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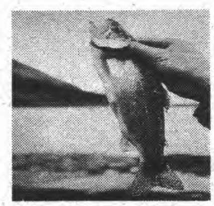
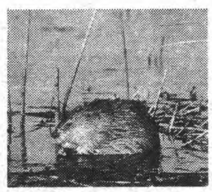
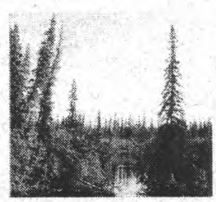


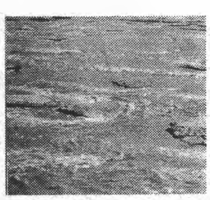





NORTHERN RIVER BASINS STUDY PROJECT REPORT NO. 147

FISH DISTRIBUTION, MOVEMENT AND GROSS EXTERNAL PATHOLOGY INFORMATION FOR THE PEACE, ATHABASCA AND SLAVE RIVER BASINS



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Prepared for the
Northern River Basins Study
under Project 5324-E1

by

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PREFACE:

The Northern River Basins Study was initiated through the "Canada-Alberta-Northwest Territories Agreement Respecting the Peace-Athabasca-Slave River Basin Study, Phase II - Technical Studies" which was signed September 27, 1991. The purpose of the Study is to understand and characterize the cumulative effects of development on the water and aquatic environment of the Study Area by coordinating with existing programs and undertaking appropriate new technical studies.

This publication reports the method and findings of particular work conducted as part of the Northern River Basins Study. As such, the work was governed by a specific terms of reference and is expected to contribute information about the Study Area within the context of the overall study as described by the Study Final Report. This report has been reviewed by the Study Science Advisory Committee in regards to scientific content and has been approved by the Study Board of Directors for public release.

It is explicit in the objectives of the Study to report the results of technical work regularly to the public. This objective is served by distributing project reports to an extensive network of libraries, agencies, organizations and interested individuals and by granting universal permission to reproduce the material.

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Whereas the above publication is the result of a project conducted under the Northern River Basins Study and the terms of reference for that project are deemed to be fulfilled,
IT IS THEREFORE REQUESTED BY THE STUDY OFFICE THAT;
this publication be subjected to proper and responsible review and be considered for release to the public.

F. J. Wrona — 6 June 96
(Dr. Fred J. Wrona, Science Director) (Date)

Whereas it is an explicit term of reference of the Science Advisory Committee "to review, for scientific content, material for publication by the Board",
IT IS HERE ADVISED BY THE SCIENCE ADVISORY COMMITTEE THAT;
this publication has been reviewed for scientific content and that the scientific practices represented in the report are acceptable given the specific purposes of the project and subject to the field conditions encountered.
SUPPLEMENTAL COMMENTARY HAS BEEN ADDED TO THIS PUBLICATION: [ ] Yes [ ] No

P. A. Larkin — 9 June 96
(Dr. P. A. Larkin, Ph.D., Chair) (Date)

Whereas the Study Board is satisfied that this publication has been reviewed for scientific content and for immediate health implications,
IT IS HERE APPROVED BY THE BOARD OF DIRECTORS THAT;
this publication be released to the public, and that this publication be designated for: **[ ] STANDARD AVAILABILITY [ ] EXPANDED AVAILABILITY**

Lucille Partington — June 6/96
(Lucille Partington, Co-chair) (Date)

Robert McLeod — June 6/96
(Robert McLeod, Co-chair) (Date)

FISH DISTRIBUTION, MOVEMENT AND GROSS PATHOLOGY INFORMATION FOR THE PEACE, ATHABASCA AND SLAVE RIVER BASINS

STUDY PERSPECTIVE

The aquatic environments contained within the Northern River Basins Study area (NRBS) were being described and monitored prior to the onset of the Study. However, disparate information bases and information gaps existed. This made it difficult to understand what was happening to the surface waters and their associated habitats as a result of development activities.

The composition of the fish community and its seasonal use of aquatic habitats for spawning, growth, overwintering and feeding can be important indicators for assessing the health of the Peace, Athabasca and Slave rivers aquatic ecosystem. The extent to which these uses are affected by existing development is a major area of interest for the Northern River Basins Study (NRBS).

One of the objectives of NRBS was to gather together existing information on fish to assist in the evaluation of effects from development. Investigations of fish population dynamics was beyond the scope of the Study. However, emphasis was directed at gathering more information on fish distribution, movement and habitat utilization. As a consequence of these investigations, supplemental material was gathered including information on the incidence of fish abnormalities.

Related Study Questions

6) What is the distribution and movement of fish species in the watershed of the Peace, Athabasca and Slave river? Where and when are they most likely to be exposed to changes in water quality and where are their important habitats?

10) How does and how could river flow regulation impact the aquatic ecosystem?

14) What long term monitoring programs and predictive models are required to provide an ongoing assessment of the state of the aquatic ecosystems. These programs must ensure that all stake holders hove the opportunity for input.

