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THE PROCEEDINGS OF THE BROAD WHITEFISH WORKSHOP: THE BIOLOGY, TRADITIONAL KNOWLEDGE AND SCIENTIFIC MANAGEMENT OF BROAD WHITEFISH (*COREGONUS NASUS* (PALLAS)) IN THE LOWER MACKENZIE RIVER

1997

Presented by the Fisheries Joint Management Committee

and the Department of Fisheries and Oceans

by

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PREFACE

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Freeman

PREAMBLE

This program was created to fill a need for information on the life of broad whitefish. The need developed with the arrival of the Inuvialuit Land Claim and subsequently with the rapid development of other land claims, such as the Gwich'in and Sahtu claims, along the length of the lower Mackenzie River system. At issue was the conservation of broad whitefish populations in the lower Mackenzie River and its delta in the face of potential commercial fisheries and a heavy subsistence use within the land claim areas.

Broad whitefish are valued for human consumption and for the maintenance of dog teams. It is considered the most likely coregonid in the area to be able to support a commercial fishery. At the time when this study commenced (1992) a test commercial fishery had been undertaken by the Inuvik Hunters and Trappers Committee. Standard assessment data such as catch-per-unit-effort and biological samples to provide size and age of the catch had been collected (Treble and Tallman 1997). However, there were good reasons to suspect that the information would not be sufficient to address key questions in developing management plans unless more was known regarding migration, the life cycle, stock structuring, and variation in vital rates within the anadromous population as a whole. In addition, the attitudes of the land claim recipients towards fishery management and the traditional knowledge of the communities of broad whitefish biology had never been brought forward. Bits and pieces of the picture had been collected, for example extensive work by Bond and Erickson (1982, 1985) had demonstrated that the broad whitefish along the Tuktoyaktuk Peninsula were mainly juveniles. Unpublished radio-telemetry work by K. Change-Kue showed that mature fish migrated to spawning rivers such as the Peel and Arctic Red River to the south but spent their resting and overwintering time in the Mackenzie River delta. Reist and Bond (1988) put together the bits and pieces to suggest a general model for the life cycle of broad whitefish which involved extensive migrations from hatching grounds downstream to rearing areas along the coastal freshwaters, upstream spawning migrations from rearing grounds on the Tuktoyaktuk Peninsula and from overwintering areas in the Mackenzie delta, and return migrations of post-spawners to the delta to rest and overwinter. At the time it was the only cohesive model for this species but much of what was proposed was untested.

The implications of a complex life cycle with extensive variation in migration, genetics and vital rates are enormous for fishery management. Rather than simple management to maintain stable catch rates, decisions made for one local fishery could affect many others, unique gene pools must be conserved and the exploitation rate suitable for one population may be unacceptable for the conservation of another. The Reist and Bond model proposed that broad whitefish migrated back and forth across all three of the settled land claims in the lower Mackenzie area. Decisions could not be independent and groups would have to cooperate to manage fisheries. Needless to say, there was an eagerness to test the critical assumptions of the model but there were not the resources to follow through.

An opportunity came in the spring of 1992. To balance the books on the land claim settlement of the Inuvialuit the federal Department of Indian and Northern Development supplied a large one time funding parcel to the Inuvialuit Game Council which passed it on to the Fisheries Joint Management Committee (FJMC). A study to investigate key biological questions using scientific methods and traditional knowledge was initiated. The study examined traditional knowledge of whitefish biology, genetic stock structure, migration patterns to and from the fishing areas, variation in vital rates, and variation in parasite composition.

The study was to take place over two years and culminate in a general workshop to bring together the all the parts. Planning for the workshop was undertaken by a steering committee consisting of Bob Bell, Don Dowler, Mike Papst and Billy Day of FJMC, the area manager of the Western Arctic Area Office (Ron Allen) and Jim Reist and Ross Tallman of DFO Science Branch. It was decided that Inuvik would be the best place to hold the workshop so that the largest number of land claim beneficiaries could attend. The workshop was structured to have three types of participants, the presenters, the general audience and a representative panel of the main groups concerned. The panel consisted of representatives of the Sahtu, Jim Perrault; Gwich'in, Alfred Francis; Inuvialuit, Billy Day; Fisheries Joint Management Committee, Don Dowler; the DFO Area Manager, Ron Allen; and an IGC member, Richard Binder. This report is the presentation of the end point of this program.

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Treble, M.A., and R.F. Tallman. 1997. An assessment of the exploratory fishery and investigation of the population structure of broad whitefish (*Coregonus nasus*) from the Mackenzie River Delta, 1989-1993. Can. Tech. Rep. Fish. Aquat. Sci. 2180: vi + 65 p.

ABSTRACT

Tallman, Ross, F., and James D. Reist (editors). 1997. The proceedings of the broad whitefish workshop: the biology, traditional knowledge and scientific management of broad whitefish (*Coregonus nasus* (Pallas)) in the lower Mackenzie River. Can. Tech. Rep. Fish. Aquat. Sci. 2193: xi + 219 p.

A workshop was held in Inuvik, NT in March, 1994 to bring together the available information on the ecology, fisheries and traditional knowledge of broad whitefish*, Coregonus nasus,* in the lower Mackenzie River Basin. Papers were presented on a wide variety of topics including fisheries management issues, traditional knowledge, information requirements for management, life history, stock structure, migration inferred from radio-telemetry and T-bar tagging, measures of abundance, the relationship of vital rates to population dynamics, the effects of experimental exploitation on vital rates, parasites, cumulative impacts and multi-species considerations. Papers on these subjects and the responses and queries of the aboriginal land claimants from the Inuvialuit, Gwich'in and Sahtu Regions are included in this report.

Key words: Arctic, broad whitefish, Mackenzie River, ecology, fisheries, traditional knowledge.

RÉSUMÉ

Tallman, Ross, F. et James D. Reist (rédacteurs). 1997. Les délibérations d'un atelier portant sur le corégone tschir (*Coregonus nasus* (Pallas)): on y traite des connaissances traditionnelles ainsi que de la biologie et de la gestion scientifique de ce poisson dans le bassin du cours inférieur du Mackenzie. Rapport technique canadien des sciences halieutiques et aquatiques 2193: xi + 219 p.

Un atelier a été tenu à Inuvik (T. N.-O.) en mars 1994 afin de recueillir des renseignements et des connaissances traditionnelles sur l'écologie et la pêche du corégone tschir (*Coregonus nasus*) dans le bassin du cours inférieur du Mackenzie. Des communications ont été présentées sur toute une gamme de sujets, notamment les questions relatives à la gestion des pêches, les connaissances traditionnelles, les besoins en information, l'évolution biologique, la structure des stocks, les comportements migratoires établis par déduction grâce à des techniques de radio mesure et de marquage (barre en T), les mesures d'abondance, le rapport entre les indices vitaux et la dynamique des populations, les effets de l'exploitation expérimentale sur les indices vitaux, les parasites, les effets cumulatifs et les considérations touchant plusieurs espèces. Le rapport comprend également les questions et les réponses des auteurs de revendications territoriales autochtones provenant des régions d'Inuvialuit, de Gwich'in et de Sahtu.

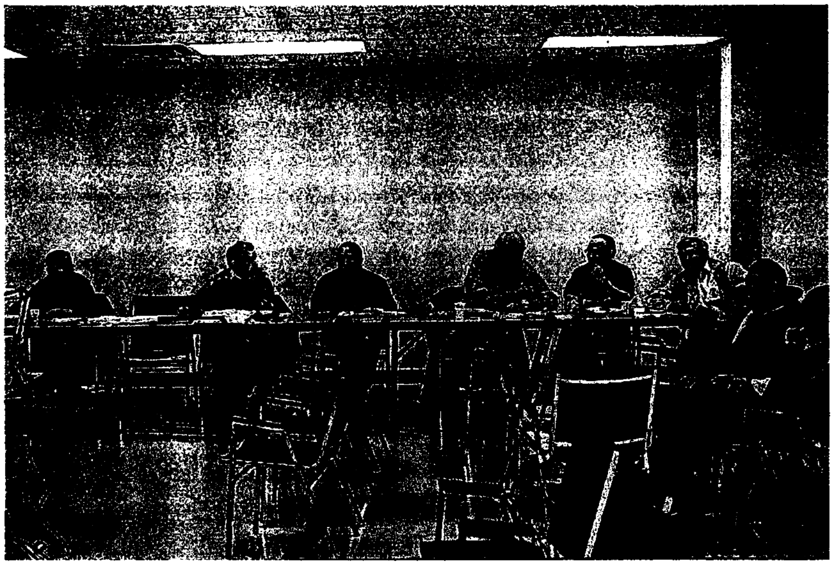
Mots-clés : Arctique, *Coregonus nasus*, fleuve Mackenzie, écologie, pêches, connaissances traditionnelles.

Top panel: Elder Panel (from left to right) Jim Perrault (Sahtu elder), Ron Allen (Department of Fisheries and Oceans), Alfred Francis (Gwich'in elder), Don Dowler (Fisheries Joint Management Committee), Richard Binder (Inuvialuit Game Council), Billy Day (Inuvialuit elder).

Left Panel: Drum Dance and Feast

Right Panel: Poster Session

Bottom Panel: Audience



WORKSHOP INTRODUCTION

Call to Order: Official Welcome and Introductions by Billy Day (Chairman, Inuvik Hunters and Trappers Committee)

Opening Remarks and Welcome by the Inuvialuit

Billy Day (Inuvialuit Elder, Inuvik): I would like to welcome everybody here from the Sahtu, McPherson, Aklavik, Inuvik, and Tuk. We also have one person I believe from Holman Island. I think that this meeting is really important and I would like people to ask questions while we have these biologists here. Our questions to the biologists may not all be answered here but we may be able to spark enough interest in the question so that they may be able to give us an answer at a later date. There will be a lot of information presented. There will be information on where fish travel and a lot of maps presented to you with information. It should be a really good session. I would like to pass the microphone to Albert Francis, an elder from the Gwich'in.

Opening Remarks and Welcome by the Gwich'in

Alfred Francis (Gwich'in Elder, Fort McPherson): I am really glad to be at this meeting. I would like to welcome you all. I think our talk about this whitefish will be really important because we all use it. Thank you.

Opening Remarks and Welcome by the Sahtu

Jim Perrault (Sahtu Elder, Fort Good Hope): I welcome everybody from all over that have come here. It is very important to think about the fish - what we are eating. I have fished all over - I have fished at Aklavik. I have been studying the problem for a long time. I hope that we can all work together to see how the fish are and bring back the information to the Sahtu. I went to Ottawa in 1982 with two doctors to ask for some money to study the Mackenzie and the fish lakes. I am very pleased to be here for this workshop.

Billy Day: I would like to ask the other three board members to introduce themselves and say what their organizations are:

Ron Allen (DFO Area Manager): Thank you Billy. My name is Ron Allen. I am the Area Manager with Fisheries and Oceans and I live here in Inuvik. I would like to say that I am very pleased to be here and see this workshop come together after two years of fairly extensive research on whitefish. We have brought together the researchers, managers, scientists working on biological and traditional knowledge research and the fishermen of the area to talk about the subject. So thank you and welcome.

Don Dowler (Fisheries Joint Management Committee Member): I am Don Dowler. I am a member of the Fisheries Joint Management Committee. I also worked for the Department of Fisheries and Oceans for 26 years in the North. I am very pleased to be here. I think it is one of the best gatherings that I've seen for a long time. It shows the importance of the subject that we are talking about. I'm really pleased to see the numbers of people that are here and I think you will find the next couple of days really interesting. Thank you.

Richard Binder (Inuvialuit Game Council): Good morning and welcome. My name is Richard Binder. I am the resource person for the Inuvialuit Game Council. I am glad we have people from all over the region together here. There has been a lot of information from studies done over the last 20 years that can be passed on to the communities. I also think that there is room for an exchange of information - there is a lot of traditional knowledge that can contribute. People have a lot of knowledge about the fish in their regions. I hope that we have a very productive workshop and people will gain a lot of information to bring back to their regions. I would like to acknowledge Andy Carpenter, Head of Game Council. Thank you very much.

REPORT INTRODUCTION

The reader will observe that the papers presented herein vary in length from brief recounts of the workshop presentation to detailed full papers. At the outset the goal was to have presenters submit extended abstracts of their papers as a record of the workshop. On the one hand a number of the presentations dealt with a few simple principles that relate to the management situation for this species and thus only a short description was necessary. On the other hand, many of the subject areas involved a large body of information directly applicable to the problem of understanding broad whitefish and the scientific management of the fishery. A great deal of useful information could be set down if the authors expanded their efforts.

The first two presentations bring forward the information contributions of the resource users and communities of the lower Mackenzie River region to the understanding of the broad whitefish resource. These contributions are often substantial but rarely formally written down. We opened the presentations with this pair of papers to stimulate further contributions from the assembled aboriginal experts and to acknowledge this valuable source of information. As well, these two papers deal most directly with the question of how many whitefish are available for harvest by commercial fishing at Horseshoe Bend. At the time of the workshop this was a very important issue in the area. Although it is a less pressing issue at present, we predict that the consideration of this issue will be important in the future. The paper by Treble and Reist summarizes historical harvest information, discusses the biological characteristics of fish harvested in the central Mackenzie Delta and local management issues. The issues summary was based on interviews with resource users from communities throughout the range of broad whitefish in the lower Mackenzie River. It therefore encapsulates the views of resource users and their communities from Fort Good Hope to Inuvik on the subject of fisheries management. The second paper by Freeman brings together the results of a study of the Inuvialuit traditional knowledge of broad whitefish from the delta communities of Inuvik and Aklavik. One key question considered is whether past harvests have been larger than at present and based on a needs calculation for dogs and people.

The remainder of the presentations deal with scientific management - aspects of biology known from scientific studies and important principles. The purpose was to bring together the available scientific information and to outline areas and approaches for improving the information base. The first paper by Tallman and Reist sets the stage for subsequent papers. It gives an overview framework for individual scientific studies.

The paper by Reist and Chang-Kue describes key aspects of the biology and habitat usage of the broad whitefish in the lower Mackenzie River system. It provides background information on the broad whitefish, especially a description of the life cycle, and key habitats for spawning, rearing and over-wintering. It was increased in size to a full paper because the information provided is one of the major transfers from the long-term scientific effort on the lower Mackenzie River. Prior to this it had not been focused in one particular document. The next paper by Reist summarizes present understanding of stock structure and life history variation in broad whitefish. Together these two papers provide the biological framework within which scientific understanding and management must proceed.

The paper by Tallman on methodologies for estimating stock size is a short outline of the possible methods and where they are most appropriately used. The paper shows that there are several options available and that the choice of methodology depends on the needs of the physical circumstances of the fishery, the biology of the species harvested and the needs of the fishery manager.

The next two papers deal with the results of specific research programs on the migratory aspect of broad whitefish. This demonstration and understanding of the trans-boundary migratory nature of this species has profound implications for the design of a management program. These papers are given more space as a result of their direct applicability.

The paper by Babaluk et al. reports the findings of a mark-recapture study on broad whitefish that was undertaken at two key fishery sites - Horseshoe Bend and Aklavik. A major finding is that fish are migrating out of the Inuvialuit Settlement Region into the Arctic Red and Peel River drainages of the Gwich'in Settlement Region.

The paper by Chang-Kue and Jessop represents some of the most significant scientific activity on broad whitefish over the last 20 years. It summarizes the findings of a number of radiotelemetry studies funded by DFO, FJMC and various other agencies between the years of 1982-1993. These results form the basis for much of our understanding of broad whitefish biology that is relevant to the fishery. The fact that the fish migrate such long distances suggested that these fishes might have a life cycle pattern more like the salmon than like most whitefishes. The findings were the basis for the need for more recent studies of stock uniqueness and discussions among the land claim boards of the need for trans-boundary management of this species.

The next two papers deal with how populations produce more fish to replace those lost when a fishery starts up. The paper by Tallman on life history variation and population dynamics outlines the key characteristics that determine productivity in fish stocks - namely growth, age at sexual maturity, the number of eggs per female (fecundity) and mortality, and then goes on to show in simplified situations how these traits will influence the numbers or biomass of fish available to the fishery. This paper simplifies the situation to give the reader a clear understanding of the importance of these traits to fishery production and hence why fishery monitoring programs take these data. The second paper by Gyselman, entitled "Effects of exploitation on fish populations" presents the results of two very important case studies, at Nauyuk Lake and at the Chitty Lakes, where these population characteristics were monitored while the populations were fished experimentally. The paper shows that not all components of the life history will respond to exploitation, and that in different species (charr in the former case and whitefish in the latter) the pattern of the response may vary.

The next paper deals with the subject of the quality of fish harvested in the lower Mackenzie River. Choudhury and Dick describe results from investigations on the parasites of broad whitefish in the Mackenzie River delta. Their results suggest that, in comparison to other species such as lake whitefish, broad whitefish have a very low parasite load.

The final two papers deal with the problems of multiple interactions or synergistic effects. The first by Reist discusses how cumulative effects of various stresses (for example, a fishery, spawning ground disturbance and pollutants) can interact to produce much greater impacts on fish stocks than each does alone. The second paper by Tallman points out that while we tend to view fisheries as operating on one species at a time, they usually have cascading effects through a species group via alterations of species interactions. The Mackenzie River broad whitefish is affected by both of these effects although presently there is no research information to say how much of a role cumulative effects and multi-species interactions play in the fishery management picture.

LOWER MACKENZIE RIVER BROAD WHITEFISH: CENTRAL DELTA BIOLOGICAL CHARACTERISTICS (1984-1989), COMMERCIAL AND SUBSISTENCE HARVEST TRENDS (1955-1993), AND LOCAL MANAGEMENT ISSUES

by

Margaret A. Treble and James D. Reist

ABSTRACT

Subsistence fisheries have been conducted on the Mackenzie River since the first human habitation. Commercial fisheries also have a long history from 1950 to the present. We examine three aspects of management of the fishery for broad whitefish in the lower Mackenzie River: 1) past and present harvest levels; 2) evidence for time trends in biological data on broad whitefish caught in a typical fishery in the middle channel of the Mackenzie River; 3) the opinions of resource users regarding the fishery and its future. Quantitative information on the subsistence harvest suggests that there has been little change in the total catch since the 1960's. The best estimate for the Inuvialuit area is 295,693 kg in 1988. Effort may have changed substantially because fewer people are fishing, there is less demand, and traditional knowledge indicates that fewer fish are taken today. Commercial fisheries have made up a very small portion of the total harvest. Length and age of broad whitefish harvested in the fishery have remained stable between 1984-1989 suggesting that there is little change in population due to increased harvest. However, sample sizes were small, from only one gillnet mesh size, and represent only one fisherman. Thus, conclusions were difficult to make. In general, resource users were positive regarding the fishery and its current co-management regime. Inuvialuit, Gwich'in and Sahtu resource users agreed that a broad whitefish management plan should be developed. Recommendations for future work in harvest monitoring, sampling of catches fishery management areas and development of a management plan are presented. [Abstract composed by editor]

INTRODUCTION

This study is composed of three sections. First there was a need to determine past and present harvesting trends if good decisions regarding requests for quota increases were to be made. Published and unpublished reports on the Mackenzie Delta fisheries were reviewed and harvest data tabulated for 1955 to 1993.

The second section summarizes biological data from broad whitefish, *Coregonus nasus*, caught using 139 mm (5.5") mesh gill nets in the middle channel of the Mackenzie River, north of Horseshoe Bend near Kalinek Channel, for the five years (1984-1988) prior to the Inuvik test fishery. The data exist as part of an ongoing broad whitefish genetics and stock identification project being conducted. These samples had not been aged or analyzed with respect to biological characteristics used to assess fish populations. Since these data immediately precede the test fishery for this species, their relevance is obvious (Note: The test fishery results are published separately - Treble and Tallman 1997).

Thirdly, fisheries management issues, of importance to the local resource users, needed to be ascertained. Interviews with members of local hunters and trappers committees and associations were conducted in October, 1992.

Based upon the findings of the previous sections, needs and suggestions for the future management of this resource are enumerated.

Until recently, southern scientists and fisheries managers knew very little about broad whitefish, whose North American range is restricted to the Western Arctic. Many unanswered questions still exist

Broad whitefish are known to move up the Mackenzie River in search of gravel reefs and shoals on which to lay their eggs, after having spent the summer feeding along the coast and in the delta channels and lakes (see Chang-Kue and Jessop 1997, in this publication). This migration takes them past the communities of Tuktoyaktuk, Inuvik, Aklavik, Ft. McPherson, Tsiigehtchic and Ft. Good Hope (Fig. 1). Low water levels in the fall at the Ramparts Rapids likely stop them from moving further up the river at this time. Many people from these communities fish for broad whitefish to feed their family and friends. Some surplus may be used for dog food although they prefer to feed lake whitefish to their dogs and save the broad whitefish for themselves. Fishing for broad whitefish is also a cultural activity, a way of life that is highly valued.

In addition to subsistence harvesting, there have been several attempts to develop an export commercial fishery and a five-year exploratory fishery project based in Inuvik was completed in 1993 (Anderson 1995; Treble and Tallman 1997). The immense size of the Mackenzie Delta and lower Mackenzie River region, coupled with the fact that the same population(s) of broad whitefish could be harvested by both the commercial and subsistence fisheries of several communities during their fall spawning migration, results in a very complex and difficult management situation.

MACKENZIE RIVER FISHERIES

SUBSISTENCE

Broad whitefish have been harvested as long as there have been people living in and near the Mackenzie River. The amount of fish caught has varied over time for a number of different reasons.

The first significant event involving outside influences was the fur trade. White trappers and traders set up trading posts at Ft. Good Hope in 1836, Ft. McPherson in 1840, and Aklavik in 1912. The missionaries who followed established churches and schools in these communities and at Tsiigehtchic in 1901 (Usher 1971). Inuvialuit who previously lived along the coast and outer delta gradually moved their families south, to be closer to these trading posts (Usher 1971). Fishing increased as these communities grew and the fur trade expanded throughout the delta.

By the 1950's the price of furs had dropped. Fewer people were making a living trapping and they started to move from their camps and cabins on the delta into the communities to look for work (Wolforth 1966). Work in town meant people had less time to spend on the land hunting and fishing.

Nylon nets were being used by the mid 1950's. They were stronger and more durable than cotton and therefore more efficient at catching fish. Finally, the skidoo had replaced dog teams by the mid 1970's so most hunters only needed fish for their family and for a few dogs they kept as pets. There are only a few people in each community that still keep teams of dogs.

COMMERCIAL

The first documented commercial fisheries were carried out in the early 1900's by the Roman Catholic and Anglican Missions, as well as the Northwest Mounted Police and trading companies (Davies et al. 1987). They either purchased fish or hired fishermen to provide them with fish. Local commercial sales continued and today commercially licensed fishermen may sell fish to local restaurants, hospitals, nursing homes or other individuals.

There have been several attempts to harvest fish for export. The first was a Ft. McPherson trader who tried to start a winter fishery in 1950, using a ski-plane to fish surrounding lakes (Bissett 1967). In 1960 and 1961 the Department of Northern Affairs and National Resources (DNANR) ran small fisheries at Aklavik, Kittigazuit, and the mouth of the Peel River (Davies et al. 1987). The Department of Indian Affairs and Northern Development (DIAND) conducted a whitefish and inconnu fishery at Holmes Creek in 1963 and 1964 (Davies et al. 1987; Bissett 1967). Menzies Fish Co. conducted a commercial whitefish fishery out of Inuvik in 1965 and 1966 (Davies et al. 1987; Bissett 1967). Holmes Creek was the site for a Northwest Territorial Government fishery initiative in 1972 and 1973 to provide fish to local markets. In 1974 the fish plant was moved to Inuvik and some fish were sold to the Winnipeg, Manitoba based Freshwater Fish Marketing Corporation (FFMC) (Davies et al. 1987). All of these fisheries failed for a number of reasons that included technical problems and a lack of markets (Davies et al. 1987).

The Ummarmiut Development Corporation exploratory fishery, based out of Inuvik, ran from 1989-1993 (Anderson 1995; Treble and Tallman 1997) and sold fish through the FFMC. The presence of this fishery and the desire to continue and expand it has stimulated much work on broad whitefish. A decision on the continuation of an export commercial fishery will be made soon.

BROAD WHITEFISH HARVEST DATA

Data available on broad whitefish harvest have been combined for all communities in order to show total estimated harvest over time for the Lower Mackenzie River. Figure 2 shows broad whitefish subsistence and domestic license fisheries harvest for 1960 to 1990, and Fig. 3 shows broad whitefish commercial and exploratory fisheries harvest sales for 1955 to 1993. Some data were recorded as numbers of fish caught. These data have been converted to kg using an average weight of 2.3 kg/fish (Department of Fisheries and Oceans 1991). Where subsistence harvest data have been reported as "fish sp." or "whitefish sp.", broad whitefish harvest has been estimated based on an average harvest (by weight) of 35% and 65% broad whitefish, respectively. For commercial harvest sales the values used were 67% for “fish sp.” and 88% for “whitefish sp.”.

Subsistence harvest data are highly variable and are often an underestimate of the true harvest because they are based on surveys and questionnaires that do not necessarily cover all fishermen in each of the communities every year. The 1988 estimate (295,693 kg) is the best estimate for recent harvests because it is the most comprehensive since the 1960's (165,738 to 352,739 kg). In 1988 the Inuvialuit Harvest Study covered Inuvialuit and Gwich'in harvesters in the communities of Inuvik, Aklavik and Tuktoyaktuk. A study of Dene and Metis communities (Lutra Associates 1989a,b) provided data on broad whitefish harvests in 1988 from Tsiigehtchic, Ft. McPherson and Ft. Good Hope.

The estimate calculated for 1988 compares well with those calculated for the 1960's suggesting that subsistence harvesting of broad whitefish has not changed significantly. However, fishermen interviewed for section three of this research project all stated that there are fewer people fishing today, and they are catching fewer fish than were caught in the 1950's and 1960's when everyone had dog teams. In interpreting these data, some points to consider include the following: 1) the harvest estimates for the 1960's could be low because they are based on approximations of individual and family needs and consumption patterns and coverage of surveys was probably less than 100%; 2) the portion of broad whitefish caught that was used for dog food is unknown; 3) there may be fewer people fishing today but they are using more efficient nets and could be harvesting almost as many broad whitefish as in the past, to supply food not only for themselves but for other families who do not fish. Therefore, although these are the best estimates we have, they are probably lower than the actual subsistence harvest.

The commercial fisheries have made up a very small portion of the total broad whitefish harvest even during development periods (Fig. 3). There have been sporadic attempts at export commercial fisheries, but up to the present most commercial licenses have been issued to subsistence fishermen so they can sell a portion of their catch to local businesses or other individuals.

In summary, it is very difficult to determine past broad whitefish harvest levels. However, broad whitefish formed a significant portion of the fisheries resource harvest from this area, most of which was used for subsistence purposes and this species continues to be a very important subsistence resource. The population(s) may be able to support a further increase in commercial quotas but this should be undertaken with caution in order to protect the subsistence portion of the total catch.

BIOLOGICAL ANALYSIS (1984-1989)

Over-harvesting generally results in the larger and older fish being removed from the population at a rate faster than the fish can compensate in growth. Therefore, if over-harvesting has affected the broad whitefish population(s), we might expect to see a greater proportion of the catch being made up of younger and smaller fish. However, gear selectivity (139 mm mesh net) and sample size will limit the interpretation of these data.

Figure 4 shows that ages ranged from 5-20 years. The distribution of ages appeared to shift slightly to younger ages for the years 1987-1989. However, the mean ages (Fig. 5) are not significantly different. The overall mean age is 12 years.

Lengths ranged from 418 mm to 574 mm (Fig. 6) with an overall mean length of 493 mm (Fig. 7). As could be expected for fish caught from one mesh size, the length distributions remain uniform from one year to the next (Fig. 6).

Age and length data for broad whitefish captured in September from the middle channel appeared to have remained stable, with relatively high mean and modal ages, for the years 1984-1989. This suggests that no overharvesting had occurred during this time. However, definite conclusions based on these data alone are difficult to make because the sample sizes are small (Table 1) and fish are from only one gill net mesh size. Furthermore, the expected responses of fish populations to over-exploitation (i.e., decreasing length, decreasing age) may not be clearly manifested in populations that migrate to marine areas (so-called open systems) (see Gyselman 1997, this publication). Also, the time frame during which these data were collected (5 years) may be insufficient to show such changes. However, these data can be used to supplement biological data collected during the Inuvik test fishery (1989-1993) (Treble and Tallman 1997) to investigate long-term population changes.

MANAGEMENT ISSUES

It is important to consider local opinions concerning broad whitefish use and management. The Inuvialuit, through their Hunters and Trappers Committees (HTC) and the Fisheries Joint Management Committee (FJMC) are instrumental in making management decisions. With the recent settlement and implementation of their own land claims, the Gwich'in and soon the Sahtu will have similar co-management arrangements.

In the fall of 1992, representatives of the HTCs and the Dene Hunters and Trappers Associations (HTA) were interviewed in order to learn as much as possible about the fisheries in their communities. Information and concerns that relate to fisheries development and management have been summarized below.

FISHERIES CHARACTERISTICS AND LOCAL KNOWLEDGE

Everyone agreed that more people were catching more fish in the 1950's and 1960's than they are today. There has been no noticeable change in the size of broad whitefish caught. However, some people have noticed changes in the numbers they have caught in their nets. They suggested that maybe the broad whitefish have moved to other areas in the Delta or their migration routes have changed. This is possible since the Mackenzie Delta is a very dynamic region influenced by the powerful hydrologic forces of the Mackenzie River waters, as well as climate and other environmental factors.

There was some local concern with fish quality and the cumulative effects of pollution from developments along the Mackenzie River as well as its tributaries.

COMMERCIAL DEVELOPMENT

Most people would welcome the social and economic benefits that commercial development of this fishery might bring. The Inuvik HTC has been working towards this goal with their five-year exploratory fishery completed in 1993.

Some people expressed concern that a large commercial fishery might deplete the broad whitefish, like the Atlantic cod on the east coast of Canada, and suggested that any development should start slowly and be monitored, so the subsistence fishery would be assured and protected.

Some communities felt that it would be difficult to establish their own independent fishery and a joint venture with another community might be more feasible.

Few people foresaw any conflicts between commercial and subsistence harvesting. They felt there were enough broad whitefish for both and those people participating in a commercial fishery would put in one or two extra nets to catch fish for their personal needs.

They stressed that any commercial development should involve Inuvialuit and Native people only.

CO-MANAGEMENT

There are eight local resource committees or councils that represent fishermen living in six communities situated along the lower Mackenzie River. Since the land claims have been settled at different times, the committees and resource councils have had different levels of experience with co-management.

The Inuvialuit have been working with a co-management system for 10 years and are very satisfied with how it has enabled them to have input into, and control over, many decisions. It was noted that more young people are starting to take an interest in learning traditional hunting and fishing skills. Many people felt this needed to be encouraged as important traditional knowledge was being lost. Everyone felt traditional knowledge should be incorporated into the management system. The Inuvialuit are working towards this goal and have sponsored a broad whitefish traditional knowledge study (see Freeman 1997, this publication).

The Gwich'in and Sahtu expect their land claims and co-management arrangements will provide opportunities to strengthen their communities through control of their resources and increased opportunities for young people to become involved in traditional activities.

There was unanimous agreement that a broad whitefish management plan involving all communities should be developed but some people suggested it was not a high priority.

Further research on broad whitefish and other fisheries questions was suggested. The people stressed the importance of sharing the information and to make sure reports got back to the communities.

SUGGESTIONS FOR FUTURE MANAGEMENT

From our current biological understanding, the past harvest levels, and the opinions expressed by members of the communities, the following suggestions are made here for future management of the broad whitefish resource.

HARVEST REPORTING

1) We recommend that the Inuvialuit continue to collect subsistence harvest data and

the Gwich'in and Sahtu establish similar programs. In the interim, the Department of Fisheries and Oceans (DFO) should survey the Gwich'in fishermen from Inuvik and Aklavik and conduct harvest surveys in Tsiigehtchic, Ft. McPherson and Ft. Good Hope. (Note: The Gwich’in harvest program began in September 1995, and the Sahtu program will begin in 1997 or early 1998).

2) We also recommend that the Department of Fisheries and Oceans continue to collect local commercial and domestic license sales data as well as any export commercial data.

Given the complex biology, all harvest data must be specific as to location and time of the catch. The number of fish caught, rather than the weight in kg or lb, has been collected in recent harvest surveys. Subsistence catches could continue to be reported as numbers of fish, if data on the average weight of fish caught and the size of net used to catch them were also collected from each community/management area on a regular basis (once a year or every few years). This would enable better estimates of the amount of fish caught by weight.

BIOLOGICAL MONITORING OF HARVESTS AND RESEARCH ACTIVITIES

1) Periodic biological surveys of the subsistence fisheries would provide very useful information to fisheries managers, particularly in the absence of any commercial fisheries monitoring. These surveys could be undertaken every other year or every third year but should be done on a long-term basis if significant changes in population parameters are to be detected.

Fishermen willing to participate in a monitoring program should be identified. They could be trained in biological sampling techniques or someone with these skills could fish with them for the duration of the survey. Data should include date and location of each catch, mesh size used, length, round weight, sex, gonad weight, maturity stage and two aging structures (otolith and pelvic finray), as well as catch-per-unit effort information.

The co-management boards for each land claim region should initiate these surveys. The Department of Fisheries and Oceans could play a coordinating role and provide technical advice and/or support.

2) If export commercial fisheries are developed, an appropriate program of harvest monitoring must be designed and implemented. Aging structures, length and dressed weight information could be collected from a portion of each fisherman's catch at the fish plant or collection site. A more complete biological sample (see subsistence monitoring above) could be collected by one or two crews stationed near, or working with, a cooperating fisherman. The data collection should be structured over the space and time of the fishery in such a way as to address migratory and life history questions and concerns. The sampling protocol will be unique to each fishery, depending on its timing and location.

3) There are still many questions concerning Mackenzie River broad whitefish that cannot be answered with data from fisheries monitoring programs: Do broad whitefish mature in delta lakes and ponds or only on the Tuktoyaktuk Peninsula? What is the difference between the lake form "lakefish" and the anadromous form? Is there more than one anadromous stock? If so, do they migrate separately or mix together? Are there riverine stocks? Failure to correctly identify stocks and manage them accordingly may result in the loss of genetic variability, and the possible collapse of a stock and the fishery relying on it (Smith and Chesser 1981; Spangler et al. 1981). Therefore, studies of life history and stock identification should continue.

MANAGEMENT AREAS

The Inuvialuit Settlement Region (ISR) Harvest Study collects harvest location information along with harvest numbers. However, the data are reported by community, not by management area. Also, commercial and subsistence harvest data have been collected and/or reported by DFO by community only, for the years 1978 to 1989. People often fish at summer camps that are located quite a distance from their home community. This makes it very difficult to determine subsistence and total broad whitefish harvest levels for the management regions as they exist at this time. To remedy this, the Department of Fisheries and Oceans and the Inuvialuit, Gwich'in and Sahtu co-management boards could ask the harvest monitoring coordinators to provide them with data based on management area and water body.

MANAGEMENT PLAN

A broad whitefish management plan should be developed soon, with input from all co-management boards and communities.

Issues to be examined include commercial development, commercial quotas, commercial harvest data collection and biological monitoring, subsistence harvest data collection and biological monitoring, management area boundaries and the use of traditional and scientific knowledge, as well as outline a process for joint decision making.

Management plans developed for migratory caribou could be used as a reference.

ACKNOWLEDGMENTS

This research was carried out as part of the requirement for a Masters of Natural Resource Management Degree from the University of Manitoba's Natural Resources Institute (NRI) (Treble 1996).

The authors thank Prof. Thomas Henley (NRI, U of Manitoba) for advice on the practicum research proposal, Lothar Dahlke (DFO, Inuvik) for providing a draft of his fish harvest report, Rick Wastle and Laura Heuring (consultants, Winnipeg) for aging structure preparation, and Billy Day (Inuvik) for providing the broad whitefish samples for 1984-1989 that were analyzed as part of this study.

Thanks are also extended to members of the HTCs and HTAs in the communities of Tuktoyaktuk, Inuvik, Aklavik, Tsiigehtchic, Ft. McPherson and Ft. Good Hope who took the time to meet with Margaret Treble to talk about their fisheries.

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COMMENTS, QUESTIONS AND ANSWERS

Mike Papst: I would like to make an additional comment. We have land claims processes on-going. The Inuvialuit claim has, of course, been settled for some time. Now the Gwich’in claim is being implemented and the Sahtu are also progressing. So, we are seeing some definition of various rights and access to the fisheries. I think that will be quite useful in developing various management schemes and getting dialogue going between various users. Perhaps, this has been a bit lacking in the past. We haven't been able to bring people together as the rules weren't all that clear. I think we are going to see some progress on that in the near future. Thank you.

Table 1. Sample code, sampling date and sample size for broad whitefish collected from the Middle Channel, Mackenzie River Delta, 1984 to 1989.

Sample Code	Sampling Date	Sample Size		
		Male	Female	Total
1984-5-1	early September	30	27	57
1984-6-1	middle of September	17	18	35
1984-7-1	middle of October	20	6	26
1984-8-1	November 7 to 11	21	30	51
1985-38-1	middle of September	14	21	35
1986-69-1	September 20 to 26	29	21	50
1987-84-1	fall	6	44	50
1988-49-1	September 22	19	11	30
1988-49-2	October 5	6	4	10
1988-49-3	October 10	6	4	10
1989-36-1	fall	31	19	50

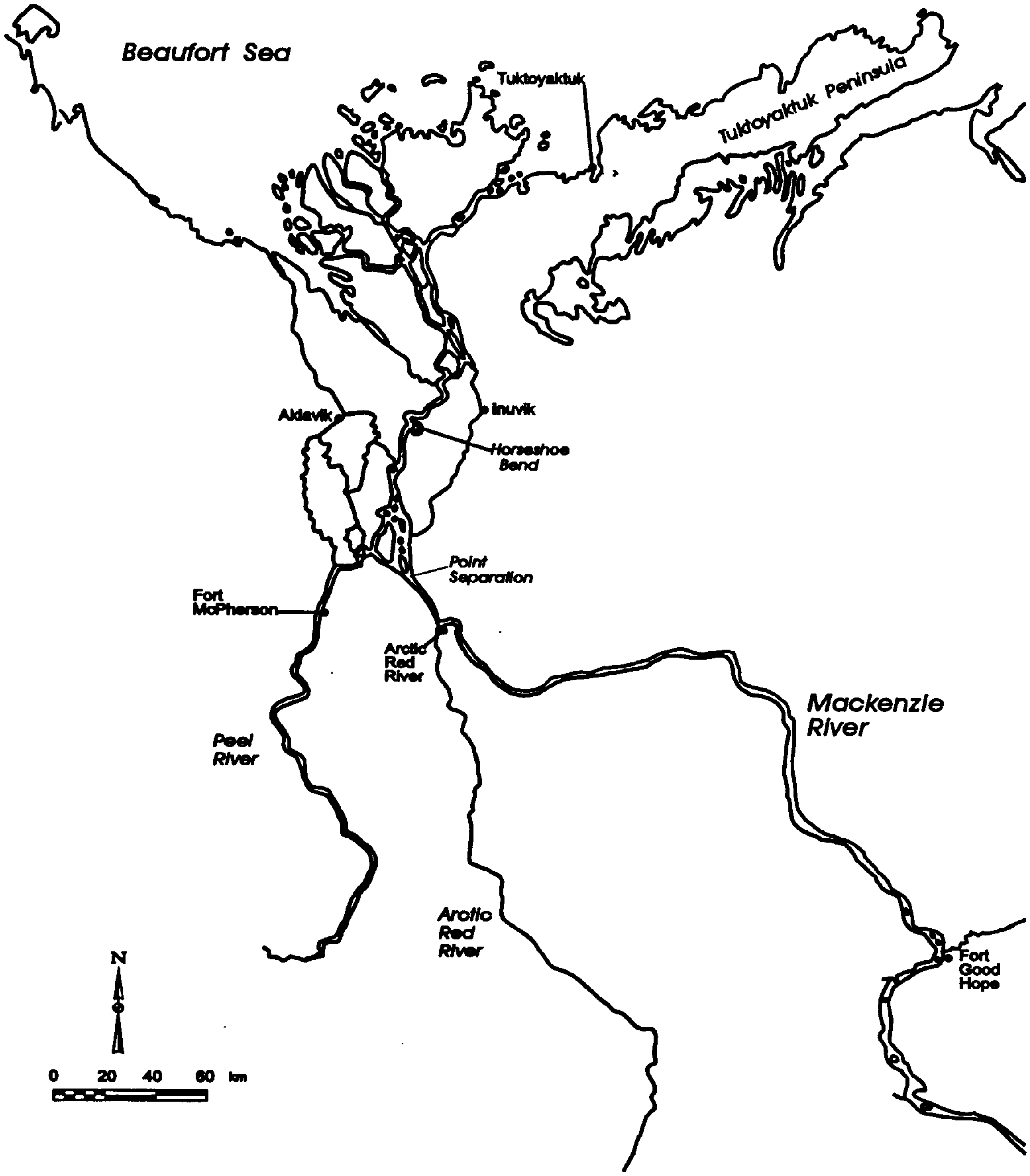

Figure 1. Lower Mackenzie River, Northwest Territories. Biological samples reported here were collected at Horseshoe Bend. The Ummarmiut exploratory fishery was conducted in the Middle Channel directly west of Inuvik for 1989 to 1993.

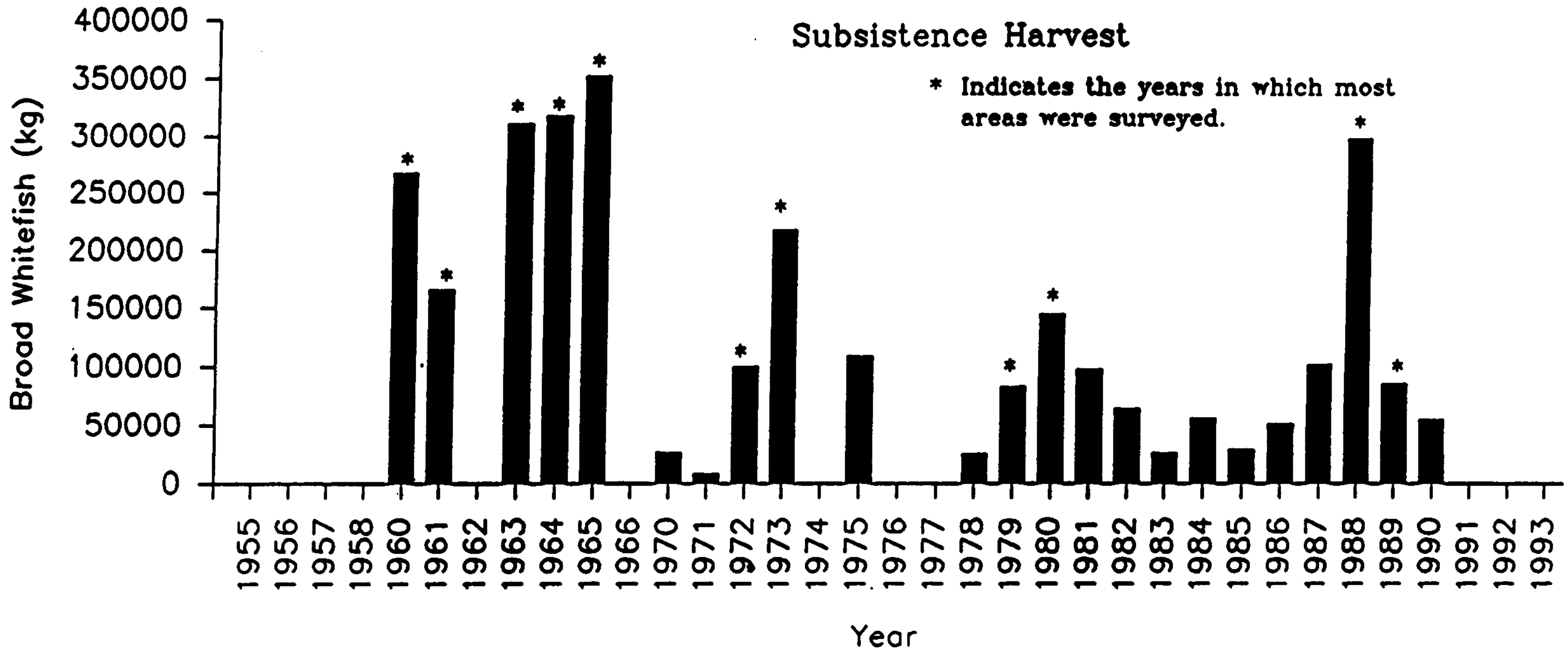

Figure 2. Broad whitefish subsistence harvest, reported and estimated, for lower Mackenzie River region communities, 1960–1990. Subsistence harvest was never zero; data for all communities/regions were not available for all years. Note that the y–axis is eight times larger than the y–axis for the commercial harvest plotted in Figure 3. Sources: Berkes (personal communication), Bissett (1967), Corkum and McCart (1981), Dahlke (unpublished report), Department of Fisheries and Oceans (1991, 1992a, 1992b, 1993, 1994, 1995, and unpublished data), Fabijan (1991a, 1991b, 1991c), Jessop et al. (1974), Lutra Associates (1989), Olesh (1979), Sinclair et al. (1967), Sparling and Sparling (1988a, 1988b), Usher (1975) and Wolforth (1966).

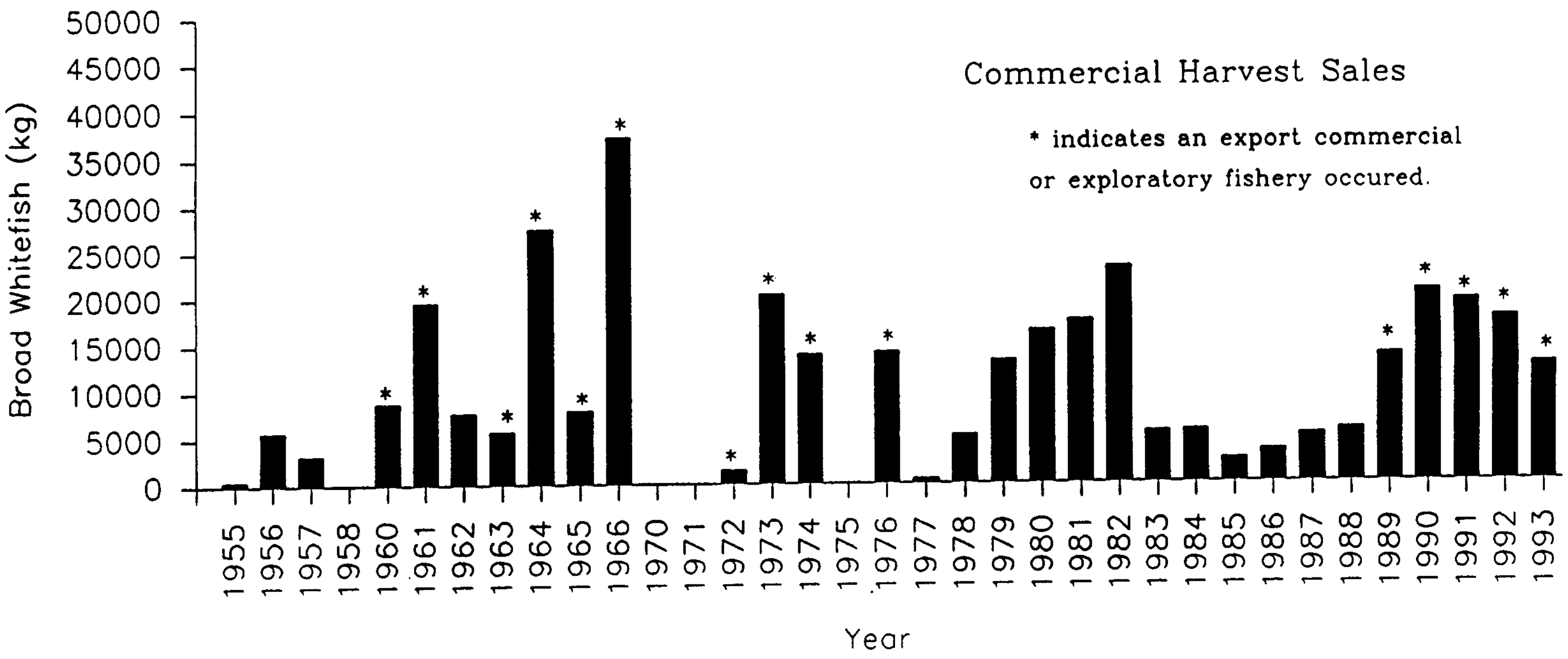

Figure 3. Broad whitefish commercial and exploratory fishery harvest sales, reported and estimated, for lower Mackenzie River region communities, 1955–1993. These data include both local and export sales for the year in which both occurred and are based on voluntary recall surveys conducted once a year by the Department of Fisheries and Oceans. These estimates may be more or less accurate depending on the percent response of licensed fishermen. Sales of 13 kg and 9 kg were reported in 1958 and 1975, respectively, and no sales were reported for 1970 and 1971. The harvest reported for 1976 may in fact have been taken in 1975 (Treble 1996). Sources: Bissett (1967), Corkum and McCart (1981), Dahlke (unpublished report), Department of Fisheries and Oceans (1991, 1992a, 1992b, 1993, 1994, 1995, and unpublished data), and Yaremchuk et al. (1989).

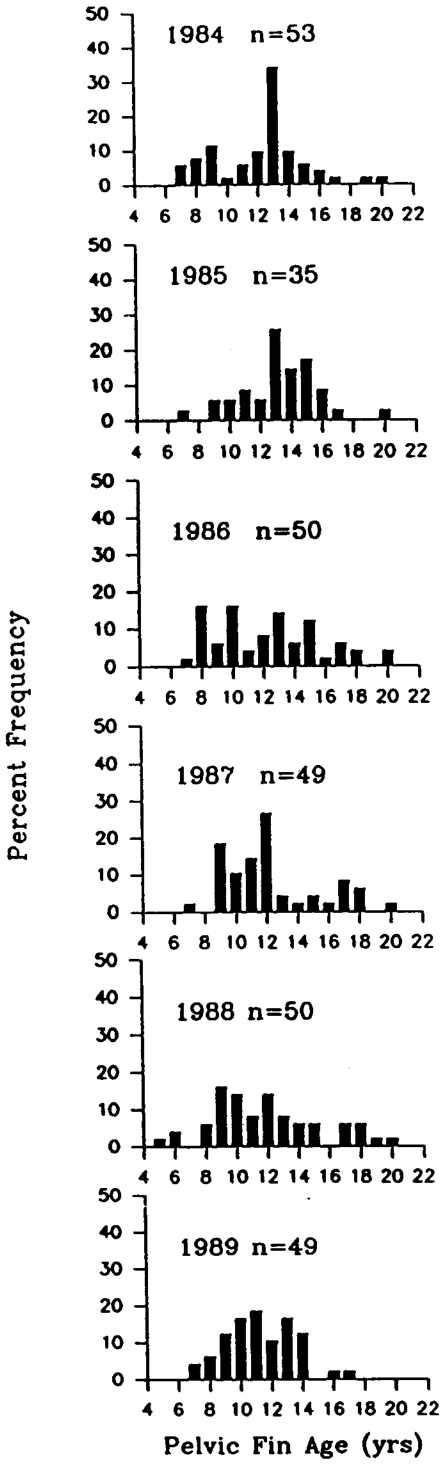

Figure 4. Age frequency distributions for broad whitefish from the Mackenzie River, Middle Channel, 1984–1989.

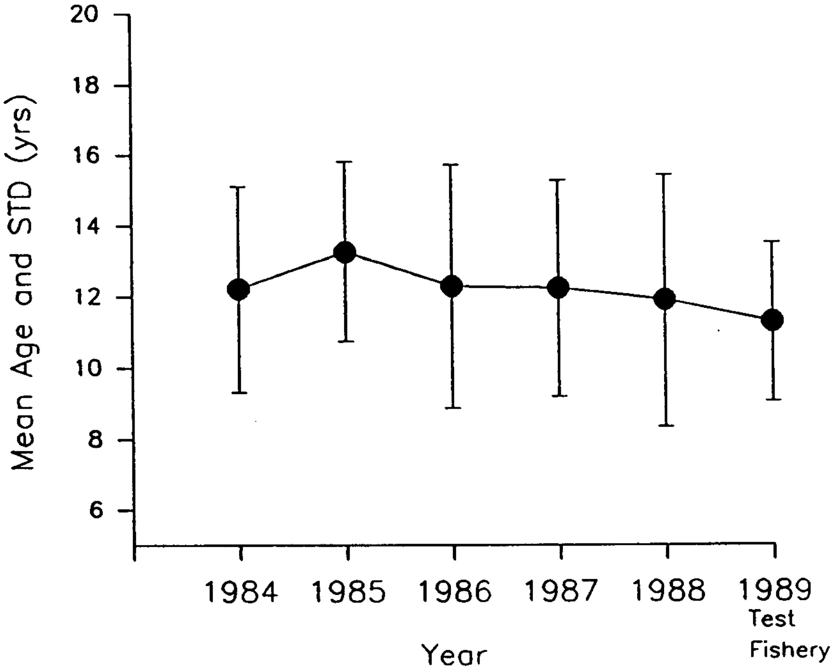

Figure 5. Mean age and one standard deviation for broad whitefish from the Mackenzie River, Middle Channel, 1984–1989. The Ummarmiut Development Corporation exploratory fishery began in 1989.

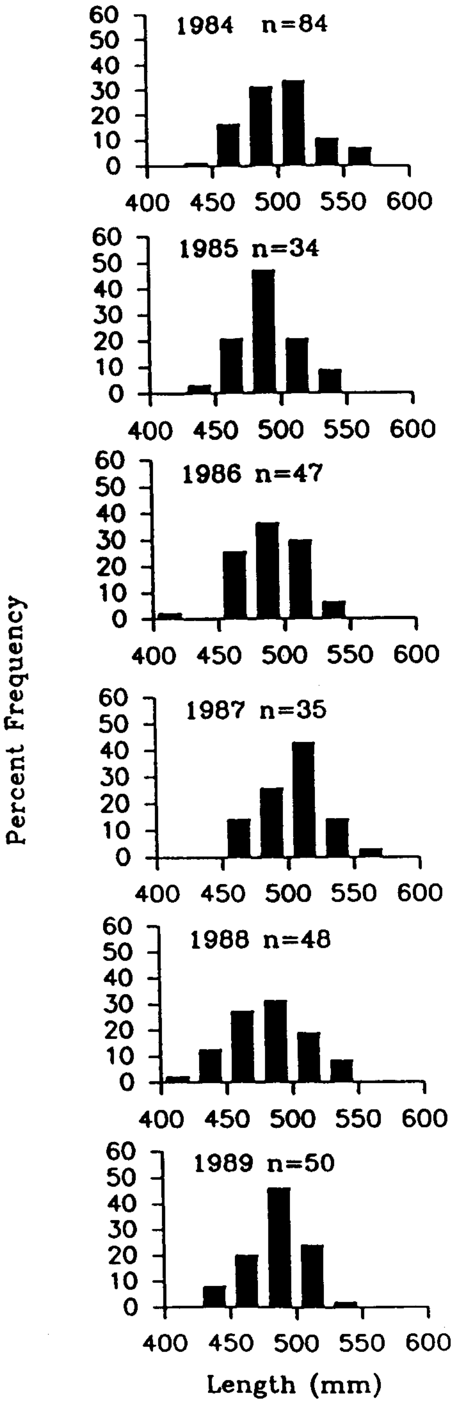

Figure 6. Fork length frequency distributions for broad whitefish from the Mackenzie River, Middle Channel, 1984–1989.

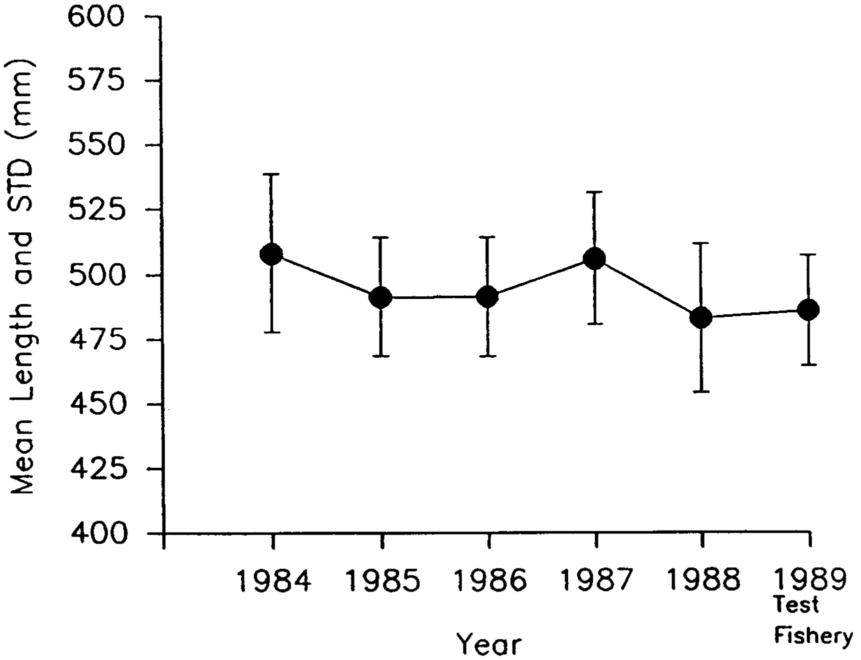

Figure 7. Mean length and one standard deviation for broad whitefish from the Mackenzie River, Middle Channel, 1984–1989. The Ummarmiut Development Corporation exploratory fishery began in 1989.

BROAD WHITEFISH TRADITIONAL KNOWLEDGE STUDY

by

Milton M.R. Freeman

ABSTRACT

To record Inuvialuit traditional knowledge on broad whitefish biology and the fishery in the lower Mackenzie River interviews were conducted during 1992 in the communities of Inuvik and Aklavik. Interviews were tape recorded and transcribed. A total of 123 residents were interviewed. This report is a summary of the responses of the elders to questions on the past and present fishery, changes in whitefish abundance, variation among broad whitefish, variation in whitefish quality, parasites, injuries to fish, reproduction of fish, the relationships with other fish species, uses of broad whitefish and management of the resource. Historic harvest levels are estimated based on descriptions of the number of days spent fishing, the daily catch, the percentage of broad whitefish in the catch and the number of households fishing. Three different methods of estimation give similar ranges of harvest levels in the Inuvialuit area with the maximum range between 112,000 and 315,000 fish harvested during the 1950s. [Abstract composed by editor]

INTRODUCTION

This traditional knowledge study of the broad whitefish is based upon a series of interviews (see Appendix 1 at the end of this report for the questionnaire) with elders and those with fishing experience living in Aklavik and Inuvik, NT. Interviews in Aklavik and Inuvik were conducted from early January to April 1992 and involved 123 community residents (28 in Aklavik and 95 in Inuvik). Interviews were carried out in English (in a small number of cases elders answered in Inuvialuktun) by seven local residents in Inuvik and two local residents in Aklavik. Except for a very few instances, all the Inuvik interviews were tape-recorded and subsequently transcribed; no tape-recording of the Aklavik interviews occurred. Individuals are identified only by numbers (placed in square brackets [ ]) in this study. Appendix 2 at the end of this report indicates gender, community of residence, and age (where known) of all those quoted in this report.

Topics covered in the 28-question interview schedule (Appendix 3) included questions on: (1) the location and nature of the past and present broad whitefish fishery, (2) behaviour and life history of the broad whitefish, (3) environmental changes affecting the broad whitefish, and (4) observations on traditional and recent fishery management beliefs and practices. Fishing locations were recorded on 1:250,000 scale topographic maps (see Fig. 1), and spelling of fish names in Inuvialuktun was standardized according to Lowe (1984). The study was coordinated by the Inuvik and Aklavik Hunters and Trappers Associations (HTAs) which were responsible for field worker selection and local administration. Prior to commencing the study, meetings took place with the HTAs on October 5 and November 10, 1992 in Inuvik and on October 8 and November 12 in Aklavik. A one-week training session, organized by Arctic College, was held to familiarize Inuvik field workers with interviewing and transcribing field notes; interviewing commenced in early January 1993 in both Inuvik and in Aklavik.

One important objective of the study was to obtain an estimate of the size of past Inuvialuit harvest levels of broad whitefish in the Mackenzie Delta region. Discussion on the best way to obtain such information was held with the Aklavik and Inuvik HTAs before the study commenced, and it was decided that the preferred method was to estimate harvest levels from locally obtained oral information, rather than devote time to searching government, church and trading company documents. It was believed that even if documentary information could be located, it would be quite difficult to interpret: for example, references to “fish” caught or used as dogfood would be most unlikely to distinguish between the species of whitefish taken, nor the extent that other species (e.g., inconnu, loche, northern pike) were included in the estimates. For these reasons, local knowledge obtained during interviews was thought to provide a reasonable basis for estimating past broad whitefish harvest levels.

PAST AND PRESENT FISHERY

In the past, the fishery was carried out at a large number of fishing and trapping camps situated on various channels of the Mackenzie River and on streams and lakes in the Delta and at whaling camps along the coast (Fig. 1). The general opinion was that despite the large numbers of camps and the large dog population to be sustained, there was a reliable and abundant supply of fish available. Indeed, people remarked that fish and caribou were staple items in the diet, and when caribou were scare, fish, and especially the broad whitefish, was a vital and dependable resource:

> "...fish camps were located about six miles apart all over the Delta and people never ran out of fish." [81A]

> "There were over 200 camps in the Delta at one time...they had thousands of dogs...when you go to visit people they fed you and your dog team...a long time ago fish were taken anywhere and it never changed...I would get a few hundred fish for my dogs before the ice was thick, every fall I would do that...a hundred feet of fish net...it used to be that we could hardly pull it out." [3]

> "We used to catch so much fish that when we had visitors we would feed their dogs. When we would visit their camp they would feed our dogs. That's the way it worked long ago." [38]

The principal fishing season for broad whitefish was from October until December or early January, during which time large numbers of fish were taken for winter use, which apart from domestic consumption, also included use as dogfood and for trap bait, and sale to a local mink farm and to local schools and hospitals:

> "Long ago [we] used to sell fish to the community and fish for the school and the hospital. Like old S., he used to buy fish in town from the community and trappers [for his mink farm]." [38]

> "I went partners with a fellow in 1948, and we went up the river here and we caught 23,000 [whitefish] from July, August, September, October - four months...and we sold the whole works. The fresh fish that we caught in the fall went mostly to the hospitals; they had an epidemic, a measles epidemic that year...we had the two hospitals, and they were full for a couple of months." [81A]

In late December and January the increased thickness of the ice and lower air temperatures caused many to suspend fishing operations until the spring. The net mesh sizes ranged from 2"-5 1/2". Whitefish were not taken with hooks nor by any other technique than the use of gill nets, homemade from cotton twine until, more recently, replaced with purchased monofilament nylon nets.

Fishing was suspended during break-up. The first part of July was considered the best time to start fishing again, and though there is still ice on the water at this time, there is sufficient open water in which to set nets:

> "The best fishing is about the first part of July, right after the open water and the ice is still on the water and the water is high. After that the water goes down and there are no more fish. They start running again the first part of August." [79A]

In the summer the nets can get clogged with debris and should be cleaned regularly if they are to continue catching fish:

> "There are times of the year when there's so much dirt in the water [and] you're usually not catching fish that you would be catching...what we do in situations like that is we take the net out and hang it up to dry and clean all the silt out of it, and then put it back in; of course, there are some places that are a lot worse than others." [81A]

There is a fish "run" in September when people obtain good catches. However, there may also be periods of a week or 10 days during September when few whitefish are taken and the catch consisted mostly of northern pike (*hiulik*, jackfish) that are leaving the creeks and entering the main river at that time. During these periods, nets may be lifted until the pike have disappeared.

The best places for setting nets in the river include the eddies and stretches of clear water and near where creeks flow into the river channels. Following northerly or westerly winds the water becomes cloudy or water levels may rise and fewer fish are caught at that time. After an east wind the water becomes clearer again and fish become more plentiful. In hot summers fewer fish are caught, for it is believed that the fish move around less in warmer water.

In October ice begins to form on the lakes and once it is safe, the most intense fishing period commences, ending in December when sufficient fish for the winter have been taken and before the ice becomes too thick and the coldest weather arrives. Large catches are made from nets set beneath the ice in certain lakes and in the river where the depth is suitable for setting nets.

