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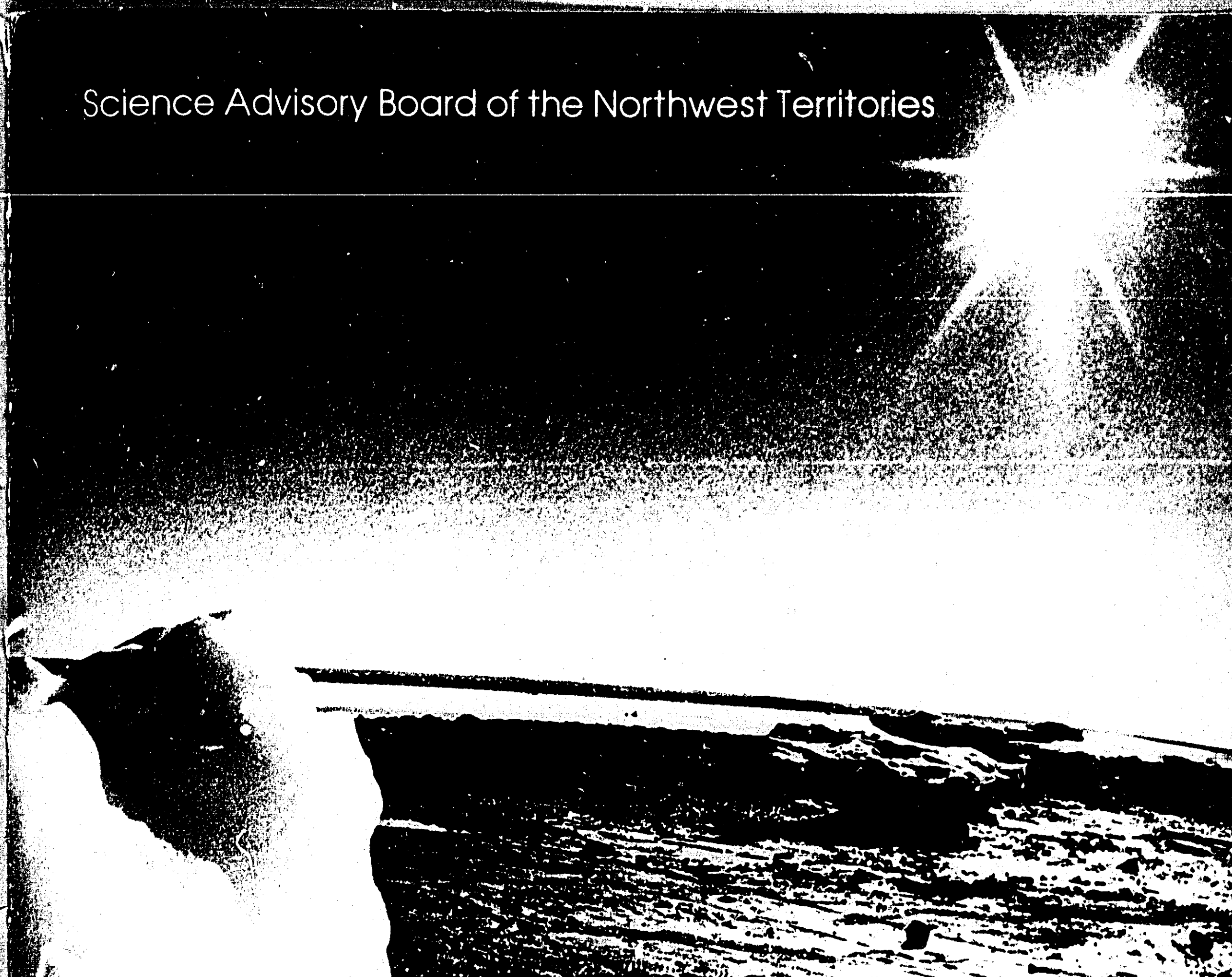

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AQUATIC RESOURCES
OF THE NORTHWEST TERRITORIES

By
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For
Science Advisory Board
of the Northwest Territories
December 1979

Aquatic Resources of the Northwest Territories
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FOREWORD

The abundance and quality of fishes was a significant factor for the pattern of pre-historic human settlement in what is now the Northwest Territories. Fish remain an important element in the traditional life style of northern society. Also, commercial fishing for export to Canadian and International markets is an important element in the economy of the Northwest Territories. In this volume the Science Advisory Board attempts to compile the available information relevant to the understanding and management of the most significant northern fish species. Where data for proper management of species and populations in northern waters are lacking the authors were encouraged to highlight these gaps and recommend procedures for correcting the short-coming. While the paper reflects the views of the authors the Board feels that the information here contained deserves attention by those in a position to effect improvements in the management of the fish resources in the Northwest Territories. Furthermore, in promoting the distribution to the public the Science Advisory Board hopes to generate a greater understanding for fisheries in the Northwest Territories by readers not only in southern Canada but also by those in the Northwest Territories.

Ben A. Hubert
Executive Secretary
Science Advisory Board
of the Northwest Territories

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OVERVIEW

The productivity of freshwater environments in the north is generally low in comparison with lakes at temperate latitudes and, as a consequence, the rates of production of fish and other consumers directly utilizable by man are also very low. Fish production per unit area may be less than 10% that of moderately to highly productive lakes further south. There are a number of factors which contribute to this low productivity including low light levels during the winter months, extended periods of ice cover, low water temperatures, and, especially, low nutrient concentrations.

In response to low productivity, northern populations of freshwater fish are characterized by slow growth, late maturity, and long life. Lake trout are an extreme example of these tendencies. They may not mature for the first time until well into their teens then continue spawning until they reach an age of 30 years or more. The low productivity of fish populations might not be immediately apparent because, in many populations, the numbers and biomass of fish are very high. As a result, unexploited lakes and streams in the Arctic often harbour dense populations of fish, providing a temporary bonanza to fishermen. However, because the biomass of each individual and of the population as a whole represent the stored production of many years, such populations are extremely sensitive to over-exploitation and collapse. Where the fishery is sufficiently intense, fish populations show typical responses:

1) There is a reduction in both the average size and average age of the population as the larger, older fish are selectively eliminated;

2) Catch per unit effort declines as the numbers of fish in the age classes susceptible to the gear declines;

3) There may be an increase in the growth rates of smaller, predominantly juvenile fish, which are too small to be susceptible to the gear, as older intraspecific competitors are eliminated;

4) Increased growth among juvenile fish may be accompanied by a reduction in the age at which they mature.

In time, heavily exploited populations may be made up almost entirely of juveniles and first time spawners. In time, stocks subject to heavy exploitation may be reduced to very low levels or, in exceptional circumstances, become extinct. On the other hand, many populations can recover if fishing mortality is reduced or eliminated. Resiliency varies considerably, however, and among major northern species, populations of Arctic char and the whitefishes have been found to recover more rapidly than lake trout.

It is likely that the dangers of collapse are even greater among northern than among fish populations in general and that, therefore, great caution and restraint should be exercised in the management of northern fisheries. In fact, the management of most fisheries in the Northwest Territories is conducted at a rather unsophisticated level, largely because of a lack of information concerning fish resources. Until more is known, it will not be possible to effectively manage fisheries or to accurately assess the fishery potential of the Territories. In order to fill these information gaps, we have made a number of recommendations. Briefly, we recommend that:

1) There should be further study of the productivity of northern freshwater ecosystems and the development of indices to fish productivity;

2) There should be further development and testing of the concept of cyclical fisheries in the Northwest Territories;

3) Every effort should be made to upgrade the quality of data describing fisheries in the north, particularly domestic fisheries for which the data are especially poor;

4) The government monitor major industrial development projects in the north to determine, in detail, their impacts on water quality, aquatic productivity, and fish populations so that a body of information is available which can be used in predicting and mitigating the impacts of future developments;

5) There be a study of the feasibility of sport fishing in the Northwest Territories and of the potential impacts of encouraging greater utilization of the fisheries resources by sport fishermen;

6) There be a study of methods of increasing the proportion of the commercial catch marketed within the N.W.T. as a method of increasing the availability of low cost protein;

7) There be a continuing effort to develop biologically and economically sound strategies for commercial fisheries in the N.W.T.;

8) That a central information depository be developed to provide easy access to information regarding fisheries and related subjects for the N.W.T.

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PRODUCTION PROCESSES AND FISH PRODUCTION IN NORTHERN AQUATIC ENVIRONMENTS

SOME GENERAL CONSIDERATIONS

In any aquatic ecosystem, a basic division can be made between the physical (non-living) and biotic (living) environments. The former includes the water itself, temperature, oxygen and other gases, dissolved substances including minerals and nutrients, light, etc. The latter includes all living things, from the simplest microorganisms to fish, birds, and mammals.

The biotic components of the ecosystem can be further subdivided on the basis of trophic status (i.e., their relationships to energy flow within the system). The basis of the ecosystem is the group of primary producers, predominantly chlorophyll-containing, photosynthetic green plants, which are able to use the energy of sunlight along with water, carbon dioxide, and various dissolved substances (e.g., nitrates and phosphates) to produce complex organic molecules. Organic molecules are all characterized by the fact that they contain carbon and the rate of primary production is usually measured quantitatively in terms of the amount of carbon (grams C) incorporated in the molecules produced. This rate can be influenced by a variety of environmental factors. In the north, light and nutrient (particularly phosphorous) availability appear to be the two most important factors limiting primary production.

Consumers are organisms, chiefly animals, which cannot themselves produce organic molecules from simpler substances and instead ingest other organisms or particulate organic matter. They are ultimately dependent upon the primary producers for the organic molecules which they use as building blocks in their own metabolisms. The process by which consumers break down and rearrange organic molecules can be termed secondary productivity. Consumers can be classified as primary (herbivores which feed directly on primary producers), secondary (carnivores feeding on herbivores), tertiary (carnivores feeding on other carnivores), and so on, depending on how far they are from the primary producer base. Decomposers are organisms, chiefly bacteria and fungi, which break down dead protoplasm, absorbing some of the decomposition products and releasing many simpler substances, such as nutrients, which are then available again to primary producers.

Food webs are diagrammatic representations of the interrelationships between primary producers and other trophic levels. In simple terms, they describe who eats whom. A simple example would be a straight-line relationship or food chain.

FOOD CHAIN

	Organisms	Trophic Level	Relative Production
decomposers	green algae	primary producers	100
	midge larvae	primary consumers	10
	Arctic char	secondary consumers	1
	man	tertiary consumers	0.1

In practice, even the simplest natural food webs are much more complex than this. There may be more trophic levels and more than one kind of organism at each trophic level. A species may occupy one trophic level at one stage in its life history and another later. Arctic char, for instance, may feed on midge larvae and other small primary consumers (e.g., copepods) when they are small, and on secondary consumers, including smaller individuals of their own species, as they grow. Individual fish may feed at several trophic levels simultaneously. The straight-line example is instructive, however, in that it does illustrate the dependence of one trophic level on preceding ones and the ultimate dependence of consumers (and decomposers) on primary producers.

Because there is considerable loss of energy between primary producers and the higher trophic levels, energy conversion within ecosystems is relatively inefficient. Using our simplified example and the average 10% ecological efficiency which Slobodkin (1962) suggests can be normally expected, it would require a production of 100 grams of algae to support a production of one gram of Arctic char. In more complex ecosystems, where there are more trophic levels and complex relationships, and therefore more opportunity for energy loss, the difference might be even greater.

Waterbodies do, of course, vary in their rates of primary production, usually expressed as grams of carbon produced per unit area per unit time (g C m^{-2} yr^{-1}).

The productivity of freshwater environments in the north is generally low in comparison with lakes at temperate latitudes and, as a consequence, the rates of production of fish and other consumers directly utilizable by man are also very low. Fish production per unit area may be less than 10% that of moderately to highly productive lakes further south.

The low productivity of northern fresh waters might not be immediately apparent because the populations and biomass of consumer organisms, particularly fish, are sometimes very high. For example, unexploited lakes and streams in the Arctic often harbour dense populations of fish, providing a temporary bonanza to fishermen. However, northern fishes are typically long-lived (ages from 15 to 30 years are not unknown) and the biomass of each individual and of the population as a whole represents the stored production of many years. In any one year, individuals have only a small share of the primary production of the system and growth rates are typically very low. The rate at which energy can be incorporated into sex products is also low and many populations of northern fish mature for the first time at advanced ages (e.g., more than 10 years for most lake trout populations) and spawn only every second or third year thereafter.

Another factor which can confuse the assessment of fisheries production data for the north is the fact that many populations are anadromous, that is, they spend at least part of their lives in the sea. These include populations of Arctic char, whitefishes, and ciscoes, all important species. While fisheries typically take place in fresh water, much of the growth of anadromous populations of these species occurs in the marine environment. In order to assess freshwater productivity properly, the two aspects of the life history must be carefully distinguished. The summer growth of anadromous fishes, which takes place in the sea, is a marine subsidy to the biomass of fishes inhabiting bodies of fresh water.

SOME EXAMPLES FROM THE NORTHWEST TERRITORIES

There are few published studies describing the productivity of various trophic levels in aquatic ecosystems in the Northwest Territories. Of those which have been carried out, the most complete is the series of studies conducted at Char Lake on Cornwallis Island near Resolute, N.W.T. The project, as a whole, is summarized by Rigler (1974) though there are numerous other papers describing particular aspects of the studies. Though Char Lake, a High Arctic lake at 75 N latitude, can be considered extreme even for the N.W.T., it has many features which are generally characteristic of fresh waters in the north.

First, the level of primary productivity is very low (Table 1). The productivity of the planktonic algae was only about 4100 mg C m^{-2} yr^{-1} which Rigler notes is about equal to the lowest planktonic productivity recorded anywhere and about 1/50 as large as that in tropical areas. An interesting feature of this lake is that benthic productivity, including benthic algae and mosses, is much more important than planktonic productivity. At approximately 17,900 mg m^{-2} yr^{-1}, it constitutes 80% of total primary productivity. In nearby polluted Meretta Lake, benthic productivity constitutes approximately two-thirds of the total primary productivity (Kalff and Welch, 1974). The relative importance of benthic primary production in northern lakes has apparently not been widely studied but would be expected to be greatest in shallow, clear lakes rather than in deeper, more turbid ones (Welch and Kalff, 1974). Even with the inclusion of benthic primary productivity, however, the total primary productivity (about 22,000 mg m^{-2} yr^{-1}) is still low, in the lower end of the oligotrophic range (0 to 100,000 mg m^{-2} yr^{-1}) defined by Hobbie (1973) for planktonic primary production alone.

For other lakes in the N.W.T. where primary production has been studied, only planktonic data are available (Table 2). The values range from about 4 g m^{-2} yr^{-1} for Eastern Great Bear and Char Lakes to 11.3 and 12 g m^{-2} yr^{-1} for Meretta Lake and Ogac Lake, respectively. None of these values equals the range (24-81 g C m^{-2} yr^{-1}) recorded for relatively unproductive Shield Lakes in the Experimental Lakes area of northwestern Ontario, considerably further south. There appear to have been no formally published studies of the primary productivity of planktonic algae in lakes within the sedimentary bedrock of the Mackenzie Valley and in the Mackenzie Delta but, because of generally higher nutrient loadings, productivity would be expected to be somewhat higher than in comparable lakes within the Canadian Shield, though still within the oligotrophic range.

There are a number of factors limiting primary productivity in the north including light and, most importantly, nutrient levels. Hobbie (1973) points out that nutrient concentrations are always low in Arctic waters undisturbed by man. Kalff (1969) suggests that these low nutrient concentrations appear to be the most important reason for low primary production. A variety of factors contribute to this including the nature of the bedrock (particularly on the Shield), poor soil development, the thin active layer available for leaching, the limited runoff which restricts the transport of nutrients, the slow microbial breakdown of organic materials and recycling of their nutrients, and even the general absence of thunderstorms which assist in the nitrification process.

Livingstone (1963) emphasizes the importance of the country rock or bedrock and its influence on the chemical composition of fresh waters. We can distinguish

TABLE 1
Productivity data for Char Lake. From Rigler (1974).

	Production		
	mg C m^{-2} yr^{-1}	as % of total primary	Biomass mg C m^{-2}
Primary Production			
Phytoplankton	4,100	18.6	
Benthos	17,900	81.4	
Total	22,000	100	
Higher Level Production			
Zooplankton	151	0.7	48
Benthos	692	3.1	561
Total Zooplankton + Benthos	843	3.8	609
Fish	30	0.14	1565

two major types within the N.W.T., the Precambrian rocks of the Canadian Shield which are resistant to weathering and the sedimentary rocks which occupy most of the Mackenzie Valley, the Arctic coast, and the Arctic Islands (Figure 1) and which have a higher solubility. Waters originating in the latter generally have higher concentrations of dissolved substances, including nutrients, than those originating in the Canadian Shield. This is demonstrated by the example of Great Slave Lake where McLeod Bay, which receives drainage from the Shield, has a dissolved solids concentration of only 22 parts per million while the main body of the lake, which receives flow from sedimentary deposits, has a concentration of 150 parts per million (Livingstone, 1963). The Task Force on Fisheries Development (1972) notes that the East Arm is relatively unproductive in comparison with the main body of the lake and is better suited to lake trout than to whitefish.

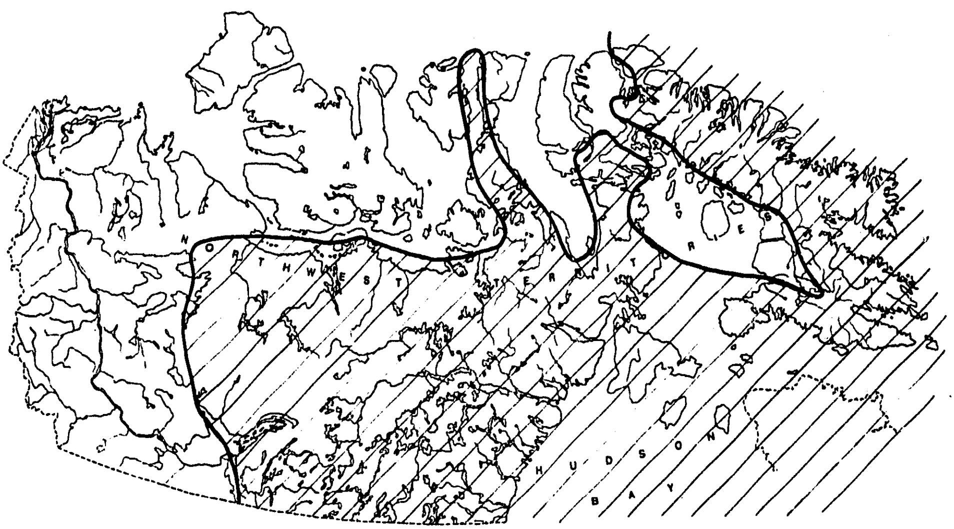
Studies (Kalff and Welch, 1974) at Meretta Lake, near Resolute, N.W.T., indicate that, like temperate ones, High Arctic lakes respond to additions of nutrients, in this case in the form of sewage, by increasing primary productivity. Phytoplankton productivity in Meretta is nearly three times that of neighbouring Char Lake which is unpolluted but otherwise similar (Kalff *et al.*, 1975).

At Char Lake, the sun does not come above the horizon for approximately three months and during this period primary production ceases. Production begins again shortly after the sun returns above the horizon in early February, rising from approximately 4 mg C m^{-2} day^{-1} in February to 15 mg C m^{-2} day^{-1} in April, May and June under ice and snow. Following the onset of the spring melt in mid-June, average daily rates rise to 32 mg C m^{-2} day^{-1} in August. Production rapidly declines after development of a snow cover in late September and terminates shortly before the onset of the polar night in early November after a growing season of nine months. About 20% of the annual phytoplankton production takes place under winter conditions between February and mid-June and a negligible quantity under

TABLE 2
Primary production of planktonic algae for lakes in the Northwest Territories and northwestern Ontario.

Lake	Approximate Latitude	Primary Production g m^{-2} yr^{-1}	Authors
Char	75	4.2	Kalff and Welch (1974)
Meretta	75	11.3	Kalff and Welch (1974)
Immerk	75	4.3	Minns (1977)
Fish	75	6.1	Minns (1977)
Stanwell-Fletcher	73	4.8	de March *et al.* (1977)
Eastern Great Bear	66	◄4	Schindler (1972)
McLeod Bay (Great Slave)	63	◄10	Schindler (1972)
Average of 11 Experimental Lakes, northeastern Ontario	50	39(24-81)	Schindler (1972)

Figure 1. Location of Canadian Shield (cross-hatched) and Borderlands (unhatched) in N.W.T. Shield also includes the east end of Devon Island and southeast corner of Ellesmere Island (not shown). From Bostock (1968).



the equivalent conditions in October and early November (Kalff and Welch, 1974). A similar seasonal pattern would be expected elsewhere in the N.W.T. with relatively longer productive periods further south where the periods of winter darkness are shorter. Available data are insufficient, however, to confirm this pattern suggesting that further studies of primary production in northern waters are essential.[a]

An examination of the data describing the higher levels of productivity in Char Lake (Table 1) demonstrates another common phenomenon in northern lakes, that is, that while the production of fish is very low, the biomass is very high. The production of Arctic char, the only fish species in the lake, has been calculated at 30 mg C $m^{-2} yr^{-1}$ (2.8 kg $ha^{-1} yr^{-1}$), only 20% of the zooplankton and 4.3% of the benthic invertebrate production, yet the biomass of fish is nearly 33 times that of the zooplankton and three times that of the benthic invertebrates. Clearly, the biomass of fish represents many years production and once cropped will only be slowly replaced. This has been a continuing problem in the north where large initial populations of fish have encouraged excessive rates of exploitation to the detriment of populations which only slowly recover.

It is appropriate here to mention once again that where anadromous populations enter the sea to feed and grow during the summer, they return to fresh water with a marine subsidy in biomass. L. Johnson (unpublished data) found that in Nauyuk Lake this ranged from 0.7 to 2.1 kg $ha^{-1} yr^{-1}$, a quantity 125 to 175% that of the production of the entirely freshwater resident population in Char Lake.

Note that the total annual production of fish in Char Lake, 2.8 kg ha^{-1}, considerably exceeds the value of 0.56 kg ha^{-1} (0.5 lbs $acre^{-1}$) which has been used as a guide to permissible levels of sustained fishing effort in lakes in the N.W.T.

[a] *Dr. B. Welsh of the Freshwater Institute has been engaged in research on primary production at Sagvakjuac Research Station in Chesterfield Inlet which should provide valuable information in the immediate future.*

DOMESTIC, COMMERCIAL AND SPORT FISHERIES

Of the more than 60 species of fishes inhabiting coastal and inland waters of the Northwest Territories, 13 are of significant importance to domestic and commercial fisheries (Table 3). Fifteen species are utilized for sport fishing under the Northwest Territories Fishery Regulations (Fisheries and Environment Canada, 1977). Although other species are of local importance to domestic fisheries, this discussion will be restricted to the freshwater and anadromous species listed in Table 3. Species of greatest domestic and commercial importance (Arctic char, lake trout, and whitefishes) have been given priority since these species are most likely to require major management decisions.

DOMESTIC FISHERIES

In this treatment, *domestic fisheries* include "all subsistence fishing by Indian, Inuit, or persons of mixed blood utilizing traditional methods to provide food for himself, his family, or his dogs" (Fisheries and Environment Canada, 1977). Persons licensed as domestic fishermen by the Fisheries and Marine Service after two years residence in the territory and natives providing gifts of fish to other residents are included as domestic fishermen.

There are few data available describing domestic fisheries of the Northwest Territories. However, due to the demand for accurate information created by the recent gas pipeline applications, some information on domestic fishing has become available for the Mackenzie Valley area (Bissett, 1967; Villiers, 1968; DIAND/MPS Assoc. Ltd., 1973; MacLeod, 1973, Environmental Social Committee, 1974; Lilley, 1975; Withler, 1976; Berger, 1977; Hunter, undated; Smith, undated; Wolforth, undated). Information on areas outside the Mackenzie drainage is sparse, particularly in the central Canadian Shield area, and is often based on personal communication with native fishermen (DIAND, 1958-67; MacLeod, 1973; Milton Freeman Ltd., 1976). In many instances, the species taken are not clearly identified necessitating some interpretation by the authors based on the known distribution of certain species.