This report presents the findings of the various field and laboratory projects as they relate to fish distribution, movement, habitat utilization and gross pathology.

In addition to describing the improvements made to the general understanding of the composition and distribution of fish species and their movements, recommendations are made for more detailed analysis of existing information. There is need for a long-term, periodic monitoring program to follow trends in fish population effects and specific work directed at fish movement and health. Analysis of 23,000 fish pathology records indicate that the overall incidence of fish abnormality is less than 1% basin wide. But occasional, high frequencies of pathological abnormalities do occur. These higher incidences of abnormalities generally appear in fish sampled near pulp mill effluents. Results in the Upper Athabasca River suggest this specific area needs more detailed study.

REPORT SUMMARY

The Northern River Basins Study board asked the following three questions that guided the scientific studies of fish within the Food Chain Component of the study:

1a. How has the aquatic ecosystem including fish and/or other aquatic organisms been affected by exposure to organochlorines or other compounds?

6. What is the distribution and movement of fish species in the watersheds of the Peace, Athabasca and Slave Rivers? Where and when are they most likely to be exposed to changes in water quality and where are their important habitats?

8. Recognizing that people drink water and eat fish from these river systems, what is the current concentration of contaminants in water and edible fish and how are these levels changing through time and by location?

The Northern River Basins Study placed special emphasis on fish in its efforts to evaluate the effects of development on the basins. Fish provide food, cash incomes and recreational benefits to visitors and residents of the northern river basins. In addition, because of their wide distribution and movements in the basins and their key positions in food webs, they can give indications of the health of the aquatic ecosystem.

It was decided early in the Northern River Basins Study, at the advice of the Science Advisory Committee to the board, that the Food Chain Component would not conduct studies to determine the population dynamics of fish. These were agreed to be too complex, time-consuming and costly to be effectively addressed within the scope of the study. Instead, the study incorporated its interest in fish in an ecosystem approach, linked closely to other study components investigating the physical, biological, chemical, resource use and traditional knowledge aspects of the aquatic ecosystems in the basins.

In adopting an integrated study component design and an ecosystem approach for the Northern River Basins Study, the study board addressed information needs about fish in several ways. First, they recognized a need for information about the distribution, movement and important habitats of fish. Study board question number six directed us to implement investigations to describe these basic elements of fish natural history in the basins to determine where and when water quality changes are likely to affect fish. Second, the board asked in question number 1-a how fish are affected by selected contaminants introduced into the rivers from industrial and municipal sources. Question number eight directly addresses the implications of contaminant effects in fish by seeking information about the accumulation of these compounds in edible fish flesh and how these are changing during the course of the study and over the area of the Northern River Basins.

Food Chain Component scientists conducted a series of field and laboratory investigations aimed mainly at responding to question number six, relating to distribution, movement and important habitats of fish. Nearly all field studies of fish conducted during the course of the study also provided samples of fish for contaminant analyses in response to question number eight. Food chain studies were conducted to determine diets of fish, food web relationships between fish and other elements of the food chain in the river basins and to help assess the likelihood and duration of exposure of fish to contaminant sources.

Forty species of fish are found in the Northern River Basins. There are 35 species in the Athabasca River Basin, 36 species in the Peace River Basin, and 25 species in the Slave River Basin within Alberta. The study found no new species but made extensive additions to our knowledge of the distribution of the known species and confirmed the presence of several questionable ones.

Knowledge of fish movements is extremely important for estimating the exposure of fish to contaminant sources. The proportion of time that the fish spend in the vicinity, or within the downstream field, of contaminants is a factor in their uptake and accumulation of the contaminants. We reviewed more than 30 studies of fish movement in the NRBS area and conducted six additional field investigations in our efforts to describe the patterns of fish movement. Important new information was added to our understanding of the seasonal movements of bull trout and of the complex movement patterns of mountain whitefish in the Athabasca River. The Northern River Basins Study confirmed that burbot are widely distributed in the mainstem portions of the rivers during most of the year. They undertake brief seasonal movements during their spawning period in midwinter. A key result of this work was the selection of burbot as a basin-wide ecosystem health indicator species and monitor for changes in contaminant burdens in fish.

Northern River Basins Study data revealed greater concentrations of contaminants in mountain whitefish than longnose sucker and northern pike collected downstream of a pulp mill. These differences in contaminant concentrations may be due to the different feeding habits of mountain whitefish and longnose sucker. Longnose sucker feed along the bed of the river. Mountain whitefish, although also bottom feeders, often feed on organisms drifting through the water column. The accumulation of contaminants in the bodies of these fish may thus be a reflection of their different feeding strategies and different contaminant burdens in these food sources.

The Northern River Basins Study provided an opportunity to collect detailed information about the health of fish. To this end, the study was designed to include specific measures of gross external and internal pathology, including external abnormalities like tumours, lesions, scars or injuries, skin discolouration, deformities and parasites.

