fisheries have been very successful (Kristofferson et al. 1986; Carder 1988). Over the long term they may be less expensive to operate than a gillnet fishery because there is little or no cullage necessary and fish can be shipped fresh (J. MacMillan, pers. comm.). Fishing can be compressed into a very short period, 4 to 5 d set-up and 3 to 4 d fishing, which increases efficiency and enables harvests of whole quotas at rivers where large runs occur over a short time. The Jayco River weir has operated successfully for 3 years and is left in the river, with the trap removed, year-round. The weir was damaged during the 1988 fishery and gillnets were used to complete the harvest. Permission is sought annually from DFO to operate the weir or, for that matter, to open any quota for fishing. If DFO permits, weirs may be used in the future at some of the other sites.

On-site ice machines with gas generators have been tried at the rivers with poor success (J. MacMillan, pers. comm.). The main problem is safeguarding the assets, one generator disappeared and weather was very hard on the others. Maintenance costs are high and repairs are difficult due to the isolation. Ice houses are also expensive when travel costs and ice cutter's wages are considered. It is also very difficult to verify the amount of ice cut. Instead, the Co-op prefers to fly ice to the rivers on empty backhauls. The DeHavilland Beaver can take from nine to fifteen 35 kg ice buckets. The ice will last for 2 or 3 d if kept covered.

The Co-op does not use freezer boats because they can only service a small area, often do not freeze the fish quickly, and are weather dependant (J. MacMillan, pers. comm.). Instead, they use local airlines to cover a larger area and ensure fish quality.

Marketing: To ensure a top quality product fishermen and plant employees are trained in fish handling techniques. No alcohol is allowed at the fishing camps, and peer pressure ensures hard work and quality control. There is an annual competition for "best" fisherman and the winner is announced on the community radio.

Only the best charr are exported to the FFMC--on average 5-10% of the charr are culled (J. MacMillan, pers. comm.). Fish with minor aesthetic flaws such as damaged fins or gills are kept and sold within the NWT (intersettlement trade), mainly in Yellowknife. Fish which have minor deterioration are kept and sold in Cambridge Bay, and fish which are going soft but not "stinky" are written off and given to the employees--these fish, sometimes 2.5 d old, are considered a delicacy. Up to 25% have been culled in years when weather prevented transport of harvested fish from the rivers to the fish plant; 5% of these culls were thrown out.

The pay-back on fresh charr is substantial because they command a premium of $2.20/kg ($1.00/lb), earning Cambridge Bay fishermen $1.21-$1.32/kg ($0.55-$0.60/lb) more than for frozen charr (J. MacMillan, pers. comm.). Only fall-caught charr are marketed fresh. Spring-caught charr are generally in poorer condition and some have warty growths--possibly the result of mineral deficiencies caused by winter starvation. Due to favourable backhaul rates from Canadian Airlines fresh charr can be flown to Winnipeg for $0.058/kg more than the cost of trucking frozen fish. The shipping companies cooperate to ensure that the fish arrive within 18 h of shipment.

While fresh charr were not shipped to the FFMC in 1988-9, the cooperative did ship 2,455 kg (5,500 lbs) in 1987-8, and 5,442 kg (12,190 lbs) in 1986-7 (B. Popko, pers. comm.). Of the 1988-9 charr, 5% weighed between 0.9 and 1.8 kg (2-4 lbs), 57% between 1.8 and 3.2 kg (4-7 lbs), 27% between 3.2 and 4.5 kg (7-10 lbs), and 11% between 4.5 and 5.5 kg (10-12 lbs).

The shipment of fresh fish requires different packing techniques which are readily learned with help from FFMC personnel. While some extra ice must be shipped to preserve the fish, there are offsetting savings to labour and equipment. For example the blast freezer need not be run, reducing electrical costs, and fish need not be glazed. However, if fresh shipments are delayed by weather they must be unpacked and frozen.

There is interest in smoking charr at the Country Foods outlet in Cambridge Bay (J. MacMillan, pers. comm.). Vacuum packing is also possible but has not been tried due to the potential for botulism within improperly sealed packages. The Co-op would also be interested in harvesting high value species like mussels, shrimp or scallop--particularly where harvests are simple, rapid, and inexpensive and there is little or no processing required.

The FFMC has strong Co-op support (J. MacMillan, pers. comm.). It provides a guaranteed market, informs producers of the minimum amount they will receive for their fish before the season begins, pays on delivery, provides advice on handling, and takes all sales and inventory risks--this should leave weather as the main imponderable in a well run fishery. If the FFMC has a successful year it makes a second payment to the fishermen. In the case of one Cambridge Bay couple the second payment in 1988 alone amounted to $14,000. While private distributors sometimes pay larger first payments than FFMC (eg. $3.35 cf $3.00), they do not make a second payment (eg. $1.35) and may want to make 50% of the payment on receipt of the fish and 50% when they are sold. At present, the FFMC is preferable to other distributors and any shift away from it risks the loss of markets which have been carefully built up through years of charr sales.

District of Keewatin

Very different approaches have been taken in the development of the Cambridge Bay and Keewatin fisheries. Where the Cambridge Bay fishery has the management and financial advantages of the Arctic Cooperatives organization, owns an efficient centralized processing facility situated on a good transportation route, and has large annual harvests of charr; the Keewatin fishery operates three independant processing facilities which have none of these advantages. A strategy has been prepared to address these problems (RT and Associates and Symbion Consultants 1989).

The Keewatin processing facilities are situated in Rankin Inlet, Chesterfield Inlet, and Arviat (formerly Eskimo Point), and there are freezer/packer vessels at Whale Cove and Coral Harbour. Each area will be described briefly, followed by general descriptions of operations and financial considerations.

Rankin Inlet: Commercial fishing for anadromous Arctic charr began in the Keewatin in 1932 when Mr. Ingebrigtsen of Churchill, Manitoba sailed 250 km up the coast and harvested some 1,000 kg of charr, marketing them as "lightly salted sea trout" (Davies et al. 1986). Despite the success of this small fishery there was little interest in commercial fishing until 1962 when the Rankin Inlet nickel mine closed. To help shore up the area economy the Department of Northern Affairs and Natural Resources (DNANR), and later the GNWT, helped to develop a commercial fishery for fish and marine mammals in the area (Carder and Peet 1983).

In 1964, following a brief survey of fish resources along the Keewatin coast (Brack and McIntosh 1963), the DNANR established a pilot cannery plant at Daly Bay, north of Chesterfield Inlet (Lantz 1965; Lantz and Iredale 1972). The cannery employed local Inuit to harvest and process Arctic charr, seals, whales, and walrus from the area. In 1966, after the fish resources of Daly Bay had proven to be insufficient and because the water supply, power, and housing facilities were limited, it was dismantled and re-established at Rankin Inlet as the Issatik Food Plant.

Exploratory fisheries were undertaken in the Rankin Inlet area to find exploitable fish stocks to support the cannery and Arctic charr were marketed in the south as a gourmet product (Carder and Peet 1983). In 1970, with the discovery of high levels of mercury in the marine mammals and decreasing local demand for the products, the cannery stopped processing marine mammals. The fish canning operation continued until 1976, when high transportation costs to southern markets forced it to close (Thompson 1976; Carder and Peet 1983). In 1990-91 the canning equipment stood idle but the facility was still registered to process fresh and frozen Arctic charr for commercial sale in the community and to the FFMC.

The Rankin Inlet plant has been expected to close annually since 1987, and a new more efficient plant is proposed. While the plant receives fish from both the Rankin Inlet and Whale Cove fisheries, it will be very difficult for a new plant to be viable or provide a return on investment if it only processes charr (Ference and Associates 1987).

Chesterfield Inlet: The Iqalukpik Fish Plant in Chesterfield Inlet was constructed to spur fishery development in the area, not in response to a proven need (B. Threadkell, pers. comm.). In 1985, prior to plant operation, fish harvested from the Chesterfield Inlet area were flown by scheduled aircraft to the Issatik Fish Plant in Rankin Inlet for freezing (Keewatin Environmental Consulting Services Ltd. 1986). Fish quality was apparently good and the shipments were cost effective at a pre-negotiated rate of $0.36/kg. The plant was funded under the Economic Development Agreement (EDA) and by GNWT Economic Development and Tourism, and built in 1985. The estimated cost was $180,000 but there was pressure to erect the plant quickly so materials were flown in on chartered aircraft, rather than barged from Churchill, and construction costs soared to $350,000 (B. Threadkell, pers. comm.)

The Chesterfield Inlet fish plant is small, with less than 90 m^2 of floorspace, and includes a blast freezer and a storage freezer which is capable of holding 4,500 kg of boxed fish (B. Threadkell, pers. comm.). It was to be portable, with a stainless steel floor, but inspection regulations dictated that the floor must be cement so the plant was constructed on a cement pad. As a result, it is no longer portable and the costs of regular floor maintenance must be borne. Steel roof girders also add to inspection problems as they collect dust and condensation, promoting the growth of bacteria. The fish plant was first registered in the spring of 1989 (L. Penny, pers. comm.).

Prior to plant construction a feasibility study was conducted on the use of freezer-packer vessels to service the Chesterfield Inlet fishery and deliver fish to the Rankin Inlet plant for processing (DPA Consulting Limited 1984). Costs associated with use of the vessels were estimated at $2.05/kg of charr ($0.93/lb) before allowing for amortization of the capital investments, so vessel purchase could not be justified.

Arviat: Kakivak Fisher Foods operates a packing station at Arviat, where fresh fish are iced and re-packed for shipment via scheduled airlines to the FFMC. Before 1987, when the packing station was established, fish were transported by boat or plane to the Rankin Inlet Fish Plant for processing. The Arviat packing station has a small holding freezer and an ice machine. It is not a certified fish plant, but DFO Inspectors have been allowing the shipment of fresh fish provided fish quality remains acceptable and there is an indication that the facility will be improved.

In 1990-91 a small modular fish plant, constructed in portable ATCO trailers, was moved to Arviat to upgrade the fish processing (G. Weber, pers. comm.). It may begin operation during the 1991-92 fishing season. Similar plants are planned for Rankin Inlet and Whale Cove.

Freezer-Packer vessels: There are two freezer-packer vessels in the Keewatin, the "Arctic Tern" at Whale Cove and the "Natsiak" at Coral Harbour. Neither vessel was registered in 1990-91, nor were they operable. The aluminum vessel in Coral Harbour was in dry-dock with a cracked transom and required expensive repairs to its freezer, and the freezer was removed from the Whale Cove vessel because condensation in the insulation surrounding it was rotting the wood hull.

Freezer-packer boats need not be registered if they are marketing their fish locally or through a registered plant. If they are shipping their fish south they must undergo the same inspection as a fish plant to obtain registration. While they provide greater flexibility than fixed processing plants, the boats are capital intensive and weather dependant. They also have restricted operating seasons and operating areas which are dictated by weather, distance, and local politics. For example, there is strong opposition to the boat from Coral Harbour fishing charr quotas near Chesterfield Inlet. There is also local opposition to one family harvesting the entire Duke of York Bay quota using a weir because this may deprive other fishermen.

Operations: In the Keewatin, the main commercial fishery is conducted during August and early September when anadromous Arctic charr are netted at or near river mouths along the coast (Carder and Peet 1983; Carder 1983, 1988; Carder and Low 1985; Carder and Stewart 1989). Nets are generally 45 or 90 m in length with 139 mm mesh, and 20 to 30 meshes deep. They are usually stretched out from shore on the surface where the water is 4 to 5 m deep and checked twice daily. The fish are dressed on site, packed in ice, and transported by boat to the fish plants for washing, fast freezing, and packing. They are then shipped south on scheduled airlines to the FFMC for distribution.

Transportation poses a problem for the Keewatin fisheries both in terms of logistics and cost. Boat transportation from the rivers to the fish plants, and air transportation from the fish plants to southern markets are both hampered by inclement weather. Fishermen are often stranded at a site for days if there is a storm on Hudson Bay. Likewise, shipments of fresh fish are often stranded in the communities and must be unpacked, frozen, and repacked, and shipments of frozen fish can be stranded in Rankin Inlet or Churchill--increasing spoilage.

Rankin Inlet is the only Keewatin community with direct scheduled jet aircraft service to Winnipeg, Iqaluit, and Yellowknife. Fish are generally flown by DeHavilland Twin Otter or Lockheed Electra from the communities to Rankin Inlet and then on to Winnipeg by Jet or Electra, either directly or via Churchill or Thompson, Manitoba. Each extra flight leg increases shipping costs and the possibility for spoilage.

In 1988, Chesterfield Inlet, Rankin Inlet, Whale Cove, and Arviat together harvested 37,085 kg of dressed Arctic charr during the open water season (Carder and Stewart 1989). Most of these fish were sold to the FFMC, either fresh or frozen. The remainder were sold locally or in nearby communities (eg. Churchill), or were culled.

The fish plant managers are hired on a seasonal basis by the local HTA's. There is a regular turnover of managers, most of whom are local, and this occasionally leads to financial mismanagement or inefficiency--not through incompetence, just inexperience. For example a freezer or the ice-maker may be inoperable at the start of the season due to lack of servicing, spare parts may not be available locally, or shipping materials may run out part way through the season.

Weirs have been used successfully to ennumerate charr in several Keewatin rivers (McGowan 1987; Sopuck 1987) but are not yet widely used for commercial fishing in the region.

Interest is growing in the winter harvest of charr. During the 1988-9 and 1989-90 seasons there were winter test fisheries at Igloolik, Repulse Bay, Baker Lake, and Arviat. Fish were frozen whole on the lake ice and shipped round to the FFMC for dressing. The FFMC made a 1988-9 first payment of $5.28/kg round weight ($2.40/lb) for the winter caught charr compared to $6.61/kg dressed weight ($3.00/lb) for frozen summer caught charr (B. Popko, pers. comm.). The winter payment was lower because FFMC dressed the charr; the final payment was the same for both fisheries. While the costs of shipping whole (round) fish are higher than for dressed fish, producers can often take advantage of cheap winter backhaul rates and do not need an expensive processing plant. The quality of winter caught charr from Igloolik has been very good.

Shipment through a registered plant is temporarily not required for test fisheries, summer or winter. To ensure that fish have not deteriorated, they are shipped under a detention order and subject to inspection by DFO on arrival at the FFMC.

Finances: The Rankin Inlet and Chesterfield Inlet fish plants have experienced substantial operating losses and have not produced a return on the initial capital investment (Ference and Associates Ltd. 1987). Neither plant receives enough fish for processing to consistently meet operating expenses.

In 1988 the Chesterfield Inlet fish plant processed 9,122 kg (dressed weight; Carder and Stewart 1989) of charr and had an operating loss of $30,000 without considering capital costs (R. Zeiba, pers. comm.). The entire second payment from FFMC was used to reduce that loss to $16,000 (B. Threadkell, pers. comm.). The Rankin Inlet plant processed 18,834 kg of Arctic charr (Carder and Stewart 1989) and actually made money, issuing a bonus to employees (R. Zeiba, pers. comm.). Again, capital costs were not included.

While initial payments to the fishermen are often higher in the Keewatin than at Cambridge Bay ($2.42-3.08/kg cf. $1.76/kg), subsequent payments are lower or nonexistent. Instead of the money being paid to the fishermen it is used to subsidize plant operations--which can include the marketing of other country foods (B. Threadkell, pers. comm.). Where the Cambridge Bay fishery shares management costs with several other small businesses, each of the smaller Keewatin fisheries must hire their own plant manager.

For comparison, a fisherman who sold 1,000 kg of dressed charr in 1988 would earn about $8,000 in Cambridge Bay campared to $2,400 in Chesterfield Inlet. The Cambridge Bay fisherman also had fewer fishing expenses. These lower returns hamper fishery development in the Keewatin by reducing incentive to the fishermen and reducing their ability to purchase equipment and supplies.

Fishermen in the Keewatin communities, with a few exceptions, participate in the commercial fishery not to earn a livelihood, but to supplement their incomes or subsidize subsistence harvests (Yonge 1988, 1989). At the prices paid for their catch, few fishermen are able to cover fixed and variable costs and still earn a return on their investment for equipment--let alone a living wage. If fish, caribou, and marine mammals harvested during the fishing trips and used for subsistence purposes were given a replacement value and included in the revenues, then fishermen's net revenues would improve. The Keewatin fisheries for the most part are not financially viable, but they may be economically viable.

In their recent review of the Keewatin fishery, RT and Associates (1989) recommended that the fishery would operate more economically if it were modernized and centralized. In particular they recommended that: 1) pairs of fishermen be outfitted with Lake Winnipeg yawls powered by 120 hp motors to permit safe access to more distant quotas; 2) processing be centralized at a new processing plant to be built at Rankin Inlet which would be supplied packing stations at Whale Cove and Chesterfield Inlet and a new packing station to be built at Arviat; 3) the freezer-packer vessels be repaired for use as collector vessels; 4) a Cessna 207 be dedicated to carry fish from the packing stations to Rankin Inlet; 5) a General Manager be hired to coordinate and oversee the entire fishery; 6) fish be marketed through the FFMC; 7) ice houses be established at the Ferguson River and in the

Chesterfield Inlet area to reduce fish spoilage; 8) the operating season be shortened to cut costs and increase efficiency; and 9) that those involved in the industry receive regular training. The extent to which these recommendations are implemented remains to be seen.

Belcher Islands

Inhabitants of the Belcher Islands in the southeastern corner of Hudson Bay harvest blue mussel, green sea urchin, brown sea cucumber, and six-rayed starfish (Jamieson 1986). They have a long tradition of harvesting these species for food, and there is an existing consumer market for the first three species in the islands' community of Sanikiluaq. There is also a market in southern Canada and abroad, particularly in the ethnic communities of New York City and in the Orient.

In 1984, Sanikiluaq's Mitiq Co-op initiated a study to quantify the species of edible invertebrates around the Belcher Islands and to test commercial harvesting methods (Jamieson 1986). Product quality and marketing were also examined. The study was funded by the federal Department of Indian and Northern Affairs and ended in 1986. A follow-up study was funded by GNWT Economic Development and Tourism in 1988 to examine other harvesting methods and possibilities for aquaculture (Giroux 1989).

Neither study estimated the standing crop or species productivity, nor did they export products to southern markets. However, they do provide useful information on an attempt to develop a northern, nearshore fishery that is labour rather than capital intensive, and depends upon a mixed harvest of benthic invertebrates.

Operations: Harvest methods that were tested during the studies included hand-picking by SCUBA divers (Jamieson 1986), pole nets, and a small bottom drag net (Giroux 1989). The SCUBA method was faster than pole netting, but may be slower than a proper drag net. It was the most expensive, and pole netting the least expensive harvest method. SCUBA harvests have the advantage that they select large, good quality individuals and do not disturb young specimens--insuring the continuation of good quality harvests in an area. Pole nets are more effective than drag nets in areas with stony or cobble bottoms, they can also be used through the ice. The drag net tested by Giroux (1989) was not heavy enough to penetrate harder substrates but caught well in softer bottom types. Larger drags require larger boats.

Winter harvests are unlikely to justify the time and effort spent, so commercial harvests would take place during the open water season, beginning in mid-June and continuing into mid-September. This means that employment generated by the project would be seasonal, lasting 4 or 5 months.

The time of spawning varies with local light and temperature conditions, so harvests must be timed to catch sea urchins and mussels before they spawn. Provided the desirable pre-spawners are harvested, the yields are similar to those on the east coast, with a 9% roe yield for urchins and 11-13% ratio of meat to total weight for mussels (Giroux 1989). The urchins are generally small relative to the 7.5 cm test diameter required for international markets.

The urchins, mussels, and sea cucumber all met Public Health standards for acceptable heavy metals and pesticide concentrations, and mussels showed no evidence of paralytic shellfish poisoning (Jamieson 1986; Giroux 1989).

To interest people in Sanikiluaq in harvesting invertebrates, they should be able to earn money at the same rate as they would carving, and have the fringe benefit of bringing several meals home to family and friends at no cost (Jamieson 1986). They harvests have the additional appeal to local villagers of being "on the land"--allowing them the freedom to vary their activities. Since harvests are related to the desire of the harvesters, piece work is the best way of producing acceptable amounts of produce.

Outfitting and training divers to harvest the marine invertebrate species is an expensive process relative to harvesting by pole net or other methods, but it does offer good quality harvests and job skills which might be used to develop tourism, for example guiding recreational divers.

In addition to the natural harvest, lines were set up in the Belchers to test possibilities for mussel aquaculture (Giroux 1989). While the local mussel population should seed the lines with larvae, and there are sheltered coves which offer suitable depth and bottom types, the growth rate and time to maturity remain unknown. If mussels can be grown to maturity in 2 to 4 years then aquaculture may be feasible. Whether it is economic will depend upon the set-up costs--estimated at $120,000 for equipment and labour funding for the first 2 or 3 years, the rate of production, and the cost of marketing the mussels.

Marketing: For the possibility of selling locally harvested produce from the sea to become a reality in Sanikiluaq, the cost of edible material harvested must approximate the cost of edible material imported from the south. Based on studies of harvesting effort and costs comparisons with imported foods, and limited test marketing, the harvested produce can be marketed locally at competitive prices with store-bought items. Indeed, it may command a premium because of the preference for fresh, locally harvested foods. With the exception of sea cucumber which are frozen, eviscerated, and dried, the invertebrates would be sold whole and alive.

While there may be a market for the invertebrates in southern Canada and elsewhere, the optimal strategy may be to aim for self-sufficiency for the community. Reasons for this include the good local acceptance of these foods, high cost of imported foods, limited local manpower, high shipping costs, unknown stock sizes, and potentially slow productivity. Intersettlement trade might be tried before export since the latter requires development of a packing plant.

Hudson Strait

The Killiniq fishery in Ungava Bay is the only "long-running" marine fishery in northern Canada. Few areas in the southeastern Canadian Arctic support the diversity and abundance of potentially exploitable natural resources that are available at or near Killiniq Island (Dunbar 1952, 1970). However, fishery development has been difficult and, although various fisheries have been attempted, no viable fishery has developed. These efforts offer valuable lessons to those contemplating marine fishery development in the Beaufort Sea. In particular, they demonstrate the problems associated with trying to develop an arctic commercial fishery based on: 1) a low-value species, the Atlantic cod; and 2) a high-value coastal benthic invertebrate, the Iceland scallop.

Background: From 1947-50, DFO studied marine biota in the Port Burwell area with a view toward possible development of an Inuit fishery (Hildebrand 1948; Dunbar 1949, 1952; Anon. 1950; Dunbar and Hildebrand 1952). Their studies showed that Atlantic cod in the area offered good possibilities for development, so experimental fisheries to provide cod as food to the Inuit were conducted there in 1950 and 1951 (Gillis and Allard 1984). Catches were apparently good, but the Inuit preferred marine mammals and did little cod fishing after the experiment ended (Evans 1958).

In 1959, following an area economic survey, the Department of Indian Affairs and Northern Development (DIAND) funded development of an Atlantic cod fishery based at Port Burwell on Killiniq Island (Evans 1958). The intent was to bridge the gap between the Arctic charr fishery which usually ended in August, and the harp seal hunt which began in October. Over the next several years an Inuit co-operative was formed and commercial fisheries for Arctic charr and seals were also started (Gillis and Allard 1984). Despite cod catches which were often limited by inadequate freezer capacity and which fluctuated from 26,800 kg in 1968 to as little as 1,340 kg in 1972, this multi-species fishery continued until the early 1970's.

Factors unrelated to the fishery led to its closure in the mid-1970's (Gillis and Allard 1984). The difficulty and expense of community re-supply and maintaining modern services led to a gradual abandonment of Port Burwell, depleting the work force for the fishery until it closed. In 1978, the townsite was officially closed and the remaining residents were dispersed among other northern Quebec communities fringing Ungava Bay. The Killiniq Inuit have not accepted this and are negotiating with all levels of government to establish a new community on the Quebec mainland some 40 km south of Killiniq. It is in this context that the potential for fishery development in the area has been examined since 1983.

Killiniq Inuit have joined with Makavik Corporation, which represents Inuit of northern Quebec and Labrador, to examine the feasibility of re-developing a commercial inshore marine fishery in northeastern Ungava run by and for native peoples (Gillis and Allard 1984). They are using the fleet from Port Burwell and some refurbished processing facilities there to conduct exploratory fisheries along the Labrador coast and in Ungava Bay (Gillis and Allard 1984, 1988; Allard and Gillis 1986, 1989; Gillis et al. 1987; Crawford 1989).

The fleet consists of multi-purpose longliners in the 13-14.5 m range (40-45 ft). Their operations are limited by weather and the gear they can carry. Normal fishing operations by vessels in this class begin to be affected by winds greater than 28 km/h (15 knots)(Gillis et al. 1987). The extent to which they are affected depends on tidal currents and wind direction. Fishing operations are suspended in winds greater than 47 km/h (25 knots). Wind speed generally increases as the summer season progresses in the Ungava. Operational efficiency is also impeded when visibility is less than half a nautical mile.

Gillnets, trapnets, longlines, and Digby scallop buckets were the main gears tested during the surveys. Variable bottom profiles make Ungava Bay unsuitable for trawling (Dunbar and Hildebrand 1952). Study efforts were directed towards Atlantic cod, Arctic charr, and Iceland scallops, with lesser interest in incidentally caught species like turbot and Greenland shark.

Atlantic cod: Atlantic cod occur in the Killiniq area for 5-10 weeks in late summer during their annual inshore migration along the Canadian Atlantic seaboard. Their time of arrival varies between years as apparently do their residence time and numbers in the area, raising doubts as to their commercial potential (Gillis et al. 1987; Crawford 1989).