COMMERCIAL FISHERIES

Commercial fishing is defined as "all fishing for the purpose of sale or barter" (Fisheries and Environment Canada, 1977). Information describing the principal commercial fisheries in the Northwest Territories (Figure 2) was obtained from the Northwest Territories Fishery Regulations (Fisheries and Environment Canada, 1977), the document entitled "Where to Now?" (Task Force on Fisheries Development, 1972) and personal communications from Roger Peet (Fisheries and Marine Service, Winnipeg). Although Figure 2 indicates a considerable area of commercial activity in the Northwest Territories, some of the indicated commercial operations are now closed (e.g., Rankin Inlet and the Mackenzie Delta) and there is only a low level of commercial activity in several others (e.g., Coppermine, Spence Bay and the Boothia Peninsula). Productive commercial fishing is limited to a few key areas including Great Slave Lake and surrounding area, Cambridge Bay and surrounding area, and streams draining into Pelly Bay (Task Force on Fisheries Development, 1972). The history of commercial fishing efforts in Great Slave Lake is reviewed by Kennedy (1956), Keleher (1972a, b), and Bond and Turnbull (1973). The history of commercial fishing in the Mackenzie Delta and Cambridge Bay is reviewed by Barlishen and Webber (1973a, b). A similar review has been prepared for the Lac La Martre fishery (Glazier and Lewis, 1973). Overall, however, information on the history of commercial fishing efforts in the N.W.T. is sketchy.

In recent years, nearly half of the commercial licences issued in the Northwest Territories were for the Great Slave Lake fishery (Task Force on Fisheries Development, 1972) and, over the last 30 years, more than 90% of the annual commercial harvest for the Northwest Territories has been taken from this area (Keleher, 1972a; Statistics Canada, 1971-75). Because of the importance of the Great Slave fishery, a great deal of information is available, particularly on lake whitefish and lake trout. Data describing other fisheries in the N.W.T. are very limited by comparison.

Beginning in 1961, an effort was made to expand the fishery in Great Slave Lake to include new waterbodies in the Camsell River drainage and other lakes in the vicinity (Wong and Whillans, 1973). This has shifted some of the pressure off the Great Slave Lake fishery but, because of poor access to many of the small waterbodies in the area, fishing has tended to concentrate on a few of these lakes. Recent studies on Hottah Lake (Wong and Whillans, 1973), Lac La Martre (Libosvarsky, 1970; Bond, 1973), Keller Lake (Johnson, 1972), and the Snare River drainage (Weagle and Cameron, 1974) provide valuable data on the dynamics of fish populations in smaller waterbodies near Great Slave Lake.

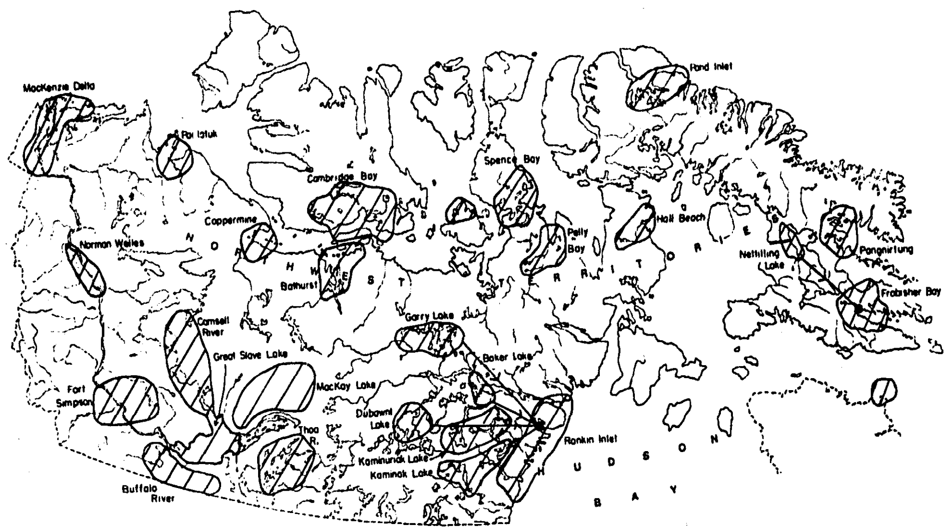
The Arctic char is the principal species taken in coastal fisheries such as those at Cambridge Bay, Spence Bay, Pelly Bay, and Baffin Island (Brian Wong, unpublished data). The cannery facility, now closed, at

Rankin Inlet also depended on char to a large extent although whitefish and lake trout were also taken (Bond, 1974c, 1975a).

Commercial fisheries in the Mackenzie Delta have largely depended on whitefish and ciscoes. Since ciscoes are taken commercially only in the northern portion of the Mackenzie drainage, our discussion of the life history of ciscoes will utilize data from this area and nearby coastal habitats.

The other species listed in Table 3 occur only incidentally in commercial fisheries in the Mackenzie Valley and are not utilized elsewhere.

Figure 2. Principal commercial fishery areas in the Northwest Territories.



SPORT FISHERIES

Access is the principal factor limiting the development of sport fisheries in the Northwest Territories. Sport fishing is presently restricted to lodges and fishing camps (Figure 3), fly-in fishing, and areas where roads provide easy access to fishable waterbodies. Most of the sport fishing areas are concentrated in the vicinity of Great Slave and Great Bear Lakes, along the Mackenzie River, and in a few lakes in the south Keewatin (Figure 3). The Task Force on Fisheries Development (1972) has suggested that expansion of sport fisheries in the N.W.T. would be a means of more efficiently utilizing the fisheries resource without risking the expense of large commercial ventures.

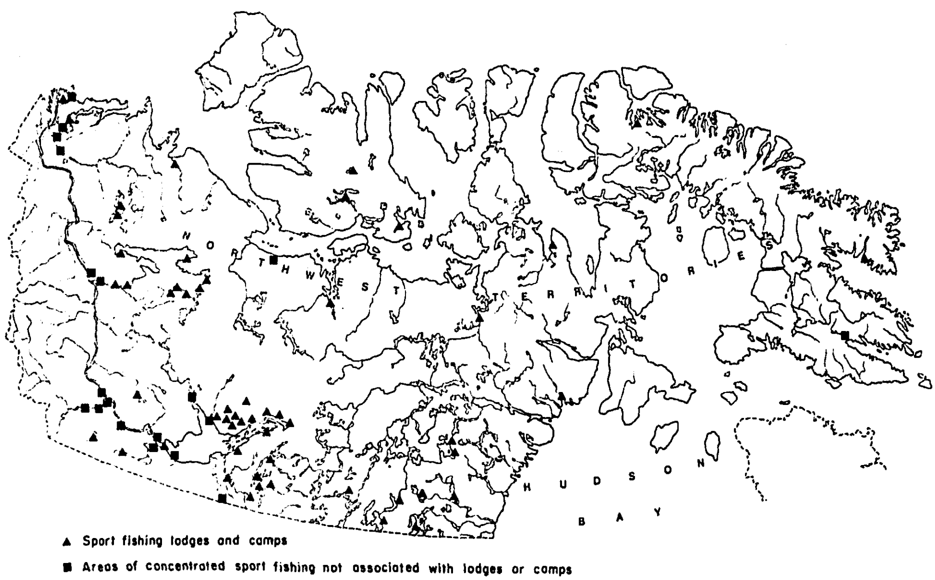
Of the 15 sport species listed in Table 3, lake trout, Arctic char, grayling, northern pike, and walleye are considered the most important to the sport fishery in terms of economic development. The East Arm of Great Slave Lake is at present managed strictly for lake trout with no commercial fishing allowed (Falk *et al.*, 1973; Anonymous, 1975). Similarly, Great Bear Lake has been harvested almost exclusively by sport fishermen. A net decline in the number of trophy-sized lake trout has occurred in both lakes as a result of excessive emphasis, by sport fishermen, on killing large fish (Falk *et al.*, 1973). Similar studies of Arctic grayling (Gillman and Dahlke, 1973; Falk and Gillman, 1974) suggest that sport fishing has caused a significant reduction in the size of fish in the vicinity of Hay River. There is also evidence of serious local reductions in sport fish populations along the Mackenzie Highway system in the southwestern portion of the N.W.T. (Brian Wong, personal communication). These studies suggest that careful management of sport fisheries is as important as management of commercial fisheries.

TABLE 3

List of freshwater fish species important in domestic, commercial and sport fisheries in the Northwest Territories (after Fisheries and Environment Canada, 1977).

Family	Species Name: Common	Species Name: Scientific	Fisheries: Domestic/ Commercial	Fisheries: Sport
Salmonidae	Rainbow trout	*Salmo gairdneri*		+
	Arctic char	*Salvelinus alpinus*	+	+
	Dolly Varden	*Salvelinus malma*		+
	Brook trout	*Salvelinus fontinalis*		+
	Lake trout	*Salvelinus namaycush*	+	+
	Lake cisco	*Coregonus artedii*	+	+
	Arctic cisco	*Coregonus autumalis*	+	+
	Least cisco	*Coregonus sardinella*	+	+
	Lake (humpback) whitefish	*Coregonus clupa eformis*	+	+
	Broad whitefish	*Coregonus nasus*	+	+
	Round whitefish	*Prosopium cylindraceum*	+	
	Inconnu	*Stenodus leucichthys*	+	+
	Arctic grayling	*Thymallus arcticus*		+
Hiodontidae	Goldeye	*Hiodon alosoides*		+
Esocidae	Northern pike	*Esox lucius*	+	+
Gadidae	Burbot	*Lota lota*	+	
Percidae	Walleye	*Stizostedion vitreum*	+	+

Figure 3. Location of sport fishing lodges and camps and location of concentrated sport fishing not associated with lodges and camps.



DISTRIBUTION, LIFE HISTORY AND UTILIZATION OF MAJOR FISH SPECIES

ARCTIC CHAR *(Salvelinus alpinus L.)*

The Arctic char form a polymorphic species complex with a circumpolar distribution. They are native to northern coastal streams and lakes in North America, Asia, and Scandinavia. Distribution in the Northwest Territories includes most coastal streams including some coastal lakes and the High Arctic Islands (Figure 4). Small populations are also present on several islands in Hudson Bay, notably the Belcher Islands.

The taxonomy of the *Salvelinus alpinus* complex is confused but in the Northwest Territories there appear to be three distinct species. The Dolly Varden *(Salvelinus malma)* is found in the Mackenzie River upstream of Great Bear River and in some tributaries to the Mackenzie. It is not common and is a minor component of domestic fisheries. It will not be further considered in this presentation.

The other two species within the complex were first described by McPhail (1961) as the Western Arctic-Bering Sea Form and the Eastern Arctic Form of the Arctic char. Recent work (e.g., McCart and Craig, 1971; McCart, unpublished data) confirms McPhail's distinction between the two forms and suggests that they are in fact distinct species.

In the Northwest Territories, the Western Arctic Form is confined to the western portion of the Mackenzie Delta and its tributaries including Big Fish River, Rat River, and the lower portions of the Peel drainage (McCart and Bain, 1974; Jessop *et al.*, 1974; Jessop and Lilley, 1975). The species has its major centers of population to the west in Beaufort Sea drainages in the Yukon and Alaska. The species is typically confined to streams and only one lake resident population is known. Both freshwater-resident and anadromous (sea-going) populations occur.

The Eastern Arctic Form also occurs as both freshwater-resident and anadromous populations. In the Northwest Territories, it is confined to areas east of the Mackenzie drainage.

AGE AND GROWTH

Considerable information is now available on the age and growth structure of Arctic char populations from the Yukon and Northwest Territories. A list of publications describing char populations has been compiled by Marshall (1977).

Studies of anadromous and freshwater-resident Arctic char from populations in the Northwest Territories and Yukon Territory indicate that anadromous fish grow considerably faster than freshwater-residents (Figure 5). The difference in growth between the two types is one of the advantages of anadromy. Anadromous Eastern Arctic char are generally slower growing than Western char, but tend to live longer, reaching a greater maximum size.

Maximum reported ages for anadromous Western Arctic char range from 10 to 14 years, while some Eastern char have attained age 29. These differences in growth may be environmentally induced or may be the result of a genetic difference between Eastern and Western Forms.

From the management standpoint, anadromous Western char would appear to be the most productive because of their more rapid growth. However, the limited stocks of Western char in the Northwest Territories prohibit their extensive utilization as a resource.

Although abundant, freshwater-resident char are extremely slow growing and seldom exceed 350 mm in fork length, too small to be practical for commercial fishery development. Although quotas have been set for landlocked char in numerous unnamed lakes in the vicinity of Cambridge Bay (Fisheries and Environment Canada, 1977), harvest of these char for sale as "pan size" fish in southern markets has proved financially unrewarding (Barlishen and Webber, 1973a).

Populations of anadromous Eastern Arctic char are, therefore, the only ones present in sufficient numbers and of high enough productivity to permit a reasonable degree of commercial and sport utilization. Anadromous char taken in commercial fisheries along Hudson Bay and on Baffin Island generally range in size from 450 to 750 mm and in age from nine to 25 (Bond, 1974c; Roger Peet, unpublished data). The large size attained by Eastern anadromous char allows more economical harvest for commercial purposes, but the slow growth rate results in slow recruitment of juveniles to an economically harvestable size (Johnson, 1976).

There is a wide range in fork length at any given age both within and among populations. It has been suggested that the variability which occurs at single localities is, in some cases, the result of the mixing of anadromous and resident stocks (Thompson, 1957; Campbell and Johnson, 1976), or the result of the utilization of different food organisms by same-age fish of the same population (Rigler, 1974; Johnson, 1975; Sekerak *et al.*, 1975; de March *et al.*, 1977). Several authors report that there appear to be two modes of growth within sea-run populations of Arctic char (Rigler, 1974; Johnson, 1975). It has been suggested that bimodal growth may be the result of a "filter" mechanism operating through limiting factors such as physical size or learned behaviour which control feeding activity in schools (Johnson, 1972).

Figure 4. Distribution of Arctic char in the Northwest Territories and locations of major commercial fishing areas.

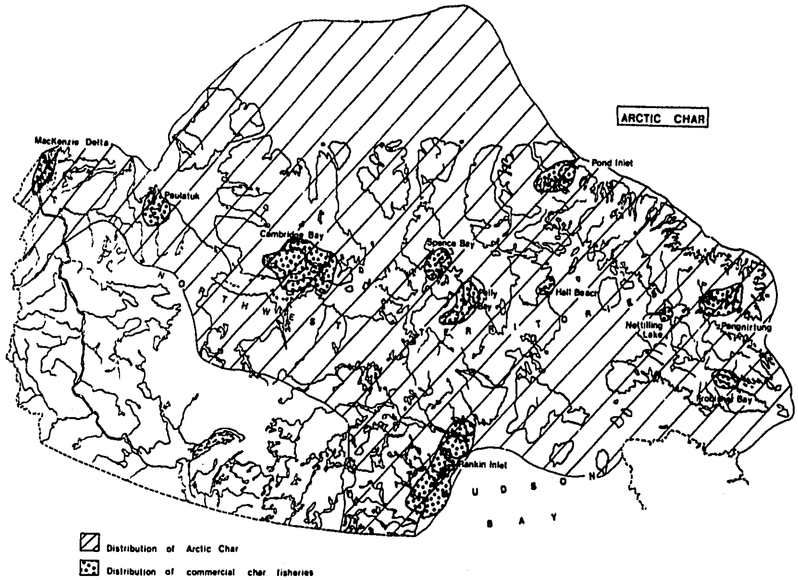
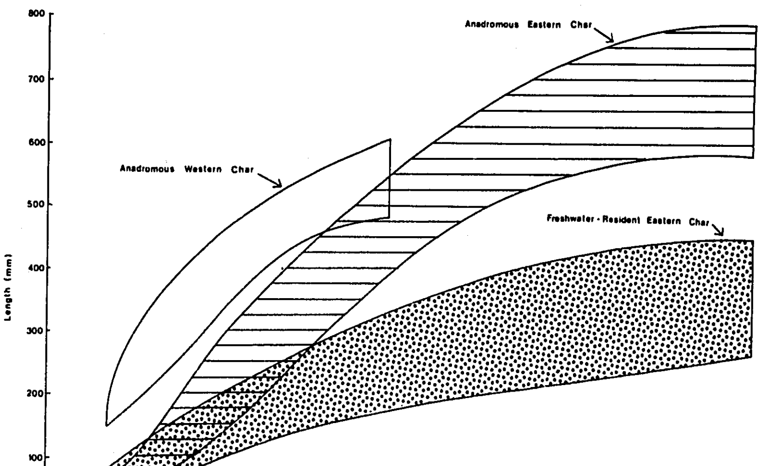


Figure 5. Range of growth rates for various types of Arctic char. Sources various, indicated in text.



AGE AND LENGTH FREQUENCIES

Changes in the age and length frequencies of Arctic char in exploited populations have commonly been utilized by fishery managers to determine whether fishing pressure is detrimentally affecting population structure. At Keyhole Lake (Hunter, 1970), the Sylvia Grinnell River (Hunter, 1976; Sopuck, 1977), the Labrador coast (Coady, 1974), and Creswell Bay (Johnson, 1975; de March *et al.*, 1977) both mean age and mean size declined as a result of excess fishing pressure. Although recovery of Arctic fish populations from the effects of overfishing has generally been assumed to be slow, Johnson (1976) presents data indicating that, even at Keyhole Lake where the char population was subjected to a very heavy experimental fishery, the original population structure was restored within a few years after exploitation ended. Management schemes which allow for a recovery period after exploitation might provide an economic means of harvesting Arctic char. For example, a system similar to the one which has been used for whitefish and lake trout in the N.W.T. (Wong and Whillans, 1973), which allows for the taking of a six year quota in two years, followed by a four year closure, might be useful in harvesting char in some portions of the Northwest Territories. Hunter (1970) calculated that even if the virgin Arctic char population of Keyhole Lake had been fished at an instantaneous mortality rate of 89% (21.34 kg ha^{-1}) the population would have recovered 97% of its original stock within five years if it were not further exploited.

MATURITY

Arctic char reach maturity as early as age three in some freshwater-resident populations (Hunter, 1970; McCart and Bain, 1974), but most authors record the age at first reproduction as four to nine years. In the Eastern Arctic, spawning fish reach ages as great as 29 years (Sekerak and Graves, 1975). In most char populations, the percentage of spawning fish is very low, ranging from two to 15% (Hunter, 1970; Campbell and Johnson, 1976; Sopuck, 1977; de March *et al.*, 1977; Roger Peet, unpublished data). Due, probably, to their slower growth rate, Eastern char reach sexual maturity slightly later (one to three years) than Western char. Available information indicates that age at first reproduction is one to three years less for freshwater-resident char than for anadromous char (de March *et al.*, 1977). Size at first reproduction generally exceeds 300 mm for anadromous Eastern char and 400 mm for anadromous Western char. Freshwater-resident char rarely exceed 200 mm at first reproduction and some individuals are mature at 120 mm (Hunter, 1970). Males tend to mature one to four years earlier than females in both freshwater-resident and anadromous populations.

The presence of small ($<$200 mm) mature char suggests that both freshwater-resident and sea-run char coexist in some lake systems (Thompson, 1957; Campbell and Johnson, 1976; de March *et al.*, 1977). In Nauyuk Lake, where no mature freshwater-resident char are present, no fish over 180 mm are caught during the summer after the larger fish have migrated seaward (Johnson and Campbell, 1975).

TABLE 4

Population estimates for landlocked char in Char Lake (Cornwallis island) and Keyhole Lake (Victoria Island), and sea-run anadromous char from Stanwell-Fletcher Lake (Somerset Island) and Nauyuk Lake (Kent Peninsula). Since data from Keyhole Lake include only fish age 7 and older, comparable data are presented for Char Lake as well as a complete population estimate.

Lake	Lake Area (ha)	No. of Fish Present	No. of Fish ha^{-1}	Fish Weight kg/ha^{-1}
Char*	52.6	23,600	449.0	104.0
Keyhole*	48.6	8,200	169.0	44.0
Char**	52.6	228,100	4,336.0	148.0
Stanwell-Fletcher***	35,900.0	90,000	2.5	2.0
Nauyuk***	2,700.0	10,600	4.0	10.3

**Landlocked char populations including only individuals age 7 and older.*
***Including all landlocked char present in the lake.*
****Sea-run anadromous char populations excluding all non-migrant individuals.*

POPULATION AND PRODUCTION ESTIMATES

Several recent studies of Eastern anadromous and freshwater-resident char provide estimates of the number and biomass of Arctic char present in High Arctic lakes. These studies include Keyhole Lake (Hunter, 1970), Char Lake (Rigler, 1974), Nauyuk Lake (Johnson and Campbell, 1976), and Stanwell-Fletcher Lake (de March *et al.*, 1977). A summary of population estimates is presented in Table 4.

Keyhole Lake and Char Lake are small lakes supporting populations of freshwater-resident char. Stanwell-Fletcher and Nauyuk are much larger lakes. The data presented in Table 4 describe only the anadromous component of Arctic char populations in these lakes. In addition to the sea-run population, both Stanwell-Fletcher and Nauyuk Lakes support populations of non-migratory spawners and/or juveniles for which no population data are yet available.

Data on char production are limited to studies of freshwater-resident populations in Char Lake and anadromous populations in Nauyuk Lake. Char in Char Lake have an annual production of 2.8 kg $ha^{-1} yr^{-1}$ (0.03 g $m^{-2} yr^{-1}$). The summer production of anadromous char (►400 mm) migrating out of and returning to Nauyuk Lake ranged from 0.7 to 2.1 kg ha^{-1} between 1974 and 1977 (L. Johnson, unpublished data). This is growth that took place at sea and can be viewed as a marine subsidy to the biomass of Arctic char in Nauyuk Lake.

SPAWNING HABITAT AND STRATEGY

Spawning habitat for Arctic char ranges from hard mud (Hunter, 1970) to coarse gravel (Fabricius and Gustafson, 1954; Glova and McCart, 1974). Freshwater-resident populations often spawn in lakes or the mouths of rivers entering lakes. Western anadromous char commonly spawn in riffle areas of streams, while in the Northwest Territories anadromous Eastern char are generally lake spawners (Campbell and Johnson, 1976; de March *et al.*, 1977). Although most spawning migrations begin in August, Johnson and Campbell (1976) report that in the Nauyuk Lake system, spawning char migrate upstream from Nauyuk Lake into Willow Lake immediately after break-up, feed in the lake, and begin spawning in September (Campbell and Johnson, 1976). Most spawning individuals do not make a seaward migration in the year of spawning, but remain in fresh water to feed until the onset of the upstream spawning migration (Griffiths *et al.*, 1975, 1977; Johnson and Campbell, 1976).

The spawning period of char ranges from as early as August 23 in Char Lake to late November along the west coast of Hudson Bay (Hunter, 1970; de March *et al.*, 1977). Spawning appears to occur later further south. In warm water springs (e.g., Cache Creek, N.W.T.), high spring water temperatures may delay spawning into late November or later (McCart and Bain, 1974).

MIGRATIONS

In most areas, anadromous char migrate seaward immediately after ice-out. Large char migrate seaward earlier than smaller individuals and arrive in coastal waters first (Johnson and Campbell, 1975; de March *et al.*, 1977; Griffiths *et al.*, 1977). On the other hand, large char are the first to return to freshwater habitats and the average size of char at sea declines as the season progresses. As the upstream migration begins, catches in coastal fisheries decline and fisheries in streams become productive. Peak char runs generally occur in August and early September, but are later in southern (than northern) streams.

At sea, char range widely along the coast occasionally moving more than 200 km from their home stream (Glova and McCart, 1974). Tagging studies of both Eastern and Western char indicate that char occasionally enter streams other than their home stream to spawn or overwinter (Craig and McCart, 1975; R. Peet, personal communication).