Nearly 23 000 fish were examined for gross pathological abnormalities. Mountain whitefish, lake whitefish, northern pike, burbot, longnose suckers and white suckers were the main species for which gross pathological measures were recorded. This is mostly due to their prevalence in the sample collections. It is not necessarily due to their susceptibility to environmental stresses, although this point requires further study.

The larger collections of several thousand fish, taken over long distances of river length, show relatively low overall levels of gross pathology. Pathological abnormalities for most species occurred in less than 1 percent of the fish in these large-scale collections. Occasional, very high frequencies of pathological abnormalities are reported (e.g., 23 of 30 lake whitefish). These may be related to physiological and behavioural responses to spawning. Similarly, suckers (especially longnose suckers) appear to have occasional very high frequencies of pathological abnormalities.

High frequencies of pathological abnormalities also appear in fish sampled near pulp mill effluents. Results in the upper Athabasca River show that detailed pathological studies of fish near pulp mill effluent sources is needed. Two field studies discovered more pathological abnormalities downstream of mill effluent sources than in the remainder of their Athabasca River study sections.

This study has added detail to our knowledge of the fish distribution and movements in the basins. It has added to our knowledge of the spawning, early rearing and overwintering habitat use of several species. Stable isotope work has revealed that much of the food production entering the base of the fish food chain originates from the terrestrial environments of the tributary river systems.

Several recommendations arise from the Food Chain Component studies for monitoring and further research.

- Radio telemetry studies of seasonal life history characteristics, habitat use and exposure to contaminant point sources should be conducted in the Athabasca River with bull trout, mountain whitefish and burbot to determine time and duration of exposure to contaminants.

- The fish inventory database needs to be subjected to detailed analyses to detect species, seasonal and basin specific trends in fish metrics (age, growth, maturity, etc.) that may exist at both the organism and population levels.

- A detailed field analysis of gross pathology should be conducted on the fish species in the upper Athabasca River.

- A long-term, periodic monitoring program should be implemented to follow trends in fish population-level effects of ecosystem change. Fisheries monitoring should include systematic recording and periodic assessment of the occurrence of gross pathology using standardized techniques to assess whether long-term trends in the health of fish are indicated.

- Further stable isotope work is needed for the tributary systems to refine our understanding of food production at the base of the fish portion of the food chain.

- In-situ bioassay studies with eggs of bull trout, mountain whitefish and burbot should be performed at key sites in the Athabasca River. This would allow us to assess the influence of natural conditions and the effects of contaminants and dissolved oxygen variation.

- Bull trout in the Athabasca and Peace Rivers and pygmy whitefish in the Athabasca River deserve additional species specific research and monitoring attention as fish species of concern.

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1.0 INTRODUCTION

The Northern River Basins Study placed special emphasis on fish in its efforts to evaluate the effects of development on the Peace, Athabasca and Slave River basins. Fish provide food, cash incomes and recreational benefits to visitors and residents of the northern river basins. In addition, because of their wide distribution and movements in the basins, and their role in aquatic food chains they can give indications of the health of the aquatic ecosystem.

It was decided early in the Northern River Basin Study, at the advice of the Science Advisory Committee to the board, that the Food Chain Component would not conduct studies to determine the population dynamics of fish. These were agreed to be too complex, time-consuming and costly to be effectively addressed within the scope of the study. Instead, the study incorporated its interest in fish in an ecosystem approach, linked closely to other study components investigating the physical, biological, chemical, resource use and traditional knowledge aspects of the aquatic ecosystems in the basins (Mill and MacLock, 1994). In 1994 the study board decided to launch more detailed work on the fisheries of the Slave River and Slave River Delta in the Northwest Territories. This work, conducted during 1994 and 1995 is written up in greater detail in a separate synthesis report for the Slave River fisheries (Tallman *et al*., 1996). Accordingly, this report addresses mainly the Alberta portions of the NRBS study area.

The fish-related questions posed by the Northern River Basins Study Board are as follows:

1-a *How has the aquatic ecosystem including fish and/or other aquatic organisms been affected by exposure to organochlorines or other compounds?*

6 *What is the distribution and movement of fish species in the watersheds of the Peace, Athabasca and Slave rivers? Where and when are they most likely to be exposed to changes in water quality and where are their important habitats?*

8 *Recognizing that people drink water and eat fish from these river systems, what is the current concentration of contaminants in water and edible fish and how are these levels changing through time and by location?*

In adopting an integrated study component design and an ecosystem approach for the Northern River Basins Study, the study board addressed information needs about fish in several ways. First, they recognized a need for information about the distribution, movement and important habitats of fish. Study board question number six directed us to implement investigations to describe these basic elements of fish natural history in the basins to determine where and when water quality changes are likely to affect fish. Second, the board asked in question number 1-a how fish are affected by selected contaminants introduced into the rivers from industrial and municipal sources. Question number eight directly addresses the implications of contaminant effects in fish by seeking information about the accumulation of these compounds in edible fish flesh and how these are changing during the course of the study and over the area of the northern river basins.