Though many made comment that whitefish (and other fish species) do have definite "runs" in freshwater, this behaviour is also observed in the coastal areas:

> "...the people down there call it "fish coming into shore", coming in. From the ocean...sometimes you could set the net and not catch any herring or whitefish...and then, all of a sudden, they're coming for a week...and then they're gone for a while again and then they come back again." [81A]

CHANGES IN WHITEFISH ABUNDANCE

Some residents observe that fish are now less abundant in the Mackenzie Delta; they state that many places where formerly nets were set are now too shallow; this is especially the case in some of the lakes and streams. There are other changes noted that are believed to affect the fish, some related to development activities taking place in the Delta a few years ago:

> "Breakup was so late last spring and it was not like it used to be when the river was high and everything was colder. Every year it's up, it used to be [every] 10 years; now it's every second year." [4 & 6]

> "When I was fishing I found out the oil companies were dynamiting all over the rivers and lakes...we had a hard time catching fish because they were killing all the fish at that time...lots of fish died...I set out a couple of fish nets and only got a few fish. That's the time everyone was short of fish... We used to have [lots of fish]...after the dynamiting...I went and set fish nets in the summertime; there were no fish for me." [39]

> "Barge traffic and seismic work does interfere with whitefish. I've seen it happen years ago when they were doing seismic blasts in the Delta. There were lots of dead fish in lakes in the springtime, after the blasts were done in winter." [RP15]

However, others dispute the observation that fish are fewer now:

> "I have never noticed that the fish get less. The broad whitefish have never changed over the years, even

> though they are not hunted they are still the same in my time." [82]

> "Ever since we have been fishing down the coast for the last 10 years...there haven't been any major fluctuations in those years...we usually take about 100 to 200 some years...We get coneys (*hiiraq*, inconnu]...and pike, but basically it's the whitefish we are catching." [00]

> "I think there's more fish now because people in the Delta were about 300 and they had camps all over the Delta and about 70 people were fishing. They used to get lots of fish for dogfood, maybe 1000-2000 [each]. Now nobody hardly goes fishing...I know around this side of Tuk[toyaktuk] they are plentiful. You could get in one fish net in the morning maybe about 50. Even in the night you could get about 80 when you have a long net. They are not really scarce now because people don't fish for them anymore." [11]

One of the most active fishermen in the region, in disputing that fish are fewer now, wonders whether the trend to using larger mesh size (because "in the 3-inch mesh nets fish really get tangled up") has resulted in fewer fish being taken thus leading to the perception that there are fewer fish. This individual, who has fished continuously over the past 18 years, has not noticed any change in fish abundance. Sometimes he nets a "jumbo" whitefish, but apart from that the catch numbers are fairly constant. However, it appears that along the coast some changes have taken place compared to earlier times:

> "Along the Mackenzie River whitefish always seem to be numerous. Down at our whaling camp [Whitefish Station] we used to...set our net in the daytime or in the morning and we would have to take the net out before night because it was catching too many fish. But [since 1983] there has been no whitefish at our whaling camp. We probably get somewhere from 60 to 100 fish during our stay there which is a month and a half. Last summer the fish were starting to come back a little bit and we were catching more." [81A]

VARIATION AMONG BROAD WHITEFISH

The broad whitefish (*anaakliq*) is everywhere in the Western Arctic distinguished from the lake whitefish (*pikuutuuq*, crooked back). People recognize that there are two kinds of broad whitefish of similar size, and also a decidedly larger form, the "jumbo" broad whitefish that people occasionally take in their large-mesh nets. The two similar-sized forms of broad whitefish are not distinguished by name in either Inuvialuktun or English, but are nevertheless readily distinguished: those that live in lakes are a darker colour and are firmer and tastier, and those from the rivers are lighter or silvery in colour, with a more watery flesh:

> "The whitefish would come from the lakes: we would call them the "lassie whitefish". The fish we got from the Mackenzie River was a different kind of whitefish, they were big in the fall time. The "lake whitefish" are small whitefish but they are fat...they come out from the lake and they have spawned already. [The] "lake whitefish" and "river whitefish" are different." [3]

> "The crooked backs are similar to the whitefish but they are different. The "lake whitefish" and the "river whitefish" are two different types. They are the same kind of fish, but the "lake whitefish" is a lot clearer and a lot tastier." [38]

> "There are two kinds of whitefish. The whitefish from the lakes are a darker colour and they are firmer. Whitefish from the rivers are more white or silvery in colour and the

> flesh, when you cook it, is more soggy with water in the meat." [200]

One knowledgeable elder believed that some recognizably distinctive broad whitefish are associated with particular localities:

> "Kendall Island has a creek I have fished around October; the fish [there] are different. They just go to that same lake because I don't see big whitefish around here in the Delta. There's big ones about 2 1/2 feet and they are fat in October. They got fat so that even at -40° they don't freeze... they are so big you can catch them by the head (in a 5 1/2" mesh net). There are some fish that stay around Campbell Creek every spring when the water starts shooting out." [11]

VARIATION IN WHITEFISH QUALITY

With regard to the quality of the flesh it is observed that fish taken in salt water are always firmer with more taste than those taken in fresh water; others believe that the quality of fish in the Delta, and especially in the Mackenzie River, has improved over the years:

> "I lived on the Mackenzie River in 1959 and we caught fish in lakes and small channels. I could not eat the fish because they were really soft and watery. Since then the quality of the fish in the Mackenzie seems to be improving, but I still could not compare them with those caught in salt water." [81A]

There seems to be a common (but by no means universal) view that there has been a change in the quality of fish over the years. People remark that in recent years there appear to be more "injuries" (scars and deformities) in the fish, and that sometimes the livers are discoloured or blotchy:

> "People were complaining a lot about three years ago. I was complaining about the fish being soft and soggy. Maybe there was a spill of some kind of chemical into the water and that could have affected the health and maybe that's why they were soggy that year. The coney, the whitefish, and the crooked back were soggy just for that one year. Even though they had been freshly caught, they were soggy." [38]

> "Not only now, but in the past it's been well known that the fish in the river are soft and there are better quality fish in the lakes. But we've been hearing of deformities in different species of fish, that wasn't common in the olden days. There is something out there that's really creating some kind of problem for our fish." [46]

However, opinions differ concerning the quality of fish in the river generally during the summer months: to some people the fish are fat and good to eat during summer, others characterize them as being soggy and of poor quality. It is generally agreed that when the summer water temperature is higher the quality of the fish is lower:

> "If you got a hot summer there would be no fish; the bottom gets warm and the fish don't move. If you take a fish out of the net your finger would go right through the fish...when it's warm in the summer there's not much fish." [82A]

PARASITES

People state that compared to lake whitefish, the broad whitefish is relatively free of parasites. Some say that after living in lakes there are more parasites in the fish; others specify particular lakes as containing more heavily parasitized fish:

> "If you go to certain lakes you get these fish and they have tapeworms inside; nice big whitefish and they have tapeworms. I never heard of any Inuvialuit saying they got sick from eating certain kinds of fish. I

> think when they are clean they could tell by the liver or the inside of the fish." [2]

Parasites are not thought to harm the fish nor to interfere with its ability to reproduce. However, other conditions exist which seem to cause more concern among Delta residents:

> "You can tell when the fish is not healthy. You feel that it's soggy and when you open the inside you can see the colour of its gills and liver and then you know the fish is not healthy." [38]

> "The diseased fish get watery and the meat is no good. If you boil it and it's watery, it's a sick fish. You can cook it for the dogs, but you don't eat it." [4 & 6]

> "We never eat fish when they get red skin. You could feel them on the back, when they are skinny; you never eat them." [44C]

> "In the spring when [the whitefish] come out of the lakes the fish scales are very dark. The fish taste very good, they are very fat...[but] when the fish are really skinny we don't eat them, also the fish skin or scales are very hard and we cannot scale them so we feed them to the dogs." [74 & 75]

INJURIES TO BROAD WHITEFISH

To many people, northern pike attacks cause many of the abrasions seen on the broad whitefish:

> "In the past, when the jackfish [northern pike] bit it and lose it that's the only time they get sick and sometimes they get skinny. Jackfish have some kind of sickness you know." [82]

> "Sometime there are scars from the pike." [91]

> "Some of the fish have scars from the other fish." [98]

> "Sometimes the fish have sores in the summer time. In the fall time they have lumps under the skin: when they get a cut it bruises then it forms a lump where the sore used to be. Maybe other fish try to eat them, especially the jackfish." [90A]

Some injuries are thought to result from contact with boats and motor propellers as well as from other fish:

> "I have seen scars on the fish from being bitten or from boats." [96]

> I've noticed some bad cuts on the whitefish from the boats or propellers." [94A]

> "One time I got some fish from someone and there was worms in it right under the scale. We don't know what that was from, but some people say it's from the boats: they get hit by the propellers...or maybe they got scars from the boats when they go back and forth." [2]

REPRODUCTION

A widespread opinion is that the broad whitefish spawn in lakes in the fall (September through October, rarely in November) and breed every year; others believe they spawn in winter (November-December). Some observed that whitefish spawned where there is a sandy substrate and in lakes with vegetation (i.e. "grassy lakes") and beneath cool shallow water:

> "Whitefish lay their eggs in the lakes in the fall before the creeks freeze up." [81]

> "In the lakes in the fall time they start coming up from the ocean and they start breeding in the lakes. They stay there until they lay their eggs and they start going back out in the spring to the ocean. Then they start coming

> back in the fall time to lay their eggs in lakes or creeks. In the fall, in the small creeks, the young fish come out, little broad whitefish and crooked back, even little jackfish [northern pike]." [82]

> "They lay their eggs right in the lakes and they stay with their eggs until they hatch. They lay eggs in the shallow lakes: we could see the eggs. After they lay their eggs they get really skinny and are no good to eat." [79A]

> "They prefer cool water, not too deep and not too rough. They would lay their eggs in calm water." [46]

> "Around the first part of September you catch a lot of whitefish that recently spawned. These fish are really white in colour and are really soft and not good quality...When the water comes out of the lakes and creeks early in November there are [large numbers] of little fish there. That is why the people go to those places to jiggle for loche: their stomachs are full of little fish. You can identify the little loche and little jackfish among these little fish; the others are coney, broad whitefish and crooked backs which can't be told apart, but certainly they must include broad whitefish among them." [81A]

However, some individuals realize that the whitefish range far upstream, and that spawning may occur outside of the areas they know:

> "The fish go spawning around Arctic Red River." [70A]

> "In fall they lay their eggs; I don't know where. May be at Great Slave Lake, because they travel up the Mackenzie River." [RP13]

> "You get whitefish all the way to past [Fort] Good Hope. I don't know where they go from there, maybe Great Slave Lake or up Great Bear River; somewhere there they lay their eggs." [48]

> "They mostly breed around Great Slave Lake or up around Yellowknife or coming down; they are always coming down going to Tuk[toyaktuk] all along the Delta...I know they spawn right along the Mackenzie when they are coming up[stream]...in December they have no more eggs. In the spring time they have small little eggs, just like a bead. Some of them, their eggs are half-size down around Whitefish Station. I know they spawn right along the Mackenzie when they are coming up. Sometimes you see female fish that spawned already, that's in October or November they are just about spawning. In December they have no more eggs." [11]

RELATIONSHIP WITH OTHER FISH SPECIES

Apart from the expressed view that northern pike are aggressive toward broad whitefish, two other inter-species observations were made during the study. The first relates to a hybrid whitefish mentioned by a few individuals:

> "Once I caught an unusual fish that looked like a whitefish. They told me the name in Inuvialuktun but I forgot it. It looked like a coney and whitefish. We caught it on a big hook, a bone hook." [89]

> "One of my boys was all excited this fall because he caught what he thought was a coney when he was taking it out of the net. But the coney head had the body of a whitefish...I've seen a few of them in my time." [81A]

The second issue related to a concern expressed about the potential for altering the "balance" that may exist between broad whitefish and lake whitefish populations if some future increase in fishing pressure on broad whitefish is to occur:

> "At the moment I believe the crooked backs outnumber the broad whitefish. If we are only going to be catching broad whitefish...and let the other fish go, we do have concerns. If [broad whitefish] get so outnumbered will this harm the broad whitefish and the system they and the crooked backs have? Is there any possibility this might harm the whitefish in some way?" [81A]

This concern illustrates well the ecological understanding possessed by Inuvialuit elders when discussing management concerns.

MANAGEMENT

> "I've always sort of bragged about the Inuvialuit probably being the best conservationists in the world. I stick to my word because they took what they needed and nothing was wasted." [81A]

The Inuvialuit expressed many attitudes and practices regarding fishing which reflect a positive conservation ethic. The most commonly expressed view cautioned against taking more fish than was required to serve subsistence needs; in this regard, individuals expressed not only reservations about taking too many fish or the danger when blocking channels and streams with long nets, but also in some cases, against fishing in the favoured fish habitats or continued fishing when the spawning fish were running:

> "I don't think they should fish too much whitefish. That's why we don't fish in the Mackenzie too much because we don't fish when the fish are running. We never bother that big eddy, only that one year when we thought there was too much fish in the lakes...I think some places should be cut off: that big eddy should be cut off because there's a lot of fish there and they should let the fish go by." [82A]

> "There's never really been concerns about the fish except when you have broad whitefish in lakes where there's no creeks coming out. People set a net in the lake and they take a certain amount each year. Once they get that amount they take their nets out and then that lake is left alone until next year. I've known the people who have a good fish lake where there was nice big fat broad whitefish and they would go in there every year catch 75 and once they caught 75 they took their nets out." [81A]

> "We used to pull our nets at certain times so we didn't hurt the spawning fish." [93]

> "I'm pretty sure that my granddad never overfished in one area; he would never fish in one spot all of the time." [79A]

People also express concern about the effect of the fall net fishery on another seasonally important fishery, namely that for loche (*tiktaliq*, burbot). Loche are fished in the fall for their highly valued livers, a local delicacy. It is understood that setting nets in locations where the loche can be taken on hooks (by jiggling) will disrupt this fall loche fishery, so in view of that, several individuals observed: "You can't jiggle and set a fish net in the same place."

There is an emphatic concern generally expressed about not wasting fish: fish should be dried or smoked, frozen, put into pits or barrels for dogfood or given away to others for their use, but never just thrown away:

> "...if you just catch too much fish you just waste the fish, just throw it away because you have no dogs. I never wasted fish, I would give it away for dogfood." [87A]

> "Long ago the old people never threw fish away, they never wasted it.

> They just caught what they needed. I was brought up by my grandparents and was told not to take more than I needed. That's how we manage our wildlife. If you have too much you give it away." [CS]
>
> "Fishing is good for the people if they don't waste it. Don't waste any of the fish!" [45]
>
> "People don't overfish. They are just carrying on tradition: get enough fish and then quit." [78A]
>
> "The people who care, they don't catch too much, they don't throw fish away. They catch them the right way, set the net in the right place in order to catch fish." [82]
>
> "We were told by our elders, this was passed down from generation to generation, to never over-harvest what you have. Like I mentioned earlier, our fish population over the years doesn't seem to have changed." [81A]
>
> "When the fish start running...the people just set their nets and caught what they needed and never threw anything away. That's the way it should be." [AG]

The view was expressed that an individual has a responsibility to minimize the potential for over-fishing by reasonably estimating household food needs for both people and dogs and the amount needed to satisfy social obligations to others:

> "In the old days...they knew how much they needed and quit fishing when they had enough for the whole winter." [78]
>
> "My dad had nets there so we could get fish with lots of eggs in them. We just set enough so we could get lots of fish eggs and then as soon as we could get enough for winter then he pulled the nets out. Then we would go down a river from where we lived...there's lots of coneys: we would get about 20 and that would last a year. Every time we feel like eating [coney] we have it for *qoak* [frozen fish] or something...My dad had two nets he would visit...once he had enough fish...he would pull the nets out. He just wanted to make sure he would have enough, because the ice is six or seven feet in the winter time and if you are hungry there is no way you could get anything." [2]

Fish caught in nets can quickly deteriorate if left too long in the nets; therefore, it is important to tend nets regularly:

> "If you have two or three days of the north wind you can't look at the net (so the fish deteriorates). But that fish never goes to waste. We take them out and put them in the pit for dogfeed. That way nothing goes to waste. In the old days, like 25-30 years ago, every fish we got was never wasted." [48]
>
> "A good fisherman knows where to fish, how to fish and what kind of fish. The proper way to fish is to check the nets 2-3 times a day to make sure the fish don't spoil." [96A]
>
> "If a fisherman is going to be a good fisherman, he would visit his nets every 5-6 hours or overnight and look at them early in the morning. In the summer the fish dies right away, they drown. I know that is a proper way to catch or net some good fish for eating. You have to be ready to get the fish when they want to be caught." [38]
>
> "When the nets get dirty they are taken out, dried and cleaned, but that's the only way to be sure to catch fish." [AG]

Some people comment on the decline in these traditional conservation practices:

> "Some traditional management methods are (still) used...People when they catch fish they don't want, they just throw them on the side for foxes and crows. When I was growing up we never left fish anywhere." [89A]

> "I think a fisherman should be really careful...and not overfish...Some people, they have a big pile of fish and they have nothing to do with it, then it gets rotten in the spring. I know birds get some of it, but a fellow has to try to get just enough. Then each person, if he looks after what they need, will manage the fish." [17 & 18]

Others, noting that today without dogs to feed some of the by-catch is thrown away, nevertheless point out that in nature nothing goes to waste:

> "Nowadays we have no dogs, so people use what fish they want and throw the rest away. I wouldn't say it goes to waste: the sea gulls or crows eat it. If a mink is swimming along and he sees that fish he is going to take it back to his young ones. Fish never goes to waste." [48]

As mentioned earlier, lake whitefish and broad whitefish are nearly always taken together in nets and the concern was expressed that the live release of lake whitefish (now no longer needed for dogfood) may in some way damage the broad whitefish (perhaps by over-populating the region). It was suggested that consideration might have to be given to removing the lake whitefish [crooked backs] from the system in an acceptable (i.e., "non-wasteful") manner: "we might have to establish a pet food cannery for crooked backs [in order] to use them." [81A]

USES AND IMPORTANCE OF BROAD WHITEFISH

The broad whitefish continues to be highly valued as food in the Delta region:

> "At the present time it is still the same: we have the same value this time as it was at that time. The broad whitefish is used all year round as a basic food, not like any other fish. Loche is mostly taken in the fall time, same with coney. You use it [broad whitefish] all through the early spring and summer. Whitefish is used all the time." [93]

However, despite its importance as food, its total importance in the domestic economy has declined now that fewer people maintain dog teams and less trapping is carried out. Also, at the present time some earlier uses no longer occur. Among the earlier practices mentioned were the use of fish oil and fish liver oil as medicine, and fish broth used to treat colds and diarrhea. The oil was formerly used as a condiment (for dipping) or for greasing bread pans, and to waterproof or preserve wood. Many people remember these uses from their childhood. A more current use reported is that whitefish eggs are good for treating hang-overs.

Though fish were widely used by trappers as trap bait, inconnu and northern pike were preferred for fox bait over whitefish. Winter dogfood would consist of all fish species taken during the fall and early winter fishery including, e.g., inconnu, northern pike, loche, and lake whitefish as well as broad whitefish. In the spring, during the muskrat season, muskrats replaced broad whitefish as food for people as well as providing another source of dogfood.

Dogs, and foxes too it seems, have definite food preferences, and Inuvialuit dog-feeding practices indicate understanding of the dogs' nutritional needs:

> "A coney is a really good fish, and even when you're trapping, if you have lots of coney you use coney for bait. If you have a pile of fish and one of your dogs gets loose, the first thing they take is a coney, but if there is not coney there, they take a whitefish; they know which is the best eating. Many people have told me

> that a coney used for bait...is the best fish, especially for foxes." [81A]

> "You have to watch the fish and some of them you have to cook. My parents used to cook the jackfish and the loche all the time for the dogs...it's just bad to feed it to them straight, they would be funny fur...there's no fat in them like whitefish. Not like a coney or whitefish or crooked back; there's a lot of fat in them, but not in jackfish: my dad said if you feed ice to the dog, then when you feed them jackfish that's just what it was like." [4 & 6]

People also have their own personal preferences about different fish as food:

> "Whitefish are one of the best fish there is. If we didn't have whitefish we have trout [*kaluakpak*] in different lakes."

> "Also arctic charr [*qalukpik*] is the best fish. For dryfish it's coney, it's really rich; really, you don't need oil with that one." [48]

There were different ways of storing fish: fish were dried (and sometimes baled), or made into stick or hand fish for *qoak* [frozen fish]. Stick fish was generally made from the better quality fish, that is, fish taken live from the nets; fish that were dead in the net were generally used for dogfood and were likely stored in pits. The better quality fish made into stick fish became *qoak* and was often hung in willows or stored on a raised stage. Stick fish placed on the stage would sometimes be covered with snow, other times with canvas. The fish placed into pits was more usually for dogfood or trap bait: the pit was 4-5 feet deep (in some cases up to 8 feet) with a log (and sometimes moss and tree branches) covering. If intended as bait, the fish was allowed to go smelly. Rotten fish was also eaten as *qoak* in the winter and was considered nourishing dogfood. Each dog was fed one (or two, depending on fish size and the dog's activity level) fish per day.

Fish would also be stored in ice cellars. Many people would keep the fish separated, even when placed in the same pit:

> "The whitefish we used for *qoak*, for eating. We stick some and then put some in pit and get them a little rotten and have it for winter *qoak* and dogfood. Beside that we don't put them with the whitefish. We put the rest on the side for the dogs: good fish is on one side and dog fish on the other side: we would have them separated." [64-70]

> "We put all the whitefish together, the crooked backs together and the jackfish together and then we knew what kind of fish to eat. We used to eat whitefish and loche, and when we started jiggling we used to get coney and we always know which one is our dog food and the one that we are supposed to eat." [72A]

> "In the winter time we stored our fish on the stage or in a big bag or pit: the food for the family and dogs would be separated." [74-75]

> "You pile your fish and sort them. Sometimes you have to bury them in the snow so you could eat them as *qoak* in March. Some you hang to dry. You take care of them." [4&6]

> "We used to keep fish until they were just rotten and the dogs ate them. People eat *qoak*, they don't like fresh fish. They put it on a stick and let it sit outside for a long time." [2]

ESTIMATING HARVEST LEVELS

It appears that during those past years (i.e., pre-1955) when people depended very heavily upon the fish, fur and game of the Delta and relied upon dogs for transport, intensive fishing occupied a considerable portion of the fall and early winter each year. In those years when caribou or moose were scarce, considerably more time would be spent on fishing for food, with the broad whitefish the principal species being fished.

In order to estimate the approximate harvest level of broad whitefish, a simple formula is applied to some of the catch estimates and their values supplied by elder residents during interviews. This formula is:

Broad Whitefish Catch = D x C x P x H

where:

D = estimated number of days spent fishing in the fall/early winter;
C = estimated daily fish catch per household;
P = estimated proportion (%) of broad whitefish in catch;
H = estimated number of households fishing.

Obtaining estimates. From the interview data (see Appendix 3 at the end of this report for sample statements) it appears that about 30-40 days on average were spent fishing for winter supplies in the October-January period. However, some individuals spent up to 100 days fishing at this season. For purposes of approximating the average family effort (D in the formula above) it is assumed that between 40 and 50 days fishing occurred each fall/early winter season.

The number of fish taken per family is clearly variable. Some people speak of about 50 fish per day, others of about 100 fish, and in a few cases up to 300 to 400 per day are mentioned (during the fall whitefish run). For purposes of calculating C in the formula above, it is assumed that on average from 80 to 120 fish per day were taken.

However, the fall fish catches consisted of several species in addition to broad whitefish. Only one person provided an indication of the estimated proportion of broad whitefish to other species in the catch, in that case about 65% (i.e., 700 broad whitefish out of about 1100 total catch). For purposes of approximation, we might estimate P in the formula to range between 50% and 75% of the total fish catch.

The number of Inuvialuit households (H in the formula) fishing is estimated at about 70 (for a total Delta population of about 300 Inuvialuit). However, no account is taken here of the many non-Inuvialuit households also operating in the Delta at the same time.

RESULTS AND ASSESSMENT

A calculation using these particular estimates give a total fall fishery of between 112,000 and 315,000 broad whitefish for the Inuvialuit. These figures are shown on line 1 in Table 1. In order to assess how reasonable such an estimate might be, two other calculations were made.

The first calculation used the most commonly cited figure of 5000 fish each fall per household as applying to each of the 70 Inuvialuit households. In this calculation it is again assumed that between 50% and 75% of the fall fish catch consisted of broad whitefish. Using this second means of estimating the Inuvialuit fall harvest, the number of broad whitefish taken by the Inuvialuit in the Delta ranges between 175,000 and 262,500 (line 2 in Table 1). This second estimate represents a narrowing of the estimated range (112,000-315,000) obtained by the first method. However, the mid-point of each estimate corresponds quite well: 218,750 and 213,500 broad whitefish respectively (see lines 1 and 2 in Table 1).

A third independently derived calculation was also used to estimate the total Inuvialuit fall fish harvest. In this case, the dogfeed needs of the 70 Inuvialuit households for the average winter was estimated. For this exercise it is assumed that each household (several having more than one dog team) had from 12 to 18 dogs, and that the length of time dogs were fed one fish per day extended over a period of 24 to 30 weeks per year. In this case, it was assumed that the dogs were fed virtually all the non-broad whitefish taken from the nets and whatever broad whitefish were additionally required to satisfy the dogfeed needs. This calculation indicates a dogfeed requirement of between 141,000 and 264,600 fish (shown in line 3 of Table 1). These needs could easily be met from the 25-50% non-broad whitefish taken in the fall fishery supplemented with broad whitefish as was the normal practice according to elders' statements.

ADDITIONAL SOURCES OF ERROR IN ESTIMATING ANNUAL HARVESTS

Broad whitefish were fished by Inuvialuit other than during the 40-50 day fall fishery, although it is much harder to attempt even rough approximations of these catch levels. It is assumed that as the fall fishery constitutes by far the largest proportion of the annual broad whitefish harvest, the comparatively small numbers taken by some proportion of the local Inuvialuit population at other times will add a relatively small number to the calculated harvest figures. Indeed, it is assumed that this relatively small number of fish is likely contained within the range of figures estimated for the fall fishery by the methods being used in this study.

A more sizable fishery harvest is represented by an unknown number of broad whitefish taken in the fall fishery and sold to the mission schools and hospitals and to the mink farm (a figure of 36,500 fish was cited for the mink operation). In addition, a large fall fishery was operated in order to feed the 50-60 dogs used in the reindeer-herding operation at Reindeer Station, and by the Inuvialuit special constables who fished for a similar number of police dogs in the Delta.

BEST ESTIMATE OF INUVIALUIT BROAD WHITEFISH HARVEST

Disregarding these unknown but additional number of fish (and greater numbers probably taken by non-Inuvialuit residents in the Delta and yet others living upstream along the Mackenzie River), the figures presented here are considered the best estimate of the annual Inuvialuit broad whitefish harvest. Given the nature of the method used to obtain this estimate, the lower and upper range of the estimates is provided in line 1 of Table 1. The two alternative methods of calculation used to obtain lines 2 and 3 of Table 1 are merely to provide two independent checks of the reasonableness of the assumptions used in the first approximation.

In conclusion, it is suggested that between 112,000-315,000 broad whitefish were annually taken in the Inuvialuit domestic fishery in the early 1950's. It is assumed that the fish taken ranged between 2 and 3 kg round weight each. Thus, the estimated minimal annual harvest of broad whitefish taken by Inuvialuit in the Mackenzie Delta ranged between 224,000 and 945,000 kg with a mid-range estimate of 534,000 kg (Table 1)

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COMMENTS, QUESTIONS AND ANSWERS

Ron Allen: I was wondering if there were any comments or information put forward as to protecting areas from people or other activities, say, spawning areas or areas of particular importance to the fish. Were there any comments made to that effect?

M. Freeman: There was a comment about it's important to find out where the fish spawn so those areas can be protected. That statement was made. The other concern was more or less in relation to good fishing practices. For example, that it's very important not to block, to put nets across, the river. There were some pretty pointed comments made about research projects that have blocked streams and rivers. People are quite upset about that, understandably. There was even talk about pulling the nets of researchers. Management was considered in relation to good fishing practices rather than protection. For example, when people are fishing in the fall and they want the fish eggs that are a delicacy; some people say that when they've had enough they would pull their nets to make sure that the spawning fish could travel by. They wouldn't keep fishing just for the sake of fishing. There was a consciousness that the spawning fish be allowed to continue upstream. There are other statements about fishing in some of the best eddies - the best fishing areas in the river. These areas should not be fished, there are lots of fish there, but those are very important areas for fish. Some people expressed the view that fishing should be watched there and limited. There were concerns expressed about the whitefish that live in lakes, especially in lakes that don't have creeks. Comments were made that people limit their fishing in those lakes to 75 fish or something and then pull the nets because they want to continue to fish year after year. They are very aware that they could fish out some of those lakes. So, that's the sort of information we were getting.

Don Dowler: I would like to make a comment from what Dr. Freeman has just said. I think a very important unanswered question concerns spawning areas for Broad Whitefish. A lot of them have been identified mostly up river. From what the people are saying that there is a good possibility that there are other spawning areas. I think that's an important issue that should be addressed in the future. It's very important to determine where they [spawning areas] are.

M. Freeman: Yes, I couldn't agree more. People did express that it's important to know where their spawning areas are because of future developments that may take place in the Delta region. We have to safeguard the spawning areas.

Ron Allen: I was wondering if perhaps

there has been any comment on the building of the town of Inuvik. Has that affected the fish? More people are residing in an area where they are able to get to the fish. Has there been any comments as to the building of the town of Inuvik changing the patterns?

M. Freeman: Not really. Nobody commented on that actual fact. The question that perhaps relates a little bit to it was whether the increase in boat and barge traffic has affected the fish. Those that expressed opinions about that felt that it hasn't caused a problem to the fish, except that a number of people made a note about possible collisions with the fish that are injured from propellers and boats.

Billy Day: I'd just like to make a comment on that. Inuvik was built hoping that everyone from Aklavik would move over here and there would be no Aklavik left. But at the time that Inuvik was being built there was no caribou here. You can catch the odd fish down in the river here in front of Inuvik but in no large amounts and they're not really of the best quality if you catch in this river. In Aklavik, you had caribou right behind the town. You had all kinds of fish right in the river in front of you. So, this really wasn't very much of an incentive for all the people to move from Aklavik to over here. [In Inuvik] they would have to travel distances to catch fish and also travel back to Aklavik to hunt caribou because the caribou migration didn't return to this area until after Inuvik was built.

M. Freeman: Thank you. Yes, that's an interesting observation. So, I guess, people don't have much basis for comparing the fish now in Inuvik or the fishing in times past because there just wasn't a great deal of fishing here in times past.

Jim Reist: I talked with Milton just a few minutes before he gave his talk about one of the outstanding problems we have to face and that is how we can make scientific knowledge and traditional knowledge come together as a better body of information. And that, I think, is still an outstanding problem that I hope this workshop will address to some extent. One of the interesting things though, well two of the things Milton mentioned, are rather interesting to me. The first is the subject of fish injuries and problems with marks on the fish. This was brought to my attention some years ago by people in the Delta communities working through the area office here. We actually conducted a study to look at this There is a poster on scarring on fish over on the side. In addition on the tables as handouts there is the scientific paper that resulted from this study. Most, if not all of the scars and the marks on fish that we observed in that study could be attributed to natural causes such as jackfish (Northern pike), and perhaps other predators such as bears and birds – especially when the fish were young and on the Tuk Peninsula. Very few of the fish problems could be attributed to other human causes with the exception perhaps of fish escaping from gill nets. You can actually see some of the pictures of the marks that we observed. So, that's a very interesting correlation between traditional knowledge and people's observations as well as some of the scientific results. The second point that I want to bring up is that, Milton mentioned hybrids between two types of fish observed in the Delta in particular between coneys [Inconnu] and whitefish [broad whitefish]. This is another question that we have addressed in work at Winnipeg. Not so much in the Delta because we only see a very occasional hybrid fish come from the Delta and most of the time we don't actually get the fish, we just hear about it. But there was some work being conducted by another fellow, another researcher from Winnipeg just to the east of the Delta on Wood Bay at the mouth of the Anderson River. A number of very strange fish were noticed that we suspected were hybrids. We examined those fish and there is another study and also a paper available at the side here on that issue as well. Briefly summarizing those results we observed what we thought were hybrids between all of the species of coregonids of this area. There are five species of whitefish (Inconnu, Arctic cisco, least cisco, lake whitefish or crooked-backs and then broad whitefish). We observed hybrids between all possible pairs of those species with the exception of broad whitefish and any of the others, and we suspect that that's tied into the very late spawning time of most broad whitefish populations. They tend to spawn a lot later than the other species. So, again, traditional knowledge and the observation of the fishermen and scientific knowledge have come together to show the same thing.

Ron Felix: I'm Ron Felix from Tuk and I was wondering if there was going to be a fish study for the Tuk area, as I saw a decline in the last couple of years in broad whitefish. I'm not getting much this year in the Tuk area. And I was just wondering?

M. Freeman: I could just comment on the traditional knowledge part. Obviously there are other biological studies, I don't know what the plans are but we are in the process of just starting [the traditional knowledge study]. Actually, we won't start until the beginning of April but there have been meetings with the HTC in Tuk and a researcher, a colleague of mine, Mark Stevenson, has been working in Tuk on a contaminant study for Inuit Tapisarit of Canada. He'll be actually doing the fieldwork with local assistance in Tuk. He was up there to talk to the HTC in February and present a report. I have sent an outline of the study to the HTC so the HTC will know what's happening. Mark will be up there discussing how the study is done and so on. The other thing with regard to that I may mention is that we did have information from people who use the Whitefish Station area. They've commented on a decline of the whitefish on the coast starting around 1983. Now they appear to be coming back. Other people around the coast, fishing along the coast have seen the numbers go down over the last few years. Maybe somebody who has knowledge of the coastal fishery can speak to that as well.

Billy Day: I know there was a number of years where we didn't catch any fish down there. I think the question was, maybe, more pointed at "is there going to be any study done to see what the population is like?". I know with whitefish using a large mesh net we were catching too many fish but when we put a smaller mesh net out for herring within a half an hour we caught 30 Whitefish - you know 3 or 4 lb. Whitefish. I think the question is, "is there going to be any research done on that population?"

M. Papst: This study is coming to a close, the one we're talking about now - but that doesn't mean that all work on whitefish is going to come to a stop. This is the first that I've heard that there is a concern in the Tuk area. What I suggest is the HTC contact the FJMC. We are now in the process of preparing our work plan for the next year. We'll certainly take a look at it and see if something can be done in that area to look at the population and the fishing trends.

Richard Binder: Just one comment. I'd like to go back to Billy Day's observations with respect to Inuvik being a larger center with a higher concentration of people. I think their concerns are more related to the quality of fish with the sewage treatment facilities and the overflow of raw sewage. People have talked more about the quality of fish today within this area.

M. Papst: That's something we've heard today both from the traditional knowledge study, from Margaret Treble's work and almost everyone we've dealt with. There is a very consistent concern among the communities about the quality. I would point out that tomorrow one of the things that's going to happen as part of this workshop is we're going to have a person talking about contaminants in whitefish. Someone is also going to be talking about parasites. Overall, my understanding is that both will give you a general good feeling about the whitefish. They are still very high quality as compared to the whitefish in other parts of the world. But, I think they are going to be two interesting talks. I agree with you, it is something that everyone has brought forward and said, "we're not so worried about the numbers but we're growing concerned about the quality".

Billy Day: This is kind of a broad question. I'm not singling out anybody to ask the question. The only thing I've heard so far about the overfishing or anything about fishing is when Margaret Treble mentioned that there does not appear to be any overfishing up to 1989. But does anybody else have a feeling that there has been overfishing since that time? Anybody's free to answer it.

John Nitsi: My name is John Nitsi, I'm from Fort MacPherson. I have a concern. It's not about the quality of fish or quantity of fish but how our people in the area are taking fish. I've been to three meetings now here dealing with trapping. At the last meeting in Ottawa the anti-fur movement was there. We're very concerned about how we're taking animals. If we're not too careful how we're taking fish and how we're treating fish, I'm sure the environmentalists will be attacking on how we're taking fish too. We've got to be very careful about how we're leaving our nets in, not checking the nets and throwing the fish away. With all the tourists coming into the area I'm sure they'll be taking pictures of when we throw our fish away because we got too many. We're not using them the right way. I'm sure they'll be pointing at the fishery next. Thank you.

Jim Reist: I'm going to try and address Billy's comments about numbers of fish. The major problem that we have in the lower Mackenzie is that it is awfully difficult to get a feel for how abundant the fish are. The fisherman knows from one day to the next how many fish he catches and he can try and use that information or knowledge to assess the relative abundance of the fish available in the given time. But as the situation changes from year to year in terms of the climate, the local weather and stuff like that, that intuitive 'feel' for the abundance of the fish is open to very large problems. Especially for things like whitefish, which concentrate and come together in very large numbers both in terms of physical space, they come from many areas down into a few areas, such as the channels in the Delta to move through, but also in terms of time. They come and they actually move over a very short period of time. The cues, the physical cues or the environmental cues, that the fish use to trigger the movements and come together are those kinds of things that are affected by weather patterns, for example, and everything else. So, the local abundance of the fish can be open very much to many sources of problems in terms of assessment, of getting some feel for numbers. The same problem exists when we try and enumerate or determine the abundance of fish using scientific methodologies. It's a very large problem and we have some possibilities for doing this and one of those is hydro-acoustics. There's a poster on the side about that topic. Determination of abundance and the changes in abundance is one of the primary problems that we have in fisheries science. Not only just for broad whitefish but for almost every other fish. We haven't yet, in terms of science at least, developed good enough methods that can give us accurate enough answers to address that kind of question. Usually what we end up doing, unfortunately, (and we have many examples in the south of Canada and on the coasts of this) is fishing until all of a sudden they're not there anymore and we don't really know the reasons or the causes for why they disappeared. That's not answering your question, it's more explaining, I suppose, the magnitude of the problem because there may be very many different kinds of causes that go into a shift in the numbers or a change in the numbers of fish. It's my feeling, and this is gut feeling, I suppose, it's my feeling that the overall abundance of broad whitefish in the lower Mackenzie hasn't changed that much over the last, say, 10 years or so. Locally, there may have been some changes but that is just a feeling on my part. You know, there's no sort of studies that can really substantiate that or anything like that. Along the coast people have a feeling that the fish aren't there and I think Milton mentioned that there were less fish or declining fish on the coastal areas beginning about 1983 but maybe they are back now. This is going to be a continuing problem and I think people have to understand that, at least from the scientific perspective, we haven't yet got the tools to address this problem to any degree of accuracy and it will remain as an outstanding problem.

Billy Day: We'd like to know where the fish migrate, where they travel. In the early 1920s or before, the caribou used to migrate through here all the time. The reindeer came in the early 1920s and that's when the caribou changed their migration route, and that's the reasoning behind having the Reindeer herds here now, or was at that time. Up until the early 1920s there was lots of caribou around here and then all of a sudden they changed their migration route and they never came back through here for probably about 60 years. Can something like that happen to fish? For example, along the coast we used to set nets and then have to take our nets out right away because we were catching too many fish. Over the past 6 or 7 years now there's been times where we're not catching any at all. Now, I don't think the fish are all dying off all of a sudden. They must be doing something else or staying out in deeper water or something.

Jim Reist: Fish are a lot like people. They use signposts along the highway to find their way. People use signposts along the highway to go from one town to another. Fish, we think, primarily use the sense of smell and taste to figure out exactly where they should be going and when they should be going there. In other words, they taste and smell the water. If there are changes in the water and, in particular, in the taste of the water to the fish, the sign post that they are trying to use, that they have been bred and learned to use during their life may, in fact, have changed also. The problem is again, we don't understand enough about the exact cues that are being used by the fish, to understand or be able to explain why they're not going in this particular creek or river or channel. What you outlined is a very real possibility. That is, the abundance may not have changed but their use of a particular area for whatever reasons may have changed. But, again, we have no really good way of understanding this.

Billy Day: When I was a youngster I had more interest in sitting around with elders and not going out and playing around. I've talked with many elders. I was born and raised in a time when this sort of knowledge was still being passed on from generation to generation. In all my talks with elders, they talked about caribou, they talked about fish, they talked about everything that they had to have to survive, and they talked about drying fish but they never, ever talked about not having enough fish.

When we fish in the Delta the only places that we fish is in the eddies. In the summertime when we're fishing we fish in the eddies but nobody seems to know really what percentage of the fish that are travelling the river go into these eddies. From the talk that Ken gave yesterday with the tagging program there seems to be an awful lot of fish that are travelling along and keeping away from the nets. Is there any possible way of finding out how many fish are really travelling through the river and what percentage are really stopping at eddies?

Jim Reist: The short answer to that question is that, yes, there is. The longer answer is that it is very expensive. The hydro-acoustic technology that Eric Gyselman is demonstrating over here with the poster and the computer is a method by which we can determine absolute abundance of fish going by a particular area. We put out sound waves into the water and those sound waves are reflected back to a receiver on the shore and from that you can actually get counts of fish. If you set it up properly you can also estimate whether the fish are moving up or down stream. Again when it's set up properly, you can also estimate the sizes of the fish and the total weight if you want. The problem with that technology right now is that it was primarily developed for lake situations and it's only recently been applied to river systems in particular in Alaska. We are attempting to develop the method to do that using hydro acoustics for these river systems. Eric, conducted a pilot study last year with his field crew to investigate the possibility of using that technology to count fish in Arctic Red River. It's developing. The problem though, as I said, is that it is a very expensive way to do it. The equipment costs a lot of money. There can be problems with putting the equipment out into the river especially when you get into bigger and more complex situations such as the Mackenzie and the Delta. So, theoretically we can do it. Practically, whether we can do it or not, is another question.

Comment: If the fish are using stop signs or signs, there must be a stop sign outside of Tuk there. Edward Lenny mentioned that what people were catching years ago we can't get that now. Someone that gets 25 barrels [in the past] is lucky to get 7 or 8 barrels of fish, today.

Jim Reist: Using traditional knowledge as well as scientific information, we can observe the changes in the fish population. What we can't do, because first of all it's very difficult and very complex to do and second of all it's behind us in time, is often determine the cause for the decline in fish populations. For example, along the Tuk Peninsula, the problem with fish is that fishing is only one of the things that affects fish populations and abundance of the fish, as well as, what particular channels they use and when they do things like migrate. There are lots of other potential causes that can affect fish numbers and fish abundance. I'll actually talk about this in a general sense tomorrow when I make a presentation on cumulative impacts. For example, if we change the habitat that the fish is in, that creates a problem. In addition to changing that habitat, if we fish those fish as well, then we've hit the fish population with two impacts. And those problems can come together and create a bigger problem. That's literally what cumulative effects are. What we have to do, and I guess the message from the talk tomorrow and I'll say it now, is that we have to proceed very carefully when we do things like increase fishing quotas and that sort of thing so as to not push the fish population beyond its capacity to absorb those impacts. If we do, they may disappear and we won't know why. We'll just be able to say, they've disappeared. I could stand here probably for the whole day and give you examples of exactly the same kinds of things that have happened to whitefish populations in the Great Lakes. There are many, many different examples.

M. Freeman: When we were asking questions about the different types of whitefish and people mentioned the crossbreed between the coney, perhaps, and the broad whitefish or the whitefish [lake whitefish], the two individuals that were talking about this mentioned that they had heard a name that the elders had for this fish but they couldn't remember it. And I'd like to very much get that name and put it in the report. So, if there is somebody here who knows the Inuvialuktun names for these crossbreeds, whitefish or coneys or whatever they are, I'd really like to hear about that. And then I have a question. It's not really part of the report that I am writing on the Inuvialuit study, but I was just wonder if people from the Gwich'in area and the Sahtu area also know about these hybrid fish. Would anybody like to comment on that?

Jim Perrault: All the whitefish were coming up above [Fort] Good Hope. I've caught fish all my life in the Mackenzie River. In the spring the little herring fish [least or Arctic cisco] come first with the coney. A long time ago, about 1945, 1935, at that time [you would] never see coney. If somebody caught coney they made a feast with it. Now today, there's lots of coney, which come with smaller little herring fish. They come [to Fort Good Hope] in June. And then those coney take off in August and then the whitefish [broad whitefish] come. Middle of June, there's some whitefish [arriving], but they [broad whitefish] come in August mostly. Then those small little herring fish they stick around yet at that time, but the coney take off - no more coney. A long time ago about 1945, [one] never heard of high catches of whitefish or coney. Now, they catch whitefish and coney at Norman Wells. Lots now. Maybe they pass the rapids now today. But it seemed to us that from 1980 until today whitefish [abundance] is going down slowly. In 1980 we caught lots of whitefish in the fall time around August but today mostly one net catches 12 [per day]. A long time ago it caught maybe 24 [per day]. So, [the abundance of broad whitefish is] going down very slowly. It might depend on the water [levels in the river]. About 1945 whitefish don't stay [at Fort Good Hope, Ramparts area] because the Mackenzie ice is rough. The whole fish take off. Today, if you set nets in the Mackenzie River you gonna catch coney and whitefish because there is no more rough ice. In November when we set nets on the Mackenzie River we caught lots of whitefish. It was the same in the Delta down here. We have seen that the whitefish [abundance] is going down very slowly. Pretty soon, maybe 5 years from now, I might catch 6 or 7 fish to one net [per day]. You see, it [the abundance] is slowly going down. We have tried to figure out how the abundance went down. At Norman Wells, where they are drilling that oil field the smoke ends up in the spring run-off to the river. We saw that was no good, but we also saw there was nothing wrong with the water. Still, the whitefish is going down [in numbers] while herring fish [least or Arctic cisco] and coney are still numerous. We see a lot of loch [burbot] now.

Comment: I lived in Fort Norman [in] 1969. People from Fort Norman never caught [broad] whitefish there. In summer, during the month of July, they do some herring [Arctic cisco] fishing. I believe that guy - what he's talking about. They went to Willow Lake to get the whitefish and they go to [Great] Bear Lake to get the trout in summer. Now, I go up to [Great] Bear Lake and Fort Norman. What happened to fishes? There's no whitefish there. They had a herring net and they fished herring in the summer a little too. I believe that guy that the fish are further up the river or some place. Thank you.

Table 1. Pre-1955 broad whitefish harvest estimates. (See text for methods employed to obtain estimates).

	Numbers			Round Weight (kg)		
Line	Low point	Upper point	Mid-point	Low	High	Mid-point
1	112000	315000	213500	427000	640500	533750
2	175000	262500	218750	437500	656250	546875
3	141000	264600	202800	405600	608400	507000

APPENDIX 1

Broad Whitefish Traditional Knowledge Study List of Questions

The purpose of the study is to gather local Inuvialuit residents' knowledge about:

a) the past and present fishery
b) the life history of the broad whitefish
c) the environmental conditions that variously affect whitefish behaviour, and
d) observations on past or present management practices.

The Fishery:

1) How is the broad whitefish fishery carried out today? What places, times of year, and fishing equipment are important in this fishery? [Mark and number fishing locations on maps].
2) When you go fishing at different times, who goes with you (family members, partners or others)? How do you share the catch (in the camp and later in the community)? How have these arrangements changed over the years?
3) Have there been any environmental changes in recent times that have influenced the whitefish harvest? If so, what are these (e.g., changes in break-up or freeze-up, river flow or water quality changes [temperature, clearness/cloudiness, etc.], ice thickness)?
4) How important is this fishery to people's diet and economic well-being today? Does the fish have other value to the community (e.g., uses of fish oil, as medicine, on special occasions maybe)?
5) How important is the present-day broad whitefish fishery compared to earlier times (in your parent's day, or five years ago say)? In earlier times, what (estimated) quantities of fish were harvested, seasonally and by what different techniques? How were fish stored and used in those days?
6) We would like to get some measure of the fishery in the past and today. Could you indicate how many fish you caught each day, or each season (or some other way of reckoning?) in the past [say when you had dogs] or in the past couple or three years say?
7) What makes a successful fisherman/ fisherwoman in Inuvialuit society? How can a person become a better fisherman/woman? Are there proper ways to treat or think about fish (or the other fish and animals people need and use)?

Naming:

8) Are there Inuvialuit or local names for different types of broad whitefish?
9) Are there other kinds of whitefish in the area, and how do you distinguish them from broad whitefish?
10) Do people distinguish (by names or other means?) between broad whitefish of different ages (young or sexually immature from adult fish maybe?) or at certain times/seasons of the year?

Life History:

11) What can people say about the <u>breeding</u> habits: e.g., where do the fish lay their eggs, how do they behave at that time, do they breed every year, are they feeding at that time, etc.?
12) Are there special conditions (of light, water temperature or other characteristics) that the fish need before they will lay their eggs?
13) What are the best environmental conditions to ensure the eggs hatch and the young fish do well (and in contrast, what conditions do not favour the survival of eggs and young fish)?
14) With regard to whitefish populations <u>numbers</u> or abundance, do you know of any times when whitefish were very numerous, or alternatively, very scarce? Do these changes in population numbers occur regularly or irregularly, say every few years? If there are "cycles", about how many years are there between high and low population numbers?
15) What about <u>migration</u> (i.e., what time of their lives are the fish in lakes, rivers, salt water)? Are these migrations regular, say every year, or do the fish spend several years in some parts of

the territory they move over during their lifetime?

16) Do the fish move in the groups having similar characteristics (say, certain age groups moving together from the sea to river, or out of lakes)?
17) What can people say about the habitat choices the fish make or seem to prefer while they are in lakes, rivers, or the sea (that is, do they avoid certain types of water if it is maybe too cloudy, shallow, fast moving) or avoid certain bottom characteristics (e.g., muddy, vegetated, rocky, etc.)?
18) If the fish do seem to make these choices [of different locations] do they do so at particular seasons of the year, or when the fish reach certain sizes or ages perhaps?
19) Do broad whitefish suffer from diseases or parasites that you think cause problems (to the fish, to other animals or to people that eat them)?
20) If they have these parasites, then what problems are caused (e.g., do they affect the fish's ability to breed or to survive, cause dogs to lose stamina, etc.)?
21) Are fish living in some places more heavily diseased (or have more parasites) than in some other places?
22) Apart from diseases or parasites you can see, are there differences in fish quality that you can taste, smell or feel, or differences in texture or colour that have occurred at any time in the past or recently?
23) If there are differences in quality, do you have any thoughts on what might cause them, or any other information related to these changes?

Management Issues:

24) If it is necessary to limit the size of the catch for any reason, how is this best done (e.g., by only allowing certain fishing gear to be used, or to close certain areas to fishing, or not allowing fishing at certain times of year, or by some other means perhaps)?
25) Do you think quotas are a good way of regulating a fishery?
26) Some fisheries are regulated by fishing until it's no longer worth continuing and then moving away from that fishing place to another area in order to let the fish stock in the first area recover. What do you think of this as a management strategy? Could this be a method that was used in earlier times or could be used in future?
27) What are your views on fishery management carried out today? Do you have problems with the way it's done at present, and if so, how could management be improved?
28) Are there any traditional management methods that Inuvialuit used but that are now no longer used or have become weaker or less often used? Could these methods be brought back into use now? What sorts of changes might have to be made to make these traditional management methods work today?
29) Though I/we have taken a lot of your time, are there any other bits of information that you think could help us in this study that we haven't asked you about?

APPENDIX 2: Characteristics of Inuvialuit Quoted in this Report

Individual	Gender	Birth Year	Residence
2	F	1933	Inuvik
3	M	1935	Inuvik
4-6	M&F	1937; 1941	Inuvik
11	M	1923	Inuvik
15-16	M&F	1936; 1932	Inuvik
17-18	M&F	1933; 1935	Inuvik
23	M	1939	Inuvik
38	M	1936	Inuvik
39	M	1931	Inuvik
44	F	1922	Inuvik
44B	M	1937	Inuvik
44C	F	1932	Inuvik
45	M	1945	Inuvik
46	M	1922	Inuvik
48	M	1927	Inuvik
50	M	1937	Inuvik
58	M	1942	Inuvik
64-70	F&F	1922; 1926	Inuvik
70A	M	?	Inuvik
72	M	1917	Inuvik
72A	F	1917	Inuvik
74-76	M&F	1920; 1918	Inuvik
77	M	1941	Inuvik
78A	M	1940	Inuvik
79A	F	1920	Inuvik
80	M	1947	Inuvik
81	M	?	Inuvik
81A	M	1931	Inuvik
82	F	1940	Inuvik
82A	M&F	1910; 1911	Inuvik
86	M	?	Inuvik
87	M	?	Inuvik
87A	M	1931	Inuvik
88A	F	?	Inuvik
89	M	?	Inuvik
89A	M	?	Inuvik
90A	F	?	Inuvik
91	M	?	Inuvik
93	M	1933	Inuvik
94A	M	?	Inuvik
96	F	?	Inuvik
98	M	?	Inuvik
00	M	?	Inuvik
200	M	1969	Inuvik
AG	M&F	1908; 1912	Aklavik
CS	M	1934	Aklavik
RP13	M	1952	Aklavik
RP15	M	1926	Aklavik

APPENDIX 3
Sample Statements of Information Considered in Estimating the Inuvialuit Broad Whitefish Harvest

"We used to get lots of fish, 500 fish using three nets. I would put the fish in the smokehouse...I would get crooked back, whitefish, jackfish, coneys and sometimes loche. We ate only the whitefish." [44]

"We used to catch 1000 fish." [44B]

"One fall when the fish were running we got 100 fish a night." [46-7]

"I had 25-30 dogs; one year we had 10,000 fish." [48]

"We used broad whitefish for eating and dogfeed and also for mink food. We had up to 800 mink at [the mink farm at] Napozak; the mink would eat 100 fish a day. We had about 30 nets out; we never made stock [fish] or anything, just put them in the ice house." [50]

"We used broad whitefish for ourselves and our dogs; we used to catch about 5000 a year." [58]

"Long ago we had 6 to 7 nets in the winter and fall. We used to catch about 3000-4000 fish in a year, enough to last a long time." [72]

"We used to catch lots of fish every year, maybe 1000 or more. We gave any kind of fish to our dogs." [74-75]

"We used to have to get at least 5000 to feed the dogs for the whole year." [77]

"We used to set about 3 or 4 nets; we got about 5000 [fish] during that one fall." [80]

"Sometimes in the summer we would get over 100 fish every time we checked the nets a couple of times a day." [86]

"We had to fish lots for the dogs; fishing was important as it was for family and dogs. We ate the whitefish, made dryfish and stored some in the ice house for later use. We used to get about 50 fish a day." [87]

"We caught 150-200 fish a day long ago. When we used to look at the net in the winter we used to get about 40-50 fish; we looked at the nets about twice a week." [88A]

"We had about 20 dogs, and we used to feed them one fish a day. We used to put some fish in the ice house and we used to make dryfish. Our average was about 50 fish a day, and multiply that by 100 days." [89]

"I would get a few hundred fish for my dogs before the ice was thick; every fall I would do that." [3]

"We got about 80 whitefish a day when they were coming out [of the creeks] in the fall time...One time I got about 700 whitefish one day and about 400 other fish that added up to about 1100 fish after freeze up...That time, when JFK got shot around November, I counted all the fish I caught; sometimes some people count their fish. We used to make stick fish, 10 in one row and stick about 50 fish a day. In about a month we would have about 500-1000." [11]

"We used to get about 300-400 fish a day because we used to set two fish nets." [15 and16]

"Depending on how many nets we set, we caught usually about a hundred or a little over." [23]

"When the fish were running [soon after freeze up] you could get about 150 a day." [78A]

"They used to catch about a hundred fish a day in the fall for one month around November. They used about nine or 10 fish nets for about 14 days. They used to set about 10 13-14 ft nets. They used to catch about 200-300 fish a day for a month and a half." [82]

“In one August to November fishing season at Horseshoe Bend, two of us caught 23,000 fish...I’ve caught 300-400 a day out here. One year we had 36 dogs, and we had to get enough fish for these dogs for the whole winter, so we kept out nets out fairly late and we had stacks of fish.” [81A]

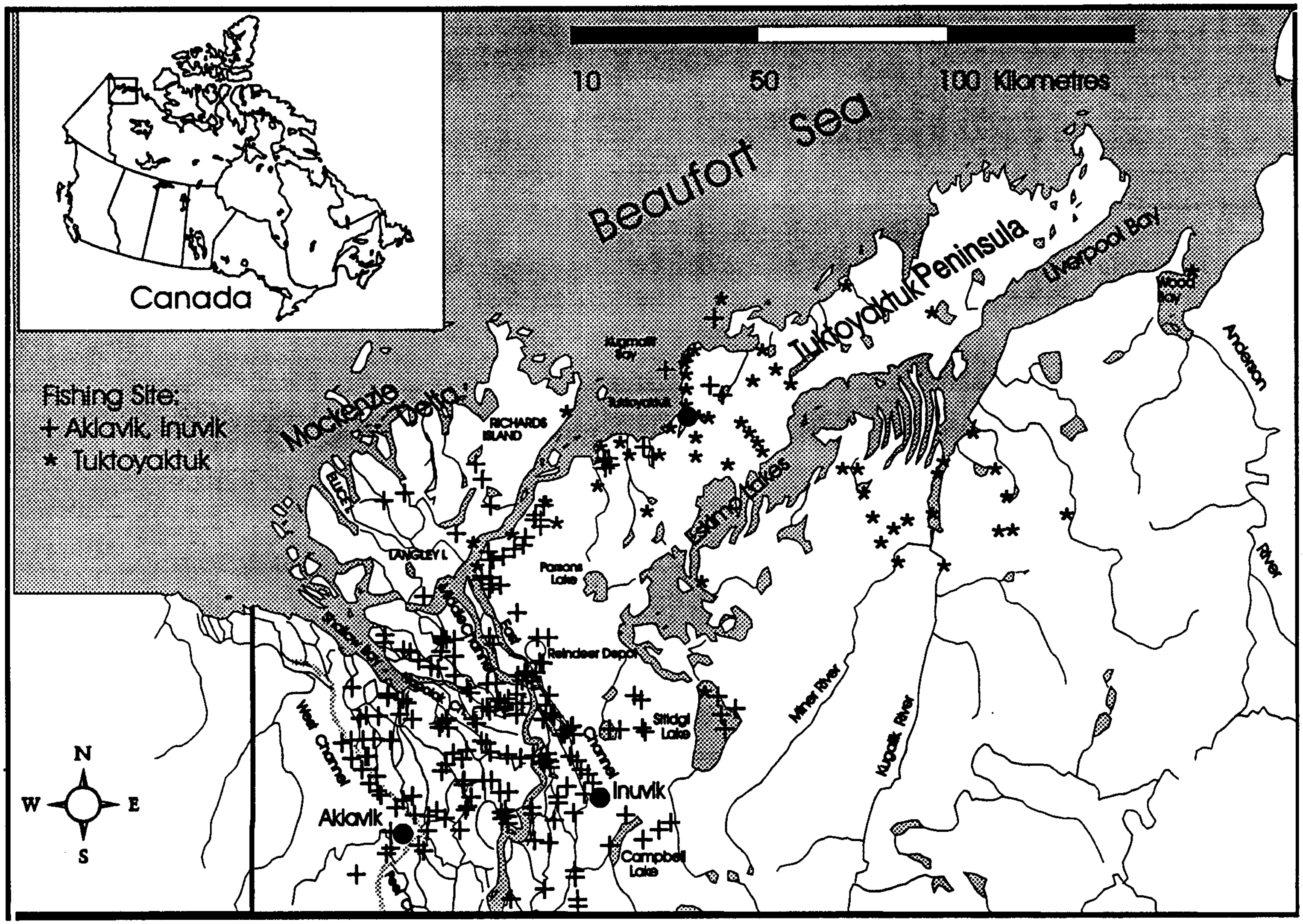

Figure 1. Fishing sites for broad whitefish based on Inuvialuit traditional knowledge from the communities of Inuvik, Aklavik, and Tuktoyaktuk.

INFORMATION REQUIREMENTS FOR FISHERY MANAGEMENT AND OVERVIEW OF SCIENTIFIC APPROACH

by

Ross F. Tallman and James D. Reist

ABSTRACT

We discuss the information needs for scientific fishery management of the broad whitefish in the lower Mackenzie River and present a rationale to unify the scientific studies undertaken between 1992-94. The basic principles are to define clearly the biological unit of management and to determine how this unit produces a sustainable resource. The Mackenzie River broad whitefish problem can be best fitted into a framework of a model for mixed-stock fishery analysis. Thus, the scientific program focussed on studies of migration, genetic and morphological variation, inter-stock variation in productivity and vital rates.

SUMMARY

Catch information and an understanding of the biology are required to effectively manage a fishery. Land claim natural resource management boards are presently gathering information on harvest in their respective areas but knowledge of the relevant aspects of the biology of the harvested species is limited.

Relevant biological information needs can be summarized into two major categories: What is it? and How does it work? Identification of what one is working with must be investigated at three levels: 1) the species of interest; 2) any races, subspecies or ecotypes (forms that differ by their ecology, such as landlocked and sea-run types) within the species; and 3) the degree of population (stock) uniqueness within the species and its ecotypes. In the Arctic, the taxonomy of many species is poorly known, as is knowledge of the variation within species. For example, charr from the Yukon north slope have only recently been confirmed to be more closely related to the Dolly Varden charr, *Salvelinus malma*, than to Arctic charr, *Salvelinus alpinus* (Reist et al. 1997). Because the biology differs between stocks and species, without clearly defining the management unit in biological terms, managers may recommend inappropriate measures for the conservation of the resource. Once the harvested units are identified, the understanding of how the species, its ecotypes and populations function to produce more fish and grow them to harvestable size is essential. Population function can be summarized in terms of variation in population size, growth, age at sexual maturity, fecundity (egg number), and mortality (death) rates. A model including all of these statistics could allow prediction of the response of a stock to harvesting and help managers in recommending appropriate yields. Another critical information requirement is to understand the extent of migrations (if any) in time (when during the year and when in the life) and space (from what place to what place) undertaken during the life cycle. With a clear understanding of these aspects of the biology the manager can develop harvesting strategies that will conserve the abundance of the fish while providing the maximum catch. To monitor the results of mangement decisions it is important to be able to reliably estimate the stock size or abundance of fish.

The broad whitefish, *Coregonus nasus,* and its fisheries in the lower Mackenzie River present considerable challenges to fisheries management. The Mackenzie River is one of the longest and most complex rivers in North America. Its delta is rivalled in size and complexity only by the Mississippi River delta. Imposed on this is the great variability of the arctic climate. From the limited scientific information available and from the traditional knowledge of the communities a general model of the life cycle has been developed (see Reist and Chang-Kue 1997, this publication). The broad whitefish apparently possess a

complex life cycle undergoing extensive migrations between over-wintering areas in the outer delta and spawning areas to the south at Point Separation, the Peel River, Arctic Red River and at the Ramparts Rapids (see Fig. 1). In doing so they regularly cross the boundaries between the land claim areas of the Inuvialuit, Gwich'in and Sahtu peoples. The spawning stocks are hypothesized to be genetically distinct (meaning that on average a fish from one stock will be more closely related to other members of that stock than it is to fish from another stock; see Reist 1997, this publication for confirmation of genetic distinctness). If this is the case then each stock should be managed separately. However, harvesting at Horseshoe Bend, the West Channel near Aklavik and other sites along the Mackenzie River is done while the stocks are mixed together, making stock-by-stock management difficult. The geographic scale also makes direct monitoring of each stock prohibitively expensive in time and resources. In addition, individual stocks may be harvested several times during the course of their migrations. Finally, the turbid waters of the Mackenzie River preclude simple methods of estimating escapement such as aerial surveys that have been used successfully for salmon management in large rivers.

To overcome the problem of estimating stock size a research plan was developed to provide the necessary information for mixed-stock fishery analysis. This type of analysis has been used effectively to manage mixed-stock fisheries such as the Stikine River sockeye salmon, *Oncorhynchus nerka,* fishery and the West Coast chum salmon, *Oncorhynchus keta,* fishery (Wood et al. 1987). Mixed-stock fishery analysis requires three major steps in information gathering. First, the degree of population variation must be characterized in terms of genetic, morphological, and demographic characteristics. Learning sample data are collected from each major spawning stock unit to define stock distinctness. In the Mackenzie River broad whitefish this meant we characterized the units as Point Separation, the Peel River, Arctic Red River and upper mainstem/Fort Good Hope stock. Second, samples must be collected from the major fishing areas where mixing of stocks occurs. The percentage contribution of each stock to the fishery can be determined by using a statistical technique known as maximum likelihood estimation (Wood et al. 1987). Thus, for example, at Horseshoe Bend the fishery might be composed of 20% Point Separation, 20% Peel River, 50% Arctic Red River and 10% Fort Good Hope fish. Finally, a direct estimate of absolute or relative abundance for one index stock will allow the calculation of the overall stock size (the combined total number of fish available to the fishery from all stocks) and the abundance levels of each individual stock unit. For example, using the above percentages, if it is determined that the Arctic Red River stock is 50,000 fish then there must be a total of stock of 100,000 with contributions of 20,000 from Point Separation, 20,000 from the Peel River and 10,000 from the Fort Good Hope stock. Gathering of this information over a number of years can tell the manager if a particular level of harvest is sustainable (can be maintained over a long period of time) or if it is damaging to the future of the fishery (harvests will decline with time).

The scientific program for the Mackenzie River broad whitefish focusses on the first phase of the process to develop mixed-stock fishery models. It encompasses studies of migration, genetic variation, morphological variation, variation in traits important to stock productivity and understanding the demographics of populations to determine what is it? and how does it work? (see Fig. 2). This information will be combined with the findings of the traditional knowledge component to help managers make fishery decisions.

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COMMENTS, QUESTIONS AND ANSWERS

Billy Day: I think there's still a lot of us having a problem with the statement that all the spawning is being done outside of the ISR. In the fall time we do a lot of fishing through the ice at the mouth of the creeks [in the Delta]. When the creeks start drying up there's millions and millions of minnows [juvenile coregonids] coming out of the lakes. Now, where are those minnows coming from if they're not spawning somewhere up in the lakes.

R. Tallman: It appears from some of the information you're saying that there probably is some spawning areas in the ISR. In the case of the large number of small fish coming out of lake systems down the river, what's been found around the Tuktoyaktuk Peninsula is that those fish are almost all immature except for fish that are about to come to spawn. In the creeks that have been sampled in previous research, there didn't seem to be a resident spawning population. The current model for migration of broad whitefish proposes that the larvae (the very, very tiny post-egg fish) are swept down the Mackenzie up into the Tuktoyaktuk Peninsula area. That model describes the sea run, long distance migratory type but I suspect that there are probably a number of undiscovered spawning stocks of a lake-dwelling type in the ISR. The lake type spawns in tributaries of the lake. As well, they could be migratory but we don't know and I would take the traditional knowledge as indicating that the story isn't complete on this question.

Billy Day: Once the eggs are laid, how long does it take for them to hatch and become a fish?

R. Tallman: I've done some experiments on that. We have reared fish from eggs taken in November and they've hatched in the last month or so. We think they probably take a little longer than that in the wild and probably are hatching pretty close to breakup. When they hatch they are like a small ribbon. They don't look much like a whitefish at all. They are just a pair of eyes and a long ribbon-like body about this big [less than 10mm]. So, when you see young fish that are clearly identifiable as whitefish, they are probably a year or more old. Somebody mentioned seeing them in the stomachs of some fish this morning. Those aren't necessarily hatched from that site.

Billy Day: The minnows that I'm talking about are tiny little fish and they only come out into the creeks when water is flowing out of the creeks [in spring]. When the water [in the main channel] comes up a little bit you don't find a lot of jackfish or coneys around the mouth of the creeks because these little minnows are not flowing out. But once the water starts to drop and the water starts coming out of the lakes that is when they start coming down by the millions.

Ross Tallman: Those might be fish that have grown for a while, for a few months or they could even be fish that have put in a year [in the lakes]. We don't have very good information on the very young fish such as the size of a one-year-old.

Ken, I should ask you about your findings on the Peninsula – I recall that you had many age one fish.

Ken Chang-Kue: We had many [age] 0's and one year olds.

R. Tallman: So what's the size of 0's when you were there?

K. Chang-Kue: They varied anywhere from 20 to 75 or so mm.

R. Tallman: So they would be within that size range within their first year, which means they grow very rapidly. They are a quarter of an inch long, initially. So what Ken's saying is that they would be between about an inch to a few inches long [at age 0].

Billy Day: All the creeks that are running out of the lakes in the Delta, most of them have lakes above where these are coming out of. This is where people go for loch and coney in the fall time.

K. Chang-Kue: I'll maybe be able to shed some light on that. There was one study done, I think it was 1982 or 81. There was a company called LGL that was given the job of studying a few Delta lakes, especially the ones that had connections to the Mackenzie Delta channels. They found that at spring breakup a lot of little fishes got flushed into these lakes. The water flows into the lakes from the flooding of the Mackenzie Delta. They spent the summer counting all of the fishes that were coming in and out of some of these lakes. What they found was that there was a lot of small jacks [northern pike], loch and [broad] whitefish but mainly the crooked-backs and least ciscos, small inconnu and small Arctic ciscos. The broad whitefish were very few and far between. In fact, the people that have been doing that research came to me and said 'how come we can't find any broad whitefish'? And I said when we were studying coastal streams in Tuk Peninsula we saw a lot of small broad whitefish coming up those rivers but we couldn't figure out where the small crooked-backs and the small least ciscos were. So, somehow by the way the currents flow in the spring, the small least cisco and the crooked-backs get washed into the delta lakes and channels. The broad whitefish, maybe by their behaviour, stay up in the main current and get washed out to the coast. They use the coastal lakes. So, these species have sort of divided the places where they spend their summers. As you've observed when these lakes freeze in the winter time a lot of these little fishes come out of these lakes. They spent their summer feeding but as it starts to freeze they come out. It is not broad whitefish that are coming out, it's mainly other whitefishes. That's where the loch are sitting at the mouths of streams feeding on them. So, broad whitefish are found along the coast and the outside edges of the delta but the delta lakes and channels have the other species of whitefishes and ciscos.

Lyle Lockhart: Ross, I wanted to question you a little bit about that last slide where various modules of study fitted in with the overall model. From what I heard this morning, many of the questions that people raised have as much to do with the quality of fish as the quantity. I'm just wondering if you are developing an overall model. Shouldn't we have a quality component in there? That question came up, I think, about four times this morning. I could think of ways to start building that in but it doesn't seem to be there now. I'm wondering if we are answering great biological questions and that maybe we're not answering questions that the people are asking.

M. Papst: When the study was designed the question of quality was one of the things that was in the forefront. The difficulty was that we were also getting a great deal of concern at the time that contaminants and quality type data have been collected and never brought together. So it was decided to make a general effort to bring the quality questions and the contaminants information together in a way that people could see it and then begin to select which particular species we were going to want to do more work on. So, as part of the same funding and the same plan as the project that Ross was talking about there was this effort to bring together the general data on the quality and contaminants in all the animals. And it's our hope that over the next several years we'll concentrate on those that we're either concerned about or those that we want to continue monitoring their usage. So, there was a plan to it.

R. Tallman: I'd be quite interested in talking to you about the model you have in mind but probably not worked out at the moment. I guess for this there seems to be that when contaminants occur it's important to put them in the ecological context. So, as ecologists we've pursued that side of it.

Lyle Lockhart : I don't really mean contaminants. That's one component of quality, things like the water we flush. You can imagine three or four ways to explain that. Yet it was consistently mentioned this morning as an issue brought up in the communities is that if you're out there getting samples to analyze for genetics or to analyze for morphological characteristics where you've got to kill the fish it just seems a shame not to extract information relevant to a question like that at the same time on the same specimens.

R. Tallman: Those specimens are available. I believe Jim made them available each year for people to work on that. So, the information is available for someone to do that. I'm not an expert on doing that so I assumed others would.

Don Dowler: This is more of a comment that a question. This discussion has brought up what seems to be a recurring unanswered problem - small fish coming down the creeks in the outer Delta. I think there's a real need to identify them, what they are. It seems to me that if the bulk of the spawning of the broad whitefish is up the river I can't see that they [juvenile broad whitefish] would be getting washed down the Mackenzie and coming out of a coastal streams at the same time. I certainly think that this is a problem that needs to be addressed.

Jim Reist: If we go on much longer in this discussion then I won't have anything to talk about in the next talk. The short answer to your question, I think, Don, is that we have very poor understanding of the role of all the many myriad hundreds of thousands of lakes and small channel systems in the Delta. That's one big area of research that must be, I think, put on a plate and addressed at some point in time. As Ken explained just a moment ago, it seems that the species are splitting up the habitat and their use of the habitat. I'll explain the broad whitefish model as we understand it. We can, maybe, address some of the questions for other species at that point in time. The short answer is that the delta lakes are used. They may not be used by broad whitefish to the same degree as the Tuk lakes and the outer delta/ Richard's Island's systems are but they are used by other species. They are very important. There may be some level of broad whitefish usage of those lakes. The young broad whitefish may actually live in those lakes through that summer and come out in the fall as Billy has observed. It may be that they also overwinter in some of those lakes and come out the next year as one plus year olds and then continue on down the systems out through the delta and the Tuk Peninsula. There are lots of unanswered questions.

Don Dowler: That's why I say I think it's important to really find out what these small fish really are. It's more understandable if they were two-year-old broad whitefish than if they were just recently hatched. When you go back put in for lots of money because we're gonna need it up here.

R. Tallman: I guess I'd like to say one thing to that. Larval fish that have hatched would be out in the water column and completely incapable of resisting any current at that stage. On the other hand, within a couple of months if we can keep them going, they will probably be strong enough to then migrate against a moderate current. So, that may explain how they can be pushed downriver at first and then go upstream into lakes on the Tuktoyaktuk Peninsula. [The Mackenzie] spring freshet is very strong and there is tremendous flow pushing along. The one thing that we didn't find in a place like Arctic Red River is any juvenile whitefish. But we did find lots of big fellows ready to spawn.

Don Dowler: Just one more question. Ross, you mentioned about the fish that you hatched. I didn't quite understand how long it took for them to hatch.

R. Tallman: At approximately 3 degrees celsius (which would probably be a little warmer than they would incubate at in the river), they took from November until just about a month ago. So, from last November when they were taken [it took] about 3 months [to hatch]. Of course, they probably incubate, in the wild, very close to 1 degree or zero. So, they would take longer. They may take twice that time in the wild. I suspect hatching is timed with [spring ice] break up

Don Dowler: The general consensus is that fall spawners hatch in the spring?

R. Tallman: There is no contesting that idea.

Billy Day: In the lakes out in the Delta and in the creeks I've seen during my time around here, I've seen many, many juvenile whitefish from about that size to maybe about that size. So, there's many, many juvenile whitefish out in these lakes out here.

R. Tallman: I would sure like to get out and see some of this because we could not find juveniles in the south. There may be some other fishermen who do find them. We did find them in the big lakes like Travaillant Lake but not in Arctic Red River. I think it's without doubt that this area, the Delta, Tuk area, is very important for the young animals.