RECRUITMENT AND MORTALITY

Johnson (1975) suggests that, in unexploited populations at equilibrium, recruitment of juvenile char into the adult population equals the mortality of adults. Exploitation of the adult population triggers increased recruitment of juvenile char ensuring that normal size and age distributions are maintained. If the harvest is excessive, recruitment is insufficient to maintain the population structure resulting in a decline in both size and age. Rapid recruitment often results in an increase in the growth rates of juvenile char and a reduction in natural mortality. With the onset of heavy exploitation, an upsurge in growth of juveniles already present in the system occurs (Hunter, 1970). If the harvest is terminated, recruitment tends to return the population to its original size and age structure (Johnson, 1975). However, in situations where a number of species are present in a system, recruitment of other species could interfere with the return of the population to an equilibrium condition.

Estimates of annual mortality rates for char indicate a gradual increase in natural mortality with increasing age. Hunter (1970) found that, in Keyhole Lake, annual mortality of landlocked char ranged from 0.25 for age seven fish to 0.94 for age 16 fish. Studies of anadromous char in the Sylvia Grinnell River drainage (Sopuck, 1977) and Nettilling Lake (R. Peet, unpublished data) indicate that the annual mortality rates of sea-run fish range from 0.40 to 0.50.

Fishing exploitation using gillnets has been shown to increase mortality to older, larger fish, while decreasing the mortality of younger, smaller fish. Studies at Keyhole Lake indicated that, for char younger than age seven, mortalities in gillnet meshes as small as 2.5 inches (6.35 cm stretched mesh) were negligible and that, as previously indicated, the growth rates of juvenile char increased dramatically after exploitation began (Hunter, 1970).

Although these studies suggest that a rotational harvest (e.g., six year quota caught in two, then four years closed) would actually result in increased production in char populations due to more rapid growth and recruitment and lower mortality of juvenile char, the presence of species other than char could complicate the situation. Johnson (1976) states that "whereas a single species of fish, as in the char of Keyhole Lake, will return rapidly to the equilibrium position, a more complex system will have many alternative pathways through which the energy can move. . . . In Canadian freshwater fisheries, it is usually the dominant species that are sought after; it is therefore essential to think in terms of sustained populations rather than sustained yields."

If a rotational harvest scheme were utilized as a means of managing char in systems containing other species with similar ecological requirements, these species might interfere with char recruitment and prevent the rapid return of the char population to an equilibrium state. A sustained harvest management scheme, despite its economic problems, might be the only way to protect the char population in such circumstances.

FOOD HABITS

Freshwater resident char and the juveniles of anadromous populations feed almost exclusively on aquatic insects and small crustaceans (MacCallam, 1972; Rigler, 1974; Sekerak and Graves, 1975; de March *et al.*, 1977). Fish are seldom utilized by small char (<300 mm), with the exception that young-of-the-year are eaten in some areas (Grainger, 1953; Glova and McCart, 1974; Griffiths *et al.*, 1975; Lawrence *et al.*, 1978). The diversity of food items utilized by char in fresh water is generally lower in populations inhabiting the Arctic Islands and portions of the Canadian Shield than in populations west of the Mackenzie River (McCart *et al.*, 1972; McCart and Craig, 1973; Bain, 1974; Glova and McCart, 1974; Sekerak and Graves, 1975). This probably reflects the lower productivity and the lower diversity of food organisms in the former areas.

Anadromous char achieve a considerable growth advantage over freshwater-resident char due to the high availability of food organisms in the marine environment. Studies of anadromous char stomach contents reveal that crustaceans (notably amphipods, euphasids, and mysids) and fish are the predominant food items (Grainger, 1953; Sekerak and Graves, 1975; Griffiths *et al.*, 1975, 1977). The fish species utilized include whitefish and several marine species (e.g., fourhorn sculpin, Arctic cod, Pacific sand lance). Species diversity of stomach contents is often considerably higher in marine environments than in fresh water (Grainger, 1953).

Studies of anadromous char populations in fresh water indicate that migrant anadromous char do not feed extensively in fresh water (Sprules, 1952; McCart *et al.*, 1972; Bain, 1974; Glova and McCart, 1974; Sekerak and Graves, 1975). Freshwater juveniles of anadromous populations and freshwater-resident char commonly feed more intensively as indicated by low percentages of empty stomachs among these groups. A few populations of freshwater-resident char have been found with high percentages of empty stomachs during the summer feeding period (Hunter, 1970; Sekerak and Graves, 1975). The intensity of feeding in anadromous populations varies considerably among coastal locations and tends to show some seasonal variation depending in part on the availability of food items (Grainger, 1953; Griffiths *et al.*, 1977; de March *et al.*, 1977). Among migrant char with food in their stomachs, saltwater-caught individuals contain greater quantities of food than those taken upstream in fresh water (Sekerak and Graves, 1975; Sekerak *et al.*, 1975).

UTILIZATION

DOMESTIC CHAR FISHERIES

Anadromous Arctic char are utilized in domestic fisheries centered near coastal villages in the northern and eastern portions of the N.W.T. (Figure 6). Although some freshwater-resident populations have been fished on occasion, anadromous fish are preferred due to their larger size and the ease of capture resulting from the concentration of fish in rivers during late summer and fall spawning runs. Historically, the number of areas fished was probably much larger than today and several of the known fishing sites have been utilized only rarely in recent years (Milton Freeman Research Ltd., 1976). Char still, however, provide an important source of food to many native villages, both for human consumption and as food for dogs.

COMMERCIAL FISHERIES

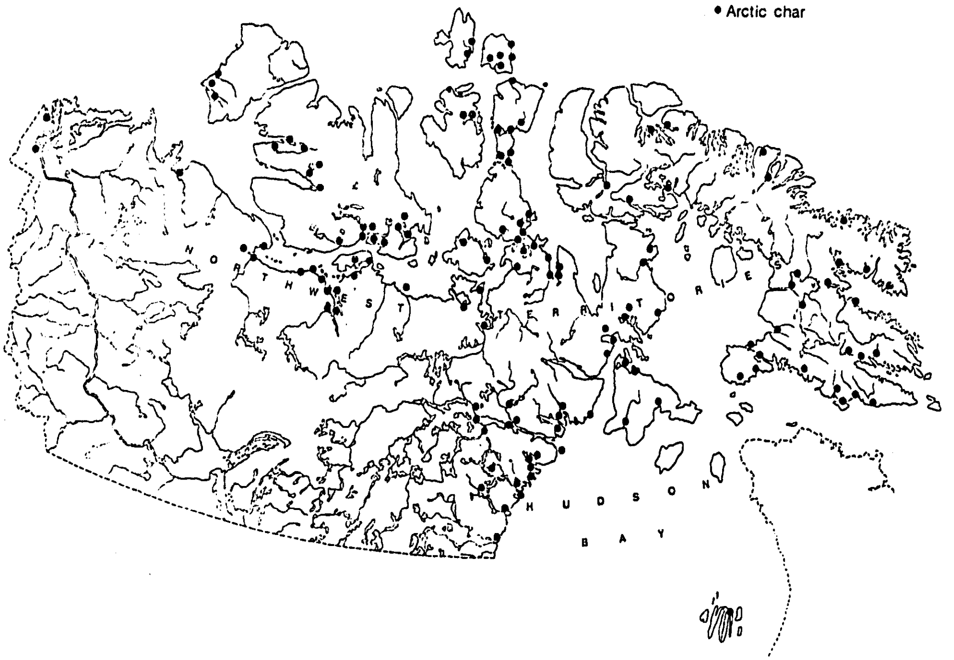
The location of major commercial char fisheries in the N.W.T. is shown in Figure 4. Catch records for several of these fisheries are presented in Table 5. The catch statistics are only approximate. Information on catches from commercial fisheries originates with the operators of freezers, canneries, and shipping personnel who have occasionally been delinquent in maintaining accurate catch records. In addition, the dividing line between commercial and domestic fisheries is poorly defined and many char sales within northern communities may not be recorded.

The char fisheries at Rankin Inlet, Cambridge Bay, Pelly Bay, and Nettilling Lake account for most of the commercial char sales in the Northwest Territories in recent years (Table 5). Data compiled by Statistics Canada (1971-75) on total fish sales in the Northwest Territories suggest that these four major fisheries account for over 80% of commercial char sales in most recent years. Other small scale fisheries serve primarily local needs and may not be accurately represented in the total fish sales statistics.

In some instances, large commercial harvests of anadromous char have resulted in a drastic population decline. For example, a commercial fishery established at Frobisher Bay in the Sylvia Grinnell River in 1958 greatly reduced fish stocks and was eventually closed in 1967 due to the low catch per unit effort and small size of the remaining fish stocks (Hunter, 1976). Since closure, the Sylvia Grinnell fishery has been subject to domestic and sport fishing only. Despite this, the population has not recovered and recent studies (Sopuck, 1977) present clear evidence of overexploitation.

Economics is often a major factor limiting development of large scale char fisheries in the N.W.T. The Rankin Inlet cannery, which began operation as a commercial fishery in 1961 (Brian Wong, unpublished data), utilized a large area of Shield lakes and coastal streams to provide fish to the facility. There was some

Figure 6. Location of important domestic char fishing areas in the Northwest Territories (based on Milton Freeman Ltd., 1976).



localized reduction of char stocks but the major reasons for the closure of the facility in 1977 were the high cost of transportation, the low return on investments, and lack of interest on the part of local residents (R. Peet, personal communication). While there was a market for canned char products as gourmet food, even at relatively high prices, the fishery suffered from limited and sporadic production (B. Wong, Fisheries and Marine Service, Yellowknife; personal communication). Had the Rankin cannery been able to produce one to two million pounds a year, there should have been little problem marketing the product.

The Cambridge Bay commercial fishery is a community freezer operation which began operations in 1960 and has utilized anadromous Arctic char and lake trout. In summer, runs of anadromous char are harvested in the rivers. During the winter, lakes are gillnetted to capture overwintering char and lake trout. Fishing in coastal waters is generally restricted to a few areas in the immediate vicinity of major char streams. Overfishing of some streams has resulted in a decline in the average size of char necessitating temporary restrictions on fishing in these areas (e.g., Ekalluk, Paliryuak, Halovik, and Lauchlan Rivers) but, in general, the Cambridge Bay fishery for anadromous char has proved an economically viable operation and has resulted in only limited depletion of fish stocks.

Efforts to utilize freshwater-resident char populations in lakes near Cambridge Bay have proved uneconomical (R. Peet, personal communication). Both summer and winter fisheries were tried. The fish were hard to handle: they quickly went soft during the summer and large numbers were required to reach the required weight. No feasible system of harvest was worked out (B. Wong, personal communication). The harvest was uneconomic despite the unusually high quotas which were set to aid in the establishment of the freshwater-resident fishery. Barlishen and Webber (1973a) report that pan-sized freshwater-resident char were in direct competition with domesticated rainbow and brook trout which sold for a lower price on southern markets thus limiting freshwater-resident char sales.

Commercial fishery activity in Pelly Bay also centers around a community freezer concept, but on a much smaller scale than at Cambridge Bay. While lake trout, taken during fisheries for freshwater-resident char, form an important part of the total harvest at Cambridge Bay, char are the only species fished commercially at Pelly Bay. The Kellett, Bacher, Kuugarjuk, and

Arrowsmith Rivers provide most of the harvest. Due to the relatively low annual catch (<50,000 lbs annually) and the short period of operations (since 1969), char stocks have remained relatively constant in the area. Both economically and biologically, the Pelly Bay fishery appears to be sound. By providing for community needs first and selling only surplus catches to southern markets, annual investment in the fishery is kept minimal and fish stocks are not depleted by the demands of a large scale operation.

In 1974, a commercial fishery was established by residents of Frobisher Bay at Nettilling Lake to exploit stocks of anadromous char. There was a net decline in catch per unit effort in the 1976 season (Sopuck, 1977) resulting in a reduced total catch (Table 5). In 1977, however, the total catch quota of 50,000 lbs was again attained but data on catch per unit effort are not yet available (R. Moshenko, Fish and Marine Service, Winnipeg, personal communication). Data are insufficient at present to determine the long term effect of this commercial fishery on the Nettilling Lake anadromous population.

Hunter (undated) reports that the Mackenzie Delta area offers considerable potential for fisheries development. Char, however, are extremely limited in distribution in this area with most of the important char streams (Cache Creek and the Rat River) draining from the Yukon Territory. Although records indicate that small catches of char from local streams and areas along the Yukon coast have contributed to commercial catches, the resource appears to be too limited for economic development without severely reducing char stocks. The anadromous populations in Cache Creek and the Rat River are already heavily exploited by domestic fishermen.

Other commercial char fisheries shown in Figure 4 are local community ventures which have operated sporadically in past years and generally concentrate on providing fish for local needs. In many cases, the fish are utilized directly by the fishermen who catch them, with commercial sales limited to surplus fish.

Fishery regulations restrict the mesh size utilized in commercial char fisheries to 5.5 inch (13.9 cm stretched mesh) for anadromous populations and 2.5 inch (6.35 cm stretched mesh) for freshwater-resident char (Fisheries and Environment Canada, 1977). These mesh sizes effectively reduce the number of small fish caught providing for adequate survival to insure maintenance of the population. Larger fish are selectively removed, often resulting in a reduction in the average size of char taken in subsequent years. In cases where spawning stocks are severely reduced, a decline in population size may occur. Sound management of char populations, therefore, depends on the establishment of quotas and seasons which control the harvest sufficiently to insure that yields are maintained. A discussion of factors governing the establishment of present commercial quotas and harvest seasons is presented in the management section.

SPORT FISHERY

Anadromous Arctic char are one of the most prized sport species caught by anglers in the Northwest Territories. Due to the small size of freshwater char and

TABLE 5

Summary of commercial catch data for Arctic char from six fisheries in the Northwest Territories (from B. Wong and R. Peet, Fisheries and Marine Service, unpublished data). All figures are in pounds round weight. ND = no data. (1 pound = 0.45 kg).

Year	Rankin Inlet	Cambridge Bay	Pelly Bay	Mackenzie Delta	Nettilling Lake	Sylvia Grinnell River	Cambridge Bay Landlocked Char
1960	—	19,500	—	—	—	12,195	—
1961	4,988	13,863	—	—	—	10,304	—
1962	38,840	16,955	—	—	—	10,336	—
1963	42,547	31,157	—	—	—	10,647	—
1964	29,974	35,522	—	—	—	8,430	—
1965	41,900	47,000	—	16,084	—	12,319	—
1966	60,207	37,000	—	800	—	10,270	—
1967	44,604	62,205	—	—	—	—	—
1968	5,253	95,622	—	—	—	—	—
1969	57,522	107,048	1,500	—	—	—	—
1970	17,265	98,459	850	—	—	—	—
1971	59,437	93,250	35,000	—	—	—	28,444
1972	36,353	127,266	7,363	—	—	—	45,115
1973	40,635	62,683	49,228	—	—	—	21,827
1974	93,695	67,555	46,629	—	50,000	—	4,070
1975	65,941	71,207	40,791	—	59,400	—	2,760
1976	ND	ND	ND	—	24,739	—	—

poor access to lakes containing them, this form is little sought after in comparison with andromous fish.

Most of the sport fishing for char occurs a) in coastal streams in the vicinity of Rankin Inlet; b) in streams entering Coronation and Queen Maud Gulf; and c) on Baffin Island. Char are fished both from lodges and fly-in groups which establish temporary camps. Most sport fishing is restricted to the late summer and fall runs when the fish are heaviest after a summer of feeding at sea.

Regulations allow anglers a daily catch limit of four char with a possession limit of seven (Fisheries and Environment Canada, 1977). The Tree River, draining into Coronation Gulf, is an exception with only two fish per angler allowed and a total harvest limited to 700 char per year. (The limit has recently been raised from 500 as the population has recovered.) The Tree River has a quota in order to protect a vulnerable population which is only able to utilize a short section of river near the mouth before encountering impassable barriers (R. Peet, personal communication). At one time, a combination of sport fishing by tourists and domestic fishing by residents of Coppermine caused a marked reduction in the char population. In recent years, strict catch limits and yearly quotas on sport fishery combined with a voluntary reduction in the domestic fishery by residents of Coppermine have allowed the population to recover. Sopuck (1977) indicates that the sport fishery of the Sylvia Grinnell River near Frobisher Bay might also be improved by a "voluntary limit" on the domestic fishery for a few years to allow depleted stocks to recover. The conflict between domestic harvest and sport fishing is a significant problem to management due to the priority that the domestic fishery normally takes over sport fishing.

WHITEFISH

Three species of whitefish, the lake or humpback whitefish *(Coregonus clupeaformis)*, the broad whitefish *(C. nasus)*, and the round whitefish *(Prosopium cylindraceum)*, are common in the Northwest Territories and are harvested in domestic and commercial fisheries. Historical domestic and commercial catch records and commercial quotas established by the Fisheries and Marine Service, lump all three species under the single category of "whitefish". The relative importance of each species in domestic and commercial catches varies from area to area but, in most cases, literature references to "whitefish" catches refer to the lake (also known as humpback) whitefish.

DISTRIBUTION AND HUMAN UTILIZATION

The lake whitefish is widely distributed in lakes and rivers in the mainland portion of the N.W.T. and is known to occur in brackish coastal estuaries in the vicinity of the Mackenzie Delta and near Cambridge Bay on Victoria Island (Figure 7). Commercial quotas for this species have been established for approximately 200 waterbodies across the N.W.T. Many of these quotas have, however, been established without prior knowledge of the presence or absence of whitefish within the waterbodies and most often, the quotas for whitefish and lake trout have been combined.

The areas of most concentrated domestic and commercial fishing for lake whitefish are in the immediate vicinity of communities in the Mackenzie River Valley and Great Slave Lake area, in the Coronation-Queen Maud Gulf area, and along the west coast of Hudson Bay (Figure 7). Lake whitefish are rarely the sole object of commercial fisheries in the N.W.T. Table 6 presents available information on commercial landings of whitefish in four regions of the N.W.T. which have historically been centers of commercial fisheries. Although no commercial fisheries are presently operating in the Mackenzie Delta, whitefish (in this instance, primarily broad whitefish) composed an average of at least 72% of the total commercial landings during the years in which the fishery was operating. The Great Slave Lake commercial fishery has been operating continuously since 1945, and until 1967, whitefish comprised an average of 61.5% of the total commercial landings. Recently, due to a drastic decline in the harvest of lake trout from Great Slave Lake, lake whitefish have formed the mainstay of the commercial fishery, totalling approximately 80% of landings from 1968 to 1977. The total landings of whitefish from Great Slave Lake remained stable at 3.5 to four million pounds annually until recently (1965 to present) when, in spite of the increased efficiency of the fishery (as the result of the introduction of nylon nets, installation of mechanical net lifters, and the removal of yardage restrictions), catches have continued to decline (Keleher, 1972a; Bond and Turnbull, 1973; Bond, 1974a, 1975b).

Commercial fisheries in the eastern Arctic have traditionally concentrated on anadromous Arctic char to a much greater degree than whitefish. While whitefish are generally common in lakes near Rankin Inlet, char command a much higher market price and there was therefore a greater economic incentive for fishing them (Bond, 1974c). While the Rankin Inlet cannery has recently closed due to economic problems (R. B. Tinling, Supervisor, Resource Development, Yellowknife, N.W.T., personal communication), records indicate that, during the period of operation, whitefish comprised an average of approximately 24% of the total commercial landings (Table 6).

The Cambridge Bay commercial fishery concentrates on Arctic char. Whitefish are at the northern limit of their distribution and constitute a small portion (approximately 3%) of the total commercial landings (Table 6).

TABLE 6

Commercial whitefish fishery landings in the N.W.T. Landings are expressed in pounds round weight. Whitefish landings are included in the "mixed" category in an unknown proportion.

MACKENZIE DELTA AREA (includes both humpback and broad whitefish)
Data Source: B. Wong, Fisheries and Marine Service, unpublished data, 1978.

Year	Whitefish	Mixed	Total	% Whitefish of Total
1955	—	1,654	1,654	—
1956	—	18,699	18,699	—
1957	1,345	8,728	10,227	13.2
1958	—	28	28	—
1959	—	—	—	—
1960	12,000	13,148	25,148	47.7
1961	40,049	11,000	53,178	75.3
1962	19,324	—	37,478	51.6
1963	77,354	—	105,626	73.2
1964	—	74	4,146	—
1965	19,930	—	36,014	55.3
1966	62,116	—	63,138	98.4
1967	—	—	—	—
1968	—	—	—	—
1969	—	—	—	—
1970	—	—	—	—
1971	—	—	—	—
1972	3,774	—	3,774	100.0
1973	49,000	—	49,000	98.2
1974	35,000	—	35,000	100.0
1975	—	—	—	—
Totals	319,892	53,331	444,010	72.0

RANKIN INLET AREA
Data Source: B. Wong, Fisheries and Marine Service, unpublished data, 1978.

Year	Whitefish	Mixed	Total	% Whitefish of Total
1960	—	—	23,350	—
1961	660	—	8,367	7.9
1962	nil	—	49,856	0.0
1963	731	282,300	349,745	0.2
1964	169,794	—	467,297	36.3
1965	98,564	—	288,146	34.2
1966	54,800	—	238,025	23.0
1967	19,611	15,250	85,074	23.1
1968	—	191,964	197,679	—
1969	15,000	66,228	144,744	10.4
1970	104,772	—	149,990	69.9
1971	34,759	—	119,286	29.1
1972	52,671	—	126,026	41.8
1973	25,905	—	104,017	24.9
1974	1,014	—	102,687	1.0
1975	41,316	—	136,772	30.2
Totals	619,597	555,742	2,591,061	23.9

CAMBRIDGE BAY AREA

Data Source: B. Wong, Fisheries and Marine Service, unpublished data, 1978.

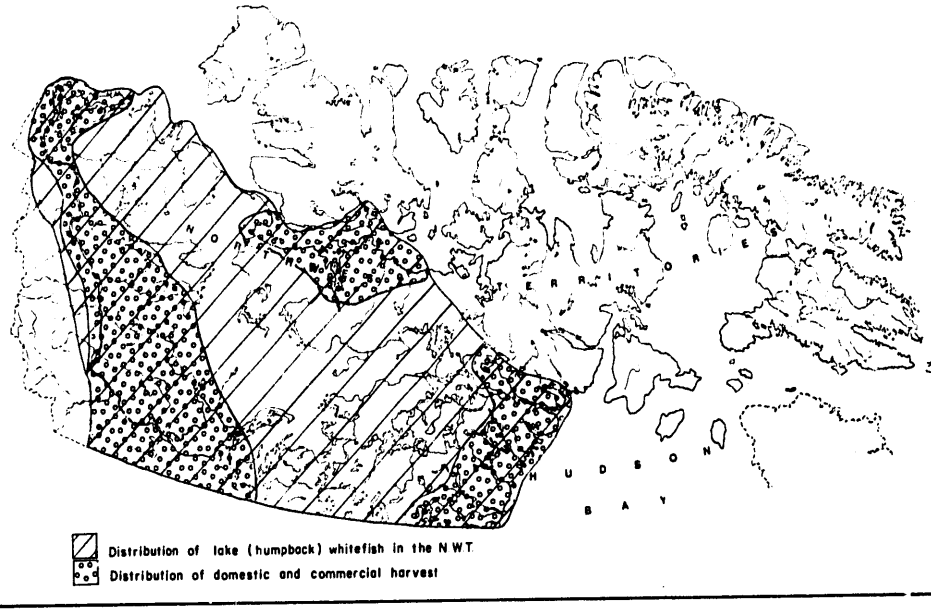
1960	nil	—	19,500	0.0
1961	nil	—	13,863	0.0
1962	nil	—	44,842	0.0
1963	nil	—	49,028	0.0
1964	1,076	—	53,822	2.0
1965	300	—	85,300	0.4
1966	nil	—	67,207	0.0
1967	nil	—	151,825	0.0
1968	28,076	—	131,833	21.3
1969	nil	—	107,048	0.0
1970	9,188	—	122,089	7.5
1971	1,000	—	133,694	0.7
1972	nil	—	202,798	0.0
1973	nil	—	92,525	0.0
1974	nil	—	82,603	0.0
1975	nil	—	77,886	0.0
Totals	39,640	—	1,435,863	2.8

GREAT SLAVE LAKE

Data Sources: Bond and Turnbull (1973); Bond (1974a, 1975a); Ken Roberts, Fisheries and Marine Service, Hay River, N.W.T.; personal communication.