Food Chain Component scientists conducted a series of field and laboratory investigations aimed mainly at responding to question number six, relating to distribution, movement and important habitats of fish. Nearly all field studies of fish conducted during the course of the study also provided samples of fish for contaminant analyses in response to question number eight. Food chain studies were conducted to determine diets of fish, food web relationships between fish and other elements of the food chain in the river basins and to help assess the likelihood and duration of exposure of fish to contaminant sources.

The major programs that the Food Chain Component conducted to address these questions are:

- Field surveys of fish movement, distribution, habitat and life history in each of the rivers;
- Field surveys and laboratory experiments of food sources and food chain pathways; and
- Measurement of fish health based on frequency of gross external abnormalities.

An extensive bibliographic database was constructed of all the known literature about fish from the basins, including the many reports on tributary rivers and lakes. This work is available as a publication in the Northern River Basins Study report series (Barton and Courtney, 1993).

The Food Chain Component has provided a large, detailed database of information on fish to permit us to assess how fish are affected by contaminants and other basin development. These data are available as a research legacy of the Northern River Basins Study.

1.2 Previous Fisheries Work in the Basins

A great deal of work has been conducted on fish in the northern river basins in the past. Much of this work concentrated on fish in lakes draining into the mainstem rivers and tributaries of the Athabasca, Peace and Slave Rivers. Frequently the work concentrated on species of fish with commercial or recreational value. Seldom were studies conducted that focused on the population of fish, their communities or their place in the aquatic ecosystem. Recent work has been often in response to the need to evaluate the status of fish in the rivers and to assess the impacts of industrial development on them.

Our present understanding of northern rivers fisheries comes from numerous books and reports written by scientists, government employees, consultants and others. Three major sources summarize the work of previous studies up to and including the early 1980's in each of the study area main basins. They are listed below in Table 1. The works for the Athabasca and Peace Rivers were prepared to summarize all available information on fish for river basin planning purposes by the Alberta Government. Dr. Joseph Nelson and Dr. Martin Paetz completed a complete revision of their book ***Fishes of Alberta*** in 1992. This volume describes all of the known fish in Alberta waters, gives general details of their distribution, life histories and uses, and discusses their names and origins.

Table 1. Major River Basin Summary Reports on Fisheries in the NRBS Study Area

Author	Year Written	Title	Coverage
Nelson, J.S. and M.J. Paetz	1992	The Fishes of Alberta	All species known to all waters in the Province of Alberta
Paetz, M.J.	1984	The Fish and Fisheries of the Peace River Basin: Their Status and Environmental Requirements	Peace River and eleven major tributary sub-basins within the Province of Alberta
Wallace, R.R. and P.J. McCart	1984	The Fish and Fisheries of the Athabasca River Basin: Their Status and Environmental Requirements	Athabasca River and ten major tributary sub-basins

Together, these sources are themselves an important synthesis of knowledge. They provide a comprehensive benchmark of fisheries information that the Northern River Basins study is able to expand upon.

The following summaries give a brief overview of these works.

The Fishes of Alberta (Nelson and Paetz, 1992)

This book is a general taxonomic and distribution overview of most of Alberta's fish fauna. It is not, however, intended to be a broad review of the literature. It provides information to identify all known fish species from Alberta, and states generally where they occur.

Before describing individual species, the book discusses a number of special topics: Alberta's river systems, the origins of Alberta's fish fauna, fish classification, and Alberta's fish species and their evolution. The book then presents a key for identifying any specimen to the family level.

For each species the common and scientific names are given, along with a picture. A descriptive section provides information on the general characteristics. Descriptive comments include the colour, body characteristics and size. The "Distribution" section shows both worldwide occurrence and the Alberta range. A section on biology gives information on life history and other aspects. The game fish include a section on "Angling." Lastly, the "Historical Note" section says how the species was first described and other historic or taxonomic information.

The Fish and Fisheries of Athabasca River Basin: Their Status and Environmental Requirements (Wallace and McCart, 1984)

This report was prepared for the Planning Division of Alberta Environment and the Fish and Wildlife Division of Alberta Energy and Natural Resources.[1] The purpose of the report was to summarize all known fisheries data for the Athabasca River basin to help in river basin planning.

The report reviews the current knowledge of the fish ecology and production of the Athabasca River basin up until 1984. The basin is discussed using ten sub-basins, which are grouped under four main headings: Upper Sub-Basins; Lower Sub-Basins; Central Sub-Basins; and Athabasca Sub-Basins. For each of the sub-basins, Wallace and McCart review the river environment (including fish habitat), the fish populations, sport and commercial use of fish, water quality and quantity, environmental problems, data gaps, and fisheries management strategies.