Billy Day: For me to put in a little plug for our trainees here. Can you remember, Ross, before we got this training program started, we met in my hotel room in Winnipeg. We talked about this training program and I mentioned that if we had people in place then we would have to look at a short season of doing things that we would have the people here to do it at different times of the year.

R. Tallman: Yes, and that's going to be a real asset. I think those people might be able to go in and sample at certain sites and get the information. We even have an aging lab here [Inuvik]

M. Papst: I think we'll move on to our next topic. I think we’ve already started it on life history. Two other quick comments I'd like to make are, as we go on we're going to hear a lot about aging. If you want take a look at some point at some aging material that's over on the side there. It belongs to, for lack of a better term, the Inuvik Aging Lab. [This] is something that came out of this program and is conducted here in Inuvik and is doing aging and some field sampling on contracts. They're doing an excellent job. It's worthwhile taking a look at their display. The other comment I'd like to make is that there has actually been an independent study of whitefish quality for the experimental fishery. I have had an opportunity to visit the Freshwater Fish Marketing Corporation's plant operation in Winnipeg when they were processing whitefish from here. The common opinion of all the people there and their clients was that the quality of the whitefish from here was beyond reproach, even though there was a delay because of the distance to get it there. It was actually some of the best whitefish. The older people working in the plants said they hadn't seen whitefish of that quality in 10 or 15 years. This wasn't part of this study and there certainly has been an independent assessment on the quality of whitefish. The quality is very high.

Joe Benoit: A couple of points before you go to far into the workshop, first being you've got a lot of elders here from the area that use Broad Whitefish and so on. I think that during your traditional knowledge study taking all the information they had to offer and now you have a lot of information to offer them, I think you should give them the courtesy of providing them with some English terminology. There are a lot of words you guys are using that they can't understand. Many of us can but they can't.

M. Papst: It's a point very well taken. We're trying as best we can. All I can say is that I'm available either up here or at the front when we take our breaks. If there is any indication that particular words are giving them a problem have them come and ask me or I'll seek you out. We'll sort that issue out. But we are trying to avoid it as much as we can. You know, it's like everything else, the scientific community has a little bit of slang. When we start slipping into that, I'm going to try and catch them. If not, give me a nudge as you've just done and we'll try and correct it.

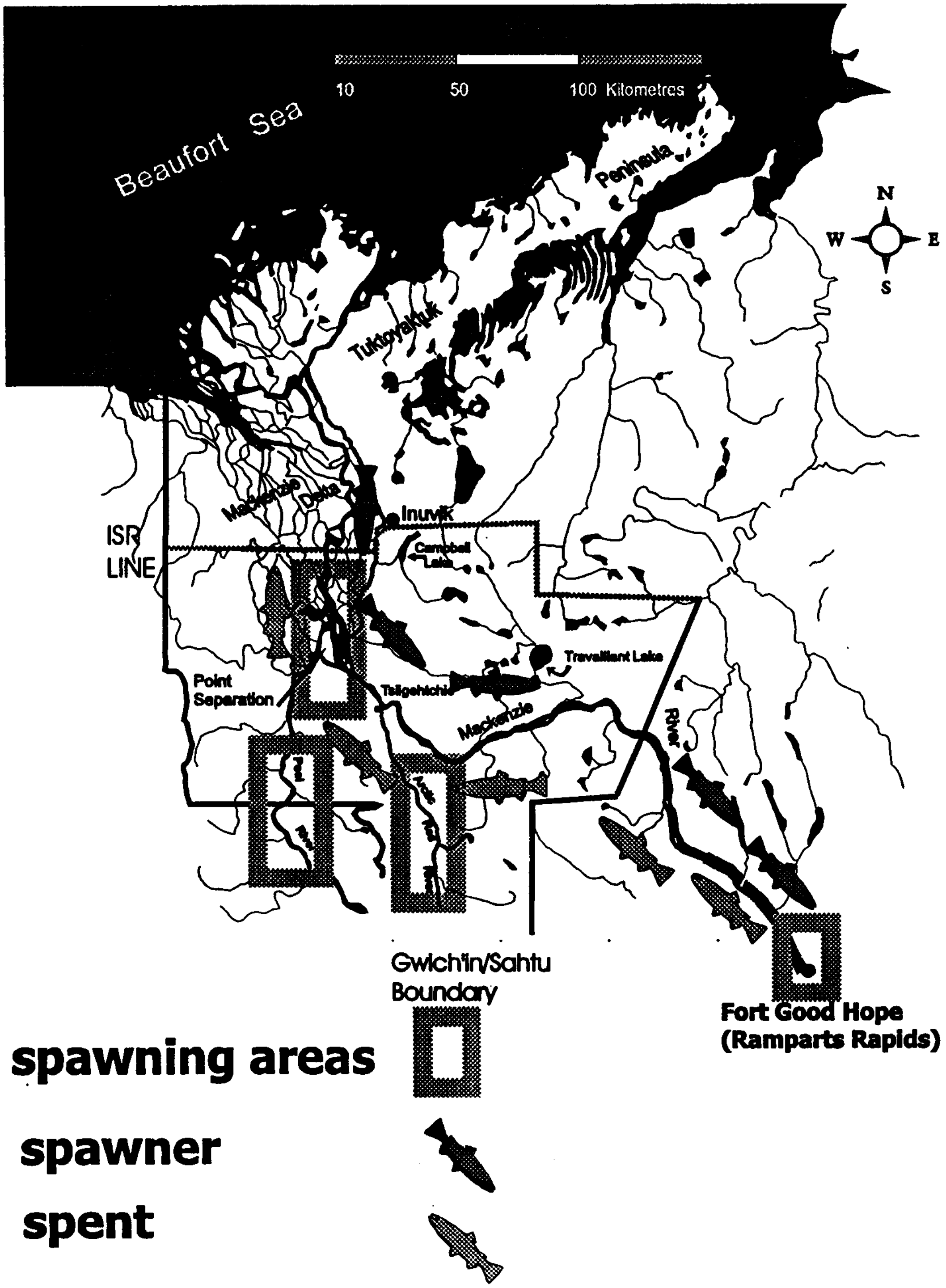

Figure 1. Migratory movements of broad whitefish in the lower Mackenzie River. Anadromous spawners migrate from the Tuktoyaktuk and outer Mackenzie Delta to the spawning areas marked as rectangles at Arctic Red River, Peel River, Point Separation and the mainstem Mackenzie River at Fort Good Hope. Spent fish return to the delta to over-winter and feed.

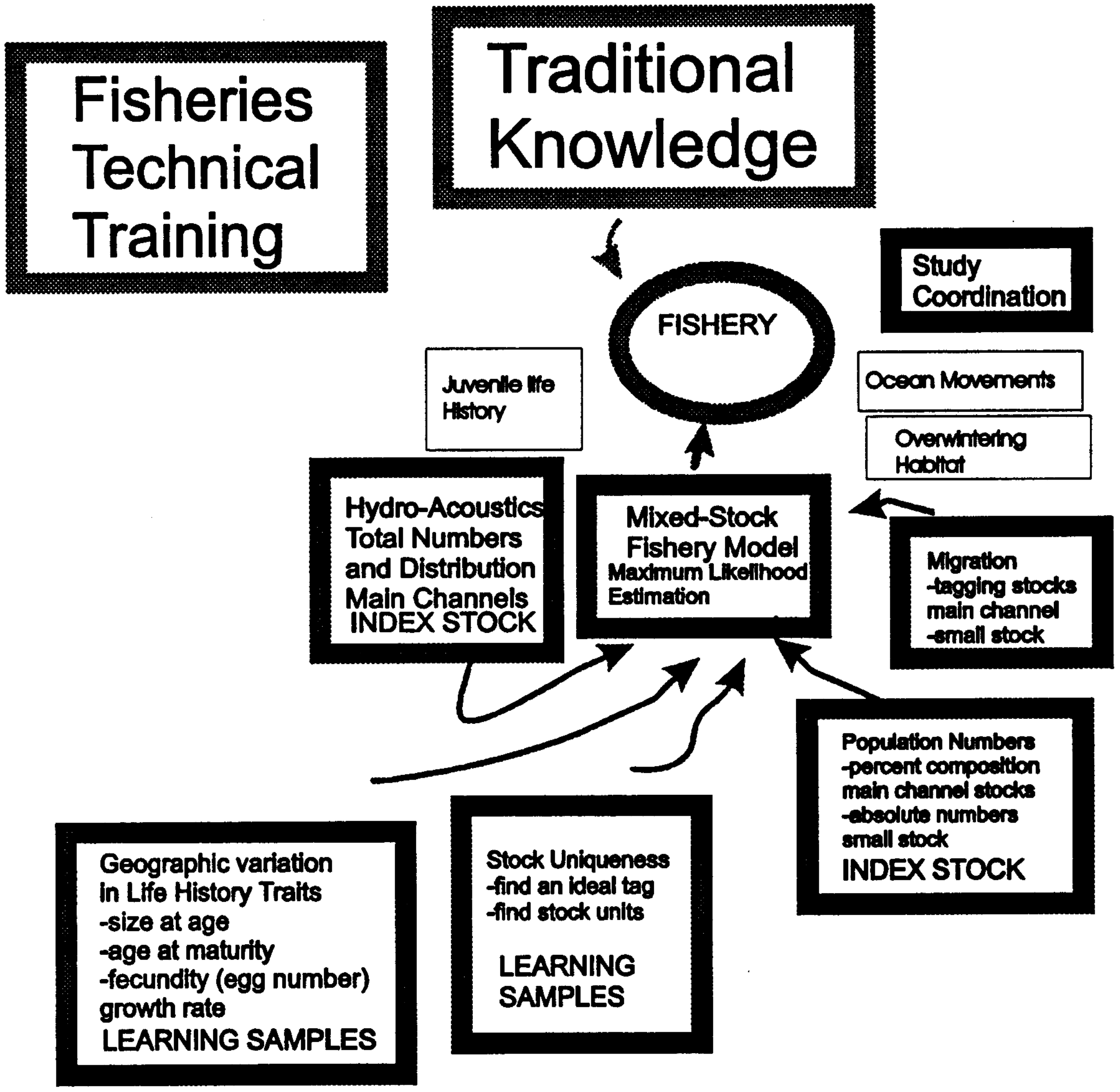

Figure 2. Knowledge required and plan for fisheries management research of broad whitefish in the lower Mackenzie River and its delta area. Fishery management must combine fisheries technical training, traditional knowledge, and scientific knowledge. The cells represent the knowledge needs, biological and otherwise. Cells with heavy borders were addressed in this study.

THE LIFE HISTORY AND HABITAT USAGE OF BROAD WHITEFISH IN THE LOWER MACKENZIE RIVER BASIN

by

James D. Reist and Ken T.J. Chang-Kue

ABSTRACT

The current understanding of broad whitefish life history in the lower Mackenzie River system reveals a complex pattern that involves multiple life history types and numerous aquatic habitats throughout the area. Both semi-anadromous and lacustrine life history types are known.

The semi-anadromous form exhibits a complex life history that throughout the year involves migrations between aquatic habitats in the Inuvialuit, Gwich'in and Sahtu regions. The life history of the lacustrine form is poorly known but appears to be restricted to local situations involving larger lakes and their tributary river systems. The semi-anadromous form supports numerous fisheries by all native groups throughout the area whereas the lacustrine form supports only local fisheries. The complexity of the life history results in significant problems for the management of this resource.

INTRODUCTION

Life history is the typical pattern followed by most individuals within a particular group of fish (e.g., taxon, species, etc.) throughout their lives. The characteristics of life history include the area the group occupies at different stages of their life, movements between those areas, and the various activities conducted within those areas.

Broad whitefish, *Coregonus nasus*, of the lower Mackenzie River exhibit a complex life history that may consist of more than one general type. This life history involves regular migrations which result in complications for the management of fisheries on this species. Several previous publications have summarized the general life history to some extent (e.g., Bodaly et al. 1989; Chang-Kue and Jessop 1991; Reist and Bond 1988). However, these publications have not provided the detail necessary to understand the entire picture of the complex life history of broad whitefish. This paper describes the life history in detail and focuses primarily upon the anadromous type (see below) because this is the most well known. Additionally, the different aquatic habitats of the lower Mackenzie River basin are categorized and those critical to life history of broad whitefish highlighted. This paper is intended as a summary of previous work, thus relies heavily upon the following publications: Bond 1982; Bond and Erickson 1985; Chang-Kue and Jessop 1983, 1991, 1992; Lawrence et al. 1984; and, Reist and Bond 1988.

DEFINITIONS

Before examining the life history in detail some definitions are necessary. Broad whitefish are **migratory**. This means that they undertake regular, usually directed movements away from and return to specific habitats to conduct particular life history functions (Northcote 1978). These life history functions include activities such as spawning, feeding and overwintering. Some migrations can be very short involving only a few kilometers of distance and others can be very long involving hundreds or even thousands of kilometers. The degree of migration is usually determined by the habitats in which a particular group of fish conducts critical life history functions. Migrations usually are seasonal and repeated on an annual cycle.

The group that exhibits a particular set of migrations and that utilizes particular habitats is usually referred to as a **biological population**. Such populations can also be defined in genetic terms and thus are genetic stocks (Reist 1997a, this publication). Usually several biological populations exhibit the same general type of life history and differ from each other only in the use of particular habitats. For example, members of several different stocks may all feed in the same area but each may spawn in a separate habitat such as a specific tributary. All the individual populations that exhibit a similar type of life history can be generally referred to as a specific **life history type**. Within a particular species, several life history types may be possible. For example, three life history types have been described for broad whitefish from Siberia: 1) lacustrine, 2) riverine, and 3) anadromous (Berg 1962). These life history types differ greatly in the types of habitats used and in the distance of migration necessary to travel between those habitats.

Migratory fish that use both freshwater and saltwater habitats can be of several types. **Anadromous** fish spawn as adults and hatch as fry in freshwater habitats, but spend most of their life in marine water (McDowall 1987). As will be seen below, broad whitefish do not usually enter wholly marine water but rather stay near to the coast in brackish water areas. The immature stages also feed in freshwater. Also, the adults may make several round trip spawning migrations between freshwater and coastal areas. Thus, despite the label given by Berg (1962), in the strictest sense this life history type properly should not be termed anadromous. A more appropriate descriptive term is **amphidromous** which describes fish that migrate regularly between freshwater and marine habitats (Craig 1989; McDowall 1987). However, because anadromous has commonly come to mean breeding in freshwater with at least some time in marine environments, it will be used as the general term describing this life history type in broad whitefish. Because broad whitefish rarely occur in waters with salinities greater than 20%, that is, they prefer the brackish water habitats, the term partially or **semi-anadromous** might be a better descriptor. The latter is used here.

Fish that spend most of their life history within lakes or perhaps also the tributary rivers to those lakes are termed **lacustrine**. These fish may also exhibit seasonal migrations between different habitats but these are usually very much shorter than those of anadromous fish and never involve marine waters or coastal environments.

Fish that confine their life history to environments found in very large arctic rivers and in particular to the mainstem areas of those rivers are termed **riverine**. These fish may show seasonal migrations between different habitats and perhaps enter nearby lakes, but as for lacustrine fish, the migratory distances tend to be very much shorter than those of anadromous fish. This life history type also does not regularly enter estuarine or marine environments during its life.

The key defining criteria for designating life history type are the place where the fish spawn, the place where they gather most of their food to grow to adults, whether they enter or pass through sea water or estuarine environments, and the distance they migrate to conduct these activities.

It is also necessary to differentiate the **life history stage** during which key events occur. A stage in the life history is a particular period in the life of a typical individual which is demarcated by distinct developmental events. The life cycle stages of broad whitefish include: egg, fry, juvenile, and adult. Within the last two of these, several sub-stages of life history may be definable for at least some life history types of broad whitefish. Juvenile fish may be separated into small and large juvenile groups, each of which tends to conduct life history somewhat differently. Small juveniles generally do not undergo regular seasonal movements between freshwater and saltwater (but may do so within freshwater), whereas large juveniles may spend some time feeding in estuarine, nearshore or partially marine waters. In broad whitefish, small juveniles may include young-of-the-year (i.e., age 0+ fish which are older and larger than fry) and fish which are approximately one to three or four years old and a range of sizes. Large juveniles may be from about three years old to about seven or eight years of age and also may consist of fish of a range of sizes. Large juveniles become adult when they mature sexually for the first time. In a similar way, adult broad whitefish exhibit sub-groups defined by their readiness to spawn – that is, being in either resting or spawning condition. Spawning adults are fish that exhibit states of the gonads indicating they will, are, or have recently completed spawning. Resting adults are fish that have spawned in a previous year but are not going to spawn in near future (i.e., usually that year). Resting fish are typical in northern fishes, especially in females. This occurs because the short growing seasons, lower productivity of the environments, and yearly climatic variation may not allow the fish sufficient time or a productive enough environment to accumulate all the food needed to produce a sufficient number of eggs. Thus, northern fish typically skip one or more years between spawnings in order to accumulate enough energy to spawn. Broad whitefish can also spawn many times during their life. This is referred to as an **iteroparous** life history. This contrasts with species like Pacific salmon (*Oncorhynchus* spp.) which are semelparous - that is, maturing as adults and spawning only once immediately prior to dying.

Defining the range of stages and sub-stages which are possible within a life history type may seem irrelevant. However, most fish species including broad whitefish tend to separate the various stages of life history into spatially distinct areas. This decreases competition and interactions between the fish in different stages of life, and is thought to enhance survival of all stages. Thus, to understand the possible effects of human activity on a species of fish the entire context of life history and the habitats used by all stages and sub-stages must be known.

WHY DO FISH MIGRATE?

Migration costs a fish in terms of energy - it takes energy to swim, especially upstream to spawning areas. Physiological changes associated with switching from freshwater to brackish and marine waters also require energy. Finally, moving into different areas exposes the fish to predators, diseases and parasites they might not encounter in the particular area in which they were spawned. So the question is, in the face of these costs, why do fish migrate? It is generally believed that the benefits of anadromy exceed the costs. These benefits may accrue in many ways: 1) the number of eggs produced by anadromous fish may be three times that produced by non-anadromous counterparts, 2) the number of spawning events in the lifetime of the individual may be greater, 3) the maximum size overall as well as length upon maturation are much greater, and 4) the growth rate may be larger because marine environments are more productive than freshwater areas (Gross 1987). Thus, for migratory anadromous fish the combination of greater energy intake is seen as faster growth and more reproductive potential which far outweigh the costs of migration. Faster growth may also be advantageous in that it results in lessened susceptibility to predation. Greater reproductive output is advantageous because more young fish are produced some of which are likely to survive to adulthood. Both of these factors are also important if the population is exploited because increased growth and reproduction usually means more fish can be harvested at a sustainable level from the population.

THE AREA

Whether a particular species exhibits several life history types depends to a significant degree on the complexity of the environment in which the species exists. The lower Mackenzie River basin is a very complex area consisting of the following (Fig. 1): the mainstem Mackenzie River itself; several major tributary rivers (e.g., Peel and Arctic Red rivers); large lake and river tributary systems (e.g., Travaillant Lake, Campbell Lake); a maze of channels and small lakes comprising a very large delta of about 12,170 km^2 that is annually inundated (inner delta on Fig. 1); and, a stable Outer Delta consisting of numerous small lake and creek systems which is not regularly flooded during the spring. In addition to this, the Tuktoyaktuk Peninsula, which is an old delta of the Mackenzie River, consists of numerous small lake and creek systems draining directly to the Beaufort Sea.

Many of these areas provide habitats that are particularly suited for specific life history needs of the various stages of broad whitefish. For example, areas in rivers may form good spawning locations but be very poor as feeding areas. Thus the fish must spawn in one area and move to another area to feed and grow. Habitat use by specific life history stages of broad whitefish is discussed below.

LIFE HISTORIES

As noted previously, broad whitefish from Siberia can exhibit three possible life history types: anadromous, lacustrine and riverine. Some scientific evidence (e.g., genetics, Reist 1997a, this publication) indicates that at least the first two of these life history types are present in the lower Mackenzie River. This is confirmed by traditional knowledge from the local fishermen. Because the details of life history including the places occupied, and the timing and the length of migrations all differ, the life history for each of the types present in an area must be described separately. Because most of our current understanding is based upon the semi-anadromous life history type of broad whitefish, the description for this type will form the majority of this paper.

LIFE HISTORY OF SEMI-ANADROMOUS BROAD WHITEFISH

The generalized life history of broad whitefish is divisible into two major components: 1) maturing fish (i.e., the life prior to first sexual maturation) which consists of the following stages - egg, fry, young-of-the-year, and both small and large juveniles up to about eight years of age; and, 2) mature fish (life after first maturation) which consists of the following stages - juveniles that are sexually maturing for the first time, adults in various degrees of readiness for spawning, and resting or non-spawning adults (Fig. 2). The individuals in these two major categories tend to occupy different habitats and conduct the seasonal aspects of their life history somewhat differently. Each component lasts several years for a typical whitefish and the link between the two is when juveniles mature into first-time spawners. Recent work discussed in detail below indicates that major phases of life history are principally passed in association with general environments of the area. For example, juvenile maturation occurs primarily in association with the Outer Delta and Tuktoyaktuk Peninsula, although many important possibilities and hypotheses remain untested.

YOUNG-OF-THE-YEAR AND SMALL JUVENILES (FIG. 3)

Semi-anadromous broad whitefish spawn primarily in the mainstem and major tributaries of the Mackenzie River under the ice during late October and early November when water temperatures are near $0^{o}C$ (Stein et al. 1973a; Jessop et al. 1974). Eggs hatch during the early spring (perhaps April-May). Upon emergence from the gravel substrate on the spawning bed, free-swimming fry presumably migrate or are flushed downstream under the ice during May and June with the spring flood. No definitive studies have yet been conducted, but it is believed that fry can have one of four possible fates (Fig. 3). 1) The majority are carried through the delta and swept eastwards along the Tuktoyaktuk Peninsula by the prevailing currents. 2) A significant proportion is carried out of the western channels of the delta and then eastwards along the outer margin of the Outer Delta (e.g., Richards Island). 3) A smaller proportion is carried westwards along the Yukon north slope at least as far as Phillips Bay (Bond and Erickson 1987). 4) An unknown but perhaps significant number are swept into ponds and lakes of the inner delta during the spring floods and may or may not become isolated there once flood waters recede. Those in the latter group which survive the winter may possibly re-join the anadromous populations during the flood of the following year as small juveniles (Taylor et al. 1982).

Young-of-the-year (YOY, i.e., fish which are larger than fry but still in their first year of life) of groups 1 and 2 (Fig. 3) reach the outer delta and the Tuktoyaktuk Peninsula with the spring flood in large numbers, and range between 25 and 75 mm in length. Soon after the freshwater creeks become ice-free in late June to mid-July, thousands of young-of-the-year (<75 mm), 1+ (75-200 mm), and 2-4 year old small juveniles (<300 mm), migrate up the creeks to feed in the warm, productive lakes of the Tuktoyaktuk Peninsula (Bond 1982; Bond and Erickson 1985; Chang-Kue and Jessop 1991, 1992) and also the Outer Delta. Most of these fish also overwinter in these systems.

In a study of Freshwater Creek on the Tuktoyaktuk Peninsula by Bond and Erickson (1985), a weir was constructed to enumerate upstream and downstream movements of fish. Initially larger whitefish moved up into the lakes followed by fish of progressively smaller size over the summer (Bond and Erickson 1985). A similar scenario was found in another weir study of an adjacent system, Kukjuktuk Creek by Chang-Kue and Jessop (1992). In 1979 a total upstream run of 1,190,972 fish was counted with broad whitefish representing 98.2% of this. Young-of-the-year and one-year old fish, which were present in the run from mid-July to late-August, composed 93.8% of the total upstream run.

Based upon a net upstream movement of fish, a significant number of fish, primarily YOY and yearlings (1+), will remain in the lakes to overwinter. The whitefish must be very selective in choosing lakes in which to overwinter because most lakes in the Outer Delta and on the Tuktoyaktuk Peninsula are quite shallow (<2 m) and freeze solid during the winter. However, there are many lakes in the major streams along the Peninsula which are of sufficient depth to provide overwintering habitat (Lawrence et al. 1984). A small percentage of young fish may also move out of the system to overwinter in the Mackenzie River or coastal bays of the estuary (Chang-Kue and Jessop 1992). While their subsequent fate is unknown, it is most likely that these fish contribute to the upstream runs into the coastal watersheds in the following years (i.e., as 1 to 4 year old juveniles).

Lakes on the Tuktoyaktuk Peninsula and the Outer Delta provide important summer feeding and overwintering habitat for small juvenile broad whitefish. The relative importance of Mackenzie Delta lakes is presently unknown. Also, it is not known if the lower turbidity of lakes on the Tuktoyaktuk Peninsula is more favourable than the very turbid delta lakes, nor is enough known about primary and secondary productivity to make statements concerning the food base (Ramsay and Ramlal 1985). Compared to the lakes of the Mackenzie Delta, there is a relatively low abundance of predators (northern pike, lake trout, burbot) in the lakes of the Tuktoyaktuk Peninsula. This would significantly enhance survival of YOY and juvenile whitefish. Regardless of the reason, recent research by Bond (1982), Bond and Erickson (1982, 1985), Lawrence et al. (1984) and Chang-Kue and Jessop (1992) suggests that the Tuktoyaktuk Peninsula stream and lake systems are of critical importance to YOY and juvenile broad whitefish as nursery and overwintering habitat.

The importance of the delta lakes as nursery areas for fish of group 4 (Fig. 3) is as yet unknown and may be under-estimated. Taylor et al. (1982) captured YOY broad whitefish during the summer, even in delta lakes not connected to the Mackenzie River after early June. Young-of-the-year and juvenile broad whitefish as well as their predators, northern pike and burbot, were found in all lakes with a constant connection to the Mackenzie (Type I lakes). In these lakes and in lakes only seasonally connected to the Mackenzie River (Type II lakes), broad whitefish were present. Taylor et al. (1982) observed that most adult broad whitefish as well as YOY, juvenile and immature whitefish emigrated from Type I lakes during September, presumably to overwintering areas in the delta or to spawning grounds. Whitefish trapped in Type II lakes may die if conditions are not favourable, or they may overwinter for periods of one to several winters. Presumably survivors, if any, eventually leave such lakes during a subsequent spring flood as 1+ or older fish. These fish may then utilize either one of the many lakes along the Tuktoyaktuk Peninsula, or move to summer feeding areas in the delta. It is not known whether whitefish can pass their entire early life history in delta lakes, leaving only at the onset of sexual maturity. DeGraaf and Machniak (1977) found that broad whitefish were also widespread in lakes on Richards and Langley Islands of the Outer Delta. Lawrence et al. (1984) found patterns of movement and habitat usage for locations in the Outer Delta similar to those observed on the Tuktoyaktuk Peninsula. Thus it is likely that the Outer Delta, which in many areas is topographically similar to the Tuktoyaktuk Peninsula, provides similar habitats for use by small juvenile broad whitefish. The situation for larger lake systems of the Outer Delta (e.g., Ya Ya Lake) may be more complex. For example, McCart (1986) believed that broad whitefish of the Ya Ya Lake system were part of the Mackenzie River whitefish population. However, the size, stability and complexity of this drainage basin suggests the possibility of a lacustrine life history type present in this area. It is equally possible that the semi-anadromous type utilizes portions of this lake system during some stages of their life history thereby mixing with the lacustrine type if this is present here. Further research is necessary to address these questions.

The fate of young broad whitefish of group 3 (Fig. 3) which are swept westwards along the Yukon north coast at least as far as Phillips Bay (Bond and Erickson 1987) is unknown. The nearshore migratory corridor of the north slope is characterized by a narrow but unstable zone of brackish water which varies in salinity. This is frequently disrupted by storm events on the Beaufort Sea. Also, the land in the area is characterized by mountainous topography and fast flowing rivers which are generally not suitable for whitefish. Broad whitefish do occur in some of the tundra lakes found along the narrow coastal plain further west (Reist 1987). However, it is unknown whether these populations are self-sustaining or are derived from those of the lower Mackenzie River. It is also unclear as to whether young-of-the-year broad whitefish of group 3 can gain access to these lakes. If so, then these lakes may provide a small contribution to the total nursery area for broad whitefish. If access to these fresh-water systems is not possible, or if storm events disrupt the nearshore brackish water zone, then the fate of the majority of group 3 fish is likely death due to predation or osmotic stress because of immersion in full-strength seawater. Clearly, research is required to estimate the proportion of group 3 broad whitefish relative to those of the other groups, and to determine the ultimate fate of these fish.

The timing of spring break-up, flow, volume, river stage and discharge has considerable influence on the abundance and composition of fish populations in the delta during the summer. Thus, indirectly such physical parameters may have a significant impact on year-class strength and survival of broad whitefish. Similarly, the proportion of total flow and of the young fish emerging from the various channels of the delta (i.e., western, central, or eastern) is unknown. The area of emergence from the delta into coastal habitats likely has considerable impact on the subsequent survival of the young fish which may be quite vulnerable to local variation in habitat characteristics. Such density-independent influences that may regulate population abundance have not yet been adequately investigated for broad whitefish but could be very significant.

LARGE JUVENILES (FIG. 4)

Large juvenile broad whitefish (age 4-8, length 300-450 mm) are distributed throughout the Mackenzie River and in lakes of the delta and Tuktoyaktuk Peninsula. Less is known of the life history or distribution of juvenile broad whitefish within the delta because the vast majority of work has been concentrated on the Tuktoyaktuk Peninsula. Analysis of length frequency of samples captured in various locations indicates that the presence of large juveniles in the delta is very low in comparison to that in the fish migrating upstream in the coastal streams (Chang-Kue and Jessop 1991, 1992).

During the early summer as soon as water begins to flow and earlier than was seen for the young-of-the year and small juveniles, large numbers of large juvenile broad whitefish migrate upstream in the coastal streams of the Tuktoyaktuk Peninsula to spend a variable amount of time feeding in the extensive lake systems (Bond and Erickson 1985; Chang-Kue and Jessop 1992). These fish were primarily large juveniles, although a mixture of ages and sizes was present. The source of these fish is unknown, although it is hypothesized they overwintered in the Outer Delta or nearshore environment (Chang-Kue and Jessop 1992). Downstream runs begin about 2-3 weeks later than the upstream runs and characteristically consist of fewer fish overall, and of older, larger juveniles (Bond and Erickson 1985; Chang-Kue and Jessop 1992). In 1982, approximately equal numbers of broad whitefish (upstream = 100,178; downstream = 105,148) passed through the weir on Freshwater Creek, however, the up- and downstream components were composed of quite different sizes and ages of fish (Bond and Erickson 1985). Fish in upstream migrations in Freshwater Creek ranged from 51 to 546 mm with most fish (54%) exceeding 225 mm. The run was dominated by one to eight year old fish (Bond and Erickson 1985). The downstream run contained very few YOY or young juvenile fish (only 2% <225 mm). A similar pattern was observed on Kukjuktuk Creek (Chang-Kue and Jessop 1992). It can be inferred from this that most fish less than three years of age and a small proportion of older fish, tend to remain in the lake system to overwinter while the majority of older fish (i.e., large juveniles) leave the Peninsula lakes to presumably overwinter in the outer delta and nearshore bays such as Whitefish Bay (Chang-Kue and Jessop 1992). It is also possible that a portion of these fish may re-enter adjacent streams later that same summer to overwinter after having fed in the nearshore. In many cases, tagged fish which left a system in the fall returned to the same stream the following spring (Chang-Kue and Jessop 1992).

Some of the earliest downstream migrants out of both the Freshwater and Kukjuktuk Creek systems included very large fish not counted during the earlier upstream runs (Bond and Erickson 1985; Chang-Kue and Jessop 1992). Analysis of gonadal maturities indicated that these fish would spawn the coming fall. Thus these individuals were the first-time maturing stage of the population that joins the mature components of the life history. These fish presumably join in the movements of pre-spawning mature whitefish to the aggregation areas of the Inner Delta. Once having matured and left the lakes of the Tuktoyaktuk Peninsula, these fish never return, instead joining the mature adult segment of the population for the remainder of their life.

The direct linkage of the immature juvenile components of broad whitefish life history with the mature adult components as outlined above has been demonstrated by tag-recapture studies. Fish tagged and released in Kukjuktuk Creek as juveniles in 1978 and 1979 were subsequently recaptured at upstream river sites in subsequent years (Chang-Kue and Jessop 1992). At the time of capture these fish were of the correct age to be spawning adults (i.e., 8+ years or older).

Thus, it appears that the majority of the nursery area used by large juvenile semi-anadromous broad whitefish consists of the lake and creek systems of the Tuktoyaktuk Peninsula and Outer Delta (Fig. 4). The majority of these large juveniles appear to overwinter in the nearshore coastal environments in the outer delta and along the Tuktoyaktuk Peninsula, likely in freshened areas which result from the continuous outflow of freshwater under the ice. These fish may also overwinter in the lower reaches of delta channels (Fig. 4). During spring these fish may move into the creek and lake systems to feed during the summer subsequently moving back into nearshore environments in the fall. Alternatively they may feed in the nearshore zone.

ADULTS (FIG. 5)

The transition from juvenile to adult is marked by sexual maturation (Fig. 2). First maturation occurs in the summer prior to actual spawning the following fall, between seven and nine years of age at a minimum size of 420-450 mm in length (Bond 1982).

Mature individuals or current-year spawners spend the summer prior to spawning feeding in the delta and peninsula lakes or the nearshore estuarine environments. In late July and early August, maturing fish move towards pre-spawning aggregation sites in the Inner Delta at major eddies (e.g., the large eddy downstream from Horseshoe Bend in the Middle Channel) (Chang-Kue and Jessop 1983, 1992; Jessop and Chang-Kue 1993). Fish which spawn far upstream in the Ramparts Rapids area presumably begin to migrate earlier in the year and may aggregate in pre-spawning areas in the Mackenzie River mainstem downstream of Fort Good Hope. Pre-spawning adults may congregate in such areas for several weeks awaiting water temperatures to drop to near 0^{o}C before making a concerted upstream migration, usually in early November, to a number of spawning sites in the Mackenzie River mainstem and major tributary rivers. Major spawning areas identified by radiotelemetry studies include Point Separation, several sites on the Mackenzie River mainstem, Ramparts Rapids and at least one upstream site in both the Peel and Arctic Red rivers (Chang-Kue and Jessop 1983, 1997). Capture of ripe or spent fish also indicates that spawning occurs in the Arctic Red and Peel rivers, and likely in major lake systems such as Campbell and Travaillant lakes, although these latter fish may represent the lacustrine life history type (Reist unpublished data). Once spawning has been completed, spent adults migrate downstream to overwintering areas in the Outer Delta (Chang-Kue and Jessop 1997, this publication).

Adult broad whitefish are believed to spawn several times during their lives, but not necessarily in consecutive years. Rather, reproduction at two- to three-year intervals especially by females is suspected because of the energetic demands of producing gametes and the long migrations necessary. Indirect evidence for this comes from fish of up to 12 years of age which have been classed as immature. These individuals are probably in a "resting" phase between spawnings (Reist, unpublished data). Mature broad whitefish are also believed to return to their natal area to spawn, however, this has not been directly demonstrated. Homing to natal areas to spawn is a prerequisite for the differentiation of the population into distinct genetic stocks as has been found for broad whitefish in this area (Reist 1997a, this publication).

The majority of current-year spawners are composed of larger, older individuals, probably spawning for at least their second time, presumably having come from summer feeding areas in the Outer Delta and nearshore areas. A small portion of current-year spawners consists of individuals which matured in the Tuktoyaktuk Peninsula lakes and which are now spawning for the first time. Bond and Erickson (1985) found a considerable number of maturing fish among the downstream migrants of Freshwater Creek. However, no mature individuals have ever been found moving up Tuktoyaktuk Peninsula creeks. This suggests that the Tuktoyaktuk Peninsula is used exclusively as a nursery and summer feeding area for young and juvenile fish (Bond and Erickson 1982, 1985; Lawrence et al. 1984; Chang-Kue and Jessop 1992).

Resting broad whitefish which have spawned at least once, apparently restrict their movements to areas of the Outer Delta and nearshore used in the summer for feeding and in the winter as stable locations to overwinter (Fig. 5). Once gonadal maturation has again been achieved, these fish then participate in upstream migrations in the fall to spawning areas.

SUMMARY

In summary, the semi-anadromous life history type of broad whitefish undergoes extensive seasonal migrations involving several hundred kilometers and uses a variety of habitats throughout the entire lower Mackenzie River. It appears that there is some degree of separation of different stages of life history which use different habitats for critical life history functions. All stages up to and including large juveniles tend to occupy lake and creek systems in the Outer Delta and Tuktoyaktuk Peninsula for much of their life history although some portion also use nearshore habitats regularly. In contrast once having matured sexually for the first time, adult fish do not frequent these lake and creek systems - instead using delta channels and nearshore areas. As far as is known from scientific studies, the mature adults of this life history type only spawn in upstream riverine locations in the Gwich'in and Sahtu areas. However, traditional knowledge suggests that some spawning populations may also occur in the Inuvialuit Settlement Region (Billy Day, Inuvik, personal communication). Clearly further work to understand these details and other questions noted above is necessary.

MANAGEMENT ISSUES FOR THE SEMI-ANADROMOUS TYPE

The migratory aspect of life history of the semi-anadromous type and the use of a variety of distinct habitats complicates management of the populations of this type. The migratory fish may cross several jurisdictional boundaries between land claim settlement regions and be fished a number of times by Inuvialuit, Gwich'in and Sahtu people. Thus, the cumulative effect of both subsistence and any commercial fishing may be significant on individual populations and this life history type generally (Reist 1997b, this publication). This must be taken into account when developing management protocols to ensure sustainability of the populations. The vulnerability of this life history type of broad whitefish to adverse impacts is increased due to the following: 1) the concentration of significant components of the entire group into a few, often very local habitats for a large proportion of the year (e.g., overwintering lakes on the Tuktoyaktuk Peninsula); 2) the concentration of major components of the entire group into local habitats at very specific times (e.g., pre-spawning staging of adults in the Middle Channel); 3) the concentration of fish from specific biological populations during short periods of time (e.g., upstream migration of spawners in rivers); and, 4) the diversity and spatial distribution of habitats necessary for life history. Obviously appropriate caution must be exercised when managing human activities which may affect these concentrations of fish or the habitats critical for their survival. The effectiveness of management of this life history type is further complicated by the diverse strategies of some stages which are possible within the type (e.g., four possible fates for young-of-the-year), and our lack of understanding of the overall significance of this.

LIFE HISTORY OF LACUSTRINE TYPE

The existence of a separate lacustrine life history type of broad whitefish that remains in freshwater throughout life is based upon the following evidence. First, traditional knowledge identifies a lake form and a river form (M.A. Treble, Dept. of Fisheries and Oceans, personal communication; Freeman 1997, this publication). The latter is presumed to be the semi-anadromous form described above. In addition to differences in the type of habitat primarily occupied, differences in colour can be used to differentiate the forms - the body of the lacustrine type is slate gray in colour whereas the type in the river has a golden cast to the body. Second, summer field surveys in Travaillant Lake have captured broad whitefish of various sizes including young-of-the-year (Strange and MacDonnell 1985). Winter collections have yielded mature adults thus indicating spawning occurs nearby (Reist, unpublished data). Third, genetic evidence indicates that the broad whitefish from both Travaillant Lake and Campbell Lake comprise populations that are very distinct from those in the major rivers of the area (Peel, Arctic Red, and Mackenzie rivers) (Reist 1997a, this publication). The degree of difference present between stocks from the various rivers is very much less than that between samples from the lakes in comparison to those from the rivers. Thus, it is concluded that a distinct, lacustrine life history form of broad whitefish exists in this area and is associated with the large lake systems present on the east side of the Mackenzie River. It is also likely that this life history type occurs in smaller lacustrine systems in the area (e.g., upstream areas on the Peel and Arctic Red rivers) and perhaps in other areas such as the Outer Delta (e.g., Ya Ya Lake). Studies to demonstrate the existence and determine the characteristics of these populations are necessary; perhaps best conducted through traditional knowledge studies within the various settlement regions.

Definitive scientific studies of the life history of the lacustrine form are lacking, although considerable traditional understanding of this form likely exists but has not yet been summarized. In general, it is expected that the life history involves similar timing for major events (spawning, feeding, etc.) as that of the semi-anadromous form. It is also suspected that although migratory patterns may exist, they are much more localized than those described for the semi-anadromous form. Thus, in Travaillant Lake, for example, the following hypothetical scenario can be developed. Adults spawn in the fall in rivers tributary to the lake and/or on spawning beds in the lake at the site of river inflow. Early life history of fry, small juveniles, and perhaps large juveniles occurs in the lake itself or in other small lake and creek systems tributary to Travaillant Lake. Adults may migrate out of the lake during summer and enter the Mackenzie River but likely return well before spawning time. Adults never proceed downstream to the Outer Delta area as was described above for the semi-anadromous type. Studies are necessary to confirm this general life history and to determine the basic biological parameters of this life history type (e.g., age-at-first maturity, periodicity of spawning, growth characteristics, etc.).

MANAGEMENT ISSUES FOR THE LACUSTRINE LIFE HISTORY TYPES

Because the life history of the lacustrine type is local and in most cases contained within the boundaries of a single settlement region, the management of this form can usually be conducted by the locally responsible board without reference to trans-boundary issues. The exception to this may be areas such as Campbell Lake where both the Inuvialuit and Gwich'in people may exploit broad whitefish and where mixing of both the lacustrine and semi-anadromous types may occur. Generally only local impacts will significantly affect such populations and management protocols are accordingly simpler. However, the possibility of impacts originating outside the local area (e.g., airborne contaminants, Reist 1997b, this publication) must also be considered when making management decisions for such lacustrine populations.

LIFE HISTORY OF THE RIVERINE TYPE

A third life history type of broad whitefish has been described from the large arctic rivers of Siberia (Berg 1962). For the lower Mackenzie River system, there is no scientific evidence which suggests that a riverine life history type is present in the mainstem areas of the river. However, the size and complexity of the system may allow for such a form. If present this form would be restricted to the larger rivers themselves and likely utilize habitats in the delta for portions of life history. Clear criteria to differentiate this form from either the lacustrine or semi-anadromous type in the lower Mackenzie River basin do not exist. Thus, if it does exist in this area it may be mis-identified as one of the other two types or it may mix with them. Records of broad whitefish in areas of the upper Mackenzie River (i.e., the area upstream of Ramparts Rapids) are known (see Scott and Crossman 1973; Stein et al. 1973b), thus a separate type occupying this area can not be ruled out. Appropriate work is required to address this issue.

MIXING OF THE DIFFERENT LIFE HISTORY TYPES

Because most studies have focused on the semi-anadromous type and because substantial adequate descriptions of the semi-anadromous and lacustrine form were lacking and not used in previous research, the degree of mixing, if any, of both (or all three) types during some stages of life history (e.g., migrations) is unknown. No physical barriers exist to fish movement between many of the major lakes (Campbell and Travaillant lakes) and the Mackenzie River especially at high water times of the year. Thus, mixing may possibly occur at some times. Furthermore, a sample of fish collected in South Travaillant Lake (downstream towards the Mackenzie River) and a sample collected in one year from Campbell Lake were not genetically different from samples collected in the Mackenzie River (i.e., semi-anadromous type), but were quite different from other samples from those lakes which were attributed to the lacustrine type (Reist, unpublished data). If widespread mixing of the forms, or if simultaneous use of specific habitats during some portion of life history occur, then management of this species will be greatly complicated and appropriate research to address this issue is necessary.

HABITATS AND USAGE BY BROAD WHITEFISH

AQUATIC HABITATS PRESENT

The lower Mackenzie River basin is a very complex area that provides numerous types of aquatic habitats for fish. This complexity is, in part, responsible for the diversity seen with broad whitefish in the area.

The lower Mackenzie River is defined as that area north of the Ramparts Rapids area on the mainstem (i.e., immediately north of Fort Good Hope). From the perspective of coregonids such as broad whitefish this definition is biologically meaningful. A prominent feature of the Mackenzie River at the Ramparts area is the presence of a discontinuity in the bedrock forming the river bed. This discontinuity consists of a vertical displacement of bedrock extending almost completely across the river bed. The upstream bed is a few meters higher than the downstream bed. Thus, during the low water levels present at the time of the fall upstream migration of broad whitefish, most of the flow of the Mackenzie River occurs through a narrow chute near the east bank of the river. The high flow associated with this feature likely prevents any upstream movement of migratory fish at this time of year. Effectively, from the perspective of the fish and for fishery management this barrier delimits the broad whitefish in the lower portion of the Mackenzie River.

Within the lower Mackenzie River system as defined above, nine major types of aquatic habitat can be differentiated. Within some of these, sub-types can also be determined. The habitat types are (Fig. 1): 1. Mainstem Mackenzie River; 2. Large tributary rivers arising in western mountains (e.g., Peel and Arctic Red rivers); 3. Small lake and creek systems tributary to the mainstem (e.g., Attoe Lake and Pierre Creek); 4. Large multiple lake and river systems (e.g., Travaillant and Campbell lakes); 5. Inner Delta (Point Separation north to tree line) - a) channels, b) channel-connected lakes, c) unconnected lakes; 6. Outer Delta (treeline northwards) - a) channels some of which may have periodic marine incursions, b) levee protected small connected lakes (e.g., Wolf Lake), c) large deep complex lake systems (e.g., Ya Ya Lake), d) coastal lakes and creeks (e.g., Burnt Creek system), e) outer islands nearshore habitat; 7. Tuktoyaktuk Peninsula - a) nearshore habitat and protected embayments with marine incursions (e.g., Tuktoyaktuk Harbour), b) lake and creek systems draining to the sea (e.g., Freshwater Creek, Kukjuktuk Creek), c) unconnected lakes; 8. Continental north slope nearshore; and, 9. Beaufort Sea marine environments.

HABITAT USE BY SEMI-ANADROMOUS BROAD WHITEFISH

The likely uses of particular habitats by specific life history stages of the semi-anadromous life history type of broad whitefish are presented in Table 1. It should be noted that the expected use derives from the life history outlined earlier. In most cases the use pattern is based on the best guess derived from our present information. Additional understanding will greatly modify this table. Furthermore, there are likely numerous undiscovered exceptions to the rule; the Table is designed to summarize overall tendencies only.

SUMMARY

The general consequences of this life history are as follows. The semi-anadromous life history type which likely forms the great majority of the broad whitefish in this area moves across the boundaries of the settlement regions during its life cycle. In general, the only known spawning areas for this type are in the Gwich'in and Sahtu regions. However, the major rearing areas, feeding areas, and staging areas for migration are in the Inuvialuit region. Thus a cooperative management program for this life history type must be implemented which involves all aboriginal groups from the lower Mackenzie River area. Clearly the fish are a joint resource and must be managed in that manner. The lacustrine life history type is likely more localized and with the exception of perhaps Campbell Lake can be managed on a local basis. However, it is quite possible that the anadromous, lacustrine, and riverine (if it exists) forms inter-mix at times during their life history. This possibility further complicates management because different life history types (similar to different genetic stocks) likely have different production characters (e.g., growth rates, age structure, etc.) and abundances.

Despite the work that has been conducted in the past, there are many unanswered questions about the detailed life history of both the semi-anadromous and lacustrine types. The previous description is a generalized summary only and exceptions may be found upon further research (e.g., some areas of the Outer Delta may be used for spawning by the semi-anadromous type). Further research is necessary to investigate the possibilities.

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COMMENTS, QUESTIONS AND ANSWERS

Billy Day: I still have a lot of questions on migration. It seems that I'm building up more questions than I'm really getting answers. I know that it's a bit frustrating at times. When we're talking about catching whitefish, Jim Perreault gave data a while ago where they catch whitefish sometime in August or late August, and it seems all the way from Fort Norman down to Tuk we have a run of whitefish pretty well all at the same time. Now how can you explain that?

Jim Reist: I'm going to hedge my bets and explain that in two ways. The first way is, number one, fish can move very fast especially adult fish. We had a bit of a conversation about this yesterday and we have no idea how fast these broad whitefish can move upstream. The example I'll use to support this is an example of a Dolly Varden Char that was tagged in western Alaska in a river system near Nome at the end of June one year. The biologist caught the fish, he put a floy tag, one of the floy marking tags, on in late June, I think it was the 29th of June. That fish, again a Dolly Varden that was this long, looked, from colour and everything else, looked like it was getting ready to spawn. It was probably going to spawn that year. A little over a month later - almost 5 weeks or so later - that fish was caught by a Native fisherman in Siberia about 100 kilometres up a river called the Anadyr River. So, in little over 5 weeks that particular fish moved a total of about 2900 kilometres almost 1600 miles, the distance from here to Winnipeg. And it was clear at the point it was captured that it was going upstream to a Siberian river to spawn. So, if you work out the distance traveled and the number of days involved that fish had to move at least 40 kilometres every day, about 30 or 35 miles actually, every day to get from where it was tagged to where it was caught. And that was down a river, that's easy; across the ocean, that's not so easy; and up-stream the other river, a very long distance with the current flowing against it. We may not think of it, but fish can move very, very fast when they want to, especially if it is a spawning run. So the short answer is that the fish that you see in the Delta and then a few days later upstream, could be that the same fish which have moved that fast in those intervening days. Another possible explanation is that the fish that have to go the furthest move earlier than the those that stick around and don't have so far to go. So, they split themselves out into different groups, into different stocks, and I'll talk about stocks in a few minutes. And if they've got a long way to go, the cues that they use to cause them to move may cause them to move earlier in the season. It may be only a matter of a couple of days different. That’s why you'll see a large number of fish going by Fort Good Hope at the same time that you see a large number of fish moving upstream, say, in the Arctic Red and in the Peel. By that time we suspect that if you tracked it on a day-by-day basis, you wouldn't see those same large numbers of fish in the Delta area at your camp, for example. Those fish will have already moved past and gone upstream to spawn.

Table 1. Habitat use by the anadromous life history type broad whitefish in the Lower Mackenzie River: + = used, - = not used, ? = unknown. See the text for a description of habitat types.

		Habitat Types																
Life History Stage	Activity	1	2	3	4	5a	5b	5c	6a	6b	6c	6d	6e	7a	7b	7c	8	9
Egg	incubation	+	+	?	?	?	-	-	-	-	-	-	-	-	-	-	-	-
Alevin	development	+	+	?	?	?	-	-	-	-	-	-	-	-	-	-	-	-
Fry (Y-O-Y)	migration	+	+	?	?	+	-	-	+	-	?	+	+	+	+	-	+	-
(26-75mm FL)	feeding	?	?	?	?	+	+	?	+	-	?	+	?	?	+	-	+	-
	overwintering	?	?	?	?	?	+	?	?	-	?	+	?	?	+	-	-	-
Small Juvenile (1-4)	migration	+	+	?	?	+	+	?	+	-	?	+	+	+	+	-	?	-
(76-300 mm FL)	feeding	?	?	?	?	+	+	?	+	-	?	+	?	?	+	-	?	-
	overwintering	?	?	?	?	?	+	?	?	-	?	+	?	?	+	-	-	-
Large Juvenile (4-8)	migration	-	-	-	?	-	-	-	+	?	?	+	+	+	+	-	?	-
(300-450+mm FL)	feeding	-	-	-	?	-	-	-	+	?	?	+	+	+	+	-	?	-
	overwintering	-	-	-	?	-	-	-	?	?	?	+	+	+	?	-	-	-
First-Timed Matured (6-8)	migration	+	+	?	?	+	+	-	+	?	-	+	+	+	+	-	-	-
(>450mm FL)	feeding	-	-	-	-	-	-	-	+	?	-	+	+	+	-	-	-	-
	spawning	+	+	?	?	?	-	-	?	-	?	-	-	-	-	-	-	-
	overwintering	-	-	?	-	-	-	-	+	?	?	-	+	?	-	-	-	-
Mature Adults (8+)	migration	+	+	?	?	+	+	-	+	?	-	-	+	+	-	-	-	-

(>450mm FL)	holding (pre-spawn)	?	?	?	?	+	-	-	+	?	-	-	?	+	-	-	-	-
	feeding	-	-	-	-	-	-	-	+	?	-	-	+	+	-	-	-	-
	spawning	+	+	?	?	?	-	-	?	-	?	-	-	-	-	-	-	-
	overwintering	-	-	?	?	?	-	-	+	?	?	-	+	+	-	-	-	-
Resting Adults (8+)	migration	?	?	?	?	?	-	-	+	?	?	-	+	+	-	-	-	-
(>450mm FL)	feeding	-	-	?	?	?	-	-	+	?	-	-	+	+	-	-	-	-
	overwintering	-	-	?	?	?	-	-	+	?	?	-	+	+	-	-	-	-

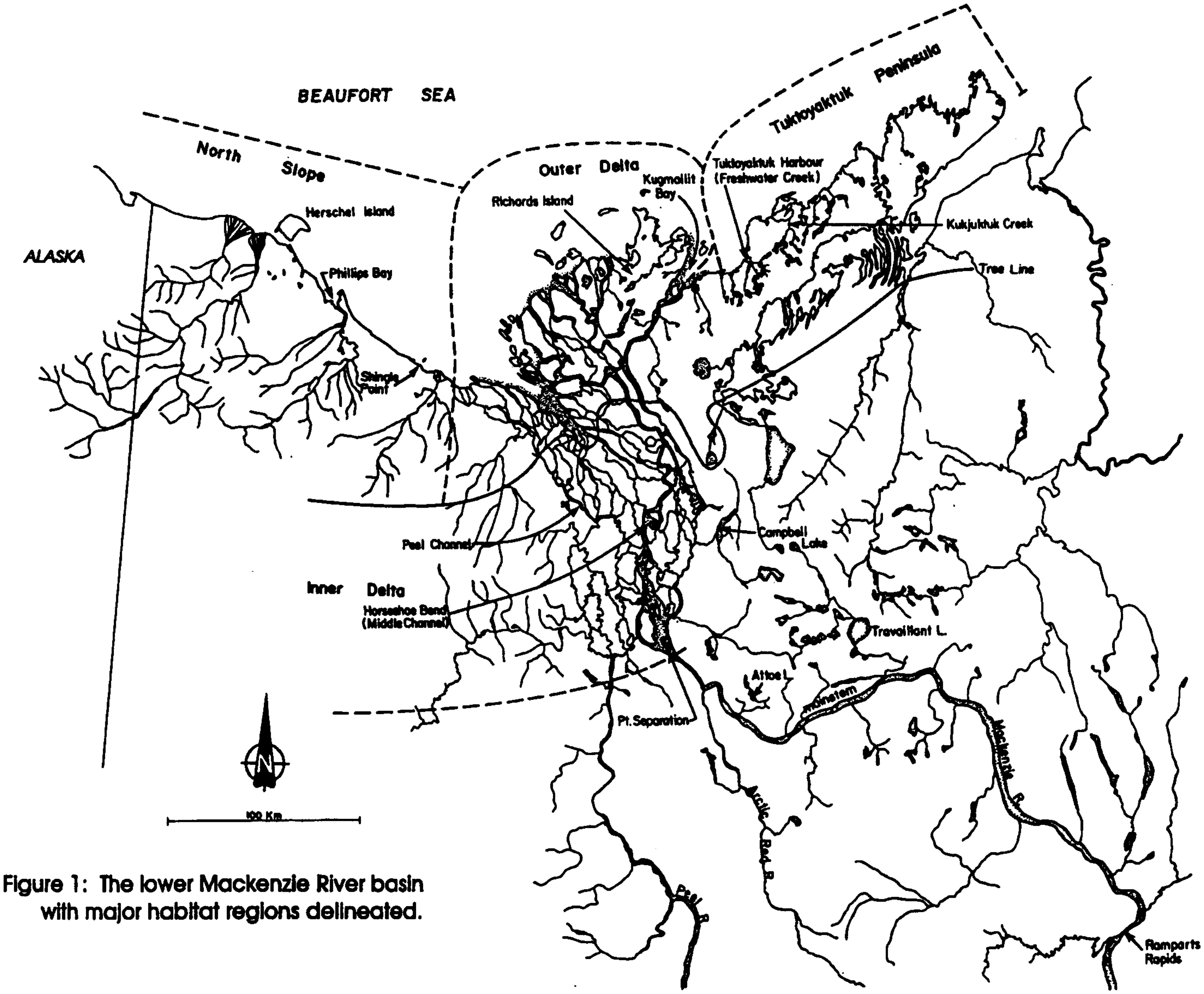

Figure 1: The lower Mackenzie River basin with major habitat regions delineated.

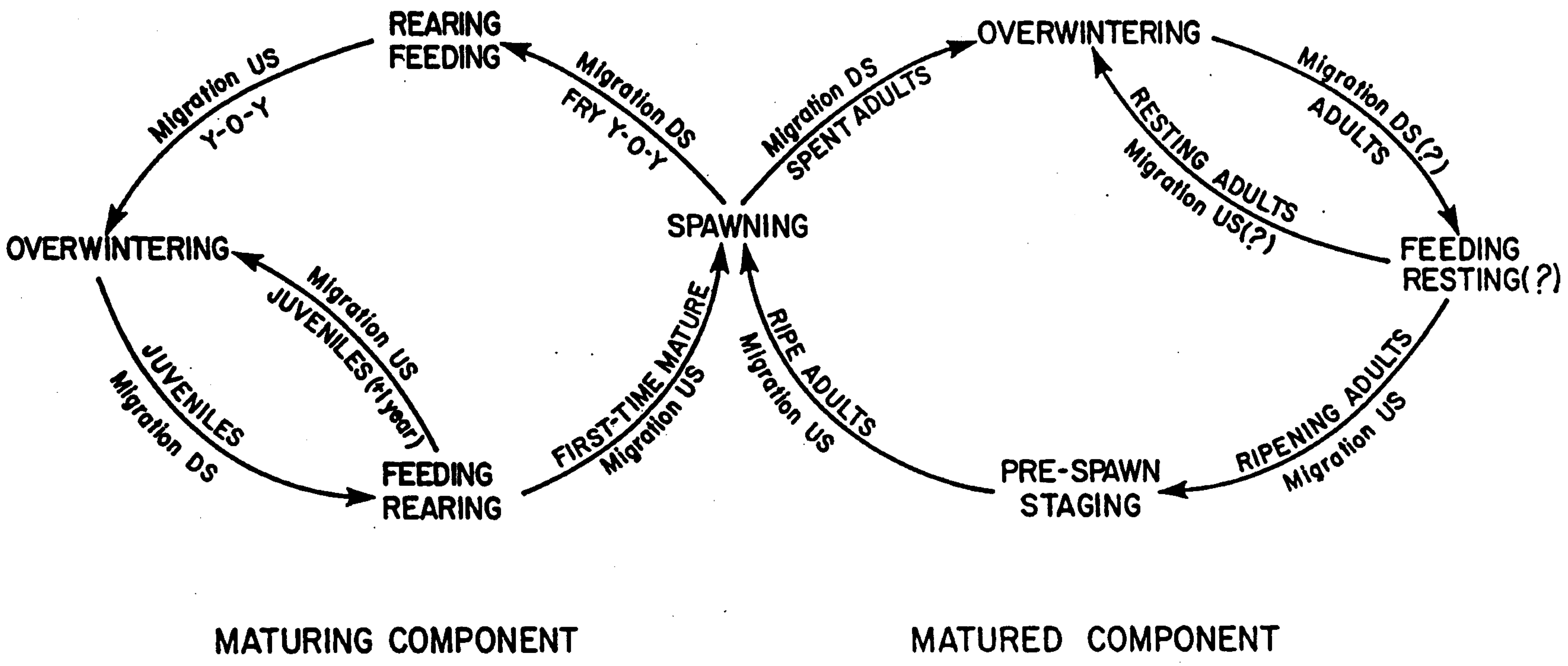

Figure 2: A generalized life history applicable to broad whitefish.

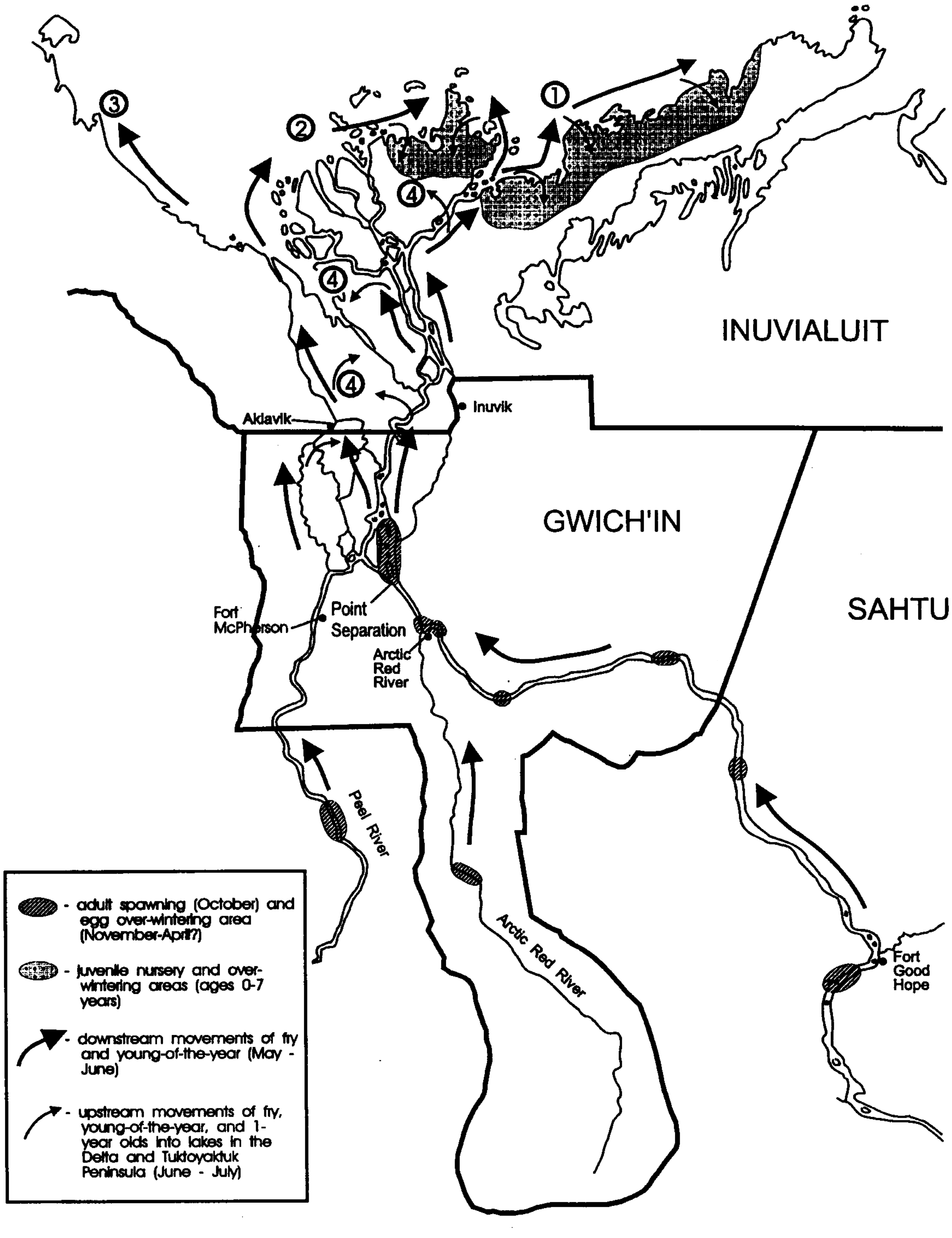

Figure 3. Habitats used and movement patterns of the fry, young-of-the-year, and small juveniles of the semi-anadromous life history type of broad whitefish. To maintain clarity, not all possible areas or movement patterns are shown. The numbers correspond to one of four possible fates of the fry as described in the text.

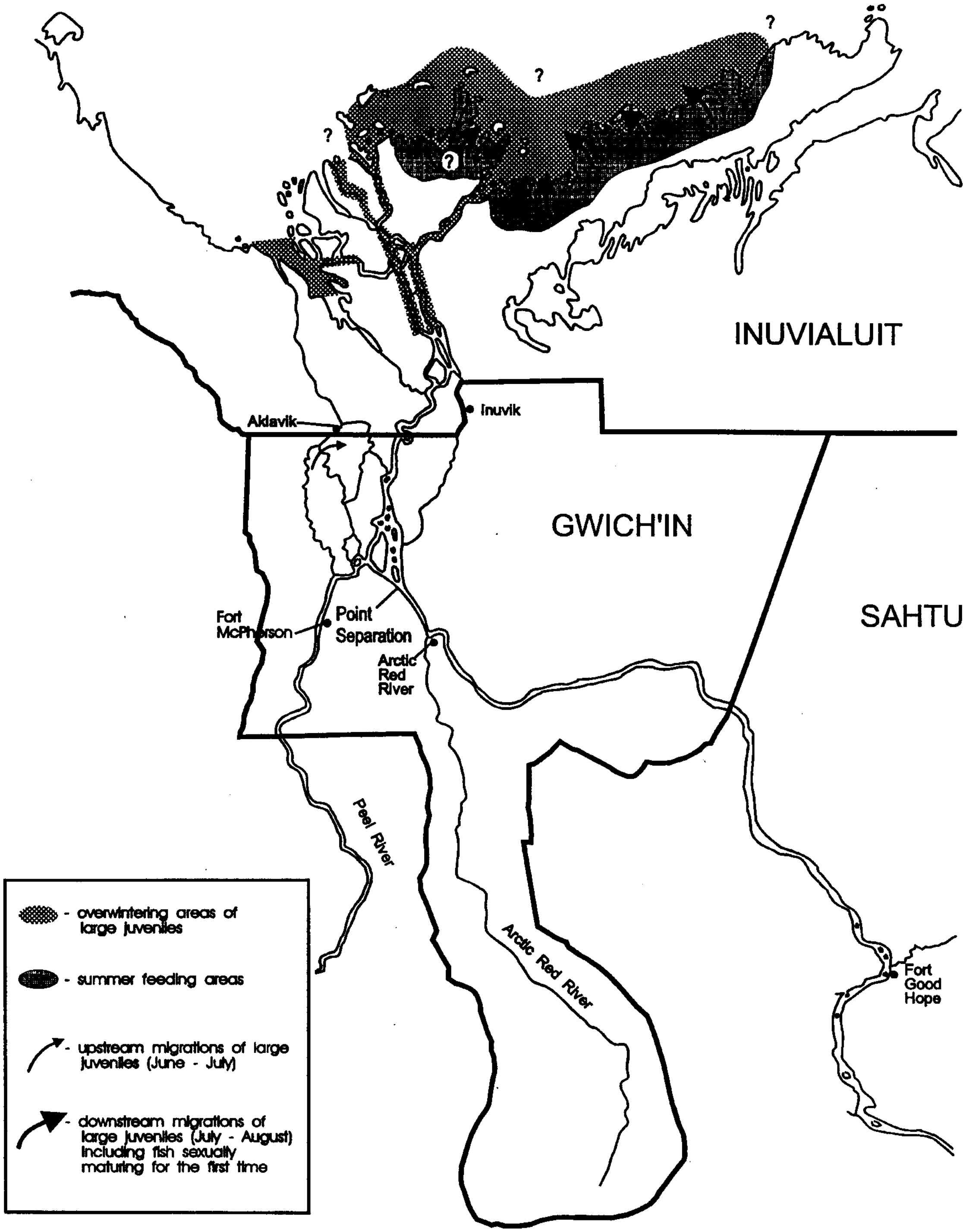

Figure 4. Habitats used and movement patterns of large juveniles of the semi-anadromous life history type of broad whitefish. Question marks indicate uncertainty regarding actual distribution of habitats used or timing of migrations.

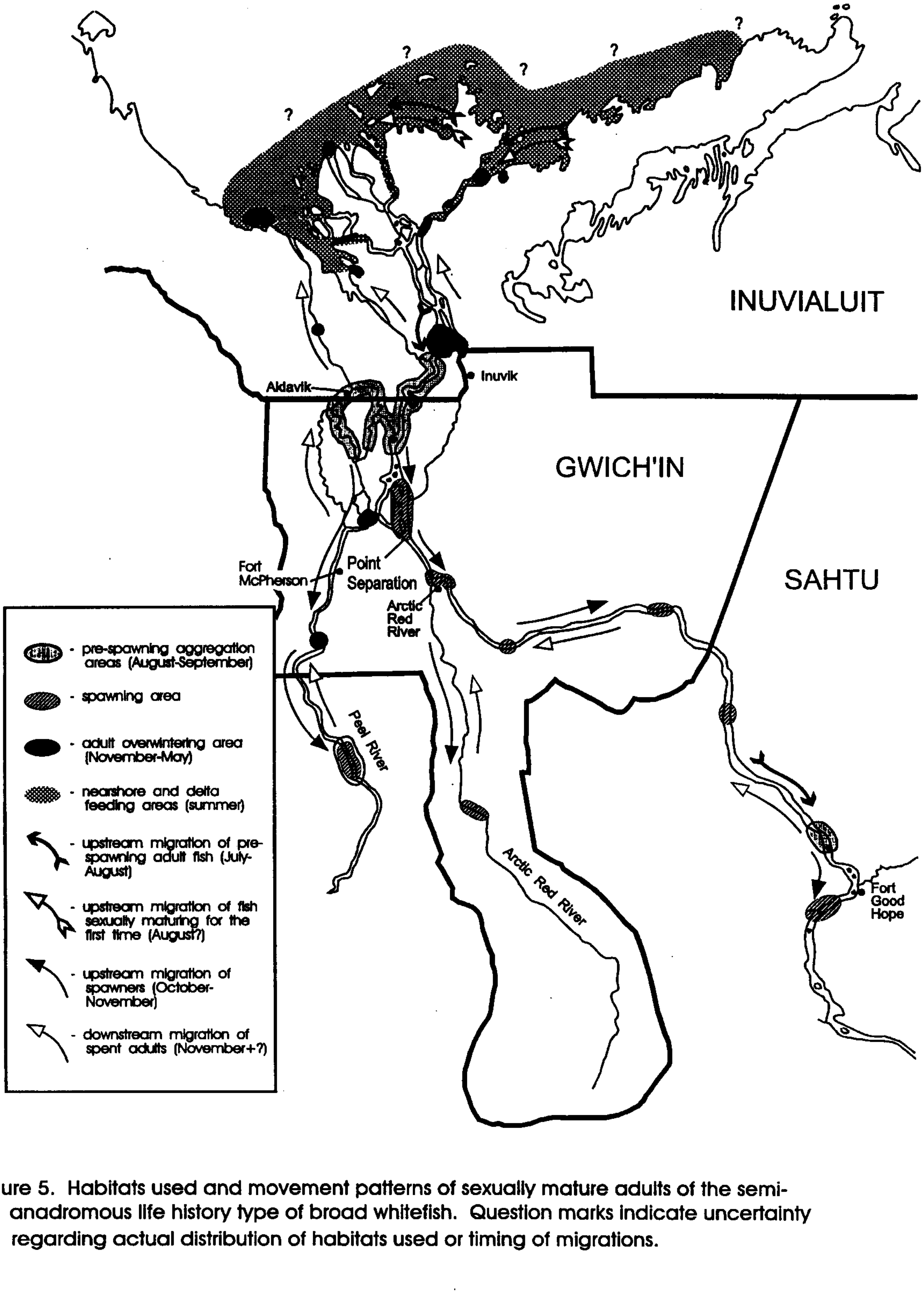

Figure 5. Habitats used and movement patterns of sexually mature adults of the semi-anadromous life history type of broad whitefish. Question marks indicate uncertainty regarding actual distribution of habitats used or timing of migrations.