	$x10^3$		$x10^3$	
1945	502	—	1,655	30.3
1946	1,255	—	2,985	42.0
1947	1,984	—	3,735	53.1
1948	4,831	—	7,246	66.7
1949	5,430	—	9,843	55.2
1950	5,737	—	8,670	66.2
1951	4,208	—	7,373	57.1
1952	3,664	—	6,903	53.1
1953	3,933	—	6,608	59.5
1954	3,936	—	6,639	59.3
1955	4,381	—	7,474	58.6
1956	4,100	—	6,942	59.1
1957	4,384	—	6,672	65.7
1958	3,372	—	5,759	58.6
1959	3,425	—	5,691	60.2
1960	3,789	—	5,308	71.4
1961	3,692	—	5,464	67.6
1962	4,493	—	6,222	72.2
1963	4,492	—	5,853	76.8
1964	3,880	—	5,037	77.0
1965	3,759	—	5,145	73.1
1966	2,707	—	3,871	69.9
1967	2,310	—	3,724	62.0
1968	3,170	—	4,002	79.2
1969	3,009	—	3,793	79.3
1970	3,232	—	4,162	77.7
1971	3,025	—	3,734	81.0
1972	2,348	—	2,922	80.4
1973	2,212	—	3,022	73.2
1974	2,145	—	2,389	89.8
1975	2,029	—	2,677	75.8
1976	2,155	—	2,764	78.0
1977	2,583	—	3,296	78.4
Totals	110,172	—	167,490	65.8
Year	**Whitefish**	**Mixed**	**Total**	**% Whitefish of Total**

Figure 7. Distribution of lake whitefish in the Northwest Territories and locations of major domestic and commercial fishing areas.



The domestic harvest of whitefish in the N.W.T. is concentrated in the immediate vicinity of population centers (Figure 8A). Areas of particular importance include the Mackenzie Delta and Beaufort Sea coast, the Mackenzie River and most of its major tributaries, Great Slave Lake and surrounding lakes, and lake and stream systems bordering the west coast of Hudson Bay.

Data documenting trends in the domestic harvest of fish in the N.W.T. are limited and those which are available are largely unreliable (DIAND/MPS, 1973; Bond, 1973; Environmental-Social Committee, Northern Pipelines, 1974; Withler, 1976). The best available estimates of domestic fishery harvest are those for communities in the Mackenzie River Valley; however, few document the relative importance of whitefish in catches. Table 7 lists the most recent estimates of domestic fish harvest for several Mackenzie Valley and Great Slave Lake area communities. From these data, it is apparent that at least 68% of the domestic harvest in the western N.W.T. was taken within and in the immediate vicinity of the Mackenzie Delta. A detailed study of domestic fish consumption in the Delta community of Aklavik (Jessop *et al.*, 1974) indicates, however, that the DIAND/MPS (1973) estimate of total domestic harvest for the Mackenzie Delta region may have been conservative. The estimated total harvest for this community alone is 294,923 lbs, greatly exceeding the estimate for the entire Mackenzie Delta in 1972 (111,000 lbs) by DIAND/MPS (1973). Jessop *et al.* (1974) provide a breakdown of the estimated consumption of each fish species in the domestic harvest by dogs and humans in Aklavik (Table 8). Lake (humpback) whitefish and broad whitefish comprised 38 and 25%, respectively, of the total poundage harvested by the community in 1973.

The broad whitefish has a more restricted distribution in the N.W.T. than the lake whitefish (Figure 8B). The species has been captured as far upstream in the Mackenzie River as Fort Simpson (Stein *et al.*, 1973); however, within the N.W.T., broad whitefish are present in harvestable numbers only in the lower Mackenzie River and Mackenzie Delta areas (Jessop *et al.*, 1974). Broad whitefish are tolerant of a wide range of salinities and are frequently captured in brackish coastal waters in the outer Mackenzie Delta (Percy, 1975) and as far east as Coronation-Queen Maud Gulf (Scott and Crossman, 1973). Although broad whitefish are widely distributed in coastal waters, substantial domestic catches of this species occur only within the Mackenzie Delta.

There is little information available which specifically details the relative importance of broad whitefish to the Mackenzie Delta domestic and commercial fisheries. Several authors have suggested that broad whitefish may be more abundant than lake whitefish in the Delta (Stein *et al.*, 1973; Jessop and Lilley, 1975).

Recent, detailed studies of consumption of the domestic fish catch by the two Mackenzie Delta area communities of Aklavik and Arctic Red River (Jessop *et al.*, 1974) indicate, however, that broad whitefish comprised only 36 and 39%, respectively, of the total number of whitefish captured by each community in 1973. In Aklavik, at least, broad whitefish are preferred over lake whitefish for human consumption (Jessop *et al.*, 1974).

The degree to which broad whitefish have supported the various attempts at commercial fishing within the Mackenzie Delta (1963, 1965, and 1972) is not known; however, broad whitefish probably made a significant contribution. For various reasons, including lack of local markets, high transportation costs to southern markets, and poor product quality, all attempts at establishing a commercial fishery in the Mackenzie Delta have failed (MacLeod, 1973) despite government subsidies.

The round whitefish is widely distributed throughout the lakes and rivers of the N.W.T. and is often captured in brackish waters near the mouths of the Mackenzie, Coppermine, and Churchill Rivers (Figure 9). This species has been taken in small numbers in the Great Slave Lake commercial fishery (Kennedy, 1956); however, nowhere within the N.W.T. does it occur in sufficient abundance to be of great domestic or commercial importance. No commercial quotas have been established for round whitefish and the species has been lumped under the general category of "whitefish" for this purpose.

Figure 8A. Locations of domestic whitefish harvest in the Northwest Territories.

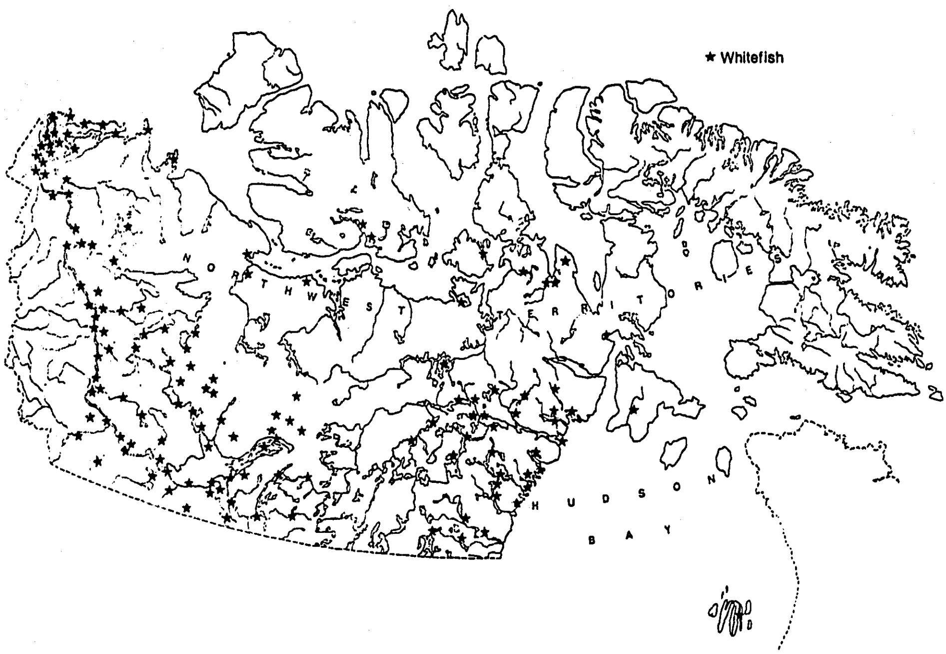


TABLE 7

Estimated annual harvest of the Mackenzie Valley domestic fisheries, 1972. (From DIAND/MPS, 1973).

Community	No. of lbs.	Main Types of Fish Harvested
Mackenzie Delta and Tuktoyaktuk	111,000	Arctic char, whitefish, inconnu, herring.
Fort McPherson and Arctic Red River	450,000	Whitefish, herring, Arctic char, northern pike, suckers.
Fort Good Hope, Colville Lake	100,000	Whitefish, herring, inconnu, trout.
Fort Norman, Norman Wells	29,000	Lake trout, Arctic grayling, whitefish, herring, inconnu.
Wrigley	2,500	Whitefish, northern pike, suckers.
Fort Simpson	1,000	Whitefish, northern pike, suckers.
Jean-Marie River	800	Whitefish, northern pike, suckers.
Trout Lake	1,000	Whitefish, northern pike, suckers.
Nahanni Butte	6,000	Whitefish, northern pike, suckers.
Hay River Area	129,000	Whitefish, northern pike, suckers.
TOTAL ESTIMATED DOMESTIC HARVEST	824,900	

Figure 8B. Distribution of broad whitefish in the Northwest Territories and location of major domestic and commercial fishing areas.

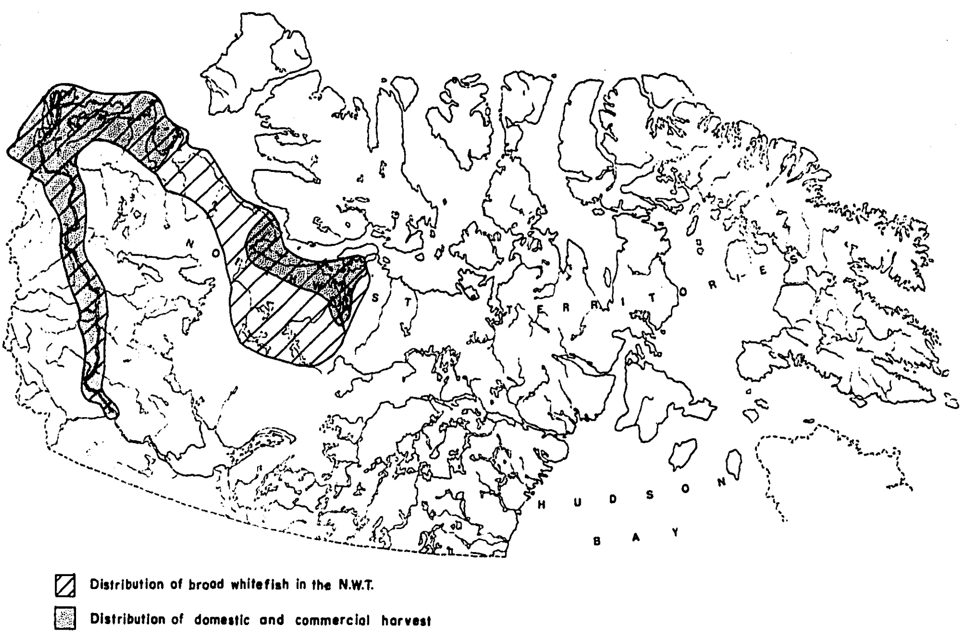


Figure 9. Distribution of round whitefish in the Northwest Territories.

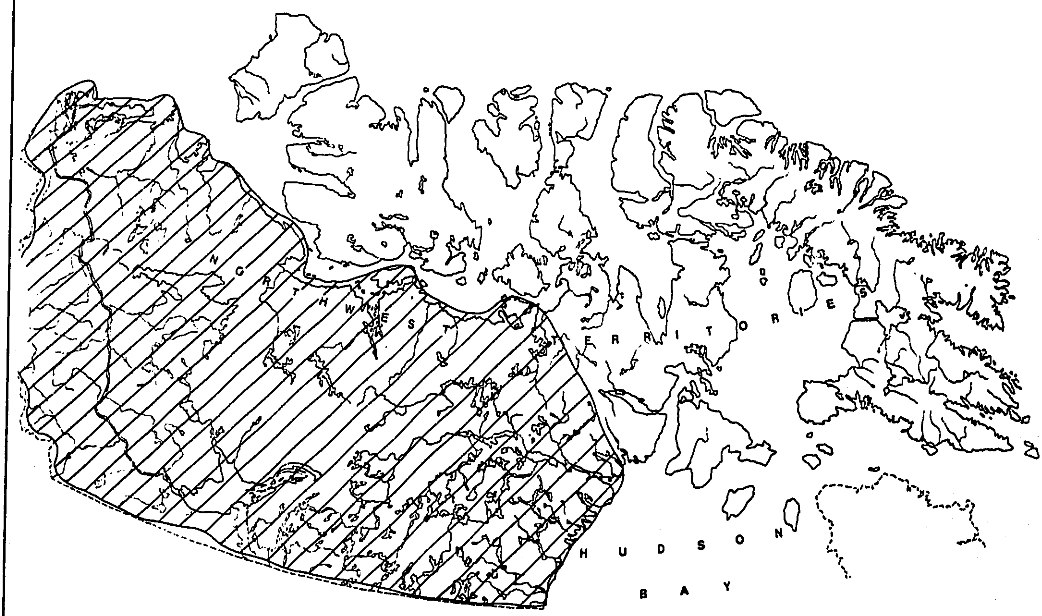


TABLE 8

Estimated species composition by weight and by number, and total estimated numbers of fish consumed in Aklavik, 1973. From Jessop *et al.* (1974).

Species	HUMAN FOOD	Annual Consumption		DOG FOOD	Annual Consumption		TOTAL Annual Consumption	
	Per Cent	Pounds	Number	Per Cent	Pounds	Number	Pounds	Number
Broad whitefish	40	27,379	8,173	20	45,295	13,521	72,674	21,694
Humpback whitefish	0	0	0	50	113,238	39,047	113,238	39,047
Inconnu	25	17,111	3,641	5	11,324	2,409	28,435	6,050
Arctic cisco	0	0	0	15	33,972	37,747	33,972	37,747
Arctic char	15	10,267	6,845	0	0	0	10,267	6,845
Northern pike	0	0	0	5	11,324	3,775	11,324	3,775
Burbot	15	10,267	2,053	5	11,324	2,265	21,591	4,318
Other	5	3,422	1,141	0	0	0	3,422	1,141
TOTALS		68,446	21,853		225,477	98,764	294,923	120,617

LIFE HISTORIES AND FACTORS LIMITING PRODUCTION

LAKE (HUMPBACK) WHITEFISH

Lake whitefish exhibit a variety of life history types in the N.W.T., ranging from lake-resident, to lake and river migratory, to semi-anadromous populations. All types have been exploited at some time for domestic or commercial purposes; however, lake-resident populations and in particular the Great Slave Lake population are of the greatest economic importance.

The mechanisms controlling lake whitefish production in closed systems (i.e., lakes) in the N.W.T. have been studied including both exploited (e.g., Great Slave Lake — Keleher, 1972a; Healey, 1975a) and unexploited (e.g., Keller Lake — Johnson, 1972, 1976) populations.

Comparisons of mortality rates in exploited and unexploited whitefish populations have provided valuable insight into the effects of fish harvest. Healey (1975a) examined natural mortality rates for 13 unexploited and 14 exploited whitefish populations in Canada and found an average mortality rate of 0.49 (range 0.19 to 0.74) in unexploited and 0.64 (range 0.36 to 0.94) in exploited populations. Although there are several possible sources of bias in his data (e.g., differing methods of calculation, errors in ageing, variability in rates between age classes, and variable year class strength), Healey concluded that there is a very wide range in natural mortality rates and that, in many instances, fishing mortality contributes only a small amount to total mortality.

Lake whitefish exhibit a great deal of variability in growth rate across their geographic range in Canada (Figure 10). Healey (1975a) examined the growth rates of 32 unexploited and 24 exploited whitefish populations throughout the species range. He noted a number of trends of significance to management of the species:

1) The lake whitefish is a cold adapted species and growth rates are best in the central and northern parts of its range and poorest in the southern, warmer parts of its range.

2) Populations subjected to high fishing mortality also have a high growth rate. Numerous instances have been documented where whitefish populations have responded to exploitation by increasing their growth rate (Miller, 1947, 1949, 1956; Bond and Turnbull, 1973).

3) Populations which were classified as heavily exploited exhibited growth rates at or near the maximum rate observed for unexploited populations. This maximum rate has been suggested as the biological limit to the range of growth compensation for exploitation by the species.

In addition to variability in growth rate, lake whitefish populations also exhibit a wide range in age at maturity (Healey, 1975a). In the south, whitefish mature as early as age three (Fenderson, 1964); however, among unexploited northern populations, mature fish younger than age six are uncommon but most populations are 100% sexually mature by age nine (Healey, 1975a). A major consideration in managing whitefish stocks is to avoid overcropping the mature portion of the population so that serious reductions in egg deposition and, subsequently, in recruitment, do not occur. However, the most frequently used fishing gear, large mesh gillnets, actively selects against the largest and oldest members of the stock (i.e., those with the greatest fecundity). At least some whitefish populations are capable of responding to increased mortality by maturing at younger ages and, possibly, at smaller sizes. At least one instance of this type of response has been documented in the N.W.T. (Great Slave Lake — Kennedy, 1956; Bond and Turnbull, 1973).

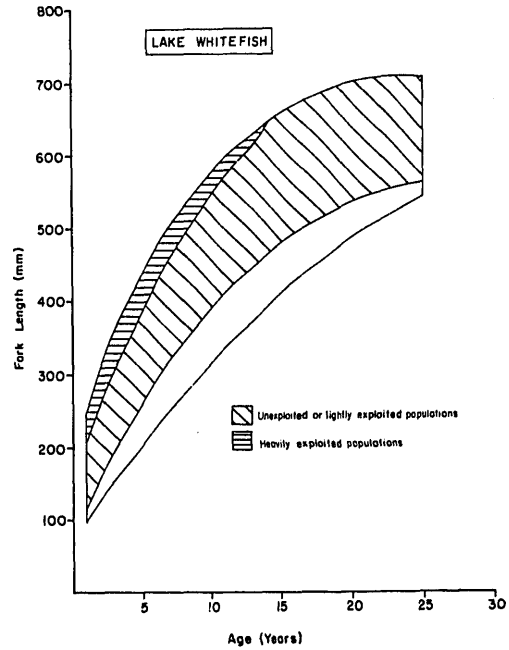


Figure 10. Range of variation of published growth curves for lake whitefish populations across the geographic range in North America. The range of variation of published growth curves for unexploited or lightly exploited populations and heavily exploited populations in the Northwest Territories is also presented. Data sources include: Healey, 1975; Bond, 1975a; DeGraaf and Machniak, 1977.

Many whitefish populations which have been examined in the N.W.T. are unexploited or lightly exploited and when sampled with gillnets show catch curves with a high degree of clustering around the modal length, irrespective of mesh size (Johnson, 1976; Power, 1978). This clustering has been interpreted as a "climax" population structure in which there are large numbers of old individuals of a relatively uniform size. Recruitment into this group is controlled so that juveniles are only "accepted" in numbers which are sufficient to replace the annual loss due to mortality among the adult population.

Johnson (1976) has postulated that this steady-state population structure is maintained in unexploited Arctic fish populations by the presence of a long term "filter" mechanism whereby juveniles are restricted to peripheral habitat where conditions for growth are less than ideal and where increased predation may occur. Disruption of the climax condition through heavy fishing pressure will result in loss of equilibrium and a considerable length of time may pass before a stable population is re-established. In simple systems involving a single fish species, return to equilibrium after cessation of fishing may be rapid (e.g., char in Keyhole Lake, N.W.T. — Johnson, 1976); however, in complex systems involving several fish species, possible pathways for energy flow are numerous and recovery may be slowed.

Power (1978) concurs with Johnson (1976) in his assessment of the predominance of older, larger individuals in Arctic lake populations, but disagrees with Johnson's reasons for the existence of this climax population structure. Power argues that the apparent tight grouping of the reproductive segment of many Arctic lake whitefish populations around the modal length is an artificial compression of this group and is largely a result of gross underestimation of age for these large individuals.

Healey (1975a) has proposed a simplified continuum of management schemes (Table 9) applicable to whitefish fisheries in the N.W.T. An example of a population with a high fishery potential would be one with low natural mortality and a slow growth rate. It would have wide scope for growth compensation coupled with considerable tolerance for increased mortality. An example of a situation with a very low fishery potential would be one with a high natural mortality rate and a high growth rate since the population would have a limited capacity to absorb additional mortality and a limited scope for growth compensation.

In general, whitefish populations in the N.W.T. must be cropped at extremely low levels to maintain any type of sustained yield and to avoid excessive disruption of natural equilibrium processes (Healey, 1975a; Johnson, 1976). The dilemma which is faced by fishery managers in the N.W.T. is that the low harvest levels which are necessary for maintenance of sustained yield often render fisheries in remote areas uneconomic, particularly when the object of the fishery is whitefish, which do not command a high market price, and when the cost of transportation to markets is high.

A management procedure which has been applied to the harvest of whitefish populations in several lakes (e.g., Hottah Lake) in the vicinity of the Great Slave Lake is that of a rotational or six-year cyclical harvest (Wong and Whillans, 1973). The procedure involves establishing an annual quota for a lake (usually based on Rawson's [1960] figure of one-half lb per acre). This is followed by an intensive commercial fishery which attempts to harvest six times the annual quota in one or two fishing seasons. The fishery is followed by a four or five year recovery period in which no fishing is permitted. The procedure maximizes the economic yield of the fishery; however, recovery of the fish population may not be possible within the period of the cycle. Studies by Wong and Whillans (1973) have shown that the whitefish and lake trout populations of Hottah Lake had not returned to equilibrium within the four year recovery period. Wong and Whillans (1973) recommended halving the quota and extending the fishing cycle from six to eight years.

Healey (1973) outlined a study involving the experimental cropping of four small lakes in the Precambrian Shield north of Yellowknife in the N.W.T. These experiments have now been completed but the results have not yet been fully published. Healey removed approximately 10% of the standing crop of lake whitefish and lake trout from Chitty Lake, 20% from Alexie Lake, and 30% from Drygeese Lake. Bahtiste Lake was left as an unexploited control. Healey found that:

1) Though the increase was not clearly related to either the pattern or intensity of exploitation, the fecundity of both species increased in all exploited lakes after exploitation with trout showing the greater response (Healey, 1978);

2) Growth rates of whitefish increased in the exploited lakes and the amount of increase was related to the rate of exploitation (personal communication);

3) There was a large pulse of recruitment in whitefish populations in the exploited lakes, the result of recruitment of fish already present in the populations when exploitation began, not the result of increases in fecundity or improvement in spawn survival (personal communication);

4) The unexploited lake also had a recruitment phase with a decline in the abundance of older fish and increasing numbers of older fish among the fishable population suggesting that a cyclical pattern of recruitment is normal in whitefish populations even in the absence of exploitation (personal communication);

5) The data for lake trout have not yet been fully analysed but it appears that they have not bounced back as rapidly as whitefish (personal communication).

Based on the results of his studies, Healey (personal communication) feels that a cyclical pattern of fishing is entirely feasible for whitefish populations in the north and in some cases clearly advantageous. Even in Drygeese Lake where the highest rate of exploitation removed 30% of the total and 80% of the fishable population, exceeding a normal six year quota, the population appears to have rapidly recovered.

If completed, the results of Healey's studies will be of considerable value to anyone interested in the management of northern fisheries. Given the staff fluctuations and lack of continuity in many research programs conducted in the N.W.T. by southern based researchers, it appears the work of Healey may never be completed, much to the detriment of N.W.T. fisheries management.

TABLE 9

Interpretation of growth, mortality, age structure, and maturation in management of whitefish populations. From Healey (1975a).

Growth

1. Low: Considerable scope for response to increased fishing. Indicates underexploitation.
2. Moderate: Some scope for response to increased fishing. Indicates moderate exploitation.
3. High: Little scope for response to increased fishing. Indicates heavy exploitation.