The authors gathered their data from published and unpublished reports. They also interviewed personnel from the Fish and Wildlife Division, Alberta Energy and Natural Resources. Various provincial government departments were their sources for harvest statistics and water quality information.

The Fish and Fisheries of the Peace River Basin: Their Status and Environmental Requirements (Paetz, 1984)

This report is an information document prepared for water management planning in the basin. It is an overview of the existing knowledge of fish and fisheries in the Peace River Basin up to 1984.

The report identifies 11 sub-basins of the Peace River Basin. Paetz identifies fish populations and their characteristics in each of the sub-basins. The report looks at fish species and their relative abundance, habitat conditions, water quality (as related to fish requirements), sport, domestic and commercial use of fish, recreational fishing opportunities, fisheries management objectives, and data gaps.

Fisheries information came from published and unpublished reports, data sheets, and habitat maps. Interviews with fisheries biologists and technicians were another source of information.

2.0 DESCRIPTION OF THE BASINS

The following sections briefly introduce the physical habitat of the study areas referred to in this report and refer to the key literature sources for more detailed information. Information about recreational, commercial and domestic fishing, and important fisheries issues in each of the northern river basins can be found in the Other Uses Component Synthesis Reports (Lyons and MacLock, 1996; MacLock and Thompson, 1996).

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[1]Both of these divisions are currently part of Alberta Environmental Protection.

This part of the report introduces the reaches that are used to describe the Athabasca, Peace and Slave rivers. River reaches are lengths of the river that show similar physical characteristics (eg, gradient, width, bottom materials, bank structure and water quality).

2.1 Description of the Athabasca River

For food chain field studies and collections of fish for laboratory experiments, the Northern River Basins Study divided the Athabasca River into 14 river reaches. These reaches were selected based on differences in channel characteristics, point sources of effluent discharges to the river, and where major tributaries enter the mainstem. These detailed reaches are described in R.L. & L. (1994a, 1994b, 1995). Another important source of further information is Wallace and McCart (1984), which describes the fish habitats in the Athabasca River.

For this synthesis report, the authors have combined the 14 study reaches into fewer sections of river length (Figure 1). These four consolidated reaches reflect administrative boundaries (e.g., Jasper National Park), major barriers to fish movement (e.g., Grand Rapids), similar habitat characteristics, or key environmental influences (e.g., the pulp mills at Hinton, Whitecourt and Athabasca). Each consolidated reach has generally consistent physical characteristics of gradient, width, bottom materials, bank structure and water quality. The consolidation permits a simpler description and understanding of the findings of the study.

2.2 Description of the Peace River

The Northern River Basins Study divided the Peace River into eleven study reaches. The major criterion for assigning these reaches was the channel morphometry. For detailed descriptions of these study reaches, consult Boag (1993) and Hildebrand (1990). Another source of information is Paetz (1984), which describes the fish habitat of the Peace River.

These study reaches have been combined into three consolidated reaches (Figure 1). This combination was based mainly on the physical characteristics of the river (e.g., type of channel, bottom materials, bank habitats) and major barriers to fish movements (eg., Vermilion Chutes).

2.3 Description of the Peace-Athabasca Delta

The Peace-Athabasca Delta is a lowland area of about 3900 km^2. It is located near the west end of Lake Athabasca and is one of the largest freshwater deltas in the world. The delta is mainly formed by the deposition of silt from the Peace, Athabasca and Birch rivers. It consists of mainly flat terrain with active and inactive river channels that meander across the delta, joining the major lakes in the area to Lake Athabasca.