The harvests of Atlantic cod were 13,050 kg in 1983 (Gillis and Allard 1984), 7,590 kg in 1984, and 4,370 kg in 1985 (Allard and Gillis 1986). Gillnets proved to be a more effective harvest method than longlines but in 1985, when most of the fishing was by gillnet, losses from spoilage and scavenging by benthic invertebrates amounted to 37.6% of the total catch. Cod traps which were used effectively in the 1970's might offer an effective alternative with less waste.

Three major markets are available for Killiniq cod: the southern Canadian market for frozen cod products, the northern market for fresh and/or frozen products, and the export salt cod market--each with their own set of products, processing requirements, and logistical considerations (Gillis et al. 1987).

In view of the amount of fish available, high transportation costs, relatively low market prices, and limited local demand, the infrastructure costs associated with marketing frozen cod cannot be justified--even when the analyses are based on the higher 1983 catches, and despite the good quality, parasite-free flesh (Gillis et al. 1987). If freezing facilities were available and their operating costs were covered by another resource, excess freezer capacity might be used to produce whole frozen cod for northern sales.

Killiniq cod were salted during the studies because freezer facilities were inadequate. Fish heads and internal organs are wasted during the salting process and with shrinkage the yield of salt fish was about 28% of the round weight. In 1985, the Killiniq fishermen received $1,020.43 for their catch or an average of $1.256/kg for the 812.7 kg of salted fish sold (Gillis et al. 1987). Salted fish generally command low prices because they are marketed mainly in Third World countries (Dunbar 1970).

Break-even scenarios for the production of salt fish at Killiniq for export required either high cod prices ($4.50-$5.75/kg FOB Montreal) and catches of 20 to 26 mt, or catches of 60 mt and a blended market price of $2.50/kg (Gillis et al. 1987). They were based on 1985 costs for 6 fishermen working 12 h/d for 50 d at minimum wage ($4.35), 28% yields of salt bulk fish from round fish, and the use of trap boats and existing processing facilities and equipment. The catch would be transported south to CN Marine's Newfoundland Terminal on a local longliner and then on to a private broker in Nova Scotia or Gaspe--other modes of transport being prohibitively expensive.

The present cod fishery is not economically viable, and given the uncertainty of cod availability at Killiniq and fluctuating market prices any arctic development based on cod would seem to be tenuous.

Iceland scallop: Iceland scallops were known to the Killinimiut as "kokiuyaq", meaning fingernails (Gillis et al. 1987). While they were taken on longlines and in gillnets, their occurrence in waters near Killiniq was not widely known. Scallops were studied during the exploratory fisheries in 1984 (Allard and Gillis 1986) and 1985 near Killiniq (Gillis et al. 1987) and further afield in Davis Strait and Ungava Bay in 1987 (Gillis and Allard 1988) and 1988 (Allard and Gillis 1989). Production for these fisheries was 35.5 kg (round weight), 1,395 kg, 550 kg, and 1,667 kg respectively.

In 1985 and 1988 scallops were harvested by 12-14 m inshore Longliner/gillnetters using Digby scallop buckets (0.76 m mouth) towed three-together along the bottom, and in 1987 by the 35.5 m offshore scallop dragger "Anne S. Pierce" which was fitted with two (4.57 m) deep sea dredges. Most exploratory work was conducted in coastal waters less than 115 m deep.

Growth rates of scallops taken in the Killiniq area in 1984 and 1985 were comparable to those of scallops from the Gulf of St. Lawrence (Gillis et al. 1987) while scallops from western Ungava Bay, Diana Bay, and southern Baffin Island were relatively slow growing (Gillis and Allard 1988; Allard and Gillis 1989). Mean age in the 1985 catch was 12.93 years, and by weight the total and commercial meat yields were 13.23% and 11.64%, respectively--total meat weight includes both the smooth and striated adductor muscles whereas the commercial meat weight includes only the large striated adductor muscle. The best catch rates were at Diana Bay where catches averaged 131 kg/h (Allard and Gillis 1989).

Peak catch rates in areas which would require an offshore vessel did not reach the level required for a standard Canadian offshore scallop vessel to operate on a sustained basis (Gillis and Allard 1988). Indeed, it would need better than normal catch rates because of the relatively short fishing season. If offshore fishing vessels were fitted with sophisticated ($100,000) navigational aids which might enable them to take advantage of the "windrow-like" beds, a cost effective catch per unit effort might be attained. In any case an offshore vessel like the "Anne S. Pierce" would require shore-based freezer and storage facilities.

Inshore fisheries may offer better potential, but are not yet economically viable (Allard and Gillis 1989). Economic analyses of a full-season fishery predict a break-even 1988-9 wholesale market price ex-Quaqtaq (northwestern Ungava Bay) of $21.13/kg of shucked meats for a vessel towing three Digby drags--$14.94/kg if five drags were towed. These analyses were based on the operating costs of a 12 m fishing vessel with a crew of 3 working in Diana Bay. The catch would be processed and frozen on shore at Quaqtaq.

There is local interest in scallops, particularly for whole-live scallops, but high transportation costs may preclude the shipment of products other than shucked meats outside the Quaqtaq community (Allard and Gillis 1989).

Baffin Island

Baffin Island fisheries offer those interested in fishery development in the Beaufort Sea worthwhile examples of an arctic winter fishery, for turbot, and a small-scale pilot project, for scallops. The Sylvia Grinnell River fishery for Arctic charr also provides a graphic example of what can happen when a commercial fishery is established to exploit stocks already harvested by a subsistence fishery.

The HTA in Pangnirtung on southern Baffin Island has been conducting marine test fisheries since 1985, assessing the resource base, training fishermen, and testing equipment and economics. The main species of interest are Iceland scallop which is a high value species, and turbot which command lower prices. Prices paid for fresh turbot peak in January through April, the main Baffin fishing period, when ice conditions limit fishing along the Atlantic coast. A community-owned company was formed to conduct the 1989 turbot fishery. There are successful turbot and scallop fisheries in nearby Greenland.

Turbot: Turbot or Greenland halibut (Reinhardtius hippoglossoides) are caught from mid February until the end of May through the ice near the floe edge by groups of fishermen using longlines (MacKay 1987; Canadian Fishery Consultants Ltd. 1988; D. Pike, pers. comm.). Access to the fishing grounds depends on ice conditions which vary during the winter and between years. The preferred longlines are poly rope (3 mm diameter), with braided nylon leaders having 100-130 semi-circle hooks, preferably #2 or #3, which are baited with charr or turbot. They are fed through the ice with a weighted sheet metal "kite" attached which carries the line horizontally and increases the bottom area fished. The longlines are lowered to depths of 200 to 1200 m. While motorized hydraulic haulers have been tested, they are expensive and offer no time saving over hand winching so some fishermen continue to operate using hand winches. High hook losses, up to 13.4%, have been experienced, largely due to bottom snags and sharks. Shortening set time has reduced hook losses (D. Pike, pers. comm.). Sharks, skates and eelpouts are the main bycatches. Indeed, sharks were so numerous in the 1989 fishery that they were stacked for windbreaks at some locations.

Catches expressed in round weight were about 5.4 mt in 1986-7 (MacKay 1987), 13.4 mt in 1987-8 (Canadian Fishery Consultants Ltd. 1988), 150 mt in 1988-9, 255 mt in 1989-90, and 141 mt in 1990-91 (D. Pike, pers. comm.). About 28% of the round weight is head and gut, and the dressed fish average 3.5 kg. Growth rates are similar to those of turbot taken in the Greenland and North Atlantic fisheries. The Cumberland Sound stock may be migratory since limited summer test fishing for the species has been unsuccessful.

Production is limited largely by the processing capacity of the small fish plant in Pangnirtung (MacKay 1987; Canadian Fishery Consultants 1988). A major stumbling block is the need for a continuous supply of fresh running water. Fresh water is difficult to obtain in large volumes during the winter. Inadequate waste disposal and lack of freezer holding and storage space also limit plant production, as have the late arrival of processing equipment and equipment shortages.

Strong emphasis has been placed on quality control to build product reputation (Canadian Fishery Consultants Ltd. 1988). To ensure quality the fish are bled immediately after capture, headed and gutted within an hour, stored and transported to the plant in a super-chilled condition, iced on arrival, processed within 5 d of capture, and glazed immediately after freezing. There are also after-sales follow-ups with airlines and customers to ensure that the product arrived in good condition. The product must be differentiated from existing turbot so instead of using the common name "Greenland halibut" the Pangnirtung turbot may be marketed as "Baffin Island halibut".

In 1991, the highest weekly catch was 34 mt (D. Pike, pers. comm.). There was strong community interest in the fishery which involved up to 100 fishermen and 30 plant employees. The main bottlenecks in the fishery operation were posed by the fish plant's limited processing capacity and limited availability of air freight space.

Because of high equipment costs and water demand it is unlikely that minced products or surimi processing would be viable (Canadian Fishery Consultants Ltd. 1988). Instead, the plant will concentrate on producing fresh fillets which have the highest value and lower unit shipping costs than the other products. Fresh fillets are less costly to produce than frozen fillets because freezing and glazing are not required. The price for fresh fillets is often 30% higher than that for frozen fillets which in turn is higher than for other products.

In 1989, prices received for fresh fillets ranged from a high of $7.70/kg ($3.50/lb; FOB Pangnirtung) in February to a low of $6.60/kg ($3.00/lb) in April when the east coast turbot fisheries came on stream (D. Pike, pers. comm.). Most of the fish were exported to southern markets. This represented a significant price increase over 1988, when the plant received $5.94/kg ($2.70/lb) for fresh fillets landed in Montreal (Canadian Fishery Consultants Ltd. 1988). Fishermen received $1.98/kg ($0.90/lb) from the fish plant for their turbot in February 1989, and this price fell to $1.43/kg ($0.65/lb) by the end of the fishery when market prices for the fish fell (D. Pike, pers. comm.).

Catches increased sharply in 1990, but the fishery lost about $50,000 by continuing to harvest and ship turbot in May and June after prices dropped (D. Pike, pers. comm.). The 1991 fishery harvested fewer fish but sold them while prices were high and broke even. It was a short, intense fishery that capitalized on the off-season high prices.

The fishery has exceeded all expectations with good catches, high prices for the fish, price flexibility on the part of the fishermen, and good community interest. If these conditions hold, the fishery should become a going concern.

A winter test fishery to examine the deep water fishery resource of the Canadian Beaufort Sea, testing particularly for turbot, would be inexpensive relative to a summer vessel charter and deserves consideration by proponents of fishery development in the area.

Scallops: Two local boats were active in the scallop harvest, the "Qasigiaq" and the "Tikagulik". The 21.7 m (42') "Qasigiaq" was owned and operated by the HTA and equipped with five 76 cm (30") digby scallop drags; the 13.9 m (46') "Tikagulik", equipped with eight 0.76 cm Digby scallop drags and was purchased by P and L Services Ltd. with assistance from EDA (Gillis 1989). The 1988 fishery included an experimental stock assessment program and a fall commercial fishery for economic assessment purposes. The catch was 17 mt (live weight) of scallops, of which 1,530 kg (9%) was meat (D. Pike, pers. comm.). The vessels fished independantly and delivered their catches to the HTA owned fish plant and freezer facility. Most of the scallops were shucked on shore. The meats were then cleaned and packaged at the plant in various sized units.

Growth of the Cumberland Sound scallops is the slowest recorded, with a mean age at harvest of 17-18 y (D. Pike, pers. comm.). Testing with small mesh nets during the fishery also produced very few small scallops, suggesting slow recruitment.

Economic analyses determined that a full-season fishery operating on the same basis as the fall commercial fishery would not be economically sustainable (Gillis 1989; D. Topolniski, pers. comm.). Returns from the fishery would be too low to pay shore processing and vessel operating expenses and still pay fishermen the target wage of $7.50/h. Indeed, at 1988-9 market prices ($14.85/kg frozen, ex-Pangnirtung) losses to fishermen would be equivalent to an hourly fishing wage of -$2.05/h with government subsidies, or -$13.46/h without government subsidies (D. Topolniski, pers. comm.). Landings might be improved by increasing daily fishing time, improving fishing efficiency, or locating more productive scallop beds. Scallop prices might also be increased, wages decreased, or a single vessel fishery instituted. The latter alternative might improve fishing efficiency and lead to a better return to the fishermen.

At 1988-9 wholesale prices in southern Canada ($7.75/kg; Allard and Gillis 1989) the Pangnirtung scallop fishery could not compete with established southern fisheries. Even if prices rise to levels seen in previous years ($16.50/kg) landings and efficiency would have to improve substantially. Most of the 1988 catch was marketed in Iqaluit where frozen scallops were still available in June 1989 (D. Pike, pers. comm.). Reductions in the price of the frozen meats to $11.20 ($5.00/lb FOB Pangnirtung), suggested that immediate northern markets alone were unable to absorb the production.

There has been little scallop fishing since 1988, although a small-scale test fishery using a Lake Winnipeg fishing yawl (7 m) is planned for 1991 (D. Pike, pers. comm.).

The Pangnirtung scallop fishery experience is illustrative, and likely typical, of the problems faced by a small, isolated, coastal summer marine fishery for bethic arctic molluscs.

Sylvia Grinnell Arctic charr: One of the hazards of commercial fishery development in an area where there are existing subsistence or sport fisheries is overfishing. The Sylvia Grinnell river near Iqaluit, the "place of fish", was a noted subsistence fishery which, like the Diana River near Rankin Inlet and Freshwater Creek near Cambridge Bay, was decimated by commercial fishery development.

Commercial fishermen have harvested anadromous Arctic charr from the Sylvia Grinnell River system on and off since 1947 (Grainger 1948, 1953; Wright 1950; Hunter 1958, 1965, 1976; Kristofferson and Sopuck 1983). Fishing was initiated by the Shaw Steamship Company who removed large quantities of charr in 1947, 1948, and 1950. Most fishing took place adjacent to the river mouth, but during early fisheries nets were also set in Koojesse Inlet, the Bay of Two Rivers, and Foul Inlet. Between 1951 and 1957 there was only subsistence and sport fishing at the Sylvia Grinnell River but, in 1958, DIAND re-established the commercial fishery with an annual harvest quota of 4,500 kg (round weight). An estimate of the 1958 subsistence and sport harvest was 12,000 kg (Anon. 1959). From 1958 to 1962, the commercial quota was filled quickly and fishing was good, but catches declined thereafter until the commercial fishery was closed in 1966. The returns on fishing effort have remained low and the fish small since then.

In 1976 and 1977, DFO researchers studied the Sylvia Grinnell charr population (Kristofferson and Sopuck 1983). They found that the size and age composition of the population had declined considerably since earlier studies (Grainger 1953; Hunter 1958), and concluded that subsistence and sport fishing efforts were probably sufficient to prevent recovery of the charr stock to commercially viable levels. To facilitate recovery they recommended closure of the river to all types of fishing from the head of the falls to a point at least 100 m downstream. Since 1983, the river has been closed to all fishing from the head of the falls to a point 25 m downstream (L. Dahlke, pers. comm.). Stock recovery is proving to be painfully slow and losses to the local economy are significant--emphasizing the need for responsible fishery development and cooperation with fishery managers.

COMMERCIAL HARVEST POTENTIAL OF THE SOUTHEASTERN BEAUFORT SEA

The literature review found that research efforts in the study area have been concentrated between Herschel Island and Cape Parry. Because of their importance to the area economy, there has been strong emphasis on coastal anadromous fishes while coastal marine fishes and invertebrates have received less attention, and offshore resources remain virtually unknown. The genetic, spatial and temporal separation of migratory stocks is not well understood.

Notably lacking from the literature are site-specific data on the harvests by subsistence fisheries. Without these data and a knowledge of stock movements and size it is very difficult to determine whether a stock might also sustain a commercial harvest. Few of the biological studies have been directed toward marine fishery development.

Based on current knowledge of their distribution, abundance, and productivity no fish or invertebrate species in the Canadian Beaufort Sea clearly offers viable commercial harvest potential. While this assertion may simply reflect our current limited knowledge of the biota or sampling methods, research to date has failed to locate species which are sufficiently abundant, productive, and/or valuable that they can be harvested and marketed at a profit.

The review of commercial fisheries found that only two fishes, anadromous Arctic charr and turbot, have supported or now support economically viable coastal or marine commercial fisheries in arctic Canada. Fisheries for charr require careful management, both biological and financial, to have longterm viability of the sort demonstrated at Cambridge Bay. Charr stocks in the Beaufort Sea-Amundsen Gulf area are either heavily utilized by subsistence fisheries or are too small and/or remote to justify commercial development. In the case of turbot, the Pangnirtung fishery is too recent to offer any indication of longterm viability, and turbot have yet to be reported from the Beaufort.

Invertebrate species have not supported financially viable commercial fisheries in arctic Canada. While there is interest in the commercial harvest of scallops, mussels, urchins, and sea cucumbers, individuals of these species generally grow slower and to a smaller maximum size in Arctic waters than do their counterparts which are harvested by competing southern fisheries. In addition to harvesting stocks which are more productive and generally more abundant, southern fisheries have the added competitive advantages of lower production and marketing costs and a longer open water season.

Several species in the Beaufort Sea might offer commercial harvest potential given either larger stock size and/or improved production and marketing economics. Pacific herring and broad whitefish offer perhaps the best opportunity. Offshore research may suggest other species in the future.

PART 2. STRATEGY DEVELOPMENT

The purpose of strategy development is to consider the factors involved in developing a fishery and to recommend a general approach to fishery development. In the sections that follow the options available to developers wishing to assess the fishery resource, fishery economics, and constraints to development will be discussed. Following this consideration a general approach to fishery development will be recommended.

FISHERY RESOURCE ASSESSMENT

Basic to any new fishery development is the need to locate a commercially attractive species in sufficient quantity to sustain a viable fishery. Sometimes this information already exists and can be obtained from the literature or through discussions; more often it is not available and the developer will want to undertake stock assessment research before risking development. Unfortunately, there is no guarantee that this research will locate an exploitable stock. This can make the research difficult to justify, particularly in the north where research costs are very high. A development that proceeds without stock assessment research does so at significant financial risk to itself, and risks damage to the fishery resource. This damage can have far reaching biological, economic, and social effects.

In our opinion Arctic marine fishery development should not precede stock assessment research. The type and scope of research required will depend largely on the resource to be examined and monies available. The options include large-scale exploratory research, small-scale phased research, and local test fisheries. Within each option, it is important that developers recognize the need for basic biological research to delineating stocks, their movements, and productivity. Economic pre-feasibility analysis can be used to direct these research efforts toward species with the best economic potential, and factors which constrain research may also constrain development.

Large-scale exploratory research is the "cadillac" option. It examines a large area, variety of species, and wide range of depths using consistent methodology. This requires a great deal of sampling effort, and versatile sampling equipment. It has the advantage of providing information on the potential of many species over a large area and range of conditions, and should provide the best information on species presence and productivity. It has the disadvantages of using survey-type rather than species specific harvesting methods, and having high costs and greater time requirements than the other options. Exploratory deep-water or offshore research programs in the Beaufort Sea are also likely to require the purchase or charter of a vessel over 20 m in length.

Small-scale, phased research is more directed than exploratory research and may offer more possibilities for cooperation with other groups. It proceeds stepwise to examine a single species over a limited area. This requires the expenditure of less sampling effort, and generally uses species or size specific harvest methods to capture all life stages of the species. These methods can provide good information on the sustainable harvest potential of the species, but provide little data on other species or on opportunities for multi-species fisheries. This approach is less expensive and time consuming than an exploratory research program, although the vessel and gear requirements will depend on the species to be examined.

Local test fisheries may offer the best gauge of local interest in fishery development, and are the least demanding option in terms of effort, cost, and time. The harvest methods are generally species specific and aimed at only individuals of marketable size. The data collected give a measure of the commercial harvest rates and costs, but provide little information on the sustainable harvest potential. This approach is the least expensive and time consuming, but it does little to reduce the risk of failure or damage to the resource if development proceeds.

In the ideal development, a developer might first conduct exploratory research to identify species with good potential for development, and then proceed with a phased program of species specific research before embarking on development. In practice, most developments begin with a local test fishery or without any biological research. The reasons for this are cost and time, and vessel support represents the bulk of the cost. Some vessel support options are discussed in Appendix 1.

The difficulty and high cost of stock assessment research programs in the Canadian Beaufort Sea make it vital that interested parties, such as the FJMC, DFO, GNWT-EDT, and others coordinate their research efforts. Optimally, they will formulate an overall research plan and work cooperatively toward its completion. In this way, research problems can be approached in a logical sequence and with the greatest possible resources, rather than piecemeal. The result should be cost effective research that provides more and better information on which to base resource development and conservation decisions--to everyone's benefit.

FISHERY ECONOMICS

Economic analyses can be used to direct stock assessment research, and to evaluate the likelihood that a financially or economically viable fishery will develop. The factors which are used in these analyses to assess the potential for profit, or viability, depend to a great extent on the degree of government involvement in a project. Where a private developer is mainly interested in short-term financial gain, government is often more interested in long-term economic benefit. A private developer analysing profit potential may consider alternate uses for his time and money, but is unlikely to consider the wider socio-economic or biological costs or benefits of the development. Because government responsibility extends beyond fishery development, it must consider factors such as spinoff employment, social benefits, and effects on other resource users and species. Considered in the context of area development, the costs or benefits of these factors may outweigh the potential financial profit or loss by a developing fishery, and can make a financially viable fishery economically inviable or vice versa.

The approach taken to assess the potential for viability of a new development can range from a purely financial analysis--wherein financial accounting methods are used to determine the difference (business profit or loss) between income and the cash (explicit) costs of doing business, to a detailed economic analysis--wherein the non-cash (implicit) costs of doing business are also considered to arrive at an estimate of economic profit or loss.

To illustrate the difference we will consider a hypothetical charr fisherman on the Hudson Bay coast who purchased a boat and motor costing $10,000 ($6,000 cash, $4,000 loan), and took a two month leave of absence from his government employment to fish for the summer. His income statements from financial and economic analyses might be as follows:

ACCOUNTING INCOME STATEMENT

	Expenses	Revenues
Fish sales		$5,000
Cost of fishing		
- equipment + supplies	$2,000	
- depreciation (linear)	$1,000	
- interest payments	$ 500	
	($3,500)	($3,500)
Financial Profit		$1,500

ECONOMIC INCOME STATEMENT

	Expenses	Revenues
Fish sales		$5,000
Cost of fishing		
- equipment + supplies	$2,000	
- depreciation (market value)	$1,500	
- interest payments	$ 500	
- imputed cost of capital	$1,000	
- lost wages	$6,000	
	($11,000)	($11,000)
Economic Loss		($6,000)

Based on these income statements, the fisherman earned a business profit of $1,500.00, but had an economic loss of $6,000.00. In both cases the money spent to fish and earned from fish sales was the same. The difference arises because the economic analysis takes into account interest that the fisherman could have earned by investing the money he spent to purchase a boat and motor in Canada Savings Bonds, and the salary he could have earned had he worked the two months at his government job. These are opportunity costs, or the amounts that could have been earned had he put his time or money to the best alternative use. In effect, the fisherman did not lose money, but he could have earned more by investing in bonds and working for the government. If he had already purchased the boat and motor for recreational use or hunting, or was unemployed, then the imputed cost of capital and lost wages would not be relevant to the analysis. The analyses of potential profit from an entire fishery are expansions of these simple examples.

As illustrated, a fishery that operates at a financial profit does not always operate at an economic profit. The reverse is also true, particularly where the economic analysis ascribes opportunity costs to a social factor. For example, crime rate may drop in communities where a fishery development provides employment for previously unemployed individuals. Crime rate then would represent a negative opportunity cost, and might enable a fishery that was not capable of operating at a financial profit to operate at an economic profit. While government might view this type of fishery as viable, and be willing to proceed with development, a private developer would be unlikely to do so.

Unfortunately, monetary values are difficult to assign to many important social and biological impacts of development. This makes these impacts difficult to include in the economic analyses. While the high profile impacts may lead to value judgements which affect the political decision-making process, "hidden" impacts like food chain affects on non-commercial species may simply be ignored.

Developments which are financially but not economically viable can be regulated to reduce the costs to society, while those which are economically but not financially viable can be subsidized. The extent of government involvement is a political decision, and the form and stability of government subsidization plays an important role in the development of most marginal northern fisheries.

Subsidies can take many forms, including capital equipment or operating grants, low interest loans, transportation or wage subsidies, product price supports, and others. The most appropriate form of support is often suggested by the results of a sensitivity analysis.

Because subsidization can foster fishery development where it would not otherwise occur, it is important that it be long-term, perhaps 10 years, and that the level of support be subject to ongoing review. This provides people who depend on the development with a measure of socio-economic stability, and ensures that the level of support is fair. If subsidies exceed a certain critical level, or if the project is not viable after 10 years, then other projects should be examined.

In examining the viability of potential developments, the FJMC should begin with a strictly financial analysis of the projected income and relevant costs of doing business. This will help to identify any need for subsidization. The analysis can then be expanded to include relevant economic costs, like the opportunity costs associated with alternative uses of capital and manpower, and the biological and social costs of development. Spinoff benefits like improved access to resources for subsistence harvest, training, and employment may be very important considerations. The resultant economic analysis may help to support requests for subsidization, and to ensure that Inuvialuit benefit from the development when all factors are considered. In some cases, the social benefits of development may justify a marginal development, but they should not justify one which is biologically unsound.