Mortality

1. Low: Considerable scope to absorb increased fishing. Considerable biomass present in the older ages and available to the fishery. Indicates either a young fishery or underexploitation.
2. Moderate: Some scope to absorb increased fishing. Less biomass available in older ages. Fishing might be increased if other factors are favourable but reduced mesh size might be required to get an improved yield.
3. High: Little hope to absorb increased fishing. Biomass concentrated in younger ages. Indicates heavy exploitation.

Age Structure

1. Old: Numerous unexploited year classes which could contribute to the fishery, fishing could probably increase.
2. Moderate: Some unexploited year classes. Fishing might be increased if other factors favourable.
3. Young: Few or no unexploited year classes. Particularly unstable situation. Fishing should probably be reduced a bit.

Maturation

1. Fish responding to fishing by maturing at a younger age. Fishery probably healthy.
2. Fish not responding to fishery by maturing at a younger age. Fishery may be in danger.

Recently, the biology of migratory and semi-anadromous whitefish in the Mackenzie River drainage has been studied in relation to oil and gas development in the region. Lake whitefish in the lower Mackenzie River-Mackenzie Delta region have been described by Hatfield *et al.* (1972), Stein *et al.* (1973), Jessop *et al.* (1974), Jessop and Lilley (1975), Percy (1975) and de Graaf and Machniak (1977). These studies have shown that whitefish movements are generally confined to the Mackenzie Delta area (including the Beaufort Sea coast and upper Delta tributaries such as the Peel and Arctic Red Rivers) and are associated with movement to and from summer feeding, spawning and overwintering areas. Such movements occur within relatively restricted time periods, generally during the spring and fall and it is during these periods that the bulk of the annual domestic harvest occurs.

Little is known of the spawning success and early recruitment characteristics of the Mackenzie River migratory whitefish populations. The population has a relatively high fecundity (14,000 to 60,000 eggs per mature female — de Graaf and Machniak, 1977) and fry and young juveniles are abundant in Delta lakes and channels as well as near the mouths of several lower Mackenzie River tributaries (Jessop *et al.*, 1974; Jessop and Lilley, 1975; de Graaf and Machniak, 1977). Studies of Mackenzie River humpback whitefish indicate minimum age at sexual maturity of seven to nine years and maximum ages of 18 to 20 years. The incidence of non-consecutive spawning appears to be extremely low in the Mackenzie River humpback whitefish population (de Graaf and Machniak, 1977; Percy, 1975) and it is conceivable that whitefish in this population could participate in spawning from nine to 13 times during their lifetime. This whitefish population clearly has a high reproductive potential and therefore a large capacity for replacement of individuals lost through natural or exploitive mortality.

There are no data available which estimate the natural mortality, rate of recruitment, or standing crop of whitefish in the Mackenzie River as these parameters are difficult to measure in such a large, open system. In addition, there are no long-term data on the response of the Mackenzie River whitefish population to the sporadic and fluctuating domestic and commercial fisheries which have occurred in the region. Without the systematic, detailed studies which would provide these basic tools of fishery management, predictions of the effects of increased harvest on the population are difficult. In view of the failure of recent attempts at establishing a commercial whitefish fishery in the lower Mackenzie River and of the basic reasons for the demise (e.g., high production costs, low product demand) which are unlikely to change in the foreseeable future, perhaps the best whitefish management policy for this region is in fact a no management policy. The low and declining subsistence fisheries which presently occur in the region probably do not significantly endanger the stability of the whitefish populations. If, however, there is renewed interest in the establishment of a large scale commercial whitefish fishery, then detailed studies of the production mechanisms of the population should precede the establishment of quotas for the region.

BROAD WHITEFISH

As previously indicated, the distribution of the broad whitefish in the Northwest Territories is centered on the lower Mackenzie River, in the Mackenzie Delta, and in the Coppermine River areas. The species is migratory and semi-anadromous; however, lake-resident populations have also been reported in the Northwest Territories (McCart *et al.*, 1976; Machniak, 1977). The biology of the species in the Mackenzie drainage has been extensively reviewed (Hatfield *et al.*, 1972; Stein *et al.*, 1973; Kendel *et al.*, 1975; Percy, 1975; McCart *et al.*, 1976; de Graaf and Machniak, 1977) but there have been few studies of its biology elsewhere (Muth, 1969).

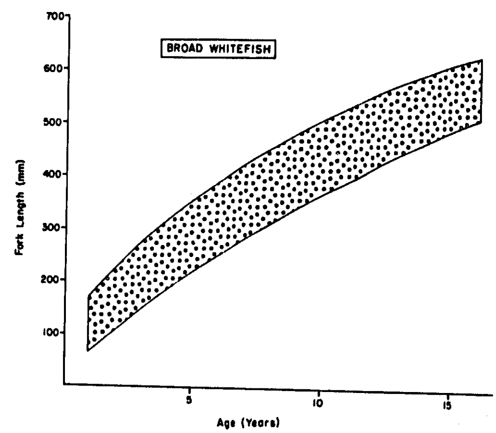
The growth rates of broad whitefish are extremely variable. Figure 11 presents the presently known range of growth curves for the species. The fastest growing populations are generally within the Mackenzie Delta (Percy, 1975) and the slowest in the Coppermine River (Muth, 1969). In the Mackenzie Valley, broad whitefish generally attain a larger size and are considered to have better flavour than the humpback whitefish. They have therefore been the major object of domestic and commercial fisheries in the region (Stein *et al.*, 1973; Jessop *et al.*, 1974).

Broad whitefish in the Mackenzie Delta mature as early as three to four years of age (Percy, 1975) and as late as seven to 10 years of age (de Graaf and Machniak, 1977). The mean fecundity of the Mackenzie Delta population is approximately 39,700 (range 25,922 to 65,798) eggs per female (de Graaf and Machniak, 1977). There is evidence that spawning occurs during October in back eddies of the Mackenzie River near Arctic Red River (Jessop *et al.*, 1974) and in the lower reaches of the Peel River (Jessop and Lilley, 1975). The upstream spawning migration through the Mackenzie Delta peaks in late September and early October (Stein *et al.*, 1973; Jessop *et al.*, 1974; Jessop and Lilley, 1975; de Graaf and Machniak, 1977) and it is during this period that much of the annual domestic harvest is taken (Jessop *et al.*, 1974).

There is little information on standing crop, mortality rates, recruitment rates, or any other factor affecting production of broad whitefish in the N.W.T. Presumably the same extrinsic and intrinsic factors limiting lake (humpback) whitefish production in the lower Mackenzie River drainage also operate on the broad whitefish population as the life histories of the two species are similar. In the absence of detailed information, it is difficult to assess what effect (if any) the currently low and apparently declining rate of harvest had on the Mackenzie River broad whitefish population.

Management of the broad whitefish in this region should have low priority at present. If, however, the level of domestic or commercial harvest increases in this region, then detailed studies of broad whitefish production mechanisms should be initiated.

Figure 11. Range of variation of published growth curves for broad whitefish in the Northwest Territories.



ROUND WHITEFISH

Round whitefish are rarely of major importance in domestic or commercial fisheries in the N.W.T. Round whitefish are taken in the commercial fishery on Great Slave Lake (Kennedy, 1956) but in such small quantities, that it is rarely marketed. During recent investigations in the Mackenzie River drainage (Hatfield *et al.*, 1972; Stein *et al.*, 1973; Jessop *et al.*, 1974; Percy *et al.*, 1974; de Graaf and Machniak, 1977) few round whitefish were captured (usually less than one per cent of total catch) and the species is of little significance in Mackenzie Valley domestic fisheries.

Although round whitefish may in the future become an important sport species, the management of this species, for domestic or commercial exploitation in the N.W.T., should be considered low priority.

LAKE TROUT *(Salvelinus Namaycush* Walb.)

Lake trout (actually a char) achieve the largest size and are among the longest-lived of any freshwater fish species in the Northwest Territories. Because of its large size (to 30 kg) and the palatability of its flesh, the species is highly sought after by sport, subsistence and commercial fishermen alike.

DISTRIBUTION

Lake trout are found in deep lakes and, occasionally, in rivers throughout the mainland portions of the Northwest Territories as well as several Arctic islands including Baffin, Southampton, King William, Victoria, and Banks Islands (Figure 12). While this species shows some variation in form in other parts of North America, there is a single form in the Northwest Territories (Scott and Crossman, 1973). Marshall and Keleher (1970) have prepared a bibliography of information on the distribution, economic utilization, and life history of lake trout.

AGE, GROWTH AND MATURITY

A general growth curve for northern lake trout populations based on studies in Great Slave Lake (Falk *et al.*, 1973), Great Bear Lake (Falk *et al.*, 1974), Lac La Martre (Bond, 1973), Kaminuriak Lake (Bond, 1975a), Ya-Ya Lake (Machniak, 1977; Den Beste, unpublished data), Clearwater Lake (Power, 1978), Mistassini Lake (Dubois and Lagueux, 1968), and Old John Lake (Craig and Wells, 1975) is presented in Figure 13. Lake trout are relatively slow growing and long-lived, commonly exceeding 30 years of age with some individuals age 60 or more. Authors using scales for age determination report faster rates of growth (Wong and Whillans, 1973) than those using otoliths but Dubois and Lagueux (1968) have demonstrated the potential inaccuracy of ageing lake trout with scales.

The fastest growth rates reported for northern lake trout populations are for those in lakes along the Mackenzie drainage, particularly in the vicinity of Great Slave Lake. Much slower growth rates have been reported for Shield lakes and lakes in northern Quebec (Bond, 1975a), possibly as a result of the lower productivity of nutrient-poor Shield lakes. Northern lake trout populations show a gradual decline in growth rate with increasing latitude (Falk *et al.*, 1973).

Studies by Johnson (1972, 1976) indicate that many northern lake trout populations show a preponderance of old, mature fish (10 plus) with mean lengths of 500 to 600 mm. Johnson reports that in unexploited lakes, the recruitment of juveniles to the modal group is relatively low. Lake trout do not appear to have the same capacity to respond to fishing pressure as Arctic char and whitefish and the rate of recruitment of juveniles is often too slow to sustain the population, resulting in a gradual decline.

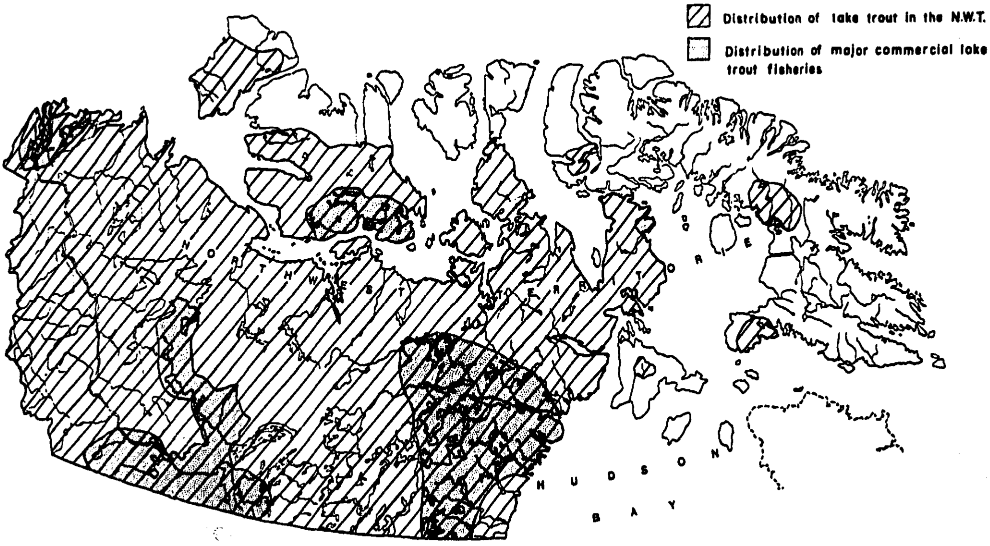
Another major concern in the management of lake trout is the late age at first spawning common for this species. Studies in the Northwest Territories indicate that the earliest spawning occurs at age eight and that some individuals do not spawn for the first time until age 22 (Falk *et al.*, 1973, 1974). These and other studies indicate that northern lake trout usually spawn only in alternate years after reaching maturity and some only every third year. In any year, therefore, at least one-half of the adult population consists of non-spawning indivuduals. Fry (1939) noted that as the density of lake trout in exploited stocks declined, the age of first spawning also declined. Other studies of exploited populations, however, dispute this claim (Healey, 1978).

Commercial fisheries utilizing gillnets are relatively unselective in capturing lake trout over a wide size range (Anonymous, 1975; Bond, 1975a). Sport fishermen concentrate on trophy size lake trout, catching fish averaging age 16 in Great Slave Lake and age 23 in Great Bear Lake (Falk *et al.*, 1973). With the heavy harvest of large lake trout in both commercial and sport fisheries, the number of mature individuals declines rapidly. Where lake trout populations coexist with commercially fishable whitefish populations, management of the whitefish stock to maintain a high sustained yield will invariably result in a reduction in lake trout stocks (Anonymous, 1975). The heavy harvest of lake trout in Great Slave Lake associated with the whitefish fishery has not only reduced the relative abundance, but also the average size of fish caught (Keleher, 1972a).

Lake trout stocks can be successfully managed for sport fishing only provided that catch limits are kept low and the number of anglers is regulated. As a result of the emphasis on the harvest of large, mature fish by sport fishermen, there has been a net decline in the availability and size of trophy lake trout in both the eastern end of Great Slave and in Great Bear Lakes within the last 10 years (Falk *et al.*, 1973). This decline will not necessarily affect the continued survival of these populations provided that a sufficient number of mature fish remain for spawning purposes.

Studies by Miller and Kennedy (1948) and Falk *et al.* (1974) indicate that a change in the growth rate of lake trout occurs at the age of maturity. Fish in Great Bear Lake grew more slowly from ages 12 to 14 than younger fish. From age 15 on, however, growth rates return to about the same level as before maturity. Additionally, after age 15, weight increases much more rapidly than it does in younger, immature fish. Lake trout populations are, therefore, most productive in terms of weight gain after first spawning. If stocks of large, mature lake trout are fished down, the fastest growing segment of the population is removed and a decline in net productivity occurs.

Figure 12. Distribution of lake trout in the Northwest Territories and distribution of major commercial fishing areas.



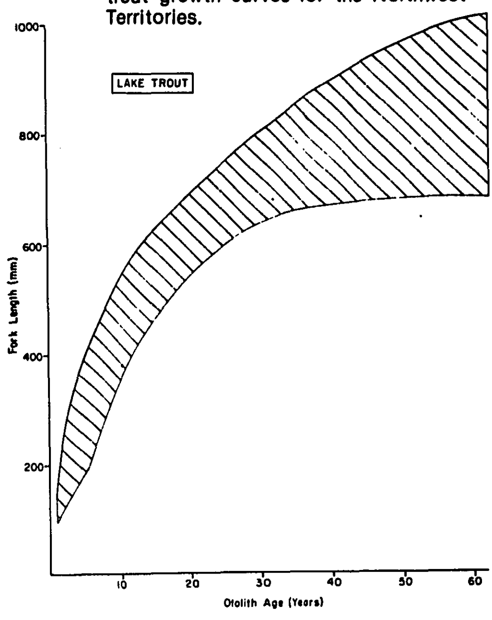
MOVEMENTS

In northern lakes, distribution varies with the season and is usually dependent on water temperature (Rawson, 1961). In the autumn, mature lake trout move into the shallow water (◄12 m) of lakes to spawn usually utilizing coarse rock or rubble substrates (Scott and Crossman, 1973). Time of spawning varies considerably depending on water temperature and light intensity. Spawning has been reported as early as mid-August in Great Bear Lake (Miller and Kennedy, 1948) but most authors report that spawning in the northern Territories occurs in late September or in October.

After spawning, lake trout tend to disperse throughout the waterbody to overwinter. Some may move up to 150 km to other streams and lakes. At break-up, a concentration of feeding fish occurs in surface waters for several weeks until increasing water temperatures force them into deeper waters. Studies indicate that lake trout prefer temperatures in the vicinity of 10° C although periodic excursions into warmer surface waters do occur.

While there is some evidence that lake trout home to the same spawning area in years when an individual is going to spawn, homing is generally considered to be incomplete (Martin, 1960). Incomplete homing combined with the wide ranging movements of this species suggest that natural restocking can occur in areas where populations have been reduced or eliminated.

Figure 13. Range of variation of published lake trout growth curves for the Northwest Territories.



Unlike anadromous Arctic char, lake trout only rarely enter salt water and are seldom found in salinites exceeding 11 to 13% (Boulva and Simard, 1968). They are considered to be the least tolerant of salt water of all the char.

MORTALITY AND RECRUITMENT

Studies in Great Slave and Great Bear Lakes (Healey, 1975b) indicate that lake trout have relatively low rates of annual mortality (ranging from 0.20 to 0.55) in comparison with whitefish (0.20 to 0.90) and anadromous Arctic char (0.40 to 0.50). Exploited lake trout populations generally show higher mortality rates than unexploited populations, although there is some evidence that recruitment of juveniles increases with slight declines in mortality under mild exploitation. Healey (1975b) suggests that the low mortality rate of lake trout may be a reflection of their trophic status (i.e., a piscivorous species preying on other species).

Recruitment in lake trout populations is low due largely to the long lifespan of the adult population, low mortality of older individuals, low average fecundity (1,000 to 3,000 eggs per kg), and low spawning success. Lake trout do not show the same increase in recruitment in exploited populations that is common in whitefish stocks; lake trout stocks typically decline when whitefish and lake trout are managed together (Anonymous, 1975). Since present commercial harvest quotas combine trout and whitefish in most Northwest Territories lakes (Fisheries and Environment Canada, 1977) and commercial fishermen are unable to selectively fish the two species utilizing present techniques, lake trout populations will invariably decline if harvest quotas are based on equilibrium yields of whitefish. Present management schemes assume that this decline is inevitable if whitefish stocks are to be utilized by commercial fisheries at an economically viable level (R. Peet, Fisheries and Marine Service, Winnipeg, personal communication).

FOOD HABITS

Lake trout utilize a wide range of food items depending on the size of the fish. The prey species utilized become progressively larger as lake trout grow. Fish are the predominant food item in the diet of most mature lake trout, while a wide range of aquatic dipterans, crustaceans, and small fish are utilized by juveniles. Lake trout often cannibalize small juveniles of their own species but there are no data to suggest that this limits recruitment.

Studies at Ya-Ya Lake on Richards Island in the Mackenzie Delta indicate that many large lake trout utilize only crustaceans during the summer feeding period (Machniak, 1977; Den Beste, unpublished data). Lake trout which feed exclusively on plankton and small invertebrates are slower growing, have a smaller maximum size, and are shorter-lived than individuals utilizing fish as a predominant food item (Martin, 1966). Type of food may, therefore, be more limiting to production than availability.

Ciscoes are the commonest food fish for lake trout, although other species may dominate in individual lakes. Other species which have been reported in the diet include whitefish, smelt, sculpins, shiners, sticklebacks, trout-perch, and longnose suckers (Scott and Crossman, 1973). Sculpins, primarily the deepwater sculpin *(Myoxocephalus quadricornis)*, are of particular importance since this species is often the first fish available to juvenile lake trout which tend to inhabit deep waters during much of their early life.

UTILIZATION

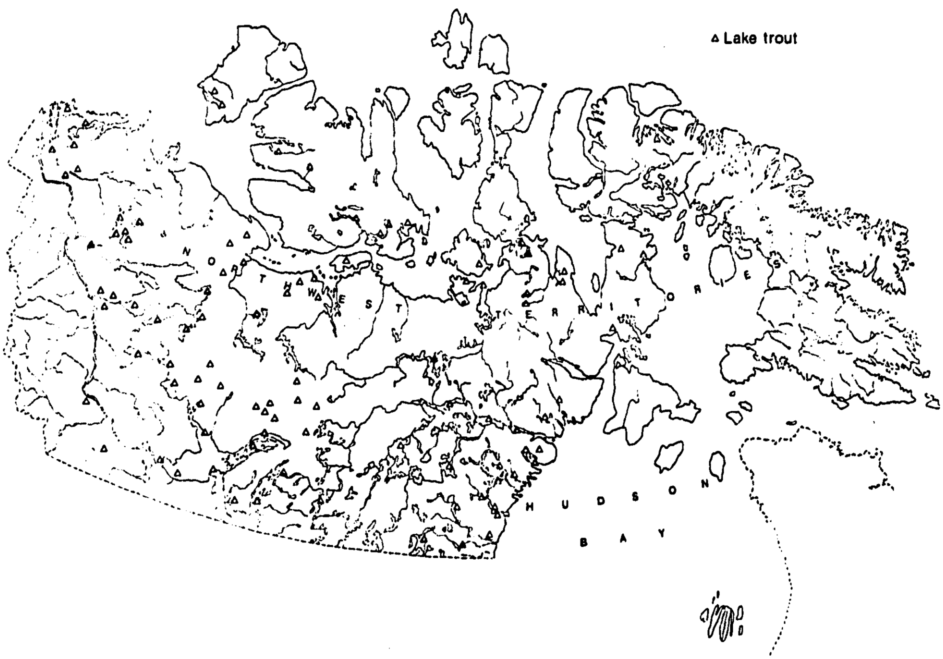
DOMESTIC LAKE TROUT FISHERY

Most major domestic lake trout fishing areas are located in the Mackenzie Valley, including the area surrounding Great Slave and Great Bear Lakes, and in inland lakes near the coast of Hudson Bay and in the vicinity of Queen Maud-Coronation Gulf (Figure 14). Natives generally prefer whitefish for human consumption and lake trout form a much smaller percentage of their diet (Bond, 1973) though lake trout are often taken incidentally in domestic fisheries for whitefish. Studies in the Mackenzie Valley suggest that a considerable number of lake trout is utilized as dog food (Bond, 1973; Jessop *et al.*, 1974). Data obtained from natives in coastal areas are often unreliable since many natives refer to Arctic char as "trout". Some domestic lake trout fisheries shown in Figure 14 may in fact be Arctic char fisheries misidentified in the literature.

Few reliable data are available concerning the number of lake trout taken in domestic fisheries in the Northwest Territories. At Lac La Martre (Bond, 1973), lake trout constituted 10.9% of the 72,000 pounds of fish utilized annually. Domestic fisheries in the vicinity of Tuktoyaktuk took approximately 4,000 pounds of lake trout, 3.0% of a total harvest of 135,000 lbs (Abrahamson, 1962). Although data on lake trout harvests in other portions of the Territories are presented in the area economic surveys (1958 to 1967), most of this information is based on minimal data and is too dated to provide an accurate measure of lake trout utilization in current domestic fisheries. The data do, however, suggest that lake trout rarely comprise more than 20% of the total fish taken in domestic fisheries in most areas within the Territories.

The usual methods of catching lake trout are angling and gillnets. Jigging through the ice in winter is common in many domestic fishing areas, particularly in the Mackenzie Valley. In coastal areas, winter fishing is generally restricted by intense cold and thick ice (Bissett, 1967).

Figure 14. Locations of domestic lake trout harvest in the Northwest Territories.



COMMERCIAL LAKE TROUT FISHERIES

Areas of commercial lake trout utilization are centered around Great Slave Lake, the Cambridge Bay area, and inland lakes in the vicinity of Rankin Inlet (Figure 12). Although some commercial lake trout fishing has taken place in the vicinity of Hall Lake and in the Mackenzie Delta, this fishery is a small one. Much of the lake trout harvest has been dependent on air transport due to the poor accessibility of many inland lakes.

The Great Slave Lake fishery is the only major fishery still producing significant catches of lake trout, although even this fishery has declined considerably in recent years (Table 10). Declining catches in the west portion of Great Slave Lake forced closure of the east portion to protect the lake trout there from a similar fate and to assist the sport fishing industry (Anonymous, 1975). Although lake trout catches in Great Slave have not fluctuated greatly in the last few years, present management policy, which emphasizes whitefish production, will probably result in the near elimination of lake trout in the commercially fished western portions of the lake (R. Peet, personal communication).

The sensitivity of lake trout to the effect of overfishing combined with the scattered distribution of the species in numerous inaccessible lakes limits the potential for the development of viable commercial fisheries. To date, lake trout populations have only been economically harvested when they occur in conjunction with commercially harvestable whitefish populations.