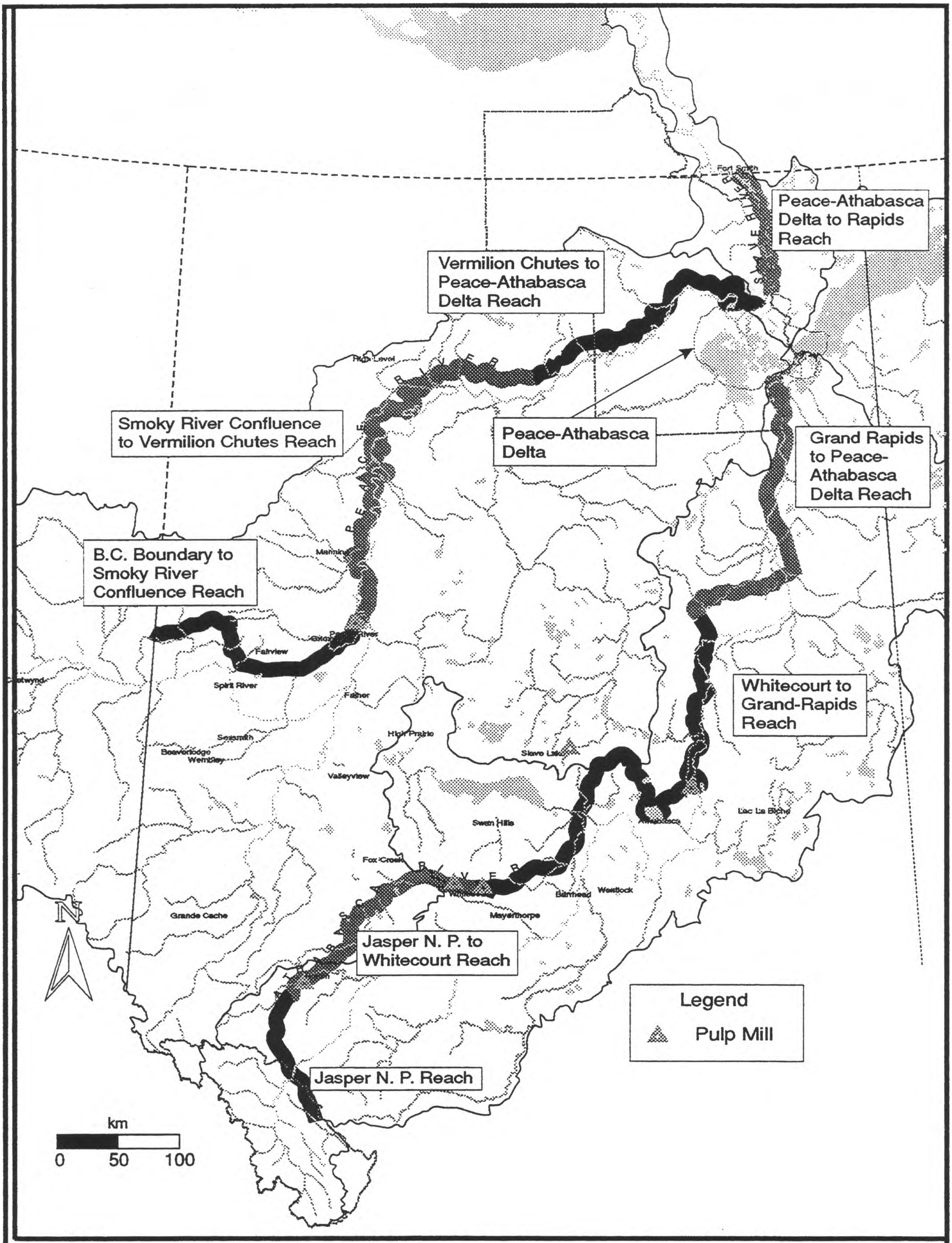

Figure 1. Consolidated River Reaches in the Alberta Portion of the NRBS Area

2.4 Description of Lake Athabasca

Lake Athabasca is about 7770 km^2 in area, with a maximum depth of 124 m and an average depth of 20 m. Flows to the lake come from the Athabasca, Fond du Lac and Birch rivers, and from several lesser streams. Rivière des Rochers and Chenal des Quatre Fourches drain the lake into the Slave River.

The main, eastern basin of the lake is unproductive, because it is deep and cooler than the western basin. However, the lake's western basin (near the Peace-Athabasca Delta) is shallow, more turbid, and more productive.

2.5 Description of the Slave River

This synthesis report addresses one consolidated study reach for the Slave River (Figure 1). This is based on a natural, physical division of the river which happens to coincide with the boundary between Alberta and the Northwest Territories. There is a series of rapids between Fort Fitzgerald and Fort Smith that ends in the Rapids of the Drowned. The rapids provide an effective barrier to the upstream movement of fish. The Slave River fisheries downstream of the rapids, within the Northwest Territories, are reported on by Tallman *et al.* (1996).

2.6 Peace-Athabasca Delta to Rapids Reach (Alberta portion of Slave River)

This reach includes the Slave River from its beginnings at Peace Point to Fort Smith. In this reach, the river flows through low relief muskeg and bedrock. In this reach, the Slave River receives waters from several tributaries—Ryan and Murdock creeks, and La Butte, Hornaday, Bocquene and Dog rivers. The latter three are the largest of the tributaries.

3.0 IDENTIFICATION AND DISTRIBUTION OF FISH SPECIES

Paetz and Nelson (1992) is the authority on fish in Alberta waters. Common English names, scientific names and the most common colloquial names for fish in this report are taken from their book. Their identification of species taxonomy follows the convention of the American Fisheries Society for nomenclature of fish. Abbreviations of fish names used in tables and figures are according to a convention presented by Mackay *et al.* (1990).

The common names of fish tend to differ, depending on language and region. Many residents of the Northern River Basins will no doubt have names for these species that differ from those used in this report. Readers should refer to Paetz and Nelson (1992) and the Traditional Knowledge Component (Flett *et al.*, 1996) synthesis report for the detailed identification of species.