STOCK STRUCTURE AND LIFE HISTORY TYPES OF BROAD WHITEFISH IN THE LOWER MACKENZIE RIVER BASIN – A SUMMARY OF RESEARCH

by

James D. Reist

ABSTRACT

Based upon body morphology, two life history types of broad whitefish are present in the lower Mackenzie River basin – non-migratory, lake-dwelling (lacustrine), and migratory between the nearshore Beaufort Sea and freshwater (anadromous). Genetic evidence confirms this. Also, several genetic stocks likely exist within each of these life history types. Within the lacustrine life history type, fish from different complex lake systems (e.g., Travaillant and Campbell Lakes) are different from each other. Within Campbell Lake, differences between samples of spawners from different years suggest either the presence of more than one stock or mixing of the lacustrine and anadromous life history types. Within the anadromous life history type, several stocks also likely exist. These separate genetic stocks are found in the Peel River, the Arctic Red River and nearby mainstem of the Mackenzie River, and the Ramparts Rapids area near Fort Good Hope. Although the degree of difference is not significant, the fish from Arctic Red River and the mainstem Mackenzie River may also comprise separate stocks. Some phenotypic evidence suggests that structuring into stocks may also be maintained during life history at times other than spawning – for example, juveniles that are present in nursery streams on the Tuktoyaktuk Peninsula, and pre-spawning adults in Horseshoe Bend in the late summer and fall. These findings greatly complicate the management of individual stocks of this species.

INTRODUCTION

Biological populations should be managed in a natural way. That is, each population which may exist should be managed so it is conserved in the face of all possible impacts (Reist 1997, this publication). A biological population or genetic stock is defined as a natural unit which is genetically distinct. Basic biological parameters which are important in fisheries management differ from one stock to the next. Such parameters include abundance of the stock, growth rate, reproductive rate, age-at-maturity, and so on. Thus, to effectively manage individual stocks, the management unit must coincide with the natural, biologically defined genetic unit.

The aim of this paper is to provide a summary of results of studies on stock structuring of broad whitefish from the lower Mackenzie River basin. This research has been conducted over a number of years and represents work funded by the Northern Oil and Gas Action Program, DFO/Inuvialuit Fisheries Joint Management Committee, and DFO.

Broad whitefish in this area may migrate between nearshore coastal environments and upstream spawning areas (Reist and Chang-Kue 1997, this publication). The presence of a substantive bedrock shelf in the vicinity of Ramparts Rapids immediately upstream of Fort Good Hope provides an environmental feature that divides the upper and lower basins of the Mackenzie River. This drop in the river bed combined with low water flows at fall spawning times prevents upstream movements of broad whitefish beyond this area (K. Chang-Kue, Freshwater Institute, pers. comm.). Therefore, broad whitefish in the lower Mackenzie River likely comprise a group of fish separate from any found upstream of this area.

Broad whitefish of the lower Mackenzie River basin are one of the most important food fishes for residents of the lower Mackenzie River basin (Treble and Reist 1997, this publication; Chang-Kue and Jessop 1991). Therefore, there is a significant need to understand basic biology such as structuring into genetic stocks.

DEFINITIONS

The terms and general methods used need to be defined. A **genetic stock** is a local population that maintains recognizable genetic differentiation as a result of separation of spawning place or time from other populations (Bailey and Smith 1981). Stocks may be different for both genetic (**genotypic**) and non-genetic (**phenotypic**) characters. Genotypic characters are those such as different forms of the same enzyme (allozymes) or variation at the level of the basic genetic material itself (DNA). Phenotypic characters are those which are expressed in particular ways depending upon the local environments occupied (Booke 1981) and which can be measured directly such as size and shape of body parts. Characters that define phenotypic stocks may have a genetic basis, an environmental basis, or both. It must be recognized that both genotypic and phenotypic differences can be used to identify and discriminate between genetic stocks. Agreement among several different types of information greatly strengthens the confidence which can be placed in the results. However, if any differences are noted between groups of fish, this suggests that for at least some portions of their life history those groups occupied different habitats. That means that all broad whitefish in an area can not simply be treated as members of the same group. A convenient synonym for the term genetic stock is **biological population**. Thus, biological populations can be discriminated as a genotypic stock, a phenotypic stock, or both, depending upon the type of data used to differentiate among the possible groups.

Groups of fish can also exhibit different patterns during their life history. These patterns are referred to as **life history types.** At least two life history types exist for broad whitefish in the lower Mackenzie River area (Reist and Chang-Kue 1997, this publication), and these can be recognized using external characteristics (see below).

WHY DIFFERENTIATE LIFE HISTORY TYPES OF STOCKS?

Each biological population and each life history type represents a specific group of fish different from other groups. Over evolutionary time, the characteristics of each group change to maximize the survival, growth and reproduction of members of the group. Successful individuals will reproduce more than less successful ones, and over time will come to dominate the population. The development of these biological traits and the selecting of specific characteristics occurs within the environment occupied by the specific biological population. Because no two geographic areas or habitats are exactly the same, the characteristics possessed by one stock will be most efficient in the particular area in which that stock occurs. Other stocks will be less well-adapted to those habitats (and better adapted to their own habitats). Individual genetic stocks maintain their genetic integrity over time, thus the characteristics evolved are specific to that particular stock. As a consequence of this, important fishery management parameters such as overall abundance, recruitment rate, growth rate, reproductive rate, and so on, all may differ between stocks. This means that the response of different stocks to impacts such as environmental variability, human-caused habitat change, or exploitation will be stock-specific. Thus, knowledge of how organisms are grouped into life history types and genetic stocks is a vital prerequisite for fishery management to ensure sustainability and continued survival of all stocks and types present in an area. In this way, management can be conducted in a way to prevent the depletion of specific stocks and the development of conservation issues.

HOW ARE LIFE HISTORY TYPES AND GENETIC STOCKS DIFFERENTIATED?

Different types of information can be used to differentiate both life history types and genetic stocks. In general, samples of fish are examined for both genotypic and phenotypic differences. If such differences exist then more than one type or stock is present in the area. Genotypic differences represent actual genetic differences in characters such as the basic genetic material itself (i.e., DNA) or in various products of the genetic material (e.g., variable forms of enzymes used in biochemical processes within the fish – allozymes). For example, in human beings the eye colour or hair colour of an individual are characters that result solely from the genetic information present in the individual. Phenotypic differences observable in organisms represent differences that have both a genetic basis but may be influenced by the environment in which the fish grew. In fish, phenotypic characters known to have both genetic and environmental components include things such as the size and shape of body parts (e.g., length of fin), the number of meristic or countable parts on the body (e.g., number of rays in a fin), the characteristic rate of growth, fecundity, and so on. Equivalent types of characters in human beings are things such as adult height and weight.

Both genotypic and phenotypic types of characters can be used to distinguish between groups of fish. However, if a difference is found in a phenotypic character, this difference cannot be specifically attributed to a genetic or environmental cause. Conversely, if a difference is found in a genotypic character, this can of course be attributed to an underlying genetic difference between the types or stocks. Therefore, the most useful characters for distinguishing groups in fish are those that are genetically based. Phenotypic characters are still useful because, at the very least they provide evidence of the occupation of different habitats by the groups. Phenotypic differences may also reflect underlying genetic differences between the groups which we may not discover in any other way. Phenotypic characters may also allow us to identify individual fish to the group to which they belong using easily recognizable characteristics.

OVERVIEW OF POPULATION STRUCTURING ON BROAD WHITEFISH

Because of the complex life history pattern and migrations by the different life history stages of broad whitefish in the lower Mackenzie River (Reist and Chang-Kue 1997, this publication), a number of different questions can be asked regarding population structuring. 1) Do separate and distinct life history types exist within broad whitefish of the lower Mackenzie River basin? 2) Within each of these life history types, do distinct genetic stocks exist? 3) If stocks exist, is the grouping into stocks maintained throughout life history at all times and stages, or is there mixing of different stocks (or types) during non-spawning periods of life history? 4) If stocks exist, can we develop criteria by which we can identify individuals to their stock-of-origin, especially during times when individuals from different stocks occupy non-spawning areas and/or may form mixed-stock groups? 5) Are the broad whitefish of the Mackenzie River distinct from those elsewhere? Because broad whitefish live a long time, because of the details of the timing and places that life history events occur, and because broad whitefish may not spawn every year, a number of specific questions exist within several of the general questions above. These questions and the relevant evidence to address them are examined below.

1) Do separate and distinct life history types exist?

Based upon scientific knowledge (e.g., occurrence in Siberia) and traditional knowledge, two life history types of broad whitefish were suspected to exist in the lower Mackenzie River basin (Reist and Chang-Kue 1997, this publication). This is confirmed by the research summarized here. For samples collected from Campbell Lake (1985, 1988) and from Travaillant Lake (1985), both genotypic and phenotypic differences indicate the presence of two distinct life history types of broad whitefish in this area (Fig. 1). For example, the frequencies of the alternative forms of the variable enzymes (alleles) differed greatly between the samples from these lakes when compared to samples from the river systems (e.g., Arctic Red, Peel, Mackenzie) and from samples taken in the Delta. Thus, at least two life history types are present - a non-migratory, lake-dwelling (lacustrine) type and a migratory anadromous type. In general, observation of these types indicates that the lacustrine type has a dark gray to black back, yellowish belly, golden highlights on the sides of the head, white-grayish pectoral and pelvic fin, high fat content, a very thick ventral body wall, and is generally more robust. In contrast, the anadromous type has a slate or light gray back, white belly, no golden highlights, dark or black paired fins, low fat content, thinner belly wall, and generally is a lighter, less robust fish. These types may mix during non-spawning times in some areas such as the Mackenzie mainstem and the delta. However, because little is known of the migrations of the lacustrine type, the degree of this mixing is not known.

2) Within each life history type, do distinct genetic stocks exist?

For the lacustrine life history type, based upon the size, complexity and the number of separate lake systems in the area, it is likely that each separate, large lake system contains a distinct genetic stock. However, insufficient sampling has been conducted to test the generality of this supposition. Genetic and morphological results to date suggest that the lacustrine type from Travaillant Lake is distinct from that of Campbell Lake. Given the size and complexity of the Campbell and Travaillant Lake systems, it is also possible that separate genetic stocks of the lacustrine life history may exist within each of these aquatic systems. Once again insufficient sampling has been conducted to answer this question. However, two samples from Campbell Lake (1985, 1988) were significantly different for allozyme allele frequencies and morphological results (Fig. 1). Thus, at least in Campbell Lake, multiple genetic stocks of the lacustrine type seem quite likely. Therefore, in summary, at least two distinct stocks exist for the lacustrine life history type (Campbell and Travaillant lakes). It is also possible that more than one stock exists within Campbell Lake.

For the anadromous life history type, the genetic and morphological evidence also suggests the presence of distinct genetic stocks. These stocks as expected correspond to the major known spawning locations in the different rivers of the area. Thus, fish from the Peel River, Arctic Red River and the Ramparts Rapids area are likely distinct from each other, although the degree of difference is much less than that observed between life history types, or between the two samples from Campbell Lake (Fig. 1). Samples from the upstream and confluence areas of Arctic Red River and the mainstem Mackenzie River at Tree River showed very little difference from each other, thus cannot be differentiated into distinct stocks using these genetic criteria. It should be noted that the failure to demonstrate a difference does not preclude the possibility of such differences - further tests may reveal such differences. Thus, simply because we have not discovered a difference, we cannot conclude the fish from the different areas comprise only one stock. Therefore, in summary, at least three genetic stocks exist within the anadromous life history type (Peel River, Arctic Red River, Ramparts Rapids). Further structuring of the Arctic Red River and mainstem Mackenzie River fish may occur but is not confirmed using these data.

3) Is the stock structuring maintained during times of life history other than spawning?

Association into different genetic stocks during spawning must occur in order for us to observe any groups in the fish. However, such segregation is not necessary during other phases of life history. That is, even if the fish are structured into genetic stocks which separate at spawning time, these genetic groups can mix at non-spawning times. If mixing of stocks occurs at non-spawning times, it can greatly complicate both the management of individual stocks as well as the overall population. The complexity of management depends upon the number of stocks and how they mix during non-spawning times of the year.

Broad whitefish in this area are highly migratory and different life stages of the species utilize different aquatic habitats for specific life history activities (Reist and

Chang-Kue 1997, this publication). Because of this life history and due to the great complexity in the aquatic ecosystems available in this area, many questions can be asked about stock structure during non-spawning periods of life history. Many of these questions are especially relevant for fisheries upon broad whitefish which concentrate primarily upon the migratory pre-spawning and spawning components. Those questions for which some sampling has been conducted are addressed below.

3a) Are anadromous, juvenile broad whitefish (i.e., 0-8 years of age) segregated into distinct genetic groups when in the coastal nursery systems on the Tuktoyaktuk Peninsula? Sampling of four known nursery systems on the Tuktoyaktuk Peninsula (McKinley, Kukjuktuk, Freshwater and Canyanek creek systems) has revealed the following (Fig. 2). Only minor, but non-significant variation in frequencies of alleles of allozymes was observed. A limited number of meristic differences were observed; however, a large number of morphometric differences were observed. Generally, the number and degree of differences were proportional to the geographical proximity of the systems - that is, adjacent pairs of systems tended to have fewer differences than were observed for more distant pairs. Therefore using phenotypic information, some structuring into groups exists for juvenile broad whitefish in the nursery systems of the Tuktoyaktuk Peninsula. Such phenotypic structuring can be due to underlying genetic differences, environmental differences, or both. Despite the cause, these results indicate that the juveniles on the Tuktoyaktuk Peninsula are not homogenous mixtures derived from all of the upstream spawning stocks. Thus, any potential impacts which affected only one of these creek systems would result in uneven effects upon the genetic stocks identified from upstream areas.

Given the above conclusion, the obvious question is whether individual subgroups of juveniles can be associated with particular upstream stocks of spawners? Preliminary analyses of morphology indicated that the juveniles from the four creek systems more closely resembled each other than any specific adult stock. This is likely due to age-related differences between the juveniles and the adults. However, all samples of juveniles from the Tuktoyaktuk Peninsula most closely resembled the anadromous life history type that spawns in the major rivers tributary to the lower Mackenzie River. This observation is consistent with our current understanding of life history of this species in this area (above, Reist and Chang-Kue 1997, this publication).

3b) Are pre-spawners that congregate and migrate through the Mackenzie River Delta structured into distinct assemblages representative of genetic stocks (or life history types)? Because of the complexity of the Mackenzie Delta system, this question has a number of possibilities which are dealt with in turn below. First, within a year but throughout the pre-spawning aggregation and migration season of late August to late October, is there evidence of structuring into genetic stocks? For 1984, analysis of a series of four temporal samples from the Horseshoe Bend area of the Middle Channel revealed the following. No differences were found for polymorphic enzymes, but meristic and morphometric differences were found. The greatest degree of difference occurred between the samples collected the furthest apart in time. Also, some association of a sample from a particular time with a particular upstream genetic stock was apparent. Thus, the anadromous, migratory fish which support the most extensive fisheries are not a homogeneous temporal mixture of fish from all the possible genetic stocks. Rather, the different genetic stocks appear to migrate as individual groups which overlap in time. It should be noted that these results are based upon characters for which statistically significant differences have been observed. These characters are not capable of specifically identifying any individual to their stock-of-origin. Such capability exists (e.g., DNA analysis, otolith elemental composition) but this type of research has not yet been applied to this problem.

Secondly, between years at the same site within the Delta, do the fish represent the same genetic stock or are they a homogeneous mixture of the available stocks? - For samples spanning several years (1983-1989) from Horseshoe Bend taken at approximately the same time in the season (i.e., late September to early October), no genetic differences were found but all the meristic and morphometric variables examined showed significant differences. In general, as may be expected, samples from temporally adjacent years showed fewer differences than did samples from more distant years. Specific samples from Horseshoe Bend from particular years associated with specific samples of spawners of both life history types, although individual associations may simply be due to chance. The observation that between-year heterogeneity exists in pre-spawning migrating broad whitefish further strengthens the conclusion of structuring into genetic stocks in this area. Because the local environmental cues used by the pre-spawners to time critical events such as final gonadal maturation and upstream migration vary from year-to-year, heterogeneity in between-year sampling is to be expected if stock structure exists.

Third, within a year, but spatially across the Delta, do broad whitefish occupying different habitats or those forming pre-spawning aggregations consist of a homogeneous mixture of the available stocks? - Adequate sampling to sufficiently address this question has not been conducted to date. However, some fortuitous collections of broad whitefish have been conducted that can be used to attempt a preliminary answer (Fig. 3). Comparison of samples from the East Channel at Inuvik, South Lake near to the eastern side of the Delta, Horseshoe Bend (Middle Channel) and the West Channel at Aklavik revealed the following. No genetic differences were observed. Some meristic differences and a good number of morphometric differences were observed. The Horseshoe Bend-East Channel pair exhibited the fewest differences and may be a mixture of several stocks (Fig. 3). Fish from near Aklavik were different from those of the eastern part of the delta (Fig. 3). Fish from South Lake near Inuvik also were a distinct group separate from the others. All of these samples associated with the spawning stocks of the anadromous life history type rather than the lacustrine life history type. However, no clearly explainable pattern based upon geographical proximity of the Delta site to a particular upstream spawning site was apparent. Thus, it is likely (but inadequately tested) that spatial heterogeneity of pre-spawning aggregations of migrant broad whitefish exist throughout the delta. That is, as was found for the studies within and between years, migratory groups of whitefish are not homogeneous mixtures of all possible stocks.

4) Are criteria available to identify individuals to their stock of origin?

Two approaches to this question are possible - identification based upon probability and absolute identification. The former can be based upon differences in the frequency of specific characters among samples. Absolute identification is only possible if the stocks consistently differ with respect to a particular character. For genetic criteria this could be the presence of a particular allele in one stock and the presence of an alternative allele in the other. In general both allozymic genetic variation and morphological variation between different genetic stocks of a species differ only with respect to frequency. Thus, these criteria are not useful at this level of question. Alternative methodologies such as DNA analysis and detailed elemental analysis of hard body tissues such as otoliths which once laid down do not undergo chemical change both show promise for such application but have not yet been applied to the broad whitefish stock structuring problem. Thus, the exact stock-by-stock composition of migratory fish that are the subject of fisheries throughout the area cannot be determined at this time.

5) Are broad whitefish present in the lower Mackenzie River basin and nearby coastal areas different from those found in other river systems of northwestern North America?

Samples of broad whitefish from central, western and northern Alaska, Yukon north slope, lower Mackenzie River Basin, Miner-Kugalik Rivers, Anderson River, Hornaday River, and the Coppermine area were used to test this question. Significant genetic differences for allozymes and significant morphological differences were found for most variables. Thus, the broad whitefish of the lower Mackenzie River basin including those from the river spawning areas, the large lake systems, the Mackenzie Delta, the Tuktoyaktuk Peninsula, and Phillips Bay along the Yukon north slope all comprise an assemblage of fish distinct from those of both eastern and western rivers in the northwestern arctic of North America. The lacustrine life history type was similar to, but still distinct from, the anadromous life history type. Thus, these genetic and morphological results substantiate the general view of life history of lower Mackenzie Broad Whitefish (Reist and Chang-Kue 1997, this publication). That is, despite at least one type being migratory to coastal areas near to the Mackenzie River, no mixing occurs of these fish with those of other arctic river systems.

SUMMARY OF RESULTS

The broad whitefish of the lower Mackenzie River basin are distinct from those of other systems in the western Arctic, thus the management of this species in this area can be restricted to the Mackenzie River basin itself. However, within the Mackenzie River basin considerable spatial and temporal heterogeneity exists for the various groups of broad whitefish. Two life history types exist, and within each, multiple genetically distinct populations exist. These populations are each others most closest relative within each type. The fish that constitute non-spawning groupings, whether as juveniles in nursery streams on the Tuktoyaktuk Peninsula or as pre-spawning migratory assemblages temporally or spatially across the delta, all are members of the anadromous life history type. Thus, the genetic and morphological results to date are consistent with the general view of life history of anadromous broad whitefish built up from observation of migration and biological investigations (Reist and Chang-Kue 1997, this publication). Pre-spawning fish which form the basis for most fisheries in the area are not homogeneous mixtures of fish from all possible stocks. This complicates attempts at stock-by-stock management.

For the lacustrine life history type, the situation appears much simpler. So far as has been tested, each lake system appears to be a specific stock which likely does not migrate very far. Therefore, the broad whitefish in each lake system can be managed on a local basis. The only complicating factor is the potential for mixing of the two life history types in some situations. Such mixing is possible for both Campbell Lake and to a lesser extent for Travaillant Lake. However, because the fish are easily identified to life history type using external criteria, mixtures of the two types can be managed separately as necessary and providing the appropriate data are collected.

MANAGEMENT CONSEQUENCES OF STOCK STRUCTURING

The structuring into both distinct life history types and genetic stocks necessitates the development of suitable management protocols to ensure the continued survival of the individual genetic units. This is further complicated by the migratory nature of at least the anadromous life history type (i.e., across land claim boundaries), the nature of habitats occupied at various times, the size and complexity of the physical area, and the number and distribution of potential impacts (including exploitation) (Reist 1997, this publication; Reist and Chang-Kue 1997, this publication). To ensure the viability of each genetically distinct unit, the biological integrity of both that unit and the aquatic ecosystems necessary to it must be maintained in the face of all impacts on it. This means that the management of the various stocks must be conducted in such a way that effects of human activities are a) distributed among the stocks to the same degree as those stocks can absorb the effects, and b) must be below the ability of the individual stock to absorb and compensate for the effects.

The immediate problem that results from biological structuring into stocks and life history types is one of insufficient knowledge. By definition, unique genetic stocks likely possess unique biological parameters that are related to sustainable exploitation including individual growth and reproductive parameters. Furthermore, the association of an individual stock with an unique environment at least during some portion of its life cycle means that because the carrying capacities differ between areas, the absolute abundance of the individual stock will also differ. Clearly, the ability to determine at least the relative abundances of the individual stocks and the production parameters of the individual stocks, and to estimate the effects of human actions on individual stocks requires much more detailed and structured biological investigation in the future.

In a biologically complex situation as described herein for broad whitefish, two extremes of management of the stock complex are possible. First, the complex can be managed as a whole at least insofar as the migratory anadromous type is concerned. Alternatively, the management can be conducted upon the smallest biologically definable meaningful unit - in this case, each individual genetic stock. Lack of biological understanding and insufficient resourcing combine to severely curtail the latter option. Thus, the only practical option available is to manage the anadromous life history type as a complex of individual stocks. Because of both the transboundary migratory nature of this life history type and of our lack of knowledge of the vulnerability of individual stocks, the most conservative management approach possible is recommended. Thus, the total effect of any and all management decisions must be within the limits of sustainability of the individual stock least able to withstand the impact. To ensure a conservative approach to management, the development of a suitable overall management plan is recommended for the anadromous life history type of broad whitefish. Such a plan must have input by all concerned groups (Inuvialuit, Gwich'in and Sahtu peoples as well as DFO fishery researchers and managers).

Management of the stocks of the lacustrine life history type is generally much simpler because these fish do not make extensive migrations. Thus, management of the individual populations of this type can be conducted on a local basis by the relevant co-management board. The only possible complication to this is if the anadromous and lacustrine life history types mix together in some situations (e.g., Campbell Lake).

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COMMENTS, QUESTIONS AND ANSWERS

No comments.

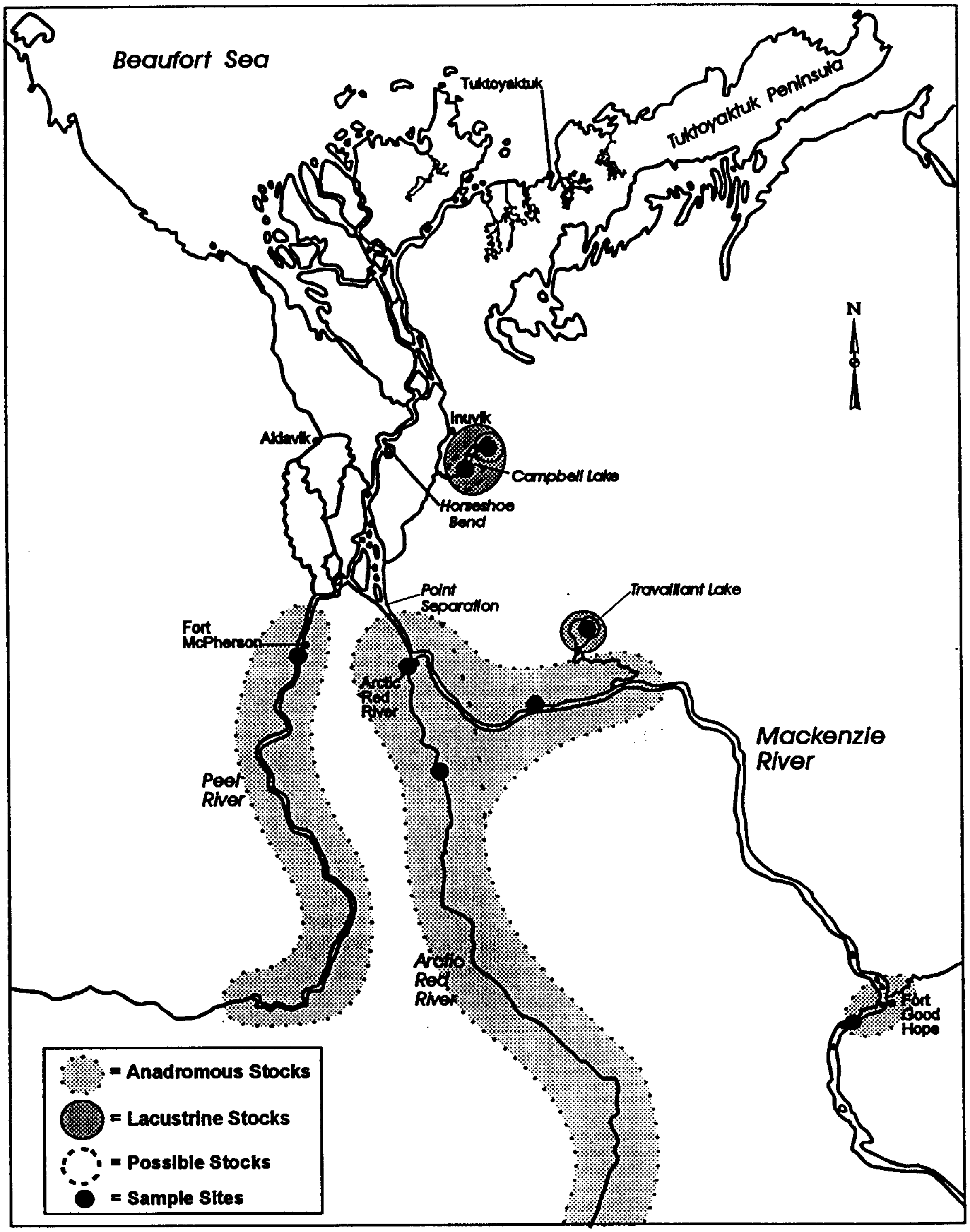

Figure 1. Summary of tests for discrimination of life history types and stocks of adult spawning broad whitefish. Note that boundries presented for the individual stocks are hypothetical generalizations. Also, the sampling of potential spawning assemblages was incomplete, thus these stocks represent the minimum - there is a high potential for multiple stocks within the complex habitats in some areas.

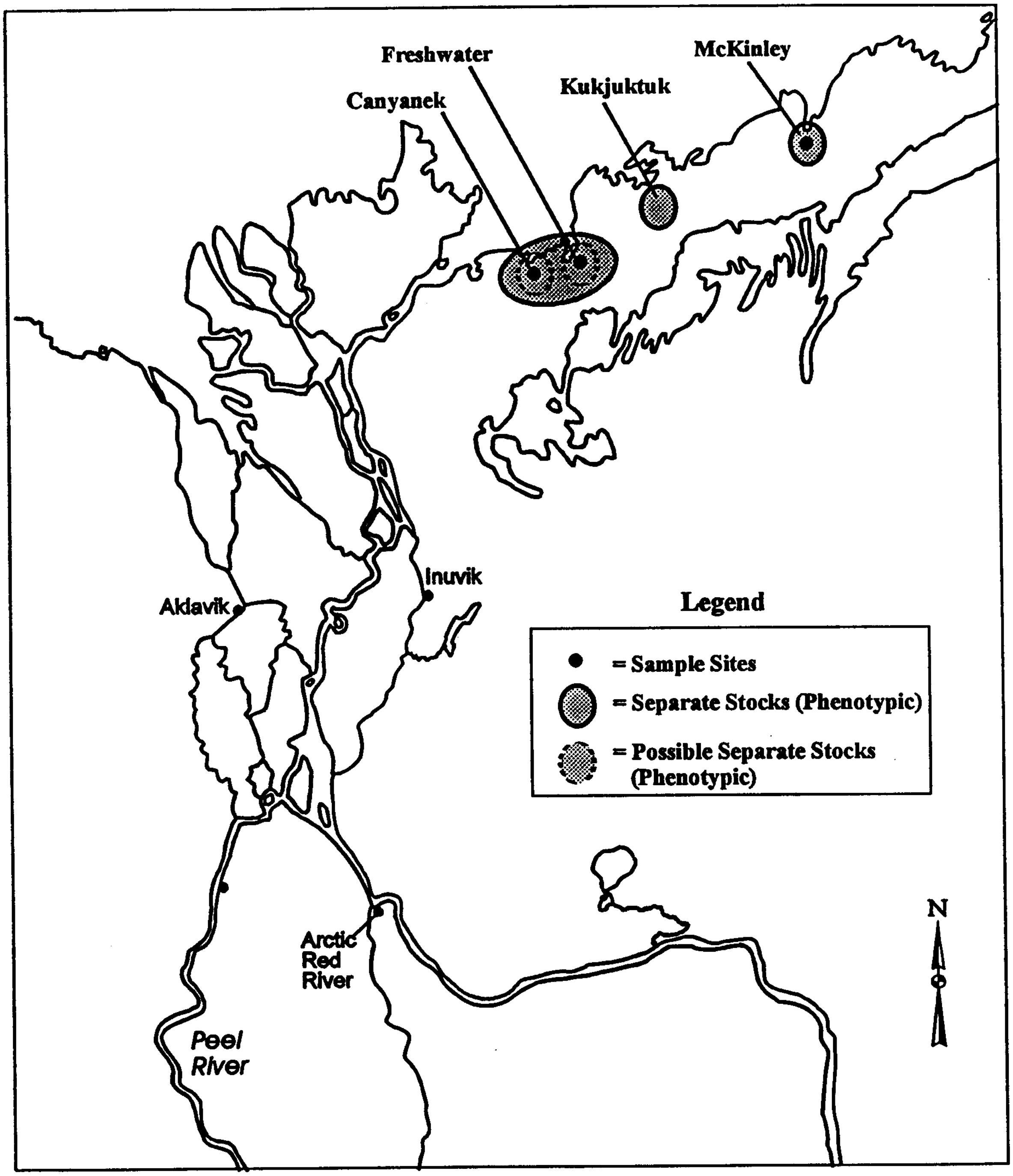

Figure 2. Summary of tests for discrimination of stocks of juvenile broad whitefish of the anadromous life history type from four creek systems on the Tuktoyaktuk Peninsula.

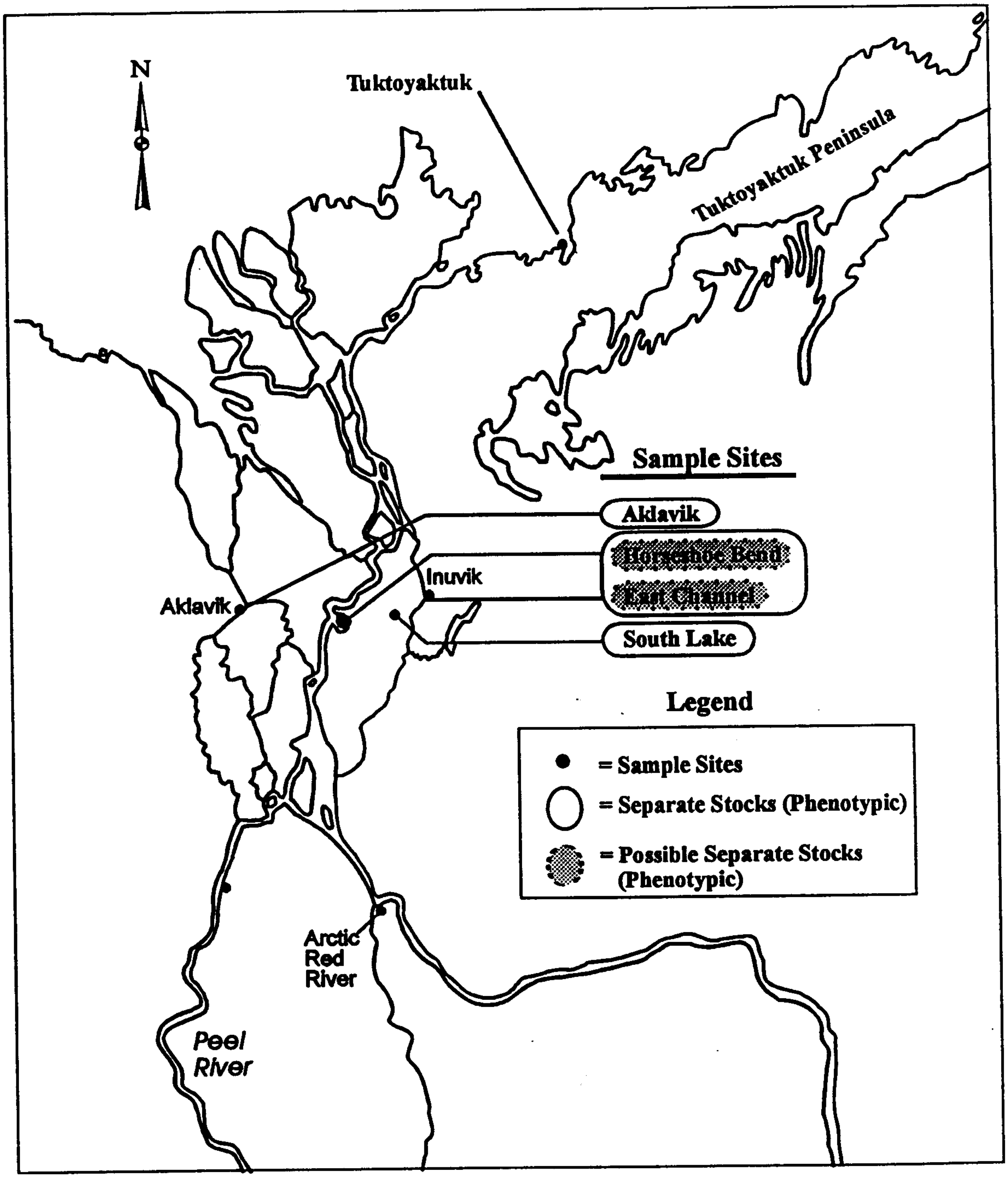

Figure 3. Summary of tests for discrimination of stocks of the anadromous life history spatially across the delta. These samples do not necessarily represent a single life history stage, rather they may be mixtures of pre- or post-spawners.

METHODS FOR ESTIMATING STOCK SIZE: APPROPRIATENESS FOR MACKENZIE RIVER FISHERIES

by

Ross F. Tallman

ABSTRACT

Six methods used in fisheries to give an index of stock size are discussed. Catch-per-unit-effort, weir counts, mark-recapture methods, density-based methods, population analysis and mixed-stock fishery analysis are briefly described using graphical presentation. The reliability of each method for estimating stock size of the Mackenzie River broad whitefish is considered. It is concluded that mixed-stock fishery analysis is the best method for anadromous stocks of broad whitefish in the Mackenzie River.

SUMMARY

Fisheries cannot be managed by knowledge of catch alone. To determine the effect of fishing practices and to formulate policies that will produce sustainable harvests it is important to estimate stock size (Cushing 1981; Walters and Hilborn 1993) (Figs. 1 and 2).

Various techniques to track stock size are used such as catch per unit effort (CPUE), weir methods, mark-recapture methods, density-based methods, population analysis and mixed-stock fishery analysis. The methods vary in their effectiveness depending on the characteristics of the fishery, the physical setting and the biology of the species being harvested.

Catch per unit effort (CPUE) assumes that stock size is proportional to number of fish caught in a given net of standard mesh size and length set for a standard length of time. Thus, if stock size increases CPUE will increase proportionately (Fig. 3). Estimates of stock size may be violated if the behaviour of fish change with density changes. In the Mackenzie River it is likely that fish might change the channels that they migrate through from year-to-year and hence bias CPUE estimates.

Weir methods involve direct interception of all fish entering into a system via a barrier (a weir) to obtain a complete count of the resource. Effective monitoring using weirs is possible on small river systems but not on larger rivers such as the Mackenzie River and its tributaries (see Fig. 4). Another method is to create an acoustic weir. This methodology could estimate numbers in larger systems (Fig. 5).

Mark-recapture methods involve estimation of the stock size by marking or tagging a sample of fish with the percentage recaptured at a later date being used to calculate stock size using the following equation:

$$S = M \text{ X } \frac{H}{R}$$

Where S = stock size, M = the number of fish initially marked, H = the number of fish caught in a second sample or harvested, and R = the number of marked fish in H.

Estimates can be biased if marks do not re-distribute themselves evenly (Fig. 6).

Density-based methods are used in open water fisheries in very large lakes and in the marine system. Population analysis involves the use of age-structured models to project ahead into the future. It is a very effective method (Rivard 1989).

Mixed-stock fishery analysis requires three major steps in information gathering. First, the degree of population variation must be characterized in terms of genetic, morphological, and demographic characteristics. Learning sample data are collected from each major spawning stock unit to define stock distinctness. In the Mackenzie River broad whitefish this meant we characterized the units as Point Separation, the Peel River, Arctic Red River and Upper mainstem/Fort

Good Hope stock. Second, samples must be collected from the major fishing areas where mixing of stocks occurs. The percentage contribution of each stock to the fishery can be determined by using a statistical technique known as maximum likelihood estimation (Wood et al. 1987). Thus, at Horseshoe Bend, the fishery might be composed of 20% Point Separation, 20% Peel River, 50% Arctic Red River and 10% Fort Good Hope fish. Finally, a direct estimate of absolute or relative abundance for one index stock will allow the calculation of the combined total number of fish available to the fishery from all stocks and the abundance levels of each individual stock unit. For example, using the above percentages, if it is determined that the Arctic Red River stock is 50,000 fish then there must be a total of stock of 100,000 with contributions of 20,000 from Point Separation, 20,000 from the Peel River and 10,000 from the Fort Good Hope stock. This is the only method that takes into account the stock structure present in the Mackenzie River broad whitefish and therefore is the most appropriate for management of the Mackenzie River anadromous broad whitefish. Alternative methods such as CPUE or mark-recapture may be more appropriate for landlocked non-migratory populations such as in Travaillant Lake.

The scientific program for the Mackenzie River broad whitefish focusses on the first phase of the process to develop mixed-stock fishery models. It encompasses studies of migration, genetic variation, morphological variation, variation in traits important to stock productivity and understanding the demographics of populations to determine what is it? and how does it work? This information will be combined with the findings of the traditional knowledge component to help managers make fishery decisions.

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COMMENTS, QUESTIONS AND ANSWERS

Billy Day: We're talking a lot about stock size and questions on the abundance of fish. How are we going to decide how abundant the fish are out there?

R. Tallman: The best methodology would be the mixed-stock analysis. The number that you arrived at would be the total stock available in the Horseshoe Bend area. That methodology is used for sockeye salmon on the Stikine River, which is another turbid river. While the river is not the same size as the Mackenzie, it’s still a fair size. The mixed-stock fishery analysis approach has been quite successful. Rather than relying on a single method, I think we should combine a number of methods. I think we need to know long-term trends. We can't use the mixed-stock method to go backwards but we do have traditional knowledge, and we have things like Margaret Treble showed where she did an analysis of some historical records. Overall, throughout the Delta the belief is the fishermen are getting about the same number of fish per net. That's like a 'catch-per-unit- effort' for everything. I think that would be a reasonable relative measure. It may not give you exactly how many fish in the stock, but it may suggest your fishing is not having a serious effect on the abundance. The other methods that may be possible are by using tagging. Providing some of the assumptions are met, we could get an estimate of abundance through 'mark-recapture techniques'. Each of these methods has strengths and weaknesses. When that's the case, we try to use a number of techniques. That would be my overall recommendation: to use a number of methods.

Joey Amos: I know that for the last five years with the test fishery, we're talking about estimation of stock size and with DFO doing a lot of the sample work. Now five years of test fishery have been completed and we're waiting for a quota size. What's leading up to it? How are you guys going to determine what size of quota we're going to get for the oncoming years knowing that all of the samples were done in the last five years? Now, this five years is done. How soon can we expect a turnaround to say "OK you have 75 thousand pounds of whitefish"?

R.Tallman: When I did yield calculations working in other situations, I had the catch information, the catch-effort information, and the population biology information all in one place. The problem here is that another group is collecting the biological information. I can't answer for that other group doing the test fishery. I don't have that data. Those things have to be put together and then if that information is sufficient; it's possible to make a calculation to future years. At this point, I do not actually know if the information is sufficient to make what I would consider an appropriate yield calculation, because I don't have all the information. That doesn't mean that would automatically forestall decisions but, on the other hand, I think the best decisions are made with all the information together.

Joey Amos: But my question was basically how long of a turnaround, seeing that all this information has been sent to you in Winnipeg?

R. Tallman: I don't have it.

Joey Amos: Is it going to be a month before the fishery starts again? That way we could plan how big of a scale we are going to go.

R. Tallman: Well, I think that's really has to be answered by somebody other than me because I'm not in a position to control those events.

Ron Allen: I think the next step is for DFO to sit down with the Joint Management Committee and arrive at what would be considered to be in the best interests of this area. Part of what will come out of this week will influence that decision. At this point it would be premature for me representing DFO to say what number we would set. Basically, at this point it's time to sit down with FJMC and say “okay the community has certain interests, what's your advice to the Minister or the Department on where we are going on this? There are other players to be consulted here, given that there are people living elsewhere on the river outside this particular claim area that may have a vested interest. How do we deal with their interests or concerns? So, there's a certain amount of information available. Maybe it not as complete as we would like, but we still have to arrive at a decision at some point given what we have in hand.” We can't afford to wait forever for more information. We've arrived at this point and it's time to get on with it. So, I really hope that there will be some issues raised in the next couple of days that will assist FJMC and ourselves in deciding where we go from here and what level do we set as the highest number.

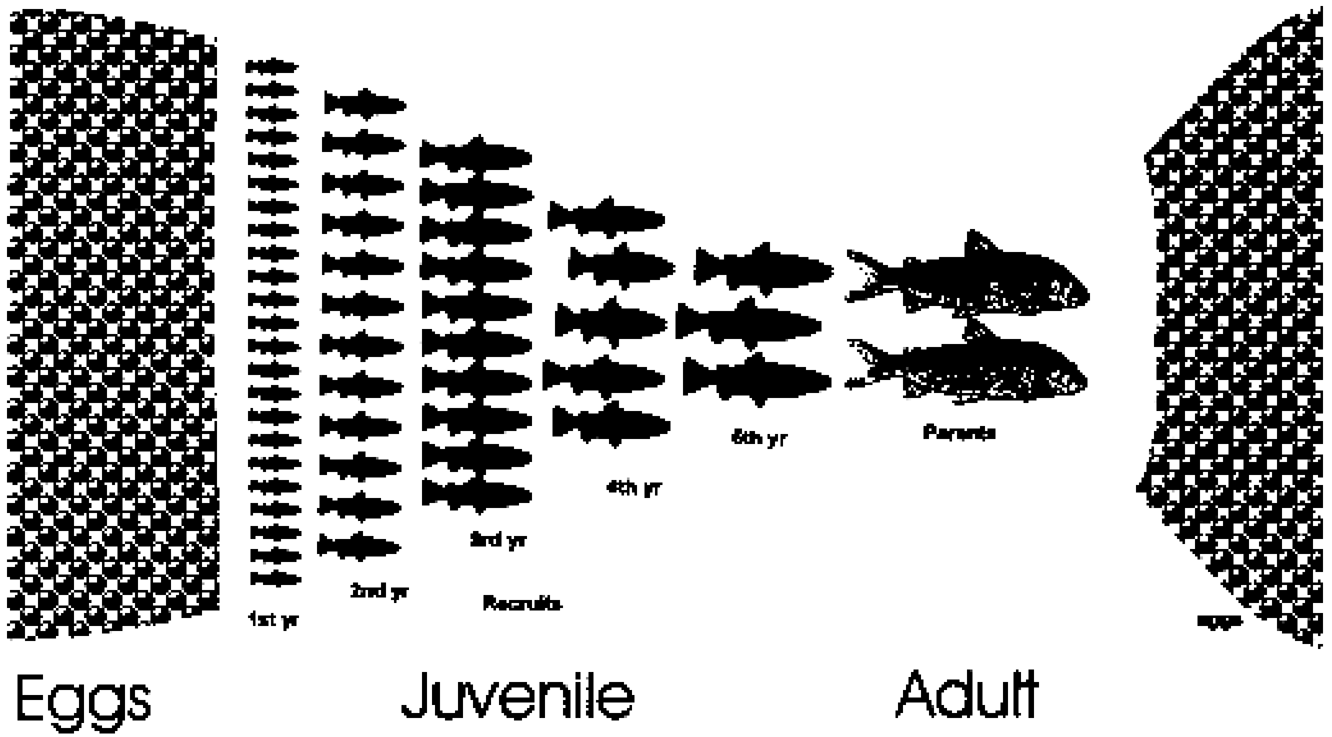
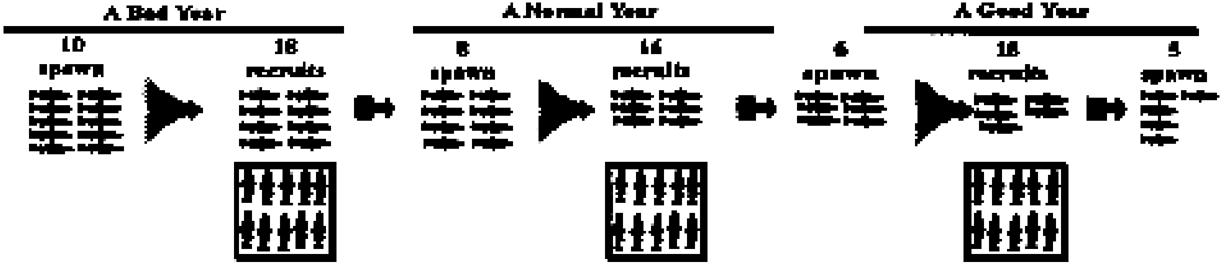


Figure 1. Schematic of a model of fish life cycle. The model above illustrates several simple concepts used in developing fishery models. First, many eggs are produced but on average only two will survive to become adults. Natural mortality is most intense in the earlier life stages. Second, the life is a cycle - all components must be present for persistence of the population. An effect on one part of the life cycle will affect all other parts. Third, as fish age they generally get larger. Mathematical modeling involves translating simple but obviously true ideas about the biology into mathematical terms so that changes can be explored.

A model is a tool used by managers to find out approximately how many parent fish and recruits there are and whether they are increasing, decreasing, or remaining stable in number. This is important because managers want to set harvest quotas without harming the stock.

♦The fishery below is poorly managed because managers do not have the necessary information on the fish stocks to predict abundance and change the quotas respectively.



♦Below is a well managed fishery with quotas assigned to match abundance with the use of models.

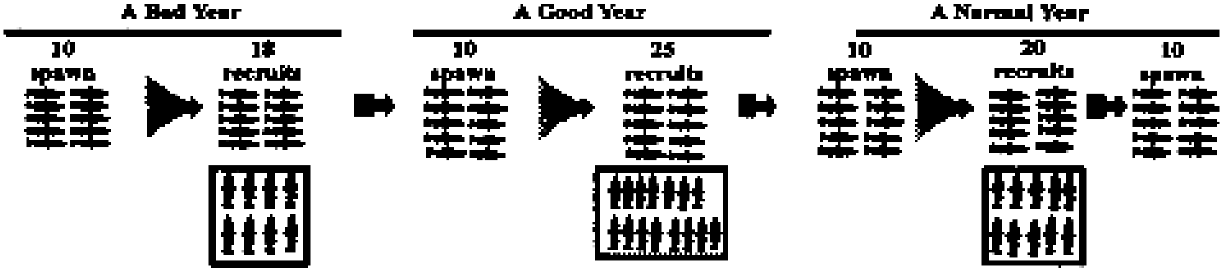


Figure 2. A schematic model of a fishery showing how knowledge of population size is important to fishery management. There are several important considerations in managing a fishery:
Quotas should be set based on the information available to fishery managers on fish stocks.
If not much information is available or if not all fishing is reported, managers have a hard time estimating what the best quotas should be.
Fishery managers monitor the stocks by; measuring and weighing fish, taking otoliths, recording number of nets each fishermen sets, how many hours they are fished and how many fish are caught.
With this information managers are able to perform mathematical and statistical calculations in order to determine how many fish there are in total, how many fish are in each age group, and how big fish are at each age.
Therefore, in order manage a fishery effectively, managers require detailed information and a useful model.

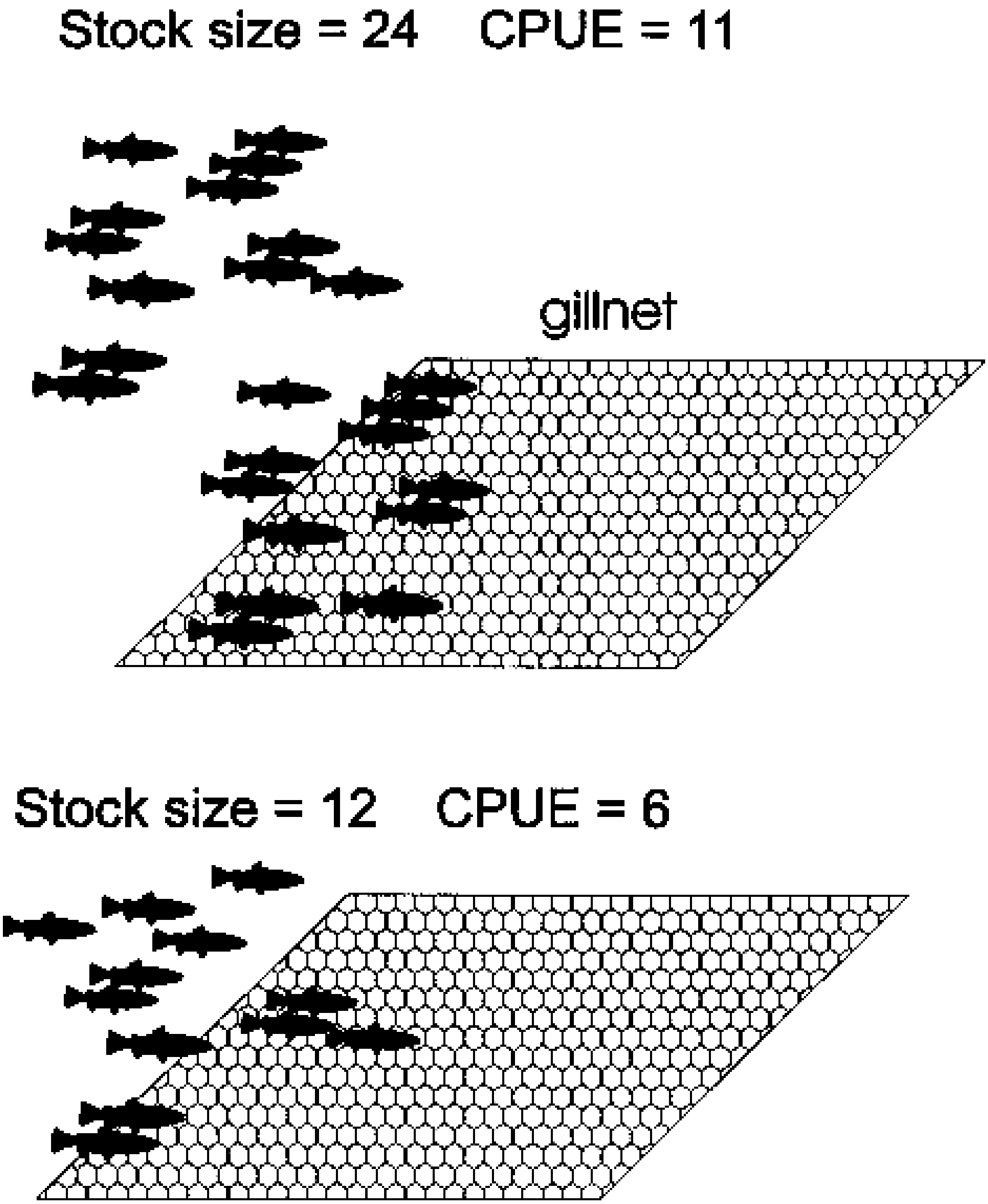
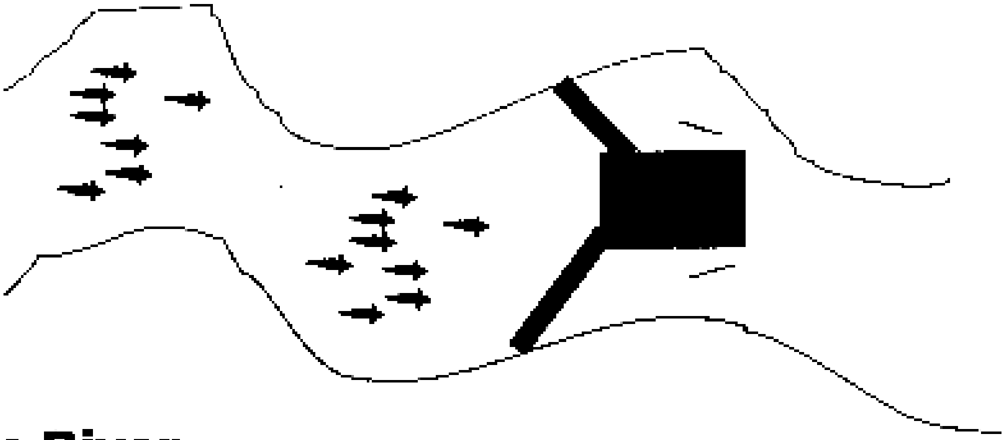


Figure 3. Schematic to illustrate the methodology of Catch-Per-Unit-Effort (CPUE). As the stock size decreases or increases the CPUE will decrease or increase porportionately.

Small River



Large River

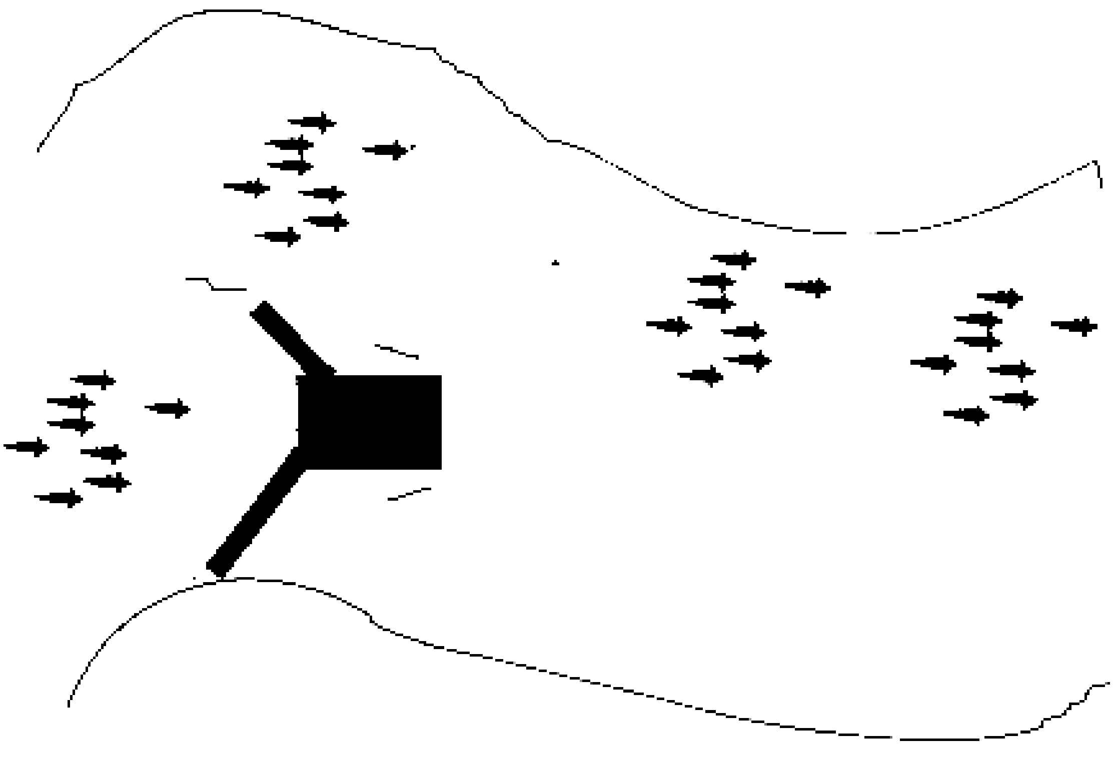


Figure 4. Illustration of the use of a weir on small and large rivers. In large rivers such as the Mackenzie River weirs could not be effective.

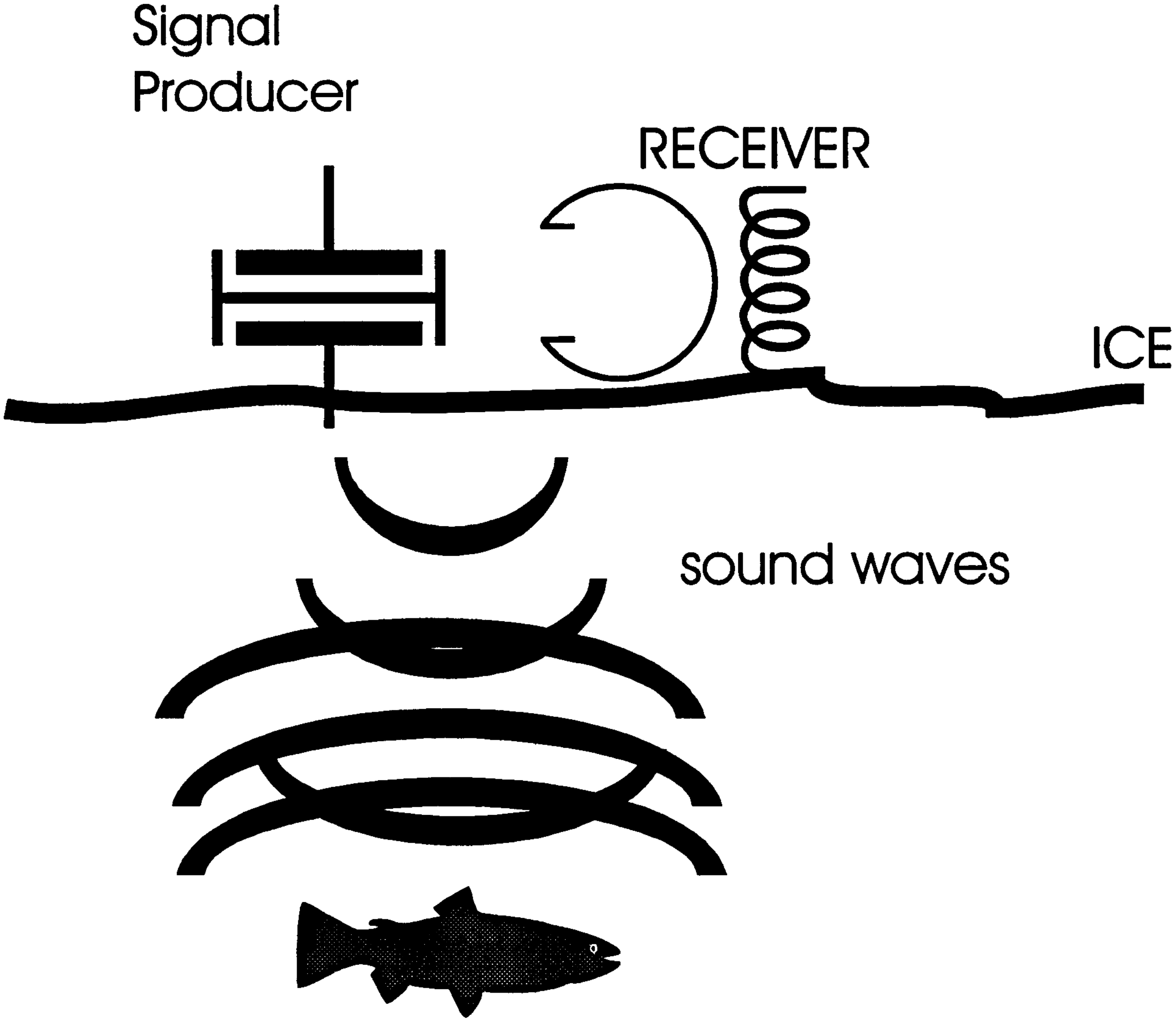


Figure 5. Hydroacoustic detection of fish. Sound waves are sent through the water. When a fish passes through the sound beam it is detected.

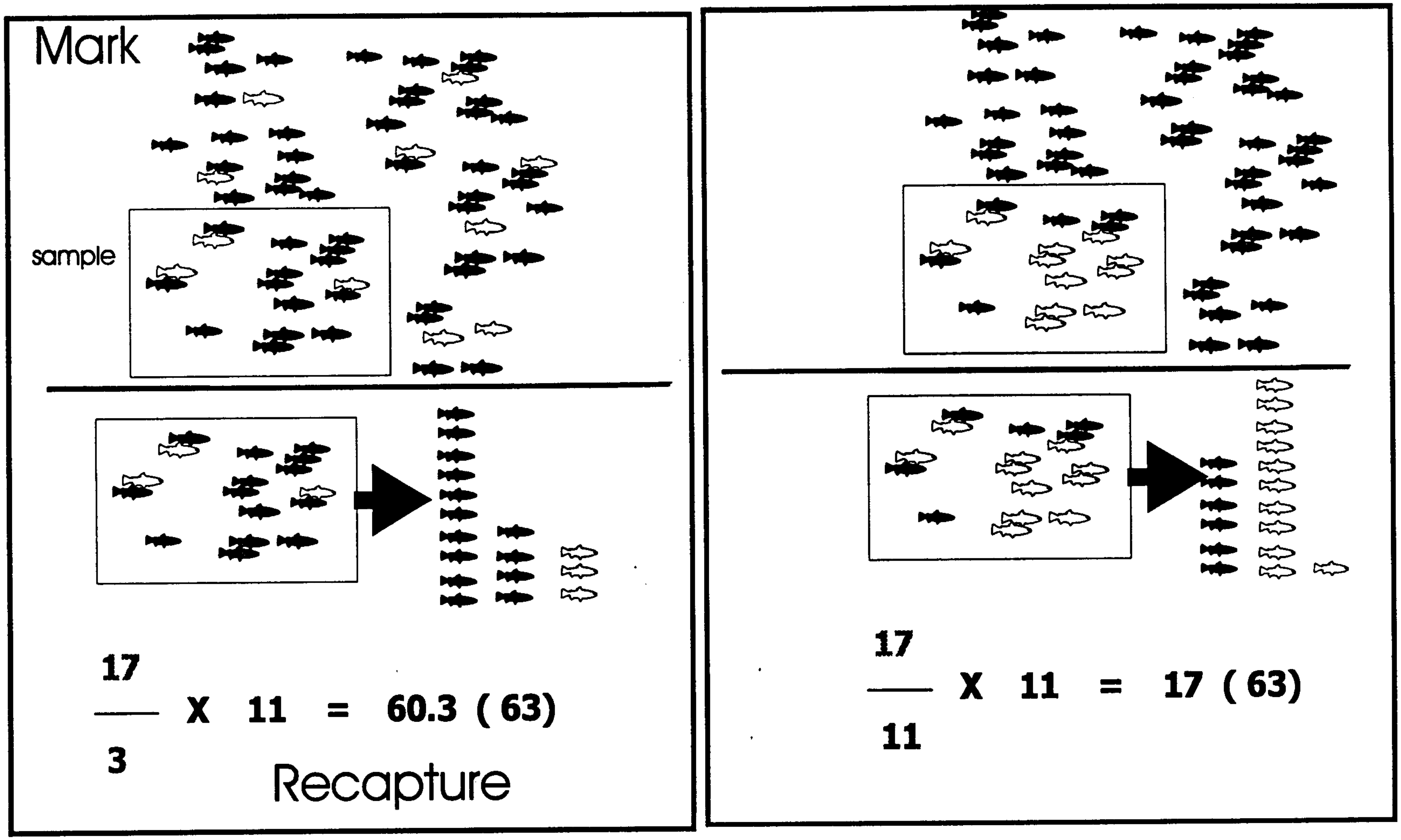


Figure 6. Mark-recapture technique of estimating population size. The upper portion of the panel represents a population with marked fish. The solid symbols represent unmarked fish and the open symbols represent marked fish. The lower portion of each panel represents the recapture and tabulation phase. Note that in the first panel the marked fish distributed themselves randomly throughout the main population. Therefore, the calculated population size of 60.3 fish is close to the real population size of 63 fish. The second panel illustrates the result when marked fish do not distribute at random. The estimate of the population size of 17 fish is far off from the real population size of 63 fish.

BROAD WHITEFISH T-BAR ANCHOR TAGGING IN THE MACKENZIE RIVER DELTA, NT, 1992-1993

by

John A. Babaluk, Rick J. Wastle,
and Margaret A. Treble

ABSTRACT

Tagging operations using T-bar anchortags at Aklavik in 1992 and at Horseshoe Bend in 1993 are described. At total of 113 broad whitefish were tagged in 1992. Of these, 34 were injected with oxytetracycline for age validation. Four fish were recaptured: 3 in the Peel River or channels leading to it and one in the Arctic Red River. Of the 1225 broad whitefish tagged in 1993, seven were captured at Horseshoe Bend, one on the Peel River, seven were caught at the Arctic Red River and two were caught at the Ramparts Rapids. These results confirm that broad whitefish migrate across the various land claim boundaries in the area, and thus that management must be conducted jointly. [Abstract composed by editor]

INTRODUCTION

The Inuvialuit and Gwich'in of Mackenzie River Delta communities depend on broad whitefish, *Coregonus nasus*, as a major source of food (Fabijan 1991; Treble 1996). Maintaining or enhancing fisheries for broad whitefish is important for traditional lifestyles and may even have the potential for economic development in the form of commercial fisheries. In order to accomplish these goals, management of existing and potential fisheries is required and by tagging broad whitefish some of the information necessary to properly manage the fisheries can be obtained. Tagging studies can provide information about stock identification, migrations, age and growth rates, mortality rates and abundance (Hilborn et al. 1990). This broad whitefish tagging study conducted during 1992 and 1993 in the Mackenzie River Delta was initiated to address some of these concerns. The information gathered as a result of this tagging project and previous tagging work (Chang-Kue and Jessop 1992) could be used towards developing a sound management plan for broad whitefish.

MATERIALS AND METHODS

FISHING METHODS

Between August 25 - September 7, 1992, broad whitefish were captured near Aklavik, NT (68°13'N, 135°00'W) along the Peel/West Channel of the Mackenzie River using floating gill nets. The nets were 23 m (75 ft) long, 1.8 m (6 ft) deep and composed of 114 mm (4.5 in) stretched measure, multifilament nylon mesh. Nets were set in eddies with the majority of nets set at a bend in the West Channel, locally known as Fish Point (68°18'N, 135°10'W). Nets were set out perpendicular from shore according to traditional, local methods. Net set duration was approximately one hour. Live-captured broad whitefish were removed from the gill nets and placed in a floating holding pen where they were held until tagged.

Between July 20 - August 21, 1993, broad whitefish were captured near Horseshoe Bend (68°14'N, 134°19'W) along the Middle Channel of the Mackenzie River, also, using floating gill nets. The nets were 50 m (165 ft) or 100 m (330 ft) long, 1.8 m (6 ft) deep and made of 140 mm (5.5 in) stretched measure, multifilament nylon mesh. The nets were set in eddies and were set in the same manner as at Aklavik the previous year. Net set duration was also approximately one hour. Live-captured fish were removed from the nets and placed in a large holding tub containing fresh water in the boat where they were held until tagged.