SPORT LAKE TROUT FISHERIES

One of the best means of utilizing lake trout in the Northwest Territories is through the development of sport fishing lodges and camps in remote areas. At present, most lodges which offer lake trout fishing are located on inland lakes north of the Manitoba border, in the area surrounding Great Slave Lake (including the East Arm) and on Great Bear Lake (Figure 3).

Data describing the total estimated harvest of lake trout in Great Slave and Great Bear Lake, the two largest sport fisheries, for the years 1971 to 1974 are presented in Table 11. Although these figures appear low in comparison to commercial landings in Great Slave Lake (Table 10), lake trout sport fishing represents a major industry in the north. Falk *et al.* (1973) report that a total of 649 guests stayed at the three major lodges on Great Slave Lake in 1972, providing a gross revenue of $443,000. In comparison, the commercial fishery operating in the East Arm had a gross revenue of only $49,096 in the same year.

In large lakes, sport fishing concentrates on the shallow productive zone while in smaller lakes, productivity and fishing effort are much more evenly distributed. Falk *et al.* (1973) suggest that the best means of managing lake trout sport fisheries in large lakes is to restrict the fishery to trophy-only fishing minimizing the loss of fish in younger age classes. Trophy-only fishing would probably tend to disperse fishermen over a wider area since intense pressure in any one area would quickly eliminate most trophy fish.

The development of lake trout sport fisheries would seem to be preferable to commercial exploitation, providing greater income with less impact on the species. Recent studies of the sport fisheries in Great Slave, Great Bear, and other lakes suggest that, while sport fishing causes a decline in the abundance of trophy-sized fish, the population structure is altered much less than with intense commercial exploitation (Falk *et al.*, 1973; Anonymous, 1975). Fly-in camps in remote areas would provide the optimum use of the lake trout fishery since a large number of lakes could be utilized with minimal impact on any individual population. Establishment of permanent lodges for lake trout sport fishing should be restricted to lakes containing relatively large trout populations to avoid overexploitation.

TABLE 10

Summary of lake trout landings (lbs) at five major commercial fishing areas since 1960. Data from Bond and Turnbull (1973); Bond (1973, 1974a, 1975a); Brian Wong (personal communication, Fisheries and Marine Service, Yellowknife); and Ken Roberts (personal communication, Fisheries and Marine Service, Hay River).

Year	Cambridge Bay	Slave Lake	Rankin Inlet	Lac La Martre	Hottah Lake
1960	—	1,095,000	—	—	—
1961	—	1,069,000	2,719	—	—
1962	27,638	1,172,000	—	—	—
1963	10,547	698,000	806	—	8,913
1964	17,224	667,000	267,464	—	227,348
1965	38,000	812,000	147,682	—	157,623
1966	—	590,000	123,018	—	5,921
1967	89,620	667,000	3,009	—	—
1968	8,135	268,000	480	—	—
1969	—	300,000	5,964	48,854	—
1970	14,442	491,000	18,953	52,525	—
1971	11,000	322,000	20,000	29,123	7,005
1972	30,417	189,000	37,002	40,008	—
1973	8,015	202,802	37,477	—	—
1974	10,678	244,028	6,594	—	—
1975	3,919	218,000	26,659	—	—
1976	—	184,000	—	—	—
1977	—	239,000	—	—	—

TABLE 11

Summary of lake trout harvested by anglers in Great Slave and Great Bear Lakes, 1971 to 1974. Includes only fish killed. (From Falk *et al.*, 1973, 1974, 1975).

	Great Slave Lake		Great Bear Lake	
Year	Total Number	Total Weight (kg)	Total Number	Total Weight (kg)
1971	7,037	22,359	5,808*	20,333*
1972	8,051	23,635	18,152	62,704
1973	10,591	26,551	15,352	53,350
1974	7,534	21,566	5,720*	23,780*

**Includes only Great Bear Lodge and Branson's Cameron Bay Lodge.*

OTHER SPECIES

NORTHERN PIKE *(Esox lucius L.)*

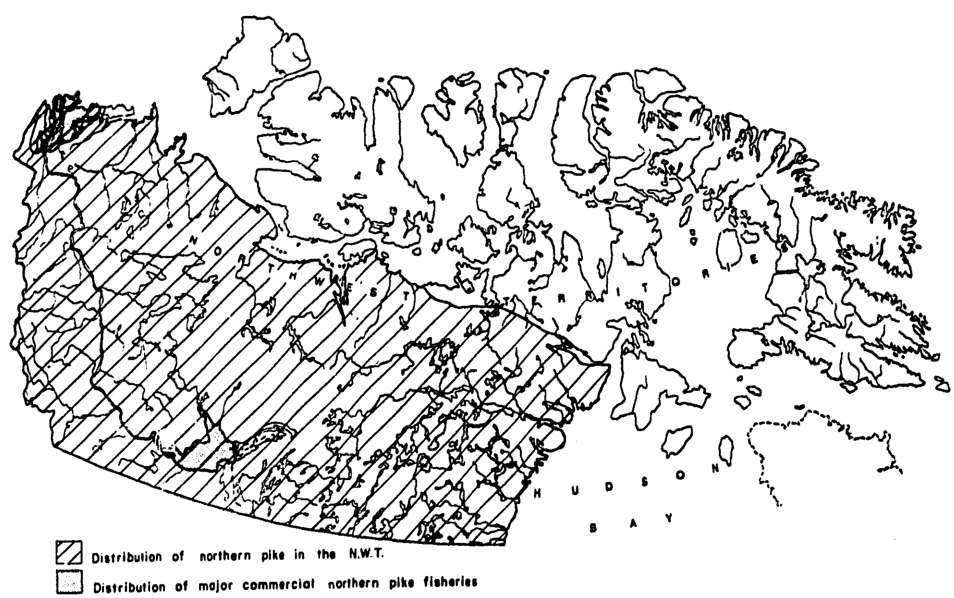
Northern pike are common in lakes and streams throughout the mainland portions of the Northwest Territories with the exception of the extreme northern portions of the District of Keewatin (Figure 15). Although circumpolar in distribution, pike are primarily a freshwater species, only rarely entering brackish water. A considerable amount of information on their growth, reproduction, and food habits is available (Miller and Kennedy, 1948; McPhail and Lindsey, 1970; Hatfield *et al.*, 1972; Stein *et al.*, 1973; Jessop *et al.*, 1973, 1974; Falk and Dahlke, 1974; Falk and Gillman, 1975a, 1975b; Percy, 1975; de Graaf and Machniak, 1977; Machniak, 1977).

Northern pike are important domestic and sport species (McPhail and Lindsey, 1970), but have been utilized commercially to a very limited extent (Figure 15). An exception is the Great Slave Lake fishery which has taken pike as a commercial species for the last 30 years. Pike were taken commercially in the Mackenzie Delta in the mid-1960's but fishing has generally been restricted to domestic and sport activity in recent years (Brian Wong, unpublished data).

Domestic and sport utilization of pike is greatest in the Mackenzie River Valley and in the vicinity of Rankin Inlet and Baker Lake (Milton Freeman Ltd., 1976). Lakes and streams outside these areas have fishable pike populations, but access is generally poor. Pike are utilized most often as dog food by domestic fishermen, but are occasionally eaten by humans. Due to the preference of most native fishermen for whitefish, the greatest potential for future expansion of pike fisheries probably lies with sport fishermen. Pike are considered the third most important sport fish in the Northwest Territories (after char and lake trout) to non-resident anglers (Brian Wong, Fisheries and Marine Service, Yellowknife, personal communication) indicating considerable potential to expand sport fishing of this species.

Pike are one of the fastest growing northern fish species, commonly reaching 600 to 900 mm by age 10 (Figure 16). Growth rates tend to decrease northward with a corresponding increase in longevity. Populations in the Northwest Territories often contain individuals 23 to 26 years of age with sexual maturity oc-

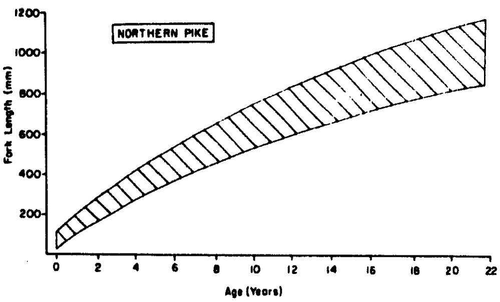
Figure 15. Distribution of northern pike in the Northwest Territories and location of major commercial fishing areas.



curring at ages four to seven. Pike tend to mature at greater ages in more northern populations and males tend to mature one to two years earlier than females.

Spawning occurs in the spring closely following break-up (May to June). Pike spawn in both streams and shallow areas in lakes generally utilizing patches of aquatic vegetation as spawning habitat (Scott and Crossman, 1973). With the abundance of lakes and streams with shallow vegetated shorelines in the Northwest Territories, it is unlikely that the availability of spawning habitats is a major limiting factor to pike production. Young-of-the-year emerge in late June to July and commonly exceed 100 mm in length by freeze-up.

Figure 16. Range of variation of published growth curves for northern pike in the Northwest Territories.



MOVEMENTS

Pike are generally non-migratory, but do undertake limited seasonal movements, particularly in streams. They generally overwinter in deep channels and in lakes. Few individuals are caught in deep portions of lakes during summer months since most pike remain in warm nearshore waters. This preference for warm water tends to segregate pike from lake trout during much of the summer season reducing interspecific competition for food.

The food habits of northern pike are similar to those of lake trout with fish comprising an even higher percentage of the diet. In the Mackenzie Delta, the principal species eaten include whitefish, cisco, pond smelt, stickleback, burbot, trout-perch, walleye, and sculpin (de Graaf and Machniak, 1977). In addition, pike are known to be cannibalistic, often consuming their own kind up to one-half their own body length. A wide range of other vertebrates and intervebrates are utilized depending largely on availability. One of the principal reasons for the success of the northern pike in exploiting such a wide range of northern habitats is probably its ability to utilize whatever prey item is available. Food availability may, therefore, be less limiting to pike than to other northern fish species.

INCONNU *(Stenodus leucichthys* Güldenstadt)

In the Northwest Territories, inconnu are restricted to the Mackenzie River drainage (including the Slave and Liard Rivers) and the Anderson River (Figure 17). Inconnu may be anadromous and some enter coastal waters in the vicinity of the Mackenzie Delta during the summer months, but are restricted to fresh water after freeze-up. Studies of the life history of inconnu in the N.W.T. include Hatfield *et al.* (1972), Stein *et al.* (1973), Jessop *et al.* (1973, 1974), Percy (1975), de Graaf and Machniak (1977), and Jones and Den Beste (1977).

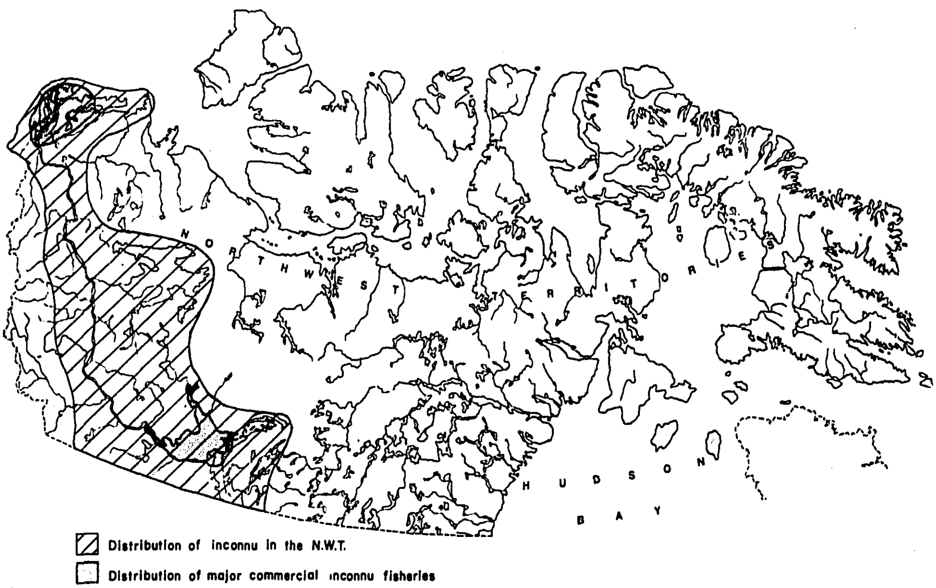
Commercial utilization of inconnu in the Northwest Territories is limited (Figure 17), with the only commercial fisheries located in the Mackenzie Delta and Great Slave Lake. Since the Delta fishery is not operational at present, commercial utilization occurs only through the Hay River plant on Great Slave Lake. At present, commercial gillnet catches in Great Slave Lake average slightly below 200,000 lbs per year (Ken Roberts, Fisheries and Marine Service, Hay River, personal communication) and have varied only slightly since the Great Slave fishery began operations in 1945. Sinclair *et al.* (1967) report that the demand for inconnu as smoked fish in the United Markets controls the number harvested annually. To date, no quota has been set by the Fisheries and Marine Service for inconnu harvest in Great Slave Lake, although a quota has been established for the inactive Mackenzie Delta fishery (Fisheries and Environment Canada, 1977).

Data presented by Jessop *et al.* (1974) and DIAND/MPS (1973) indicate that inconnu are of greatest importance to domestic fisheries in the Mackenzie Delta and adjacent coastal waters. Elsewhere in the Mackenzie drainage, their relative importance is lower. Inconnu are utilized for both human consumption and as dog food, but no accurate data are available on the relative proportion of the domestic harvest devoted to each. Most inconnu taken in domestic fisheries are captured in the same nets with other coregonid species. Native fishermen also take a small number of inconnu by angling since inconnu, which are piscivorous, will take lures more readily than other whitefish species.

Utilization of inconnu by sport fishermen in the Northwest Territories is extremely low. While inconnu are occasionally angled, this generally occurs while anglers are fishing for other species and not while they are specifically attempting to catch inconnu. Keleher (1967) found that Great Slave Lake supported sufficient inconnu to provide a valuable "connie" fishery, but suitable angling techniques had not been developed to utilize this resource. In future an increased emphasis on inconnu as a sport species might help relieve increasing pressure on lake trout, pike, and grayling.

Inconnu are the fastest growing of the whitefish species and reach the largest maximum size. Individuals

Figure 17. Distribution of inconnu in the Northwest Territories and location of major inconnu commercial fisheries.



ranging from five to 15 kg in weight are common in Mackenzie Delta fisheries and specimens exceeding 20 kg have been taken in Great Slave Lake (Scott and Crossman, 1973). Females live longer and grow to larger sizes than males (Alt, 1969). In the Mackenzie Delta, de Graaf and Machniak (1977) report that all fish beyond age 14 were females. Maximum ages reported for inconnu in the Northwest Territories are age 22 in the Mackenzie Delta (Stein *et al.*, 1973) and age 11 in Great Slave Lake (Fuller, 1955). Inconnu mature between the ages of six and 14 with most individuals maturing at ages eight to 11 (de Graaf and Machniak, 1977).

Spawning movements of inconnu are poorly documented in the Northwest Territories and no data are available on spawning habitat, areas utilized, timing, fecundity, or rearing areas for young. It has been reported that an upstream migration of spawners begins in late June in most areas and continues throughout the summer (Stein *et al.*, 1973; Jessop *et al.*, 1974). Although tributaries of the Peel River, Arctic Red River, Rengleng River, Pierre Creek, Oscar Creek, Big Buffalo River, Taltson River, Slave River, Little Buffalo River, and Hay River are suspected spawning areas, there have been no direct observations of spawning activity (Scott and Crossman, 1973; Stein *et al.*, 1973; Jessop *et al.*, 1974; de Graaf and Machniak, 1977). In Alaska, spawning occurs in late September in swift water at depths from 1.5 to 1.8 m over coarse gravel substrates (Alt, 1969). After spawning, a large downstream run has been reported in rivers draining into Great Slave Lake and in the lower Mackenzie River. Mature inconnu are believed to spawn only every two to four years and seldom venture into marine environments in the year of spawning (de Graaf and Machniak, 1977; Jones and Den Beste, 1977). Juveniles are abundant in coastal waters during the summer season, but return to fresh water to overwinter.

Inconnu are predominantly piscivorous. Other whitefish, including inconnu, are most commonly eaten, although northern pike, ninespine sticklebacks, sculpin, and pond smelt are also utilized (de Graaf and Machniak, 1977). Crustaceans and insects have been reported in inconnu stomachs from the Mackenzie River, but these items have generally been taken along with fish. Inconnu in some areas are reported to gorge themselves with smaller inconnu (Scott and Crossman, 1973). No accurate estimates of mortality or other population parameters are available for this species.

WALLEYE *(Stizostedion vitreum* Mitchill)

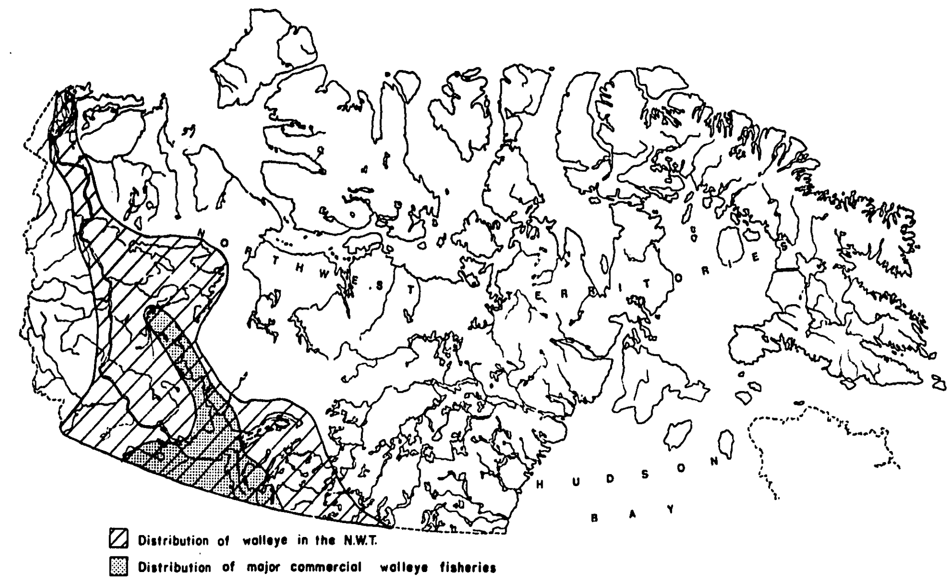
Walleye occur throughout the Mackenzie River drainage, but are only found in abundance in the area south of Great Bear Lake (Figure 18). They are generally restricted to fresh water and tolerate only extremely low salt concentrations. Few data are available on the biology of this species in the Northwest Territories, although considerable information is available from other areas (summarized by Machniak, 1975).

While considered one of the most important commercial and sport fishing species in Canada (Scott and Crossman, 1973), walleye are utilized only in very limited quantities in the Northwest Territories. Commercial fishing is restricted to Great Slave Lake and a number of smaller lakes located in the southwest portion of the Northwest Territories (Table 12). Commercial landings of walleye from Great Slave Lake range from 7,000 to 13,000 kg per year over the last 10 years (Ken Roberts, personal communication) and rarely exceed 70,000 kg per year for all of the N.W.T. (Statistics Canada, 1971 to 1975). Most of the walleye sold commercially are processed through the Hay River fish plant (Sinclair *et al.*, 1965). Harvest from other parts of Canada amounts to over a million kg annually (Scott and Crossman, 1973). Since most of the demand for walleye exists in southern markets and fisheries elsewhere in the country can supply most of this demand at lower cost, further expansion of walleye commercial fisheries in the Northwest Territories is probably impractical.

Domestic fisheries utilize small quantities of walleye throughout the Mackenzie River drainage (Lilley, 1975), but these are generally incidental to catches of other species. Data describing the utilization of walleye by natives are not available, but the high palatability of this species would suggest that much of the annual domestic catch is utilized by human consumption.

Since walleye occur in commercially fishable numbers in only a limited number of waterbodies in the N.W.T., the greatest potential for fishery development may lie with the sport fisherman. Walleye are highly prized by anglers throughout Canada and are the most important sport species in some provinces (Scott and Crossman, 1973). In the Northwest Territories, walleye sport fishing is restricted to areas where road access is possible, in the vicinity of Great Slave Lake and at lodges throughout the area (Figure 3). While some sport fishing already occurs in nearly every part of the walleye range, improved road access to other lakes and streams containing walleye would redistribute the angling pressure and provide considerable potential for future development of the sport fishery.

Figure 18. Distribution of walleye in the Northwest Territories and location of major commercial fishing areas.



Sport fishing regulations allow a daily catch limit of five walleye and a possession limit of 10 per angler (Fisheries and Environment Canada, 1977). The concentration of anglers in a few areas could jeopardize stocks even with relatively conservative catch limits. As localized sport fishing pressure increases, management policy may require regulation through stricter catch limits and temporary closures to protect spawning migrations.

While the growth rate of walleye is probably slower in northern populations than in more temperate areas, no data are available describing the growth of this species in the N.W.T. Studies in southern environments suggest that the availability of prey items is probably a limiting factor controlling the growth rate of walleye (Forney, 1965; Morsell, 1970). According to Carlander (1948), the productivity of the water, population density, and length of growing season are the principal factors affecting walleye growth. The low productivity and short growing season in waters of the N.W.T. probably serve to limit the distribution of this species and reduce its productivity.

In the N.W.T., yellow perch have a distribution similar to that of walleye. The perch is a common prey of walleye and its presence or absence may influence the growth rate of walleye. Where yellow perch do not occur, walleye utilize a wide range of other fish species including boreal smelt, ciscoes, ninespine stickleback, suckers, lake whitefish, shiners, trout-perch, burbot, and goldeye (Scott and Crossman, 1973). Although highly cannibalistic, no data are available indicating that self-predation is limiting to walleye production. Several authors suggest that enhancement of yellow perch populations in lakes would tend to increase walleye production (Smith and Krefting, 1953; Maloney and Johnson, 1957). No data are available, however, on the effectiveness of such a management program for walleye in northern environments.

Walleye spawn in June in the Northwest Territories, but apparently do not spawn in years when water temperatures are unfavourable (Scott and Crossman, 1973). In most areas, spawning takes place when water temperatures are between 10 and 12° C. The littoral zones of lakes are the preferred spawning habitat, although some spawning occurs in the white water areas of rivers over rocky substrates. The failure of this species to spawn in unfavourable years may limit production in northern environments.

GRAYLING (*Thymallus articus* Pallas)

Grayling distribution in the Northwest Territories is similar to the distribution of northern pike (Figures 15 and 19). While abundant in lakes and streams throughout the mainland portions of the N.W.T., the species is absent from the Boothia Peninsula and the Arctic Islands. Despite its wide distribution, detailed studies of the growth, reproduction, and food habits of this species in the Northwest Territories are extremely limited. To date, the most comprehensive study of the growth and productivity of grayling in the Territories is a study conducted on Vermilion Creek, N.W.T. (D. Tripp, M.Sc. Thesis in progress, University of Calgary).

Due to their relative small size, grayling are of little importance as a commercial species. They are utilized principally by sport fishermen and, to a limited extent, by domestic fishermen. The Mackenzie River and its tributaries provide most of the domestic and sport fishing, although some sport fishing does take place in the vicinity of lodges and fly-in camps in the District of Keewatin and near settlements in coastal areas.

Domestic fishermen utilize grayling to a limited extent for human consumption and as dog food. Grayling are often caught by domestic fishermen incidentally while fishing for other species (e.g., whitefish) but they make up a significant portion of domestic harvest only in the central portions of the Mackenzie Valley. Domestic fishermen harvest most grayling during spring spawning runs and in the fall when large aggregations often occur in preparation for overwintering.