The opportunity costs of some alternate uses of the Beaufort Sea fishery resource which should be considered by the FJMC include: 1) the values of herring, capelin, and cod to marine mammals, 2) the value of Arctic charr or broad whitefish to subsistence fishermen, and 3) the sport fishery value of Arctic charr.

The evaluation process involves three main steps: 1) a survey of costs and earnings, 2) pre-feasibility analyses, and 3) sensitivity analyses.

Cost and earnings survey

In a new fishery, estimates of the costs of harvesting, production, and marketing, and current market values for the product are needed before economic analyses can be completed. They can be obtained by surveying existing fisheries, local residents and enterprises, and service and marketing agencies. The aim is to determine the cost and return per unit of fishing effort or finished product. These values can then be used to predict breakeven harvests, and to study the effects of different approaches to development.

Table 5. lists the main categories of data required. Many of the specific questions that would be asked in a survey are species or location dependant. They should be clear and concise, and must be tailored to the group being surveyed. Surveys conducted in person are likely to provide more accurate and complete information than those conducted by mail or telephone, particularly where there is a language or literacy barrier. They are also apt to be more expensive. Sometimes these surveys have already

been completed by a government agency (eg. DFO, EDT, FFMC) that may be willing to furnish the necessary information.

Pre-feasibility modelling

Before embarking on fishery development it helps to understand the relationships among costs, revenues, and profits. One way of doing this is to use breakeven analysis to study the volume of product that must be produced to break even given estimates of the operation's fixed and variable from the cost and earnings survey.

The relationship between costs and revenue are illustrated in Fig. 4. For a particular development option, such as a weir fishery for Arctic charr with a small fish plant, the fixed costs are constant. They include plant management and administration, depreciation, interest on debt, land lease, plant start-up and shut-down, and others costs. The variable costs depend on the fishing effort and product output. They include labour, transportation, freight, packing materials, utilities, maintenance and repair, fuel and lubricants, food provisions, and other costs; and increase with the units produced and sold per unit time (eg. kg of frozen charr harvested, processed, and sold per d).

The total costs of the fishery are the sum of the fixed and variable costs. The total revenue also increases with the units produced and sold per unit time, and indicates the price/demand relationship for a firm's product. The point at which the total costs equal the total revenue is the breakeven level of production. In the case of a new fishery development this would be the annual harvest that might sustain a financially viable fishery. In practical applications, the total costs and total revenue relationships are generally assumed to be linear in order to simplify the analysis (Fig. 4). These linear functions are probably reasonably accurate over the output range of interest, but they must be applied with care. The linear model assumes that price for the product is constant. This is seldom the case in the fish market where prices can fluctuate widely depending on quality, supply, and demand. Costs can also vary with the output level. The model does not take into account sharp increases in variable costs that can be caused by overtime, or unanticipated equipment requirements. With this in mind, analyses should be prepared for a range of prices, and cost estimates used in the analyses should be generous. Many of the fixed and variable cost estimates used to calculate the breakeven point will be species and/or area specific.

If results of the analyses suggest that a development might breakeven given a particular harvest level, then the developer may wish to undertake stock assessment research to determine whether the necessary stocks exist, or proceed with a test fishery or pilot project. It is important that the harvest level required to support a viable fishery development be realistically attainable before risking the expense of development.

Pacific herring is one species for which the rough pre-feasibility estimate of the stock needed to support a financially viable fishery might be useful. Similar estimates for broad whitefish and Arctic charr are less useful, since a more accurate commercial assessment is ongoing for whitefish, and stock sizes of accessible charr populations in the area are generally known. The pre-feasibility analysis for herring in Appendix 2. serves as a simple illustration of the process. While only a very rough estimate, it does indicate that a significantly larger stock of herring than has hitherto been located, perhaps 1,000 mt of standing stock, should be identified before development of a fish plant is seriously considered.

Sensitivity analysis

Where pre-feasibility analysis provides a rough estimate of the annual harvest required to sustain a viable fishery, sensitivity analysis uses the biological estimate of the annual sustainable harvest to analyse the outcomes of various projects or strategies. It is a simulation technique that gives a developer a better idea of the financial risk.

The simulation begins with "best guess" estimates of each variable in the fishery, based on the cost and earnings survey, and changes them within reasonable limits to determine which ones most affect profitability. Some variables which might be varied in the sensitivity analysis of a weir fishery for Arctic charr are the number of days fished, catch rate, total harvest, prices paid to fishermen for the charr, labour rates in the fish plant, freight rates, and product market value.

Based on the literature review, Arctic charr is the only species in the study area with stocks whose annual sustainable harvest is known and for which a sensitivity analysis might be worthwhile. Unfortunately, the charr stocks are either heavily exploited by subsistence fisheries, or too small and/or remote to justify the development of a fish plant. Appendix 3. examines the sensitivity of fishermen's wages to fluctuations in the market price for charr, in air charter costs, and in harvest quotas for several possible fishery developments in Prince Albert Sound. None of the development options examined appears to offer good potential for financial viability or a living wage to the fishermen, and the wages are very sensitive to small changes in fish prices or air charter costs. Any development at this time, given the potential for a drop in charr prices and for increases in transportation costs, would be high risk. However, a consideration of economic factors, particularly the subsidization of subsistence activities, may make a small scale fishery at the Kuuk River economically attractive to local fishermen.

CONSTRAINTS TO FISHERY DEVELOPMENT

To accurately assess the potential for fishery development a developer must take into account factors that constrain harvesting, production, and marketing. Fishery developments are constrained by regulatory and political, environmental, biological, social, and economic factors which combine to make each new development unique. They can also be constrained by developments in other sectors of the economy. These constraints are considered in the following sections.

Regulatory and political

The regulatory and political framework within which Canadian fisheries must develop is formulated to safeguard the fishery resource and the public, and help to ensure that the resource is fairly distributed. In the Canadian Beaufort Sea the main agencies involved in fishery development are the Government of Canada, Inuvialuit, and the Government of the Northwest Territories. As yet, they have not agreed on overall development priorities or a development strategy (Topolniski et al. 1987). Brief descriptions of their roles in fishery development follow.

Government of Canada: The Federal Government departments of Fisheries and Oceans (DFO), Indian and Northern Affairs (DIAND), and Industry Science and Technology (ISTC) play important advisory, research, regulatory, and financial roles in northern fishery development. The Freshwater Fish Marketing Corporation, a Federal Crown corporation, is responsible for marketing freshwater and anadromous fish caught in the NWT.

DEPARTMENT OF FISHERIES AND OCEANS: The Central and Arctic Region of the Department of Fisheries and Oceans (DFO) is responsible for the conservation and management of fish resources, and their habitats, throughout the study area. Fish, as used in this context and defined in the **Fisheries Act**, include all life cycle stages of fish, marine mammals, crustaceans, and shellfish. The region is also responsible for delivering services to the people who use or enjoy these resources through the Fish Inspection, Fishing Vessel Insurance, and Small Craft Harbours programs.

The proposed objective of DFO in the Arctic is "To conserve Arctic fish and marine mammal resources, enhance the net value of the economic and social benefits received by Canadians from these resources, and provide for the equitable distribution of benefits" (Department of Fisheries and Oceans 1988). Discussions of the strategy and administrative guidelines that DFO proposes to use to meet this objective can be found in "The Ice Goes Out" (Department of Fisheries and Oceans 1988), and in the "Department of Fisheries and Oceans work plan in support of the Government of the Northwest Territories' Renewable Resource Development Strategy" (Department of Fisheries and Oceans 1989c).

Depletion of the fishery resource, inequitable distribution of the benefits from fishing, development of fisheries which are not financially or economically viable, and the sale of inferior quality product are not in the public interest. It is the task of DFO to prevent the occurrence of these and other problems by regulating fishery development such that it reflects, and occurs within, the operative biological, economic, and social constraints. The Minister of Fisheries and Oceans can do this using provisions of the **Fisheries Act, Fish Inspection Act, Freshwater Fish Marketing Act**, and other statutes. This is a cooperative process with consultation between DFO, the people who use or enjoy the resource, and others who will be affected by resource development. Within the Inuvialuit Land Settlement Area this process is facilitated by the FJMC which serves as a forum for the consultations and advises the Minister on fishery management issues.

New fishery developments in the Beaufort Sea region must be consistent with DFO policies on safe harvesting levels, fair resource allocation, monitoring, inspection, and marketing to obtain licensing and/or federal funding. Proponents of a new fishery development must submit a written development plan to DFO for review before the development will be licensed to proceed. Each proposal must describe the resources to be harvested, fishing methods, and timing of the fishery. It must also address the issues of community support, compatibility with existing fishery management and economic development plans, the adequacy of fish stocks, the potential social and economic benefits, and product quality and marketing.

The Department of Fisheries and Oceans, through the Area Manager, will assist proponents of a fishery development with information and advice. Examples of the assistance include: information on fish stocks and the regulation and allocation of access to those stocks under the **Fisheries Act**; information on landings, prices, and costs from existing fisheries in other areas; information and advice on plant and product inspection requirements under the **Fish Inspection Act**; marketing requirements under the **Freshwater Fish Marketing Act**; and the requirements of DFO's Fishing Vessel Insurance Plan under the **Appropriations Act**.

Important considerations in the review and licencing process include:

1) the level of community support and compatibility with the Inuvialuit Land Claims Settlement;

2) compatibility with fishery management and economic development plans;

3) the productive capacity of the stock to be exploited--which may need to be determined by a cost-shared stock assessment;

4) long-term maximization of the net benefits from fishing and prevention of conflicts between fishery sectors--DFO gives first priority in allocation to native subsistence fisheries (Yaremchuk and Wong 1989), but allocative priorities in land claims settlements take precedence over DFO allocation policy (Department of Fisheries and Oceans 1989c);

5) the potential for long-term financial or economic viability--DFO support and licensing of a development that does not show the potential for financial or economic viability will be conditional on the statement of funding support from the relevant economic and social development agencies;

6) the maintenance of product quality--Fish Inspection Regulations will be applied in a way that facilitates development while assuring the maintenance of product quality;

7) the marketing of freshwater and anadromous fishes consistent with the provisions of the **Freshwater Fish Marketing Act**--fishermen in the Inuvialuit Land Settlement Area are not obligated to market fish through the FFMC due to provisions in the C.O.P.E. agreement; and

8) the elegibility of vessels for coverage under the Fishing Vessel Insurance Plan.

To facilitate management decisions, DFO proposes to measure the benefits of alternate resource uses, and to consider trade-offs among them when management decisions are made (Topolniski 1991). The benefits to conservation, culture, regional development, employment, and economic efficiency would all be examined. The Department is very interested in finding a way to develop an Arctic fishing industry that benefits the people of the region.

OTHER FEDERAL GOVERNMENT DEPARTMENTS: Most of the involvement in new fishery development by other federal departments is in the area of funding. Both the Department of Indian

Affairs and Northern Development (DIAND) and Industry Science and Technology Canada (ISTC) have important roles in funding fishery development in the NWT. The two major initiatives are the Canada-NWT Economic Development Agreement (EDA), and the recently announced Canadian Aboriginal Economic Development Strategy (CADES) (S. Kerwan, pers. comm.).

The EDA purpose is to: "Strengthen the traditional economy while strengthening the linkages to the wage economy through the promotion of responsible development of renewable resources" (Ference and Associates Ltd. 1987). To this end, funds are directed towards renewable resource business development, and product development and test marketing. Program funding runs out on 31 March 1996 (R. Zeiba, pers. comm.).

The CADES replaces several previous programs, including the NWT Special Agricultural Rural Development Agreement (NWT S/ARDA), the Native Economic Development Program (NEDP), and the Indian Business Development Program (IBDP) (Government of Canada 1989). The federal government has committed $873,700,000 to the program over 5 years, beginning in 1989. The funds will be used to foster development of commercial enterprises by Canada's Aboriginal population. Particularly relevant to fisheries developments are the Business Development Component, through which Aboriginal individuals or communities can obtain the capital and support services they require to get started or expand; the Resource Access Component, which will assist them to develop their economic and employment base by gaining access to commercially relevant renewable resources; and the Skills Development Component, which will provide for training.

Access to funding from these programs has to be a major consideration of fishery developments in the study area.

FRESHWATER FISH MARKETING CORPORATION: The Freshwater Fish Marketing Corporation (FFMC) was created in 1969, in response to turmoil in the Canadian freshwater fishing industry (Touchette 1985). The FFMC is a self-sustaining Federal Crown corporation which purchases, processes, stores, and distributes commercially caught freshwater and anadromous fishes from northwestern Ontario, the prairie provinces, and the NWT. It is charged with marketing fish in an orderly manner; increasing returns to fishermen; and promoting international markets for, and increasing interprovincial and export trade in, fish.

Prior to its creation, there were some 30 small, private companies marketing fish in the region now covered by the FFMC (Touchette 1985). A great deal of energy and capital were wasted in duplication of services and, because of their small size, the companies were often at the mercy of large brokerage firms who played them against one another to lower prices (Lyon 1965; Touchette 1985). The small companies were seldom able to take advantage of market fluctuations because they lacked information on market trends, and the capital necessary to hold fish into the winter. Fish prices often fluctuated wildly. A company might do well if there were shortages of a particular product, but fishermen often did not know the price they would receive for their catch until the end of the season. Indeed, by not setting a price at the time of delivery, the companies were able to pass on the risks of marketing to the fishermen. The industry was confused and unprofitable, and fishermen suffered low incomes, poor living conditions, and low morale.

The Freshwater Fish Marketing Act (R.S., c. F-13, s.1) addressed these fishery concerns by establishing a central marketing agency, the FFMC, which is administered by an 11 member Board of Directors. The Board includes representatives of participating provincial and territorial governments, and is advised on matters relating to commercial fishermen by a 15 member Advisory Committee. Both Board and Committee members are appointed by the Governor in Council, and the latter are generally fishermen. Because of its size and financial strength the corporation is better able to compete in the international marketplace than were the small firms (B. Popko, pers. comm.). It can take advantage of market trends by holding onto large volumes of fish and "metering out" the production to maintain good prices through the open water season. This has the effect of increasing returns despite the risks of high inventory. The FFMC can also market fresh fish year-round to take advantage of the low supply and high prices in

January and February, when ice conditions slow or stop east coast fisheries. Fishermen are told before the season begins what they will be paid for their catch, and are paid on delivery--not when the fish are sold.

The FFMC is not a supply management corporation like the egg, grain, and milk marketing boards which purchase on a quota basis. Instead, it must buy all fish that are offered for sale--provided they are of acceptable quality. It does influence fish production through prices, incentive programs, and education, and also controls the product production. If, for example, the FFMC has an ample supply of deboned whitefish, then it may pay a bonus to fishermen who cut back their production and re-direct their efforts toward other products. The FFMC can do this economically because it does not have to pay the costs of holding the excess fish or interest on the money borrowed to purchase the fish (B. Popko, pers. comm.). Without an oversupply it is also in a better bargaining position with the brokers.

In theory, the FFMC is the only purchaser and distributor of freshwater and anadromous fish in the region; in practice, it can make exceptions by issuing special dealers licences (B. Popko and A. Drobot, pers. comm.). These licences can permit fishermen or small fish plants to sell direct to restaurants or stores. They are designed to facilitate local marketing and intersettlement trade. Licences may also be issued for products which are not offered by the FFMC. These are generally value-added products which may be marketed over a wider area--for example Ulu Foods in Inuvik had a licence to market smoked fish. Licences have not been issued for fresh or whole frozen fish products.

Regional fisheries can opt out of the FFMC in order to market their catch privately (B. Popko, pers. comm.). Fishermen from fisheries that choose this course should be prepared to compete with the FFMC in the market place over the long term. They cannot expect to market their catch privately one year and through the FFMC the next, since the FFMC relies on a stable source of supply to develop and service its markets. The introduction of additional marketing agents would likely have the effects of decreasing marketing and production efficiency and fish prices, as infrastructures are duplicated and producers are played off against one another by large fish brokers.

Through provisions in the C.O.P.E. agreement, fishermen in the Inuvialuit Land Settlement area are not obligated to market their fish through the FFMC. The FFMC is willing to work with developing fisheries in the settlement area and to be flexible as marketing strategies and transportation routes evolve during development.

There is sometimes a perception on the part of fishery developers that private buyers offer better prices than the FFMC. In practice this is seldom the case. Private buyers may make a high inital payment and no final payment, require fishermen to bear inventory costs, or simply may not follow through on their offer to purchase.

The FFMC operates like a large cooperative in that it returns corporate profits to the fishermen (Toucette 1985). The initial payment to fishermen, on delivery, is based on 80% of the projected net return per unit weight of a fish species; the final payment is based on the actual net return and paid at year end. Fishermen receive roughly $0.70 on the dollar of fish sold by the corporation (B. Popko, pers. comm.). They are dealt with individually and profits are paid based on individual catches. Arctic charr fisheries are different in that the FFMC buys in bulk from the local cooperatives which pay their costs and then pay fishermen--both for the initial and final payments. The FFMC pays an FOB Winnipeg price which is the same for all fishermen for a given species and grade of fish. Fishermen bear the cost of transporting the fish to Winnipeg, and the FFMC bears the costs of processing, storage, and distribution.

Where in the past fishermen dealt with the FFMC on a confrontational basis--as they were used to dealing with the small fish companies--there is now better understanding of the cause and effect of FFMC activities on their earnings, and growing acceptance of the corporation.

<u>Inuvialuit Final Agreement:</u> In 1984, the Government of Canada and the western arctic Inuvialuit negotiated a comprehensive land claims settlement. Terms of the settlement agreement were set out in the Inuvialuit Final Agreement (IFA) which translates aboriginal title into specific rights to land,

resources, and participation in land and resource management (Yaremchuk and Wong 1989). To facilitate management of the fishery resource within the Inuvialuit Settlement Region, which encompasses the study area, the Fisheries Joint Management Committee (FJMC) was created. This joint Inuvialuit-government committee was established in 1986.

FISHERIES JOINT MANAGEMENT COMMITTEE: Under its terms of reference the FJMC is to allocate subsistence fishing quotas among communities, recommend harvest quotas for subsistence and commercial fisheries, manage the public right to fish on Inuvialuit lands, monitor fish harvesting within the settlement region, and advise the Minister of Fisheries and Oceans on all aspects of fishery management within the settlement area (Fisheries Joint Management Committee 1989; Yaremchuck and Wong 1989). Through the application of conservation principles and practices, the FJMC hopes to protect and preserve the area's fishery resource, and to provide for the optimal harvest by Inuvialuit.

Government of the Northwest Territories (GNWT): The GNWT's role in fishery development is still evolving. Its departments of Economic Development and Tourism (EDT), Renewable Resources (RR), and Health are involved in fishery development.

Economic Development and Tourism has a strong interest in development and works to obtain funding support for fishery development proposals. There are no set funding guidelines but in general there must be evidence, based on a resource assessment, that a development has the possibility of viability before funding is considered (G. Fricke, pers. comm.). The department does not have provisions for funding resource assessment programs, but can support training opportunities and studies of economic viability (S. Ransom, pers. comm.).

Officers from the Department of Renewable Resources (RR) help to enforce the Fisheries Act and to conduct test fisheries. The department also has administrative responsibility for recreational fishing, and may gain responsibility for other aspects of inland fisheries through devolution of authority from the Federal Government. Its role in fishery development is still poorly defined, but it is involved in the review of funding proposals for fishery developments in the NWT (Government of Canada 1989).

Both EDT and RR are implementing agencies under the EDA (R. Zeiba, pers. comm.). They can submit work plans to the EDA for funding of specific regional fishery programs. These plans are assessed by a Fishery Management Committee which makes recommendations to the Policy Committee for funding approval. Project funding is allocated on a regional, sectoral basis.

The GNWT Health Department is preparing guidelines for the regulation of the quality of country foods marketed within the NWT (S. Ransom, pers. comm.). The guidelines for fish will likely be similar to those in the Fish Inspection Act which govern the quality of fish exported from the NWT.

Environmental

Climate and weather dictate that Arctic fisheries are seasonal in nature. They limit the types of fishing equipment that can be used successfully and, by making water-borne or on-ice activity dangerous, they can also limit access to the resource during the fishing period. All of these constraints limit the quantity of resource that a fishery can harvest.

From July through September, winds in the southern Beaufort Sea tend to blow from the east and southeast, paralleling the coast (Parker and Alexander 1983). Wind velocity exceeds 20 km/h over 40% of the time and 40 km/h between 5 and 10% of the time, with the highest velocities generally coming from the west to northwest. Wave height exceeds 2 m for 25% of August and 48% of September, and can reach 6 m. Higher wind velocities and wave heights are more common in September. Visibility is greater than 9 km for about 65% of each of the summer months, and less than 2 km for about 24% of July, 19% of August, and 13% of September.

From July through September, winds in the Amundsen Gulf marine area tend to blow from the east and northwest (Parker and Alexander 1983). Wind velocity exceeds 20 km/h between 50 and 60% of the time and 40 km/h between 10 and 20% of the time--coastal areas near Paulatuk and central Prince Albert Sound are particularly exposed. While sea ice has a damping effect on wave action, wave heights of 1 m are common, and heights of 3 m do occur. Higher wind velocities and wave heights are more common in September. Visibility is greater than 9 km for about 80% of the summer, and less than 2 km for about 9% of July and August, and 5% of September.

Ice and icing are major concerns of fishing vessels operating in the Beaufort Sea and Amundsen Gulf. The extent of ice coverage varies from year to year. During August of a "good" year the entire area may be open water with relatively little drifting ice; during August of a "bad" year drifting pack ice may predominate (Markham 1981; Maxwell 1981). Late ice break-up following a harsh winter can severely constrain summer fishing operations by shortening the season, limiting access to fishing grounds, or limiting the use of towed fishing gear. Vessels operating in the area will have to be reinforced to withstand ice, raising the costs of vessel construction, maintenance, and insurance. Drifting ice will also limit the use of stationary fishing methods such as weirs and traps.

The problem of ice formation on vessel superstructures constrains fishing operations in Amundsen Gulf and the Beaufort Sea in the late summer and fall, when freezing spray can cause potentially serious ice build-up. Parker and Alexander (1983) predicted that ice would form on vessels in open water at a rate of 13 to 15 cm every 24 h, when an air temperature of -10° to -15°C was combined with a water temperature of 0° to +1°C, and wind of 60 km/h. While these temperatures are not unusual in September and October, the wind velocity is seldom maintained over 12 h so that periods of high rates of accumulation should be of relatively short duration. The problem of icy decks and cold crew members remains.

Ice generally clears from southern Banks Island in late June or early July, and nearshore travel in small open boats is possible into September (Sachs Harbour HTC, pers. comm.). Unpredictable weather limits this travel--during July, for example, such travel may be possible for as many as three weeks or as few as one. South, east, and west winds all make small craft travel in the Thesiger Bay area dangerous, and residents think that a larger vessel (>12 m) is the only safe way to conduct a fishery over the long term. Coastal areas north of Sachs Harbour are only accessible for a brief period since the ice there breaks up late in the season.

Coastal small craft travel is possible in the Holman area from mid-July through into mid September (Holman HTC, pers. comm.). Drifting ice limits this travel during July and August, and higher winds and waves limit it in September. A marine test fishery could be conducted in Safety Channel, an area which is sheltered by islands, using 6 m open boats from mid-July through mid-August. About 20 d of fishing could be expected during this period--after the ice leaves and before the weather deteriorates. To improve the safety of small craft travel in the study area, residents often travel together in several boats and cache gas at convenient intervals.

Weather severely hampers coastal small craft travel in the vicinity of Paulatuk (Paulatuk HTC, pers. comm.). Travel along the coast is possible from early July until the second week of September, but small craft are very vulnerable to a north wind. On occasion it has taken the HTC's 10 m Cape Island fishing boat 15 d to make a round trip from Paulatuk to the Horton River (the boat has a ford diesel engine and is used for coastal transportation). Most boats in the community are open and less than 6 m. They could not be relied upon to conduct a safe fishery.

Spring fisheries which use snowmobiles and operate through the ice, or at leads or ice edges, are an alternative to the summer open water fisheries and have been used to conduct the herring fisheries near Tuktoyaktuk. They too are constrained by weather, in particular by blizzards which affect visibility or by combinations of strong winds or warm temperatures which cause rapid ice deterioration or ice shifting--making travel unsafe. Low temperatures can also affect spring and fall weir fisheries for migrating anadromous fishes by causing ice build-up on the weirs which can lead to their washing-out.

Biological

While the fishery resource is renewable, it is also finite and can be depleted. Two major considerations of any developing fishery in the Beaufort Sea-Amundsen Gulf area must be the biological productivity and the species diversity, both of which are low relative to biological communities that support competing southern fisheries.

The main determinant of marine productivity in the Arctic Ocean is the vertical stability of the water masses (Dunbar 1970). The greater the vertical stability, the less the biological production. In the Beaufort Sea area, freezing and melting of the surface layer and large inputs of fresh water from the Mackenzie River both act to dilute the surface waters, increasing density stratification and therefore vertical stability. This traps deep nutrient-rich waters and leads to chronic low productivity. Availability of these inorganic nutrients appears to be the main limiting factor, except perhaps near shore where the disruptive effects of temperature and salinity fluctuations and ice scour may also limit primary (Parsons et al. 1988) and secondary productivity (Wacasey 1975).

Water masses in the Beaufort Sea are still being characterized, but nutrient rich upwellings have been described in Herschel Basin on the east side of Herschel Island (MacDonald et al. 1987), the Cape Bathurst polynia, Mackenzie Bay, and east of Cape Bathurst (M. Lawrence, pers. comm.). Other areas which the HTCs describe as biologically rich include Safety Channel near Holman, the Cape Kellett and Nelson Head areas near Sachs Harbour, and Darnley Bay near Paulatuk. These are the areas most likely to offer marine commercial fishery potential. They are also important marine mammal and seabird habitat.