TAGGING AND SAMPLING METHODS

At Aklavik in 1992, at the end of each day's gill netting operation, the broad whitefish held in the holding pen were dip-netted out and anaesthetized with benzocaine (Laird and Oswald 1975) prior to tagging. The fish were weighed (nearest g), measured for fork length (nearest mm), tagged (Hallprint TBA-2 T-bar anchor tag) and had the first two fin rays from the left pelvic fin clipped and collected. Approximately 30% of these fish received a second tag and were also injected with oxytetracycline (OTC) (Fig. 1). All tagged fish were returned to the holding pen and held overnight to fully recover. The fish were released the next morning.

At Horseshoe Bend in 1993, the tagging procedure was modified. Gill netted broad whitefish were placed directly into a tub, containing fresh water, in the boat. At the end of each net lift, the boat was driven to the middle of the channel and the fish were processed as they were at Aklavik in 1992, except anaesthetic was not required. Approximately 12% of the broad whitefish received a second tag and were injected with OTC. As the fish were not anaesthetized, they were released over the side of the boat immediately after processing. The majority of the fish swam out of sight within seconds. Those that were lethargic were held by the caudal peduncle (tail) and slowly moved in the water until they were fully revived and swam away.

At both tagging locations all other species of fish that were caught were counted and released. Any fish, including broad whitefish, found dead in the nets were sampled for length, weight, sex, maturity and age.

AGE VALIDATION METHODS

Knowing the age of a fish and checking or validating the accuracy of the ageing method is important for understanding the biology of the fish. Broad whitefish ages are determined by using the otoliths or pelvic fin rays. One method for validating the otolith and pelvic fin ray age determination methods is to inject OTC into the fish so that a known-time mark is deposited on these bony structures. Another method for validating the pelvic fin ray method for age determination is to clip fin rays when the fish is tagged. When the fish is recaptured, another fin ray can be removed.

In 1992, all broad whitefish captured and tagged in the vicinity of Aklavik had the first two fin rays from the left pelvic fin clipped and approximately 30% of these fish also received an intraperitoneal (into the body cavity) injection of OTC at a dosage of 35 $mg{\cdot}kg^{-1}$ body weight.

In 1993, all broad whitefish captured and tagged at Horseshoe Bend had pelvic fin rays clipped and approximately 12% of these fish received an injection of the same dosage of OTC.

RESULTS AND DISCUSSION

TAGGING

A total of 113 broad whitefish were tagged at Aklavik in 1992. Of these, 34 were also injected with OTC. In 1993 at Horseshoe Bend, 1225 broad whitefish were tagged. One hundred and fifty-one (151) of these were injected with OTC. As of March 31, 1994, 27 tagged fish had been recaptured (Table 1). The percent recovery (2%) is low but should increase as more fish are recaptured in subsequent years.

Of the 113 fish tagged in 1992, four were recaptured later in 1992. One was caught in the Peel Channel upstream of Aklavik, two were caught in the Peel River upstream of Fort McPherson and the fourth was caught in the Arctic Red River (Fig. 2). The fish caught in the Peel and Arctic Red rivers were probably migrating to known spawning areas in these rivers (K. Chang-Kue and E. Jessop, Canada Department of Fisheries and Oceans, Winnipeg, pers. com.). Four more of the broad whitefish tagged in 1992 were recovered in 1993, after one year at large (Fig. 2). One was recaptured in the Peel River upstream of Fort McPherson which, again, suggests migration to a known spawning area. Two were recaptured near Aklavik and another was recaptured in the East Channel, south of Inuvik suggesting that while some fish may migrate along the same route to spawning areas (via Aklavik), others may stray.

Of the 1225 broad whitefish tagged at Horseshoe Bend in 1993, 19 were recaptured before local fishing operations ended for the year. Seven (7) were recaptured soon after tagging during the experimental commercial fishery conducted in the Middle Channel around Horseshoe Bend in September, 1993. The information obtained from these tag returns agrees with an earlier radio tagging study that suggested that broad whitefish spend some time in the Mackenzie Delta before moving quickly to spawning areas (end of October) (K. Chang-Kue and E. Jessop, pers. com.). One of the fish tagged at Horseshoe Bend was caught in the Peel River upstream of Fort McPherson, seven were caught in the Arctic Red River and two were caught at the Ramparts Rapids upstream of Fort Good Hope, another known spawning area (Fig. 2) (K. Chang-Kue and E. Jessop, pers. com.).

AGE VALIDATION

As of March 31, 1994 whole carcasses of only two tagged, recaptured broad whitefish had been recovered. One of these had been injected with OTC. However, this fish was caught later in the same year that it had been tagged and injected. An OTC mark was visible on both the broken and polished section of the otolith and on cross sections of the pelvic fin rays. As expected, though, no annulus after the OTC mark was evident on either of the structures. The second tagged broad whitefish carcass recovered had been tagged and fin clipped in 1992 and was recaptured and fin clipped again in 1993. Preliminary results show one annulus more on the fin rays from the recaptured fish than on the fin rays collected at the time of tagging. This suggests that the pelvic fin ray method for determining broad whitefish ages may be accurate. Further recoveries are expected in subsequent years.

OTHER SAMPLING RESULTS

Currently, a more extensive report describing tagging operations, biological characteristics of all fish sampled and other pertinent information is being prepared and will be published by the Department of Fisheries and Oceans as a Canadian Data or Manuscript Report of Fisheries and Aquatic Sciences.

ACKNOWLEDGMENTS

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COMMENTS, QUESTIONS AND ANSWERS

Alfred Jackson: I'm just gonna say a few words about the fish talk today. Over 50 years ago I remember there were lots of whitefish. There's still lots. Also coneys, herring, you name it, there’s lots. But since the scientists started taking fish on the Husky River things have changed. When they never used to tag it, Arctic char, used go up that Rat [River] route every year. Now they are scared off that Rat route. I know it [the run of char] goes up and next August it goes backward again. Seems to me, every time they tag it [the run], next year is nothing. Three summers ago when they tagged and there were lots of Arctic char. Last two summers I went back down there and caught nothing. I didn't even get tag. I wanted to find out why is that.

John Babaluk: I must admit I know next to nothing about char. It's not my specialty. The people who have been working on char ... Lothar can you address that question?

Lothar Dalhke: I'm not familiar with all the information that's come out of the Rat River as a result of the tagging program. The last one that was done there was in 1989 when they did a partial hoop net population study there. I've collected some information from the Kay's camp since that period of time. Most of the indications are that there were some good years and some bad years but the tagging doesn't really seem to affect there catch at all. And any effects seen seem to be more from the weather than just from general, natural variation in the years.

Alfred Jackson: It seems to me like it's not coming back after it goes up the Rat River. This is two summers now.

L. Dalhke: It could be from your site that things have changed somewhat but just generally from the Destruction City camp, from the Kay's, it didn't really seem to make that much difference at all, the tagging anyway. They caught normal fish.

A. Jackson: It's funny for me.

Lothar Dalhke: It could be the mouth of the river changed somewhat and the fish are going around in a different manner, I don't know.

A. Jackson: The Kay camp too, that's where they tag it. That's above from the Rat River.

L. Dalhke: Yeah, it was above your camp, that's true.

A. Jackson: And there again, there is nothing they do?

L. Dalhke: From indications of the stuff they've given me, they've done all right. One year was really bad but the weather was bad that year, high water. But the other three years their catches didn't seem to have change terribly much.

A. Jackson: This time was really running thick, the water came right out. So. I think it's the fishery. They couldn't do nothing. They just stopped talking right there.

L. Dalhke: I can't comment on that. I don't know.

A. Jackson: There was a woman tagging fish.

L. Dalhke: Yes, Tasha Stevenson. But, as I say, things seemed to be normal afterwards and nothing abnormal as far the Kay camp.

Question: Are you gonna do any tagging around Tuk area?

J. Babaluk: At this point there are no plans I know about. If people from around Tuk feel that a tagging project is in order, they should contact the FJMC and request for some assistance. There's enough local people who could do the work to initiate a tagging program. We can offer some input too but at this point I don't think there are any plans.

Question: I think they were doing that by the Freshwater Creek there.

J. Babaluk: Yes. I think that was Bill Bond and Rick Erickson from DFO in Winnipeg. I think that they are finished with their work up there for now. I don't think they are planning for anything in the near future.

Colin: I'm Colin from Inuvik here. I want to ask about this tagging fish in the Mackenzie River. We do summer fishing, making dry fish in the Delta during the summer, in the summer season. When the school is out, we take our children out to the camp. When we fished we found a small tube, a piece of plastic [attached to the fish]. Removed it from the whitefish, for the radios - that’s before 1992, I guess. I took it to the office and I asked someone there “What's this anyway?” [I was told] that the fish had a radio before and he dropped it someplace. Do you fellows know where he dropped it? I don't know. I never knew that fish could drop the radio when the fish travel like that.

J. Babaluk: Ken, can you address that, the radio-tagging?

K. Chang-Kue: I'm sorry I didn't quite get what you wanted to know.

Colin: Well, I'll tell you more about it. I took it there and they said it had radio before. They knew from that piece of tube that I brought it in.

K. Chang-Kue: Was it a yellow tag or an

orange tag?

Colin: All he said was that it had radio before. The guy told me he pays me $20.00. He had radio before and I gave him the piece and he gave me $20.00.

K. Chang-Kue: I see what you mean. One year, about 1984, we tried a new type of radio-tag. We tried a different type of radio-tag that wasn't well manufactured. While the wire harness was still in the fish the tag had slipped out, so there were a few tags that lost that kind of information. I guess that's what you must have brought in.

Colin: That's what the guy told me anyway. They had radio-tag and gave me $20.00 because we're supposed to take the radio back and give us $20.00 for it, but I just bring that little piece of wire or whatever.

K. Chang-Kue: I remember that tag now. Even though we didn't have the number of that fish there was still very valuable information about where one of our radio tagged fish from that year had gotten. This is a good chance to thank you for bringing in that tag. I'd like to mention to anyone who brings in any one of our radio-tags - even if you caught the tag early before we had a chance to track it, by bringing it in we can actually use the tag again. There's a $20.00 reward. It allows us to use that tag again. To anyone who has brought in a radio-tag, my thanks goes to them.

Colin: Then after that he asked me how the fish was healthy or looks sick. I tell him I never tested it. I don't know how to test fish. Thank you.

Table 1. Summary of broad whitefish tagged in the Mackenzie River Delta, 1992-1993.

		No. of broad whitefish tagged		No. of broad whitefish recaptured in 1992		No. of broad whitefish recaptured in 1993	
Year	Tagging location	tag only	tag + OTC	tag only	tag + OTC	tag only	tag + OTC
1992	Aklavik	79	34	4	0	2	2
1993	Horseshoe Bend	1074	151	-	-	17	2

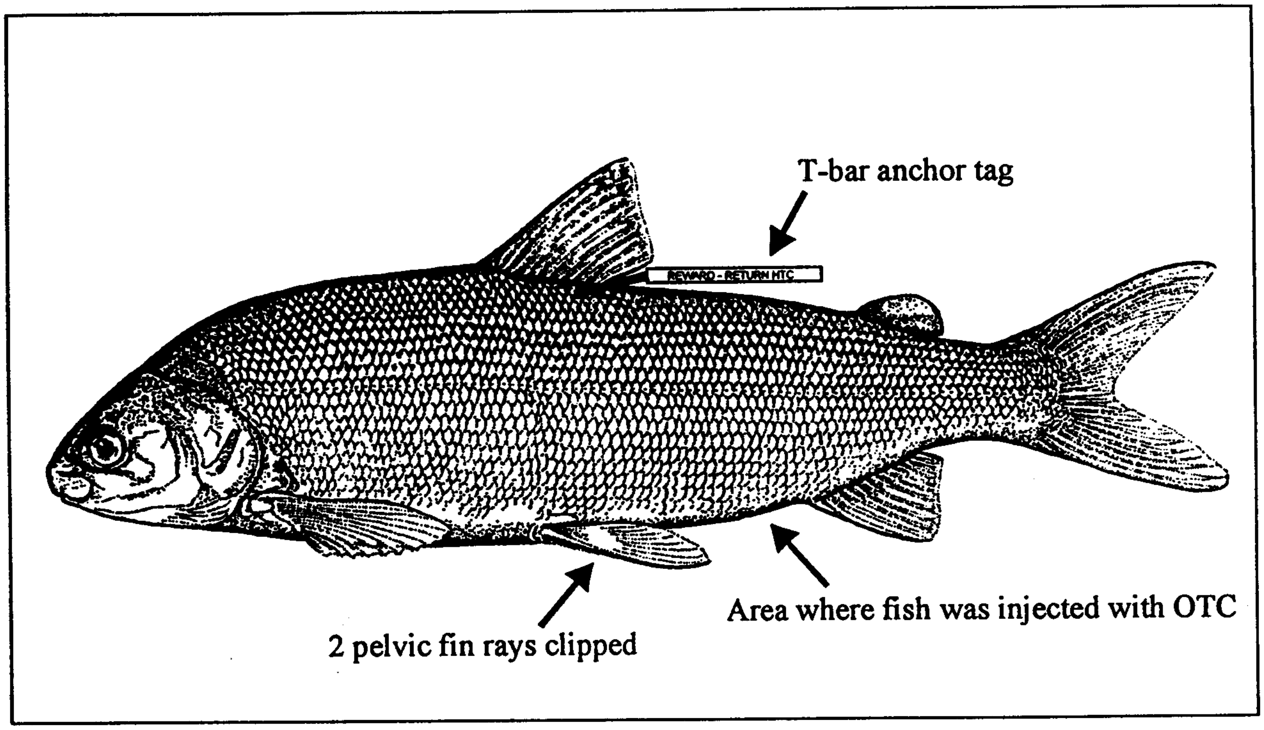

Fig. 1. Diagram of a broad whitefish showing a T-bar anchor tag, the pelvic fin rays that were clipped and where the fish was injected with OTC.

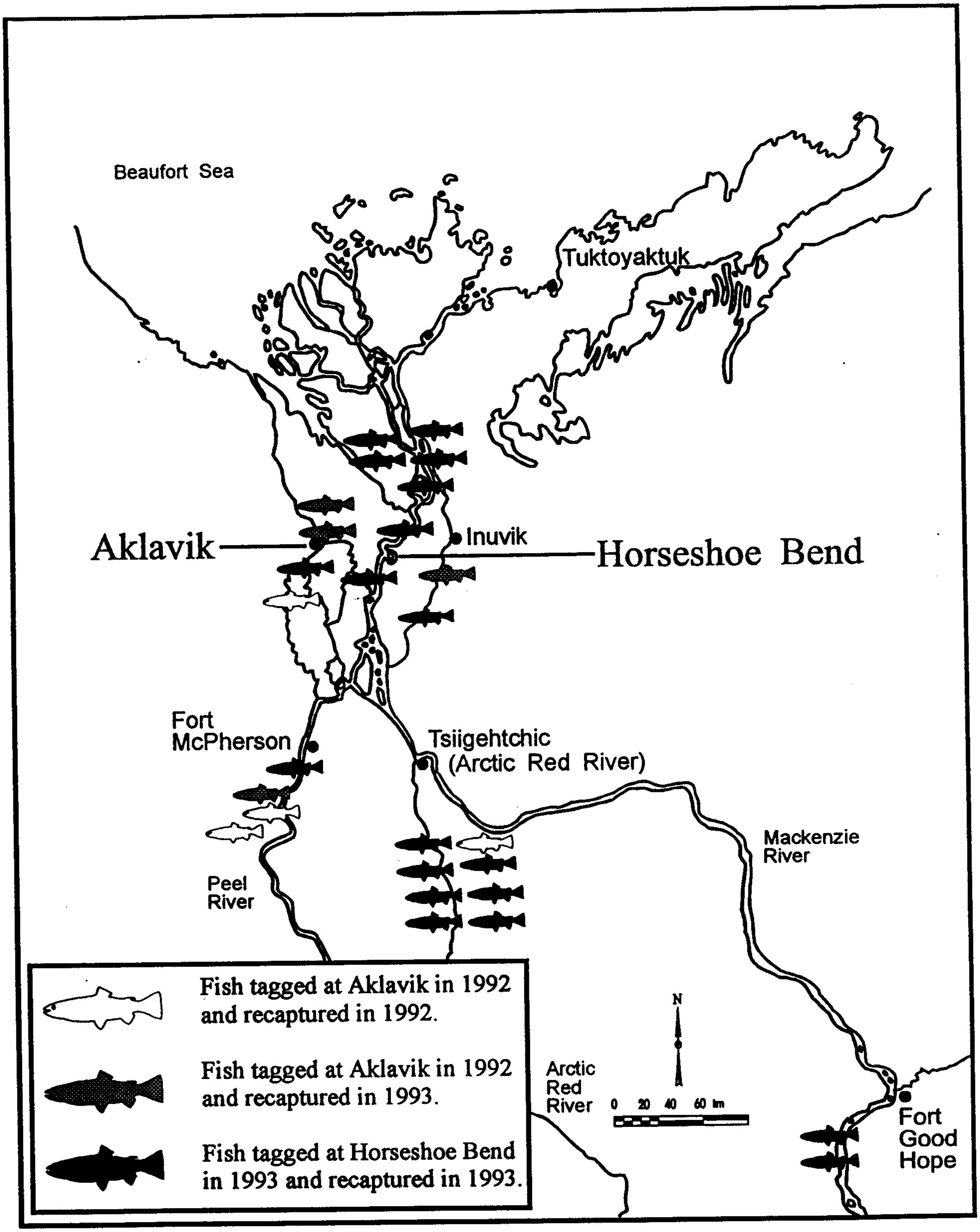

Fig. 2. Map of the lower Mackenzie River showing tagging locations (Aklavik and Horseshoe Bend) and approximate reported locations of recaptured broad whitefish during 1992 and 1993.

BROAD WHITEFISH RADIOTAGGING STUDIES IN THE LOWER MACKENZIE RIVER AND ADJACENT COASTAL REGION, 1982-1993

by

Ken T.J. Chang-Kue and Earl Jessop

ABSTRACT

Radiotags were used to study migrations of broad whitefish *(Coregonus nasus).* Tagged fish were tracked with aircraft to upstream spawning and downstream overwintering destinations. We tagged three groups of fish: 1) *Mid-delta migrants* in the Mackenzie Delta (1982-1984); 2) *Coastal migrants* from five watersheds on the Tuktoyaktuk Peninsula (1985-1987) and Richards Island (1991); and, 3) *Tributary migrants* in the Peel and Arctic Red rivers (1992-1993).

Mid-delta migrants spawned at several sites in the lower Mackenzie River, the most important of which was the 20 km reach of the Middle Channel below Point Separation. Spawning occurred in late October and early November each year. Post-spawning fish migrated rapidly downstream, arriving by late November at overwintering sites in the Delta's lower East Channel, lower west channels and Whitefish Bay. *Coastal migrants* moved west-ward toward the Mackenzie River with most adult fish reaching the middle of the Delta by late August. Their subsequent migration pattern to spawning sites was consistent with that of the *mid-delta migrants*. Most immature *coastal migrants* overwintered in Whitefish Bay. Tracking of the *tributary migrants* in the Peel and Arctic Red rivers located one major spawning site in each river and revealed additional overwintering sites in the Peel River, Arctic Red River and west side Mackenzie Delta. The cumulative data from this radiotelemetry program enhanced our life history knowledge of the migratory broad whitefish in the lower Mackenzie River basin.

INTRODUCTION

Fish population studies conducted by the Department of Fisheries and Oceans (DFO) during 1971-1975 established that large schools of broad whitefish (*Coregonus nasus*) migrate annually through the Mackenzie Delta and lower Mackenzie River on late summer and fall spawning runs (Hatfield et al. 1972; Stein et al. 1973a, 1973b; Jessop et al. 1974; Jessop and Lilley 1975; Percy 1975). By Mid-September, spawning migrants gather in pre-spawning aggregation sites until the late fall spawning period (Chang-Kue and Jessop 1991; Jessop and Chang-Kue 1993). Another series of studies by DFO in the Beaufort Sea coastal region documented significant numbers of broad whitefish in the coastal bays and small watersheds of the Tuktoyaktuk Peninsula (Bond 1982; Lawrence et al. 1984; Hopky and Ratynsky 1983). Complex migration patterns of adult, juvenile and young-of-year fish into and out of these coastal streams were also documented (Bond and Erickson 1985; Chang-Kue and Jessop 1991, 1992).

In our 1978-1979 detailed study of fish in the Kukjuktuk Creek watershed on the Tuktoyaktuk Peninsula, we tagged numerous broad whitefish with numbered "Floy" anchor tags and monitored where fish were recaptured in the following years (Chang-Kue and Jessop 1992). We observed that tagged fish recaptured in coastal areas were generally younger than the minimum age of maturity (7-8 years). On the other hand, tagged fish recaptured in the Mackenzie Delta and lower Mackenzie River were older fish that had reached spawning age. These data provided a link between the coastal and Delta broad whitefish (Fig. 1).

Broad whitefish is the coregonid species most valued in the local subsistence fisheries and has been the target of intermittent commercial fishery efforts in the Delta. The prospect of impacts from future hydrocarbon exploration and production activities and the need to identify important fish habitats prompted our decision in 1982 to use radiotransmitter tags (radiotags) to study broad whitefish migrations. At that time our knowledge of broad whitefish life history was lacking specific details on migration behaviour, major spawning grounds and critical overwintering areas. We conducted three separate radiotelemetry programs, each involving three seasons of study: 1982-1984, 1985-1987, and 1991-1993. The purpose of this paper is to describe the three study programs and provide a summary of the results obtained during nine field seasons of fish radiotagging.

OBJECTIVES

The initial study objective was to determine the routes and timing of migrations undertaken by the migratory broad whitefish of the lower Mackenzie River. The next objective was to locate spawning and over-wintering areas. A third objective was to detect any variation in migratory behaviour among possible spawning populations of broad whitefish by tagging in different water-sheds or other pre-spawning aggregation areas.

METHODS

Based on previous field encounters with large groups of migrants, we identified three general categories of broad whitefish that required investigation:

1) *Mid-delta migrants* describe the mature spawning migrants present in Mackenzie Delta channels in September and October.
2) *Coastal migrants* describe the mature and immature fish leaving coastal drainages in the southern Beaufort Sea during July and August.
3) *Tributary migrants* describe the mature spawning migrants present in the major tributaries (Arctic Red River and Peel River) from one to two weeks before spawning in late October.

Low frequency radiotelemetry equipment was purchased from Advanced Telemetry Systems Inc.,[1] Isanti, Minnesota (ATS). Radiotags (transmitter tags), manufactured for external mounting, were used (Fig. 2). Tag size ranged from 13 to 20 g in weight, depending on the size of battery used. Tag life span varied from 60 to 150 days, again according to tag and battery size. In 1983-1987 we used a few large experimental tags with a longer life span to potentially detect fish up to six months after release. Continual improvements in transmitter design by ATS resulted in tags that by 1992-1993 had become more compact and efficient in performance and offered a longer life span of up to 300 days.

Broad whitefish were captured with a 23 m long gillnet (mesh size: 102 or 140 mm stretched measure) or a portable stream hoopnet where appropriate. Large, adult fish (>400 mm fork length), which were most likely to be spawning fish, were selected for tagging. Smaller, immature fish (<400 mm fork length) were also tagged for comparison of migratory behaviour in 1985-1987. Each fish was first anaesthetized in a tub containing a solution of tricaine methanesulfonate. A radiotag was then mounted subdorsally just below the dorsal fin and oriented with the tag's whip antenna trailing parallel to the body and extending towards the tail of the subdued fish (Fig. 2). Tag mounting usually took less than two minutes to complete and the fish was then revived in fresh water before release. Tagged broad whitefish usually revived within a few minutes. The radiotag used was matched to the size of the fish, never exceeding one to two percent of the weight of the fish (Winter et al. 1978).

We could identify individual fish because each radiotag had a unique frequency in the 48.000 to 50.000 mHz range. A loop antenna was mounted on each wing strut of a fixed-wing aircraft used for tracking. Each antenna was connected to a scanning receiver (ATS Challenger 200 Model). Tag frequencies were stored in the receiver's memory and all fish being tracked were scanned at a rate of 2-4 seconds per

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[1] Reference to trade names does not imply endorsement of commercial products.

frequency while flying at 250-400 m altitude. Fish were tracked for 2-4 months and followed to their ultimate upstream location and, if possible, to their ultimate downstream destination. We interpreted these sites as **spawning** and **overwintering** sites, respectively.

Factors limiting the successful tracking of each year's sample of fish included premature battery expiry, tag failure or disappearance of a fish, and recapture of the fish by the subsistence fishery. In many cases however, the recapture location or a partial set of tracking data still contributed to the overall interpretation of results. A map showing all tracking locations by date was prepared for each fish which provided either a full or a partial set of useful tracking data.

STUDY AREA AND NUMBERS OF FISH TAGGED

Our study area was the lower Mackenzie River basin north of the Mackenzie River's Ramparts Rapids (Fig. 3). It included the adjacent Beaufort Sea coastal region and the Tuktoyaktuk Peninsula. Over the nine field seasons, *mid- delta*, *coastal* and *tributary migrants* were selected from the following regions:

A. two pre-spawning aggregation sites in the main stem of the lower Mackenzie River near Fort Good Hope,
B. a major pre-spawning aggregation site (Horseshoe Bend) in the Mackenzie Delta,
C. four coastal streams on the Tuktoyaktuk Peninsula,
D. a coastal stream on the west side of Richards Island,
E. an upstream site on the Peel River, and
F. an upstream site on the Arctic Red River.

Figure 3 is a map of the study area showing all the sites where broad whitefish, tagged with radio tags, were released between 1982 and 1993.

Our primary study tagging site in 1982 was in the main stem of the Mackenzie River near Fort Good Hope. Twenty broad whitefish were tagged at two known pre-spawning aggregation sites, one near the Loon River confluence and the other at the Ramparts Rapids (Fig. 3).

During 1982-1984, a total of 49 *mid-delta migrants* in the Mackenzie Delta were tagged near Horseshoe Bend, an incipient oxbow lake on the Middle Channel. Fish were released in mid-September each year at a large west bank back eddy located four kilometers downstream from Horseshoe Bend. This site is a known pre-spawning aggregation area for mature broad whitefish, lake whitefish (*C. clupeformis*), and least cisco (*C. sardinella*) during September and October (Jessop and Chang-Kue 1993). This big eddy is often referred to as "Horseshoe Bend" by local residents and this name is used likewise in this paper. Our hypothesis was that mid-delta migrants, tagged at Horseshoe Bend, were expected to migrate further upstream to presumed spawning sites in the lower Mackenzie River, or in major tributaries like the Peel River and Arctic Red River. Accordingly, tracking flights with fixed-wing aircraft were scheduled to cover the whole Delta, the two major tributaries, and the lower Mackenzie River up to Fort Good Hope.

During 1985-1987, we tagged a total of 97 *coastal migrants* migrating in mid-July out of four coastal river systems on Tuktoyaktuk Peninsula (Fig. 3). Our mid-July timing allowed us to target the first group of large downstream migrants for radiotracking. Our hypothesis, based on our previous work in the area (Chang-Kue and Jessop 1992), was that the earliest downstream migrants at age eight years and older were mature fish on a spawning migration. Non-spawning adults or immature downstream migrants (younger than eight years) were expected to migrate to presumed outer Delta or coastal over-wintering sites. Study streams included Kukjuktuk Creek (1985), Canyanek Creek (1986), Keneksek Creek (1987) and Kittigazuit Creek (1986 and 1987). Tracking flights covered the main Delta channels and the nearshore coastal waters westwards to the Mackenzie Delta and eastwards as far as McKinley Bay. An additional 19 broad whitefish were tagged in mid-September 1987 in Whitefish Bay, a coastal bay next to the East Channel (Fig. 3), to investigate the role of this site as an overwintering area.

During 1991-1993, we tagged 22 *coastal migrants* from one additional coastal watershed and a total of 67 *tributary migrants* in two major Mackenzie River tributaries. Downstream migrants (N=22) at Burnt Creek, a west side drainage on Richards Island, were tagged in July 1991. Upstream migrants were tagged in the late Fall in the Peel River in 1992 (N=20) and in the Arctic Red River in 1992 (N=11) and 1993 (N=36). We hypothesized that all of the Burnt Creek coastal migrants belonged to a spawning population migrating only to the Peel River to spawn. We also hypothesized that the Peel and Arctic Red tributary migrants, tagged close to the spawning period, were committed to continue their upstream migration to spawn in headwater spawning grounds.

RESULTS AND DISCUSSION

MIGRATION BEHAVIOUR, SPAWNING AND OVERWINTERING SITES

Mid-Delta Migrants: 1982-1984

Fort Good Hope was the site of our first tracking study. Previous Floy-tagging studies had established that some broad whitefish migrants from the Mackenzie Delta reach the vicinity of Fort Good Hope by mid-September every year (Stein et al. 1973a, 1973b; Jessop et al. 1974; Chang-Kue and Jessop 1992). Tracking of broad whitefish radiotagged at pre-spawning aggregation sites near Fort Good Hope in 1982 gave us our first insight on subsequent fish movement patterns in the weeks before and during spawning (18 September to 21 November). A few tagged fish moved downstream immediately after tagging, suggesting a possible negative reaction to the tagging procedure; however, many returned gradually upstream to reunite with those fish that did not stray as far. Localized movements were evident until the first week of November when tagged fish made a concerted run upstream to the Ramparts Rapids or the lower section of the Ramparts Canyon (Chang-Kue and Jessop 1983). After staying in place for 1-2 weeks, these fish left the spawning sites and were in the middle of a downstream run by the last date of tracking on 21 November. While the extent of the post-spawning migration was not documented completely, the recapture of one fish in the mid-Delta by a subsistence fisherman in December 1982 indicated that this migration had extended as far downstream as the Mackenzie Delta.

Tracking data for many broad whitefish from Horseshoe Bend in 1982, 1983 and 1984 provided a set of consistent data that revealed the migration behaviour of *mid-delta migrants*. We allowed for a longer tracking period in 1983 and 1984 to ensure that post-spawners could be followed to their over-wintering sites after spawning. Tracking maps for two Horseshoe Bend broad white-fish from the 1984 study illustrate two general migration behaviour patterns observed for spawning fish (Figs. 4 and 5). We discovered that most tagged fish showed very little movement for several weeks after release at their pre-spawning aggregation site. Some fish appeared to drift downstream into secondary channels; however, these fish gradually returned upstream to Horseshoe Bend and to points further upstream on Middle Channel. A concerted upstream run began in the last week of October with many fish reaching and holding their positions at upstream destinations in the first week of November; this last phase usually coincided with freeze-up in the Mackenzie River. After maintaining their position for several days at a spawning site, the broad whitefish began moving downstream. We interpreted this behaviour as the start of the post-spawning migration.

The post-spawing migration generally commenced in mid-November each year and was characterized by a rapid rate of down-stream movement with post-spawners reaching their overwintering sites in the outer Delta by late November (Chang-Kue and Jessop 1997a). The overwintering site for the fish shown in Fig. 4 was Whitefish Bay on the East side of the outer Delta, whereas the fish shown in Fig. 5 overwintered in Shallow Bay on the west side of the outer Delta.

While most fish spawned in the main stem of the lower Mackenzie River, two fish recaptured in the Peel River suggested that a minor proportion of *mid-delta migrants* migrated into this major tributary for their final spawning run. No fish were actually tracked moving into the Peel or Arctic Red rivers.

The complete set of fish migration maps for 1982-1984 is included in Chang-Kue and Jessop (1997a).

Figure 6 is a map of the study area showing a summary of spawning areas and overwintering areas reached by *mid-delta migrants* tracked in 1982, 1983 and 1984. The number of radiotagged fish reaching each site is also shown. The Ramparts Rapids and the area at the downstream end of the Ramparts Canyon were the main spawning sites for broad whitefish tagged near Fort Good Hope. The most important spawning destination for *mid-delta migrants* was the 20 km reach of the Middle Channel downstream from Point Separation. A few individual fish migrated further upstream into the lower Mackenzie River, reaching sites located between 17 and 256 km upstream from Point Separation. Overwintering destinations for *mid-delta migrants* included Whitefish Bay, the lower East Channel, Middle Channel, the vicinity of Tent Island (Shallow Bay), and the confluence of delta channels flowing into Shallow Bay (Fig. 6).

Coastal Migrants: 1985-1987

The *coastal migrants,* which were tagged as they were leaving the four coastal watersheds on the Tuktoyaktuk Peninsula, migrated along the shallow nearshore waters as they proceeded westwards towards the Mackenzie Delta. There was no evidence of an eastward coastal migration. Most of the migrants that were seven years and older moved into the Mackenzie Delta by the end of August. This observation supported our earlier Floy-tagging study results which showed that mature fish from adjacent coastal watersheds contributed to the broad whitefish upstream migration seen annually in the Mackenzie Delta and lower Mackenzie River. The subsequent migratory behaviour of these coastal migrants from September to November was consistent with behaviour seen previously in the *mid-delta migrants* (spawning adults) tagged in the Delta in 1982-1984 (Chang-Kue and Jessop 1997b).

Figures 7 and 8, the migration maps for two individual fish from Kukjuktuk Creek, are examples of two migration patterns exhibited by *coastal migrants*. The first example, a broad whitefish (age 8 years) released on 25 July 1985, shows a migration pathway along the coast as this fish proceeded towards the Mackenzie Delta during July and early August (Fig. 7). It reached the Middle Channel by 7 September and stayed in the Horseshoe Bend area for several weeks before making a final run upstream to the Point Separation area in the last week of October. Almost the entire sample of fish that escaped recapture at Tuktoyaktuk, behaved in this manner. The second example, another broad whitefish released on 19 July 1985, followed the same coastal pathway except it only went as far as Whitefish Bay where it remained from 14 August until the last tracking date, 15 November (Fig. 8). The behaviour of this single fish, the size and age of which suggested a possible mature fish (fork length 505 mm; age 9 years), led us to make a tentative conclusion in 1985 that we had observed a non-spawning fish which was only migrating to this bay to overwinter.

We tagged a larger proportion of small, immature-sized fish in the three other coastal streams in 1986 and 1987 to detect where the non-spawning coastal migrants overwintered. As we obtained tracking data on these fish, we accumulated more evidence showing that Whitefish Bay was a major overwintering destination for immature broad whitefish (age 5-8 years) from Keneksek Creek, Canyanek and Kittigazuit

Creek (Chang-Kue and Jessop 1988, 1997b). This conclusion was of particular interest because our data from 1982-1984 had shown previously that Whitefish Bay was also an important overwintering destination for post-spawning adults from Mackenzie River spawning grounds.

Although several adult-sized *coastal migrants* from Canyanek, Kittigazuit and Keneksek Creek (age 8-12 years) made the expected migration into the Mackenzie River to spawn, a large proportion (age 9-12 years) overwintered in Whitefish Bay, matching the behaviour of the non-spawning adult first seen in the one fish from Kukjuktuk Creek in 1985 (Fig. 8). Their random movements within the bay during October and November indicated overwintering instead of spawning behaviour. These non-spawning adult fish, as well as the juvenile fish (age 4-8 years), return to coastal streams the following spring for another season of summer feeding in headwater lakes (Chang-Kue and Jessop 1991, 1992).

All tracking maps for *coastal migrants* from 1985-1987 are presented in Chang-Kue and Jessop (1997b).

Figure 9 is a summary map showing the spawning and overwintering destinations for *coastal migrants* from the four Tuktoyaktuk Peninsula coastal drainages, as determined by radiotelemetry in 1985-1987. The number of radiotagged fish reaching each site again illustrates the important role of the Point Separation area as a spawning site for mature coastal migrants and Whitefish Bay as an important overwintering site for immature coastal migrants. These data verified that mature *coastal migrants* leaving coastal feeding areas in mid and late summer contribute to the *mid-delta migrants* seen in the main channels of the Mackenzie Delta in the late summer and early fall (Chang-Kue and Jessop 1997b).

Burnt Creek and Major Tributary Migrants: 1991-1993

Our final three-year study program differed from the two previous programs because we selected and tagged broad whitefish from presumed separate populations to observe if their migration behaviour was unique or similar to that of the *mid-delta* or *coastal migrants* studied previously in 1982-1987.

1991: Our hypothesis stated that all *coastal migrants* originating from Burnt Creek, a summer coastal foraging area on the west side of Richards Island, would migrate up the west side of the Delta to spawn only in the Peel River. We observed that tagged fish left the creek and were moving along the coast within seven days after their mid-July release date. When we resumed tracking in mid-September, we discovered that most tags that year were defective because many had either expired prematurely or were on the verge of expiry. We were, however, able to detect examples of two migration patterns from the remaining tagged fish. We tracked three fish proceeding towards the Peel River of which two were recaptured at Aklavik while the third one provided a complete set of location data showing its migration up the Peel River to the Trail River confluence area. The migration of the latter fish is shown in Fig. 10. Spawning occurred here in the first week of November 1991.

The data from 14 other fish showed a migration pattern that disproved our hypothesis. Although many fish, carrying the defective tags, were detected only once or twice in September, the information was sufficient to indicate that these fish had migrated into the Middle Channel and were most likely proceeding up the Mackenzie River. Four fish provided a full set of data that confirmed their progress to spawning sites in the main stem of the lower Mackenzie River, including the Point Separation area, by early November. We concluded that the summer feeding habitats in this west side coastal drainage are used by broad whitefish from at least two different spawning populations (Chang-Kue and Jessop 1997c).

1992: In a 1992 minor study, we tagged 11 *tributary migrants* in the lower 10 km reach of the Arctic Red River on 13-15

September 1992. Nine of our fish had been recaptured downstream by the subsistence fishery at the river mouth by the first scheduled tracking date (16 October 1992). No fish were found upstream on the Arctic Red River and tracking data were only obtained for one fish. This latter fish spawned in the Mackenzie River five kilometers upstream from Arctic Red River (Chang-Kue and Jessop 1997c). During a late winter radiotracking flight five months later (March 1993), we located this fish plus one other at known overwintering sites in the outer Delta (Chang-Kue and Jessop 1997c).

In our 1992 main study, we tagged 20 *tributary migrants* which were already at pre-spawning aggregation sites (back eddies) near the Trail River confluence in the Peel River on 18-19 September 1992. Preliminary tagging and tracking of broad whitefish within the Peel River had been done by the DFO Inuvik Region office in 1990 when the above pre-spawning aggregation area and a spawning area near the confluence of the Trail River tributary were identified (personal communication: Mr. Lothar Dahlke, DFO regional management biologist). The example tracking map for one of our Peel River tagged fish (Fig. 11) shows that this fish remained in the area for a month and that spawning occurred just downstream of the release site in late October. The predominant cobble and gravel bottom of the adjacent main channel had been a good indication that spawning habitat was close and abundant. The downstream, post-spawning migration was in progress by 27 October and this fish overwintered in the lower Peel River. Most of the tagged fish behaved in a similar manner. Three post-spawning fish, however, left the Peel River to overwinter in the Mackenzie Delta's West Channel and Peel Channel (Chang-Kue and Jessop 1993, 1997c).

__1993__: We returned to Arctic Red River as our main study area in 1993 where we relocated our tagging operations to a site 32 km upstream to minimize the chance of tagged fish being recaptured in the subsistence fishery at the mouth of the Arctic Red River. We tagged 36 *tributary migrants* at this site, known locally as Twenty Mile Cabin. Our specific intent was to capture fish at or soon after freeze-up so that only fish in the middle of a concerted run to upstream spawning grounds would be tagged and released. A warm, extended fall season in 1993 delayed river freeze-up until the last week in October. We set up our tagging operations on the river ice on 25-27 October, about two weeks later than expected. Fish were caught through the ice on the east bank and were released through another hole in the ice into a back eddy located on the opposite side of the river.

Tracking data showed that only four fish proceeded with the expected upstream migration into the headwaters of the Arctic Red River (Chang-Kue and Jessop 1997c). While two tags were never detected, the remaining 30 of our sample of 36 tagged broad whitefish moved downstream instead of upstream. Twenty-six of the latter were recaptured in the subsistence fishery at the mouth of Arctic Red River within a few days after release and only four escaped into the Mackenzie River. This premature recapture of most tagged fish appeared to limit our ability to evaluate the overall behaviour of these tributary migrants; however, the remaining fish that we were able to track provided very interesting results.

The dissimilar behaviour of the above tributary migrants prompted several possible interpretations for the downstream migration. The first interpretation is that late freeze-up conditions in 1993 may have impaired the natural progress of the upstream spawning run in the Arctic Red River to the extent that many spawning fish returned downstream without spawning. A second interpretation is that some tagged fish had already spawned and were already on a post-spawning downstream migration at the time of tagging. We were fortunate, however, in having the opportunity to examine several of these recaptured fish, brought intact to DFO by the subsistence fishermen at Arctic Red River. We found that the gonads of most were still in spawning condition and no spent gonads were evident (Ken Chang-Kue, unpublished data). It was feasible, therefore, that these fish were migrating downstream to spawn in the Mackenzie River. This speculation led to a third and fourth interpretation.

The third interpretation is that we had tagged some coastal and mid-delta migrants that had made earlier pre-spawning movements upstream into the Arctic Red River before making a final downstream run out of the river towards their spawning grounds in the main stem Mackenzie River. Evidence to support this idea was provided by three fish that managed to escape the intensive gillnet fishery at the river mouth; these fish were detected in the vicinity of Point Separation or at the Arctic Red River confluence in the first week of November, the expected time of spawning in the Mackenzie River. These three fish eventually migrated to overwinter in the lower East Channel, Napoiak Channel and the Shallow Bay area, all of which were overwintering sites identified in our previous tracking work in 1982-1987 (Chang-Kue and Jessop 1997a, 1997b). We had also seen this behaviour previously for the single radiotagged Arctic Red River migrant in 1992.

A fourth interpretation, prompted more by the apparent downstream migration direction of the majority of fish so far up in the Arctic Red River, is that most fish intercepted and tagged at Twenty Mile Cabin were actually a main stem Mackenzie River spawning population that had spent their summer foraging in the Arctic Red River watershed. Emerging either from the upper river or from smaller tributary drainages, these spawning migrants were making a concerted migration downstream to spawn in their respective main stem Mackenzie River spawning sites.

While it has been suggested that our tagging procedure may have caused upstream migrants to fall back downstream, there were four Arctic Red River fish that still proceeded upstream as predicted in our hypothesis. These four broad whitefish, tagged on 26 October at Twenty Mile Cabin, continued to migrate upstream; three of this group reached a spawning area in the Arctic Red River near the confluence of Weldon Creek. Figure 12 illustrates this migration pattern, showing that spawning for this representative fish occurred on 7-8 November at the Weldon Creek area before it made a rapid downstream migration. This fish was last located in the lower reach of Arctic Red River on 17 November. The other fish followed a similar downstream movement pattern although one, recaptured by the subsistence fishery at the river mouth, may have been on its way to overwinter in the lower Mackenzie Delta eventually.

The 1992 and 1993 Arctic Red River data clearly generated more questions than answers. The Arctic Red River broad whitefish require further investigation to verify and evaluate the two apparent spawning migrations going in opposite directions. Several years of repeated study would address the suggestion that our 1993 observations simply represented a migration aberration caused by the unusual weather conditions that year.

All tracking maps for 1991-1993 are presented in Chang-Kue and Jessop (1997c).

Figure 13 is a map of the study area showing all the upstream and downstream destinations of radiotagged fish that were successfully tracked in the three radiotelemetry programs conducted during 1982-1984, 1985-1987 and 1991-1993. The higher the number of fish detected at a particular site or river reach, the stronger the evidence that we had found and identified an important spawning or overwintering area for the broad whitefish radiotagged at our selection of coastal stream, mid-delta and major tributary locations.

The cumulative data from this radiotelemetry program has improved our overall knowledge of the life history of broad whitefish in the lower Mackenzie River basin; however, in a watershed as vast as the Mackenzie River our nine-year study may have provided insight on the migration behaviour of only a small selection of broad whitefish spawning populations. Also, our series of radiotagging studies appears to have provided data mainly on the semi-anadromous type of broad whitefish. The other two possible life history types, lacustrine and riverine, still require detailed study (Reist and Chang-Kue 1997). There has been no obvious evidence for the existence of the latter type whereas subsistence fishermen continue to describe small, individual watersheds that may support lacustrine populations showing migration behaviour associated with localized spawning and overwintering activities. Examples of such lacustrine populations have been investigated and identified in Travaillant Lake and Campbell Lake by Reist (1997) and it is feasible that such populations exist within the small tributary watersheds in the Peel River and Arctic Red River. We may have already observed initial evidence of more complex migration patterns involving a possible mix of life history types (semi-anadromous and lacustrine) in the Arctic Red River. Comprehensive studies to demonstrate the existence and determine the relative life history characteristics of these possible individual populations are necessary.

CONCLUSIONS

The use of radiotransmitter tags has proved to be a successful procedure for studying the migratory behaviour of the Mackenzie River broad whitefish. Tracking groups of fish from different regions provided details on the migration timing and the routes taken by both mature and immature broad whitefish proceeding to their respective destinations in the late summer to early winter period. The spawning locations of spawning adults and the overwintering areas for immature and post-spawning fish, determined during freeze-up conditions, could not have been obtained with conventional tagging and fishing methods.

This study verified that mature *coastal migrants,* emerging from coastal feeding areas in mid summer, contributed to the *mid-delta migrants* seen in the main channels of the Mackenzie Delta in the late summer and early fall.

The major spawning area for mature *coastal* and *mid-delta migrants* is the 20 km reach of the Mackenzie Delta's Middle Channel below Point Separation.

Several other spawning sites for mature *coastal* and *mid-delta migrants* were identified in the main stem of the lower Mackenzie River; the furthest upstream site was the Ramparts Rapids area. A small number of migrants also migrated into the Peel River to spawn.

The Trail River confluence area and the Weldon Creek confluence area were the main spawning sites for *tributary migrants* in the Peel River and the Arctic Red River, respectively.

Whitefish Bay is the most important overwintering area for immature *coastal migrants*, non-spawning adult *coastal migrants*, and post-spawning *coastal* and *mid-delta migrants*.

Other overwintering sites for post-spawning *mid-delta migrants* were located in the outer delta; these included the lower East Channel, lower Middle Channel, the vicinity of Tent Island (Shallow Bay), and the confluence of delta channels flowing into Shallow Bay.

The *tributary migrants* in the Peel River overwintered in the lower Peel River and in the Mackenzie Delta's West Channel and Peel Channel. Arctic Red River migrants overwintered in the lower reach of the river and in the outer delta (lower East Channel, Napoiak Channel and the Shallow Bay).

A final major conclusion is that important spawning and overwintering sites for the migratory form of broad whitefish are distributed over the Inuvialuit, Gwich'in and Sahtu Settlement regions. Similarly, the migration pathways between summer feeding areas, spawning grounds and overwintering areas result in broad whitefish spawning populations passing through two, or sometimes three settlement regions during the year. This information presents a challenge for the management of this fish resource in the lower Mackenzie River basin and a regional approach with participation by all management boards will be required (Reist and Chang-Kue 1997).

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COMMENTS, QUESTIONS AND ANSWERS

Don Dowler:	Fishermen often report fish with damage to them. Is this because of the tagging?
Ken Chang-Kue:	Jim Reist has done a study of looking at the different kind of scars and marks on whitefish and he has a good

summary of what they are. He has made an interpretation of what they are. He has a poster session over there and he has published a paper. Cuts could come from a variety of sources - jackfish bites, prop cuts from boats if they are in shallow water, or parasites. Jim is the expert. I do not know the incidence or how often you see this but I feel it is a natural occurrence that you will see some fish with strange marks.

Comment: I asked you yesterday about the radiotag that lasts 60-300 days - was there any effort to take the radiotags out after the fish die?

K. Chang-Kue: No. Once the tag's expired we can't go after them. For example, once the fish go into Whitefish Bay it was not very good weather for us to go in and pin point the location of the tag. We did not know where to set the nets to go after them. Unless it was a fish that went into a stream, like the Arctic char that went into an overwintering stream and the pool where you could actually see the fish after the tag had expired and retrieve it. It can be done. But with whitefish it is almost impossible to find the tag on the fish while it is alive and swimming. We've had radiotags turned in with fish on a couple of occasions. People have brought the whole fish in with the tag still attached to it. The tag is not working. The one fish we did get from Fort Good Hope worked its way down from the Mackenzie Delta. It had been in the net a long time and was badly chewed up and had started to go bad. I don't think it was from the tag. We've had another fish come in with a tag and the fish looked to be in good condition after three months. The only way we get tags back is when people catch them and return the tags to us.

Comment: You guys could tag them a certain date and then you would know when to take them out - maybe 1 or 2 weeks before to find out where they are headed and then check the nets.

K. Chang-Kue: We could do that but we have always found that by the end of October or the first week of November, it was terrible weather to get up there and camp. Especially at Point Separation. It is not an easy place to set the nets to try to get the fish. The river is so wide it would be impossible to intercept these fish. It would work in a small stream but not in the Mackenzie. The Mackenzie is just too mighty for us to go and get fish anytime.

Comment: You know those radio collars on polar bears, wolves and caribou? We caught a polar bear one time and the skin wasn't worth anything because of the collar.

K. Chang-Kue: In the early days, wildlife tagging was a little different. The animals can still be growing - some of the early tags (neck collars) would stay that diameter but the animal would live several more years and continue to grow. This would cause problems because it would constrict the animal’s neck and would cause problems in terms of behaviour and feeding. They make tags now so that the collar will break open or erode after a year and fall off just to ensure it would not kill the animal. Those are the changes and advances that have been made in tags. That is a legitimate concern in any tagging study - is my tag going to affect the real behaviour of that animal? It is a concern we have to be conscious of.

Comment: Could it be doing that to the fish?

K. Chang-Kue: I won't say yes or no. I'd like to think that when you see a group of fish all behaving the same way and moving in the same direction in the same week that those fish represent what the rest of the other untagged fish are doing - that they are all traveling along with their buddies to have a great time at the spawning grounds.

Fred Wilkes: My name is Fred Wilkes. It is good to hear of the information coming out about the fish but we are always having a problem here in Tuk. In the lakes there is a lot of fish, we know that there is a lot of fish. As nature takes its course in our area there is a lot of drift wood coming up from the rivers and starting to block all the creeks. We know there is a lot of fish trying to come up but all along the coast there are those creeks being blocked up by wood. As I recall about 40 years when I was younger there were people with dog teams and a family had 20-30 dogs. They used to fish for the winter - for human consumption and for the dogs, so they tried to pile up as much fish as they could in the summer. Everyone had a dog team. It was their livelihood at that time. There was no other way of making money. They used to trap and hunt. I still remember those days when there was plenty of fish in Tuktoyaktuk all summer long. We do not see that any more. There seems to be a decline because of the driftwood piling up in those creeks. We had the fisheries open a couple of creeks to the west side of us.

K. Chang-Kue: That was Canyanek and Keneksek creeks where I did some of my tagging.

Fred Wilkes: Even though they said every time the fish come out of those creeks they start heading west from us. We see a lot of changes after they open those creeks. People were starting to get fish. Right now I think all the creeks along the coast have been piled up by wood. I do not know how we can work that out.

K. Chang-Kue: That program was back in 1987. There was money used to clear some of those creeks. They found that no matter how much clearing is done the wood still comes down the Mackenzie River. All of that wood and it seems all of those streams, the ones closest to the east channel, will continue to get jammed up by the logs. When I did the work at

Canyanek and Keneksek, the FJMC provided me with money in 1987 to look at Keneksek. Both those years when we went in July the streams were blocked and we saw fish trying to come down each of those streams. Some were trapped inside the logs, a lot of them were still holding in the river above. That is why I had such a small sample at Keneksek and Canyanek. We just tagged fish and left them at that point in the river and followed them to see what happened, expecting they would get caught up and not come out. Each year there are always these big August storms along the Mackenzie and both sea coasts and high tides. As soon as there were the August storms in 1986 and 1987 the fish left those streams. These were the ones that migrated westward. None went eastward. It seems whenever I track fish coming out of those streams at Kukjuktuk there was nothing that went eastward. All of the fish coming out of Kukjuktuk went westward past Tuktoyaktuk. Our interpretation is that if the fish are coming out of those streams they want to head towards either of those overwintering sites in [the delta] channels or else go into the Mackenzie. What you saw those years you had good fishing may have coincided with a good run of fish coming from McKinley Bay and Freshwater Creek and Kukjuktuk. The Tuktoyaktuk Peninsula is a very interesting area. We have talked about it among ourselves quite a bit to determine what could account for good years and bad years of fish running out of those streams near Tuktoyaktuk. Bill, you mentioned that today, there would be years you could not find those big fish. An interesting thing to look at was brought up by a scientist who was trying to study climate changes. If you have climate changes occurring in the region one of the things that can happen is that you have a drought, the water level may not be as high in the lakes as it used to be. These small streams that are joining these lakes may sometimes be high and dry by July. You have fish that want to come out and they can't that year and you have a bad year where the fish are not running past Tuktoyaktuk. That happened one year when Bill Bond, one of our biologists, was asked to come back to Freshwater Creek where he had done tagging in 1980 and 1981. It was 1983 or 1984 when he was asked to look at why there was so little water coming out of Freshwater Creek. He went up to that first lake above Freshwater Creek. He said that compared to 2 years ago the water level was really down. The lake had to flow through gravel bars. This is going to be a bad year for fish trying to come out of the lakes because the fish can not get into the river, thanks to the gravel bars. That taught us that if you have a good year with good water flow you can see the fish coming in and out of those rivers and they will migrate along the coast.

If you have a dry year it could affect your fish migration. That is something that can be investigated. Maybe one could look at the long-term climatic and rainfall records for the Tuktoyaktuk Peninsula and see if there are records on the fishing and the successful years for fishing. There maybe some sort of correlation. There are a lot of ideas to pursue.

Fred Wilkes: I think it is a good idea to open up these creeks once in a while. I think when we were getting the applications to open those two creeks that we were having a hard time with the fisheries. They were more worried about damaging the land than trying to help the fish to go out at that time.

K. Chang-Kue: The reason behind that is, if you try to dredge out a channel out of those lakes then there is no natural flow pattern left in the stream for the fish. What happens in the really good years when the water is high the water may now have a deeper channel to flow out and flow out faster. If the climate changes, it is a natural variation. Good years and bad years with the climate equals good years and bad years with the fishery. If you try to alter a stream too much without really understanding enough about it you may cause damage. If the water flows out too fast in the spring it may not allow the fish to get back into the lakes because you changed the channel configuration. Fisheries [DFO] was conservative at that time and hoping that things would reset and return to the natural situation.

F. Wilkes: They shouldn't be too worried about damaging the land because there isn't enough current from the lakes to damage the land. We needed at times to see that the creeks are opened up. We won't have any more fish coming out of those lakes.

K. Chang-Kue: I share your concern. I also remember that incident of trying to allow more flow in Freshwater Creek. We did not have any accurate water or weather records on the stream flow in the Tuktoyaktuk Peninsula. I think Water Surveys [Branch of Department of Environment] was asked to set up a gauging station on Kukjuktuk. I think there is a permanent gauging station there now. We have 8 or 9 years of data to allow us to see if there is a good year and a bad year for water flow. Maybe this kind of information can now be applied to the catch in the Tuktoyaktuk Harbor and see if there is any relationship to the good years and bad years for rainfall. We have been told we are in the middle of a dry spell for the Tuktoyaktuk Peninsula for the last 10 years.

F. Wilkes: We have a lot of information now for broad whitefish but what about herring and cisco herring? Do you have any information where they go and where they winter?

[Editor’s note: “Herring” commonly refers to Arctic cisco/least cisco.]

K. Chang-Kue: No. There has been a lot of work done on the population on the coast by Bill Bond. He has a couple of reports on the Anderson River study. He has looked at the herring. The problem in trying to tag herring is they are so sensitive to handle that in trying to put tags on them you will cause them to be injured. Then they may not behave naturally. With broad whitefish you can handle them, move them around and throw them back in the water and they can survive. A herring may or may not survive depending how long you have them out of the water. Some of those others, such as least ciscos, taking them out of the net, they lose 90% of their scales and you know they are not going to survive - they get fungus and die. We worked with broad whitefish because it is an important fish species in the area. I would have liked to look at crooked-backs and the herring. I have done some work on the Arctic cisco, but the money and resources are only available to work on important species and that is the broad whitefish. Maybe one day when we know everything about the broad whitefish, which will be in a thousand years, we could try to study these other fish.

Ron Felix: Hi, I am Ron Felix. I was just wondering about spawning areas. In November and December I do a lot of fishing in Eskimo Lakes. We get a lot of crooked-backs and they are all loaded with eggs. Where are they going? They are so thick with eggs they just fall out when you pull them from the net.

K. Chang-Kue: The Eskimo Lakes area is a large fresh water lake body. The crooked-backs, their spawning behaviour in that region - Ross would you know?

R. Tallman: There are several possibilities. Crooked-backs can spawn within the lake itself. In this area they spawn more in river systems. In that particular area I can't say but perhaps Jim can answer for that area.

J. Reist: We have done some sampling on the Kugaluk and Miner Rivers which are the big rivers that come in to the bottom end of the Fingers Lake area and Eskimo Lake. Those two rivers are very good broad whitefish rivers. There is a good population of broad whitefish there that move up those rivers as well as a good population of crooked-backs. For the whitefish and crooked-backs, the kind of place they need to spawn are areas where there is a bit of current that keeps the gravel or spawning substrate clean without being silted up. If it starts silting up over the winter the eggs will suffocate and die because of the mud that is covering them. As long as there is a bit of current and it keeps those kinds of areas clean and usually they try to pick gravel or cobble areas that are kept clean - as long as those areas are in a river they spawn there. If they are in a lake they will spawn there as well. They are two different kinds of fish and the broad whitefish seem to prefer rivers to spawn in but the crooked backs can spawn in either situation. A lake that has been kept clean by water current or river areas. In the situation for the crooked backs that you saw, it may be that your nets were very close to a place they were actually going to spawn or they were on their way up the river and you caught them before they got up the river.

K. Chang-Kue: Just a little plug in for Ontario - they have used radiotags to find lake whitefish spawners and spawning shoals.

Ron Felix: What we call crooked-backs is what you call broad whitefish I was just told.

K. Chang-Kue: No. Lake whitefish are known as the crooked-back here. Broad whitefish are broad whitefish [or whitefish].

Ron Felix: On the top of your picture the one you were showing with the bunch of fish there, on the top of that picture, that is what we catch in Eskimo Lakes.

K. Chang-Kue: Those are broad whitefish. You do get broad whitefish there. They must be going to spawn close to a large river. How far was your fishing site from some of the big rivers?

Ron Felix: It shows on the map here where I set my net, this is one of the fingers. If you are looking at Whitefish Bay it is across Eskimo Lakes on your map.

J. Reist: Afterwards we can go to the map and discuss this. We know there are spawning populations in the Kugaluk and Miner Rivers but there are also several other rivers that enter into that area as well. No one to my knowledge has done any studies or looked at those rivers. There is no reason why those rivers could not act as places for spawning for broad whitefish and crooked backs. Ross has a picture of what people in the Delta really refer to as a crooked back and they are very, very, different looking fish. The one you pointed to in the slide here had a bit of a hump on it. These crooked backs are strange looking.

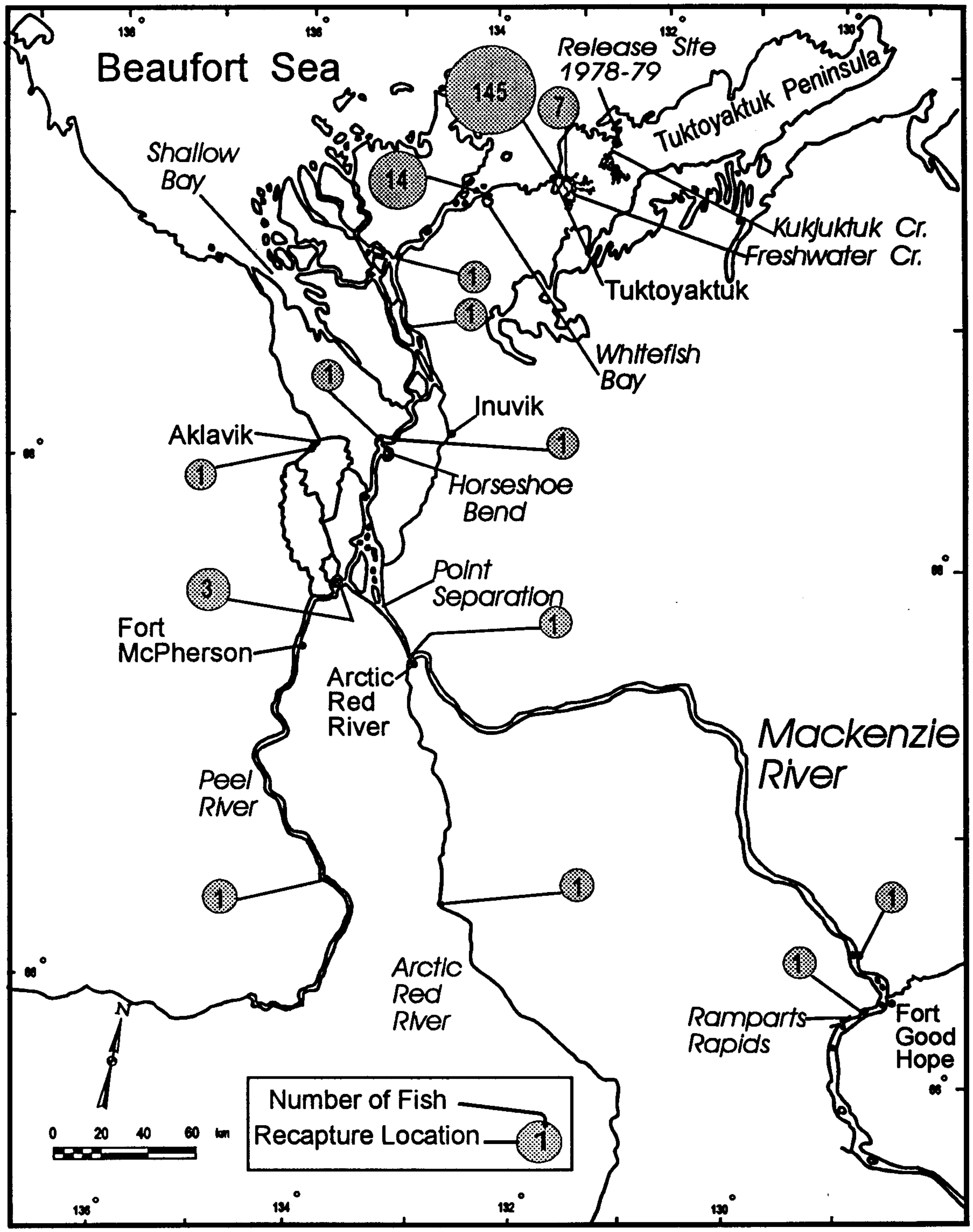

Figure 1. Map of lower Mackenzie River and adjacent coastal study area showing all sites where broad whitefish, tagged with floy tags in1978-1979 at a coastal watershed (Kukjuktuk Creek), were recaptured between 1978 and 1981.

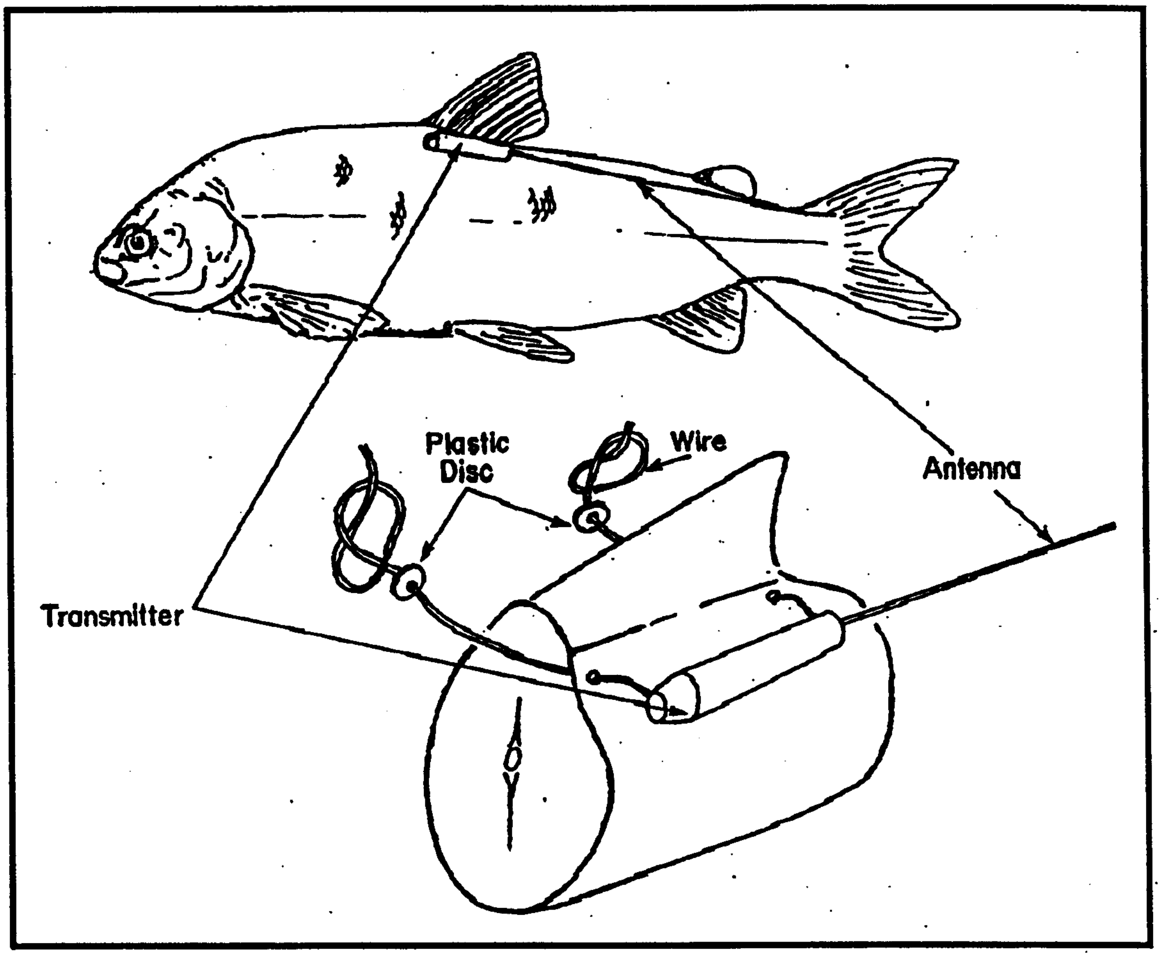

Figure 2. Attachment of external type radio transmitter tag on broad whitefish.

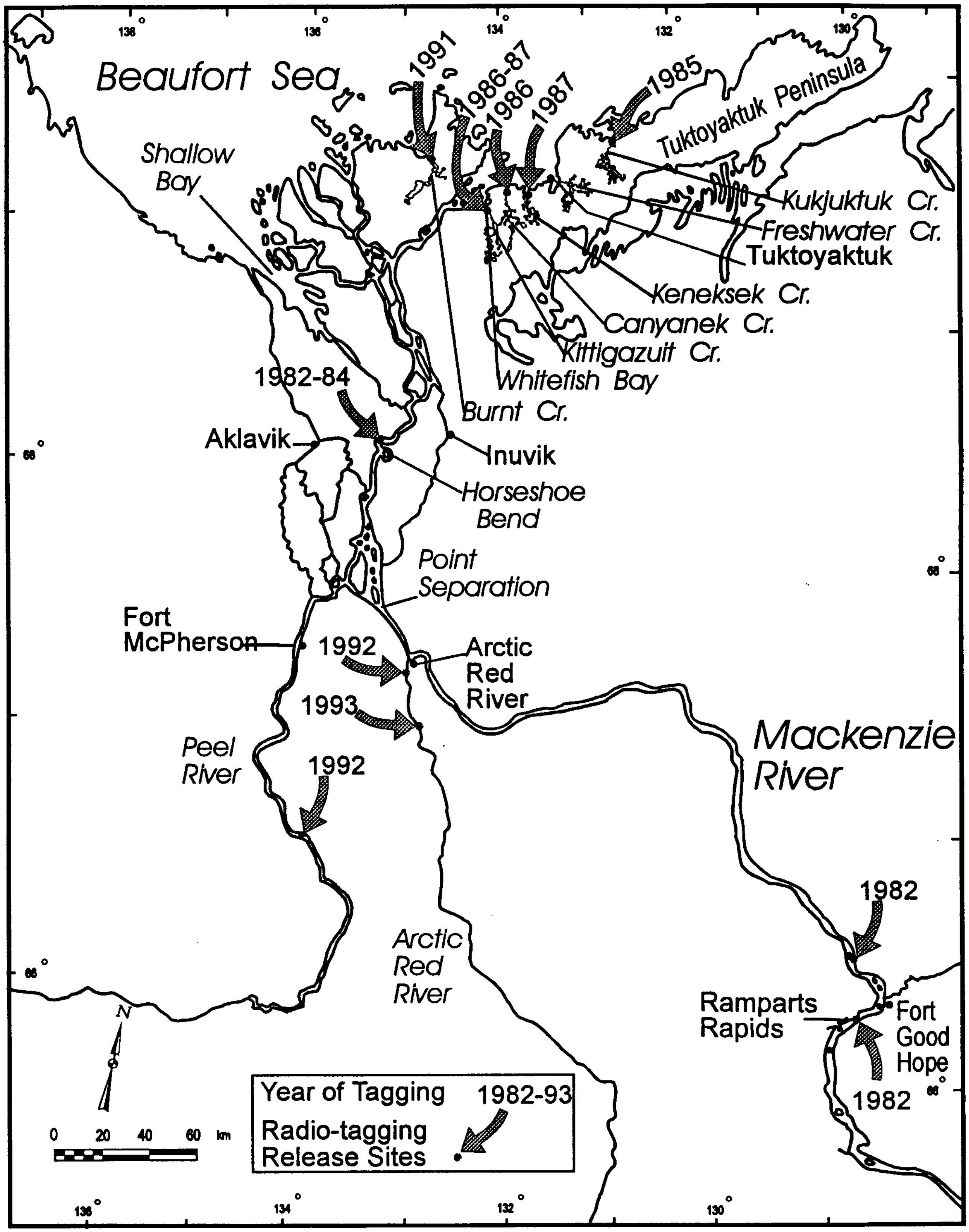

Figure 3. Study area map showing sites where migrating broad whitefish were tagged with radio tags in 1982-1993.