3.1 Fish Occurrence in the Northern River Basins

Forty species of fish are found in the Alberta portion of the Northern River Basins. There are 35 species found in the Athabasca River Basin and 36 species in the Peace River Basin. The Alberta portion of the Slave River Basin is more difficult to characterize according to species occurrence. We have records for 25 species but are able to speculate that another three species probably occur in the Alberta portion of this basin. Tallman *et al.* (1996) record a total of 28 species for the Northwest Territories portion of the Slave River Basin. This includes several additional occurrences such as inconnu *(stenodus* *leucicthys)* and salmon species that are characteristic of the Mackenzie River Basin fish fauna (Tallman *et al.*, 1996).

The study found no new species but made extensive additions to our knowledge of the distribution of the known species and confirmed the presence of several questionable ones. The species found and their occurrence by river basins are shown in Table 2.

Table 2. Fish Species Occurrence in the Northern River Basins

Species ✓ = confirmed * = probable	Abbrev	Athabasca Basin	Peace River Basin	Slave River Basin
Mooneye Family - Hiodontidae				
goldeye *(Hiodon alosoides)*	GOLD	✓	✓	✓
Minnow Family - Cyprinidae				
lake chub *(Couesius plumbeus)*	LKCH	✓	✓	✓
brassy minnow *(Hybognathus hankinsoni)*	BRMN	✓	✓	
pearl dace *(Margariscus margarita)*	PRDC	✓	✓	*
emerald shiner *(Notropis atherinoides)*	EMSH	✓	✓	✓
spottail shiner *(Notropis hudsonius)*	SPSH	✓	✓	✓
northern redbelly dace *(Phoxinus eos)*	NRDC	✓	✓	*
finescale dace *(Phoxinus neogaeus)*	FNDC	✓	✓	
fathead minnow *(Pimephales promelas)*	FTMN	✓	✓	✓
flathead chub *(Platygobio gracilis)*	FLCH	✓	✓	✓
northern squawfish *(Ptychocheilus oregonensis)*	NRSQ		✓	
longnose dace *(Rhinichthys cataractae)*	LNDC	✓	✓	✓
redside shiner *(Richardsonius balteatus)*	RDSH		✓	
Sucker Family - Catostomidae				
longnose sucker *(Catostomus catostomus)*	LNSC	✓	✓	✓
white sucker *(Catostomus commersoni)*	WHSC	✓	✓	✓
largescale sucker *(Catostomus macrocheilus)*	LRSH		✓	
Pike Family - Esocidae				
northern pike *(Esox lucius)*	NRPK	✓	✓	✓
Trout Family - Salmonidae				
cisco, or tullibee *(Coregonus artedi)*	CISC	✓	✓	✓

Species ✓ = confirmed * = probable	Abbrev	Athabasca Basin	Peace River Basin	Slave River Basin
shortjaw cisco *(Coregonus zenithicus)*	SHCS			✓
lake whitefish *(Coregonus clupeaformis)*	LKWH	✓	✓	✓
pygmy whitefish *(Prosopium coulteri)*		✓		
round whitefish *(Prosopium cylindraceum)*		✓		✓
mountain whitefish *(Prosopium williamsoni)*	MNWH	✓	✓	✓
Arctic grayling *(Thymallus arcticus)*	ARGR	✓	✓	*
cutthroat trout *(Oncorhynchus clarki)*	CTTR	✓	✓	
rainbow trout *(Oncorhynchus mykiss)*	RNTR	✓	✓	
brown trout *(Salmo trutta)*	BNTR	✓		
bull trout *(Salvelinus confluentus)*	BLTR	✓	✓	
brook trout *(Salvelinus fontinalis)*	BKTR	✓	✓	
lake trout *(Salvelinus namaycush)*	LKTR	✓	✓	✓
kokanee *(Oncorhynchus nerka)*			✓	
Trout-Perch Family - Percopsidae trout-perch *(Percopsis omiscomaycus)*	TRPR	✓	✓	✓
Cod Family - Gadidae burbot; or maria, ling, loche *(Lota lota)*	BURB	✓	✓	✓
Stickleback Family -Gasterosteidae brook stickleback *(Culaea inconstans)*	BRST	✓	✓	✓
ninespine stickleback *(Pungitius pungitius)*	NNST	✓	✓	✓
Sculpin Family - Cottidae slimy sculpin *(Cottus cognatus)*	SLSC	✓	✓	✓
spoonhead sculpin *(Cottus ricei)*	SPSC	✓	✓	✓
Perch Family - Percidae				
Iowa darter *(Etheostoma exile)*	IWDR	✓	✓	✓
yellow perch *(Perca flavescens)*	YLPR	✓	✓	✓
walleye *(Stizostedion vitreum)*	WALL	✓	✓	✓

Kokanee, found in the Peace River by the study, is noted by Nelson and Paetz (1992) as no longer existing in Alberta. Pygmy whitefish, thought to be rare in the upper Athabasca River drainage (Nelson and Paetz, 1992), was also confirmed. Aside from these observations, the Northern River Basins Study has not resulted in the addition of any species to the list of fish found in these river drainages.