Wacasey (1975) recognized four benthic zones in the Beaufort Sea. He characterized them as follows:

Zone	Water Depth (m)	Salinity (ppt)	Temperature (°C)	Species per Station	Biomass mean [range] ($g\ m^{-2}$)
Estuarine	0-15	0.1-20	up to 20	1-32	2 [0.1-20]
Transitional	15-30	20-30	7.0 to -1.58	20-40	5 [1-20]
Marine	30-200	30-33	-0.1 to -1.58	3-81	14 [1-72]
Continental Slope	200-900	34-35	-0.31 to 0.40	31-53	4 [1-8]

Unstable conditions of temperature, current, and salinity, physical disturbance by ice, and low nutrients may interact to limit both productivity and species diversity within and across the zones (Wacasey 1975).

Species descriptions in the literature review (see Section 1) illustrate the low growth and reproductive potential of fish and invertebrates in the study area. Individuals tend to grow slowly, mature late, and be long-lived; the reproductive season is short, and many species do not spawn annually following maturity. Together, these factors suggest that the populations will be slower to recover from overharvesting than their southern counterparts. They may also be more succeptible to depletion by fishing, since a fishery for Pacific herring roe, for example, would require 2 or 3 times the standing stock of a competing British Columbia fishery to sustain the same harvest. A high standing stock does guarantee a large sustainable harvest if that stock is unproductive. Slow growth to a relatively small maximum size also precludes the development of successful mariculture operations for most invertebrate species.

Anadromous species, such as Arctic charr, are particularly succeptible to overharvesting since harvesters can accurately predict where and when to catch them each year. This vulnerability is compounded by the fact that their feeding, migrating, or overwintering populations may consist of a number of genetically distinct stocks which spawn at different locations or times (Reist 1989). During their life cycles these mixed populations may be vulnerable to harvest by several fisheries. Depending upon their movements and rates of growth and reproduction some stocks may be more vulnerable to overharvesting than others. To ensure equitable and sustainable exploitation of each stock, the composition of mixed stocks and the life history and movements of individual stocks must be known.

Because the species diversity is low, food chains in the study area tend to be short and are therefore more succeptible to disruption than more complex biological communities (Percy 1975; Wacasey 1975). Depletion of one species may lead to the starvation of other species which depend upon it for food and are unable to find a substitute. This may be particularly the case with small, relatively abundant species like Pacific herring, Arctic cod, and capelin which are preyed upon by many piscivorous fishes, birds, and marine mammals. The depletion of one of these prey species could have far-reaching biological and socio-economic consequences.

The likelihood that species in the Beaufort Sea will be vulnerable to, and slow to recover from, overharvesting makes it imperative that harvest levels be set on the basis of good biological data, and that harvesters adhere to harvest quotas. Further food chain and stock assessment research and good cooperation between fishery managers and fishermen will be necessary to properly meet these needs, and to safeguard the resource.

Social

For a successful fishery to develop there must be people willing to work at a variety of jobs, and they must have the discipline necessary for the long hours of work. There must also be support from other members of the community who are not directly involved in the fishery but whose help may be needed on occasion. With long term participation and support a fishery is much more likely to be successful--the Cambridge Bay fishery which was described earlier is a good example.

In 1986, Sachs Harbour had a population of 158, Holman 303, Paulatuk 193, and Tuktoyaktuk 929 people (Government of the Northwest Territories 1988). Small populations in the first three communities, and the availability of alternate employment in Tuktoyaktuk, limit the number of skilled and unskilled workers who might be interested in seasonal, fishery-related work. However, commercial fishery development would be more compatible with the traditional Inuit lifestyle than may other forms of employment and could be community-based.

While a physical plant may or may not be necessary, good management is vital to the success of a developing fishery. Qualified, dedicated personnel are necessary to coordinate harvest logistics, ensure product quality, communicate with buyers, manage inventory, arrange transportation of the product to market, and collect receivables (Copestake 1986). In a small operation all these functions can be handled by one or two people. The challenge is to find and train suitable candidates.

Training requirements and opportunities will depend on the type and scale of fishery development. Where fishermen and other workers involved in a small charr fishery might be trained on-the-job, those involved in an offshore marine fishery or in operating complex, value-added processing equipment may need to attend training courses or to apprentice with other fisheries. People wishing to participate in a fishery development should also be willing and able to undertake the required training if the fishery is to succeed.

Conflicts with traditional subsistence fisheries must be an important consideration of fishery developers and can constrain development. Subsistence harvests generally take precedence over sport and commercial harvests. They are important to the social structure and economy of the Beaufort Sea communities, and their magnitude can preclude or limit commercial harvests--particularly for species such as Arctic charr in rivers near the communities. The long term social and economic benefits that accrue from a healthy subsistence fishery must not be jeopardized for the sake of a short term, or marginally economic, commercial fishery development.

During the community consultation process meetings were arranged with the HTC's in Sachs Harbour, Holman, and Paulatuk to assess local interest in fishery development. A general outline of the topics discussed at these meetings is found in Appendix 4.

Sachs Harbour: The HTC meeting in Sachs Harbour took place on 16 March 1989, and was attended by John Lucas Sr. (President), Earl Esau (Vice President), Andy Carpenter (Secretary Treasurer), Roger Kuptana, Roger Lucas, and Geddes Wolki (Board Members), Floyd Sidney (Resource Person), Joanne Carpenter (Secretary), Peter Sidney, and Larry Carpenter (Members).

Those present expressed strong interest on behalf of the community in fishery development, particularly in opportunities for charr fishing in the Jessie Bay area, and marine fisheries in the Thesiger Bay and Nelson Head regions. Other areas mentioned for charr were East and West lakes and the Thomsen River--which were test fished in the winter of 1987-8 with limited success, and the De Salis Bay area.

They estimated that 25 men and women in Sachs Harbour might be interested in working on a fishery, and that of these people 6 to 10 might seek oil-related employment if oil development increased. Members were very interested in the possibility of training opportunities.

There is little local fishing or history of marine fishing. Fishing occurs mainly in August, during the upstream run of Arctic charr, about 7 km upstream from the mouth in the Sachs River and at the mouth of the Masik River. Most of the fish are harvested for human consumption.

Cod are jigged at ice leads in the spring, mostly to feed the town's 8 or 9 dog teams. They are the only marine fish harvested and are generally small--probably Arctic cod. Fishermen also reported catching large "cod" on occasion which weighed up to 10 kg. It identity of these fish is not known. Fishing effort is low and the unpredictable catch was attributed to lack of knowledge of species movements rather than to a lack of cod. The flesh is apparently free of parasites.

Members also reported the occurrence of large schools of capelin in the area, large concentrations of seashells on beaches in the Nelson Head and Cape Kellet areas, and the presence of starfish, blue mussels, and small sea urchins, octopus, squid, and crabs. Shrimp were only mentioned in passing and were described as small, 4-5 cm in length, although they did describe "lobster" about 15-20 cm in length but without large pinchers--perhaps large shrimp. Herring had been caught occasionally but were not thought to be numerous or common. Seals had been seen chasing schools of small fish--perhaps sandlance. One interesting description was of red "herring shit" on the beaches of Thesiger Bay in August. The real origin of this substance is unknown, but it was apparently eaten by gulls. Members of the HTC believed that the sea must be very rich in the Thesiger Bay area to support the numerous seals and bowhead, and that with research commercially exploitable stocks might be found.

No-one in the community had marine commercial fishing experience. The only boats were the 6 m open aluminum boats used for hunting seals and coastal travel. The community freezer was too expensive to operate and had been shut down. It needed to be insulated and to have the door seal fixed. Processing equipment on order for the muskox harvest might have some use in a commercial fishery.

In terms of studies to be conducted, the HTC wanted to identify charr stocks with potential to supply the community (ie. double the current supply). However, members did not want to have to pay for the fish harvested. When asked what they would be willing to pay to recover air charter costs to Jessie Bay or another area, they responded that if they had to buy the fish they would go somewhere nearby and catch them for free, "only people with waged employment can afford to buy charr". For marine species, they preferred research by a large vessel (>12 m) in the Thesiger Bay-Nelson Head area. Alternatively, a small scale test fishery might be performed during the summer, or at the ice edge or ice leads in June using jigs or longlines. They were interested in possibilities for cooperative research with Holman or Paulatuk fishermen at Nelson Head.

Members did not express strong feelings on the sort of development organization, preferring to take the best bet for funding, whether private or public. In either case they wanted the fishery to employ local people.

Holman: The meeting in Holman on 22 March 1989, was attended by John Kuneyuna, Lena Olifie, and Joseph Haluksit (Board Members), Gibson Kudlak (Resource Person/Secretary), and Noah Ahkiatak (HTC Member).

Interest in Holman was centred on anadromous Arctic charr, for which there were ongoing test fisheries in the Prince Albert Sound area and others planned in the Minto Inlet area. They reported "whitefish" in the Kagloryuak River, in Tahiryuak Lake, and in lakes near the outlet of the Kuujjua River--each of which were subsistence fisheries.

Some cod, flounder, and herring are caught as a by-catch during summer coastal charr fisheries, but there has been little history of marine fishing in the area. The cod, "Arctic and rock", are sometimes split and dried. Most are eaten by the older people. Herring are seldom caught in the large mesh charr nets but are also eaten occasionally. Flounder are generally thrown away. Schools of herring sometimes occur offshore Holman in the fall. Blue mussels are apparently present, as are small crab and flounder. No scallops, lumpfish, or large shrimp were identified.

The preferred area for a marine test fishery is Safety Channel which would be accessible by 6 m open aluminum boats from Holman from mid-July until mid-August. About 20 d of fishing could be expected during this period--after the ice leaves and before the weather deteriorates. They thought that testing for turbot could be undertaken from late May to mid-June at the lead that forms offshore the west coast of

Victoria Island, and that Walker Bay might also be tried as a marine test fishery.

There were two larger vessels in Holman, George Okheena and Roy Inuktalik's 11.5 m wooden motor vessel "Patricia" which had not been in the water for several years, and Harold Wright's 10 m twin-masted, steel-hulled sailboat "Nur". Both vessels were used to haul freight, and the latter was used for Arctic College's summer marine camp. There was a community freezer, and there were walk-in freezers at the Hudson's Bay Company store and Co-op Hotel. The community freezer operated in summer at -30°C--residents each had boxes in the freezer. There was also an ice house, but no ice maker.

If a fishery were developed, the preferred organization would be a community co-operative--the HTC would appoint a manager. No one had marine commercial fishing experience. They anticipated that 15 or 20 people might be interested participating in a commercial fishery or in a small marine test fishery, and believed that those people would be unlikely to leave such a fishery if oil development increased.

Holman fishermen sell charr to the local Co-op Hotel, and have also sold them to Ulu Foods in Inuvik (see Appendix 3).

Paulatuk

The meeting in Paulatuk on 20 March 1989, was attended by Peter Green (Secretary), Steve Illasiak (Director), and Charlie Ruben and Jim Wolki (Members).

Those present expressed interest in testing inland lakes for lake trout and landlocked charr with sport fishery development in mind. They were also interested in having lakes on Parry Peninsula tested for anadromous charr. Sport fishing opportunities at the Hornaday River were also discussed. Fish in the river are apparently larger and more numerous since the commercial fishery was shut down. However, fall angling is not always effective at the river mouth where unpredictable fall runoffs cause high water turbidity. Most of the communities' subsistence fishing activities take place at the river.

No one in the community has experience in marine commercial fisheries and there is little local history of marine fishing. Cod and herring are sometimes angled from shore or jigged from boats during the summer, and eaten. Small crabs (8 cm across the body) occur in the area, and flounder weighing up to a kilogram are sometimes caught. Those present did not know of shrimp or clams in the area.

The members were interested in a survey of marine fishes in Darnley Bay and in participating in any test fishery. However, as discussed earlier, weather severely hampers small craft travel along the coast which is exposed to the north wind. Residents do not fish through ice leads, but do fish at shore moats in early June.

The community freezer operates mainly in summer. It is not a flash freezer and is shared by community residents. During the charr fishing season it is slow to freeze due to the volume of fish to be frozen. There is no ice maker.

Those present thought that any fishery development would be best organized as a co-operative through the HTC, since the HTC has an established organizational framework. Perhaps 30 or 40 community members, all ages and both sexes, might be interested in participating in some way in a commercial fishery development or marine test fishery. If oil development increases, five of these people might seek employment with the oil companies. Young men might be interested in fishery related training opportunities.

Economic

The economics of harvesting, production, and marketing from a remote location will place major constraints on fishery development in the Beaufort Sea-Amundsen Gulf area. Not only is the area far from major markets, it is also far from suppliers and maintainers of equipment. Where a southern fishery can make a local telephone call to a freezer repair firm and receive same-day service, or can truck its product to market; a northern fishery may have to make an expensive long distance phone call and wait weeks for parts or service personnel, or have to air freight its product to market. Some of these constraints can be lessened by good management, but the manager may also need to be imported.

New fishery developments in the study area will not be able to take advantage of existing processing facilities, nor in most cases of existing buildings. Since most developments require some type of facility to handle the catch this means that a new facility may have to be constructed. Its extent would depend on the scale and type of fishery, and on the product to be marketed. A winter fishery, where Arctic charr are lake frozen and marketed either locally or to the FFMC, may not require any facility. A summer fishery, where the charr cannot be frozen on site, may require a re-packing operation with cold storage facilities and an ice maker, or a small fish plant. The Arviat fishery operates on the former and Cambridge Bay on the latter. Both of them ship dressed charr to the FFMC for distribution. A fishery that plans to export value-added products, such as smoked or canned charr, directly to southern markets may require a sophisticated, mechanized fish plant.

The costs of constructing and operating a processing facility in the Arctic are high relative to southern locations. Building materials, freezers, and processing equipment must all be imported from the south, and the only qualified service personnel are often based in the south. The importation of these materials and services takes time and money. Heat and electricity are expensive, since they depend on imported oil, and water must often be trucked from nearby lakes, raising the cost and limiting availability--particularly in winter. Because the cost of living in arctic Canada is high, and because the major employers are governments and the oil industry, wage expectations in the study area may be high relative to comparable southern fisheries.

It is unlikely that a new fishery could develop successfully in the Arctic while bearing the costs of constructing and operating even a modest fish plant. Indeed, most of the fisheries reviewed operated at a deficit despite government capitalization. These operating deficits generally have the effect of reducing payments to the fishermen, making fishing only marginally economic and thereby reducing interest in the fishery.

The Cambridge Bay fishery is an exception. It relies on anadromous Arctic charr which can be harvested using simple equipment, require little processing, and command a good price on the current market. Careful operational and contingency planning, regular maintenance of the facilities and equipment, attention to cost saving opportunities and quality control, and the sharing of established management (Arctic Co-ops) and marketing (FFMC) infrastructures also contribute to the operation's success. These were detailed in the review of Arctic commercial fisheries (see Section 1).

Because northern markets are small, even modest-sized fisheries need to develop an export market for their product. A remote location magnifies the marketing problems that every fishery experiences with respect to the costs of shipping product to market, communication with buyers, predictable product supply, timely product arrival, and product freshness. Not only are communications and product delivery more expensive, they are also more involved and subject to the vagaries of weather. Few southern markets are prepared to put up with uncertain product supply, untimely arrival, or variable quality. This puts small, remote fisheries in a very difficult marketing position.

Developing northern fisheries also face high transportation costs when marketing their product. Where their southern competitors have a choice of transportation modes and carriers--each anxious to secure their business by offering competitive prices and service, a northern fishery seldom has these options. Transport of the product to market in the south is generally accomplished by a single carrier, whereas remote northern fisheries often have to rely on several carriers and/or modes of transportation. Most fisheries in the Beaufort Sea-Amundsen Gulf area will have to airfreight their product at least part of the way to market. This is expensive and only economic for species such as charr which have a relatively high market value per unit weight. Sealift backhauls are another option, but harvests must be coordinated with the annual sealift or significant holding costs may be incurred. Mackenzie Delta fisheries may be able to take advantage of less expensive truck backhauls.

By associating with established, successful management and marketing infrastructures such as Arctic Cooperatives Ltd. and the FFMC, a new fishery can avoid many of the pitfalls of northern development. These corporations have the advantages of scale, including greater efficiency, working capital, negotiating clout, and management depth and expertise and they have established contacts and markets. They are already dealing constructively with many of the factors that constrain fishery development and, because they operate essentially as cooperatives, these benefits can be obtained at an acceptable cost.

Where a relatively large Arctic fishery like Cambridge Bay may export 40 or 50 thousand kilograms of fish each year, the FFMC markets millions (B. Popko, pers. comm.). In order to maintain and improve its market share the corporation is constantly responding to changes in the market, placing it in a much better position to respond to these changes than a small, remote fishery. The FFMC approach to the marketing of Arctic charr is particularly interesting to developing Arctic fisheries, and serves to illustrate some of the economic considerations of northern fisheries development.

The marketing challenge with Arctic charr is to generate more production and greater local economic development; the problem is to maintain high prices given the greater availability (Fraser 1985; B. Popko, pers. comm.). The market for Arctic charr is largely North American, mainly within Canada in areas where the species is known and liked. It is sold to the "white table cloth market" in major southern cities where charr have the reputation as an exotic fish. There are upper price limits to this market, beyond which premium grades of salmon are substituted for charr. This means that there is little or no leverage created on prices by low inventories of charr.

It is vital to market development that only premium quality charr reach the consumer, and it is uneconomic for fishermen to ship less than premium quality fish to market. When the FFMC receives non-marketable fish it does not pay the fishermen an initial or final payment. The fish are thrown out and the fisherman has to pay the costs of transporting the fish to the FFMC. When the FFMC receives charr that are not premium quality it may trim fatty areas where fat leaching is occurring to salvage the fish (B. Popko, pers. comm.). This will result in a lower payment to the fisherman who must pay for trimming. These fish are generally steaked and sold to employees at a lower price.

To maximize return on charr sales the manager marketing the fish follows the international market trends to take advantage of short-term market fluctuations, and seasonal trends. For example, if cod are being "dumped" on the east coast and distributors are tying up their money in cod, there may be little demand for a specialty fish like charr and consequently a low price. Winter prices for many freshwater fishes are often twice those paid for the same fish marketed in the summer. A few weeks can make a significant difference in the return to the producer.

High prices for wild charr are proving difficult to maintain given increasing market competition from wild and cultured salmon, and cultured charr. Cultured salmon are available year-round, they are relatively inexpensive, and of predictably high quality. In 1991, the inital FFMC payment for fresh charr dropped to $7.70/kg from $8.81/kg in 1988, and for frozen charr it remained at $6.61/kg except in the smallest size range, where it dropped to $4.95/kg (B. Popko, pers. comm.). Wild Arctic charr were significantly more expensive than cultured salmon which sold in Winnipeg retail stores for only $3.33/kg. Indeed, in Seattle it was cheaper to buy pink salmon than hamburger (Globe and Mail 1991).

In Europe, competition from salmon and charr aquaculture has reduced both the market and price paid for wild lake trout (B. Popko, pers. comm.), and probably also for wild charr. Large Arctic charr cultured in Iceland and Norway are just now entering the United States market. Small cultured charr may cause consumer confusion, but are more likely to compete with cultured trouts in the supermarkets--largely because of their small size.

One way the FFMC has tried to maintain prices in the face of increasing competition and production is by marketing more fresh charr (B. Popko, pers. comm.). This is difficult because buyers such as the large supermarkets do not understand the production problems caused by weather. They require guaranteed quality and arrival. When they advertise a special on fresh Arctic charr and the charr do not arrive on time they do not buy again. Restaurants can afford to be more flexible, but their menus are often printed annually. To circumvent this problem the FFMC printed up table cards so that restaurants can advertise fresh Arctic charr as they become available. Charr marketed fresh must reach the FFMC within 24 hours of being caught.

In 1988, the premium on fresh dressed charr was $2.20/kg ($1.00/lb). With this premium it was economically attractive for fisheries to ship fresh charr and the FFMC could still make a profit after having to freeze 20% of the fresh fish (B. Popko, pers. comm.). In 1991 the premium on fresh dressed charr was $1.20 ($0.50/lb), and it was uneconomic for fisheries to ship fresh fish packed in ice. The FFMC would prefer that all of the charr were upstream fall migrants, rather than spring downstream migrants which are often in poorer condition, but this is impractical from the fisherman's standpoint.

There may be a general move away from fresh marketed fish in supermarkets because of low profits due to spoilage and the necessity for hiring qualified staff (B. Popko, pers. comm.). The FFMC is well positioned to take advantage of opportunities in the frozen market. In 1991, the cost of holding fish in the FFMC freezers was about $0.033/kg/month plus the interest cost on the fish purchase. Low fat fishes like walleye store best and higher fat fishes such as whitefish, Arctic charr, and lake trout can only be stored dressed 8 to 12 months.

The costs and financial risks of long term product holding and product development are prohibitive for a small, remote fishery. By taking advantage of the more efficient, mechanized FFMC processing facilities they can significantly reduce their capital and operating costs, while still taking advantage of market trends.

The FFMC has produced several value-added charr products, including lox, smoked charr, vaccum packed charr steaks, and charr roasts. None of these products has met with success. Charr dry out at the required smoking temperature for lox and are more expensive than salmon or trout; the quality of smoked charr is variable, perhaps due to the mixing of spring and fall caught fish which have different fat contents; and vaccum packed steaks and roasts of charr have not met with good consumer acceptance.

Unlike a small producer, the FFMC is able to undertake extensive advertising campaigns to boost fish sales. Arctic charr are advertised as coming from the cleanest and coldest waters. To maximize returns, most ads are placed in trade journals and aimed at brokers rather than the retail market (B. Popko, pers. comm.). While consumers are willing to pay a premium for fish that they perceive to be from pristine waters, this premium generally does not compensate for the higher production costs of a northern fishery (D. Topolniski, pers. comm.). There is little product loyalty, and this is increasing as the variety of products increases.

Market price fluctuations make the export of species that have a relatively low landed value per unit weight, such as whitefish, marginally economic at best in the Arctic. In 1989, for example, the initial FFMC payment for dressed medium whitefish was $1.08/kg in summer (May) and $1.87 in winter (December) (B. Popko, pers. comm.). Since whitefish fishermen generally needed to make $0.88/kg after transportation costs to operate at a profit, and could not rely on a large final payment ($0.44/kg in 1989), they had very little money left to cover the costs of transporting the fish to market. The whitefish fishery in the Mackenzie Delta region is severely constrained by transportation costs, and very vulnerable to a drop in the market price or increase in production or transportation costs. Indeed, at current prices even government subsidized truck backhauls are a prohibitively expensive means of shipping these fish from the Mackenzie Delta to the FFMC.

Marine fisheries cannot rely on the FFMC to search out markets, package and distribute their product, or ensure timely payment. This makes the infrastructure costs of developing Arctic marine fisheries higher than those for fresh water fisheries. A developing marine fishery in the Beaufort Sea would have to produce sufficient quantities of fish products to develop a market for Arctic sea products with their own reputation for quality, and to allow cost effective transportation.

The seasonal nature of fishery employment and the vulnerability of fishery developments to market price fluctuations make it worthwhile for developers to consider diversifying their harvest and/or product. These same problems make fisheries an uncertain economic base for a community.

Technological

Fishery developments in the Beaufort Sea area may also be constrained by conflicts with other developments, in particular oil and gas exploration and development, agriculture, mining, and hydroelectric development (Rosenberg 1986; Bodaly et al. 1989). It is difficult to quantify potential interactions on the basis of existing information and in the absence of an established commercial fishery with known harvest locations and target species.

A number of potential impacts of oil and gas development on fisheries in the Beaufort Sea area are being evaluated in the Beaufort Environmental Monitoring Program (LGL et al. 1985, 1987; ESL et al. 1986, 1988, 1989), Mackenzie Environmental Monitoring Program (LGL et al. 1988), Northern Oil and Gas Action Program (Griffiths et al. 1988), and the Endicott Development Fish Monitoring Program (LGL 1989). The primary goals of these programs are to identify valid potential impacts of oil and gas development in the Beaufort Sea and Mackenzie Delta areas, and to develop research and monitoring programs to better identify the location and nature of any impact so that hydrocarbon reserves in the region can be developed responsibly. Major concerns are: 1) the release or discharge of hydrocarbons or heavy metals from exploration or production facilities--particularly those near shore, which may result in tainting of fish flesh and increased heavy metal bioaccumulation, 2) the construction of causeways or other structures which could disrupt the nearshore band of warm brackish water and thereby the movements and habitat of broad whitefish and Arctic cisco, and 3) increased fishing pressure through improved access which could decrease the abundance of fish--particularly the anadromous species, and affect their distribution.

Agriculture and forestry developments are unlikely to have direct affects on the Beaufort Sea fish resource, but the possiblity of long-range air or water borne transport of pollutants does exist (Alexander 1986). Potential commercial species should be screened for heavy metals and chlorinated hydrocarbons before a fishery is allowed to develop, early in the stock assessment process.

Mining developments are unlikely to have a significant impact on fisheries in the Beaufort Sea-Amundsen Gulf area provided that any proposed developments are subjected to the environmental review and assessment process, and that mine operation is monitored to ensure compliance with licensed limits. Most potential mine sites in the Mackenzie River Basin are situated well inland and in the headwaters (Mackenzie River Basin Committee 1981).