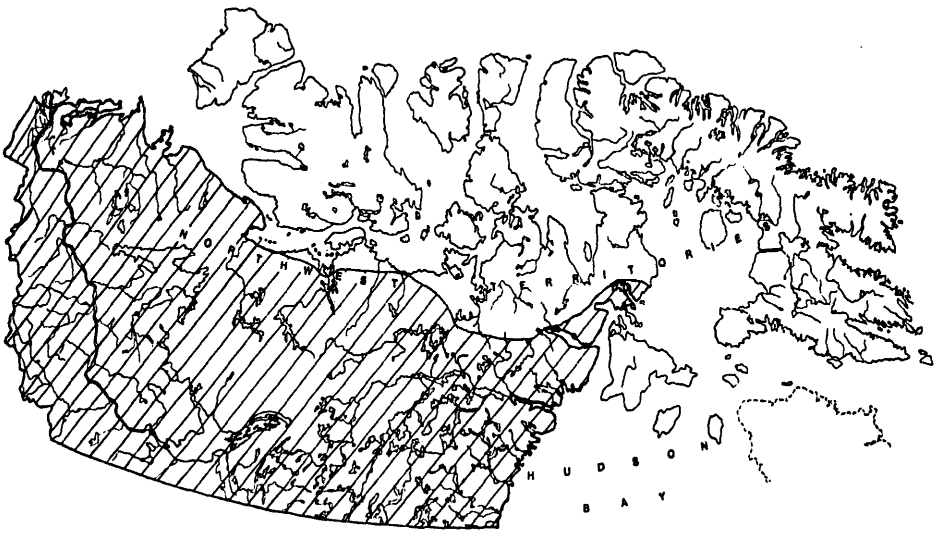
Recent studies on the effects of sport fishing on Arctic grayling in the vicinity of Great Slave Lake indicate that angling pressure has caused a reduction in the average size and age of angled individuals (Falk and

TABLE 12

Lakes and streams with commercial walleye quotas in the Northwest Territories (from Fisheries and Environment Canada, 1977). Quotas are presented as pounds round weight.

Waterbody	Location	Quota	Mesh Size (in. stretched mesh)
Dogface Lake	60.17N-119.05W	5,000	4.5
Johnston Lake	62.59N-114.12W	1,200	4.5
Kakisa Lake	60.55N-117.40W	41,000	4.5
Mosher Lake	63.06N-115.26W	2,500	4.5
Ste. Therese Lake	64.37N-121.30W	15,000	4.5
Taltson River	61.20N-112.40W	25,000	4.5
Tathlina Lake	60.30N-117.30W	68,000	4.5
Tsetso Lake	61.51N-123.01W	1,700	4.5

Figure 19. Distribution of Arctic grayling in the Northwest Territories (striped area).



Recent studies on the effects of sport fishing on Arctic grayling in the vicinity of Great Slave Lake indicate that angling pressure has caused a reduction in the average size and age of angled individuals (Falk and Gillman, 1974). Annual mortality, including both natural and angling mortality, was estimated at 65% in an earlier study (Gillman and Dahlke, 1973). Excessive daily catch limits (10 fish per day) and lack of a minimum catch size contributed to this high annual mortality. Recent reductions in the daily catch limit for grayling (to five fish per day) should provide better protection for the species although additional catch size restrictions may be necessary in some areas.

Grayling provide excellent potential as a sport species having become popular with anglers in recent years. The concentration of anglers in the vicinity of Great Slave and Great Bear Lakes will be of increasing concern as fishing pressure on this species increases. Recent improvements in road access have increased pressure on the species at a few points, but much of the potential sport fishery remains undeveloped as a result of poor access. Increasing emphasis on development of grayling as a sport species could reduce pressure on other species (i.e., lake trout and Arctic char) and produce considerable economic return.

Growth of Arctic grayling is relatively slow with mature individuals seldom exceeding 500 mm fork length. Individuals generally mature by age seven. Maximum ages for most populations are in the mid-teens but a few grayling have been aged, from otoliths, at 20 years or more.

Spawning usually occurs just after break-up, most frequently in small tributary streams.

Food items utilized by grayling include both stream drift and surface insects making this species highly susceptible to anglers. Several reports indicate cannibalism by grayling and the utilization of juvenile grayling by other species, but there is no evidence to indicate that this predation is limiting to grayling populations.

CISCOES

Three species of cisco occur in the N.W.T. including the Arctic cisco *(Coregonus autumnalis)*, least cisco *(Coregonus sardinella)*, and lake cisco or tullibee *(Coregonus artedii)*. The distribution of these ciscoes in the Northwest Territories is presented in Figures 20 to 22.

Ciscoes are taken by domestic fishermen in the lower portions of the Mackenzie River, particularly the Mackenzie Delta, and Great Slave and Great Bear Lakes. Few ciscoes are utilized for human consumption and most of the annual harvest is fed to dogs (Jessop *et al.*, 1973). While small quantities were taken in Mackenzie Delta commercial fisheries when it was operating, out-

Figure 20. Distribution of Arctic cisco in the Northwest Territories and location of domestic harvest.

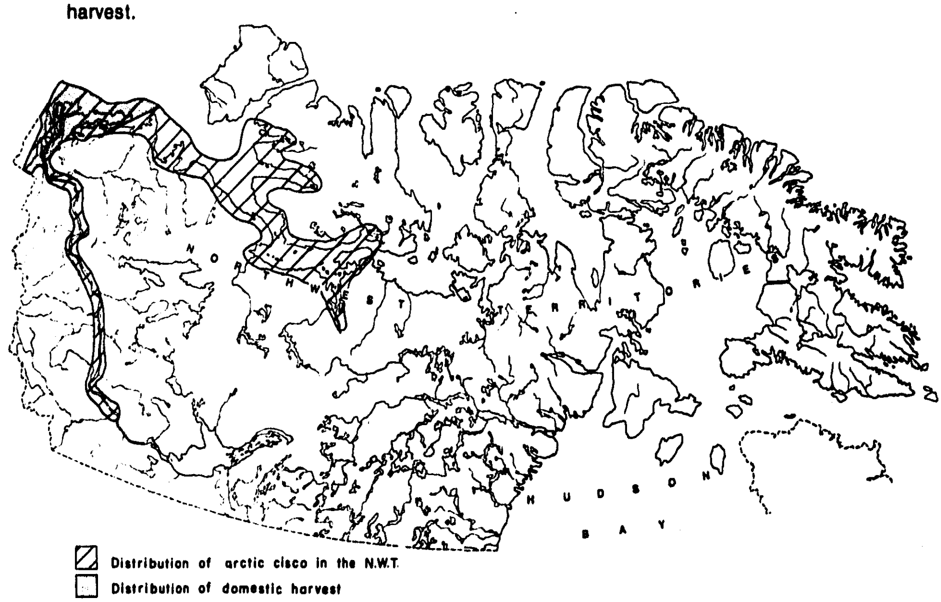


Figure 21. Distribution of least cisco in the Northwest Territories and location of major domestic fishing areas.

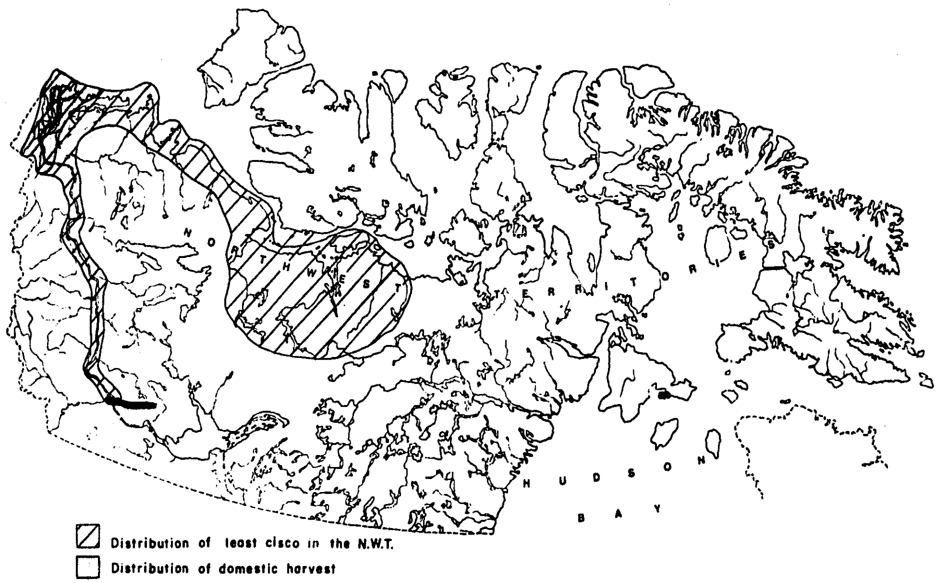
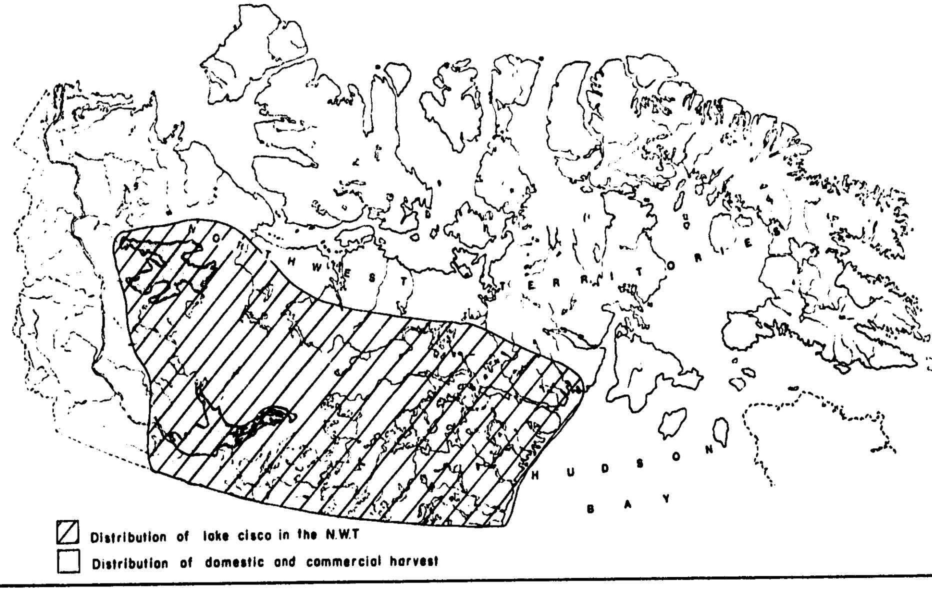


Figure 22. Distribution of lake cisco in the Northwest Territories and location of major domestic and commercial fishing areas.



side markets for these species do not exist. No effort is being made at present to commercially fish ciscoes in the Northwest Territories, although small numbers are still taken as incidental catches. Potential for utilization of ciscoes as a sport species is low since the food habits of these fish limit their vulnerability to angling.

The growth of ciscoes is relatively slow with the maximum size of Arctic cisco rarely exceeding 500 mm and the maximum size of least cisco and lake cisco rarely exceeding 350 mm. Arctic cisco are generally faster growing and have greater longevity than other cisco species (Craig and Mann, 1974; Griffiths *et al.*, 1975, 1977; Jones and Den Beste, 1977). The larger size attained by Arctic cisco makes them more desirable to domestic fishermen than least or lake cisco.

Both Arctic and least cisco are anadromous species migrating to coastal waters during the open water season where they are caught by fishermen from Tuktoyaktuk and from Mackenzie Delta settlements. Some populations of least cisco occurring in lakes are non-migratory, remaining in fresh water throughout their life cycle (Mann, 1974). Growth rates of non-migratory least cisco are generally slower than those of migratory fish. Lake cisco are commonly restricted to lakes, although some populations are known to enter salt water in the Hudson Bay region (Scott and Crossman, 1973).

Cisco spawn in the fall months as water temperatures decline. Spawning areas for Arctic cisco are not well documented, but spawning is believed to occur in tributaries of the Mackenzie River (e.g., the Peel River) over gravel substrates. Least cisco and lake cisco are known to spawn in both lakes and rivers over sand or gravel substrates.

Ciscoes are commonly plankton feeders, occasionally utilizing some aquatic and terrestrial insects. Ciscoes provide an important link in the food chain between plankton and the larger piscivorous fish which prey on ciscoes extensively. Data on the annual mortality of this species are not available, but it appears that the availability of food is probably more limiting to cisco populations than the effects of predation.

REGULATION OF FISHERIES

EFFECTS OF FISHING ON POPULATION STRUCTURE

Northern populations of freshwater fish are characterized by slow growth, late maturity, and long life. Lake trout are extreme examples of these tendencies. They may not mature for the first time until well into their teens then continue spawning at two or three year intervals until they reach an age of 30 years or more. Power (1978) reports an age, from otoliths, of 51 for a lake trout approximately 980 mm in length from northern Quebec. Lake whitefish, a species important in both domestic and commercial fisheries, show the same tendencies. Power (1978) sampled several from locations in northern Quebec which exceeded 50 years in age, one approximately 570 mm in length which was judged to be 57 years old. The fact that in these and other northern species mature fish are spread over many year classes is an advantage in that the loss of any single year class, through reproductive failure or other circumstances, will have little effect on the population as a whole.

Because of their structure, with representation among a large number of mature age classes, northern stocks commonly consist of a large biomass of big fish (Johnson, 1976). For this reason they are particularly attractive to domestic and commercial fishermen. Power (1978) points out, however, that while exploitation at a low rate can take place without endangering the stock, problems can arise when exploitation increases to the point where the reserve of old fish in the stock begins to be depleted. He suggests that in the north, reproduction is more critical than in the south and that the number of mature year classes present in a population is a reflection of the probability of successive bad years for reproduction. If the number of mature year classes is reduced, the population may be less able to tolerate even moderate exploitation when additional stress is applied in the form of a series of unfavourable years.

In fisheries in general, as well as in the Northwest Territories, the critical age for harvesting is close to the age at first maturity (Larkin, 1977). As maturity approaches, growth in weight is rapid and natural mortality is low. After maturity, growth in weight slows because a large proportion of the fish's total energy income is utilized in the production of sex products and mortality increases at least partly because of the stress and dangers associated with spawning.

As previously indicated, fisheries tend to concentrate on the larger, mature segment of the population. Where the fishery is sufficiently intense, fish populations show typical responses:

1) There is a reduction in both the average size and average age of the population as the larger, older fish are selectively eliminated;

2) Catch per unit effort declines as the numbers of fish in the age classes susceptible to the gear declines;

3) There may be an increase in the growth rates of smaller, predominantly juvenile fish, which are too small to be susceptible to the gear, as older intraspecific competitors are eliminated;

4) Increased growth among juvenile fish may be accompanied by a reduction in the age at which they mature.

In time, heavily exploited populations may be made up almost entirely of fish that are young and are first time spawners (Larkin, 1977). Such populations are potentially less stable than unexploited stocks because:

1) The quality of the eggs deposited may be reduced (e.g., small fish produce small eggs and these, in turn, produce small young which have a lower chance of survival than large young);

2) A failure in egg or larval survival for any reason is potentially far more catastrophic in its effect on long-term abundance.

In time, stocks subject to high rates of exploitation may be reduced to very low levels or, in exceptional circumstances, become extinct.

Power (1978) suggests that the dangers of collapse are even greater among northern than among fish stocks in general and that, therefore, great caution and restraint should be exercised in the management of northern fisheries.

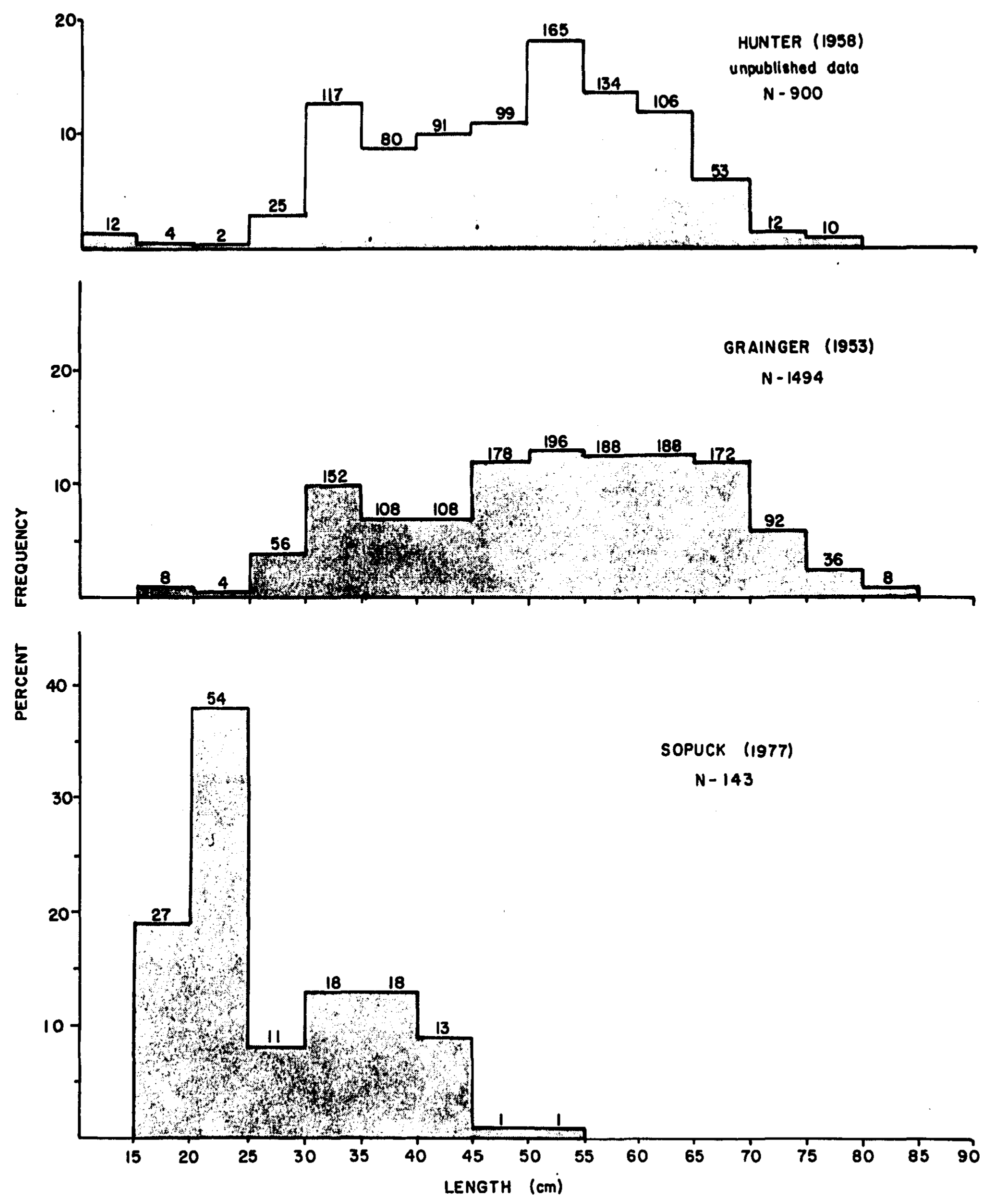
There are several examples of the effects of high rates of exploitation on fish stocks in the Northwest Territories. One of the best documented concerns the commercial fishery for lake trout and whitefish in Great Slave Lake, the most productive large fishery in the Territories. Keleher (1972a) summarized data for the first 20 years of the commercial fishery, from 1945. He found that:

1) Catch per unit effort has declined for both species, 60% for whitefish and 93% for lake trout;

2) The average size of fish in commercial catches has declined. In whitefish, there was an initial decline from approximately 1.4 kg (3.1 lbs) to about 1.2 kg (2.6 lbs) but this levelled out and has remained relatively constant in recent years. Initially, trout in the more productive western basin had an average weight of 4.5 kg (10 lbs) and those in the eastern basin about 3.2 kg (7 lbs). With fishing, average weights in both areas declined to just over 2.3 kg (5 lbs), but, unlike whitefish, no steady size state was reached during the first 20 years of the fishery and average weights continued to decline.

Bond (1974a) recently summarized the status of the Great Slave Lake stocks of the two species:

Figure 23. Comparison of the length distribution of Arctic char in the Sylvia Grinnell River between Grainger (1953), Hunter (1958) unpublished, and the present study. From Sopuck (1977).



"While commercial production of both species has decreased since the 1950's, the whitefish and lake trout populations have reacted differently to exploitation. The whitefish have reacted in the classic manner of exploited fish populations by increased growth rate and reduced age of maturity. It is felt that the whitefish populations are not being overexploited at the present time. . . . The lake trout, on the other hand, have been unable to withstand commercial gillnetting and have been reduced to the point of commercial extinction in the western part of the lake. There are indications that this process of elimination is progressing eastward. . . .

"Because the east end of Great Slave Lake supports a substantial lake trout sport fishery that warrants protection, Fisheries and Marine Service has adopted the position that the east end of the lake should be closed to commercial fishing within two years and managed for lake trout. The west end of the lake is to be exploited by the commercial fishery and managed for whitefish production without regard to trout."

The fate of lake trout in Great Slave Lake emphasizes the problem, discussed by Larkin (1977), of managing fisheries which exploit more than one species. Species of lower productivity such as the lake trout are

Figure 24. Comparison of the age distribution of Arctic char in the Sylvia Grinnell River between Grainger (1953) and the present study. From Sopuck (1977).

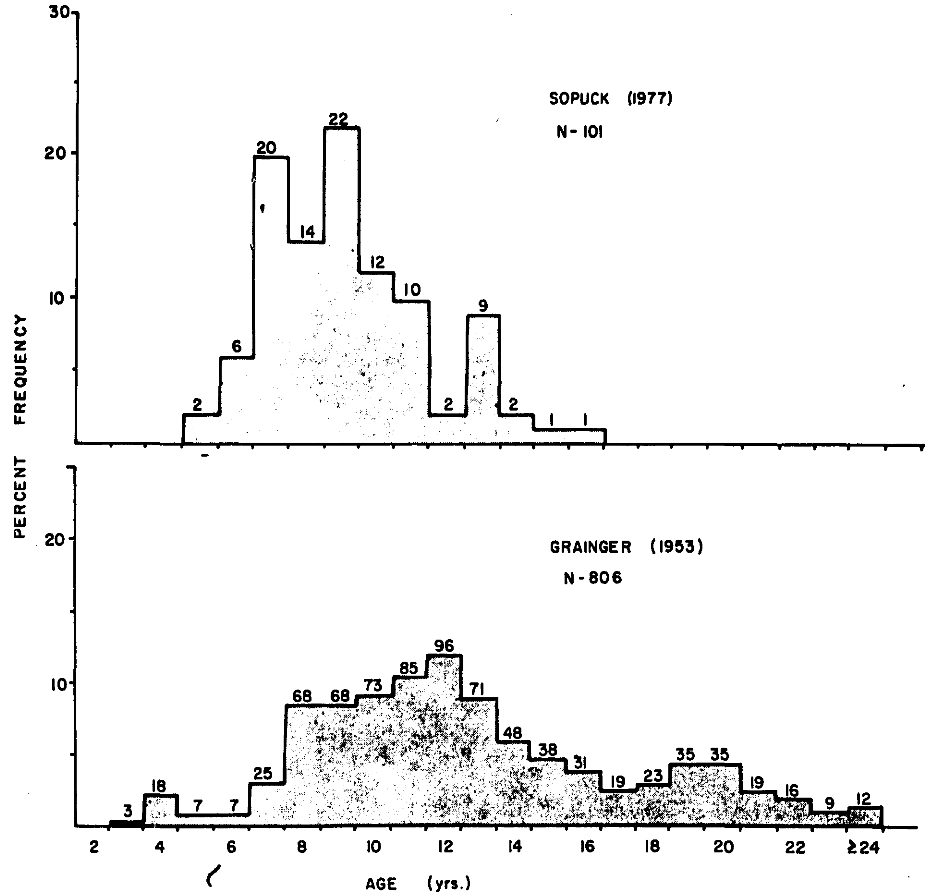
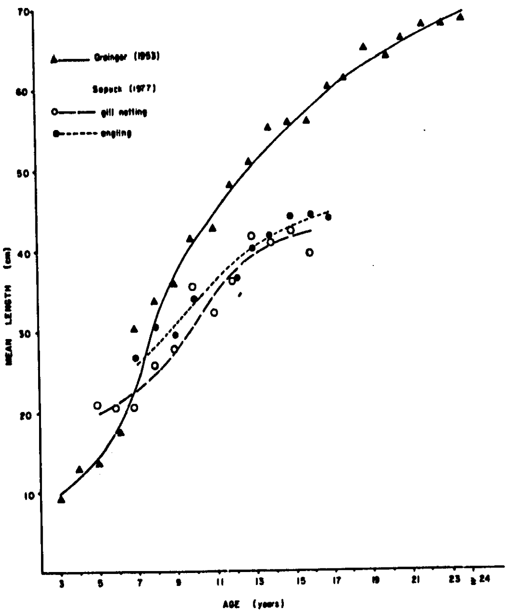


Figure 25. Comparison of age length relationships of Arctic char in the Sylvia Grinnell River between Grainger (1953) and the present study. Curves drawn by eye. From Sopuck (1971).



progressively eliminated or pushed close to extinction as the fishery harvests more productive species such as lake whitefish at a level which is still within its biological capacity to withstand.