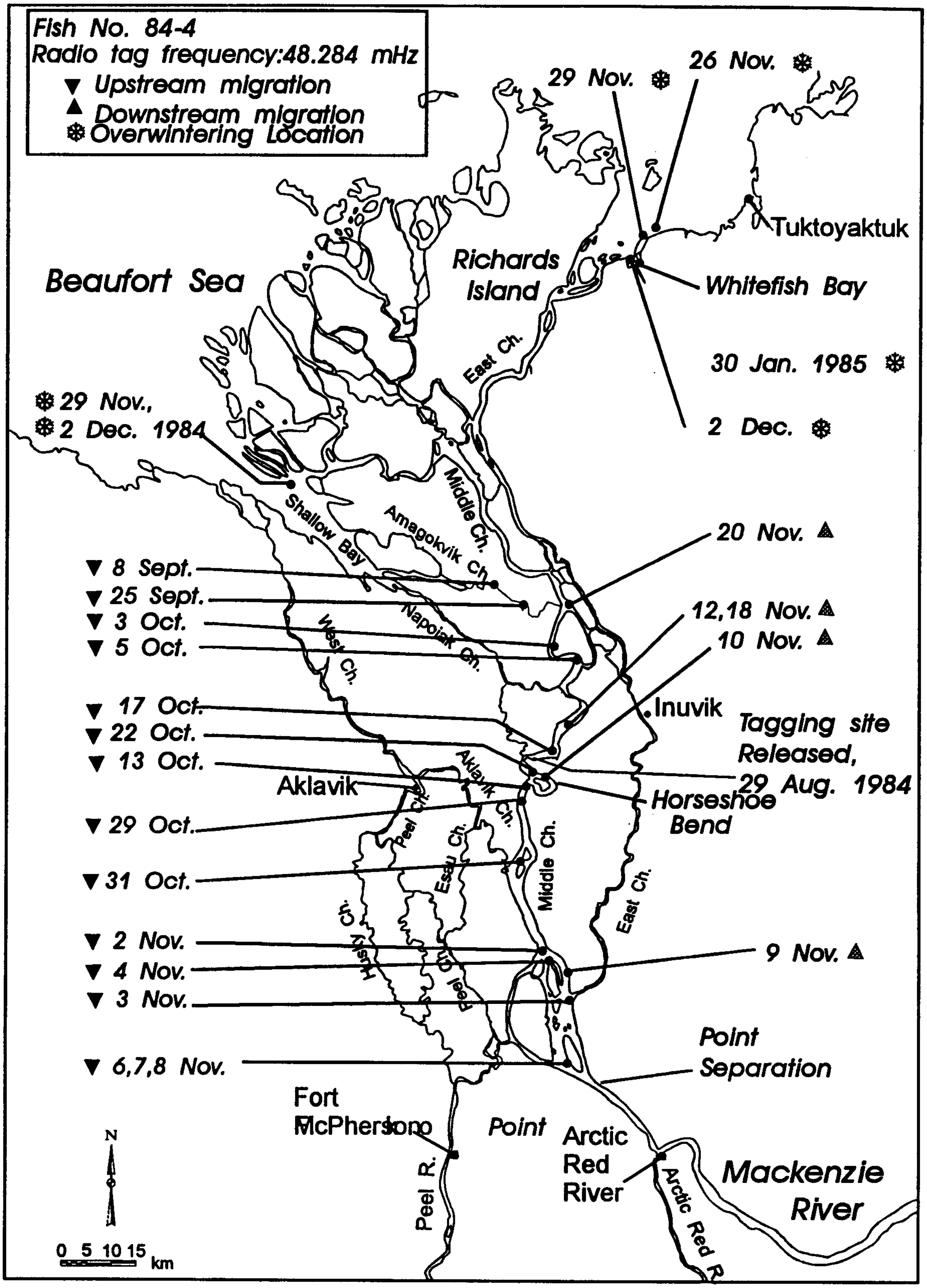

Figure 4. Tracking map for broad whitefish (Fish No. 84-4) released at Horseshoe Bend on 29 August 1984.

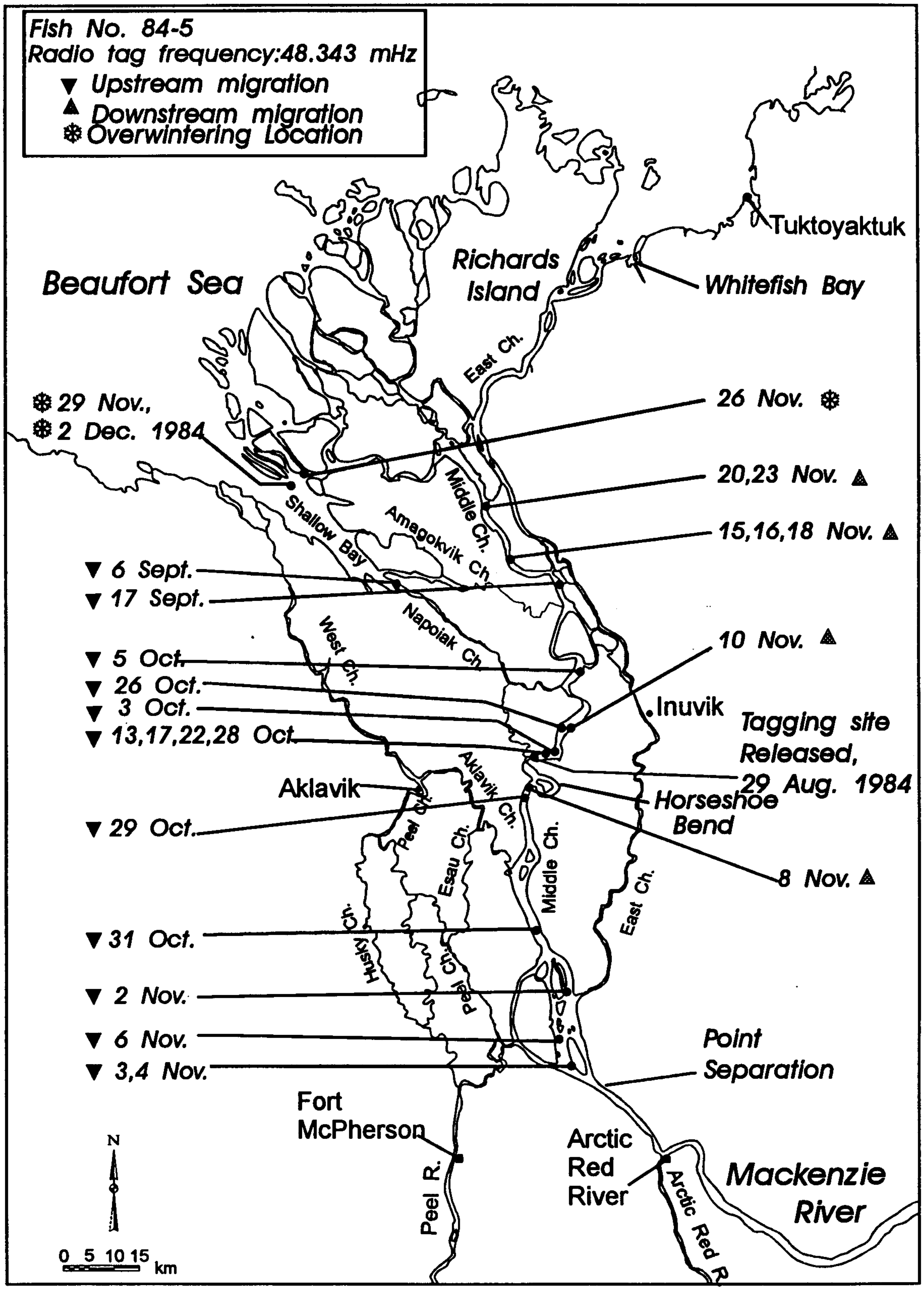

Figure 5. Tracking map for broad whitefish (Fish No. 84-5) released at Horseshoe Bend on 29 August 1984.

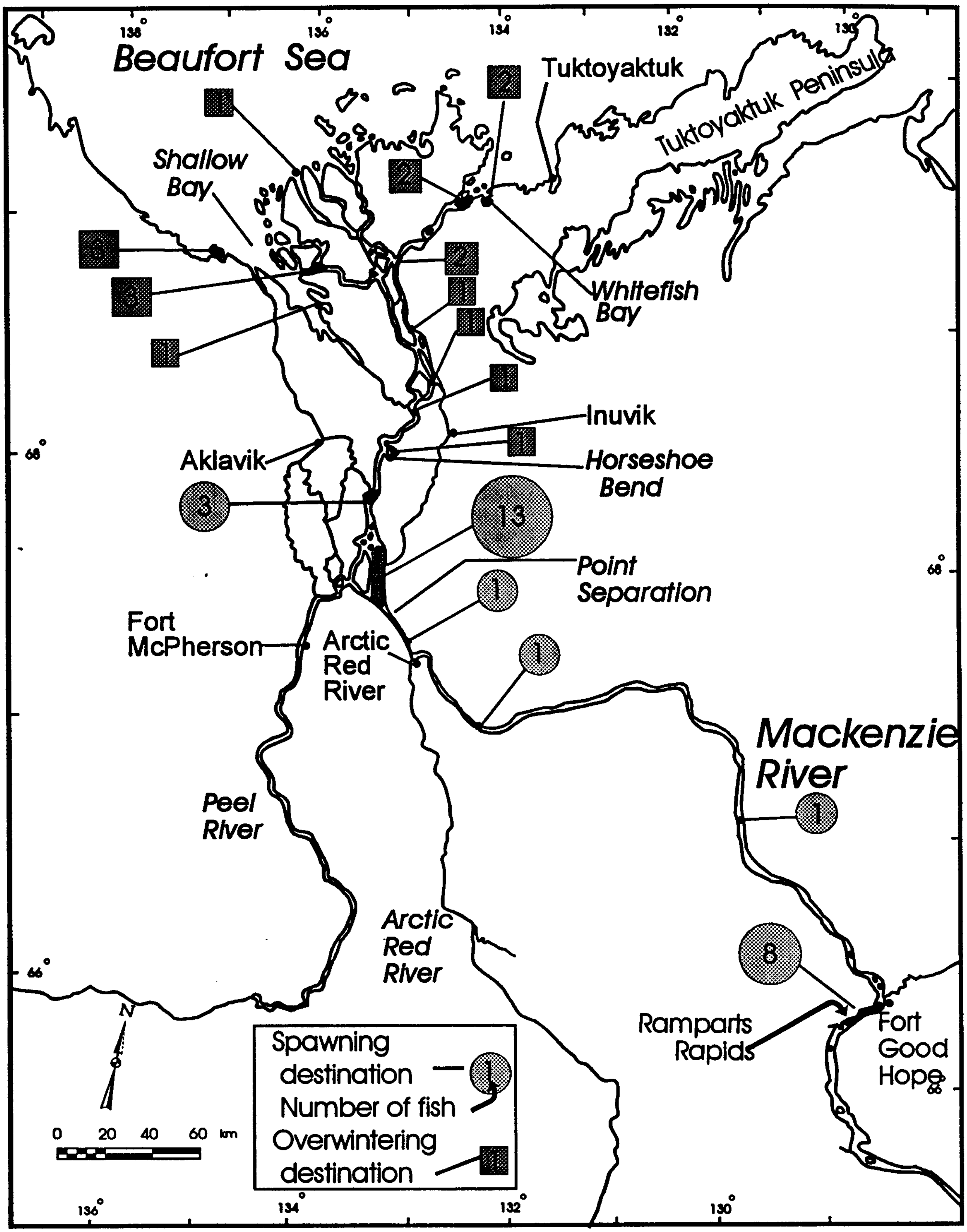

Figure. 6 Summary of spawning and overwintering destinations of radio-tagged broad whitefish tagged at Horseshoe Bend and Fort Good Hope, 1982-1984.

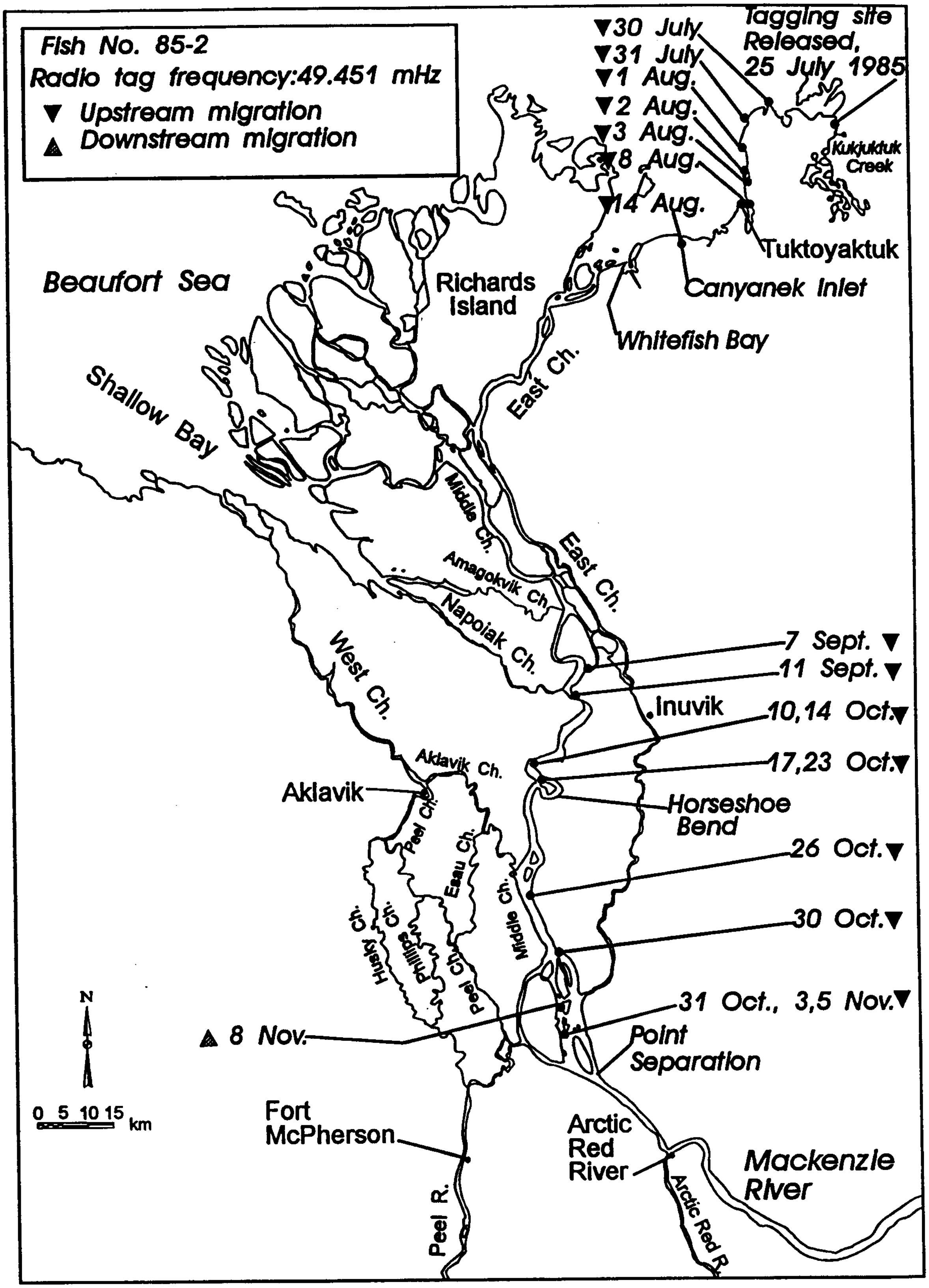

Figure 7. Tracking map for broad whitefish (Fish No. 85-2) released in Kukjuktuk Creek on 25 July 1985.

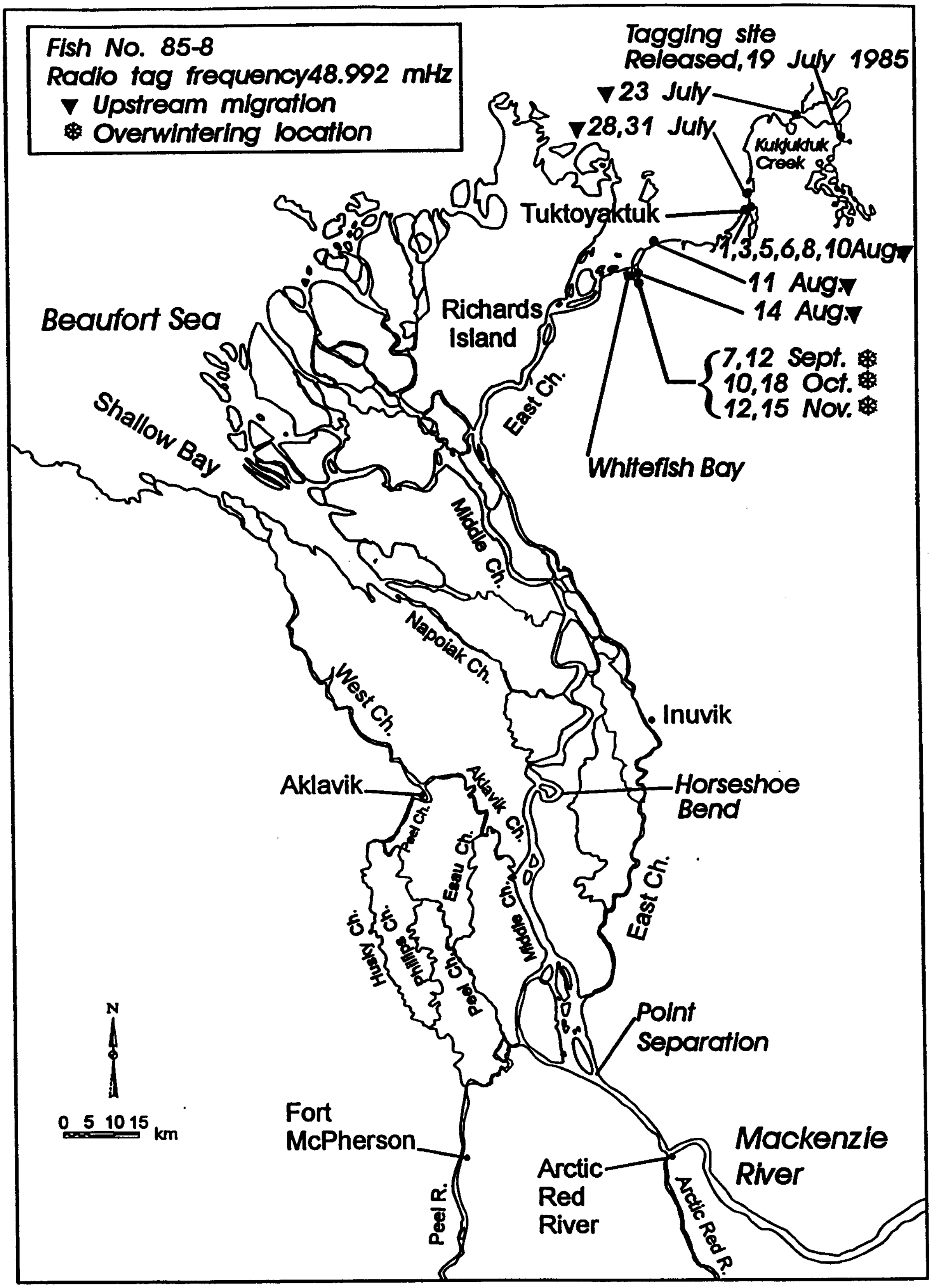

Figure 8. Tracking map for broad whitefish (Fish No. 85-8) released in Kukjuktuk Creek on 19 July 1985.

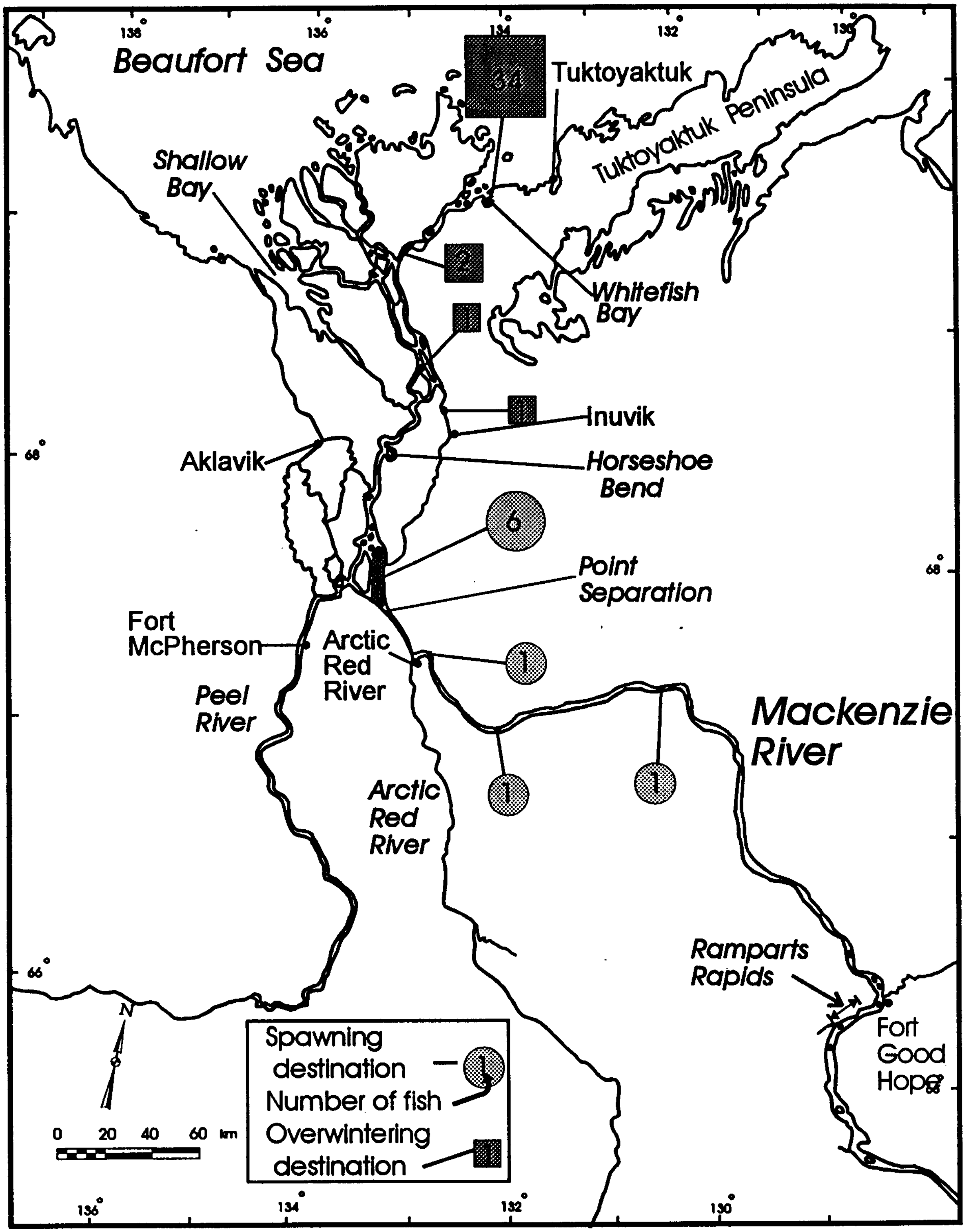

Figure 9. Summary of spawning and overwintering destinations of radio-tagged broad whitefish tagged in coastal streams on Tuktoyaktuk Peninsula, 1985-1987.

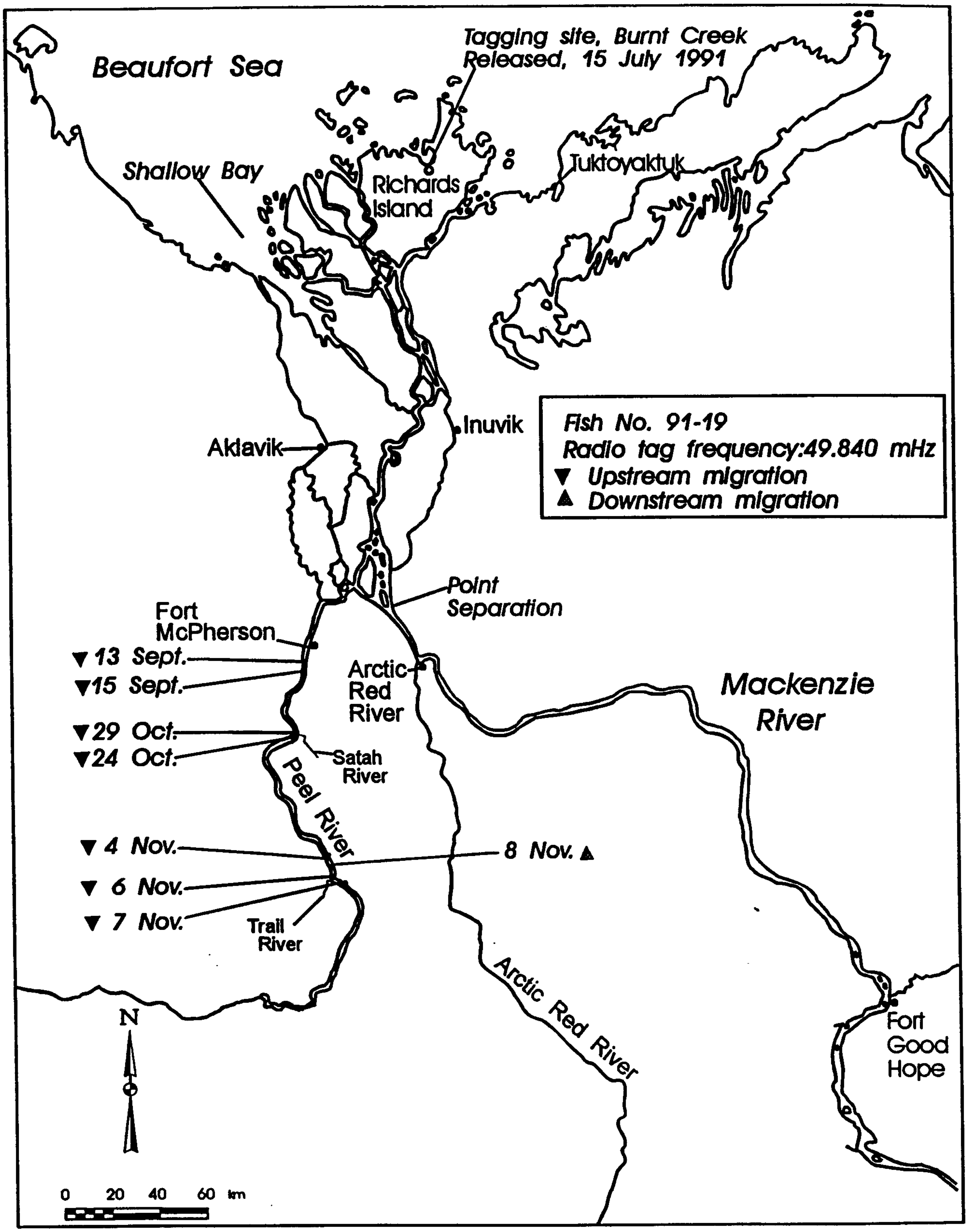

Figure 10. Tracking map for broad whitefish (Fish No. 91-19) released in Burnt Creek on 15 July 1991.

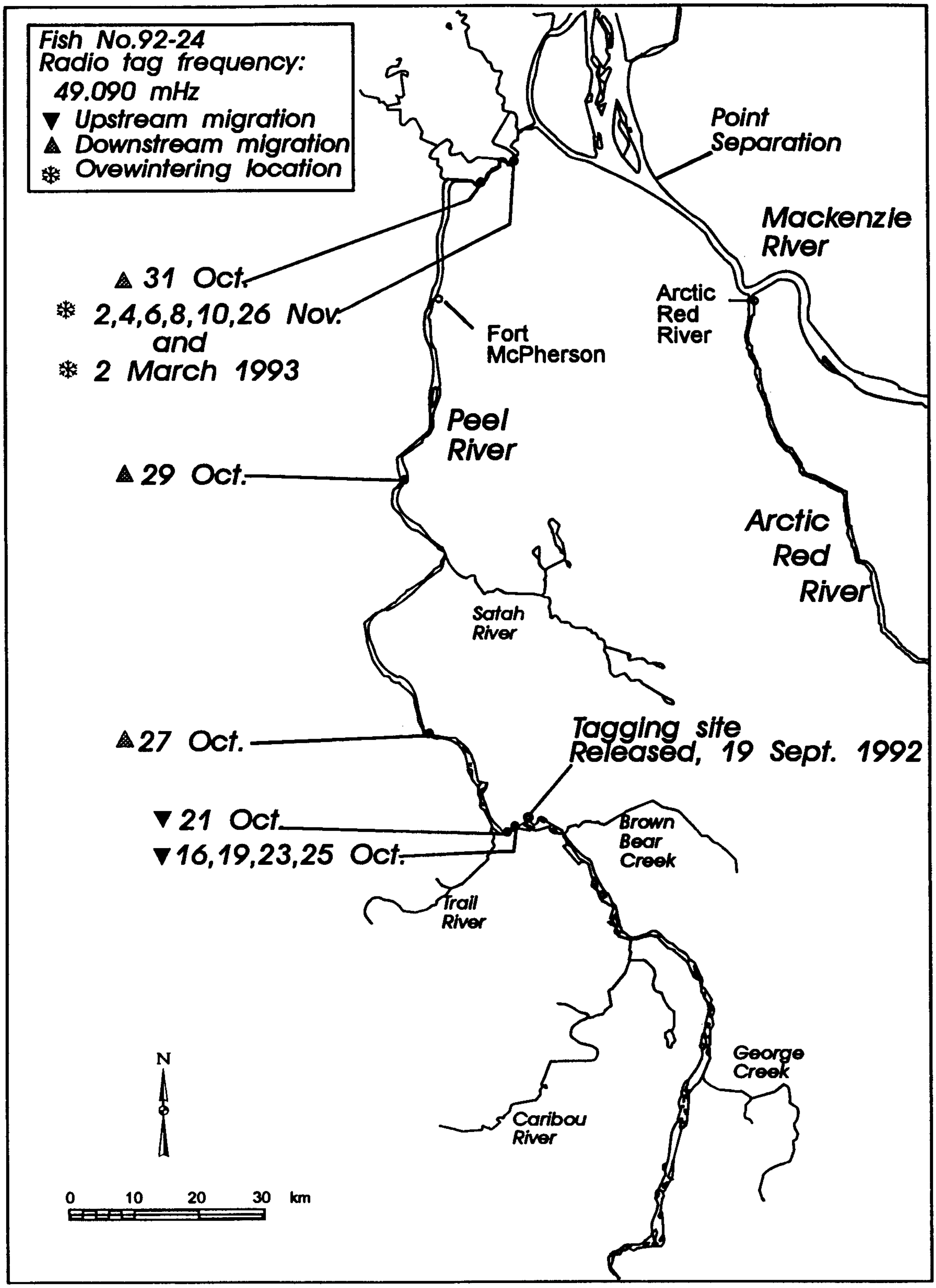

Figure 11. Tracking map for broad whitefish (Fish No. 92-24) released in the Peel River on 19 September 1992.

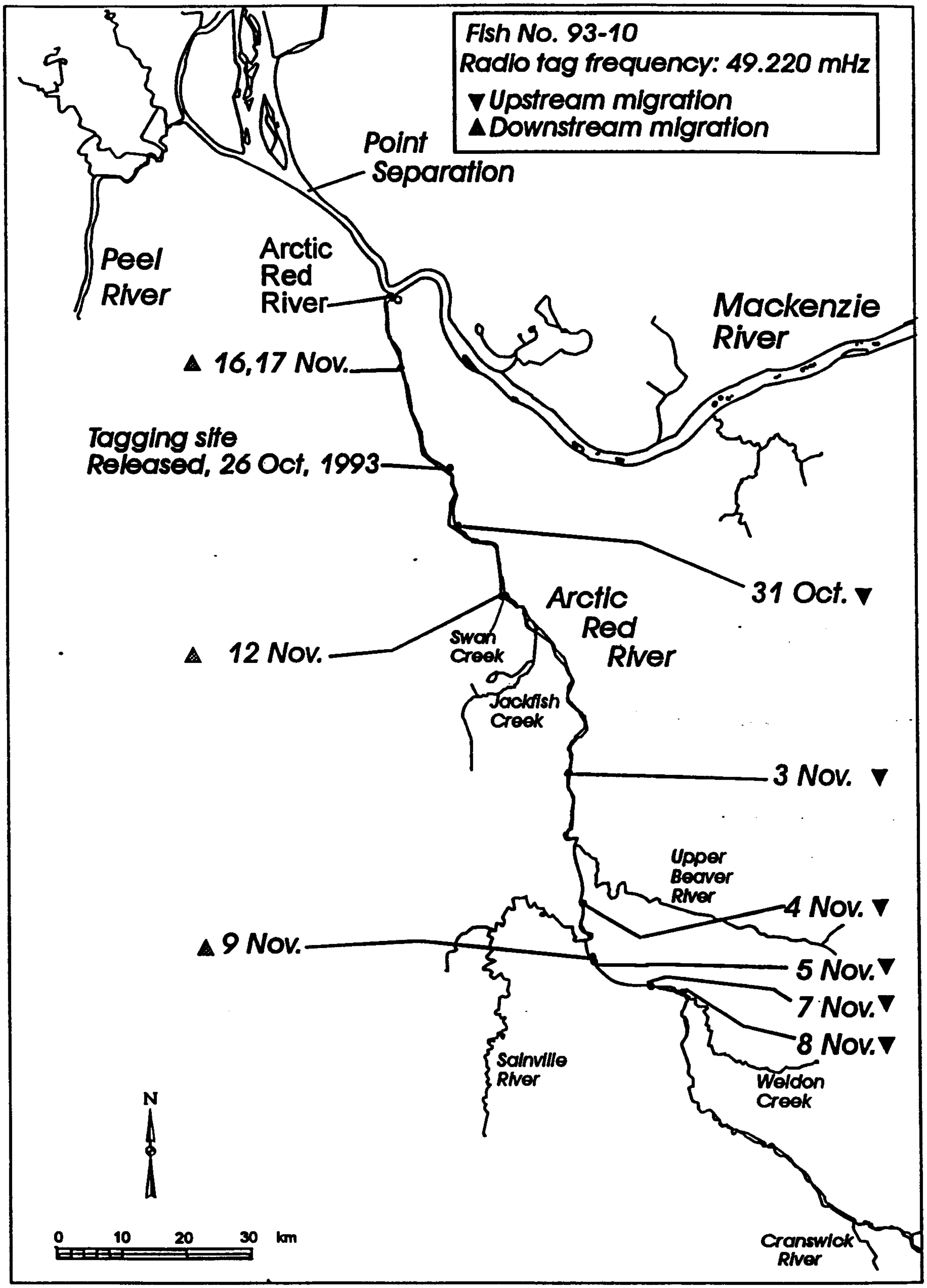

Figure 12. Tracking map for broad whitefish (Fish No. 93-10) released in the Arctic Red River on 26 October 1993.

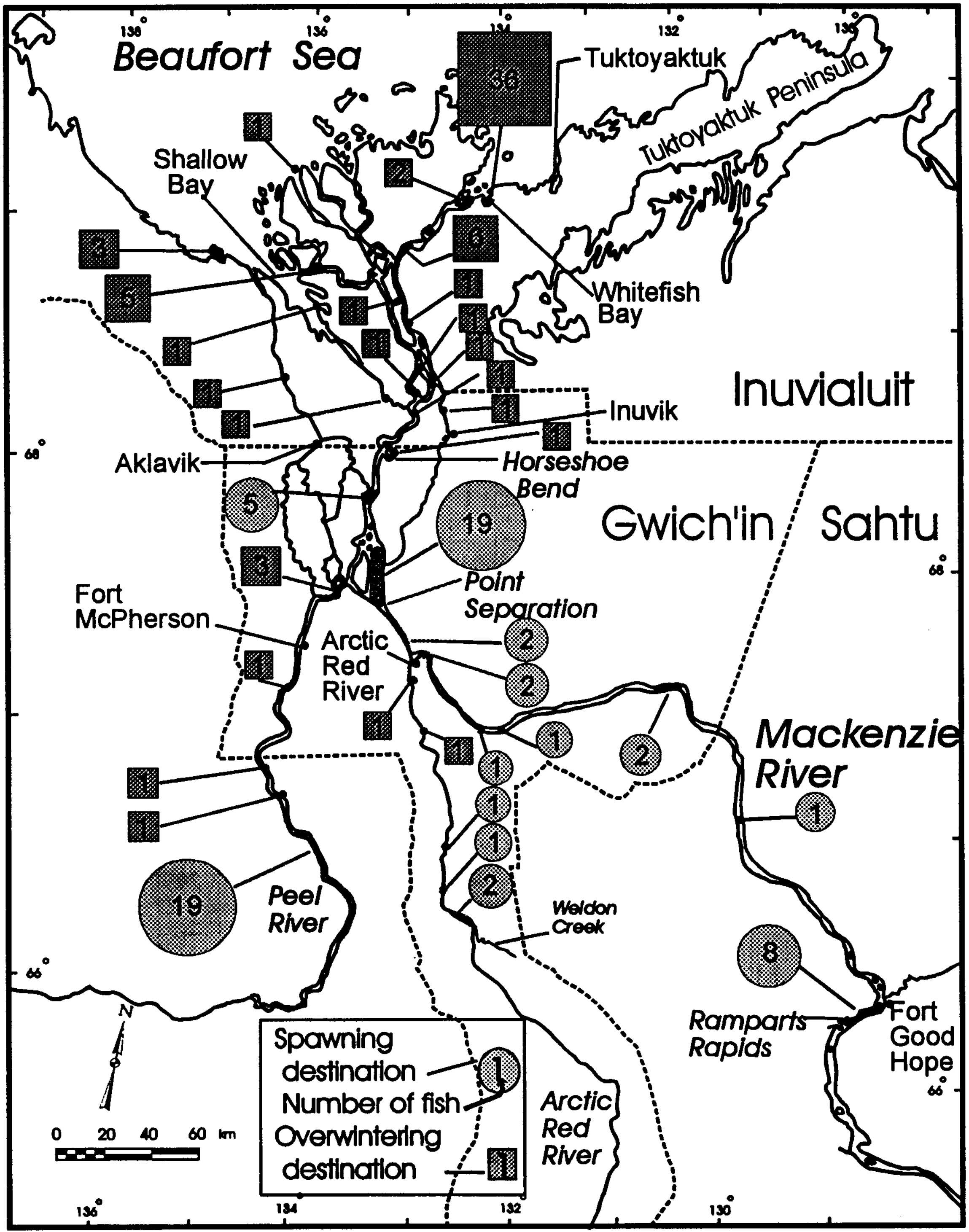

Figure 13. Overall summary of spawning and overwintering sites of broad whitefish identified in this study, 1982-1993. The three settlement areas are also shown.

LIFE HISTORY VARIATION AND POPULATION DYNAMICS: CONSEQUENCES FOR MANAGEMENT DECISIONS

by

Ross F. Tallman

ABSTRACT

The relationship between life history traits closely associated with fitness and the population dynamics of fish stocks is discussed. The effect of differences in age-at-maturity, egg number per female, mortality or growth on the productivity of fish stocks is demonstrated using schematic models. Stocks with earlier age-at-maturity, greater egg number per female, lower average mortality or higher growth rates will have higher productivity. In nature all of these traits vary simultaneously to determine the dynamics of fish stocks.

SUMMARY

Sustainable fisheries management requires an understanding of the mechanisms of productivity in the system. Fish population productivity is determined by four factors: recruitment (reproduction), growth, and both natural and fishing mortality (Fig. 1). Reproduction and individual fish growth patterns increase the biomass that is available to be harvested while mortality decreases population size. Reproduction has two major measurable components: the egg number per female at a given age (fecundity) and the age at sexual maturity. The former determines the number of potential recruits to the population. The latter determines the rate of turnover in the population - how fast the population cycles. Size-at-age (growth) determines how fast fish reach harvestable size and the yield that is available for harvest. Egg number, age-at-maturity, growth and mortality are often called fitness related life history traits (Stearns 1992; Roff 1992). Interpopulation variation in life history traits thus determines variation in stock productivity and hence the level at which they should be harvested.

In the program for broad whitefish in the lower Mackenzie River two different projects collected information on life history variation, one at the commercial fishing site and one at the Index Stock site at Arctic Red River. The data collected at commercial fishing sites such as Horseshoe Bend, involves biological sampling of a sub-sample of the harvested fish. The data are mainly focussed on length, weight and age of harvested fish. This information can be used directly in fishery calculations of yield and indirectly to analyze productivity based on life history. However, for the purposes of analysis of life history and stock productivity the data are incomplete because they do not cover reproductive productivity (age at sexual maturity and egg number per female with age). Sampling of the available population is not adequate for life history analysis because the commercial nets do not capture smaller fish that may be in the area. As well, in most cases several stocks are in the area and the sample thus does not represent a single breeding population. Therefore, more detailed sampling was undertaken at an Index Site (Arctic Red River) so that all life history traits were recorded for a single breeding population. These data will be used to monitor whether decisions made in the fishery will change stock productivity.

Variation in productivity in broad whitefish may also be linked to whether the fish migrate or not. Typically, non-migratory stocks are less productive than those that migrate (Tallman et al. 1996). Examples of migratory and non-migratory populations of broad whitefish in the lower Mackenzie River are the Arctic Red River fish which are thought to be anadromous and Travaillant Lake fish which are considered land-locked Chudobiak (1995).

To illustrate the effects that variation or changes in the major life history traits can have on fishery productivity I present a few examples below. These examples are highly simplified to illustrate the ideas and principles on why it is important to measure these traits when managing a fishery. Actual situations would be much more complex with all of these traits interacting at once. For more detailed treatment of this subject refer to Healey (1975), Healey and Heard (1984), Stearns (1992) or Roff (1992).

EFFECT OF AGE AT MATURITY (EXAMPLE)

Figure 2 shows a sample example to demonstrate the effect of interpopulation variation in age at maturity. Stocks with earlier age at maturity will have a higher productivity.

EFFECT OF FECUNDITY (EGG NUMBER) (EXAMPLE)

Figure 3 shows a sample example to demonstrate the effect of variation among stocks in egg number. Stocks with a higher fecundity will have a higher productivity.

EFFECT OF MORTALITY (EXAMPLE)

Figure 4 shows a sample example to demonstrate the effect of variation among stocks in mortality. Stocks with lower average mortality will produce larger numbers of fish to be harvested.

EFFECT OF GROWTH (EXAMPLE)

Figure 5 shows a sample example to demonstrate the effect of variation among stocks in growth. Stocks with higher individual growth rates will produce harvestable fish sooner and have a higher potential yield than stocks which have lower growth.

All aspects of the life history vary simultaneously among stocks (Fig. 6). To make predictions the life history trajectory for each population must be calculated.

Therefore, one must understand the biology in terms of the life history in order to effectively manage a fishery such as that for the broad whitefish in the lower Mackenzie River system.

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COMMENTS, QUESTIONS AND ANSWERS

No comments.

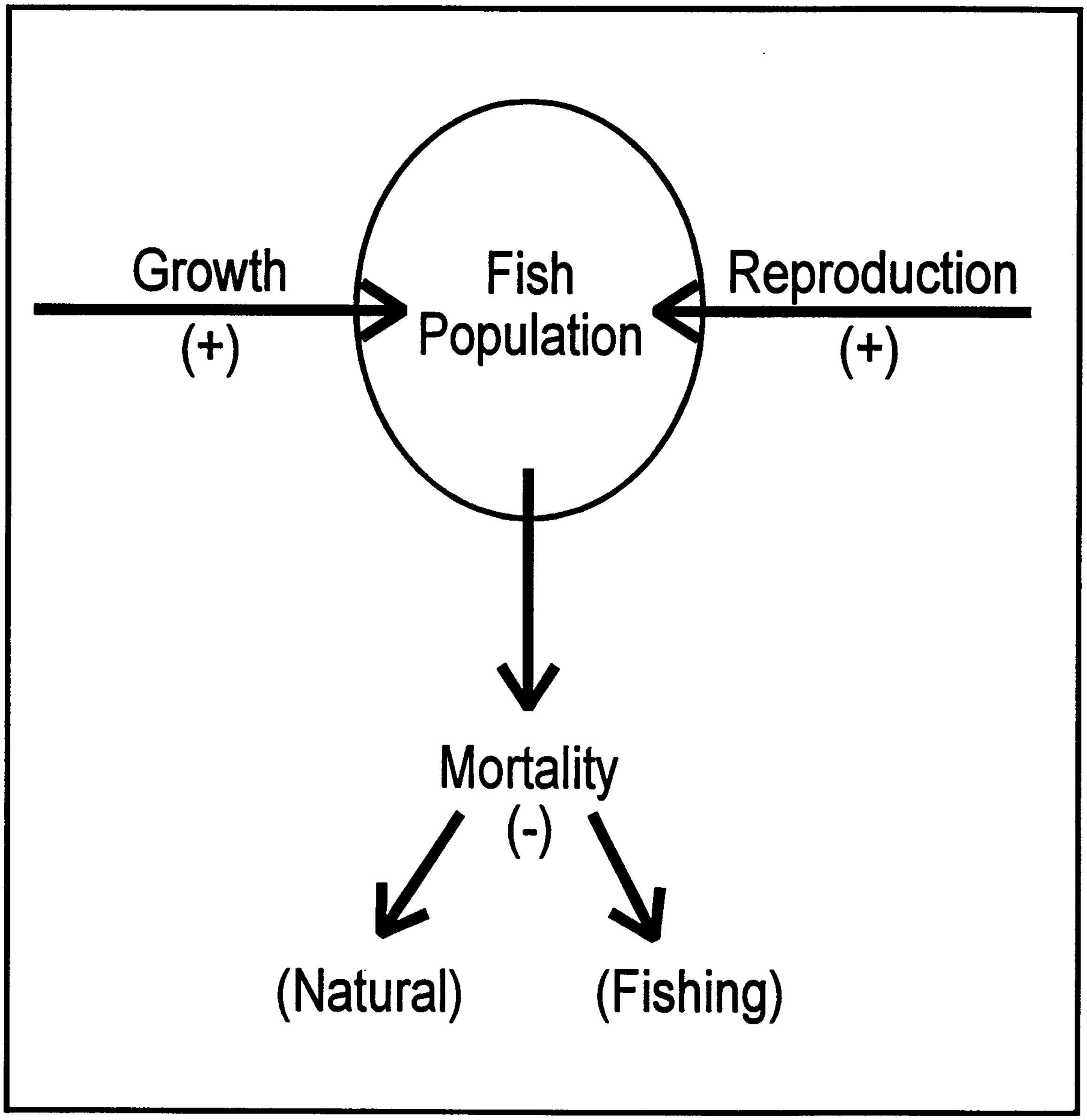

Figure 1. Basic model of a fish population. Inputs to production are reproduction and growth. Mortalities, both fishing and natural decrease future production.

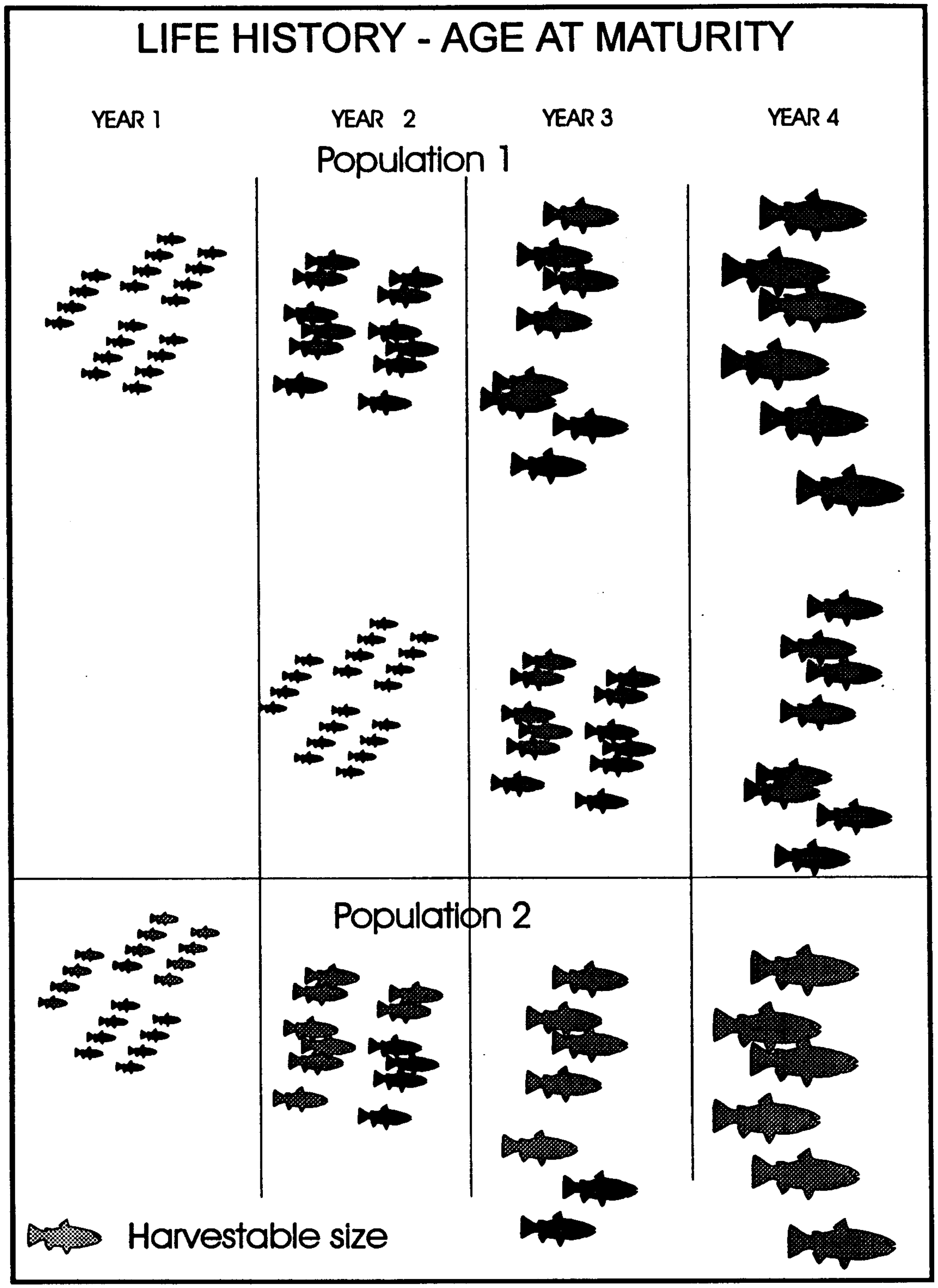

Figure 2. Effect of variation among populations in age-at-maturity on respective population dynamics . Fish in Population 1 mature at age 2 while those in population 2 mature at age 4. The darkened fish represent mortalities at each age. As a result more fish will reach harvestable size in Population 1.

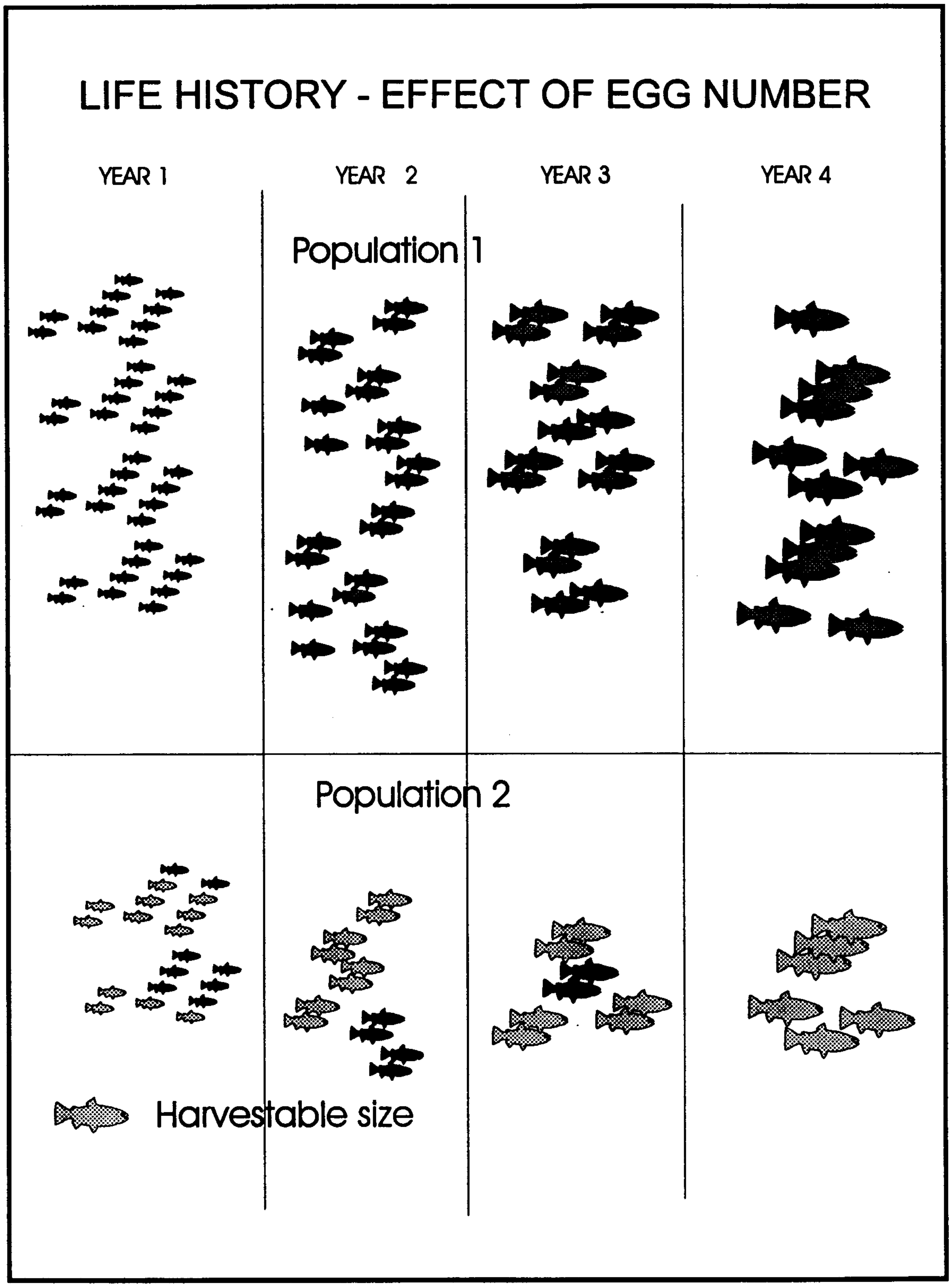

Figure 3. The effect of variation in egg number among populations on respective population dynamics. The darkened fish represent mortalities at each age. Population 1 has a higher average fecundity (egg number) per female. All other variables are kept constant. As a result more fish will reach harvestable size in Population 1.

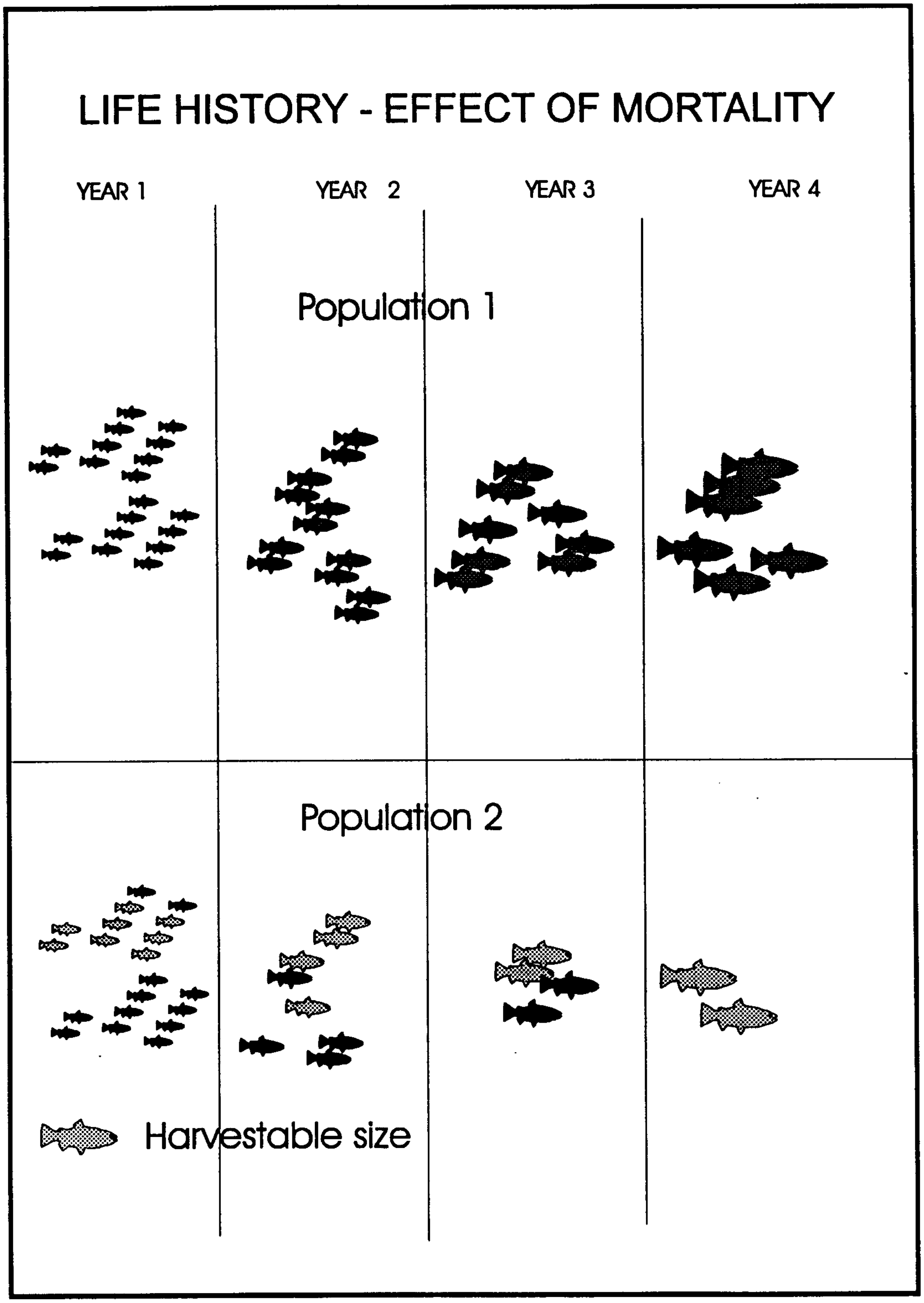

Figure 4. The effect of variation in natural mortality among populations on respective population dynamics. The darkened fish represent mortalities at each age. Population 1 has a lower average mortality than Population 2. All other variables are kept constant. As a result more fish will reach harvestable size in Population 1.

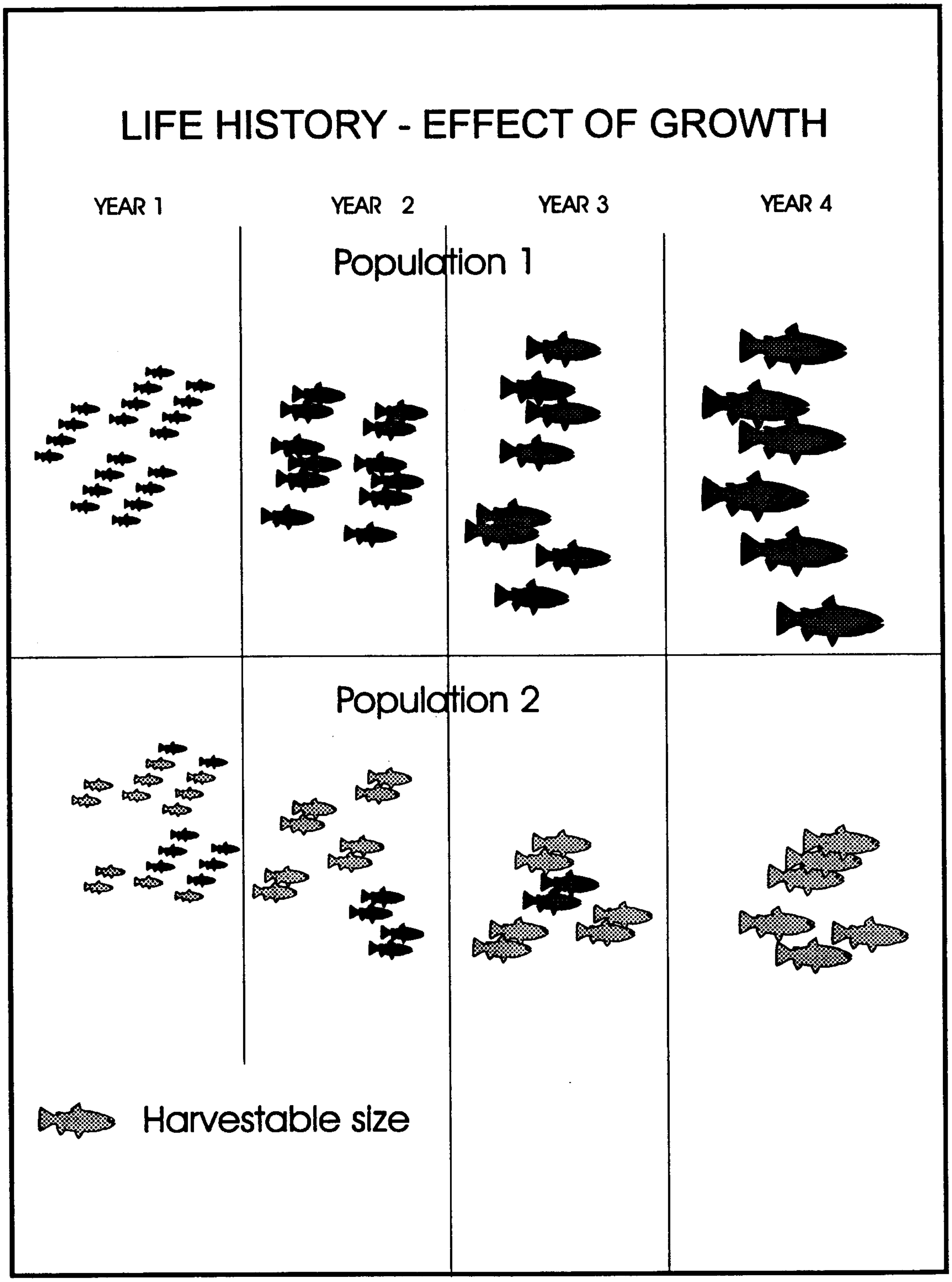

Figure 5. The effect of variation in growth among populations on respective population dynamics. The darkened fish represent mortalities at each age. Population 1 has a higher average individual growth rate. All other variables are kept constant. As a result more fish will reach harvestable size sooner in Population 1.

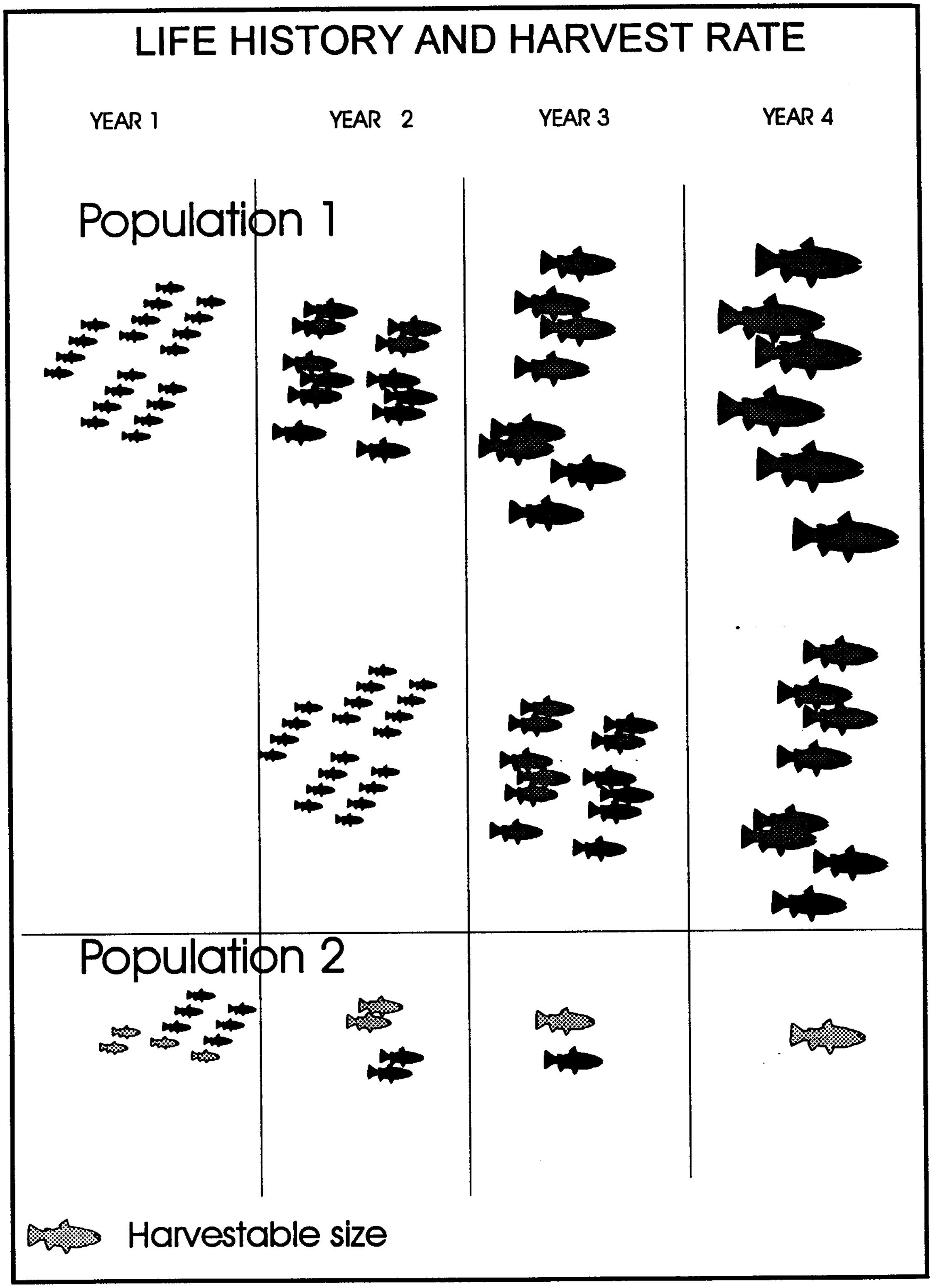

Figure 6. All major life history parameters vary simultaneously. Population 1 has a higher growth rate, fecundity, lower mortality and greater egg number per female than population 2. (The darkened fish represent mortalities at each age.) As a result more fish will reach harvestable size in Population 1.

EFFECTS OF EXPLOITATION ON FISH POPULATIONS

by

Eric C. Gyselman

ABSTRACT

A summary of two controlled field experiments in fish harvesting, one under the Experimental Cropping of Lakes Program (E.C.O.L.) on whitefish and lake trout and one on Arctic char at Nauyuk Lake is presented. A theoretical model for the effects of harvesting on fish populations is described to introduce the concepts of carrying capacity and population resiliency. Growth, reproduction and mortality are mechanisms of compensation for changes from the carrying capacity which regulate the population. Harvesting of the E.C.O.L. lakes produced no change in the natural mortality rate of adults but their growth rates increased proportionally to the harvest rate. Egg number per female and juvenile survival rate also increased in harvested lakes. Harvesting at the Nauyuk system produced no increase in growth rate or fecundity but eventually caused a reduction in the age-at-maturity. It is suggested that monitoring of the age-at-maturity, growth rate and juvenile survival may be useful in management of the Mackenzie River broad whitefish. [Abstract composed by editor]

EXPLOITATION MODEL

Fisheries management is based on a simple model. As fish are removed from a stock, the resources available to each of the remaining fish are greater, therefore, 'production' which is the amount of fish (usually measured as weight) created by the stock is increased. It is this compensation mechanism that allows us to harvest stocks on a sustainable basis.

To show how this works, consider the following. If we could count the number of fish in a small arctic lake, we would find that approximately the same number would be present from year-to-year (Fig. 1). This is because as long as environmental conditions remain relatively constant, the lake will have a constant 'carrying capacity'. The 'carrying capacity' is simply the number of fish of a particular species that the resources of the lake can support. These resources can be many things (habitat availability, size of spawning grounds, etc.), but in many cases it is the amount of food that is available.

If we decided to catch some fish in the lake for just one year then count the number of fish in the following years, we would find that the stock number would return to its original carrying capacity (Fig. 2). This is because when we remove fish from the lake there are more resources available to the remaining fish and production increases. In effect, the stock attempts to compensate for our fishing by increasing production until the carrying capacity is again reached.