There are many potential sites for hydroelectric developments and diversions along the Mackenzie River and its major tributaries. At least eight dams exist in the Mackenzie basin including those in the Lake Athabasca (2), Peace River (2), and Great Slave Lake (4) sub basins, and others are planned (Mackenzie River Basin Committee 1981). Flow regulation by these structures has the potential for severe environmental disruption in the area of the Mackenzie Delta and estuary (Rosenberg 1986). Of concern to potential Beaufort Sea fisheries are: 1) the potential effects of seasonally altered flows on access by migratory species to small delta lakes for spawning, feeding, or overwintering, and 2) changes to the pattern of ice break-up and formation.

RECOMMENDED APPROACH TO FISHERY DEVELOPMENT

Figure 3. illustrates the approach we recommend for the assessment and development of fishery opportunities.

Fishery development is catalysed by an expression of interest in development. If there is the political and/or economic will to proceed, the next step is to determine whether information that is necessary to assess development potential is already available or whether it must be collected. This involves literature reviews and discussions with biologists, economists, and others to learn what is known about fishery resources, fishery economics, and constraints to development in the study area. Gathering and interpreting that information is an important aspect of this FJMC project which is in direct response to interest expressed by the Inuvialuit.

Resource assessment research may be undertaken where the existing information is insufficient to assess fishery potential. Often this will include basic biological research to differentiate between stocks and learn their biology. Economic pre-feasibility modelling is not a substitute for biological research, but it can be used to direct it by identifying which species might support a viable commercial fishery, and at what level of harvest given the current economic climate.

Fishery developments are constrained by regulatory and political, environmental, biological, social, and economic factors which combine to make each new development unique. They can also be constrained by developments in other sectors of the economy. The effects of these constraints on harvesting, production, and marketing need to be considered if a developer hopes to accurately assess the potential for fishery development.

An economic evaluation of fishery viability can be prepared once data on the sustainable annual harvest, projected costs and earnings, and constraints to development are available. It involves the preparation of scenarios which enable developers to make informed decisions on whether to proceed with development, and on the optimal type of development if it does proceed.

Unfortunately, this approach to development is seldom followed, largely due to the high costs and time delays associated with stock assessment research. This is particularly the case when the proponents are not risking their own capital and have little incentive to safeguard funds, or when they are under political pressure to proceed with development. The current broad whitefish fishery in the lower Mackenzie River is an example of a fishery development where the economics are being examined before the stock size, productivity, or level of subsistence harvests have been determined. This sequence of development raises the potential for damage to stocks with the associated long term economic and social consequences.

A better approach would be to obtain accurate estimates of the annual sustainable harvest and the annual subsistence harvest for each target stock. This would require biological research to characterize the target stocks and to quantify their harvests by subsistence fisheries. An economic evaluation could then be used to determine whether, given their biological productivity and other constraints, the stocks might be capable of sustaining a viable commercial fishery. If such a development appeared possible, then the political considerations of how best to proceed with commercial development should be settled before proceeding further.

PART 3. A FISHERY DEVELOPMENT STRATEGY FOR THE CANADIAN BEAUFORT SEA AND AMUNDSEN GULF

The purpose of this section is to suggest rationale for fishery development by the Inuvialuit and to make specific project recommendations.

DEVELOPMENT RATIONALE

Fishery developments in the Canadian Beaufort Sea-Amundsen Gulf study area should be compatible with the lifestyle, culture, and aspirations of the Inuvialuit. They should only proceed when they: 1) have the support of the people, 2) are consistent with the principles of conservation, and 3) optimize benefits to the Inuvialuit. This necessitates the polling of public opinion, pre-development stock assessment research, and careful weighing of project costs and benefits.

Our discussions with the HTCs in Holman, Paulatuk, and Sachs Harbour suggest that the interest in fishery development is centred upon marine mammals and anadromous fishes, less so on marine fishes and invertebrates. The Inuvialuit have a long tradition of harvesting marine mammals and anadromous fishes, and still harvest them extensively. They have little tradition of harvesting marine fishes or invertebrates, and little knowledge of them. This is due in large part to the environmental constraints placed on small boat operation. Their interest in marine fishery development appears to stem more from a desire for employment opportunities, than a specific desire for marine fishery development.

Conservation means the maintenance of the fish resource so that it may continue to provide benefit to Canadians--not simply preservation of the resource (Topolniski 1991). To proceed with development in a manner consistent with the principles of conservation requires knowledge of the annual harvest that a stock can sustain without damage, and of the present harvest of that stock by competing fisheries. Otherwise, fishery development may deplete the stock and cause long term damage to other species and fisheries which depend upon it, directly or indirectly. Since there is no proven marine resource base on which to develop a commercial fishery, the FJMC is left with three main options: 1) to support biological stock assessment research, 2) to prepare pre-feasibility analyses, or 3) to seek development opportunities in other areas (Fig. 3).

Biological research has identified commercially attractive species in the study area but has not found stocks capable of sustaining a viable commercial fishery. Further data on species presence, abundance, life history, and productivity are required before realistic assessments of commercial potential can be made. However, most of the existing data are from a small geographic area, shallow depth, and summer sampling. This raises the possibility that other commercially attractive species may be present, and that stocks capable of sustaining a viable commercial fishery may exist despite the many constraints.

These questions can only be addressed through biological research which is expensive, difficult, and offers no guarantee that a viable opportunity will be discovered. That being the case, it is important to assess the costs and the potential longterm benefits of research before proceeding further.

There is a perception that for a fishery to be successful, it must create jobs processing fish. Rather, the successful fishery is one which provides a good economic return to the fishermen. If this can be acheived, the fishery will flourish and further development will occur naturally (Van Hyning 1979). Processing facilities will be established when they can be justified, and development will not be stunted by high overhead costs.

The importance of small fisheries which supply local markets should not be discounted. They may offer better potential for economic viability than export fisheries. Fishermen with proven production capacity who are involved in these fisheries should be encouraged by modest front-end grants which allow them to improve their harvesting technology on a basic level through the purchase of more seaworthy boats, new motors, safety equipment, and better nets.

Research directed at protecting or enhancing existing resources on which subsistence fisheries depend may offer greater economic benefit over the long term than research directed at fostering commercial fishery development. Initial research should concentrate on species with high value which require little processing and can be harvested using simple methods (eg. blue mussel, Arctic charr).

Pre-feasibility modelling is relatively fast and inexpensive, but is not a substitute for biological stock assessment. It can be used productively to direct research and development away from species--for example those with a low market value per unit weight such as Arctic cod or lake whitefish, which are commercially attractive but cannot support a viable commercial fishery in the study area. It can also be used to provide a rough estimate of the annual harvest necessary to support a fishery. Estimates of the costs associated with harvesting, production, and marketing and product market values which are necessary for modelling are often species specific. Some can be obtained from existing fisheries while others are area specific--both can be obtained through surveys.

Constraints posed by the harsh environment, low biological productivity, conflicts with existing fisheries and other species, and high costs make it unlikely that a viable marine export fishery will develop in the near future. However, development opportunities are likely to improve with time, as transportation routes develop, northern population increases, and the climate improves. In the interim, developments in other areas such as sport fishing and the support of existing local fisheries may offer a better return.

PROJECT RECOMMENDATIONS

Projects are recommended to examine opportunities in the areas of: 1) sport fishery development, 2) resource enhancement, 3) resource monitoring, and 4) marine resource identification.

Sport fishery development

Stocks of anadromous Arctic charr in Prince Albert Sound and Minto Inlet are either exploited by subsistence fisheries or are too small to support a viable commercial fishery. Ongoing test fisheries in the region may discover commercially viable stocks, but in our opinion this is unlikely given the high transportation costs and infrastructure requirements. However, unlike other marine fish and invertebrate the size and productivity of these charr stocks is known, or under investigation.

The Kuuk River, in Prince Albert Sound supports a stock of at least 9,000 anadromous Arctic charr. These fish are in superb condition but few grow larger than 6.5 kg. This means that the area will not support a viable commercial export fishery or attract trophy fishermen. However, it is very scenic and might be successfully developed as a naturalists camp that advertises the remoteness, wildlife, historical sites, scenery, and fishing. In this way, a modest sport fishery operated on a catch-release basis using barbless hooks, and limiting the number of fish that a fisherman takes south, might offer good financial returns to the community. Properly managed it should offer little risk to area subsistence fisheries.

The Kuuk River mouth is accessible by air or water (preferably large boat) and offers good camping sites. The setting is also very scenic and abounds with wildlife. Caribou and foxes will come right into camp, there are large herds of muskox nearby, interesting bird species are present, sik siks are ubiquitous, and seals visit the estuary to feed. Nature tours could show guests historical hunting sites, take them to the sea ice, on photographic tours to see the muskox or falcons, or across the sound to fish at the Kagluk or Naloagyok rivers.

The community already caters to sport hunters, why not sport fishermen? The interest is there, there are experienced guides and cooks, the Co-op operates a comfortable hotel, there is the added attraction of a fine artists cooperative, and sound management might be available at reasonable cost through a joint venture with the Inuvialuit Development Corporation (Guided Arctic) or Arctic Cooperatives Limited.

If the FJMC decides to investigate this sport fishing opportunity we recommend:

1) a summer field study (catch-release) to determine for what period of the summer fish are biting at the river mouth and to map area attractions; and,

2) a survey of the potential costs and earnings associated with sport fishery development.

The Inuvialuit Development Corporation and Arctic Cooperatives Limited should also be contacted to establish whether they might be interested in participating in a sport fishery development.

Since there has already been a resource assessment, it remains to conduct a feasibility analysis to assess whether the development is likely to be viable and, if so, to prepare a business implementation and operating plan. A month-long angling and area survey, cost survey, and feasibility analysis might cost $40,000. The best funding opportunity for a sport fishery development near Holman is likely through the EDA.

There is also interest in inland sport fishery development near Paulatuk, at headwater lakes on the Horton River.

Resource enhancement

Anadromous Arctic charr populations in the study area are unable to support a viable commercial fishery at present, and some are unable to support the present level of subsistence harvest. A possible solution to this problem is to increase the number of charr populations with access to the sea.

Before they were isolated by isostatic rebound following the Wisconsin glaciation, charr that inhabit coastal lakes in the study area had an anadromous component to their populations. When their route to the sea was cut off the charr were confined to the lakes and "landlocked". Since a fraction of each charr population has the capacity to become anadromous (Nordeng 1983), this process should be reversible simply by making the waterway that connects one of these lakes to the sea navigable to charr.

This project would be most attractive where a single, modest barrier could be circumvented to allow charr in a large lake freedom of movement to and from the sea. The barrier must be surmountable using a fish ladder or other means, the lake must have a reproducing charr population that is not subject to winterkill, and the connecting river should have good water depth and flow. If the lake is near a community so much the better. The result would be to increase the food resources available to the population, increasing producitivity, and creating a "new" stock of anadromous Arctic charr which could be exploited once it becomes established.

This sort of project may have strong local support, since much of the interest in fishery development is centered about Arctic charr. Its cost will depend largely on the site. If there is interest in this type of enhancement, then discussions should be held with the HTCs to identify potentially suitable sites, followed by on-site assessments, costing, and possibly construction. If it is successful the project will have long term benefits to the area. At the least it will support traditional subsistence harvests, and at best foster commercial fishery development. Indeed, commercial exploitation at a fish ladder might be very efficient and lead to an excellent product.

Resource monitoring

Ongoing development of a commercial broad whitefish fishery in the lower Mackenzie River may threaten the regional subsistence fishery for the species, since fishery managers lack the necessary information to determine what level of harvest the stock or stocks can sustain. Indeed, this is a difficult problem to address due to the wide dispersal and mixing of anadromous stocks, the presence of both anadromous and non-anadromous stocks, and other factors. If this development continues, it will be important to monitor the subsistence harvest for evidence of stock damage.

Promoting cooperation between DFO and the Inuvialuit Harvesting Study is a good way for the FJMC to help protect the Tuktoyaktuk broad whitefish subsistence fishery. Improving cooperation between the Harvest Study, which has the information, and fishery managers, who need the information, will help in the early detection of change which is vital to effective fishery management. The inclusion of site specific harvest and catch effort data, efforts to improve tag returns, and other cooperative measures would also facilitate fishery management. A survey of fishing costs throughout the area, as part of the Harvest Study, might be useful for assessing the economics of future fishing opportunities.

Another means of affording protection to the subsistence fishery is to mount a research study on one of the main streams near Tuktoyaktuk (eg. Freshwater Creek or Kugyuktuk) to monitor recruitment and harvesting levels of broad whitefish. To be effective it should be long-running (10 years) so that natural changes can be distinguished from harvesting impacts; it should run throughout the open water season--June through September; include a camp of 4 monitoring the upstream and downstream runs 24 h/d; and have a biological live sampling and tagging program that is coordinated with the Harvest Study. This should give information on population composition and size and on the rate of exploitation by subsistence and commercial fisheries at Tuk and upstream. This information might then be extrapolated.

Costs would depend on location. A study on Freshwater Creek might cost $145,000 per annum in 1992 dollars over each of the 10 years. A less ambitious study of only the large broad whitefish, which constitute the bulk of the harvest and of the spawning population, might operate from the first week of July until the end of the first week in August and cost $85,000/yr. Costs might be reduced if DFO provided a biologist/manager and undertook the data analyses.

Both of these studies are more in the realm of safeguarding the subsistence fishery than fostering commercial development, but each may have longterm economic benefit to the area. If the rate of exploitation permits, economic assessment results from the ongoing commercial developments are positive, and there is local interest, then the FJMC might conduct a feasibility analysis of comercially fishing broad whitefish at Tuktoyaktuk.

Marine resource identification

Deep water winter test fishery: Virtually nothing is known of the deep water fishery resource in the Canadian Beaufort Sea. A relatively inexpensive method of deep water sampling is by fishing with longlines at the ice edge in an area where there is deep water. Because there has been very little deep water sampling in the study area, this might turn up commercially attractive species that have not yet been reported. If it did, economic data might be obtained from the Pangnirtung turbot fishery and other sources for pre-feasibility modelling. If modelling suggests that a fishery might be viable given reasonable harvest levels, and there is good local interest, then further test fishing could be undertaken to gauge resource availability, interest, costs, and markets.

While the potential for fisheries development may be low from this type of project, so are the financial stakes. The initial test fishery would require the purchase of two hand-operated line haulers, expenditures for general fishing gear and bait, rental and operating costs for two or three snowmobiles with komatiks, wages for two 2-man crews, and either contract costs for an experienced fisherman/biologist or transportation and accomodation costs for a DFO biologist. A six-week test fishery might be undertaken for between $60,000 and $70,000.

Two deep water areas which might be tested are the spring ice lead across the mouth of Prince Albert Sound, near Holman, and the spring ice edge south of Sachs Harbour. In the initial test, all of the fishes caught should be identified and scientifically sampled for growth parameters, a subsample of each species should be preserved for subsequent confirmation of identification by the National Museum of Canada, and flesh from the remainder could be test marketed locally, or in Inuvik. DFO will likely analyse age data and might provide biological assistance given current lack of information from the area.

Summer exploratory fishery: There are several opportunities for summer exploratory marine research, including joint charters with DFO, EDT, or private fishermen. Marine research using large vessels capable of deep water sampling is very expensive (>$15,000/d), as is the purchase and outfitting of a competent research vessel (>$5,500,000). The research capabilities of small open boats are very limited.

Nutrient rich upwellings that have been described in the Beaufort include the Cape Bathurst polynia, Herschel Basin on the east side of Herschel Island, Mackenzie Bay, and the east side of Cape Bathurst. These are the areas most likely to offer marine commercial fishery potential. There is local interest in testing Safety Channel near Holman, the Thesiger Bay and Nelson Head areas near Sachs Harbour, and Darnley Bay near Paulatuk which the HTCs think may also offer potential. Species with a high landed value that require little processing and are simply harvested offer the best potential for viability.

Cooperative research opportunities with DFO will depend on the levels of program funding and on whether the unseaworthy "Salvelinus" is replaced by a new research vessel. DFO Central and Arctic Region does not undertake formal analytical marine stock assessments, but might welcome the opportunity to join the FJMC in a cooperative offshore research program.

Two general approaches are possible to a joint charter: 1) a biphasic charter where the first half is devoted to FJMC exploratory fishing in the areas of prime interest to the communities, and the second half is devoted to DFO research on Beaufort Sea ecology, or 2) a collaborative program that meets both needs at once. This former approach is simple to design and would provide information useful for scientific appraisal of the resource, the latter is more difficult to conceive and design but might be more productive over the long term.

In either case the emphasis should be on optimal use of program support each year. This will require flexibility on the part of the participants since weather or other unforseen conditions may eliminate portions of the research program in any given year. Financial arrangements for a joint charter or research program would require discussion. DFO already has a substantial capital investment and would probably be providing the expertise and manpower.

Privately operated commercial fishing vessels might also be attracted to the Beaufort Sea-Amundsen Gulf area to undertake a commercial test fishery. This type of fishery requires DFO licensing with strict sampling guidelines and conditions including having a DFO observer aboard--generally at the proponent's expense. Whether a commercial west coast fishing vessel could be attracted to the Beaufort on speculation remains to be seen; chartering a vessel in the 15 to 20 m range for a modest research program would cost upwards of $2,000,000.

EXECUTIVE SUMMARY

BACKGROUND

During the Fishery Joint Management Committee's (FJMC) annual "community tour", in 1987, the Hunters and Trappers Committees (HTC) in Sachs Harbour and Holman expressed interest in developing new and existing fisheries in their areas. In response the FJMC initiated this study. It consists of: a review of literature on invertebrates and marine and anadromous fishes in the Beaufort Sea-Amundsen Gulf area; discussions of representative commercial fisheries in Arctic Canada and reasons for their success or failure; general recommendations on how fishery development should be approached; a discussion of the factors that constrain commercial fishery development in the Beaufort Sea-Amundsen Gulf area; and project recommendations. Its purpose is to assess the potential for commercial fisheries and consider the options for fishery development in the Canadian Beaufort Sea-Amundsen Gulf area. It is also intended to provide a reference for area resource planners and managers.

COMMERCIAL HARVEST POTENTIAL

Biological research has not found fish or invertebrate stocks in the study area that are sufficiently abundant, productive, and/or valuable that they are capable of sustaining a viable commercial export fishery. Information on the occurrence, harvest, and landed value of fishes is summarized in Table 4.

Research efforts have been concentrated between Herschel Island and Cape Parry. Because of their importance to the area economy, there has been strong emphasis on coastal anadromous fishes while coastal marine fishes and invertebrates have received less attention, and offshore resources remain virtually unknown. Notably lacking from the literature are site specific data on the harvests by subsistence fisheries, without which it is impossible to determine whether a stock might also sustain a commercial harvest. Few of the biological studies have been directed toward marine fishery development, or have been conducted in winter.

Cambridge Bay's Ikaluktutiak Cooperative operates the only long-running fishery in Arctic Canada that exports fish at a profit. It relies on anadromous Arctic charr which can be harvested using simple equipment, require little processing, and command a good price on the current market. Careful operational and contingency planning, regular maintenance of facilities and equipment, attention to cost saving opportunities and quality control, sharing of established management (Arctic Cooperatives Ltd.) and marketing (Freshwater Fish Marketing Corporation) infrastructures, strong community interest, and government cooperation also contribute to the operation's success.

Only anadromous Arctic charr and turbot have supported or now support economically viable commercial export fisheries in Arctic Canada. Charr stocks in the study area are either heavily exploited by subsistence fisheries or are too small and/or remote to justify commercial development; turbot have yet to be reported from the study area.

Invertebrate species have not supported economically viable commercial fisheries in Arctic Canada. While there is interest in the commercial harvest of scallops, mussels, urchins, and sea cucumbers, individuals of these species generally grow slower and to a smaller maximum size in Arctic waters than do their southern counterparts.

Several species in the Beaufort Sea might offer commercial harvest potential given either larger stock size and/or improved production and marketing economics. Pacific herring and broad whitefish offer perhaps the best opportunities, but neither species should be commercially exploited until stock assessments have been completed and subsistence harvests are known.

STRATEGY FOR DEVELOPMENT OF A FISHERY

Fishery developments in the study area should be compatible with the lifestyle, culture, and aspirations of the Inuvialuit. They should only proceed when they: 1) have the support of the people, 2) are consistent with the principles of conservation, and 3) optimize benefits to the Inuvialuit. This necessitates the polling of public opinion, pre-development stock assessment research, and careful weighing of project costs and benefits.

Socio-economic factors may justify the development of a marginal fishery but they should not be used to justify one which is biologically unsound. To reduce the biological and economic risks, stock assessment research should precede commercial fishery development. It may include basic biological studies to describe the stocks, movements, and life histories of target species. Pre-feasibility economic analyses can be used to direct research towards species with the best economic potential, and sensitivity analyses to assess the viability of potential developments once a commercially exploitable resource has been identified. Beginning with analyses of financial factors and proceeding to analyse economic factors which take into account the biological and social costs of fishery development will enable the FJMC to identify any need for subsidization, and to better assess the costs and benefits of a development to the Inuvialuit.

Harsh environmental conditions, low biological productivity, conflicts with existing fisheries and other species, and the high costs and difficulty of harvesting, production, and marketing from a remote Arctic location will severely constrain fishery developments in the study area. The seasonal nature of fisheries employment and the vulnerability of fishery developments to market price fluctuations make it worthwhile for developers to consider diversifying their harvest and/or product. These same problems make fisheries an uncertain economic base for a community. Development of sport fisheries and fostering of subsistence or small local commercial fisheries will likely offer better long-term economic benefits to the Inuvialuit than development of a marginal commercial export fishery. There is no guarantee that research will discover a commercially exploitable stock.

Lacking a proven resource base, the FJMC has two logical options if it wishes to pursue fishery development. It can support biological stock assessment research in the hope of locating a commercially exploitable stock, or seek development opportunities in other areas such as sport fisheries. Our discussions with the HTCs suggest that interest in fishery development is centred upon marine mammals and anadromous fishes, less so on marine fishes and invertebrates.

With these factors in mind we propose that the FJMC not proceed with commercial fishery development but instead conduct research to examine opportunities for:

1) sport fishery development: at the Kuuk River, Victoria Island, where the anadromous Arctic charr and other attractions may offer a better economic return than commercial fishery development with less risk to the subsistence fishery;

2) resource enhancement: through streamflow modifications to give landlocked stocks of Arctic charr access to the food resources at sea, thereby increasing system productivity, and creating a new anadromous stocks;

3) resource monitoring: aimed at safeguarding the Inuvialuit subsistence fishery for broad whitefish which and may be damaged by commercial fishing in the lower Mackenzie River; and

4) marine resource identification: through winter deep water studies and summer offshore exploratory research to assess the distribution, abundance, and productivity of potentially exploitable offshore species.

The difficulty and high cost of stock assessment research programs and fishery development in the Beaufort Sea-Amundsen Gulf area make it vital that interested parties such as the FJMC, Department of Fisheries and Oceans, GNWT Department of Economic Development and Tourism, and others formulate an overall research and development strategy and work cooperatively towards its completion.

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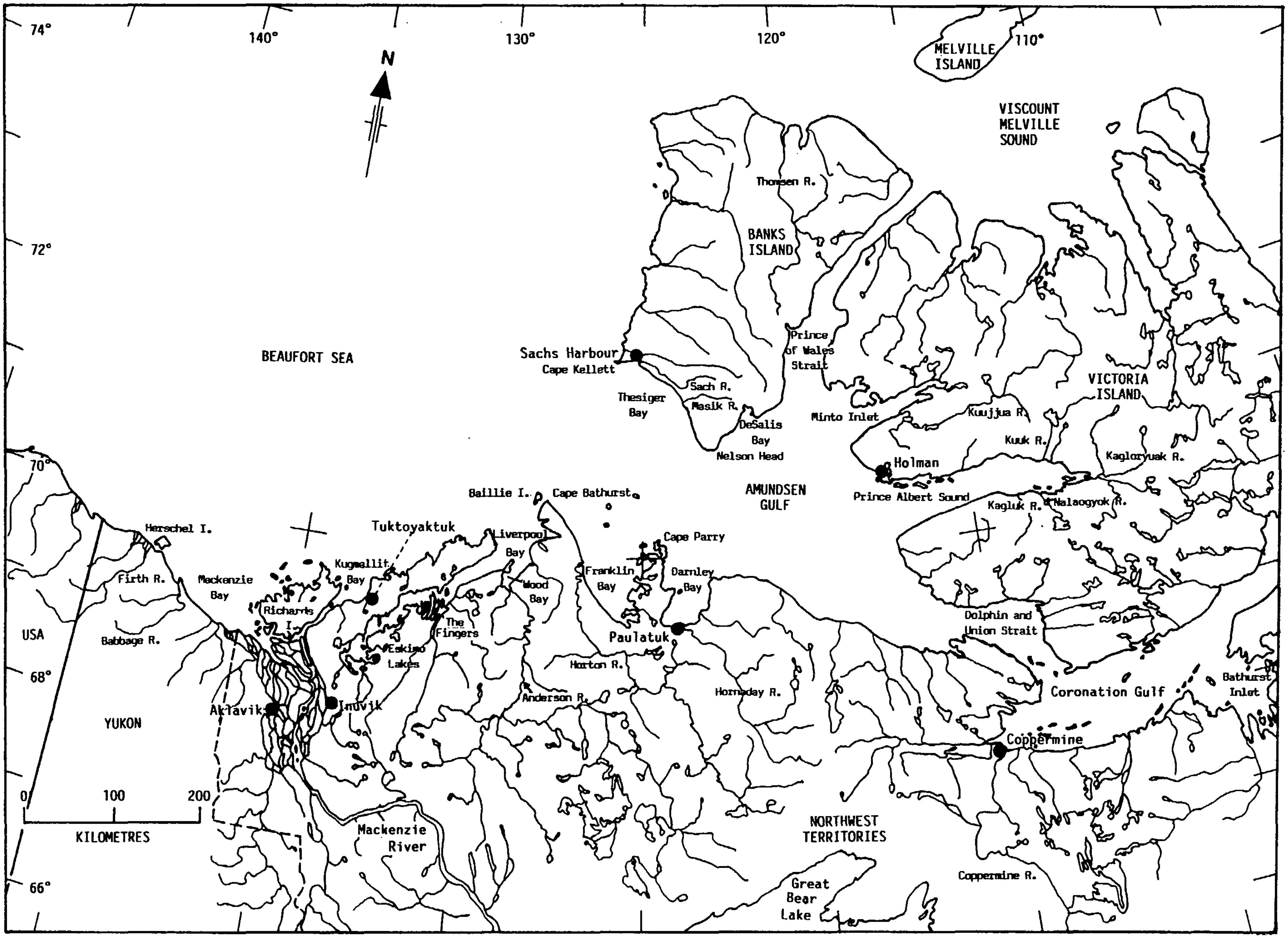

Figure 1. Map of the Beaufort Sea-Amundsen Gulf area.