An example of the effects of heavy exploitation on an anadromous (sea-going) stock is the domestic fishery for Arctic char on the Sylvia Grinnell River, Baffin Island, N.W.T., described by Sopuck (1977). The stream lies close to the town of Frobisher Bay and both juvenile and adult Arctic char are subject to intensive fishing by gillnet, angling, and snagging as they move upstream from Frobisher Bay in the late summer. Sopuck compared his data with earlier data for the same population from Grainger (1953) and Hunter (unpublished data) and showed:

1) The elimination of the largest size classes of fish and a reduction in the mean length of the population (Figure 23);

2) The elimination of the older age classes and a reduction in the average age of the population (Figure 24);

3) A change in the age-length relationship suggesting an apparent reduction in growth rates (Figure 25).

Sopuck concluded that, at present, the population is overexploited and suggested a variety of ways in which effort would be reduced to allow the population to recover.

Even purely recreational fisheries can bring about marked changes in the characteristics of populations of some species, for example, the lake trout of Great Bear Lake where there has been local depletion of trophy-sized fish by anglers who are clients of specialty fly-in lodges (Falk *et al.*, 1973). While fisheries in the Northwest Territories are demonstrably sensitive to the effects of high rates of exploitation, it is also true that most stocks have the capacity to recover when the rate of exploitation is reduced. Reductions in effort may occur either because fishermen abandon the fishery when returns are no longer economic or because the fishery is more strictly regulated.

Johnson (1976) states that Arctic char and lake whitefish have a great resiliency to harvesting and that decimated populations can rapidly recover if cropping is suspended. Lake trout, on the other hand, he believes to be especially sensitive to overfishing, having evolved toward low replacement rates to such an extent that they can only maintain a large biomass at extremely low turnover rates. Certainly there is evidence for his view in the rapid recovery of Arctic char in Keyhole Lake from the effects of an experimental fishery and in the differing sensitivities of whitefish and lake trout to the Great Slave Lake commercial fishery.

Hunter (1970) fished Keyhole Lake on Victoria Island intensively between 1961 and 1967 with the greatest catches in 1963 and 1965. During this period, close to 100% of the initial stock was removed. The stock was untouched thereafter until 1975 when the population had reverted to a condition close to that of the original one in terms of both size structure and length-weight relationship (Johnson, 1976).

SUSTAINABLE YIELD

The Northwest Territories Test Fishing Instructions (Anonymous, 1978) state that, "It is the objective of the Fishery Management Division, Fisheries and Marine Service, to manage the fish resources of the Northwest Territories on a sustained yield basis." Management of commercial and recreational fisheries is accomplished through the establishment of quotas and regulation of gear (e.g., mesh size for gillnets) and fishing season. Domestic fisheries are uncontrolled at present.

Unfortunately, while the notion that stocks should be managed on a sustained yield basis sounds fine, it is difficult to determine how this can be applied in practice. The Fisheries and Marine Service may mean only that fish stocks should be exploited in such a way that their long-term survival is not threatened. On the other hand, they may be referring to other, more complex concepts such as maximum sustainable yield or optimum sustainable yield.

Maximum sustainable yield (MSY) is the concept that any species of fish each year produces a harvestable surplus that can be taken without detriment to the stock and that quotas should be set to approximate this amount (Larkin, 1977). To use more is wasteful of effort, to use less is wasteful of food.

There are serious difficulties with MSY, however, even as a biological concept. Larkin (1977) has reviewed its history in "An Epitaph for Maximum Sustained Yield." He concludes that "... there is precious little prospect of achieving MSY either for one species or for any number of species in the aggregate." He stresses, however, that it does provide a valuable rough index of production potential and that as a basis for management policy for major commercial species it is probably acceptable.

Aside from the problems associated with its application as a biological concept, there are other difficulties with MSY, chief among them that biological constraints are frequently less important than economic and social ones in establishing the conditions under which fisheries are conducted. Recently, fisheries managers tried to incorporate these concerns into their management strategies. Roedel (1975) has defined a newer concept, *optimum sustained yield,* as

> "... a deliberate melding of biological, economic, social and political values designed to produce the maximum benefit to society from stocks that are sought after for human use, taking into account the effect of harvesting on dependent or associated species."

Roedel notes that this definition permits:

1) Recognition of non-extractive uses and values;

2) Allowance for the importance of quality (e.g., fish size and wilderness experience) to the sport fishing experience;

3) Consideration of return on investment as a major criterion in setting harvest rates;

4) Management on the basis of traditional MSY if the need for fisheries products (i.e., protein) is overriding;

5) Tempering of all these factors with knowledge of the real world and of what is acceptable to the body politic, a flexible and pragmatic formula.

This concept is obviously much more complex than that of MSY which, in theory at least, could be defined in quantitative terms. (Larkin, 1977, claims bafflement at what exactly Roedel's definition means.) The quotas which might be deemed to provide the optimum sustainable yield would appear to be more the product of compromise than of calculation and might be more, less, or equal to the MSY. They must be negotiated separately for each fishery and will change in time as biological, economic, social, and political conditions change. In fact, this seems to be the basis on which most fisheries, in the Northwest Territories as elsewhere, are actually regulated. The condition of the stocks, the biological reality, puts an ultimate ceiling on fishing effort but in some circumstances yield can exceed the MSY for substantial periods before fishing is abandoned. The intensive domestic fishery for Arctic char in the Sylvia Grinnell River near Frobisher Bay may be an example, the commercial fishery for lake trout in Great Slave Lake another.

COMMERCIAL QUOTAS

Commercial quotas (see Appendix I, Schedule V) have been arrived at in a variety of ways:

1) Through the application of a 0.5 lb/acre (0.56 kg/ha) limit. This limit has apparently been derived from Rawson (1960) who examined 12 large lakes in northern Saskatchewan and concluded that with the exception of the least productive (Lake Athabasca) all were capable of continuous fish production at a level greater than this value.

2) Through test fishing. In recent years, the Fisheries Management Division, Fisheries and Marine Service, Winnipeg, has instituted a test fishery procedure designed to provide information to be used in establishing biologically-based quotas for new commercial fisheries. These are described in "Northwest Territories Test Fishery Instructions" (Anonymous, 1978). The Division requires that, in future, if at all possible, test fishing will be done before quotas are allocated for previously unfished waterbodies in the Northwest Territories.

3) Through an analysis of the effects of existing fisheries. The best example of this approach is the Great Slave Lake fishery where information concerning the past performance of the fishery and its effects on lake trout and lake whitefish populations has been used to set quotas. Other examples would be the Tree River sport fishery for Arctic char and the Great Bear Lake sport fishery for lake trout.

There are problems with each of these approaches. First, in applying a 0.5 lb/acre limit to waterbodies in an area as large and as varied as the Northwest Territories, there is bound to be a large margin of error; overestimating the productivity of some fisheries, underestimating that of others. How can this or any other similar limit be applied to populations of anadromous species which are largely dependent on the productivity of marine rather than freshwater environments? What about multispecies fisheries where even this low quota might adversely affect the least productive species such as lake trout? What about stream-dwelling populations — e.g., those of the Mackenzie Delta which have probably the greatest potential for future commercial development of any in the Northwest Territories? While a 0.5 lb/acre limit is representative of very low productivity and is probably conservative for most of the lakes where commercial fishing might be considered, it is certainly not as good as individual assessments for proposed commercial fisheries.

The test fishing procedure (Anonymous, 1978) does provide individual assessments for proposed new commercial fisheries but the outline of requirements indicates that the approach is a relatively unsophisticated one and that, in the final analysis, a great deal is left to the judgement of the Fisheries Officer responsible for the test. It is, however, certainly better than the application of generalized quotas such as the 0.5 lb/acre limit and does provide a body of data regarding catch per unit effort, species composition, length frequencies, growth rates, weights, etc., which can be used for comparison with similar samples taken once the fishery is in operation. Should these later samples indicate that populations are being either under or over utilized (i.e., that the original quotas were either too high or too low), quotas can be readjusted.

Using information regarding the effects of existing long-term fisheries is one of the best methods of assigning quotas, both in the waterbodies in which the fisheries occur and for other similar waterbodies in which new or expanded fisheries are planned. Unfortunately, there are few good data for fisheries in the Northwest Territories. Even where there are reasonably good descriptions of commercial fisheries, for example, those of Great Slave Lake, very little is known about coexisting domestic fisheries. In fact, the almost total absence of hard data describing domestic fisheries is one of the greatest obstacles to the rational management of fisheries in the Northwest Territories.

SPORT FISH QUOTAS

Falk *et al.* (1973) point out that there are two avenues of approach to harvesting sport species:

1) To maintain the fishery on the basis of trophy fish;

2) To disregard the trophy attraction and seek a total recreational fishery, allowing many people to catch many fish.

In the first instance, the fishery must be managed to protect the young and medium-aged segments of the population from harvest and to control the catch of trophy-sized fish. The rate of exploitation may be very much lower than MSY but the yield in dollars can be very high because there are many anglers who are prepared to spend a great deal of money to catch trophy fish. The lake trout of Great Bear Lake are being managed on this trophy fish basis (Falk *et al.*, 1975). Such fisheries are easiest to manage in waters that are subject to relatively low rates of fishing due to limited access.

The second type of sport fishery is more likely to develop where there is easy access, particularly by road. In the Northwest Territories they are most likely to develop in the southwest and may involve species such as pike, walleye, and goldeye which are widespread in southern Canada and frequently described as "warmwater" sport fish. The major danger in fisheries of this kind, where numbers of fish caught are emphasized over size, is that populations may be overfished leading to serious declines in the populations of sensitive species.

Sport fish quotas for the Northwest Territories are presented in Appendix I (Schedule VI). They apply to a very large area and are not site-specific. Though they are presumably conservative, it will undoubtedly be necessary as sport fisheries develop in the Northwest Territories to introduce specific regulations to protect individual fisheries known to be at risk. Such special regulations have already been applied to the Arctic char of the Tree River, the lake trout of Great Bear Lake, and grayling in parts of the Mackenzie Valley.

SUMMATION

In closing this section on regulation of fisheries in the Northwest Territories, we would emphasize that there is really very little information available which describes, in quantitative terms, the characteristics of fish habitat and the fisheries potential of fresh waters in the Northwest Territories. There are exceptions, of course, including fresh waters in the vicinity of proposed major developments and a few International Biological Programme sites and other sites where specific studies are being conducted as well as some areas, including Great Bear and Great Slave Lakes and a few other lakes where important fisheries are conducted. Despite this, for most of the area of the Territories including the vast fresh waters of the Canadian Shield, almost nothing is known. We can only repeat the words of the Federal-Territorial Task Force of 1972:

> "This general analysis should end with a word of caution. We are extremely ignorant of the capacity of specific bodies of water to produce fish. Although it is possible to make very general statements about large regions it is not possible to be sure that a particular lake or stream in the area will conform to the general pattern. Any move to exploit specific lakes or streams should, therefore, be preceded by an adequate examination of the fish resources and potential of the waters. In a few instances this information is available but for most of the lakes and streams of the Territories it is not."

POSSIBILITIES FOR FUTURE EXPANSION OF FISHERIES IN THE NORTHWEST TERRITORIES

In 1972, a Federal-Territorial Task Force produced a report entitled "Where to Now? Fisheries Development in the Northwest Territories." As part of their mandate, they considered possibilities for the expansion of commercial fisheries in the Northwest Territories. They identified the following as having some potential for commercial development:

1) In the Mackenzie Valley
   a) the Camsell drainage included Sarah, Faber, Rae, Hardesty, Hottah, Grouard, and Clut Lakes,
   b) the large lakes bounded by Great Slave Lake, the Camsell River, Great Bear Lake, and the Mackenzie River including La Martre, Keller, Ste. Therese, Blackwater, Fish, and Willow Lakes,
   c) three lakes behind Norman Wells including Kelly, Mahony, and Bracket,
   d) the Mackenzie Delta.

2) In the Anderson River drainage, headwater lakes including Des Bois, Belot, Colville, Aubrey, and Manoir.

3) Coastal areas including the Queen Maud-Coronation Gulf and Pelly Bay areas, as well as less productive areas in the vicinity of Rankin Inlet and southern Baffin Island.

The Task Force also identified several localities where there was a potential for the development of new recreational fisheries. They state:

> "Prospects for new recreational fisheries may be summarized then as: 1) road access fisheries in the southwest corner of the Territories affecting the communities of Enterprise, Hay River, Fort Providence, Fort Simpson, Rae-Edzo, and Yellowknife; 2) local fly-in fisheries affecting principally Hay River, Yellowknife, Inuvik, and possibly Cambridge Bay and Frobisher Bay; and 3) specialty lodges in the lakes of the Taltson River drainage, east and north of Great Slave and along the Arctic coast in the Queen Maud-Coronation Gulf areas. 4) When road access is available the lakes of the Camsell drainage will provide good recreational fishing prospects as well."

Of the various commercial fisheries possibilities probably the one with the greatest potential is that of the Mackenzie Delta and its tributaries. Many fish, probably numbering in the millions, pass through the Delta during their annual migrations and could be the subject of a relatively efficient fishery. Unfortunately, population statistics are hard to come by in such large turbid rivers and we have little idea of the numbers of each species, the identity of distinct stocks, or the size of the potential harvest. Even such basic information as the location of spawning grounds is unknown. We know, for example, that large numbers of ciscoes (least and Arctic cisco) move up the Peel River each autumn to spawn but we do not know where. We have only a general idea of the location of the spawning grounds of the humpback and broad whitefishes, two potentially valuable species. These deficiencies exist despite the fact that the Mackenzie Valley including the Delta has been the subject of intensive examination in recent years as the result of proposals to build a gas pipeline in the area. Our ignorance of conditions in most of the other areas proposed for new fisheries is even greater.

RECOMMENDATIONS

CYCLICAL FISHERIES

We have suggested in several places in this review that consideration be given to cyclical or rotational fishing (e.g., taking the equivalent of a six year harvest in one or two years then allowing the population to rest for four or five years) and have outlined some of the advantages of this method. The method may be especially advantageous where a single species population (e.g., Arctic char) can be exploited. It may not be as well adapted to situations where several species (e.g., lake whitefish and lake trout) are exploited simultaneously.

There have been strong objections to this approach in the past (Task Force on Fisheries Development, Section I, 1972); however, recent unpublished work by Dr. M. C. Healey of the Fisheries and Marine Service, Nanaimo, B.C., suggests that the method is "clearly advantageous" in fisheries for lake whitefish in Precambrian Shield lakes in the N.W.T.

We recommend:

1) That serious consideration be given to the wider application of cyclical fisheries in the N.W.T.;

2) That the Test Fishing Regulations currently in force for the Territories be modified to ensure that the data required to establish rational quotas for cyclical fisheries are generated;

3) That cyclical fisheries be carefully monitored prior to, during, and after the fishing period to determine the initial status of fish populations, the impact of the fishery on population structure, and the period required for populations to recover.

We feel that careful monitoring of such fisheries is important and will eventually provide a body of data which can be used in establishing exploitation rates and recovery periods for future fisheries in similar waterbodies.

DOMESTIC FISHERIES STATISTICS

One of the major problems for fisheries management in the N.W.T. is the poor quality of catch statistics. This is particularly true of domestic fisheries. This can be a problem where quotas designed to maximize sport and/or commercial fisheries may lead to overexploitation of populations if there is an uncontrolled, even unknown, domestic fishery affecting the same population(s).

We recommend that every effort be made to upgrade the quality of information regarding domestic fisheries. We suggest that probably the best way to do this is through the use of local representatives. Such people have the advantage of living full time in settlements and being familiar with the identity of local fishermen and fishing locations. The same individuals might also record the harvest of other resources — game, fur, etc.

These representatives should be totally divorced from the enforcement of fish and game regulations, their only function being the recording of data. To ensure co-operation, they might best be employed by local hunters and trappers associations, subsidized by government funds.

The representatives should be trained in sampling procedures, data recording, and tabulation. Such training might be done at the recently opened Renewable Resources Training Program in Fort Smith, N.W.T.

MONITORING OF EFFECTS OF DEVELOPMENT

We recommend that government take advantage of industrial development projects in the north to monitor, in detail, effects on water quality, aquatic productivity, and fish populations. Too often, detailed studies of projects end with the preliminary impact assessment which accompanies the application for permission to proceed. THERE IS LITTLE STUDY OF THE ACTUAL IMPACT OF DEVELOPMENTS TO VERIFY THE ACCURACY OF PREDICTIONS!

Detailed monitoring studies would, in time, provide a broad data base regarding the general course of development and environmental impact in the N.W.T. which would greatly improve our predictive capabilities. Such information would be invaluable in assessing and mitigating the effects on aquatic ecosystems and freshwater fisheries of future developments.

SPORT FISHING

There have been recommendations in the past that more consideration should be given to encouraging sport fishing in the N.W.T. because sport fisheries can yield a far greater return for each fish harvested, generally with less stress on the resource. This is particularly true of non-resident, tourist anglers (Federal-Territorial Task Force Report, Section I, 1972). We recommend that it be the subject of a separate study which would examine the feasibility of this approach as well as methods of increasing sport fishing so as to provide the greatest benefit to residents of the N.W.T. Such a study should examine both the biological and social implications of increased sport fishing and include provisions for public participation.

INCREASING LOCAL MARKETS FOR FISH

Marketing of the product is a serious problem for commercial fisheries in the north and there is little question that more fish could be taken were economic markets available. We recommend a study of methods of increasing the proportion of the catch marketed within the N.W.T. as a means of increasing the availability of relatively low cost protein to people in settlements who are unable to fish for themselves.

CONTINUED DEVELOPMENT OF COMMERCIAL FISHING STRATEGIES

At this time, commercial fisheries in large areas of the N.W.T. are uneconomic because of high production and transportation costs and the low value of the product. This may, however, change in future as the cost of protein increases and as access increases with development.

There should be a continuing effort, on the part of both the Territorial and Federal Governments, to develop fishing, production, and marketing strategies for commercial fisheries in the N.W.T.

CENTRAL DATA REPOSITORY

We have found in conducting this review that, other than formally published material, much of the relevant information is widely scattered, poorly organized, and difficult to access. We recommend a central data repository for information regarding fisheries in the Northwest Territories.

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BIOGRAPHICAL SKETCHES

Dr. P. J. McCart obtained his Ph. D. degree in Zoology from the University of British Columbia. He has been, at various times, a Scientist with the Fisheries Research Board of Canada and a lecturer at the universities of Regina and Calgary. Dr. McCart's experience with northern fish populations began in 1964. Since that time he has conducted studies of fishes in freshwater and nearshore marine habitats throughout the North American Arctic including Alaska, the Yukon and Northwest Territories, and northern Labrador. Since 1972, Dr. McCart has been President and Principal Consultant of Aquatic Environments Limited, a biological consulting firm in Calgary, Alberta.

Mr. J. Den Beste received his B.S. degree in Wildlife Biology from Washington State University. While an employee of Aquatic Environments Limited, he had extensive experience in fisheries studies in the north including the Alaskan North Slope; the northern Yukon Territory; the Mackenzie Delta, Tuktoyaktuk Peninsula, and Baffin Island, N.W.T.; and northern Labrador. Mr. Den Beste is currently employed by the Alaska Project Division of the Alberta Gas Trunk Line Company Limited.

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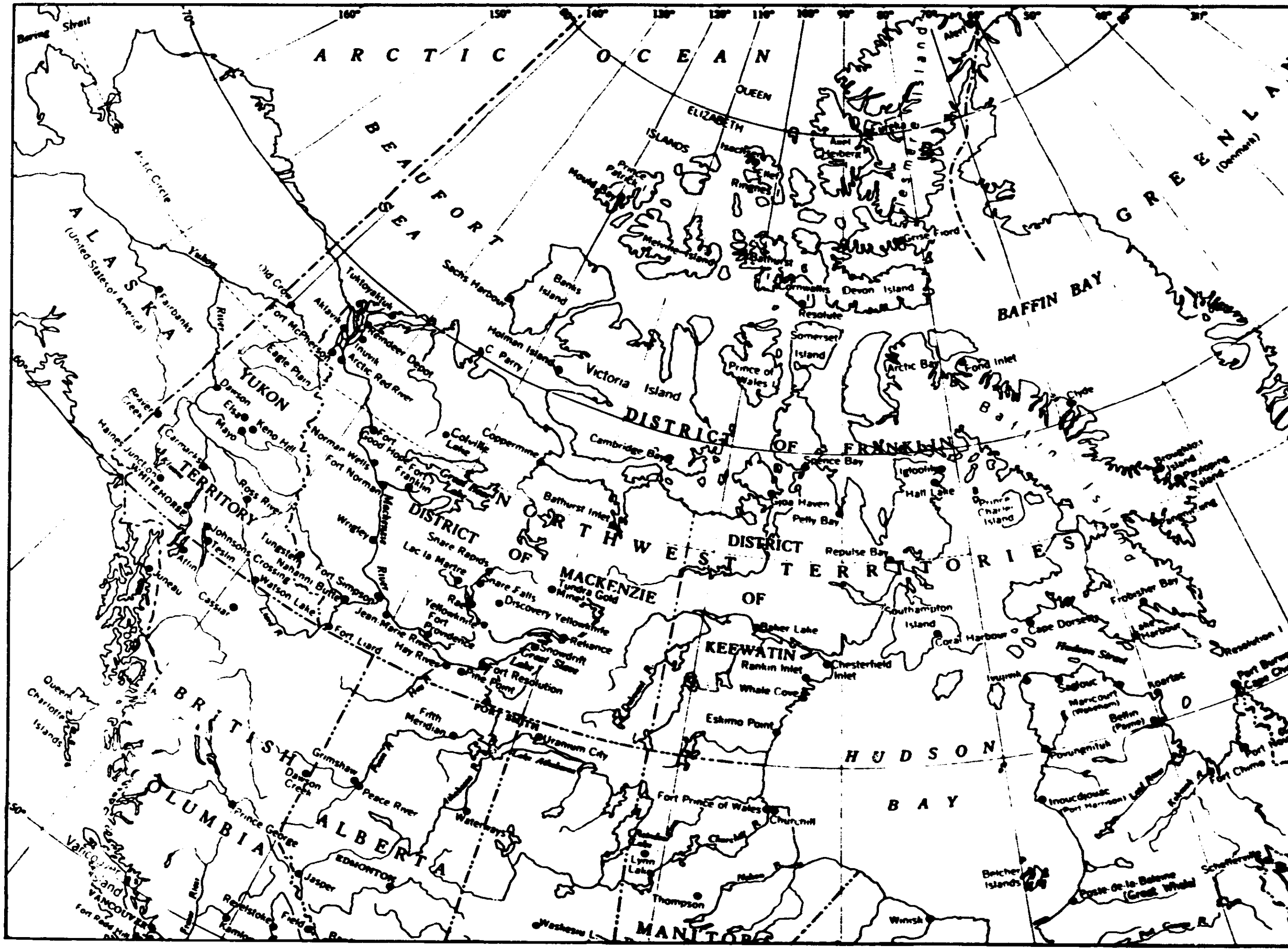
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