Suppose now that we want to harvest fish from the lake each year. As long as we harvest a moderate amount of fish, the increase in production by the fish remaining in the lake can compensate for those removed each year (Fig. 3). As long as our harvest level is at or below the production level, we can continue to harvest the same amount of fish indefinitely.

Finally, if we harvest too many fish, the fish that remain in the stock after each year's harvest cannot produce enough new fish to sustain our harvest level no matter how many resources are available to them (Fig. 4). In this case, the stock size will begin to decline. If we continue to fish, the stock will eventually be eliminated. Our catches will be good at first but eventually they will decline as the stock size declines.

The objective of fisheries management is to determine the amount of fish that can be harvested each year without resulting in a continuous decline in the stock.

Inherent in this simple model is the assumption that environmental conditions remain relatively stable from year-to-year. This is obviously not always the case. If environmental conditions change either due to natural or man-made causes, then the stock will attempt to adjust to this new set of circumstances. This adjustment will change the carrying capacity. How much a change in the environment will affect the carrying capacity is often difficult to predict. Minor year-to-year changes, such as a cold late spring one year and a warm early spring the next, rarely have any long term effect on northern fish species because they tend to live for a long time and have long generation times. As a result, the annual variations are 'averaged out' over the years. However, if a significant change lasts many years then the carrying capacity can be affected. If this occurs in a system where an active fishery is taking place then it becomes a much more difficult task to manage the fishery because the 'new' carrying capacity is unknown and therefore the safe harvest limit is unknown.

COMPENSATION MECHANISMS

There are only three parameters that can change to allow a stock to compensate for exploitation. These are: growth, reproduction and mortality. Two of these, growth and reproduction, cause the stock size to increase while the third, mortality, causes the stock to decrease (Fig. 5).

In an unexploited stock, natural mortality is balanced by growth and reproduction so that the stock size remains relatively constant at its carrying capacity. When we start to harvest a stock we increase mortality ('fishing mortality'). To compensate for this, the stock can only do one of three things:

1. Increase its growth rate.
2. Increase its reproductive rate by increasing fecundity (number of eggs per female) or reducing the age of sexual maturity.
3. Decrease its natural mortality rate.

Because these are the only three parameters that can change, fisheries biologists use them as indicators of the effects of the fishing on the stock. However, sometimes these parameters can be difficult, if not impossible to measure.

EXPERIMENTAL RESULTS

The Experimental Fisheries Management Project of DFO has conducted two experiments to measure the changes in growth, reproduction and natural mortality that followed an experimental exploitation. The first experiment, called the Experimental Cropping of Lakes Project (E.C.O.L.) was carried out on four small lakes 30 km northeast of Yellowknife (Fig. 6). The principal species in this study was lake whitefish (crooked-backs). Over a number of years, the lakes were harvested at various rates and the effect on mortality, growth, and reproduction were measured. There was no apparent change in the natural mortality rate of the adults. However, growth rates increased. These increases were proportional to the harvest rate so that the lake that had the most fish removed had the greatest increase. Fecundity (number of eggs per female) also increased in the exploited lakes but the increase was not proportional to the harvest rate. Unexpectedly, there was a significant increase in the survival rate of juveniles. This seems like a paradox. Females had been harvested from the stock so there were fewer of them to lay eggs and although the number of eggs laid by each female was higher, it was not high enough to explain the large increase in the number of juvenile fish. Therefore, less eggs were laid but the number of juvenile fish was higher. The biological processes that caused this response are not fully understood but it appears to be an important mechanism for compensating for exploitation.

The second experimental study was on a sea-run stock of Arctic charr at Nauyuk Lake, 80 km south-west of Cambridge Bay (Fig. 6). The initial size of the stock was 12,000 fish but between 1974 and 1981, a local Inuit family who were utilizing the fish for subsistence needs had reduced the stock to 2,600. Fisheries and Oceans staff monitored this harvesting and also maintained a weir across the Nauyuk River to measure the response of the stock to harvesting. At Nauyuk Lake, no increase in growth rate was observed as the stock was exploited. Neither was there an increase in fecundity. There was no increase in the number of females spawning but the age of sexual maturity did decrease once the stock had been substantially reduced. As with the E.C.O.L. Project, there was a significant increase in juvenile survival but not until late in the study (1980+). Changes in the natural mortality rate could not be measured because immigration and emigration rates were relatively high.

A sea-run charr stock represents a significantly different type of system from the E.C.O.L. whitefish stocks. Charr migrate annually between two environmental types: freshwater where they overwinter and spawn and the sea where they feed. This is called an ‘open’ system. Fish in the E.C.O.L. lakes occupy a ‘closed’ system. They cannot leave the lakes and all stages of the life cycle are confined to a single environment type. The differences in these two types of systems probably explains some of the differences in the results. For example, the increase in growth observed in the E.C.O.L. study was likely due to an increase in the availability of food for the remaining fish in the stock. Sea-run charr, however, feed in the sea where food is virtually unlimited. There is probably very little competition among individuals for food. Rather, growth is restricted by the amount of time available to feed. Summers are short and the charr must obtain their entire year's energy supply in only 40 or 50 days. Growth is therefore restricted by time not competition so growth rates did not change following exploitation.

APPLICATION OF RESULTS TO THE MACKENZIE DELTA

How can we apply the results from these two studies to the broad whitefish study in the Mackenzie Delta? Results from experimental studies such as these can be used to help predict the probable changes that may occur in other locations and with other species. However, the results cannot be used to quantify these changes in other systems or with other species. In effect, experimental results give some idea of 'what-to-look-for'. For example, as broad whitefish are exploited in the Mackenzie Delta, changes in growth rate should be monitored because it is one of the parameters that is relatively easy to measure. If it does prove to be a good indicator of stock status then monitoring the changes to the stock becomes a relatively easy task. However, broad whitefish in the delta occupy an open system similar to sea-run Arctic charr. If they follow the same pattern as was observed at Nauyuk Lake then changes in growth rates may not be apparent even if the stocks begin to decline. This does not mean that we should not measure growth rates, only that we should be aware that simply because growth rates do not change does not mean that the stocks are healthy. It only means that growth may not be a good indicator to use. What other parameters may be useful to look at? From the Nauyuk Lake example, perhaps an increase in harvest levels would cause a decrease in the age of sexual maturity. Maybe there would be an increase in juvenile survival as was observed during the E.C.O.L. study. The important point to remember is that an increase in harvest levels will cause the stock to respond. If the fishery is to be sustainable then reliable and accurate indicators of state of the stock must be found. If not and if harvest levels are allowed to continually increase then the stock will eventually collapse. The objective of good fishery management is to prevent this collapse.

COMMENTS, QUESTIONS AND ANSWERS

Don Dowler: Your presentations were very good but I still have a bit of a problem, particularly with your experimental cropping of lakes and I'm assuming - you said this was a young fish population? Maybe you could explain how you would apply that to a fishery that's been fished for many, many years. It seems to me there would be a lot of differences. The Mackenzie River, of course, has been fished for many, many years. I'm still not clear how you would apply those kinds of principles to a fishery that's been exploited for many years. It seems to me there would be already changes that happened in that fishery.

Eric Gyselman: That's true. The reason for doing this type of study is not so much to get absolute values. I don't think you could take the values, for example, the actual numbers from a study such as the experimental cropping of lakes program and use those numbers on another system. It does allow us to look at a system and say that these parameters have changed with fishing. In the experimental cropping of lakes program growth was an important parameter. We saw it change. If you can take another system with a similar sort of species and see that growth is changing, then we can use the information from the experimental study to say maybe this change in growth does mean something. I don't think that we can look at any one parameter like growth or fecundity as a measure of the health of the population. I really think you have to look at everything. There is a tendency to perhaps oversimplify and use absolute values. I think that perhaps is a little dangerous in managing a fishery. You think you have to use everything you can.

Don Dowler: Ross, you know if you're going to fish earlier in the life cycle, it seems to me you're going to end up still with the same volume or weight of fish but would they be practical in terms of being marketable.

Ross Tallman: This is a question more for an economist rather than me. What you have to do is look at the amount of value the fish has. If a big fish has a high value, then maybe it's better economically to take less big fish out of the system. Let them grow a little longer and take the bigger fish out because they have a higher value rather than exploiting the stock to the point where you're only getting, say, medium sized fish out of there. That becomes an economic issue more than a biological one. Say you have a lake where one fisherman is fishing so he has control - sort of like a farmer on a farm. It's up to him to decide what he is going to take out of the lake. By fishing with a smaller mesh he may be able to take more fish out of the lake but it may have less economical value.

Jim Reist: Don, I'm going to add a little bit to that. The problem is we really don't know, with the Mackenzie, how intensive the fishing really is. We don't really have a very good idea of how many fish are out there, that is, what the abundance is. If the fishing is very, very, very intensive the effects of fishing can be to make the average size of the population smaller over the long term. And a really good example of this is Pacific Salmon. There are cases and documented evidence for some species of Pacific Salmon that 50 years ago were almost twice the average length that they are today and the only causative factor that people can agree on is the intensive amount of fishing that went on. So, the bottom line is that people do have an effect on fish populations. We have to be careful and try to minimize those effects as far as possible.

Don Dowler: All other land animal forms like humans and other types of animals is that they may have different characteristics for the length of carrying their babies or the rate might be slower than whatever. You take a look at the elephants, you know, that's a different story altogether. So there is the possibility that you're not really giving us a true picture. The recovery of the broad whitefish might be a lot quicker than land-locked chars are.

Eric Gyselman: That wasn't really the point of my talk. My point was only to say that different types of fish in different situations behave quite differently. So, we can't take a specific example from here and say this is going to behave exactly the same as that one did. Just as a point of interest, at the Nauyuk Lake study where we had a sea run char population, we also had a number of small lakes around there that had Arctic char in them that couldn't get to sea. They were lake forms. They behaved very much like the whitefish in the experimental cropping of lakes experiment did. So, it looks like in isolated lakes to some extent it doesn't matter. The two species that we looked at in small, isolated lakes behaved quite similarly, whereas the sea run form behaves quite differently from the fish that are only a half mile away and probably came from the same original genetic stock. They have developed these different ways of dealing with different types of environments.

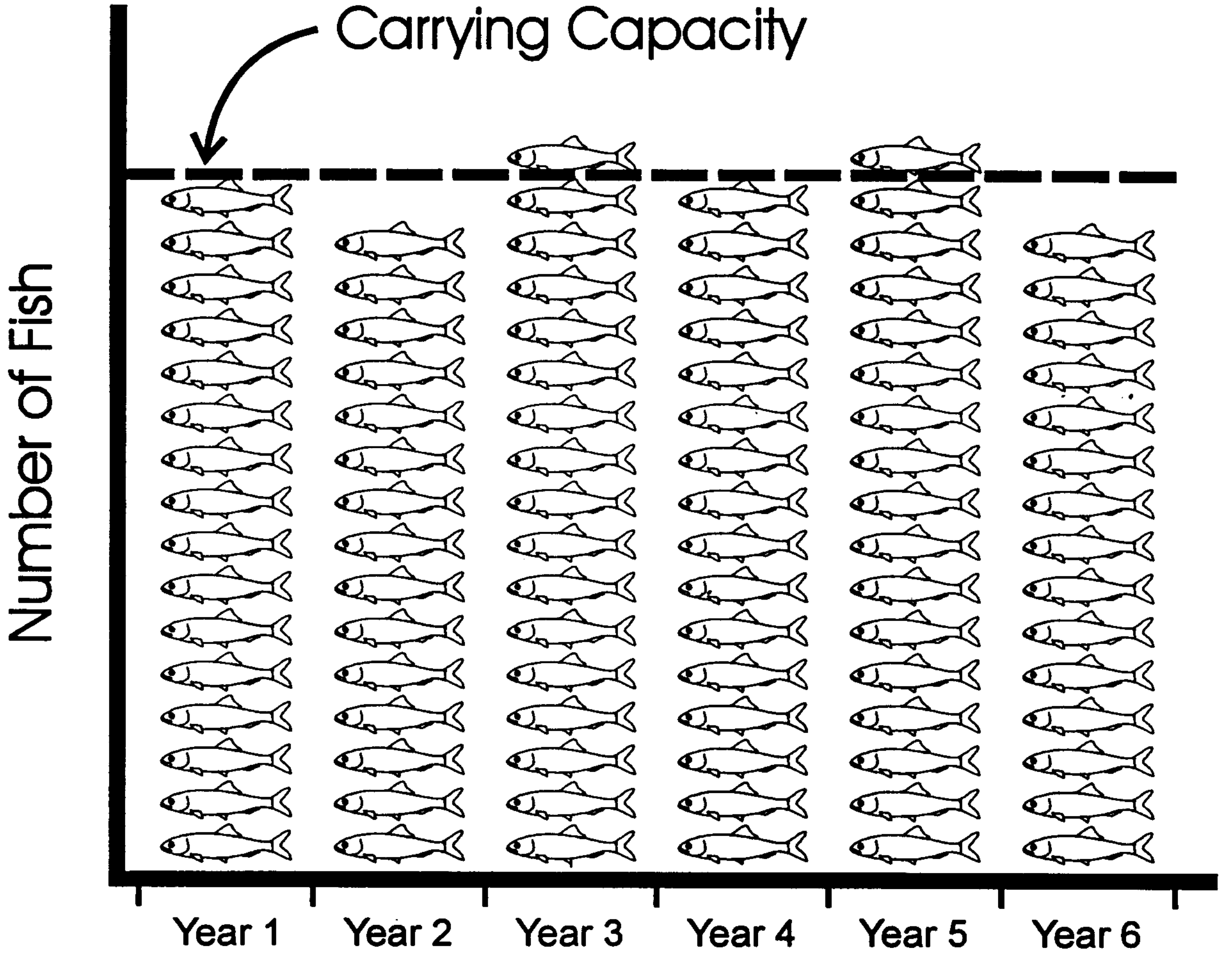

Figure 1. An unexploited fish stock.

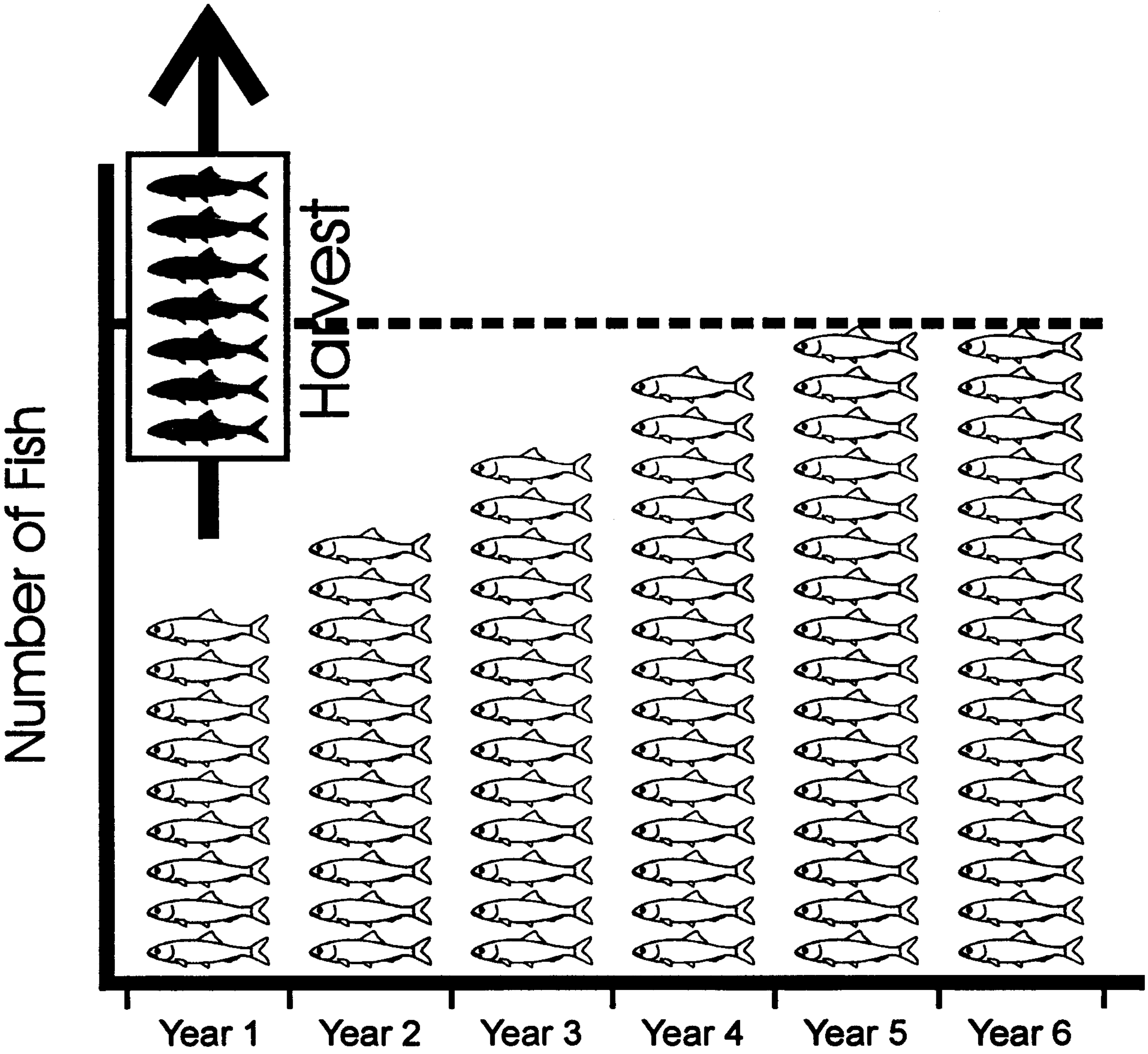

Figure 2. The effect of a single harvest on a fish stock.

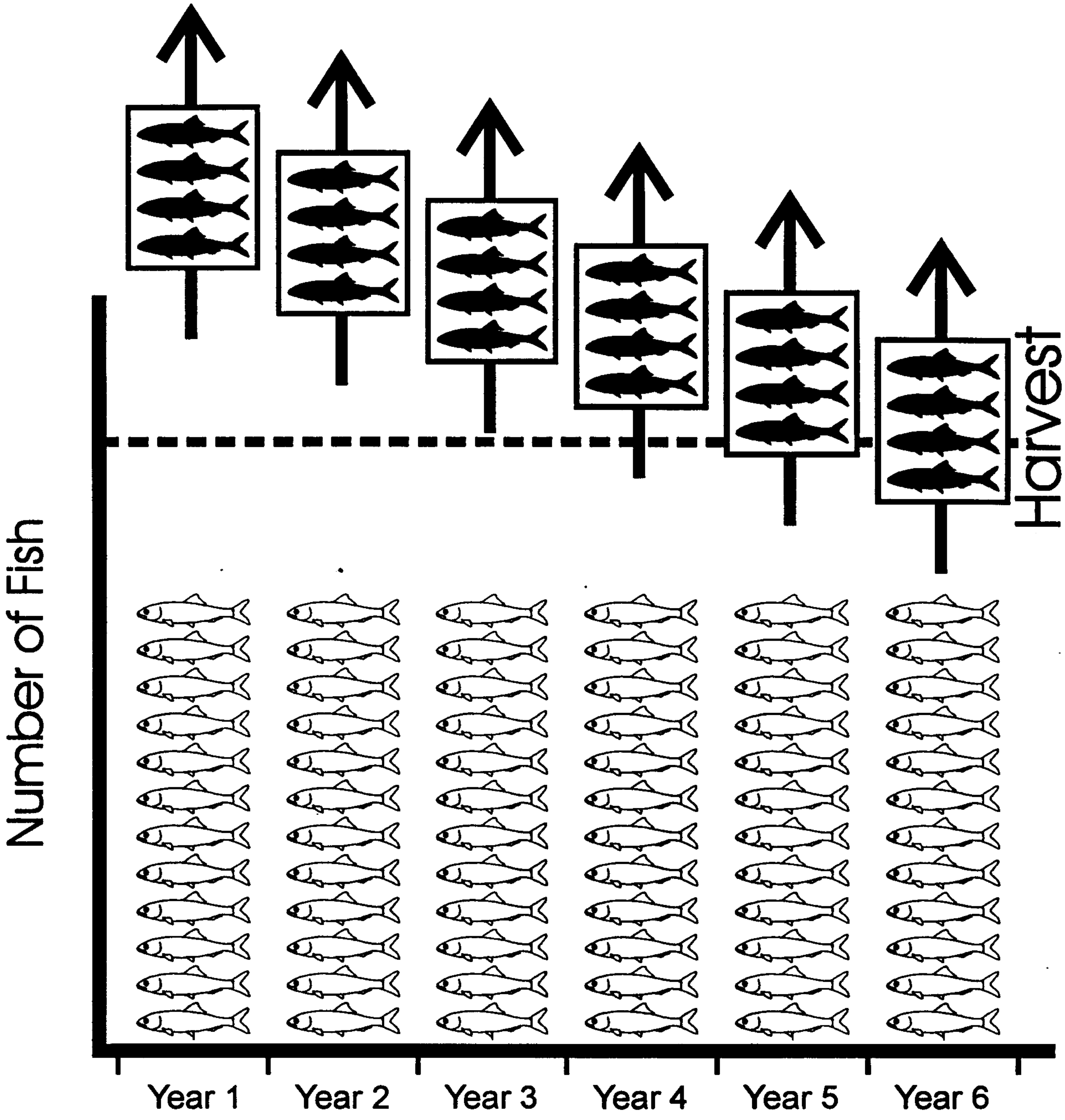

Figure 3. A fish stock harvested at an optimal rate.

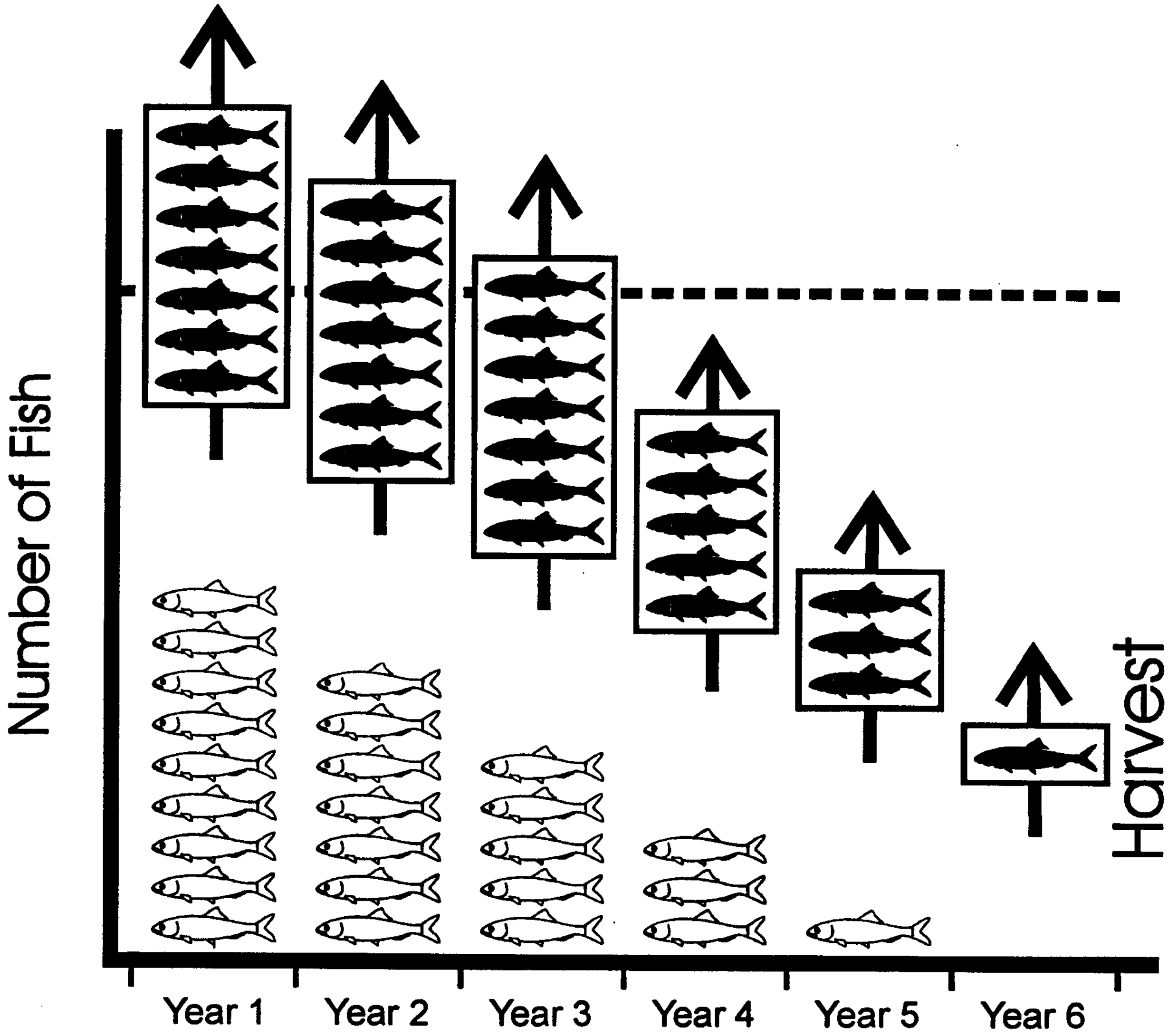

Figure 4. An over-harvested fish stock.

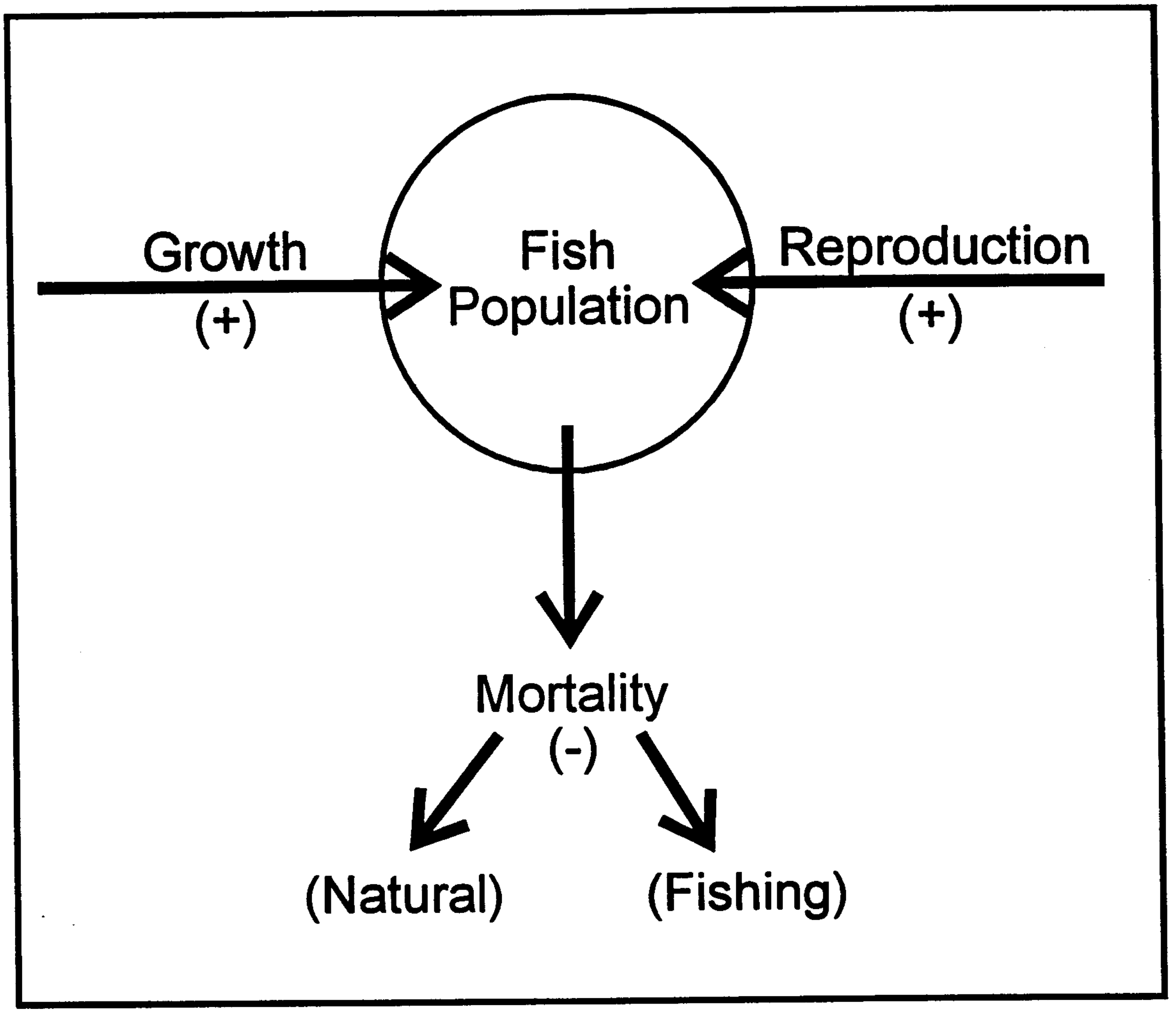

Figure 5. Controls of fish populations.

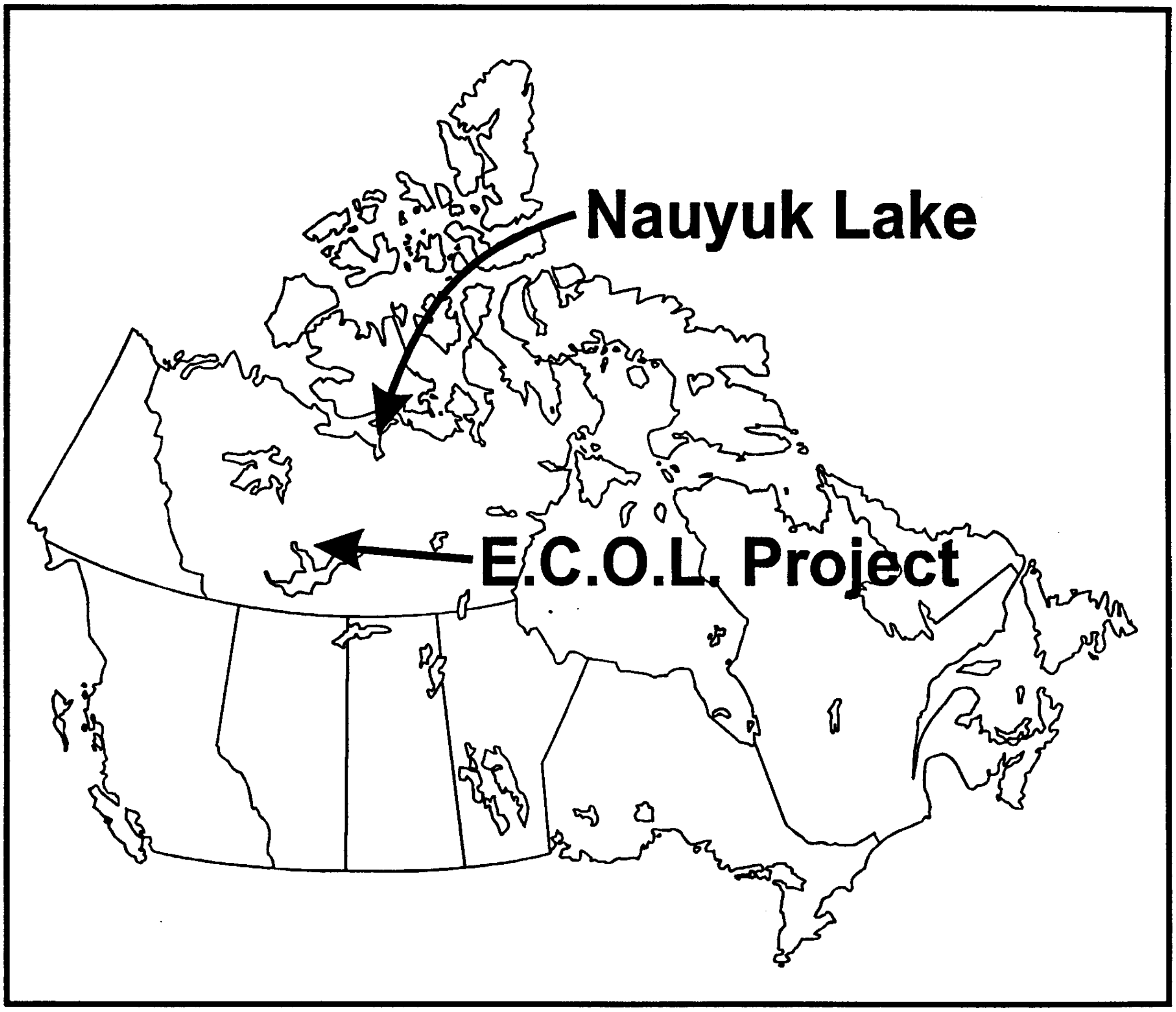

Figure 6. Location of E.C.O.L. and Nauyuk Lake study sites.

PARASITES OF THE BROAD WHITEFISH FROM THE MACKENZIE DELTA

by

Anindo Choudhury and Terry A. Dick

ABSTRACT

A survey of the parasites of broad whitefish in the lower Mackenzie River was conducted. A total of 18 parasite species belonging to 17 genera were recorded which represents the first comprehensive listing of parasites for this species in North America. The parasite fauna is dominated by freshwater species, particularly endohelminths. Plerocercoids of *Diphyllobothrium,* a parasite possibly infective to humans, were recovered. The utility of parasites for stock discrimination remains uncertain at the present. [Abstract composed by editor]

OBJECTIVES

The objectives of the study were to determine: 1) the parasite species present in broad whitefish, 2) if certain species of parasites could be used as biological tags to identify distinct populations of fish, and 3) if there were any parasites of economic importance or infective to humans.

BACKGROUND

The broad whitefish, *Coregonus nasus* (Osteichthyes: Salmonidae) is an estuarine/ freshwater species distributed in the arctic drainages (rivers and lakes) of Siberia and western North America. Knowledge of the biology of this species is obscure. While its freshwater distribution has been extensively documented, less is known about populations with anadromous habits and there is speculation about the presence of distinct anadromous, riverine and lacustrine populations. However, lack of biological information makes population discrimination difficult and inconclusive. The usefulness of parasites as biological tags is well established but there were no published reports of parasites of broad whitefish from North American waters.

MATERIALS AND METHODS

The major portion of this study was directed at 236 fish collected as part of the overall broad whitefish project from various sites of the Mackenzie River drainage system (Table 1). Of these, 151 were necropsied whole and a total of 236 were examined for *Triaenophorus crassus*. In addition, necropsies were carried out initially on fish (N = 36) obtained from samples previously inventoried and held at the Freshwater Institute of the DFO, Winnipeg (provided by Dr. J. Reist). These included samples from the following locations: Anderson River, Peel River, Kukjuktuk Creek, Freshwater Creek, Canyanek Creek, Travaillant Lake and Wood Bay. Results of the necropsies are reported as mean intensities (mean number of parasites in infected fish) ±S.D. along with ranges and prevalences (reported as percentages). Parasites were recovered through standard necropsy techniques, fixed in AFA (Alcohol: Formalin: Acetic acid) (monogeneans, digeneans, cestodes, acanthocepahalans and leeches) or 70% ethanol (nematodes and crustaceans). Identifications were carried out with reference to keys, and comparisons with original descriptions.

RESULTS AND DISCUSSION

OBJECTIVE 1

A total of 18 species of parasites belonging to 17 genera were recovered from necropsied broad whitefish, all of which are new records in North America. Data from the hosts and the parasites in Tables 1-5 comprise the first comprehensive dataset for broad whitefish in North America. This includes data from 151 full necropsies, and from a total of 236 fish necropsied for *Triaenophorus crassus*, the commercially important tapeworm larva parasitizing coregonids. The parasites are identified to genera in Tables 1-3. In addition to data from the Mackenzie delta, data from other arctic waterways are also presented (Table 3). Table 3 includes the cestode *Diplocotyle* (*olrikii*) and a Gyrodactylidae, all of which were found in samples previously necropsied and outside the Mackenzie River study area. A synopsis of the distribution and biology of broad whitefish parasites recovered in this study is given in Tables 4 and 5.

Based on the fish provided, the parasite fauna is dominated by freshwater species, particularly by endohelminths utilizing benthic invertebrates as intermediate hosts (*Ascarophis*, *Crepidostomum*, *Cystidicola*, Cyathocephalidae, *Raphidascaris,* etc.) and parasite community richness is greater in lake samples than in those of rivers. Furthermore, there is high qualitative faunal similarity in the endohelminth composition among fish from different sampling sites, indicating a conserved benthic feeding habit. No encysted marine parasites were found in fish from the Mackenzie River system. Some interesting trends are shown from the different sampling sites (Table 2, Fig. 1). The prevalences of *Proteocephalus* sp. showed little variation in contrast to cyathocephalid cestodes which were present predominantly in broad whitefish from the lakes (Campbell L. and YaYa L.), while infections with *Raphidascaris* were higher in fish from Aklavik, Pete's Creek and Fort Good Hope. Infections with *Triaenophorus* were higher in lake fish than in the river samples. Larval parasites of the genus *Diphyllobothrium* sp. were also recovered; *D. ditremum* which are parasites of fish eating birds and *D. dendriticum* which normally infects fish eating birds but can also infect humans. The composition of *Diphyllobothrium* species in the holarctic region is complicated by the potential presence of species maturing in marine mammals in addition to species in fish eating birds and terrestrial fish eating mammals such as canids and bears. More work needs to be done on *Diphyllobothrium* concerning its diagnostics, given its holarctic distribution in various definitive and intermediate fish hosts.

OBJECTIVE 2

It is well established that anadromous fish lose their marine gut parasites (if present) as they move into freshwater environments. In contrast, marine parasites in the body cavity, particularly larval stages (of Corynosomatidae, anisakid nematodes, etc.), are perhaps more suitable biological tags and are likely to occur as a result of inhabiting and feeding in estuarine/marine environments. No such parasites were found in fish from the Mackenzie River system. The cystidicolids recovered from the muscular stomachs of broad whitefish from Aklavik, Campbell L. and YaYa L. have been tentatively placed in the genus *Ascarophis* which they resemble closely. *Ascarophis* spp. are typically parasites of marine and estuarine fishes and the parasite merits closer attention. A more thorough investigation into its morphology will be carried out to allow a better assessment of its value in indicating population differences. It would be interesting to compare parasites of broad whitefish from the outer delta with the more inland samples used in this study. While it is still early to make a definitive comment, it is possible that the parasites will show a trend allowing discrimination between lacustrine and riverine populations; accumulation of parasites utilizing a more planktonic transmission (*Triaenophorus*, *Diphyllobothrium*) in lakes and higher intensities of infection with parasites transmitted through benthic insects (*Crepidostomum*, *Raphidascaris*) in riverine environments.

OBJECTIVE 3

Plerocercoids of *Diphyllobothrium* sp. were recovered. These resemble *D. ditremum* and one specimen resembles *D. dendriticum*. These two species of *Diphyllobothrium* commonly mature in fish eating birds which acquire the infection by ingesting fish infected with the larval parasites which are found encapsulated in the viscera of their fish host. However, *D. dendriticum* is also infective to humans. Considerable more work needs to be done on *Diphyllobothrium* concerning its distribution geographically and within the fish host.

COMMENTS

As samples collected from broad whitefish project were restricted to the maturing and older age classes, the parasite information is not reflective of the entire population, nor of the parasite transmission dynamics. This is particularly important for *Triaenophorus* since this study, for the first time, found that broad whitefish are a suitable intermediate host. This could have serious implications for an intensive broad whitefish fishery since it is well documented that most exploited coregonid fisheries in North America have seen an increase in parasite levels and a decline in the value of the fishery. If the current fishery is based on the fast growing component of the broad whitefish population the problem with *Triaenophorus* will likely intensify with time. It will be necessary to study samples from the outer Mackenzie River delta and the Tuktoyaktuk Peninsula before any definitive statement can be made on the use of parasites for discrimination among lacustrine, riverine, and anadromous populations.

CONCLUSIONS

1. A total of 18 species of parasites were recovered from the Mackenzie River system.

2. All parasites are new records for North American broad whitefish.

3. The parasite community is predominantly freshwater and benthic transmitted with a planktonic component (copepod transmitted cestodes).

4. The presence of the nematode, *Ascarophis* sp. may indicate estuarine feeding, and has potential as a biological tag.

5. Immature *Proteocephalus* sp. found in maturing fish (stage ii & vii; Aklavik, Horseshoe bend, Peel River, Fort Good Hope) indicate late recruitment and feeding on copepods immediately prior to final spawning run.

6. Two parasites of economical and medical importance were identified: *Triaenophorus crassus* and *Diphyllobothrium* spp.

7. Parasites of broad whitefish are most similar to those of lake whitefish (other studies) but with lower levels of *Triaenophorus* in the former, indicating similar feeding habits

COMMENTS, QUESTIONS AND ANSWERS

Don Dowler:	Just a comment. Up here around the Beaufort area the people eat muktuk for vitamin C. Down south when I was growing up we ate whitefish with *Trianophorus* worm in it for the extra calcium.
R. Tallman	I'm really glad I went to the feast last night, Terry, after seeing your talk, but I'm wondering about a couple of things. Would getting into or close to the salt water system have an effect on parasites.
Terry Dick:	I did a study years ago on Arctic char. We actually put Arctic char into cages in the marine system and we did get some purging of freshwater parasites such as

Diphyllobothrium. It's probably because the char were drinking the salt water. It works the other way too, going from saltwater to freshwater. You've got to be careful if you're looking for a biological tag. It could be short-term which is just as important as long-term depending what your management strategy is. But, you're right. Environmental changes can affect the parasite distribution. Plus it also affects recruitment.

R. Tallman: The other thing I was wondering and you didn't comment on it here too much, but I wonder if what you think the potential is for using some of this information in a mixed-stock fishery analysis.

T. Dick : I'm not sure, but we have only one parasite which would be useful. So, I think it's of limited value. But it might be very important if you can dovetail it with some of Jim's stuff. There were a lot of fish with none and a few with lots of parasites. That's what we call the negative binomial. It means that in a population a lot of fish will have no parasites and a few fish will have a lot. So that's part of the equation too.

Jim Reist: I've got two comments, Terry. First of all, the one parasite that you didn't see in your study that we know exists is the marine parasite that we found on the external part of the fish, and there's actually a picture of it on the scarring paper that's over on the side. So, from that perspective, we do know that in broad whitefish, at least some portion of the population enters the marine environment enough, at least, into saltwater to gather the marine parasites.

Terry Dick: Let me answer that. It's amazing that we've looked at a lot of fish. It must be a very rare event.

Jim Reist: It's not that often, I agree. The other comment, I guess, is partly related to that but it's partly related to the food aspect your comments that the fish are feeding in the river. Remember that the Mackenzie plume goes so far out into the Beaufort Sea and that whole near shore area, although on the map it looks marine, essentially is fresh water because of the size and the volume of water put out by the Mackenzie, and it's that area we believe the whitefish use, especially the adults. That's their primary feeding area, and it's not surprising that it's a freshwater type feeding area.

Terry Dick: But what we're finding is that no matter where we are or where the broad whitefish are in the Mackenzie they have very immature *Protocephalius,* it's that little one I showed you before. That means that they have been picking it up almost in the local vicinity [where they were caught] to be that small. So they definitely have to be feeding [in freshwater]. That's why I'm so convinced that they're doing a fair amount of feeding in the river system. Granted, it has nothing to do with the total growth of those fish because we don't know what they are doing, whether they're in Tuktoyaktuk or what but we do know that those big fish are feeding and probably getting some growth out of the food.

J. Reist: I agree. The whole aspect of feeding, what broad whitefish feed on and where they gather much of that food is just simply unknown right now.

B. Day: Terry, speaking about feeding, a lot of people eat dried fish or smoked fish. I was just wondering how those two processes would affect the tapeworm, the *Diphylloothrium* that you were talking about? What kind of health hazard might that pose?

T. Dick: Well, it doesn't here. There aren't enough *Diphyllobothrium* They are rare. I would say it's not a problem. Years ago I worked on *Triconella*. That's the one that goes into polar bears and dogs up in the Arctic here. We thought that you could kill it by freezing for about 20 days at –20 (C) for about two weeks which was what the Public Health regulations were. I started working on Arctic isolates of *Triconella* in polar bears from Baffin Island, and from all over the Arctic. What I found was that the thing would freeze for 2 years and still be infective. So you have to be careful. There is one study that's not well documented on *Diphyllobothrium,* the human tape worm (I think it was the Norwegians) that showed you could freeze that parasite down in flesh and it was still viable, and infective. It's not well documented - only one study. The drying down, I think that with *Diphyllobothrium* will kill it. But drying down *Triconella* won't kill it because it's just like freeze drying. And, in fact, there are many stories of trappers who have taken diaphragms of animals and stuck them on the wall of their cabin and got hungry later in the season and had to eat it. Of course, the diaphragm is very heavy with *Triconella*. This was just dried, the diaphragm, the muscle that's in the body cavity and they got *Trichinosis*. So, there's documented cases. I would be a little careful but I think drying down *Diphyllobothrium* in fish will kill it but it will not with *Triconella.*

Question: How does freezing affect the *Triaenophoris*?

T. Dick: It kills them and, in fact, *Triaenophoris* doesn't affect humans.

Table 1. Host statistics for necropsied broad whitefish from the Mackenzie River system.

Statistic	Geographical Location						
	Aklavik (N=30)	YaYa L. (N=31)	Campbell L. (N=27)	Ft Good Hope (N=30)	Horseshoe B (N=6)	Peel R. (N=20)	Pete's Cr (N=23)
Length (mm)	469.6 ± 35.2 (387-559)	432.4 ± 45.3 (330-512)	425.7 ± 66 (275-518)	488.1 ± 27.2 (425-549)	477.3 ± 32.6 (420-590)	477.7 ± 34.8 (415-555)	464.9 ± 32.3 (391-515)
Weight (g)	1821 ± 417 (864-2668)	1208 ± 364 (519-1945)	1319 ± 624 (265-2902)	1945 ± 337 (1464-2916)	1899 ± 424 (1353-3365)	1965 ± 499 (1023-3275)	1578 ± 324.5 (893-2282)
Age (yr)	11.4 ± 3.3 (5-21)	10.2 ± 3.9 (5-17)	7.38 ± 3.6 (3-15)	11.17 ± 3.8 (6-21)	12.8 ± 4.9 (5-24)	9.8 ± 4.0 (5-20)	12.7 ± 4.7 (4-22)
Sex	11 F 19 M	21 F 10 M	12 F 15 M	12 F 28 M	22 F 28 M	14 F 6 M	18 F 5 M

Table 2. Mean intensity ±S.D., (range) and (prevalences) of parasites of broad whitefish from the Mackenzie River system.

Parasite	Geographical Location						
	Aklavik (N=10)*	YaYa L. (N=31)	Campbell L. (N=27)	Ft Good Hope (N=30)	Horseshoe Bend (N=6)	Peel R. (N=20)	Pete's Cr (N=23)
Crustacea							
Salmincola (2 spp.)	6 ± 2.8 (N=30) (4-8)(6.7)	1 (1)(6.4)	0	1 (10) (1)	1 (N=50) (1)(4)	1 (N=30) (1)(6.6)	1(N=23) (1)(4.3)
Monogenea							
Discocotyle sagittata	8.2 ± 6.8 (1-16)(50)	5.8 ± 7.5 (1-32)(51.6)	3.6 ± 2.6 (1-10)(51.8)	5.3 ± 6.1 (1-24)(46.7)	11 ± 1.4 (10-12)(33.3)	4 ± 3.4 (1-13)(55)	5.6 ± 6 (1-21)(77.2)
Tetraonchus sp.	6 (10) 60	0	0	1.5 ± 0.7 (1-2)(6.7)	1 (1)(16.6)	0	0
Trematoda							
Crepidostomum farionis	7.7 ± 5.8 (1-17)(80)	4 ± 3.6 (1-10)(22.6)	27 ± 48.4 (1-185)(51.8)	9.9 ± 17.9 (1-76)(70)	11.4 ± 10.8 (1-24)(83.3)	11.5 ± 15 (1-42)(40)	51.3 ± 77.1 (1-293)(68.2)
Diplostomum sp.(m)	37 ± 39.5 (15-124)(70)	40.5 ± 54.7 (1-176)(80.6)	15.2 ± 26.61 (2-89)(37)	43.2 ± 53.8 (2-231)(86.7)	17.5 ± 23.3 (1-34)(33.3)	66.1 ± 150 (1-509)(55)	103.6 ± 134.1 (6-505)(86.4)
Cestoda							
Cyathocephalus truncatus	0	7 ± 9 (1-31)(32.2)	5 ± 4.2 0 (2-8)(7.4)	0	0	1.5 ± 0.7 (1-2)(10)	0
Diphyllobothrium sp.(p)	0	14 ± 18.4 (1-27)(6.4)	0	2 (2)(3.3)	0	0	0
Triaenophorus crassus(p)	1.7 ± 0.6(N=30) (1-2) (10)	1.7 ± 1.1 (1-3) (9.7)	1.25 ± 0.5 (1-2) (14.8)	0	1.33± 0.6(N=50) (1-2) (6)	3.5 ± 3.5(N=30) (1-6)(6.6)	1 (N=23) (1)(8.7)
Proteocephalus (p)	57.7 ± 69.3 (2-186)(60)	4.7 ± 1.1 (4-6)(9.7)	3 ± 2.3 (1-7)(18.5)	8.9 ± 12.6 (1-49)(46.6)	24.7 ± 17 (12-44)(50)	8.2 ± 7.8 (1-19)(40)	5.4 ± 5.4 (1-18)(36.4)
Nematoda							
Ascarophis sp.	2 (10) 2	12.8 ± 25.8 (1-78)(29)	4.3 ± 0.6 (4-5)(11.1)	0	42 ± 50.91 (6-78)(33.3)	16 ± 19.8 (2-30)(10)	0
Cystidicola farionis	0	0	4.2 ± 2.9 (1-7)(22.2)	0	1 (1)(33.3)	0	0
Raphidascaris (l)	15 ± 15.5 (2-48)(80)	3.4 ± 2.9 (1-10)(38.7)	12.4 ± 21.2 (1-70)(37)	86.1 ± 222.4 (1-1001)(73.3)	48.4 ± 33.3 (5-98)(83.3)	160.9 ± 302.2 (2-894)(40)	22.5 ± 33.9 (2-118)(68.2)
Acanthocephala							
Echinorhynchus salmonis	4 ± 4.2 (1-7)(20)	13.4 ± 22.3 (1-62)(22.6)	0	5.8 ± 5.9 (1-21)(33.3)	12 (12)(16.6)	5 ± 1 (4-6)(15)	1 (1)(18.2)
Neoechinorhynchus spp.	0	4 ± 4.2 (1-7)(6.4)	0	1 (3.3) 1	4.33 ± 5.8 (1-11)(15)	0	1 (1)(4.5)
Hirudinea							
Piscicolidae	0	2 (2) (3.2)	0	0	0	0	0
Mollusca							
Glochidia	1 (10) 10	0	0	0	0	0	

* 'N' numbers below geographical locations refer to total necropsies. p = plerocercoid.
Arctic Red River: (N=11) Triaenophorus(p): 2 ± 1.4 (1-3)(18.2) Campbell Cr: (N=4) Crepidostomum: 3 (3)(50)

Table 3. Parasites[1] (to genus only) of broad whitefish from the coastal Arctic waterways.

Parasite	Geographical Location					
	Anderson R (N=2)	Canyanek L (N=5)	Freshwater Cr (N=6)	Kukjutuk (N=7)	Peel R. (N=7)	Wood Bay
Crustacea:						
Salmincola sp.	0	1 (1)(20)	1 (1)(50)	0	0	0
Monogenea:						
Discocotyle sp.	0	2 (2)(20)	0	0	6.6 ± 4.0 (1-10)(71.1)	8 (1)(8.3)
Tetraonchus sp.	1 (1)(50)	0	0	0	0	0
Trematoda:						
Crepidostomum sp.	0	50 (50)(20)	0	30 (30)(14.3)	8.67 ± 12.4 (1-23)(42.8)	0
Diplostomum sp.	504 (504)(50)	44.6 ± 28.1 (8-84)(20)	13.6 ± 12.9 (4-34)(83.3)	0	0	67.14 ± 164.9 (1-441)(58.3)
Cestoda:						
Diplocotyle sp.	0	1? (1)(20)	3.3? ± 2.1 (1-5)(50)	1.2 ± 0.5 (1-2)(57.1)	0	1 (1)(8.3)
Cyathocephalus sp.	0	0	0	0	0	0
Diphyllobothrium sp.	0	0	0	0	0	1 (1)(8.3)
Triaenophorus sp.	0	1 (1)(20)	0	0	0	0
Proteocephalus sp.	0	0	0	0	1 (1)(28.6)	0
Nematoda:						
Cystidicola sp.	0	0	0	0	0	3 ± 1.4 (2-4)(16.6)
Raphidascaris sp.	0	0	0	0	54.9 ± 85.8 (3-237)(100)	0
Acanthocephala						
Echinorhynchus	3 ± 2.8 (1-5)(100)	4 ± 4.2 (1-7)(40)	5 ± 6.1 (1-12)(50)	2.7 ± 2.1 (1-5)(42.8)	0	p
Neoechinorhynchus	0	0	3.7 ± 1.1 (3-5)(50)	1.5 ± 0.7 (1-2)(28.6)	0	p

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[1] Mean intensity ±S.D. (range)(prevalence).

Table 4. Parasites from broad whitefish from the Mackenzie River system and their biology.

Parasite	Site	Distribution	Transmission	Definitive host	Freshwater/Marine
Crustacea:					
Salmincola corpulentus	Gill chamb.	Holarctic	Direct	Coregonids	FW
S. extensus	Skin	Holarctic	Direct	Coregonids	FW
Monogenea:					
Discocotyle sagittata	Gills	Holarctic	Direct	Coregonids	FW
Tetraonchus sp.					
Digenea:					
Crepidostomum farionis	Intestine	Holarctic	clam-mayfly/amphipod	Salmoniforms	FW
Diplostomum sp.	Eyes	Holarctic	clam-fish-bird	Gulls, etc.	FW
Cestoda:					
Cyathocephalus truncatus	Caecal gut	Holarctic	gammarids	Salmoniforms	FW
Diphyllobothrium (p)					
(D. ditremum)	Viscera	Holarctic	copepod-fish-bird	Salmoniforms	FW
(D. dendriticum)	Viscera	Holarctic	copepod-fish-bird	Salmoniforms	FW
Triaenophorus crassus (p)	Muscle	Holarctic	copepod-fish-pike	Esocids	FW
Proteocephalus(p)	Intestine	Holarctic	copepod-fish	Salmoniforms	FW
Nematoda:					
Ascarophis sp.	Stomach	Holarctic	benthic crustacean?	Salmoniforms	E/M
Cystidicola farionis	Swim bladder	Holarctic	amphipod	Salmoniforms	FW
Raphidascaris acus	Viscera	Holarctic	chironomids-fish -pike	Esocids	FW
Acanthocephala:					
Echinorhynchus salmonis	Intestine	Holarctic	amphipods	Salmoniforms	FW
Neoechinorhynchus tumidus	Intestine	Holarctic	amphipod/isopod	Salmoniforms etc.	FW
N. venustus	Intestine	Holarctic	amphipod/isopod	Salmoniforms etc.	FW

Table 5. Parasites from broad whitefish from the Mackenzie River system: distribution and biology.

Parasite	Site	Distribution	Transmission	Definitive host	Freshwater/Marine
Crustacea:					
Salmincola spp.	Gill chamb. Skin	AK,YY,FGH,HSB,PR,PCR	Direct	Coregonids	FW
Monogenea:					
Discocotyle sagittata	Gills	ALL	Direct	Coregonids	FW
Tetraonchus	Gills	AK,FGH,HSB	Direct		
Digenea					
Brachyphallus	Intestine	AK	Copepod	Marine fish	M
Crepidostomum farionis	Intestine	ALL	clam-mayfly/amphipod	Salmoniforms	FW
Diplostomum sp.	Eyes	ALL	clam-fish-bird	Gulls, etc.	FW
Cestoda:					
Cyathocephalus truncatus	Caecae	YYL, CL, PR	gammarids	Salmoniforms	FW
Diphyllobothrium(p)	Viscera	YYL, CL	copepod-fish-bird	Salmoniforms	FW
Triaenophorus crassus (p)	Muscle	AK,YY,CL,HSB,PR,PCR	copepod-fish-pike	Esocids	FW
Proteocephalus(p)	Intestine	ALL	copepod-fish	Salmoniforms	FW
Nematoda:					
Ascarophis sp.(?)	Stomach	AK,YYL,CL,HSB,PR,	benthic crustacean?	Salmoniforms	E/M
Cystidicola farionis	Swim bladder	CL,HSB,	amphipod	Salmoniforms	FW
Raphidascaris acus	Viscera	ALL	chironomids-fish-pike	Esocids	FW
Acanthocephala:					
Echinorhynchus salmonis	Intestine	AK,YYL,FGH,HSB,PR,PCR	amphipods	Salmoniforms	FW
Neoechinorhynchus sp.	Intestine	YYL,FGH,HSB,PCR	amphipod/isopod	Salmoniforms etc.	FW
Hirudinea:					
Piscicolidae	Skin	YYL	Direct	Fish	FW
Mollusca					
Glochidia	Gills	AK	Direct	Fish	FW

ALL= All locations, AK= Aklavik, YYL= YaYa L., CL= Campbell L., FGH= Fort Good Hope, HSB= Horseshoe Bend, PR= Peel R., PCR= Pete's Creek

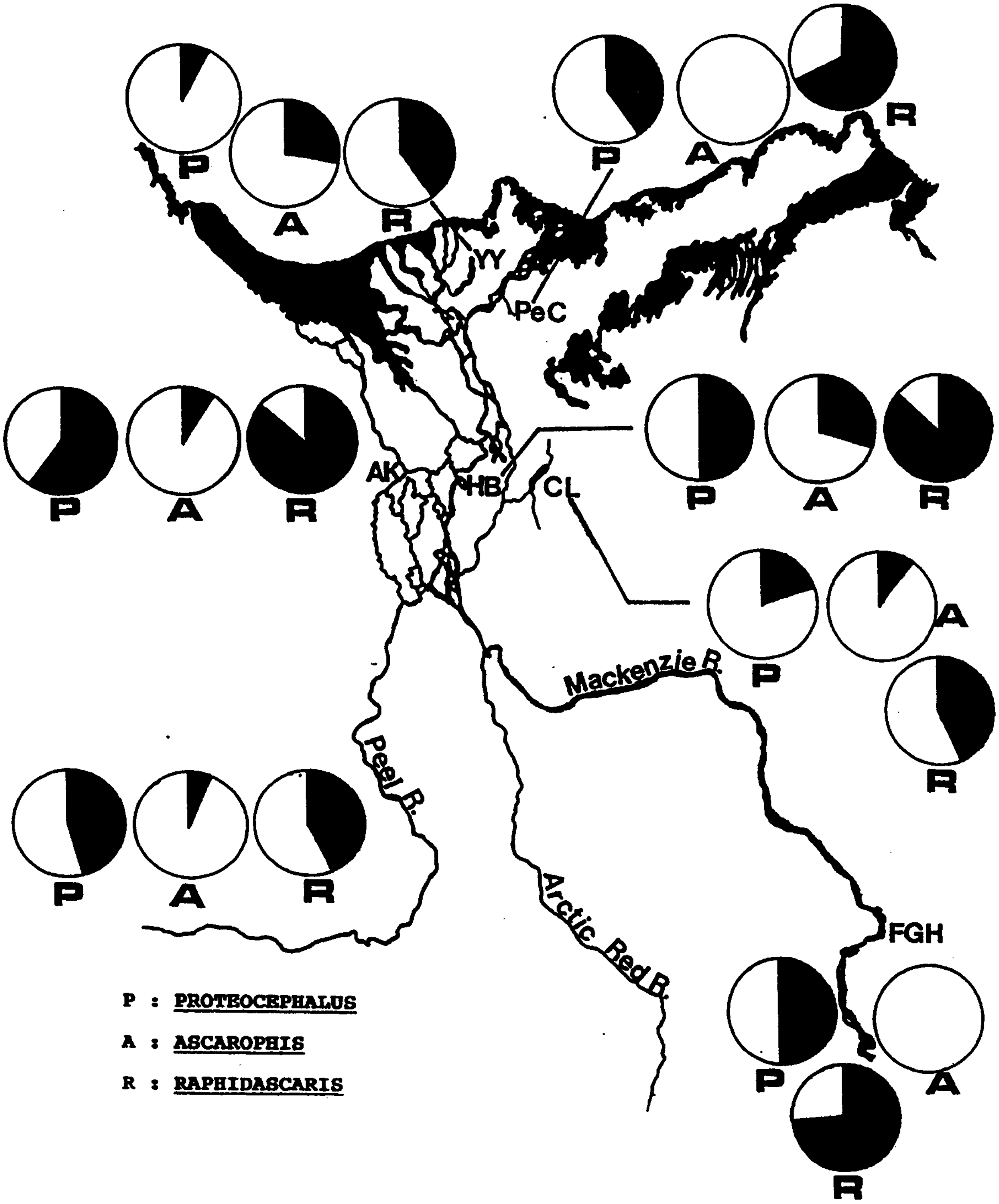

Figure 1. Proportion of broad whitefish infected with three species of gut helminth parasites from six locations of the MacKenzie River system. YY = YaYa Lake, PeC = Pete's Creek, AK = Aklavik, HB = Horseshoe bend, CL = Campbell Lake, FGH = Fort Good Hope.

Potential Cumulative Effects of Human Activities on Broad Whitefish Populations in the Lower Mackenzie River Basin

by

James D. Reist

ABSTRACT

The cumulative effects of human activities on aquatic ecosystems are now recognized as being important. This paper examines the concept of cumulative effects and applies this to the broad whitefish of the lower Mackenzie River Basin. Five general types of impacts may affect broad whitefish - exploitation, physical injury, contaminants, local habitat alteration, and global environmental change. These impacts result in effects at three levels: 1) the individual fish, 2) the biological population, and 3) the aquatic ecosystem. A specific impact may occur once or several times at each of these levels - for example, one fish population may be fished only once and another may be fished several times during migrations. Several different types of impacts may also affect the same population - for example, contaminants and local environmental change may both cause the fish to expend energy to overcome their effects thus decreasing growth and reproductive rates. The combination of several events of the same type of impact, several different types of impact, or a mixture of both may result in two different classes of effects on individuals, populations or ecosystems. First, the effects may be additive, that is, the net result of more than one impact is the addition of all the individual effects. Secondly, effects may also be multiplicative, that is, the net result of more than one impact is greater than the sum of the effects of all individual impacts. It is possible that multiple impacts on broad whitefish generate both additive and multiplicative cumulative effects. Evidence demonstrating these effects on broad whitefish is limited, however, cumulative effects have been shown to be factors which have contributed to the demise of fish populations in lower latitudes. Conservative approaches to fisheries management, research into effects of human activities on the fish populations, and the establishment of effective monitoring programs are suggested as the appropriate strategies to assess cumulative impacts and help ensure the continued health of broad whitefish populations in the lower Mackenzie River.

INTRODUCTION

The activities of human beings affect natural populations of organisms and their ecosystems in certain ways. The observable change resulting from an activity can be termed an **effect** on the population. All effects have an underlying cause, and all effects may result in changes in the natural population. For example, a fisherman sets nets to capture fish. The effect of his activity is to remove fish from that particular fish population. The removal of the fish from the population results in a change in the number of fish in the population and may also result in altered age or size distributions in the population. Usually such changes are small, and have little lasting impact on the population. This is especially true if the number of fish removed over a certain time is equal to or lower than the number that enter the fish population over the same time. The above effect of fishing can be termed a **simple effect** - that is, one cause (the fishing activity) leads to one effect (a change in abundance of the fish). However, if several fisherman are all fishing near to one another at the same time, we have several individual impacts. If all are fishing the same population of fish, these individual simple impacts combine into a **cumulative effect** on that fish population. Cumulative effects may also result from two (or more) different kinds of simple effects. For example, fishing may impact a particular population, and this same population may also experience changes in its habitat such as increased siltation of the spawning beds that results from river dredging upstream. Because the simple effects group together, there is a greater possibility that they will exceed the ability of the fish population to compensate. In this case, some negative result such as the decline of the population may occur.

Typically, fishery managers tend to focus upon well-defined human activities such as fishing and their simple effects on fish populations and manage only those. Thus, little attention is paid to more complex cumulative effects, despite the fact these may overall pose greater threats to the well-being of the populations. A more extensive and overall focus to fishery management is necessary. This paper is intended to provide the overall concepts necessary for addressing possible cumulative effects upon broad whitefish of the lower Mackenzie River Basin.

The concept of cumulative effects was originally developed for application at the ecosystem level (e.g., Bunch and Reeves 1992; Peterson et al. 1987). However, this concept also has applicability at the level of individual fish and biological populations. This paper addresses potential cumulative effects on broad whitefish but the concepts are applicable to most arctic fish species. The aims of this presentation are to: a) define cumulative effects and show how they may result from various types of impacts; b) define the various levels at which cumulative effects may occur and what the results of those effects can be on fish populations and the ecosystems in which they occur; c) list the potential sources of cumulative effects on broad whitefish populations and aquatic ecosystems of the lower Mackenzie River; and, d) suggest some possible approaches for monitoring and dealing with such effects to ensure the integrity of the fish populations and their ecosystem is maintained.

CUMULATIVE EFFECTS

DEFINITION OF CUMULATIVE EFFECT

Cumulative effects may occur in any one of three situations. 1) The net result of more than one episode of the same type of impact on a particular individual, population, or ecosystem (e.g., several fisheries operating at similar times on the same fish population as it migrates past different places). 2) The second possibility is the net result of more than one episode of different types of impacts acting on a particular individual, population, or ecosystem (e.g., the same population fished as well as impacted by another activity such as local habitat change, such as siltation of spawning beds). 3) The third possibility is simply both of the above acting together. To be cumulative, the effects in the above situations usually must impact the same population within a relatively short period of time, that is, at least within the usual recovery cycle of the population. Cumulative effects can also be defined as occurring when either a material, force or effect from a single source persistently occurs at a rate greater than can be dissipated by the recipient, or when two or more materials, forces or effects come together and produce a compounded result (Peterson et al. 1987).

It is important to note that cumulative effects of any type can affect the particular fish population in an additive as well as an interactive way (Peterson et al. 1987). That is, the effects of individual impacts may sum to result in a greater overall effect. Alternatively or simultaneously, the individual effects may also interact with each other to produce a much greater net effect than would result from simple addition of individual effects. This multiplicative or synergistic result may be greater than the sum of all additive effects. Both the degree and consequences of a multiplicative cumulative impact may be almost impossible to predict, but can be very significant.

LEVELS OF EFFECT

Cumulative effects may be seen at three organizational levels. These are: 1) the **individual** organism, 2) the **population** of organisms over both the short-term time frame (i.e., life history of individuals) and the long-term time frame (i.e., evolutionary time), and 3) the **aquatic ecosystem** within which the above occur.

Individual Impacts

Impacts on individuals can range from those having an imperceptible effect to those resulting in death of the individual. The cumulation of effects resulting from the death of individuals has consequences at the population level and are dealt with below. Impacts on individuals that do not result in death can be reduced to a single general effect - that is, the reallocation of energy from vital life history functions to address the particular effect of the impact. All organisms are energy limited and must allocate their energy to one of several basic functions. For fish, these functions include the following: homeostasis (i.e., the maintenance of a stable body through physiological processes necessary to maintain body functions such as osmoregulation), ingestion and excretion, tissue regeneration, and circulation. Individual or cumulative effects which disturb the basic functioning of these processes require the allocation of energy to neutralize their effect. For example, a toxic chemical at low levels in the environment may be ingested or enter the fish's body via the gills. In order to reduce the effects of or neutralize this chemical, various physiological processes may be initiated. The chemical may be actively transported out of the fish via excretory mechanisms or the gills. Alternatively, the chemical may be de-toxified by breaking it down into simpler less harmful or harmless constituents usually in the liver. Both active transport and de-toxification require energy and this must come from the general pool of energy available to the individual fish. If the energy is used for the maintenance of the body, this energy is no longer available to the individual to devote to other uses. This represents a cost to the individual. Those costs can cumulate both additively and multiplicatively and thus lessen the amount of energy available for other life history functions such as growth and reproduction. Increased costs for maintaining a proper internal body state can also result in a general physical weakening of the individual. If substantive, this may result in greater susceptibility to disease, predation, or parasitism which further results in decreased growth and reproduction or perhaps even death of the individual.

Trade-offs in energy allocation for fish are made between the general categories of homeostasis, growth, and reproduction. Energy used for one function is not available for use in another. Thus as a result of an external impact, any increased diversion of energy to homeostasis will reduce the energy available for growth and reproduction of the individual. Reduced growth affects the size and quality of the fish (i.e., physical condition). Reduced reproduction has consequences at both the individual level (i.e., fewer offspring produced by that individual in the next generation) and at the population level (i.e., general reduction in total numbers of the next generation).

A further example of an environmental impact on individual fish is one of increased migratory distance resulting from a local habitat modification. For example, say a particular migratory corridor usually used by the fish is no longer available because water levels were reduced by an upstream blockage. This may necessitate the fish choosing an alternative and longer route. The extra distance involved would require the expenditure of extra energy. Once again this would be diverted from other uses such as growth or reproduction. Reduced growth or reproduction represent a simple effect on the fish.