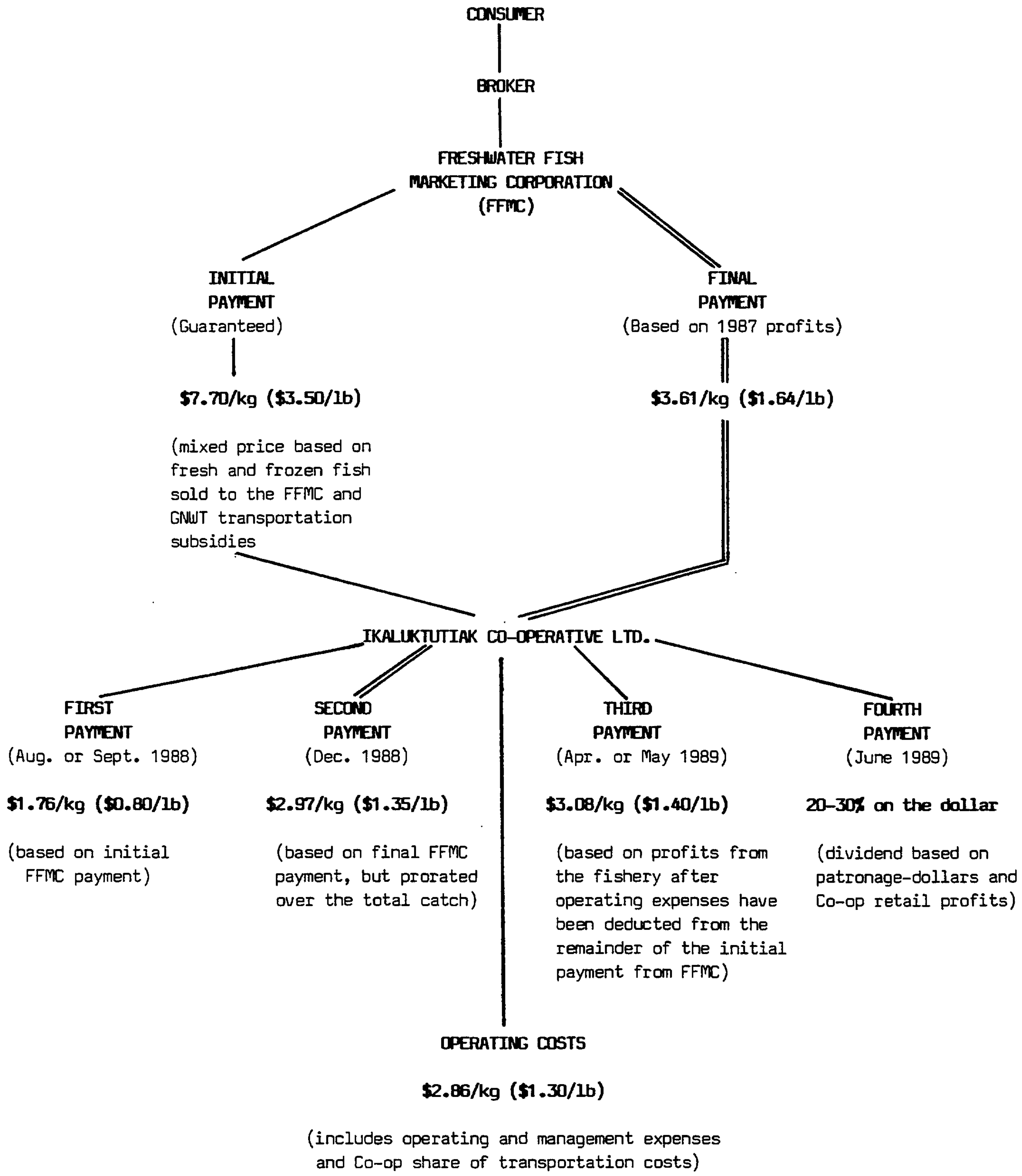

Figure 2. Schematic of payments received for Arctic charr by Cambridge Bay commercial fishermen.

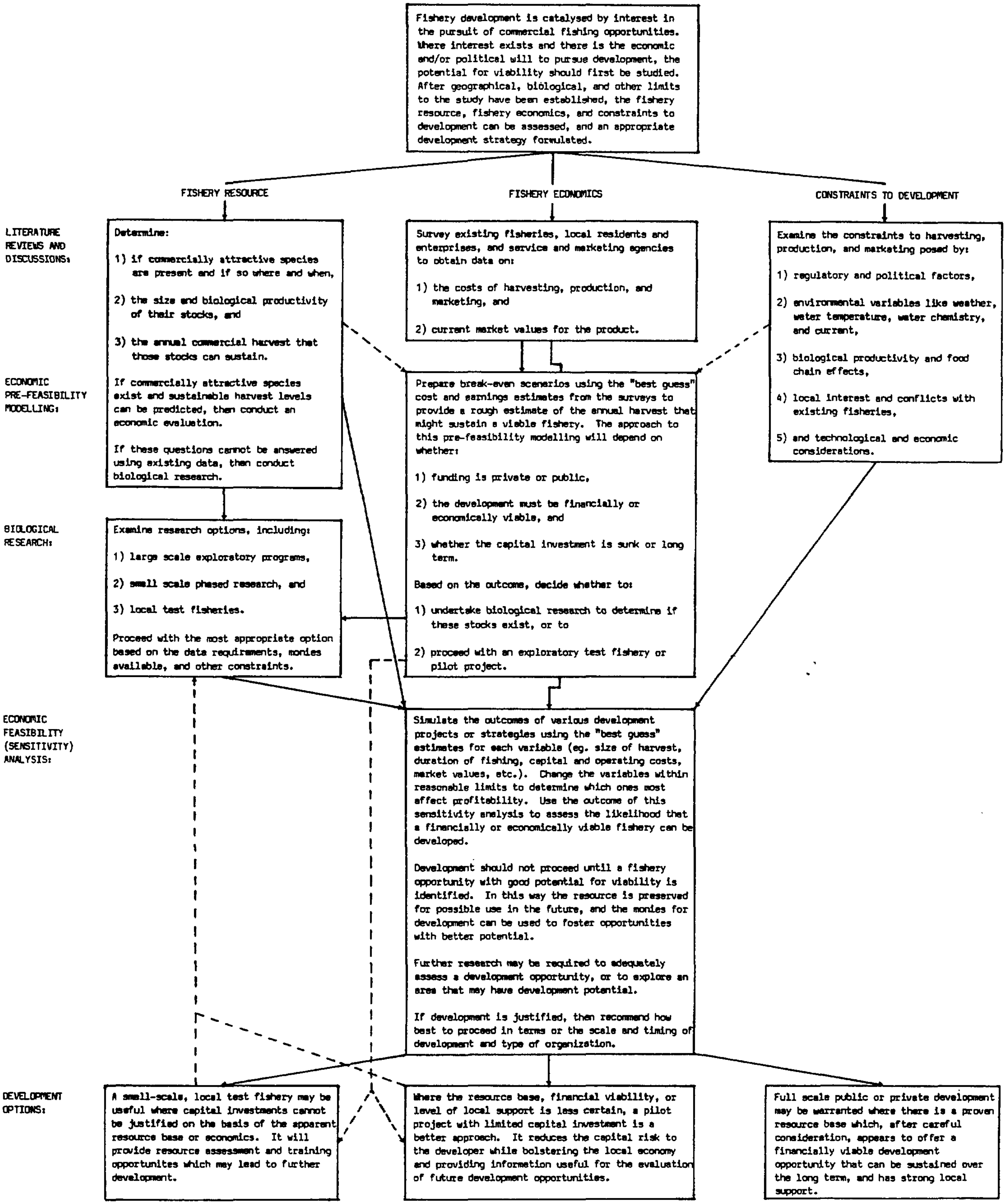

Figure 3. Recommended approach to fishery development. Solid lines indicate major, and dashed lines minor, pathways in the development process.

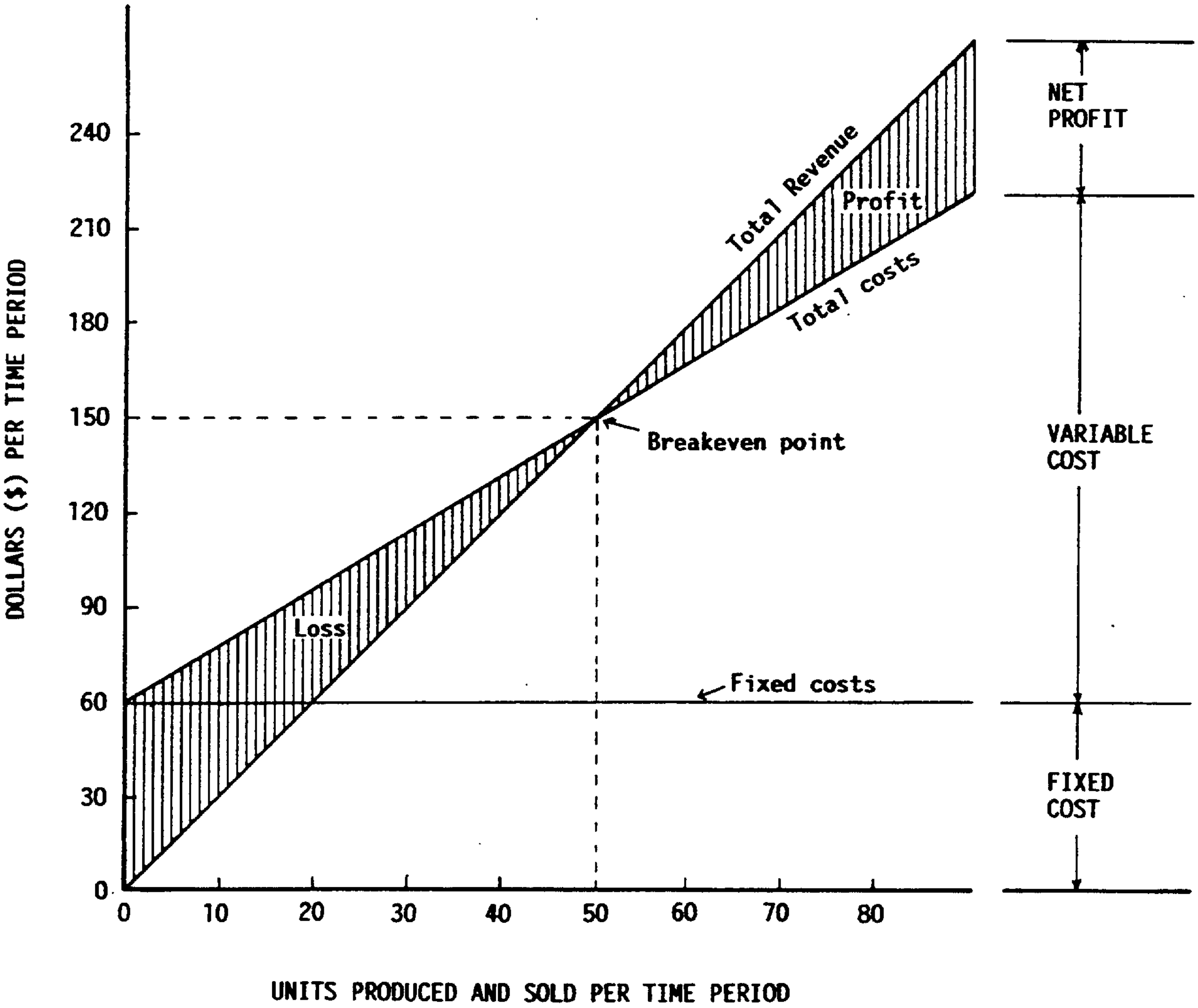

Figure 4. A linear breakeven chart illustrating the relationships between fixed and variable costs, total revenue and total costs, and profit and loss.

Table 1. Bivalve molluscs reported from the Beaufort Sea and east into Amundsen Gulf.

Family/Species	Wacasey 1975	Wagner[1] 1977	Bernard 1979	Lubinsky 1980	Frost Lowry 1983	Arctic Labs.+ LGL 1987	Wainwright et al. 1987	Atkinson +Wacasey 1989
F. Nuculidae								
Nucula belloti	X	-	X	X	-	X	X	-
Nucula mirabilis	-	-	-	-	-	-	X	-
Nucula tenuis	-	X	-	-	X	-	X	-
Nucula zophos	-	-	X	-	-	-	-	-
F. Malletiidae								
Malletia abyssopolaris	-	-	X	-	-	-	-	-
F. Nuculanidae								
Nuculana belloti	-	-	-	-	-	-	-	X
Nuculana minuta	X	X	X	X	X	-	X	-
Nuculana pernula	X	X	X	X	X	X	X	X
Nuculana radiata	-	-	X	-	-	-	-	-
Portlandia arctica	X	X	X	X	-	-	X	X
Portlandia sulcifera	-	-	-	X	-	-	X	-
Portlandia yoldiella	-	-	-	-	-	-	X	-
Yoldia hyperborea	X	X	X	X	X	-	X	X[2]
Yoldia myalis	-	X	X	-	X	-	-	-
Yoldia scissurata	-	-	X	-	-	-	-	-
Yoldiella fraterna	X	X	X	-	-	-	X	-
Yoldiella frigida	X	X	X	X	-	X[3]	X	-
Yoldiella intermedia	X	X	X	X	-	-	X	X[2,3]
Yoldiella lenticula	X	X	X	-	-	X[3]	X	-
Yoldiella tamara	X	-	X	X	-	-	X	-
F. Arcidae								
Bathyarca frieli	-	X	-	-	-	-	-	-
Bathyarca glacialis	X	X	X	X	X	X	X	X
Bathyarca raridentata	-	-	X	-	-	-	-	-
F. Mytilidae								
Crenella decussata	-	-	X	-	-	-	X	-
Crenella faba	-	-	-	-	-	-	X	-
Dacrydium vitreum	X	-	X	X	-	X	X	-
Musculus corrugatus	X	X	X	X	X	-	X	X
Musculus discors	X	-	X	X	-	-	X	X
Musculus discrepans	-	-	-	-	-	-	X	-
Musculus laevigatus	-	-	-	-	-	-	X	-
Musculus niger	X	X	X	X	-	-	X	X
Mytilus edulis	X	-	-	X	-	-	X	X
F. Pectinidae								
Chlamys pseudislandica	-	-	X	-	-	-	-	-
Delectopecten greenlandicus	X	-	X	X	X	-	X	X

Table 1. Continued.

Family/Species	Wacasey 1975	Wagner[1] 1977	Bernard 1979	Lubinsky 1980	Frost Lowry 1983	Arctic Labs.+ LGL 1987	Wainwright et al. 1987	Atkinson +Wacasey 1989
F. Astartidae								
Astarte borealis	X	X	X	X	X	-	X	X
Astarte crenata	X	X	X	X	X	-	X	X
Astarte eliptica	-	-	-	-	-	-	-	X
Astarte esquimalti	-	-	X	-	-	-	-	-
Astarte montagui	X	X	X	-	X	-	X	X
Astarte warhami	-	-	-	X	-	-	-	-
F. Carditidae								
Cyclocardia crassidens	-	-	-	-	X	-	-	-
Cyclocardia crebricostata	-	-	X	-	-	-	-	-
Cyclocardia ventricosa	-	-	-	-	-	-	X	-
F. Limidae								
Limatula hyperborea	-	X	X	-	-	-	-	-
F. Montacutidae								
Boreacola vadosa	-	-	X	-	-	-	X	-
Montacuta dawsoni	-	-	X	-	-	-	-	-
Montacuta maltzani	X	-	-	-	-	-	X	-
Mysella planata	-	X	X	-	-	-	-	-
Mysella tumida	X	-	X	-	-	X	X	-
F. Thyasiridae								
Axinopsida orbiculata	-	X	X	X	-	-	X	-
Axinulus careyi	-	-	X	-	-	-	-	-
Thyasira dunbari	-	-	-	X	-	-	-	-
Thyasira equalis	-	-	X	-	-	-	-	-
Thyasira flexuosa	-	X	-	-	-	-	-	-
Thyasira gouldii	X	-	X	-	-	X	X	X
F. Cardiidae								
Cerastoderma echiantum	-	X	-	-	-	-	-	-
Cerastoderma elegantulum	-	X	-	-	-	-	-	-
Clinocardium ciliatum	X	X	X	X	X	-	X	X
Serripes groenlandicus	-	X	X	X	X	-	X	X
F. Veneridae								
Liocyma fluctuosa	X	X	X	X	X	-	X	X
Liocyma viridis	-	-	X	-	-	-	-	-
F. Tellinidae								
Macoma balthica	X^2	X	X	-	-	-	X	X^2
Macoma calcarea	X^2	X	X	X	X	X	X	X^2
Macoma crassula	-	-	-	-	-	-	X	-
Macoma inconspicua	-	-	-	X	-	-	X	-
Macoma loveni	-	X	X	-	X	-	X	-
Macoma moesta	X^2	X	X	X	X	-	X	X
Macoma planiuscula	-	-	-	X	-	-	-	-
Macoma torelli	X	X	-	-	-	-	X	-

Table 1. Continued.

Family/Species	Wacasey 1975	Wagner[1] 1977	Bernard 1979	Lubinsky 1980	Frost Lowry 1983	Arctic Labs.+ LGL 1987	Wainwright et al. 1987	Atkinson +Wacasey 1989
F. Myidae								
Mya arenaria	-	-	-	-	-	-	X	-
Mya pseudoarenaria	X	X	X	-	-	-	X	-
Mya truncata	-	X	X	X	-	-	X	X
F. Hiatellidae								
Cyrtodaria kurriana	X^2	X	X	X	-	-	X	X^2
Hiatella arctica	X^2	X	X	X	X	-	X	X^2
Hiatella striata	-	-	X	-	-	-	X	-
F. Pandoridae								
Pandora glacialis	X	X	X	-	-	-	X	X
F. Lyonsiidae								
Lyonsia arenosa	X	X	X	X	-	-	X	X
Lyonsia schimkewitschi	-	X	-	-	-	-	-	-
F. Periplomatidae								
Periploma abyssorum	X	-	-	X	-	-	X	X
Periploma aleutica	-	-	X	-	-	-	-	-
F. Thraciidae								
Thracia devexa	-	X	X	X	-	X	X	X
Thracia myopsis	X	-	X	-	-	-	X	-
F. Cuspidariidae								
Cuspidaria arctica	-	-	-	X	-	-	-	X
Cuspidaria glacialis	-	-	X	X	X	-	-	-
Cuspidaria subtorta	-	-	X	-	-	X	-	-
F. Verticordiidae								
Lyonsiella uschakovi	-	-	X	-	-	-	-	-

[1] Living mollusc species, fossils not included.

[2] Atkinson and Wacasey (1991) from fish stomachs.

[3] Identified as *Portlandia* = *Yoldiella*.

Table 2. Tonnages of mollusc species landed by Canadian and other northwestern Atlantic and northeastern Pacific fisheries in 1989 (from: FAO 1991).

Species	Canada	Other[1]
Atlantic Ocean		
whelks (Busycon spp.)	nil	2,330
periwinkles (Littorina spp.)	276	1,735
American cupped oyster (Crassostrea virginica)	2,293	31,526
blue mussel (Mytilus edulis)	866	24,089
sea scallop (Placopecten magellanicus)	91,553	113,138
ocean quahog (Arctica islandica)	216	191,746
surf clam (Spisula solidissima)	9,417	164,125
hard clam (Mercenaria mercenaria)	216	22,026
soft shelled clam (Mya arenaria)	2,593	14,485
miscellaneous clams	178	8,546
longfin squid (Loligo pealei)	nil	22,999
northern squid (Illex illecebrosus)	2,280	10,895
miscellaneous molluscs	581	1,175
Pacific Ocean		
abalones (Haliotis spp.)	43	126
Pacific cupped oyster (Crassostrea gigas)	3,700	26,671
butter clam (Saxidomus giganteus)	3,435	nil
geoduck clam (Panopea generosa)	3,914	3,300
octopus	155	nil
miscellaneous molluscs	3,898	2,491

[1] United States fisheries contributed the largest percentage to the landed tonnages.

Table 3. Decapod crustaceans reported (X) from the waters of Arctic Canada and the western Beaufort Sea.

Species	Western Arctic Beaufort Sea						Central Arctic				Eastern Arctic				
	A[1]	B	C	D	E	F	G	H	I	J	K	L	M	N	O
SHRIMP															
Acanthephyra pelagica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
Argis dentata	X	-	X	X	X	X	-	X	X	X	X	X	X	-	X
Argis lar	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-
Bythocaris leucopsis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
Bythocaris payeri	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X
Crangon communis	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-
Crangon septemspinosus	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X
Crangon sp.	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-
Eualus fabricii	X	-	X	-	-	-	X	X	X	X	X	X	X	X	X
Eualus gaimardi	X	X	X	X	X	X	X	-	X	X	X	X	X	-	X
Eualus macilentus	X	-	X	-	-	-	-	-	-	X	X	-	X	-	-
Eualus stoneyi	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-
Eualus suckleyi	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-
Eualus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
Lebbeus borealis	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
Lebbeus groenlandicus	X	-	X	X	-	X	X	X	-	-	X	X	X	X	X
Lebbeus microceros	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
Lebbeus polaris	X	-	X	X	-	X	X	X	X	X	X	X	X	X	X
Lebbeus sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
Munidopsis curvirostra	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
Pandalus annulicornis	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-
Pandalus borealis	-	-	-	X	-	-[2]	-	-	-	-	-	-	-	-	X
Pandalus goniurus	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-
Pandalus tridens	-	-	-	-	-	-	-	-	-	-	X	-	X	-	X
Pandalus propinquus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
Pasiphaea tarda	-	-	-	-	-	-	-	-	-	-	X	-	-	-	X
Pontophilus norvegicus	-	-	-	X	-	-	-	-	-	-	-	-	-	-	X
Sabinea sarsi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
Sabinea septemcarinata	X	X	X	X	X	X	X	X	X	X	X[3]	X	X	-	X
Sclerocrangon boreas	X	-	X	X	-	X	X[4]	-	-	-	X	X	X	X	X
Sclerocrangon ferox	X	-	-	X	-	X	-	-	-	-	-	-	-	-	X
Sergestes arcticus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
Spirontocaris lilljeborgi	-	-	-	-	-	-	-	-	-	-	-	X	-	-	X
Spirontocaris phippsi	X	-	X	X	X	X	X	X	-	X	X[3]	X	X	-	X
Spirontocaris polaris	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
Spirontocaris spinus	X	-	X	X	-	X	X	X	-	X	X[3]	X	X	-	X
BRACHYURAN CRABS															
Chionoecetes opilio	X[5]	-	X	X	-	X	-	-	-	-	-	-	-	-	-
Hyas coarctatus	X[5]	-	X	X	-	X	-	-	-	-	X	-	X	-	-

Table 3. Continued.

Species	Western Arctic Beaufort Sea						Central Arctic				Eastern Arctic				
	A[1]	B	C	D	E	F	G	H	I	J	K	L	M	N	O
ANOMURAN CRABS															
Lithodes maja	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X
Pagurus kroyeri	-	-	-	-	-	-	-	-	-	-	X	X	-	-	X
Papurus pubescens	-	-	-	-	-	-	-	-	-	-	-	-	X	-	X
Pagurus sp.	X	-	-	X	-	-	-	-	-	-	-	-	-	-	-

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[1] Geographical locations of shrimp surveys:
A = Squires (1969) - southern Beaufort Sea eastward to Cambridge Bay
B = Wacasey et al. (1977) - southern Beaufort Sea
C = Frost & Lowry (1983) - northeastern Chukchi and western Beaufort seas
D = Wainwright et al. (1987) - southern Beaufort Sea (includes data from unpublished consulting reports)
E = Lawrence (pers. comm.) - southern Beaufort Sea
F = Atkinson and Wacasey (1989) - southern Beaufort Sea
G = Rathbun (1919) - Dolphin and Union Strait
H = Hart (1939) - Dease Strait and Dolphin and Union Strait
I = Squires (1968) - Queen Elizabeth and nearby islands
J = Atinson and Wacasey (1989) - Dease Strait and Cambridge Bay
K = Squires (1957) - Ungava Bay + review of historical accounts
L = Squires (1962) - Frobisher Bay, Baffin Island
M = Squires (1967) - Hudson Bay
N = Den Beste & McCart (1978) - southeast Baffin Island
O = Dunbar & Moore (1980) - Canadian eastern Arctic

[2] Reported by Atkinson and Percy (1991) from stomachs of benthic fish.

[3] Mohammed and Grainger (1974) identified Sabinea septemcarinata, Spirontocaris phippsi, and S. spinus larvae from zooplankton catches taken in Allen Bay from the northern tip of Devon Island.

[4] Stewart and Bernier (unpublished data) found Sclerocragon boreas from the coastal waters of northern Melville Peninsula--the specimen was identified by M. Keast DFO, Winnipeg,

[5] Hunter (1981) reported Chionoectes opilio and Hyas coarctatus from Franklin Bay in the southeastern Beaufort Sea.

Table 4. Summary of information on the occurrence, harvest, and landed value of fish species in the Beaufort Sea-Amundsen Gulf study area.

FAMILY/Species	Occurrence	Harvest	Landed value[1] in 1985 and [1989]
LAMPREYS (F. Petromyzontidae)			
Arctic lamprey Lampetra japonica	Large concentrations migrate along the Mackenzie River in spring and fall.	Not harvested in the study area, but harvested commercially in the Soviet Union.	unknown
SKATES (F. Rajidae)			
skate Raja sp.	Rare, but may be common in deep Atlantic water layer.	Not harvested in the study area, but are taken in the Canadian Atlantic fishery.	flesh - $0.14/kg
HERRINGS (F. Clupeidae)			
Pacific herring Clupea harengus pallasi	Common throughout the study area and sporadically very abundant. Regional abundance unknown. Spawn under the ice of Tuktoyaktuk Harbour and Liverpool Bay in June/July.	Small subsistence harvests by area communities except Sachs Harbour. Commercial test harvests at Herschel I., Tuktoyaktuk Harbour, and Liverpool Bay. Canadian and world fisheries harvest herring for flesh, oil, and roe.	flesh - $2.23/kg roe - $30.31/kg
SALMONS, CHARRS, WHITEFISHES, and GRAYLING (F. Salmonidae)			
pink salmon Oncorhynchus gorbuscha	Present in low abundance in the Mackenzie River. Rare in coastal areas.	A rare by-catch of subsistence fisheries in the Mackenzie River. Harvested commercially by west coast fishermen.	flesh - $1.03/kg
chum salmon Oncorhynchus keta	Neither common nor abundant in the study area. Small breeding stock in the Mackenzie River.	A rare by-catch of subsistence fisheries in the Mackenzie Delta and at Paulatuk. Harvested commercially by west coast fishermen.	flesh - $1.47/kg
sockeye salmon Onchorynchus nerka	Very rare, likely strays from southern systems. Reported from the Mackenzie River and Bathurst Inlet.	A rare by-catch of subsistence fisheries in the Mackenzie River. Harvested commercially by west coast fishermen.	flesh - $3.81/kg
chinook salmon Onchorynchus tsawytscha	Very rare, likely strays from southern systems. Reported from the Mackenzie and Coppermine rivers.	A rare by-catch of subsistence fisheries in the Mackenzie River. Harvested commercially by west coast fishermen.	flesh - $4.67/kg
Arctic charr Salvelinus alpinus	Common in coastal waters of the study area during the open water season, spawn and overwinter in freshwater.	Harvested by subsistence, sport, and commercial fisheries in the study area, and widely in Arctic coastal regions.	flesh - $4.70/kg [$6.61/kg]
lake trout Salvelinus namaycush	Common and abundant in freshwater drainages throughout the study area. Rarely enters marine waters.	Rarely harvested from marine waters in the study area, very occasionally harvested from central Arctic coastal waters by subsistence fishermen.	flesh - $1.35/kg [$2.20-2.43/kg]
Arctic cisco Coregonus autumnalis	Common and abundant in coastal waters of the southeastern Beaufort Sea and Mackenzie Delta during the open water season. Spawn and overwinter in freshwater.	Harvested by subsistence and commercial fisheries of the lower Mackenzie River. Not taken in large numbers. Harvested commercially in Alaska and the Soviet Union.	flesh - $0.59/kg [$0.71/kg]
lake whitefish Coregonus clupeaformis	Common and abundant in the Mackenzie Delta and brackish nearshore coastal waters of the southeastern Beaufort Sea during the open water season. Not reported from areas with higher salinity. Spawn and overwinter in fresh water.	Harvested in quantity by subsistence fishermen from the Mackenzie Delta--generally used for dog food due to parasite infections in the flesh. Large commercial harvest in Canada.	flesh - $1.00/kg [$0.40-1.37/kg]
broad whitefish Coregonus nasus	Common and abundant in the Mackenzie Delta and brackish nearshore coastal waters of the southeastern Beaufort Sea during the open water season. Not reported from areas with higher salinity. Spawn and overwinter in fresh water.	Harvested in quantity by subsistence and commercial fishermen from the Mackenzie River and Delta. Preferred over lake whitefish due to the high quality flesh.	flesh - $1.00/kg [$0.40-1.37/kg]

Table 4. Continued.

FAMILY/Species	Occurrence	Harvest	Landed value[1] in 1985 and [1989]
least cisco *Coregonus sardinella*	Common and abundant in coastal waters of the southeastern Beaufort Sea and Mackenzie Delta during the open water season. Spawn and overwinter in freshwater.	Harvested by subsistence fisheries in the Mackenzie Delta. Not taken in quantity, generally used for dog food. Harvested commercially in Siberia.	N/A
inconnu *Stenodus leucichthys*	Common in coastal waters of the Mackenzie Delta. Low salinity tolerance relative to other anadromous coregonids. Not reported from the Arctic islands, becomes increasingly rare with distance from the delta. Spawn and summer in fresh water, overwinter in coastal waters.	Harvested by subsistence and commercial fisheries of the Mackenzie Delta region. Commercially harvested in Alaska.	flesh-[$2.43/kg]
Arctic grayling *Thymallus arcticus*	Common and abundant in freshwater drainages throughout the study area. Rarely enters marine waters.	Harvested for sport from fresh water.	N/A
SMELTS (F. Osmeridae)			
pond smelt *Hypomesus olidus*	Common in fresh waters of the lower Mackenzie River and Delta.	Harvested by subsistence fisheries in Alaska.	N/A
capelin *Mallotus villosus*	Sporadically very abundant locally in the Beaufort Sea north to Sachs Harbour and east Bathurst Inlet.	Harvested very occasionally in area subsistence fisheries. Large Canadian and world commercial food harvests.	flesh - $0.17/kg
rainbow smelt *Osmerus mordax*	Abundant in estuarine coastal waters from Herschel Island to Cape Bathurst. Rare offshore and has not been reported from the north coast of Amundsen Gulf.	Few if any harvested for food in the Beaufort Sea. Significant sport and commercial fisheries in the Great Lakes and Maritimes.	flesh - $0.28/kg
PIKES (F. Esocidae)			
northern pike *Esox lucius*	Common and abundant in mainland freshwater drainages of the study area. Rarely if ever enters marine waters.	Harvested by subsistence, commercial and sport fisheries from fresh water. Seldom is ever harvested from marine waters.	flesh - $0.76/kg [$0.88-1.21/kg]
SUCKERS (F. Catastomidae)			
longnose sucker *Catastomus catastomous*	Occurs in mainland freshwater drainages of the southeastern Beaufort Sea east to Franklin Bay. Rarely if ever enters marine waters.	Harvested as "mullet" by commercial fisheries in southern Canada. Seldom if ever harvested from marine waters.	flesh - $0.22/kg
TROUT-PERCHES (F. Percopsidae)			
trout-perch *Percopsis omiscomaycus*	Occurs in freshwaters of the Mackenzie River and lakes on Tuktoyaktuk Peninsula. Rarely if ever enters marine waters.	A small forage fish, it is not harvested except from southern fresh waters for bait.	N/A
CODS (F. Gadidae)			
Toothed cod *Arctogadus borisovi*	Occurs in coastal waters and river mouths of the Beaufort Sea, either close to the bottom or pelagically.	Occasionally harvested by subsistence fishermen in spring and dried for food or fed to dogs. No known commercial fishery for the species.	N/A
Polar cod *Arctogadus glacialis*	Occurs pelagically in the Beaufort Sea, seldom enters brackish waters.	Occasionally harvested by subsistence fishermen in spring and dried for food or fed to dogs. No known commercial fishery for the species.	N/A
Arctic cod *Boreogadus saida*	Common in offshore waters of the Beaufort Sea-Amundsen Gulf, uncommon in brackish nearshore waters. Occasionally very abundant. Very important food for other fish, birds, and marine mammals.	Seldom harvested except for sport due to its small size. Commercially harvested by the Soviet Union for processing into animal food and oil.	unknown
Saffron cod *Eleginus gracilis*	Common and locally abundant near shore in moderately saline waters between Richards Island and Cape Dalhousie. Not reported from far offshore waters or northern coasts of Amundsen Gulf.	Captured incidentally by subsistence fisheries in the Beaufort Sea and used for dog food or occasionally eaten. Harvested commercially from the northwest Pacific Ocean.	unknown

Table 4. Continued.

FAMILY/Species	Occurrence	Harvest	Landed value[1] in 1985 and [1989]
Greenland cod Gadus ogac	Occurs in the Beaufort Sea and Amundsen Gulf. More common east of Cape Bathurst. Prefers coastal marine waters but may enter estuaries.	Harvested occasionally by subsistence fishermen jigging through ice leads in spring, or angling in summer. It is eaten or fed to dogs. Commercially harvested in the eastern Arctic by Canadian and Greenland fishermen.	unknown
burbot Lota lota	Occurs in mainland freshwater drainages of the Beaufort Sea coast. May on occasion enter brackish coastal waters.	Harvested by subsistence fishermen from the Mackenzie River for the large livers. Seldom if ever harvested from marine waters. Very limited Canadian commercial fishery for burbot.	flesh - $0.08/kg
EELPOUTS (F. Zoarcidae)			
bigeye unerak Gymnelus hemifasciatus fish doctor Gymnelus viridis shulupaoluk Lycodes jugoricus saddled eelpout Lycodes mucosus pale eelpout Lycodes pallidus polar eelpout Lycodes polaris Arctic eelpout Lycodes reticulatus threespot eelpout Lycodes rossi archer eelpout Lycodes saggitarius longear eelpout Lycodes seminudus	The eelpout species listed here have all been captured along the southeastern Beaufort Sea coast between Mackenzie and Darnley bays, most of them in bottom trawls. Small fishes, they are important prey for larger predaceous fishes.	None of the eelpouts found in the southeastern Beaufort Sea are harvested either domestically or commercially, locally or elsewhere.	N/A
WOLFFISHES (F. Anarhichadidae)			
northern wolffish Anarhichas denticulatus	A single specimen was collected from Amundsen Gulf. Wolffish inhabit moderately deep waters and may prove to be common given more deepwater sampling effort. A specimen of the Bering wolffish, A. orientalis was also collected from Bathurst Inlet.	Wolffish are not harvested in the Beaufort Sea-Amundsen Gulf area. Northern wolffish are eaten by Greenlanders, and other wolffish are commercially harvested from the Atlantic Ocean.	N/A
PRICKLEBACKS (F. Stichaeidae)			
blackline prickleback Acantholumpenus mackayi stout eelblenny Anisarchus medius fourline snakeblenny Eumesogrammus praecisus daubed shanny Leptoclinus maculatus slender eelblenny Lumpenus fabricii Arctic shanny Stichaeus punctatus	The pricklebacks listed here have all been captured in the southern Beaufort Sea between Herschel Island and Darnley Bay--generally offshore or east of Cape Dalhousie. They are small fishes and may be important forage for larger commercially valuable species.	Pricklebacks are not harvested in the Beaufort Sea-Amundsen Gulf region. They are harvested by the Japanese for the manufacture of fish cakes.	unknown
SAND LANCES (F. Ammodytidae)			
northern sand lance Ammodytes dubius stout sand lance Ammodytes hexapterus	Sand lances occur in the southeastern Beaufort Sea from Herschel Island to Franklin Bay. Northern sand lance occur mainly offshore and stout sandlance inshore, neither has been reported from the northern shores of Amundsen Gulf. Both are important forage for cod, salmon, and charr.	Sandlance are not harvested from the Beaufort Sea. There are important fisheries for the species in the northwest Atlantic and Pacific oceans. They are processed into fish meal.	unknown
SCULPINS (F. Cottidae)			
rough hookear Artediellus scaber slimy sculpin Cottus cognatus spoonhead sculpin Cottus ricei Arctic staghorn sculpin Gymnocanthus tricuspis twohorn sculpin Icelus bicornis spatulate sculpin Icelus spatula fourhorn sculpin Myoxocephalus quadricornis Arctic sculpin Myoxocephalus scorpioides shorthorn sculpin Myoxocephalus scorpius bigeye sculpin Triglops nybelini ribbed sculpin Triglops pingeli	The sculpins listed here all occur in the southeastern Beaufort Sea. Fourhorn and Arctic staghorn sculpin are ubiquitous in brackish and marine coastal waters of the Beaufort Sea-Amundsen Gulf. The other sculpin species have not been collected as frequently because they occur in colder, more saline waters offshore, or in coastal areas beyond the freshening influence of the Mackenzie River where sampling efforts have not been as extensive. These sculpins are small benthic species. They are eaten by cod.	Sculpin are seldom harvested by area subsistence fisheries. There is no developed Canadian commercial harvest. They are harvested by Spain from the northwest Atlantic Ocean.	unknown

Table 4. Continued.

FAMILY/Species	Occurrence	Harvest	Landed value[1] in 1985 and [1989]
POACHERS (F. Agonidae)			
Arctic alligatorfish Aspidophoroides olriki Atlantic poacher Leptagonus decagonus	The two poachers listed here are small marine fishes which occur offshore the southeastern Beaufort Sea coast. They may be forage for commercially important species.	Poachers are not harvested.	N/A
LUMPFISHES and SNAILFISHES (F. Cyclopteridae)			
leatherfin lumpsucker Eumicrotremus derjugini Atlantic spiny lumpsucker E. spinosus sea tadpole Careproctus sp. gelatinous snailfish Liparis fabricii dusky snailfish Liparis gibbus kelp snailfish Liparis tunicatus	The cyclopterid species alisted here have been captured in the southeastern Beaufort Sea. They they are small, benthic marine fishes-- L. fabricii is also pelagic.	None of these species are harvested. The lumpfish Cyclopterus lumpus is harvested in the Atlantic for its caviar and meat.	N/A
STICKLEBACKS (F. Gasterosteidae)			
ninespine stickleback Pungitius pungitius	Occurs in freshwater coastal drainages of the mainland and Banks and Victoria islands. May enter brackish water on occasion. Small, it is an important forage species for piscivorous freshwater and anadromous fish.	Not harvested.	N/A
RIGHTEYE FLOUNDERS (F. Pleuronectidae)			
Arctic flounder Liopsetta glacialis	Common in shallow nearshore marine-to-brackish waters of the southeastern Beaufort Sea. It has not been reported from offshore waters or from the north side of Amundsen Gulf. It is a small species of flounder.	Fed to dogs when taken as a by-catch in Beaufort Sea subsistence fisheries. It is harvested by Alaskan subsistence fishermen and on a small scale by Soviet commercial fishermen.	unknown
starry flounder Platyichthys stellatus	Occurs in shallow inshore waters of the southeastern Beaufort Sea. It has not been reported from offshore waters or from the north side of Amundsen Gulf. It is a small species of flounder, and is less common in the area than the Arctic flounder.	Fed to dogs when taken as a by-catch in Beaufort Sea subsistence fisheries. Harvested commercially along the Pacific coast from B.C. to California.	unknown

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[1] Landed values are given for Canadian fisheries. The 1985 values are from Department of Fisheries and Oceans (1989a), and the 1989 values are from the Freshwater Fish Marketing Corporation, 1 April 1989, (B. Popko, pers. comm.). Values are listed as N/A for fish which are not harvested. Species for which Canadian values are listed as unknown, are not harvested in Canada or are not harvested in quantity in Canada. None of these species has a high commercial value.

Table 5. A summary of fishery cost and return information which may be obtained from personal interviews for use in economic analyses.

FISHING OPERATIONS:		- length of fishing season less weather days.
		- travel time between base and fishing grounds.
		- days fished and hours fished each day.
		- total catch (by weight in kg and number).
		- capital cost of vessel and equipment.
FISHING COSTS:	**Variable costs:**	- fuel, oil, grease.
		- fishing supplies (eg. nets, bait, ice).
		- food and provisions.
		- vessel and/or vehicle repair and maintenance.
		- labour (wages to skipper and crew, UIC, CPP, WC).
		- freight, and other expenses.
	Semi-variable and fixed costs:	- insurance and interest payments.
		- depreciation on capital items.
		- mooring, launching, beaching, storage.
		- rentals (eg. boats, motors, equipment).
		- licences.
		- other (eg. power, phone, accounting).
PLANT OPERATIONS:		- period of plant operation (d).
		- number of days to start-up and shut-down plant.
		- number of employees.
		- wage rates.
		- rate of plant production (kg/h).
		- yeild of finished product per kg of product harvested.
PLANT COSTS:	**Variable costs:**	- general freight ($/kg).
		- transportation cost ($/kg) of product to local, intersettlement, and export markets.
		- packaging materials.
		- advertising.
		- maintenance and repair.
		- packing and processing labour (wages, UIC, CPP, WC).
		- utilities, and other costs.
	Semi-variable and fixed costs:	- insurance, taxes, licenses.
		- plant management and administration.
		- depreciation.
		- interest on debt.
		- land lease.
		- plant start-up and shut-down.
		- rentals, and other expenses.
REVENUES:	**Fishing:**	- gross landed price of catch ($/kg).
		- quantity sold to fish plant, direct to the consumer, or kept for own use.
		- capital and operating grants and contributions.
	Plant:	- gross wholesale selling price to local market, FOB intersettlement markets, or FOB export markets.
		- quantity sold locally, to intersettlement markets, or to export markets.
		- capital and operating grants and contributions.

APPENDIX 1.
SOME OPTIONS FOR RESEARCH VESSEL SUPPORT

At present there are no vessels in the Canadian Beaufort Sea area with deepwater fishing capability, nor are there vessels with the species specific harvesting equipment necessary to conduct commercial stock assessments. This section outlines five vessel support options in the Canadian Beaufort Sea, including: 1) the possibility of obtaining research time on the DFO ship "Tully", 2) charter of an oil supply vessel, 3) vessel purchase, 4) charter of a west coast fishing vessel, and 5) local vessel charters.

RESEARCH TIME ON THE "TULLY"

The "Tully" is a 45 m DFO vessel with deepwater research capability. It has conducted hydrographic, geotechnic, oceanographic, and fisheries research in the Beaufort Sea for the past several years (M. Lawrence, pers. comm.). Unfortunately, 1989 is likely its last season in the Beaufort Sea for the forseeable future. Research time on the "Tully" is gratis but difficult to access, and there is seldom the flexibility to do exploratory fisheries work. Researchers provide their own nets and sampling equipment but can arrange for the installation of winches and other deck equipment. The ship also has 45' launches for coastal work.

CHARTER OF AN OIL COMPANY VESSEL

Oil companies operating in the Beaufort Sea offer their supply boats for charter. They range from 27 to 45 m in length and cost from $15,000 to $50,000 per day to charter in 1989 (M. Lawrence, pers. comm.). Costs of sampling equipment are extra.

VESSEL PURCHASE

The costs of purchasing and operating a vessel that is capable of conducting fishery research in the Canadian Beaufort Sea are very high. The DFO Central and Arctic Region has planned to purchase such a vessel to replace the aging and now unseaworthy "Salvelinus", but these plans are now "on hold" (D. Chiperzak, pers. comm.). As designed, the vessel would be 21.8 m in length, designed, equipped, and powered to do bottom and mid-water trawls, and strengthened to routinely overwinter in the ice. In 1989, the estimated costs were: $5,000,000 to build, $600,000 to equip for research, and $300,000 annually to operate--without accounting for contingencies.

CHARTER OF A WEST COAST FISHING VESSEL

Several constraints affect the cost of chartering a fishing vessel from the west coast. Most fishermen are licensed; the licence is not transferable and represents up to a third of the operating costs. It is possible to have the licence deferred, but the licence costs and loss of opportunity to fish increase the cost of chartering a licensed vessel significantly. Few charters are "bareboat"--most are conditional on their supplying a qualified captain and crew. There is no guarantee that a vessel from the west coast can reach the Tuk area until August or leave the area after September. Indeed, this period can be shortened by insurance requirements. This means that on a one year charter there may only be one month of research for a three month charter. On a longer charter the final year will also be limited to a month of research.

In 1985, DFO called for tenders on a 3 year charter of a west coast fishing vessel to conduct research in the Beaufort Sea (M. Lawrence, pers. comm.). Year one of the charter would have seen the vessel travel to Tuktoyaktuk and conduct a month of research; year two would have been devoted entirely to research, about a 90 day season; and in the final year the vessel would have conducted a month of research and then returned to the west coast. Tenders were received from vessels ranging in size from 19.7 to 27.3 m and ranged in price from one to six million dollars. These prices included general insurance and crew. DFO was to assume all responsibility for winter ice damage, guarantee a fourth year of charter in the event that the return to the west coast was not possible in the third year, and supply fuel ($25,000 annually). The lowest charter bid without contingencies would have cost over $6,800 per research day. The minimum cost of a west coast charter will have increased substantially since 1989.

A single year charter is very expensive and, because of the short research season and possibility of poor weather or mechanical problems, is only worthwhile to address specific, known research problems.

LOCAL VESSEL CHARTERS

Most vessels in Sachs Harbour, Holman, Paulatuk, and Tuktoyaktuk are either motorized inshore, cargo vessels in the 10 to 14 m length range, or open boats in the 5 to 7 m range. The M.V. "Sequel" is an example of the former, and a 5.5 m Lund aluminum boat is an example of the latter.

"Sequel" is the 12.7 m motorized vessel that DFO has been using in the Beaufort for the past several seasons (M. Lawrence, pers. comm.). In 1989, it cost $1,200 to $1,800 per day to charter depending on length of charter, whether the costs of launch and retreival must be borne entirely or are shared between several charterers, and on whether food is provided. It was converted into a dragger, largely at DFO expense, and is capable of bottom and mid-water trawling. It has good hydraulic capacity and can operate a mid-water trawl with a 12'x 12' mouth opening to a depth of 200 m provided the boat is equipped with a better net sounder. At present it can only trawl to 75 m.

The present net sounder is operated on a cable which is subject to breakage, and its single transducer is mounted atop the net aiming downward. It provides a reading of the net opening and of the distance from the net to the bottom. The ship sounder must be used to determine water depth and with practice the trawl can be operated within 2 m of the bottom. The industry standard net sounder has 2 transducers, one on the bottom of the net aiming upward and the other at the top of the net aiming downward, and the electronic signals are relayed to the boat by transducers--eliminating costly wire breakages. Together they provide a better picture of the catch and the net location--measuring mouth opening, depth to the bottom, from the top, and catches of large fish. They allow more sensitive adjustment of net position in the water column.

Other vessels in a similar size range are located in the communities. Few of the vessels are still operating, and all would require substantial modifications before they would be capable of conducting a marine test fishery. This could change if EDT were to proceed with plans to purchase a commercial fishing vessel for the Beaufort Sea.

The 5.5 m (18') open aluminum boats that are available in the communities are potentially useful for inshore surveys, but are very succeptible to weather dangers. They are used for coastal travel, whale and seal hunting, and fishing, and are available in all of the communities. In 1989, the cost of purchasing a Lund 5.5 m open aluminum boat with a 70 hp outboard motor ranged from $8,700 (landed) in Sachs Harbour and Paulatuk to $10,500 in Holman. Gasoline costs ranged from $0.63 in Sachs Harbour to $0.68/L in Holman, and motor oil from $4.09 to $4.25/L. Boat rental costs are negotiable, but tend to be high because boats are vital to the owners livelihood and difficult to quickly repair or replace. Costs in the range of $1,000/month or $150/operating day should be anticipated. They do not include operator wages or fuel and oil costs, and will depend to some extent on the flexibility allowed for the owners personal use of the boat. A damage deposit may be necessary.

APPENDIX 2.
PREFEASIBILITY BREAKEVEN ANALYSIS FOR A PACIFIC HERRING ROE FISHERY AT TUKTOYAKTUK, NWT

This breakeven analysis uses a financial model. It does not include economically important factors such as the social or biological costs or benefits of development. The cost and productivity estimates used are rough and based on 1988-9 dollar values, but they do serve to illustrate the need for a significantly larger herring stock than has yet been identified if a financially viable roe fishery is to be developed. Further, these stocks must be predictably accessible.

ASSUMPTIONS

For the purpose of this analysis we have assumed that:

1) since there is no existing facility, a fish processing facility with a blast freezer and holding freezer similar in scale to the Cambridge Bay fish plant would need to be built in Tuktoyaktuk;

2) due to the risks associated with spring ice travel the venture would supply fishermen with snowmobiles and fishing equipment;

3) fishermen would be paid a reasonable wage during the early years of the fishery, with a provision for profit sharing to encourage production;

4) the fishing would occur over a 10 day period, mainly in the Fingers; roe yield would average 8.7% of the landed weight of all herring (D. Iredale, pers. comm.); and an annual harvest of 10% of the spawning stock is sustainable (A.H. Kristofferson and D.V. Gillman, pers. comm.);

5) herring caught at The Fingers would be flown by Twin Otter aircraft to Tuktoyaktuk for processing, unsorted;

6) processing would be spread out over 30 days and plant operation over 60 days;

7) a qualified manager would be employed for 3 months annually on the fishery, with long term arrangements for seasonal employment or for full-time employment which encompasses several ventures;

8) fishermen would work in teams of 2, and that each team could harvest an average of 2 mt of herring per day;

9) plant workers could strip or process a tonne of herring per day (T. Scott, pers. comm.); and

10) that government would assist with training.