Both the contaminant effect and the environmental effect used in the above examples can be viewed as simple effects. However, if they combine to affect the same individual they become cumulative. The extra expenditure of energy to de-toxify the chemical and the extra energy required to migrate further both add together to result in a substantive energy reallocation by that fish. This affects other functions negatively. Thus, that individual's growth and reproduction are not as much as they could have been. If for some reason the net effects of these two forces are greater than their sum (i.e., a multiplicative or synergistic effect results), the consequences to the individual are more serious. For example, if the toxic chemical also impairs swimming ability then a synergistic effect is possible. That is, not only must the fish expend energy to de-toxify the chemical and also to migrate further as a result of environmental impact, but greater energy expenditure is necessary because the efficiency of migratory swimming is reduced.

From the perspective of the individual fish, the cumulative impacts may result in one or more of the following: reduction in growth rate, delayed sexual maturation and lowered reproduction through decreased fecundity, frequency of reproduction, or life-time reproductive output. Because many of these parameters are inter-related - e.g., fecundity is related to the size of the fish which in turn is dependent upon growth, the impact of multiple factors results in a cumulative response in the fish as well. Furthermore, the impacts noted above can also function to place the individual fish in more risky circumstances - e.g., delayed migration, decreased ability to swim, and increased probability of being preyed upon or contracting diseases.

Therefore, although each possible impact and its simple effect on the individual fish may seem small, the interaction of these simple effects results in a large cumulative effect which may have significant consequences. Although each simple effect may only debilitate the individual fish, the overall cumulative effect of all impacts may be beyond the ability of the individual to survive. This will affect the population structure over the short term. Individual-level effects as noted above and the resulting diversion of energy to homeostatic mechanisms will generally result in fish of poorer condition. From the perspective of a fishery, this means that the product may be of lower quality.

Short-term Population Impacts

The cumulative effects of several types of impacts at the level of the individual that are outlined above are also applicable to the fish population generally. Some population-level effects will be seen over the short-term time frame of a few years (i.e., within generations). In addition, other impacts at the population level may also affect the specific population. These include factors such as fishing. Note that at the individual level, the effect of fishing obviously is death. At the population-level the effect of fishing may be a change in the characteristic parameters such as size and age structure which describe the population.

Thus, a population, which is experiencing multiple impacts such as exploitation, some level of contaminant stress, some level of local environmental impact, and perhaps also physical injury (e.g., scarring, Reist et al. 1987), may over time exhibit compensatory effects to the impacts. These may be seen as changes in the age and size structure and relative abundances of particular age or size groups. In general, the shift may be expected to be towards relatively more younger and smaller individuals. The decreased reproductive output of individuals may also result in changes in the productivity of the population. That is, the rate of replacement of individuals in the population may decline. If continued for a number of years, the result of such continued and cumulative effects may be decline in the overall abundance of the population as well as a shift to younger and smaller individuals.

In summary, at the population level over the time frame of a few years, the typical potential cumulative effect of a number of individual effects on the population will initially be a shift to relatively more younger and smaller fish, and ultimately a decline in overall abundance. Should all the original impacts continue, the population may remain in this shifted state indefinitely. That is, a new stable equilibrium will result between the forces acting to increase population abundance (e.g., reproduction and growth) and those acting to decrease it (e.g., individual effects of contaminant, local environmental impact and physical injury which are not lethal to the individual fish; and lethal effects such as exploitation). In the worst case, the cumulative impacts may exceed the replacement capacity of the population, and a decline in population abundance will continue and perhaps accelerate with time. Ultimately, extinction of that population may result over the short time frame of a few years.

Long-term Population Impacts

Over the longer time frame of several generations, the individual-level effects (both sublethal and lethal) and the short-term population effects of multiple impacts may cumulate to result in evolutionary change in the population. That is, activities such as exploitation act to selectively remove a specific subset of individuals - for example, the larger, older fish. Genetically such individuals are likely to be the fast-growing members of the population. Continued selective removal of such individuals acts as an evolutionary force that causes the population to evolve towards slower-growing individuals that mature earlier and at a smaller size. Because they are smaller when they reproduce such individuals would have lower reproductive output, thus the overall productivity of the population would decline. Differential susceptibility to sublethal factors such as those outlined above (e.g., contaminants, physical injury, local environmental change) could enhance the evolutionary changes in the population. In general, such evolutionary changes are not reversible. That is, once the genetic basis for fast growth and other related characters has been eliminated from the population, only slow growing individuals would be left. Ultimately, if factors such as exploitation were not reduced, continuing decrease in population abundance or even extinction might occur.

Ecosystem Impacts

Some cumulative effects of human impacts may be generalized and affect the entire aquatic ecosystem. For example, aquatic ecosystems are composed of many biological populations at several different levels of organization called trophic levels. These levels generally are primary producers (e.g., algae), primary consumers (e.g., insects, clams), and secondary consumers (e.g., fish). In addition, aquatic ecosystems also include the habitats occupied by those populations and various types of inputs into the system. Ecosystem-level cumulative effects may result in significant restructuring of the ecosystem itself. For example, fishing can significantly alter the biological structure of the exploited fish population. If, in addition, contaminant burdens affect different species in similar ways (e.g., cause the expenditure of energy to neutralize them), the individual effects of exploitation and contamination may cumulate to negatively affect the fish population. However, the contamination may also affect organisms upon which the fish depend for food. Reduction in the population abundance of prey items will then further enhance any negative effects of these impacts on the fish population. In this way, the basic structure of the ecosystem such as the trophic relationships between the fish and its prey may change. In such cases instability in the ecosystem structure and function may further accelerate the negative effects of the impacts upon the fish population. As above, the probability is quite high for significant change to the fish populations within the ecosystem and perhaps to the ecosystem itself.

TRANSPORT OF IMPACTS

From the arctic perspective, it is clear that many impacts are local in origin and in their effect. Such local impacts include exploitation, local habitat degradation or modification, physical injury to the fish due to various causes, and local sources of contamination. It is equally clear that many other impacts originate in areas far removed from the Arctic.

Impacts originating outside the Arctic may be transported there through several mechanisms (see Pfirman et al. 1996). For example, the airborne transport of contaminants from southern regions to the Arctic is now well understood. Such transport can result in significant levels of contaminants being deposited in arctic water bodies or in local drainage basins leading to the water body. Once present in the water, the contaminant may then directly affect the fish. It is equally important to realize that the river itself acts as a major conduit delivering contaminants to the north which originate in the industrialized southern portions of the Mackenzie River Basin. The presence of large lakes (e.g., Lake Athabasca and especially Great Slave Lake) along the basin may act as settling ponds for some substances which dissolve poorly in water. Those which readily dissolve will be both diluted and transported north in the water flow. Such contaminants when combined with other localized impacts will contribute to the various effects at different levels noted above. In addition to both airborne and river transport of some types of impacts, currents in the Arctic Ocean can also deliver some impacts to areas used by important fish species. Therefore, the level of some types of impacts such as contaminants may be far greater than first anticipated, and may result in significant effects on species such as broad whitefish which travel between the freshwater areas of the lower Mackenzie River Basin and the nearshore Beaufort Sea.

MIGRATORY FISH AND EFFECTS OF IMPACTS

Fish such as broad whitefish, which undergo substantive migrations to perform vital life history functions (Reist and Chang-Kue 1997, this publication), are potentially more vulnerable to both the simple and the cumulative effects of impacts than are fish which do not migrate. By moving across several habitats, migratory fish may encounter several local impacts during a short time. Thus, the total effect of all these impacts can be very much greater for migratory fish than for fish which do not migrate.

This concept is perhaps best visualized using the example of a migratory group of fish being fished at several points during their migration. Because the migrations of fish are triggered by specific environmental cues such as change in water temperature, water clarity, or day length, they are concentrated over a short period of time. Similarly, especially in rivers the migrating fish are concentrated into a small spatial area. This increases their vulnerability to human activities such as fishing. Fishing such stocks becomes a focused activity of many individuals and thus the migrating fish usually are successively fished at different locations during their migration. The catch then represents the cumulation of several individual fishing events which can become quite substantial in total (e.g., Treble and Reist 1997 this publication).

MAJOR POTENTIAL IMPACTS ON BROAD WHITEFISH OF THE LOWER MACKENZIE RIVER

There are five major categories of impacts on broad whitefish of the lower Mackenzie River. These are: 1) exploitation in various fisheries, 2) physical injury, 3) contaminants present in the water, 4) change in the local habitats, and 5) global environmental change.

EXPLOITATION

Figure 1 represents a compilation of many of the locations where fishing for the anadromous form of broad whitefish (Reist 1997, this publication) occurs in the lower Mackenzie River Basin and in the Delta. It is likely that this is an underestimate and the location of some fish camps may not be shown. As was described above, fishing represents an impact on the fish primarily at the level of the population. Fisheries for broad whitefish can at times be significant (Treble and Reist 1997, this publication). If, as can be seen in Fig. 1, there are numerous fisheries along a particular channel that intercept and capture fish from the same migratory group, the total effect of all fishing can be cumulative. As a result, fewer fish are left in the population. If these are not replaced through growth and reproduction, the abundance of the population may decrease over time. Fisheries usually target large and old fish. Thus fishing can also change the structure of the population over the short and perhaps long term usually by increasing the relative abundance of smaller and younger fish.

PHYSICAL INJURIES

If the fish physically encounters an object in its environment, a physical injury may result. For example, some fish encounter fishing nets, are caught briefly, but then escape. In doing so scales are lost, fins may be torn, and open sores may result. Similarly, some industrial activities such as dredging or construction if conducted at inappropriate times may cause physical injury to the fish. Injuries also result from natural causes such as predators (e.g., bears, birds, predatory fish) and external parasites. These physical injuries often leave scars upon the fish (Reist et al. 1987). The process of healing of any injury requires energy be devoted to it. Energy expended in this way is no longer available to the individual fish to use for activities such as migration, feeding, growth or reproduction. Thus, a major effect of physical injury is lower growth and reproduction. Severe injuries may result in the death of the fish and thus in effects similar to those described above for exploitation. Less severe injuries may heal, but during that time may make the fish more susceptible to predation or disease and death may ultimately result.

CONTAMINANTS

Various human activities often geographically far removed can result in contaminants entering aquatic ecosystems (Fig. 2). Activities such as industry, sewage disposal, boating and runoff of precipitation from town streets can all contribute locally to contaminant levels in the river. Similar activities conducted elsewhere, for example upstream on the Mackenzie River basin or in another country, may also contribute waterborne or airborne contaminants to the local ecosystem (Pfirman et al. 1996).

If the contaminant is highly toxic, affected fish may die and thus the overall effect will be at the level of the population. For less toxic contaminants, individual fish must either swim elsewhere to avoid it or neutralize the effects by some mechanism. Both of these activities consume energy, thus the fish will grow slower and reproduce less, or it may become more susceptible to disease, parasites or predators. Also, if the contaminant affects a habitat critical to the fish for a particular life history function, the fish may avoid that area until the contaminant dissipates. Thus, activities such as feeding, migration or reproduction may be disrupted with negative effects at both the individual and the population level.

HABITAT CHANGES

Some human activities may result in alteration of the particular aquatic habitats in which the fish live. For example, dredging to open navigable channels creates large amounts of silt, thus if conducted at an inappropriate time such as just prior to spawning may alter the local spawning habitat making it less suitable for survival of the eggs. Such changes are likely short-lived, but if they occur at a critical time in the life history of the fish they may have a significant negative effect on the fish population. Other types of habitat change are more pervasive and originate elsewhere. For example, proposed hydroelectric dams on upstream tributaries of the Mackenzie River will, if constructed, alter the flow regime of the water. Generally this would be greatly increased winter flows and slightly decreased summer flow. These changes in flow regime will likely affect the ice dynamics and timing of breakup of the delta, and may also alter the channel morphology and characteristics. These local habitat changes may alter the intensity and timing of cues the fish use to trigger life history activities such as upstream migration for spawning and so on.

Thus, effects of habitat change at the level of individual fish may be disruption of migratory patterns and decline in growth and reproduction. Effects at the level of the fish population may include reduction in numbers of fish either directly or through disruption of life history events.

GLOBAL ENVIRONMENTAL CHANGE

Scientists have recently become aware that human activities across the entire globe may be resulting in changes in the environment. These include things such as ozone depletion thus increased ultraviolet light levels and general climate warming. Such changes, especially those predicted as a result of climate change, may result in significant effects to the habitat and aquatic ecosystem of the lower Mackenzie River. Generally, warmer temperatures and increased precipitation are predicted with the amount being greater in the winter than the summer. Such changes if realized to the degree predicted will have profound effects on the fish populations in the Mackenzie River. These changes include: 1) alteration of the species of fish present in the lower Mackenzie River, with the loss of some and the northward colonization by others, 2) change in the production characteristics (growth, reproduction, etc.) of the fish species now present in the area, and 3) habitat changes and perhaps alteration of the structure of the aquatic ecosystems (e.g., change in food web pattern) (Reist 1994).

From the perspective of broad whitefish, the migratory routes and timing of movements (Reist and Chang-Kue 1997, this publication) would likely be altered. Specific habitats may also be lost or altered - for example, oxygenated overwintering areas in lakes may be reduced and fewer fish would survive the winter. This would lead to a decline in overall abundance.

CUMULATION OF EFFECTS

The effects of all the individual classes of impacts discussed above combine in unknown ways to affect individual fish, the fish populations, and the ecosystem they inhabit. In some cases the impacts seem to be minimal and in fact may not be readily seen because they are hidden by compensatory mechanisms which exist within the fish. However, it is important to realize that there are impacts from all activities and that these individual impacts can combine to produce significant cumulative impacts. In an attempt to provide a specific, but hypothetical, example of how that may possibly occur, a series of possible impacts and their potential impacts on broad whitefish are presented in Fig. 3. The individual simple effects consist of the following. 1) Multiple fishing events occur on the same group of migratory fishes thus fewer adults go to the spawning areas. 2) Low levels of contamination in the water cause the fish to expend energy to remove the contaminants from their body, thus these fish do not grow as much nor produce as many eggs as they otherwise would. 3) In addition some eggs die as a result of habitat effects. These individual events all cumulate to result in a significant decrease of young produced by that stock in that particular year. Thus, fewer adult fish will ultimately be present in the population. This decline in the population may be short term but if the impacts continue may become long term resulting in overall and continued decrease in population abundance.

It is also important to realize that the impacts discussed above originate from human activities. These impacts are superimposed on the natural changes and events the fish populations also face. Thus, the individual and cumulative effects as described above may combine with the natural events and result in even greater impact on the fish populations.

AN EXAMPLE OF CUMULATIVE IMPACT FROM A SOUTHERN FISHERY

There are many examples of the negative impacts of human activities on fish populations. However, for many of these, the relationship between effect (e.g., decline of the population) and cause (e.g., some human activity) is not clear. An example of the likely cumulative effect of exploitation and environmental impact comes from Southern Indian

Lake, Manitoba (Bodaly et al. 1984). The Churchill River diversion re-routed 760 $m^3 \times sec^{-1}$ of water flow to the Nelson River. In addition to immediate effects such as fish contamination by mercury, the commercial fishery for lake whitefish collapsed. Catch-per-unit-of-effort after diversion fell to half the pre-impoundment levels but the quota for the fishery was not adjusted downward. Total catch was maintained by increasing effort and fishing a basin of the lake containing a lower grade of fish. The initial population decline resulting from lake impoundment and disruption of migratory patterns cumulated with a continued high level of exploitation. Together these factors, perhaps combined with other habitat changes such as increased siltation of spawning areas, hastened the collapse of the fishery.

At present it is unlikely that the cumulative effects of all human activities are irreversibly affecting the broad whitefish of the lower Mackenzie River. However, the above example illustrates the possibility for cumulative effects. Therefore, caution in the overall approach to management of this resource is required.

STRATEGIES FOR MANAGING FISH POPULATIONS IN THE FACE OF CUMULATIVE IMPACTS

Many of the impacts discussed above, for example global environmental change, can only be dealt with through concerted world-wide efforts. Such efforts are now underway but it may be decades before negative effects of such widespread change decline. For impacts such as climate change, efforts to reduce the effects will likely not be totally effective, thus some degree of change can be expected over the next 50 years or so. Other impacts are under more local control and can be effectively dealt with by management at the local level. Thus, the overall management strategy for renewable natural resources such as fisheries must consider not only local impacts but also must involve understanding of potential global impacts on that resource. Also, the possibility of additive or multiplicative cumulative effects must be taken into account.

The following suggestions for management of fisheries in the face of potential cumulative effects should be implemented. 1) All impacts must be identified with respect to their simple and cumulative effects on individuals, biological populations, and aquatic ecosystems. 2) Baseline information on the status of populations should be established and include factors such as biological parameters, abundance, contaminant loads, details of life history, and specific habitat usage and timing. 3) Long-term monitoring programs should be implemented to determine changes in baseline parameters and the levels and effects of exploitation, contamination, and other impacts upon individual populations. 4) Research should be conducted to better understand cause-effect relationships, ecosystem structure and function, and the inherent compensatory mechanisms in fish populations. Included in such research should also be the quantification of effects from specific impacts. Analyses of risk associated with specific management actions should also be conducted within the context of local and global impacts and their simple and cumulative effects on the resource. 5) Groups responsible for management must understand the potential for cumulative effects, and act from the widest possible viewpoint and as conservatively as possible when making decisions.

As pointed out above, local managers of natural resources can not significantly affect global issues. This means that management of local resources must be conducted within the context of some level of global impact originating from outside the local region. This is complicated by the fact that the exact nature and degree of effect of such impacts on the local resource usually is unknown. Thus, with respect to the management of a specific resource such as broad whitefish, the focus of management activity should be directed towards those impacts which can be locally controlled. Usually these are impacts such as the level of exploitation, local environmental impacts and habitat changes. Therefore, to ensure continued viability of natural resources and the ecosystems they occupy, managers must act conservatively with respect to local issues. For impacts such as exploitation this means setting allowable catch limits well below the maximum possible which could be theoretically sustained by the population if fishing was the only human influence. Similarly, decisions made with respect to other local issues must also be conservative from the perspective of the natural resource being affected. By managing conservatively, a degree of resilience is left in the resource and compensation by the resource is possible for both local and global impacts and their additive and multiplicative cumulative effects.

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COMMENTS, QUESTIONS AND ANSWERS

Don Dowler: It's not really a question, but a comment. Looking at the last part of what you were saying there about the effects of fishing on the population - I'm not sure that it's clear that net fishers in the Delta Area are not exactly 100% efficient. I'm sure that lots of fish get by the gill nets. So, I just don't want the impression to occur that it has as bad an effect as say habitat changes or contaminants. It could leave the wrong impression.

J. Reist: I agree. This was designed to be a model for a set of possibilities to get people thinking about it. The problem that we have with most of this is we don't have a very good idea of the magnitude. We can't measure directly the effect of any one of the individual causes or potential problems. And you're right there's a lot of fish that are obviously getting by the nets. I think that from the data that was presented by Margaret Treble, it's clear that fishing has gone on for a number of years and the population seems to be able to compensate for that and continue to be viable in the face of that. That wasn't the point. The point is that if you add to that fishing mortality then things may start cumulating and become negative over time.

Comment: On your map, I notice from the last two speakers that you try to keep away from the pulp mills, and also from showing which communities along the Mackenzie and Peel River are letting their sludge drain into the river system.

J. Reist: I agree. The map which you saw and was in your handout was actually created many years ago for another purpose, and I just went back to an old thought and borrowed it. You're quite right, though. The map is meant to illustrate some of the potential effects that could get transported downstream, but not all by any means. There could be many, many, more of them of many different kinds.

Billy Day: When you're talking about cumulative effects and cumulative impacts, are there a number of impacts that you know of now? I keep hearing you say possible and maybe.

Jim Reist: The point is that we know these individual impacts have an effect on the population. We can just intuitively think and understand that. The problem is we don't know the magnitude - we can't measure exactly what the effect is because first of all it's very difficult to do in many cases and it often hasn't been done. The reason I said possible is simply because it's a measurement problem.

R. Binder: So when you're considering possible effects, do we have to wait on the sidelines for proof or are there suggestions that organizations such as FJMC and up the river can deal with, with regard to regulation or legislation?

J. Reist: It's my personal belief, that if we wait until there's proof for everything, it's going to be too late. My recommendation is that people who can see the potential for an effect on them, their fisheries, or their environment from somewhere else, should act now to lessen insofar as possible or prevent that effect. So, for example, if B.C. Hydro ultimately decides that they do want to put the dam in on the Liard River and change the flow pattern for the Liard, people from here should be part of that process. You know the newspapers will make that known to the public and at that point then people have to be organized, and make representation to places or to proponents of things like that. In the same sense, if there's perceived problems with raw sewage coming into the river, people should make that an issue. They should talk to their leaders and perhaps the local politicians and the local relevant government agencies and try to increase awareness first of all and then push for some solutions, second of all. I don't think we should wait. That, I think, is the basic message here, when I said we should try to act as conservatively as possible for all of these kinds of things.

J. Benoit: Maybe a last point here - with all of these cumulative effects and impacts and the like, wouldn't it be logical to begin to work with other organizations all the way up the river in Alberta if need be to bend government's ear so that we do get the recognition that we deserve?

J. Reist: I agree and I think that you see the whole concept of cumulative effect is actually fairly new. It's only less than ten years old, in terms of people's thought processes and the general scientific community. It's understood now in the scientific community and I'm trying to bring it to you as a concept. It is likely that it's not understood in the minds of the politicians and the major decision makers. They are somewhat insulated from the real world situation, if you want. I think what we have to do is to make those people aware of these possible effects so that they can be thought out before they become problems - before we see significant negative effects. I would encourage you to increase the awareness of that by bringing these issues forward.

J. Benoit: An effort that we've been trying in Inuvik and Fort McPherson is to have DFO and the Department of Health work on our sewage issues. I know recently that FJMC has taken a role in dealing with those two problems. Is DFO also going to take a stand on those two issues?

J. Reist: I'm going to hand that one over to the area manager to make a response simply because it's not my area of expertise within the department. Sorry.

R. Allen: Thanks.

J. Benoit: That should be considered

also. That's been going on for forty years.

R. Allen: DFO has a mandate to deal with fish habitat and alterations to that habitat. What's happened with the sewage lagoons, of course, is that the municipalities and so on, obtain licenses to deal with their sewage disposal and treatment. As such, those are basically set aside from DFO's mandate to deal with them as fish habitat because they're no longer considered habitat. The problem is worse in places like Aklavik when perhaps the sewage system isn't up to acceptable standards anymore in terms of how we'd like the world to be now. There's spillage, runoff and other associated issues that then affect fish habitat, but the lagoon itself is no longer within our mandate as being fish habitat because it is a declared sewage lagoon. So it makes things a little complicated and that's why we get into these kinds of jurisdictional issues. Okay, who really is responsible - the town has a license to operate this, you know. Are they within their license, or not, or are the conditions of their license as stringent as they might be or should be? Generally we get our kick at the cat as Fisheries and Oceans when that license comes up for renewal, but once the license is issued basically the operation of that isn't within our mandate. However, we have an interesting situation in a place like Iqaluit where the town was charged with a sewage system that didn't operate properly and discharged large quantities into the sea. Court battles are still going on over that one. Although, it would appear that we won the initial round and that the town is found guilty of not operating that properly. So, it's a complex problem. At this point in time with the water license in place we're sort of bouncing it back and forth to environment protection and health. Part of the problem is the sampling so far hasn't been adequate to prove danger to health and this type of thing. I don't think it's over and done with by any means. I appreciate that people are getting more and more concerned about this type of issue.

J. Benoit: I'd like to know if DFO is moving towards or away from a reactive position to a proactive position. I remember back a few years when I started in the environmental field that citizens were allowed to bring charges on federal officials, territorial government officials with regard to crimes against the environment. Does DFO also have that in their mandate?

J. Reist: I'm going to answer a part of that, from my role and position within DFO as a research scientist and concern with our fish populations, how they work, and what effects people have on them. This whole workshop is an example of our attempt to act proactively in terms of understanding fish populations, people's effects on them, and what we can do to lessen those effects and thereby make sure that the populations survive into the future. I'm going to turn it over to Ron to answer the second part with respect to the management issue.

Ron Allen: It's a situation where we're trying to involve people more in the management of various fisheries, and part of that relates to government needs to involve its people in the decisions it makes. These things don't work nearly so well. Also I think you will find that we've moved as a department more towards compliance. You see that in programs involving inspection of fish products where it used to be by act and regulation and inspection of those facilities. We would enforce it, whereas now there is more onus put on the plants to design their own quality programs and carry them out - with less involvement of DFO in the actual running of the quality control. As far as your comment on what individuals can or can't do - that's across the board and outside DFO 's purview but individuals can bring various kinds of action with regards to departments, individuals or whatever - not performing as they're required to by law.

Johnnie Charlie: I'm Johnnie Charlie from Fort McPherson. There are a lot of things that we learned in the past from the elders. There is a lot of things that they told the young people that are true. By that we know some of the things that we're talking about here and a lot of others things that we don't know that we're learning from the scientist or the biologist. One of the things I'd like to know - we're talking about the broad whitefish. In the Mackenzie delta there's a lot of fish lakes. You fish on these lakes in the fall. Like yesterday somebody said you take so much from the lake - leave some for next year and this is the way our elders used to fish on the lakes. But if the fish die off in the lake, how many years would it take for that fish to come back?

J. Reist: You mean if the fish completely die out of the lake?

J. Charlie: Or get killed?

J. Reist: It depends a lot on the individual type of fish and the particular species. It would depend a lot on whether the fish population that was originally there was a separate biological stock - a separate group of fish from all others. If it was a separate group of fish from all others, it could be a very, very long time before it came back. If on the other hand it was part of a bigger population of fish that wasn't just specific for that lake and it occurred elsewhere and migrated or moved through, it would come back very quickly. If it was a fish that reproduces very little, that is a small number of eggs, only several hundred or something like that, it would come back slower than a population of a fish species that would be making 10,000 eggs or more. I'm not sure that I answered your question exactly, but without knowing the specific details it's very difficult.

J. Charlie: Okay - now what effect does dynamite do to fish in the lake? You blow up two, three sticks in the lake - does that kill half the fish?

J. Reist: If the fish are relatively close to it - yes - and it obviously would have a very negative effect on those fish. The fish further away would be affected to a lesser degree

J. Charlie: The reason I asked is - back in the 70's - they put a road right across this lake and they told me that they blasted three holes in that lake. That spring people used to go around paddling for rats and me and my son went over to that lake and the whole lake was just rotting - just fish floating all over - after they blew the dynamite in this lake.

J. Reist: We have regulations in place now to govern exactly how that kind of activity is supposed to occur. In 1970, of course some 20 odd years ago, those regulations may not have been in place or they may not have been enforced and done properly as they were supposed to. If they did it improperly there is no doubt that they could kill fish that were trying to overwinter in that lake and then you would see those fish in the springtime. That's perhaps what happened in this particular case. Unless it was a very large set of charges in a very small lake eventually you should see the population come back. Those fish should come back to normal in a few years I would think.

J. Charlie: Well, it was a couple of years after that we set a net on that lake and we never got a fish. Three years ago I told my son to try a net on that lake again and never got nothing. Yet, there's a lake beside that lake trying to drain out. It hasn't all drained out but half of the water on that fish lake is gone by breaking out into another lake that runs into the river and some of the fishes are still living in there.

J. Reist: There are still fish living in there?

J. Charlie: Yes.

J. Reist: Well it sounds like what happened is that the lake has changed for whatever reason - perhaps the seismic and the blasting. I don't know. The lake has changed and maybe the amount of habitat available to the fish has decreased as a result of that change and perhaps the fish can't survive there over the winter because the water levels are lower. It could be any number of causes and they may never come back to the numbers that you remember. If the lake habitat has changed and it never changes back to what it was twenty-five years ago, the fish themselves may potentially never come back to those same numbers that you saw twenty-five years ago.

J. Charlie: You're telling us now that the broad whitefish goes up the Peel [River] and goes up Arctic Red [River] and they spawn. We know that the conies and the herring that go up the Peel are spawned way up but when they come back they're just skinny - no more fat in them. But the broad whitefish when they come back up to freeze - you're sitting on the lake you catch these whitefish with eggs. It's on the lake that's running out - the same with the whitefish. Where do they spawn after breakup - after freeze-up?

J. Reist: They go up the river. You remember Ken Chang-Kue's talk about radiotelemetry - he actually tracked fish up the Peel River to where the confluence of the Trail River comes into the Peel, so actually into the Yukon Territory. That appears to be one spot that they actually spawn. There's probably several - as you know, the Peel River is a big river - and there are probably several areas in the Peel that we don't know about that the broad whitefish spawn in. To answer the other part of your question, why there might be eggs in the fish as they're coming back down - there are a couple of possible explanations for that. One - if the individual fish was too late in going upstream for whatever reasons. And fish are like people - they're variable. One person is very fast moving and the other is very slow moving. The same occurs for fish. If the fish was too late in getting to the spawning site, all of the other fish may have finished spawning and the water temperature had gone down a little bit, things had changed, and it may no longer be appropriate for that fish to spawn in which case it would turn around and come back down. If you caught that fish you would see the eggs. The other possible explanation is that when fish spawn they don't necessarily completely spawn out all of the eggs. They may only spawn 75% of the total amount of eggs that they have available. They'll spawn and turn around and start migrating back downstream and if you catch that fish and pick it up it may still have some eggs in it that will come out when you capture it. It's just the way fish are. That's a very frequent occurrence.

J. Charlie: Thank you.

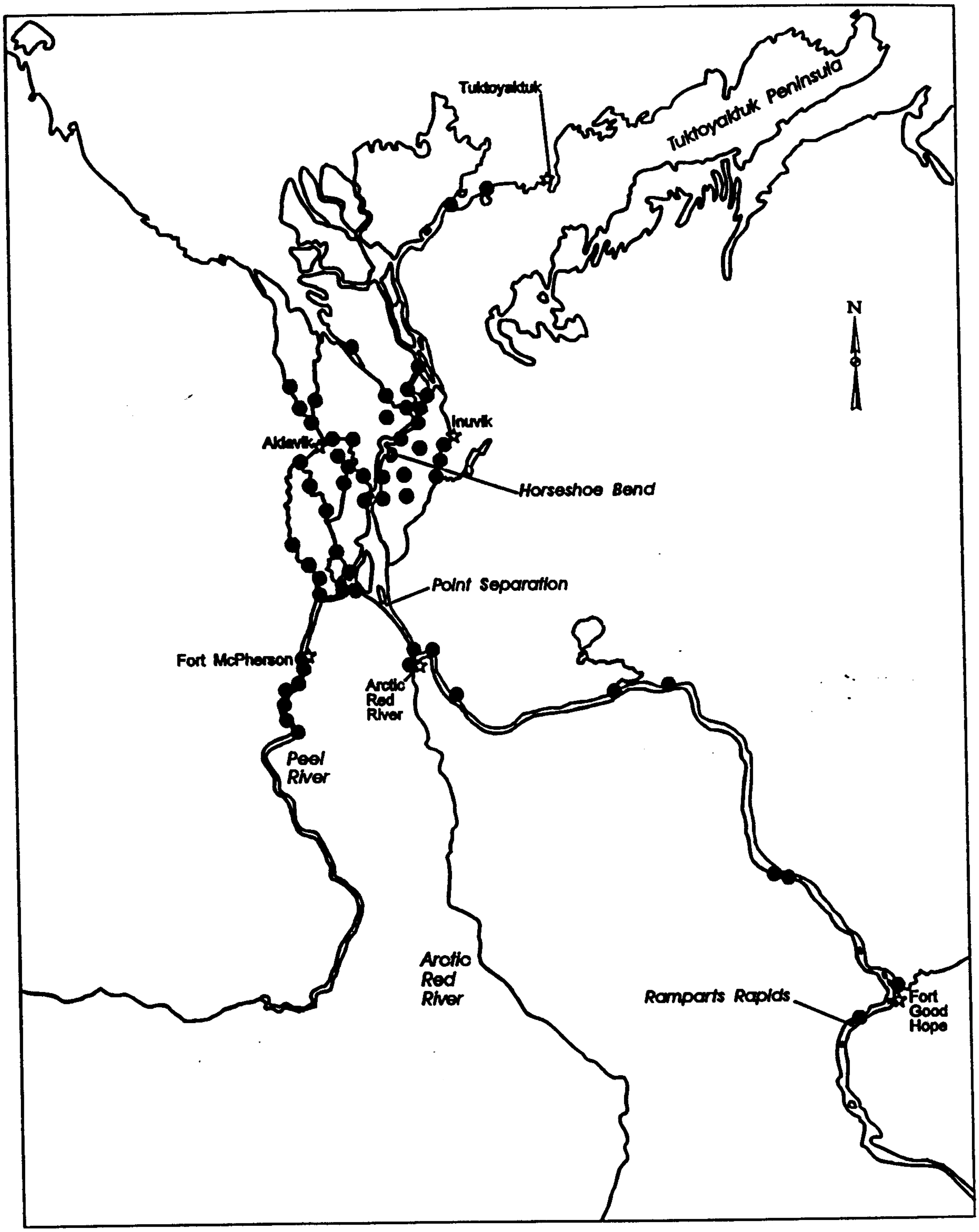

Figure 1. A summary of fishing locations in the lower Mackenzie River basin.

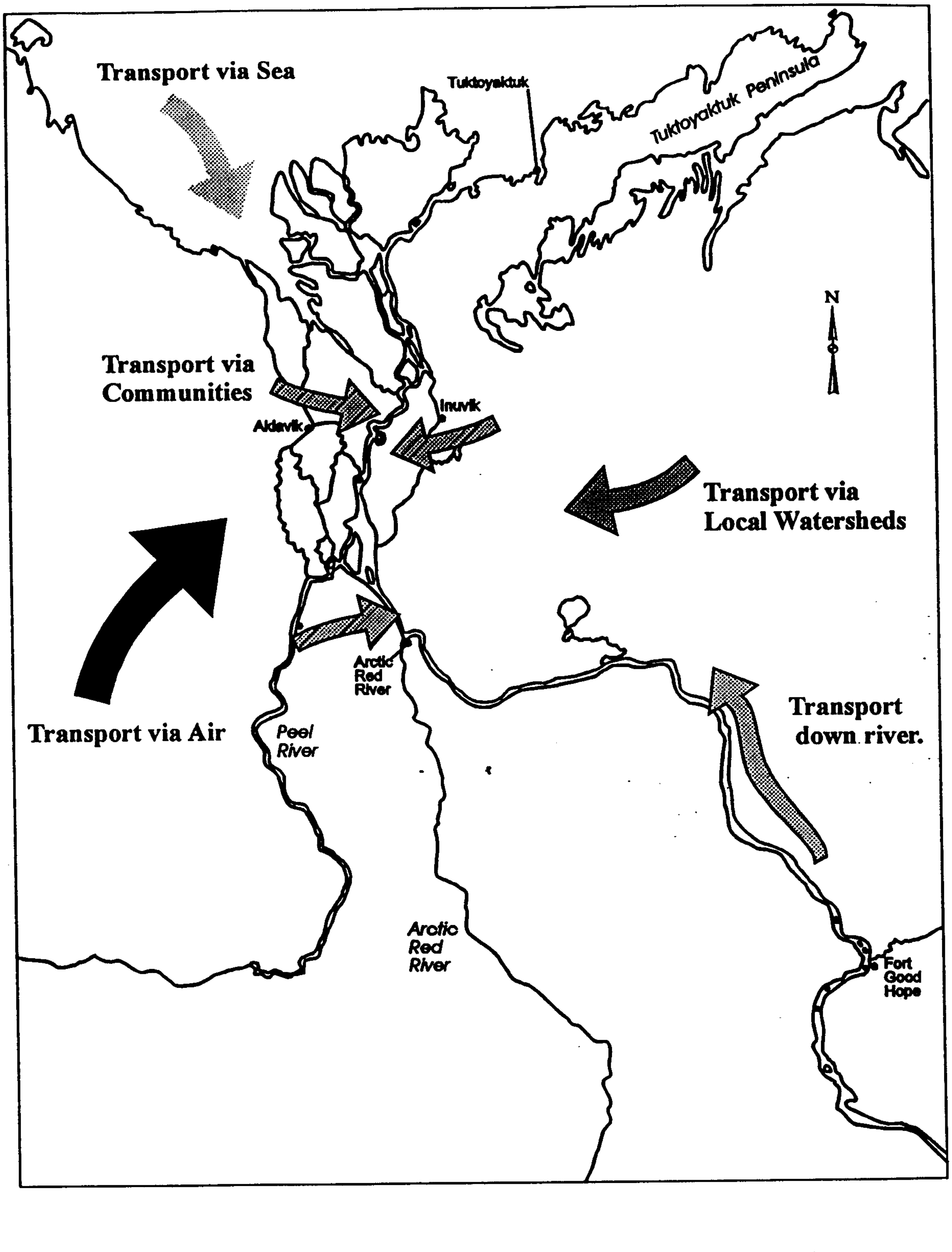

Figure 2. Possible sources of contaminants to the aquatic ecosystems of the lower Mackenzie River basin.

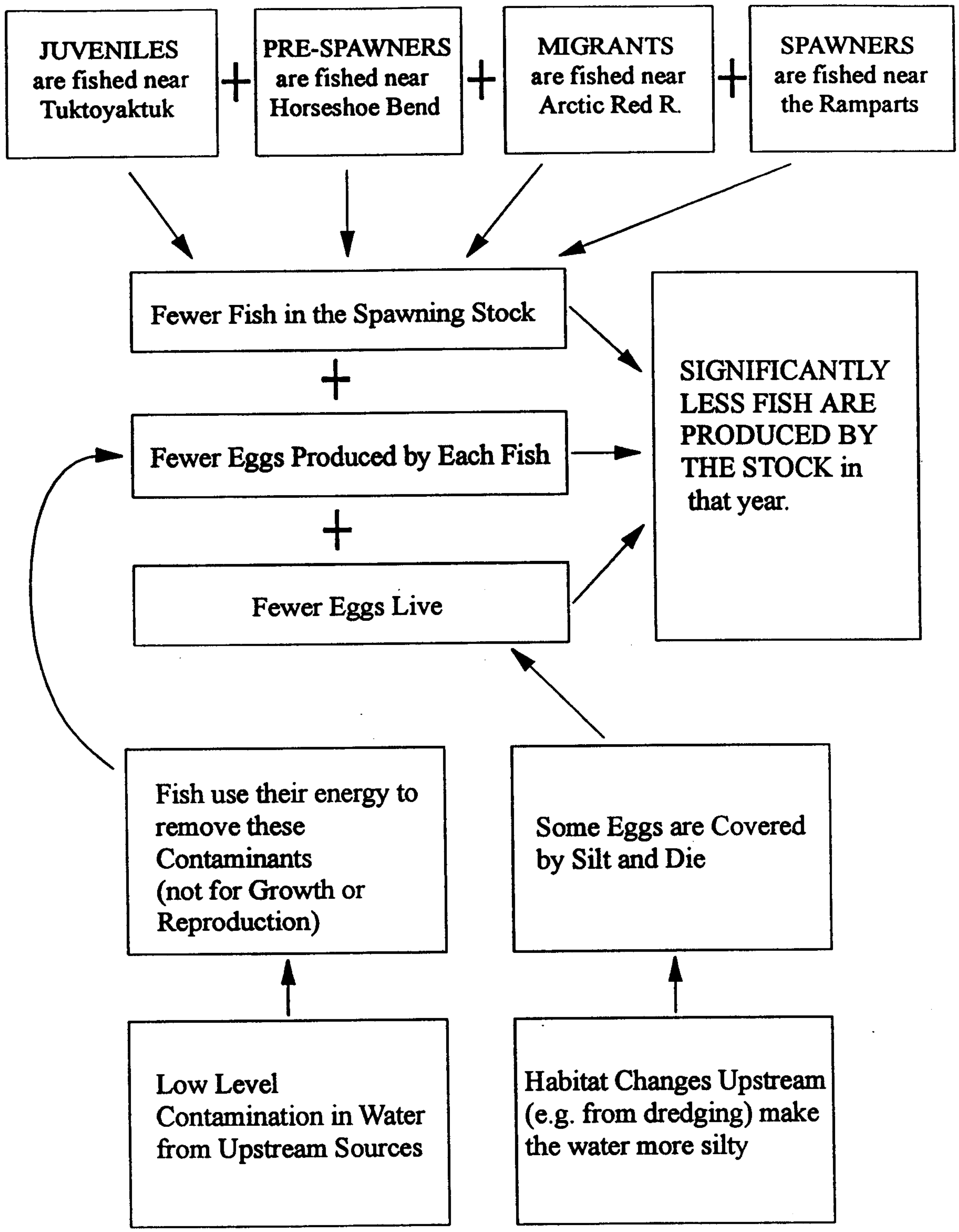

Figure 3. An example of possible impacts and their cumulative effects on the broad whitefish populations of the lower Mackenzie River basin. Note that this is for illustrative purposes only - no specific effects have been quantified.

SOME MANAGEMENT CONSIDERATIONS WHEN HARVESTING IN A MULTI-SPECIES FISHERY

by

Ross F. Tallman

ABSTRACT

Six species (five coregonids and one esocid) are harvested together in the fisheries of the lower Mackenzie River. The multi-species nature of the fishery has previously not been considered in management decision making. A rationale for using a multi-species approach to fishery management is presented.

SUMMARY

Traditional approaches to fisheries mangement have tended to treat species as if they existed independently of other species and were harvested independently of other species (Mercer 1982). This approach ignored the gear (technological) interactions, whereby the capture of one species also resulted in capture of other species, and the biological interactions involving predation and competition. Clearly, there are inter-relationships between species in an ecosystem and management regimes should consider this.

The Mackenzie River fisheries harvest five coregonid and one esocid species. These are the broad whitefish, *Coregonus nasus*, inconnu, *Stenodus leucichthys*, crookedback (lake whitefish), *Coregonus clupeaformis*, Arctic cisco, *Coregonus autumnalis*, least cisco, *Coregonus sardinella* and Northern pike, *Esox lucius* (Fig. 1). The fishery is multispecies in that several if not all species may be caught with the same gear. The species will differ in life cycle and life history traits. Thus, they will have different productivities and abilities to withstand fishing pressure. It follows that an exploitation rate appropriate for one species could be too low or too high for another. As well, harvesting could change the inter-relationships between the species and cause an imbalance in their respective ecologies resulting in lowered productivity.

Dickie and Kerr (1982) list several reasons why multi-species analysis may be a more effective methodology for fisheries management than the single species approach:

1) The overall production of freshwater fish production systems is highly predictable from basic system parameters (Ryder et al. 1974);
2) The overall production of at least some marine systems is substantially more stable than is relative production of individual species (Sutcliffe et al. 1977);
3) For many fisheries, individual species fluctuations are more strongly predicted by environmental than fishery parameters (Fry and Watt 1957; Sutcliffe 1972, 1973; Sutcliffe et al. 1977; Loucks and Sutcliffe 1978).

It is important to understand the relative productivities and the interrelationships between the species before imposing a harvesting strategy. Unfortunately, the biology of these species in the area is poorly known at best. In some cases there is no published information on species productivity in Canada that management biologists can use to give advice. More research is required into the biology of the various harvested species and their interrelationships in order to develop a comprehensive fisheries management plan for the lower Mackenzie River.

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COMMENTS, QUESTIONS AND ANSWERS

M. Papst: I think this is something that Ross has touched on that can't help but be recognized by anyone who spends any time up here. That is, you come up with a head full of foodwebs and diversity. In fact there's going to be a big conference in Winnipeg shortly about foodwebs and how things relate to one another. I know a friend of mine, a Cree elder, looked at me in quite amazement when we were gabbing and said, "You just figured it out?". He was relating the fact that they had figured it out a long time ago. I think what we'll do is - I'd like to ask for a really quick coffee break because what we'll do is come straight back and FJMC will present some comments and some questions perhaps about where we go from here. We'll give an opportunity for the distinguished panel to say their last comments and put it out to the floor and then we'll be finished. So go over and have some of the last coffee and we'll finish up.

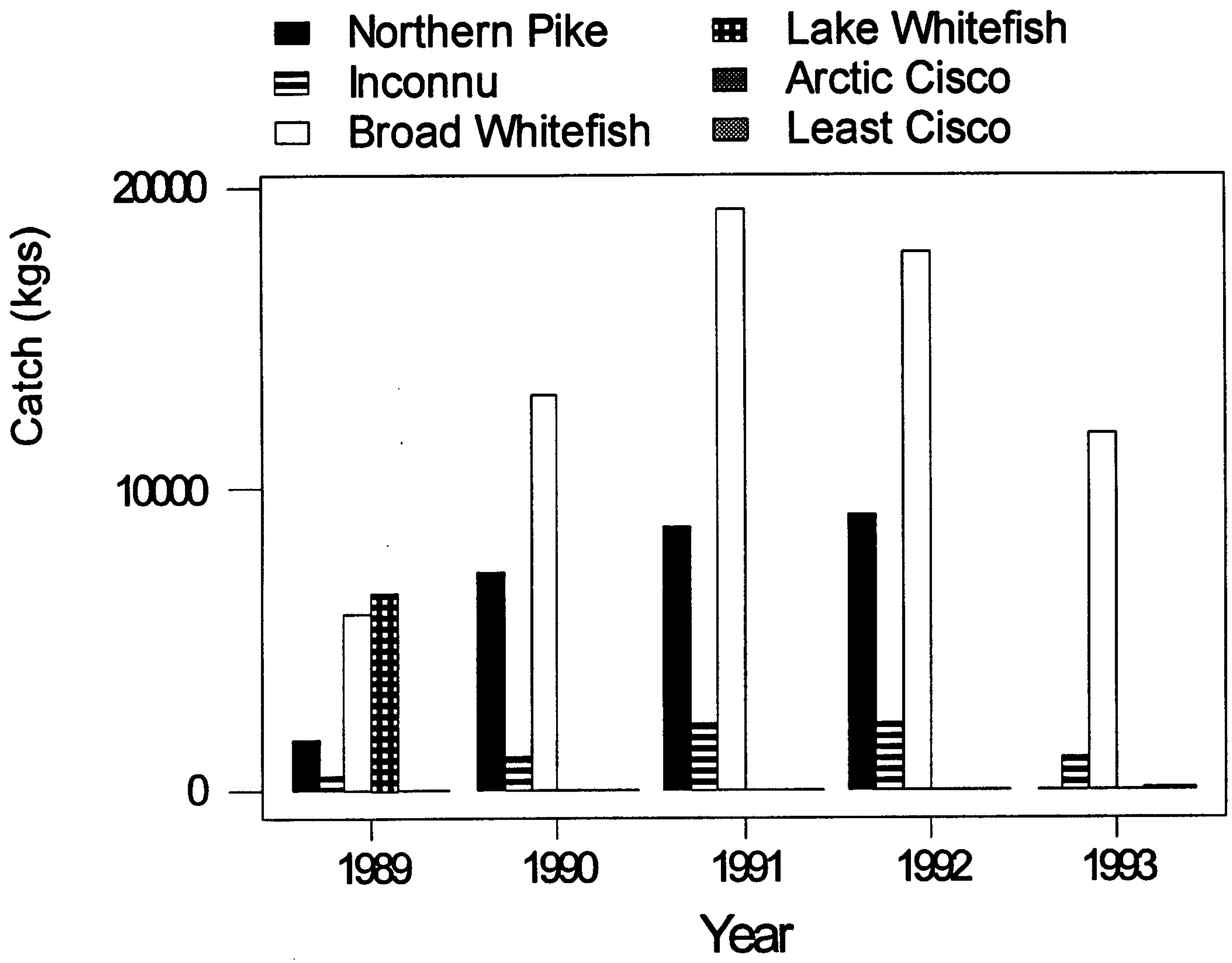

Figure 1. Catch by species in exploratory fishery in Mackenzie Delta.

ROUND TABLE DISCUSSION

Don Dowler: I've never been very good at speeches or public speaking. I like to get half a dozen guys in the corner and then I can convince them, but this is a pretty awesome audience and so I'm going to read from some of my notes and I hope you'll bear with me.

This two day workshop is more or less the result of a one-time funded study. The study was conducted by DFO's Science group and included traditional knowledge and training of local people and also incorporated traditional knowledge as well as historic information. Two years work is certainly not going to answer all the questions, and as we've seen over the last couple of days, it has raised a lot more questions. But, I think it's a significant start in what we're trying to do which is develop a fishing plan for the Mackenzie River. The information provided here over the last two days has I'm sure made everyone aware that there's a lot of parts to the puzzle that are still missing. It's pretty evident, too, that we're going to need lots of funding to answer some of these remaining questions. It's also evident that money's going to be harder to find. If this happens, I think we should all try to at least accomplish and to develop where necessary and certainly maintain it - a basic monitoring program to keep records of how many fish are caught. Harvest studies are extremely important and this sort of activity can mostly be done by local people. I think it's of particular importance that this is also done by Gwich'in and the Sahtu people. I think it's safe to say that the broad whitefish that we've been talking about in the Mackenzie River system are stocks that are shared by people in the Inuvialuit and the Gwich'in and the Sahtu areas. That, to me, is not a serious problem as long as people are willing to sit together and to talk and develop a cooperative, co-management fishing plan for the Mackenzie River fishery. The information we have heard over the past couple of days, which certainly included a lot of traditional knowledge, in my opinion has clearly determined that scientific research and biological work by itself can't answer all the questions. And, of course, the traditional knowledge and historic knowledge has shown that in the past there's been a lot more fish harvested than are harvested now. It's probably safe to say that there's room for some expansion and development in the Mackenzie River fishery as long as it's done carefully and includes input from everybody. By that, I mean starting right with the community fisherman, the scientific experts and the fishery managers. I'll say a little bit about the Inuvialuit Final Agreement (IFA) and particularly concerning fish which we're talking about. The IFA states that the fish and [Fisheries] Joint Management Committee shall be used as a mechanism to facilitate the distribution of harvest limits for harvest assistance purposes among all native people living in the vicinity of the ISR (Inuvialuit Settlement

Region) who traditionally depend upon the resource for food. I don't interpret that as an established law by any means. It's intended to demonstrate that the Inuvialuit as represented in fishery matters by a joint management committee will do everything possible to achieve a fair solution for the managing and harvesting of this shared stock. The question, of course, is where do we go from here and I hope we'll hear from some other people. They said earlier that the main objective of this broad whitefish project and a priority of our committee was to establish a good fishing plan for the Mackenzie River - broad whitefish, in particular. One of the first steps I think has to be to establish formal dialogue and talks between the Sahtu and the Gwich'in and the Inuvialuit and their appropriate wildlife management boards or committees**.** This should result in an agreeable fishing plan for the Mackenzie River fishery. The Minister of Fisheries and Oceans has a responsibility for management, and the Department of Fisheries and Oceans is committed certainly to cooperative management. They have an obligation I think to continue research activity and should certainly be encouraged to do so, hopefully with a lot more of their own money. The Fisheries Joint Management Committee will also continue to make every effort, as we have in the past, to directly involve and train local people in a lot of the aspects of fisheries management. I think I have to say again or emphasize the most important objective for the near future which is to develop a good cooperative fishing plan for the Mackenzie River and the delta, which is certainly not be easy. It's not going to be inexpensive. It's going to cost money. Of course, it's going to have to involve people from Tuktoyaktuk to Fort McPherson and maybe as far as Fort Norman. I really think it can be done. I think that's about all I have to say at this time. I'll turn you back to our moderator.

R. Tallman: I think those are very wise words. I wonder if we could get comments from the audience now and then go to each panel member, but there might be some comments relating to what was just said from the audience.

John Nitsi: My name is John Nitse from Fort McPherson. I wanted to bring up a point I brought up to the Department of Public Works last spring about the amount of shale that they're putting into the Peel River at the ferry landing and also at the Arctic Red ferry landing. I work on the ferry there and tons and tons of that - might as well call it mud. It comes up when it rains. The river rises and all that stuff goes back down and washes away down the river. That causes a lot of concern for fishermen because all the eddies are getting filled with all this mud they're putting in. The other one, again, is about the sewage lagoon in McPherson running into the Peel River. A lot of our people, even younger people now, are starting to die from cancer and we figure from that sewage lagoon running to the river and people are living down below the creek there and drinking the water, eating the fish and we're very concerned about it. Every time we bring it up to the Chief and Council and the Tribal Council and all the government agencies, nobody seems to be listening to us. If that's not the case and we have a chance to go down to Ottawa again and I'll bring it up with the Prime Minister, if I have a chance. I've had enough of going to meetings, and I've been to a lot of bigger meetings than this and they brought it up and nobody seems to care. They seem like they care but after we go from this meeting it's probably going to be the same thing again. I'd like to say thank you for inviting me and Alfred Francis and Johnny Charlie from Fort McPherson. We had a good meeting and hope you take our concerns with you.

R. Felix: First of all I'd like to thank DFO and FJMC for inviting Tuktoyaktuk HTC and members - thank you. My question here is about commercial fishing done here in Inuvik. Why weren’t other communities like Tuktoyaktuk and Aklavik, Fort McPherson, Arctic Red and all these other communities that weren't involved this year?

R. Tallman: All of these groups should be communicating with each other. As to why we developed a program with the Inuvik HTC: the Inuvik HTC has taken an initiative here and developed a project and brought it up through the process.

Ron Felix: This is part of what I'm talking about when I say a fishing plan involving everybody. These things are just getting started. In the future if people sit down and talk together and iron things out and share the stock. Because it is a shared stock, those are the kinds of things you can work out.

Billy Day: We've tried to talk to people over the years and our fishing project has lasted five years as a test fishery. Although we're able to sell the fish commercially, at the test program we were funded through economic development and actually we worked on this as a hunters and trappers committee for about three years before we got it started. We worked both with economic development and the Department of Fisheries and Oceans to make sure that when we were doing this test program that the Department of Fisheries and Oceans and FJMC would be involved so as much scientific knowledge could be taken from the whitefish as possible. It was a long, drawn out process and I think when you talk about why the other communities were not involved - we put a lot of effort in it to get it started up here within our area. There was no reason why any other communities could not have devised the same type of project to work on.

Ron Allen: During the different times of the year when you submit proposals to do the test fisheries, we seek letters of support from the HTCs the Aklavik and Inuvik and also the renewable resource councils on the side of the settlement region. It also goes to the game council so it's not like people don’t know about the proposal. The information is there.

R. Felix: I've been on the hunters and trappers board for two years and not once did we ever get a letter from DFO or from the Inuvik HTC.

R. Tallman: I think that maybe part of it is that what is presented here is to show the interconnectedness between regions on this issue. When this project was conceived not all that information was available. We have a kind of fresh start here. So, it would be natural for each community to develop something and it wouldn't be seen as such a global unified thing. I don't know all the historical details - but it strikes me, from here on you have a very good model to develop projects. These fellows have done a lot of work and you could pursue it.

Ron Allen: Just a little further comment on that. I think some of the terms we use are confusing and people get the wrong impression. As Billy said this fishery that has been going on in Inuvik now for what - five years now, is a test fishery. I guess the most important part of it is to explore the markets, whether there's going to be good markets for these fish. It's not a big deal. It's not a big fishery. It's coming to the end of the test fishery. Whatever happens in the future will fit into this fishing plan that we're talking about. Everybody's going to be involved in that. So, down the road I'm sure it will work out to everybody's benefit and satisfaction.

Joe Benoit: I guess sitting back and watching through the workshop is an eye-opener. I have heard a number of good things. I guess my concern would be that everyone mentioned that it's a shared stock amongst other things. It is important that if we continue to utilize that stock that we make our best efforts for the communities and government agencies and other agencies to communicate as best they can. I have not been in an official capacity for very long. Now that I'm there it's my turn to kick up as much dust as I can so I guess what I'm saying is that if organizations have the chance to communicate and provide their decisions then they should also be able to sit down at a table and look at each other and say this is what I think, without worrying about backlash from other people and community and other organizations. We've come to a point where it has to be written. If you're going to tell me something, I can ignore it; but if I see it on paper then I have to react. I'm sure that within the next few months that it's going to be the same further on up the river and then within a few years further on up the river. With all these cumulative impacts that's being mentioned and then you talk about a test fishery, there are chances that this test fishery isn't going to last very long if cumulative impacts continue. So, I guess the point I was trying to make earlier was that if you want to continue to utilize something that we have now but is threatened from elsewhere then there's got to be a better attempt at unifying the voice. If we were to do that why stop up the river. We have legislation that gives us all kinds of powers and all kinds of abilities. Now if you scale all that back down to the individual at the community, he should be able to come into my office and say - this is not right. Can you help? And I should be able to say, yes I can. Now during the past three years things have gone on that didn't seem appropriate - that didn't fit the time or the day and those are things in the past and we won't dwell on them. I firmly believe that members of your HTCs and your game councils should take a moment of their time to provide input, whether it's verbal or not or otherwise. I guess I'm being an advocate of working together - there's got to be better communication. We all have instant communication now. I've got a FAX machine that's three steps away from my office so all it is knowing what my number is and letting me know what your concerns are. I know I can do the same with Don and Ron. I just want to leave you that opinion.

R. Tallman: Any other comments? What I'd like to do now is have comments from our elders from the three communities about how things have gone and where they think things might go from here, and anything they wish to mention regarding this event. So comments from Jim Perrault and the Sahtu, please.

Jim Perrault: Thanks for a good meeting about fish. It's important for us because we're all fishing in Good Hope and down here too. In the past I went to Ottawa to get money with two doctors [scientists]. We made very short comments. The first time it was a long process and we worked at it and worked at it – wrote five, six or seven letters. The one word that makes it really heard is 'health'. The federal government is looking at the health of the people. So for one word [health] - they [gave] money. So we can do the research and we can look at the fish and how it's happened to the fish. It's not only whitefish but loch too but it's really bad for some of them. So, we send out my daughter - 12th grade – we sent her to Ottawa – to study all the water – whitefish, loch, jackfish - any kind of fish and beaver, rats and then we tell them to study that. Then she came back and tells us what signs to look for if the fish is bad.

Don Dowler: Jim related a story to me at coffee time that was interesting about a couple of tagged fish that he found. Could Jim just tell the audience about that, please.

Jim Perrault: First, there's some fish - we Indian people - we live with the animals and even fish – we know what they are doing. We all know that the Mackenzie River fish are travelling fish. Colville Lake has one little spot - good for whitefish! If I take that whitefish and put it in the river, it's not going to travel. Oh he said "you guys I am not going to travel now." "I'm going to stay in the creek". That's what he might say. Just like ducks, too. So, it's the same thing under water - the same thing. The Mackenzie fish is travelling. One time I was fishing about a mile up river from Good Hope. Then I caught the herring fish - small little fish and then you got a tag on his back. It [the tag] came from Vancouver. He got a big lump on his back because the wire was too tight - big lump behind his back. It was all red. Maybe he traveled all along Alaska and then come up river. You see that it is a traveling fish. And then there's the jack fish. The local fish lake is about twenty miles from the river, but there's a creek going to it. And then there was a guy named Dominique fishing there and then he caught jackfish. He caught one with a tag on his back. That tag come from Yellowknife. Maybe he comes down the river. This is how the fish get traveling but some fish really travel a long way.

R. Tallman: I'd like to ask Alfred Francis to speak.

Alfred Francis: I'm not going to say too much but, I think this a really good meeting we had and in the future we should just get together like this and talk about fish. More meetings like this together would be better. Me - I've never been to school and I don't know too much, but I know quite a bit on the land side. I think there was a meeting we had not too long ago - there was me and John Nitse and a bunch of us. They brought us in for RRC council and as soon as they got us in there and started traveling around to meetings like this. That's all I wanted to say - we should have more meetings like this. It would be good for us and I hear lots of people ask questions, which is really good to hear. I want to thank everybody who has come to this meeting. It was a good feast and dance. One thing was - I had no fiddle. When I see a crowd like this, I get kind of nervous. I go to Fairbanks for music festival. Last year November I was there and didn't even know who I was facing 3,000 and then when I got home I got nervous. Thanks for a good meeting and I learned quite a bit.

R. Tallman: I would like to pass things on to Billy Day.

Billy Day: Thank you, Ross. I have a few comments I'd like to make. First, I was thinking of Columbus who discovered North America just a little over 500 years ago but after he discovered North America it seemed it took many, many years that we were finally discovered way back up north here. I have made comments many times about my belief that the people in the North here are the best conservationists in the world because people many years ago - that's all they had and they had to make sure that they had to conserve and look after their wildlife and everything. In listening to elders talk my father in law was born sometime in the early 1880's and up until the 1950's he used to make his own fishnets. I watched him many times. He told me that when he was a little boy he learned that from his father who taught him how to make fishnets and his grandfather before him. They have been used for many years. We even have a song and dance which we did last night. It was a song made up by person on the seas. It was made up in a small community or a camp, and they were running out of food so he was going out to set the sea net. Because he had no food and he's telling the story and he set the net - he chisels a hole in the ice and sets his net. He wanders around for awhile and looks and he caught a seal and he talks about how happy everybody will be back at the camp because he's bringing home fresh meat for them. Today no one would know who made up the song, but these things go back and back and it was a part of communication and passing on history to people. If the people around here had not been such good conservationists and had not been able to look after their animals - and not only make sure that they're here today but also tomorrow - all the biologists and scientists may not have been able to find fish in any of the lakes. I feel this went really well, but I'm still just a bit disappointed that people can't come out and tell us how many fish we have exactly. I know this is a real problem and maybe some day we will know, but I was directed to a report from 1993 and graphs here show fish data. I have one comment on the test fishery. We have four reports out for the last four years, and Joey can correct me if I'm wrong, but we have been sending out copies of these reports from the trappers committee and maybe when you go back to your community you could check and see if you do have these reports. The fishery is not run by the hunters and trappers committee now. It's run by our Ummarmiut Development Corporation. I'm sure that if you got in touch with Joey or Danny Lennie who is the chairman of their board he could certainly supply you with copies of our reports. We've had good attendance and people seem to be very interested.

R. Tallman: There are other members of the panel who might like to comment. Richard Binder. Would you like to come up?

Richard Binder: Thank you. I guess I'm the youngest elder here. I would like to apologize for not being here for most of the day. We had some other matters that we had to take care of. Before I came down I spoke with Andy Carpenter and he also would like to apologize and wishes he would have been able to be here. On behalf of the [Inuviauit] Game Council I would like to thank the participants from the various communities, especially the elders who passed on so much valuable information. I would also like to thank the organizers of FJMC and the Fisheries and Oceans and those that brought the scientific data to this group. We'll all be able to go back with a little more knowledge. I know I will. Unfortunately not all the questions were answered, but in time those answers will come. I know when I go down to my whale camp this summer and I'm out checking my nets, I'm going to be a little more observant and watching for various signs. I want to beat Billy Day in locating the spawning area back behind the camp here. So, I'm going to be looking for things like that. We have to go back and talk about how important the resource is to us, the things that might affect the resource, and we must make a conscious effort to protect the habitat of the fish. With that I'd like to thank everyone again and I hope we'll be able to do this again someday.

Ron Allen: I'm not an elder, but some mornings when I drag myself out of bed I think that I may be. It's been a very good couple of days. I'd like to ask everybody to think about some of the issues that still face us all in developing a management plan and management system. I want to mention a few of those items and ask you to take them away and think about them. Everybody that's involved in creating that plan is going to need all the advice that they can get. We're facing a lack of information in some areas. That is definitely an issue. We're going to have to make decisions without the complete picture. We don't know how many fish we've got in the whole river. We don't know where all the spawning beds might be - Richard will solve that one for us shortly. There may be some other gaps in this type of information. So we're going to have to deal with that fact - that we don't know everything about everything. We do have a lot of pieces that we can put together and use and make decisions on those. How do we deal with the fact that we don't know certain other aspects? Also we have a very complex regulatory environment. There's a variety of regulations that apply to the situation, the Fisheries Act and related regulations, several land claims in effect and those prescribe certain obligations to government and rights and privileges to various people, and those vary slightly from place to place on the river. We need to keep those in mind when we make decisions and make sure they fit those regulatory schemes as best we can or make what adjustments are necessary. That will impact on how management occurs and what decisions might be made. There will be a question of setting priorities for the available resources. Meetings like this are very good but they cost money. Money to do monitoring of harvest - money to bring people together to communicate, and as we all heard people say over and over that it is necessary that we communicate up and down the river. All this will take funds and those are going to be somewhat limited. We have to decide what's the most important aspects that needs to be done and make those kinds of decisions. There is the possibility of some competing interests. By that I mean - we need to be in a situation where we're talking about industrial development, competing with the fishery and expansion of communities and all the things that involves. We may be talking again about limited resources. Two of three communities want to get into commercial fisheries and they want to build a fish plant and there probably won't be funding available. How do you resolve those kinds of conflicting interest? We may run into situations there and definitely need to deal with those. I think that everybody agrees that the subsistence fishery is of utmost importance. It will take top priority, but later down the line there may be competing interests. There's still the issue of traditional knowledge, which has certainly made some progress in the last few years but in marrying those kind of sources of knowledge in the past sometimes they certainly need a marriage counselor. I think we've made some progress there and counseling has paid off but there's still a requirement to integrate knowledge that is available. There is also a requirement to integrate knowledge that may be available in different places and held by different groups of people. The Mackenzie River is a very long, large river and there's knowledge up and down the river that maybe isn't readily accessible to any one group or person. You may be faced with trying to draw some of those knowledge, bases and sources together. Technological advancements that occur quite often will change a fishery. Everywhere else in the country we've seen that happen. It happened to a certain extent in this part of the word with the advent of monofilament nets, for example, and that type of thing, that impacted on the fishery. I think we may see further technological advances or changes which would impact on how people fish and how efficient they are at fishing and so on. The other thing that would relate to that would be that in a commercial fishery if you have to buy a machine that will process fish very efficiently and if that machine costs a million dollars you have to put a lot of fish through to make that thing pay. So even though it's very, very efficient and if you were to run it at that scale maybe your fishery would pay for itself. Can you really afford to do that or should you maybe look at different technology and do a lot more by hand. So there may be those kinds of decisions to make. The political and environmental climate is going to impact on certain things as was mentioned the other day. It's quite possible that animal rights groups may have some kind of impact politically upon how fish are treated, how they are caught, how they are killed, and how they are handled. The last thing I'd like to mention are the environmentally related issues. There may be dangers from up river in terms of water-borne pollutants or factors. We may have situations where things will change in terms of the geography. In the Tuktoyaktuk area, for example, there has been a lot of erosion over there in the last few years; gravel removal, maybe one cause or issue related to that. So it would be those kind of habitat changes or environmental issues that will have to be looked at as well. Those are some of the issues that I'd like people to go away and think about and if there are opportunities to make suggestions or get those people involved in developing a plan; please bring those ideas back into the various groups that are working on this. Again, thank you very much. It's very nice to see this many different groups of people together at one place discussing a common interest. It would appear that the will is there to do a plan and develop an overall global approach to the situation. That's very encouraging and I'm very glad to have been here and participated in this. Thank you very much.

Don Dowler: I guess it's just about time to wind it up. Certainly the Fishery Joint Management Committee is privileged to have been co-sponsors of the workshop along with DFO and I think we were particularly pleased with the number of people in the audience and their participation in the meeting. Of course, the representatives from the Gwich'in and Sahtu areas were certainly welcome. It's really unfortunate that our chairman, Bob Bell and also Alec Aviagana couldn't be here. They are very important and a key part of our committee and I'm sure that they both feel quite badly that they couldn't be here. However, Pat Ekpakolak from Holman, a member of our committee, is here and of course Mike's here and everybody knows I'm here. I've talked enough. There's certainly a lot of people to thank for their contribution to this workshop. Of course, DFO and the scientists that are here I think have done a first class job with the posters and have presented their talks in pretty good English. Talking about English and dialects - there's a lot of dialects even in the north. Scientists have their own dialect. Sometimes it gets so bad they even fight amongst themselves. I think in this case, they've really done well. The posters that you see here are going to remain here for some time. We're going to try and put them up in the windows here and they can also be made available for other communities, if they have an interest in them sometime later on. The feast and the party and the drum dance was better than first class. It was just great. There will also be a summary available of these proceedings available to anyone that wants it. And, of course, we've got lots of handouts and reports available and I'd certainly encourage people to make use of them. I certainly don't want to forget to thank our committee's right hand man, Matt Stabler, for his contribution in organizing and coordinating this workshop. He did a real good job of it. I guess over the past thirty years or so I've attended a lot of meetings and workshops in the north and I think this is one of the best ones. I'm sort of privileged, too, to be sitting at this table with the elders, except this guy next to me. I think I'm an elder. Billy Day doesn't agree but I'm older than him. He hasn't really accepted that fact yet. If I stay around long enough, he will. I think, again, I just want to thank everybody for coming and participating and may the good Lord look favorably upon all of us and our future tasks. Thank you very much.

R. Tallman: I'd like to thank everyone here and must give recognition to one other fellow, Fernand Saurette sitting beside the projector who has been my helper through all of this. So, for myself, - thank you all for coming - all groups. It's been a great experience.

LIST OF POSTERS

Babaluk, J. and R. Wastle. Broad Whitefish Age Determination.

Babaluk, J., R. Wastle, M. Treble, F. Saurette, and R. Tallman. Broad Whitefish T-bar Tagging.

Chang-Kue, K. and E. Jessop. Broad Whitefish Radio Tagging.

Dick, T. and A. Choudhury. Fish Parasites in the Canadian Arctic.

Dick, T. and A. Choudhury. Life Cycles of Parasites of Commercial and Medical Importance.

Gyselman, E. and J. Jorgenson. Using Hydroacoustics to Count Fish.

Johnson, J., T. Carmichael, and J. Reist. Stock Identification of Broad Whitefish.

Reist, J. Scarring in Whitefish in the Western Arctic.

Tallman, R. Outline of Plan for the Broad Whitefish Project in the Mackenzie River Delta Area:
  - Part 1 The Problem,
  - Part 2 So What to do?

Tallman, R., D. Chudobiak, and J. Reist. Broad Whitefish Life History.

Thera, T. and R. Tallman. How Do We Know How Many Fish There Are?

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