The subsidized version assumes that government would pay all capital costs, 50% of the cost of shipping the roe to market, and that all fish would be harvested within snowmobile range of Tuktoyaktuk--not from the Fingers. The estimated costs and rates of production are both likely to prove optomistic.

BREAKEVEN SCENARIOS

As was discussed in text, prefeasibility analyses provide a rough estimate of the harvests and stocks necessary to support a viable fishery development. This prefeasibility analysis for Pacific herring suggests that a spawning stock in the order of 1,000 to 2,500 mt, depending upon the level of government subsidization and the location of the harvest, may be required to support a financially viable fishery development in the Tuktoyaktuk area. Stocks of this magnitude might support roe production of between 8.7 and 21.2 mt, and a development might breakeven at an average roe price of $15 to $20/kg. The 1985, estimates place the known stocks in The Fingers at 8.2±5.6 mt (Shields 1985), less than 1% of the breakeven stock. Before development of a herring roe fishery is seriously considered in the Tuktoyaktuk area a predictably accessible spawning stock of Pacific herring in the order of 1,000 mt should be identified.

The modest fish plant used for this analysis would be unlikely to handle the higher production volume need to breakeven at a roe price of $10/kg, and variations in egg maturity which render roughly 30% of the eggs worthless make it unlikely that the average roe price would approach the higher prices (eg.

Prefeasibility breakeven analysis for a Pacific herring roe fishery at The Fingers without government subsidization, and in Tuktoyaktuk Harbour with government subsidization. In both cases the roe processing plant is located at Tuktoyaktuk, NWT.

	Without subsidies	With subsidies
FISHING COSTS ($):		
Variable costs:		
- fuel, oil, grease	7,500	7,500
- fishing supplies (eg. nets, tubs, augers, jiggers)	10,000	10,000
- food and provisions: 16 people for 12 d @ $20/d/person	3,840	nil
- snowmobile repair and maintenance: est. 10% of cost/yr	5,000	5,000
- labour (wages to fishermen, UIC, CPP, WC): 16 fishermen @ $16/hr x 200 h	51,200	51,200
- air freight: Twin Otter 60 h @ $900/hr including fuel	54,000	nil
Semi-variable and fixed costs:		
- insurance	1,000	1,000
- interest payments on the purchase of 8 snowmobiles and komatiks: cost $50,000; term 5 yr @ $12.5%	13,500	nil
- depreciation on capital items (linear over 5 years)	10,000	nil
- licences	80	80
- other (eg. camp supplies)	10,000	nil
PLANT COSTS ($):		
Variable costs:		
- general freight	2,000	2,000
- transportation cost of product to market (land)	20,000	10,000
- packaging materials	5,000	5,000
- maintenance and repair	25,000	25,000
- packing and processing labour (wages, UIC, CPP, WC): 12 workers @ $12/hr x 240 h	34,560	34,560
- utilities, and other costs	6,000	6,000
Semi-variable and fixed costs:		
- insurance, taxes, licenses	2,000	2,000
- plant management and administration	15,000	15,000
- plant depreciation: linear over 25 y	10,000	nil
- plant mortgage interest: cost $250,000; term 25 y @ 12.5%/yr	32,710	nil
- land lease	nil	nil
COST ESTIMATES:	$318,390	$174,340
BREAK EVEN HARVESTS AND STOCK REQUIREMENTS (kg):		
- Weight of processed roe needed to breakeven at $10/kg	31,839 kg	17,434 kg
- Weight of herring needed to breakeven at 8.7% roe yield	365,966 kg	200,391 kg
- Spawning stock needed to sustain this yield on an annual basis at an allowable annual harvest rate of 10%	3,659,655 kg	2,003,908 kg
- Weight of processed roe needed to breakeven at $15/kg	21,226 kg	11,623 kg
- Weight of herring needed to breakeven at 8.7% roe yield	243,977 kg	133,594 kg
- Spawning stock needed to sustain this yield on an annual basis at an allowable annual harvest rate of 10%	2,439,770 kg	1,335,939 kg
- Weight of processed roe needed to breakeven at $20/kg	15,920 kg	8,717 kg
- Weight of herring needed to breakeven at 8.7% roe yield	182,983 kg	100,195 kg
- Spawning stock needed to sustain this yield on an annual basis at an allowable annual harvest rate of 10%	1,829,828 kg	1,001,954 kg
- Weight of processed roe needed to breakeven at $25/kg	12,736 kg	6,974 kg
- Weight of herring needed to breakeven at 8.7% roe yield	146,386 kg	80,156 kg
- Spawning stock needed to sustain this yield on an annual basis at an allowable annual harvest rate of 10%	1,463,862 kg	801,563 kg

$25/kg) paid for top Quality roe (D. Iredale, pers. comm.). It is also unlikely that an unsubsidized fishery of this scale could breakeven below $15/kg, since the higher production volumes necessary to breakeven at lower prices would require a larger plant and production costs would increase. If the fishery were to employ fewer fishermen, then each fisherman would need to catch more fish for the fishery to breakeven; if it employed fewer processors then the freezer holding capacity would need to be expanded to facilitate longer term holding.

In practice there are a number of constraints which make viability even more remote. They include unpredictable ice conditions, widely fluctuating catches, unstable roe prices, and the low fat content of spawning herring which makes them sub-optimal for pickling.

The herring carcasses might be used for fertilizer, fish meal, or dog food. These products command a low price per unit weight and could not be exported from the area economically, nor would they contribute much to the financial viability of the fishery. Their availability might however foster the development of a fox farm.

ALTERNATIVES

As an alternative to a roe fishery, there is an established market in the Mackenzie Delta communities for home pickled herring. The fish are caught during the open water season, pickled, and bartered or sold to subsidize subsistence fisheries. If demand for the product is sufficient, the home operations will likely evolve naturally to serve the market. Because the product has a low value per unit weight it is unlikely that an export market will develop, and inter-community trade will likely be restricted to areas connected by road. Planned changes to the NWT Health Regulations with respect to the handling of country foods for sale within the NWT may require that producers operate from approved facilities. If it becomes apparent that the home operations are expanding, then equipment subsidies to help them meet the food handling requirements should be considered.

APPENDIX 3.
SENSITIVITY ANALYSIS FOR A PRINCE ALBERT SOUND ARCTIC CHARR FISHERY

This analysis uses a financial accounting model. It does not include economically important social or biological costs or benefits of development. The cost and harvest estimates, while based on 1988-9 prices, serve to illustrate the marginal nature of a fishery based on the known stocks of anadromous Arctic charr in the Kuuk and Nalaogyok rivers, and the sensitivity of fishermen's wages to fluctuations in fish prices and transportation costs. A discussion of the rationale and information used to construct the analysis follows.

HARVEST POTENTIAL

There are migrations of 9,000 anadromous Arctic charr in the Kuuk River (Stewart and Sparling 1987) and 22,000 charr in the Nalaogyok River (Lemieux and Sparling 1989). Johnson (1980) found that sustained annual harvests of 11% were excessive and depleted charr populations. In predicting annual sustainable harvest levels, we have assumed that up to 5% of each population may be harvested on an annual basis by subsistence fishermen, and that a further 5% might be safely harvested by a commercial fishery. Based on the mean round (3.3 kg) and dressed (2.9 kg) weights of charr at the Kuuk River (Stewart and Sparling 1987), a 5% harvest would be about 1,300 kg dressed (1,485 kg round) at the Kuuk and 3,190 kg dressed (3,630 kg round) at the Nalaogyok. The sustainable harvest could be doubled if the stocks were commercially harvested only every second year.

FISH HARVESTS AND PROCESSING

Weirs offer the most efficient method for harvesting charr from the rivers and were included in the analysis. They permit fish to be held until conditions are favourable for mass harvest with little deterioration in quality, small and poorer specimens can be released unharmed, and the fish are processed fresh and do not bear gillnet marks.

The upstream migration of fish in the Kuuk River peaks about 25 August (Stewart and Sparling 1987) and in the Nalaogyok about 30 August (Lemieux and Sparling 1989). There will be some yearly variation, but fishermen should be able to harvest both quotas between 19 August and 2 September. Four adults can erect and operate a weir and should be able to conduct the harvests on the scale examined in the analysis. Holding pens would have to be erected at both sites to enable simultaneous harvests.

The available harvests are not sufficient to support a fish plant, let alone provide a return on the capital investment. With annual harvest of over 45,000 kg dressed weight of charr (Carder and Stewart 1989), the Cambridge Bay fishery can operate at a profit, but it does not have the burden of high interest payments on capital debt. With an annual harvest of over 9,000 kg the Chesterfield Inlet plant operates at a loss and does not provide a return on the capital investment (see review of commercial fisheries). Both plants are closer to the rivers being fished and have better transportion routes to their markets than would a plant at Holman. Alternatives for processing the fish include dressing the fish on site for transportation to local markets or having them processed for export at the fish plant in Cambridge Bay.

LOGISTICS

Transportation of fish from the rivers to the markets is the major cost to the fishery. Poor weather, distance from markets, and limited aircraft availability increase costs and the potential for spoilage. Possible means of access to the rivers include small open boats, the 38' wooden motor vessel "Patricia", and single or twin engine aircraft. Fish could be carried to Holman by any of these methods and then distributed via scheduled commercial aircraft, or sent by charter aircraft directly to Cambridge Bay or Inuvik.

Access to the rivers by small boat is by no means assured. Fishermen can and do travel to and from the rivers in small open boats, but a safer method should be considered if development is planned. Launching and retrofitting the "Patricia" to haul fish to Holman would be safer but is not financially attractive for a fishery of this size. While the vessel is capable of travelling to the rivers in most weather, it has not been in the water for several years and it does not have cold storage facilities.

The Cambridge Bay fishery uses a DeHavilland Beaver aircraft to transport charr from the rivers to the fish plant. Because of the longer distance a DeHavilland Twin Otter would probably be a better method for carrying fish from the rivers in Prince Albert Sound to markets in Holman, Inuvik, and Cambridge Bay. The higher costs are offset by greater cruising speed and range, less vulnerability to poor weather, and larger payload all of which help to reduce spoilage and time spent at the rivers. For this reason Twin Otters have been used in the analyses to transport the fish, except in the last case. At present the aircraft would have to be chartered from Inuvik, but costs could be substantially reduced if a side or joint charter could be arranged or if an aircraft were based closer to the fisheries.

Twin Otter charter costs are prorated from flights taken to the Kuuk River in 1987, the mileage and flying time varies between cases in the analysis. Fully loaded, a Twin Otter carries a payload of about 1,350 kg of fish and 150 kg of tubs and ice provided there are no passengers or other freight. Small boat values ($10,500) and operating costs are based on the interviews (Appendix 1), and experience with the Kuuk River fishery. The fishermen own or have access to boats, and fuel can be brought to the river on incoming Twin Otter flights or cached during winter hunting expeditions without incurring extra costs.

For the analysis, boats were depreciated over 5 years (linear) and it was estimated that the fishery would account for 25% of each boat's annual use. This will help fishermen to replace their boats. Few of the fishermen purchase vessel insurance for their boats. To avoid personal losses should a boat be damaged they were insured at a premium rate of 3% of the purchase price. Repairs attributable to the fishery were estimated at 5% of the purchase value of the boats per annum.

MARKETS AND PRICES

The Holman market cannot absorb the potential production from both rivers. Indeed, the fish marketed from test fisheries in 1987 through 1989 were mostly sold to the Co-op Hotel. Sales volumes ranged from 1,390 kg round weight in 1988 (Sparling and Stewart 1988) to about 500 kg in 1989 (P.D. Sparling, pers. comm.), with landed prices of $5.50/kg. Ulu Foods and hotels in Inuvik purchased about 900 kg in 1987, 500 kg in 1988 at a landed price of $4.40/kg (Sparling and Stewart 1988), and about 500 kg in 1989 at a landed price of $5.00/kg dressed (P.D. Sparling, pers. comm.). We estimate that a Twin Otter load of fish, about 1,350 kg, might be marketed in each community at these prices, with the remaining harvest being processed in Cambridge Bay for export to the FFMC.

Provided the FFMC is able to maintain frozen charr prices at $6.61/kg dressed and they manage to make a modest final payment, the Holman fishermen might negotiate a landed price for round charr in Cambridge Bay of about $3.50/kg. This assumes Cambridge Bay fish plant operating costs of $2.86/kg, a fee of $0.50/kg for dressing the charr at the plant, continued government subsidization of transportation of the fish to the FFMC, and a second payment of at least $0.75/kg (ie. $6.61/kg dr. initial payment + $0.75/kg dr. final payment - $2.86/kg dr. plant operating costs - $0.50/kg dr. dressing fee = $4.00/kg dressed landed, or $4.00/kg dressed landed x 0.87 kg dressed/kg round = $3.50/kg round landed) (see Part 1).

On a cautionary note, there is no guarantee that current charr prices can be maintained. In November 1989, fresh cultured pink salmon sold in Winnipeg for $6.59/kg dressed or frozen for $5.91/kg headless dressed. This competition may erode charr prices in the near future.

COMMUNICATIONS AND MANAGEMENT

The Holman HTC might want to offer the services of their resource person to coordinate the activities of a developing fishery with weather, aircraft movements, and markets by telephone and radio. Radios can be rented by the fishermen for a nominal fee from the HTC.

SUBSIDIES

The analysis assumes that the initial weir materials and fishing supplies will be provided by a one-time start-up grant from government. If the existing weirs were sufficient, a grant of $10,000 would likely cover the costs of fishing supplies, including: fish tubs, waders, protective clothing, disinfectant, seine nets, etc. Small sums have been allocated to keep the weirs operating, replace worn out fishing equipment, and meet office expenses.

Transportation subsidies are not likely to apply to the Twin Otter charter as they do not apply to the Cambridge Bay Beaver charter. However, in the pricing section it is assumed that the subsidy on transport of fish to the FFMC from Cambridge Bay will continue.

OPTIONS

Based on the above, three options have been chosen for examination, they include: 1) a biannual harvest at the Kuuk and Nalaogyok River, 2) an annual harvest at the Kuuk and Nalaogyok Rivers, and 3) an annual harvest at the Kuuk River. The sensitivity analyses for each option follow the text, with their characteristics listed in point form. Fishermen's wages provide the measure of financial viability for each option, and the sensitivity of those wages to fluctuations in fish market price, transportation costs, and harvest quotas is examined over a range of ±20% of the estimated costs. The results of the sensitivity analyses for the three options are summarized following the analyses of the options.

DISCUSSION

The sensitivity analysis (see below) suggests that the options examined are marginal at best. Each option would require government start-up grants for fishing equipment and weirs and--given the stock sizes, current market prices for charr, and distance from markets--fishermen would be unlikely to earn the equivalent of minimum wage for their labours. Wages would be very sensitive to changes in the market price for charr and also to changes in air charter costs. None of the options examined is likely to be financially viable given the likelihood that the charr prices will decrease and transportation costs will increase.

If charr prices did increase and transportation costs remained stable, a biannual fishery or an annual fishery at the Kuuk River might be economically viable. In either case, a fishery would offer the benefits of subsidized access to caribou and charr resources, boat insurance and recovery of some repair and depreciation costs, and the opportunity to pursue traditional harvesting activities.

Discovery of a large, commercially exploitable charr stock at the Kagloryuak River, near the head of Prince Albert Sound, might improve the chances for economic viability but--given the sensitivity to market prices and transportation costs--any venture would still be very risky indeed.

The area charr resources might be best used to attract tourist dollars and sustain the local subsistence fisheries.

OPTION 1: BIANNUAL FISHERY AT THE KUUK AND NALAOGYOK RIVERS

- Twin otter chartered from Inuvik, makes 5 trips from the fishery to Cambridge Bay, and 1 each to Holman and Inuvik.
- no fish plant at Holman, fish kept cold with sea ice.
- employs 4 people at each river for 2 weeks between 19 August and 2 September.
- fishermen travel to and from the fishery by open boat, 2 boats per location.
- fish marketed in Holman and Inuvik dressed, in Cambridge Bay round.
- weirs and fishing gear supplied.
- biannual fishing to double quota.

EXPENSES ($)

Variable	**Base case**	**FISH PRICES**				**AIR CHARTER COSTS**				**HARVEST QUOTAS**			
		+ 20%	**+ 10%**	**- 10%**	**- 20%**	**+ 20%**	**+ 10%**	**- 10%**	**- 20%**	**+ 20%**	**+ 10%**	**- 10%**	**- 20%**
- fuel, oil, grease	1,000												
- weir and fishing supplies	N/C												
- boat repair (5% of $42,000)	2,100												
- weir repair	500												
- freight, and other expenses	500												
Semi-variable and fixed													
- boat insurance (3% of $42,000)	1,260												
- boat depreciation ($42,000; linear over 5 y/4)	2,100												
- licences for 8 fishermen	40												
- other (eg. power, phone, accounting)	200												
- Twin otter:													
charter ($5.50/mi x 3300 mi)	18,150					21,780	19,965	16,335	14,520	20,268	18,150	16,033	16,033
fuel (20 hr x 370 l/hr @ $0.80/l)	5,920					7,104	6,512	5,328	4,736	6,660	5,920	5,180	5,180
Total expenses ($):	31,770	31,770	31,770	31,770	31,770	36,584	34,177	29,363	26,956	34,628	31,770	28,913	28,913
INCOME ($)													
- fish sales:													
Holman: $5.50/kg x 1350 kg	7,425	8,910	8,168	6,683	5,940					7,425	7,425	7,425	7,425
Inuvik: $4.50/kg x 1350 kg	6,075	7,290	6,683	5,468	4,860					6,075	6,075	6,075	6,075
Cambridge: $3.50/kg x 6000 kg	21,000	25,200	23,100	18,900	16,800					27,090	24,045	17,955	15,260
Total income ($):	34,500	41,400	37,950	31,050	27,600	34,500	34,500	34,500	34,500	40,590	37,545	31,455	28,760
NET INCOME ($):	2,730	9,630	6,180	(720)	(4,170)	(2,084)	323	5,137	7,544	5,963	5,775	2,543	(153)
Fisherman's weekly wage ($):	171	602	386	(45)	(261)	(130)	20	321	472	373	361	159	(10)

OPTION 2: ANNUAL FISHERY AT THE KUUK AND NALAOGYOK RIVERS

- Twin Otter chartered from Inuvik to move fish, one flight each from the fishery to Holman, Inuvik, and Cambridge Bay.
- no fish plant at Holman, fish kept cold with sea ice.
- employs 4 people at each river for 2 weeks between 19 August and 2 September.
- fishermen travel to and from the fishery by open boat, 2 boats per location.
- fish marketed in Holman and Inuvik dressed, in Cambridge Bay round.
- weirs and fishing gear supplied.
- biannual fishing to double quota.

EXPENSES ($)

		FISH PRICES				AIR CHARTER COSTS				HARVEST QUOTAS			
Variable	**Base case**												
- fuel, oil, grease	1,000												
- weirs and fishing supplies	N/C												
- boat repair (5% of $42,000)	2,100												
- weir repair	500												
- freight, and other expenses	500												
Semi-variable and fixed													
- boat insurance (3% of $42,000)	1,260												
- boat depreciation ($42,000; linear over 5 y/4)	2,100												
- licences for 8 fishermen	40												
- other (eg. power, phone, accounting)	200	**+ 20%**	**+ 10%**	**- 10%**	**- 20%**	**+ 20%**	**+ 10%**	**- 10%**	**- 20%**	**+ 20%**	**+ 10%**	**- 10%**	**- 20%**
- Twin otter:													
charter ($5.50/mi x 1750 mi)	9,625					11,550	10,588	8,663	7,700	9,625	9,625	9,625	9,625
fuel (11 hr x 370 l/hr @ $0.80/l)	3,256					3,907	3,582	2,930	2,605	3,256	3,256	3,256	3,256
Total expenses ($):	20,581	20,581	20,581	20,581	20,581	23,157	21,869	19,293	18,005	20,581	20,581	20,581	20,581
INCOME ($)													
- fish sales:													
Holman: $5.50/kg x 1350 kg	8,250	8,910	8,168	6,683	5,940					8,250	8,250	8,250	8,250
Inuvik: $4.50/kg x 1350 kg	6,750	7,290	6,683	5,468	4,860					6,750	6,750	6,750	6,750
Cambridge: $3.50/kg x 1350 kg	5,250	6,300	5,775	4,725	4,200					7,560	6,143	3,308	1,890
Total income ($):	20,250	22,500	20,625	16,875	15,000	20,250	20,250	20,250	20,250	22,560	21,143	18,308	16,890
NET INCOME ($):	(331)	1,919	44	(3,706)	(5,581)	(2,907)	(1,619)	957	2,245	1,979	562	(2,274)	(3,691)
Fisherman's weekly wage ($):	(21)	120	3	(232)	(349)	(182)	(101)	60	140	124	35	(142)	(231)

OPTION 3: ANNUAL FISHERY AT THE KUUK RIVER

- fish sold in Holman, mainly to the Co-op Hotel.
- no fish plant or aircraft suppport required.
- employs 4 people for 2 weeks from 19 August to 2 September.
- fishermen travel to and from the fishery using 2 open boats.
- weirs supplied

EXPENSES ($)

	Base case	FISH PRICES				AIR CHARTER COSTS				HARVEST QUOTAS			
Variable													
- fuel, oil, grease	1,000												
- weirs and fishing supplies	N/C												
- boat repair (5% of $21,000)	1,050												
- weir repair	250												
- freight, and other expenses	250												
Semi-variable and fixed													
- boat insurance (3% of $42,000)	630												
- boat depreciation ($21,000; linear over 5 y/4)	1,050												
- licences for 4 fishermen	20												
- other (eg. power, phone, accounting)	100	+ 20%	+ 10%	- 10%	- 20%	+ 20%	+ 10%	- 10%	- 20%	+ 20%	+ 10%	- 10%	- 20%
- Twin otter:													
charter:	NIL					0	0	0	0	0	0	0	0
fuel:	NIL					0	0	0	0	0	0	0	0
Total expenses ($):	4,350	4,350	4,350	4,350	4,350	4,350	4,350	4,350	4,350	4,350	4,350	4,350	4,350
INCOME ($)													
- fish sales:													
Holman $5.50/kg x 1350 kg	7,425	8,910	8,168	6,683	5,940					8,910	8,168	6,683	5,940
Total income ($):	7,425	8,910	8,168	6,683	5,940	7,425	7,425	7,425	7,425	8,910	8,168	6,683	5,940
NET INCOME ($):	3,075	4,560	3,818	2,333	1,590	3,075	3,075	3,075	3,075	4,560	3,818	2,333	1,590
Fisherman's weekly wage ($):	192	285	239	146	99	192	192	192	192	285	239	146	99

SENSITIVITY ANALYSIS OF FISHERMEN'S WEEKLY WAGE

	Option 1 Biannual	Option 2 Annual	Option 3 Kuuk
Fish prices			
+ 20%	$602	$120	$285
+ 10%	$386	$3	$239
base case (fall 1989)	$171	($21)	$192
- 10%	($45)	($232)	$146
- 20%	($261)	($349)	$99
Air charter costs			
+ 20%	($130)	($182)	$192
+ 10%	$20	($101)	$192
base case (fall 1989)	$171	($21)	$192
- 10%	$321	$60	$192
- 20%	$472	$140	$192
Harvest quotas			
+ 20%	$373	$124	$285
+ 10%	$361	$35	$239
base case (fall 1989)	$171	($21)	$192
- 10%	$159	($142)	$146
- 20%	($10)	($231)	$99

APPENDIX 4.
OUTLINE OF PRESENTATION TO HUNTERS AND TRAPPERS COMMITTEES TO ASSESS COMMUNITY INTEREST IN FISHERY DEVELOPMENT

During the FJMC's annual "community tour", in 1987, the HTC's in Sachs Harbour and Holman expressed interest in the development of new and existing fisheries in their areas. In response to their interest the FJMC decided to do three things: 1) to review information on marine fish and shellfish (clams, shrimp, crabs) in the Beaufort Sea, 2) to examine whether any of these species might support a marine commercial fishery, and 3) to develop a sensible plan for pursuing marine fisheries opportunities.

Like the oil industry which does years of exploratory work with no guarantee of finding oil fields worth developing, there is no guarantee that the FJMC will find marine fishing opportunities worth developing.

I am here to ask for your views on marine fishery development, and for information that might be helpful in determining whether a marine fishery is worth developing in your area. I will also be visiting several of the other communities, talking with government biologists and economists, and gathering information from written reports. Perhaps I can begin by asking for your answers to a few questions.

** Is there community interest in developing a fishery based on marine fish or invertebrates?

** What marine fish are eaten locally? Are there fish, clams, or shrimp that you think might support a commercial fishery?

** Are there people in the community with experience catching marine fish?

** What sort of boats, nets, and freezer facilities are available in the community? What are they used for now?

** If a fishery developed, what sort of organization would you recommend?

** When could a fishery operate?

** How many people might be willing to supplement their incomes by working on a seasonal fishery? Would it be primarily older or younger people? How many of those people would still be interest if oil development increases?

** What are the costs of fuel, lubricating oil, boats purchase or rental, and air freight. What is an acceptable wage?