The study has, however, added a great deal of information to the knowledge of the distribution and movement of fish within the drainages. In addition, some useful indicators of relative abundance of fish within reaches of the major drainages have been observed.

3.2 Fish Distribution and Relative Abundance in the Mainstem Rivers

Northern River Basins Study food chain investigations did not include efforts to determine the population sizes of fish species in the study area. The field studies were intended to improve understanding of the distribution of fish in the mainstem rivers of the basins. The following series of maps (Figures 2 to 10) summarize distribution and relative abundance information for those fish species for which the Northern River Basins Study produced substantive data (Boag 1993; R.L.&L. 1994a, 1994b).

The distribution and relative abundance information is shown for the consolidated reaches of the Athabasca, Peace and Slave (Alberta portion) Rivers. These data are indicated in a standard format as catch-per-unit-of-effort (CPUE). While they include data from a wide range of sampling intensities and different times of the year, they give an overview of the relative abundance of species occurring in the mainstem rivers and of the differences in occurrence among the consolidated reaches within them. The species listed in the captions for each consolidated reach occurred in the fish collections for that reach. Catch-per-unit-of-effort figures were calculated for species with sufficient numbers in the catch. The CPUE values are also shown graphically in the figure captions; where several data sets were available the minimum and maximum CPUE values for each species are indicated by different colours in the graph.

Athabasca River electrofishing abundance data show a very strong predominance of mountain whitefish in the catches of the upper and middle consolidated reaches of the river during spring (Fig. 2). The predominance of mountain whitefish in the catch is even greater during fall when this species is aggregated or moving to spawn (Fig. 3). Goldeye and walleye appear in the spring electrofishing catch as seasonally abundant in the lower consolidated reach of the Athabasca River (Fig. 2).

Peace River surveys included beach seining, set lines and gill netting (Figs. 4 to 7). Similarly to the Athabasca River, mountain whitefish are relatively abundant in the upper consolidated reaches with goldeye and walleye appearing in the middle and lower reaches. Longnose and white suckers also figure strongly in the fish samples from the Peace River.

Slave River data show a rather limited frequency of occurrence of fish species but give a more even distribution of relative abundance among the six species shown (Figs. 8 to 10).

4.0 FISH MOVEMENT

The aquatic environment in northern rivers is extremely variable through the annual cycle of seasonal change in temperature, hydrologic regime, turbidity, bed morphology and productivity. Changes within years are often surpassed among years by extreme changes in hydrology and resultant morphology. Consequently, the fish species that live in these aquatic environments are adapted to these extreme environmental fluctuations with life history strategies that permit them to survive seasonal, annual or extreme episodic changes in their environment. A key strategy for many species is extensive movement. Knowledge of these movements, in turn, is extremely important for estimating the exposure of fish to contaminant sources. The proportion of time that the fish spend in the vicinity of, or within the downstream field of, contaminants affects their uptake and accumulation of the contaminants.

We reviewed more than 30 studies of fish movement in the NRBS area and conducted six additional field investigations in our efforts to describe the patterns of fish movement. Fish movement is very difficult to study in large river systems because of technical problems arising from strong current, turbidity and the open-ended nature of the physical boundaries in which the fish are contained. Fish can be very difficult to capture alive, mark, release and then recapture to determine where they have moved.

Important new information was added to our understanding of the seasonal movements of bull trout and of the complex movement patterns of mountain whitefish in the Athabasca River. The Northern River Basin Study confirmed that burbot are relatively sedentary in the mainstem portions of the rivers during most of the year. They undertake brief seasonal movements during their spawning period in midwinter. A key result of this work was the selection of burbot as a basin-wide ecosystem health indicator species and monitor for changes in contaminant burdens in fish.

This section synthesizes the available information on the movements of fish through space and time in the northern river basins. The movement data were collected using two types of studies: fish tagging and radio telemetry. Tagged fish are released and some are later recaptured. The place where they are recaptured, and the timing of the recapture, provide information on movements. Radio telemetry studies are a specialized form of fish tagging. Radio transmitters are attached to fish which are then able to be located at regular intervals using radio receivers. This can provide detailed information on their movements.

In addition, indirect information about movement of smaller fish species was determined by studying the response of two species to pulp mill effluent. Gibbons *et al.* (1995) investigated the responses of spoonhead sculpin and lake chub to mill effluents in the Whitecourt area of the upper Athabasca River. They determined that these 'small' fish species were likely localized in their movements by observing different responses in sampled fish across the width of the river. Fish on the side of the river adjacent to the effluent plume responded differently to fish from the far side of the river; these far side samples were intermediate in response between the near side samples and reference site samples. This study added to our basic knowledge of the biology of these two species and lead to the conclusion that we should consider them as effective sentinel species for monitoring the aquatic effects of pulp mill effluents.

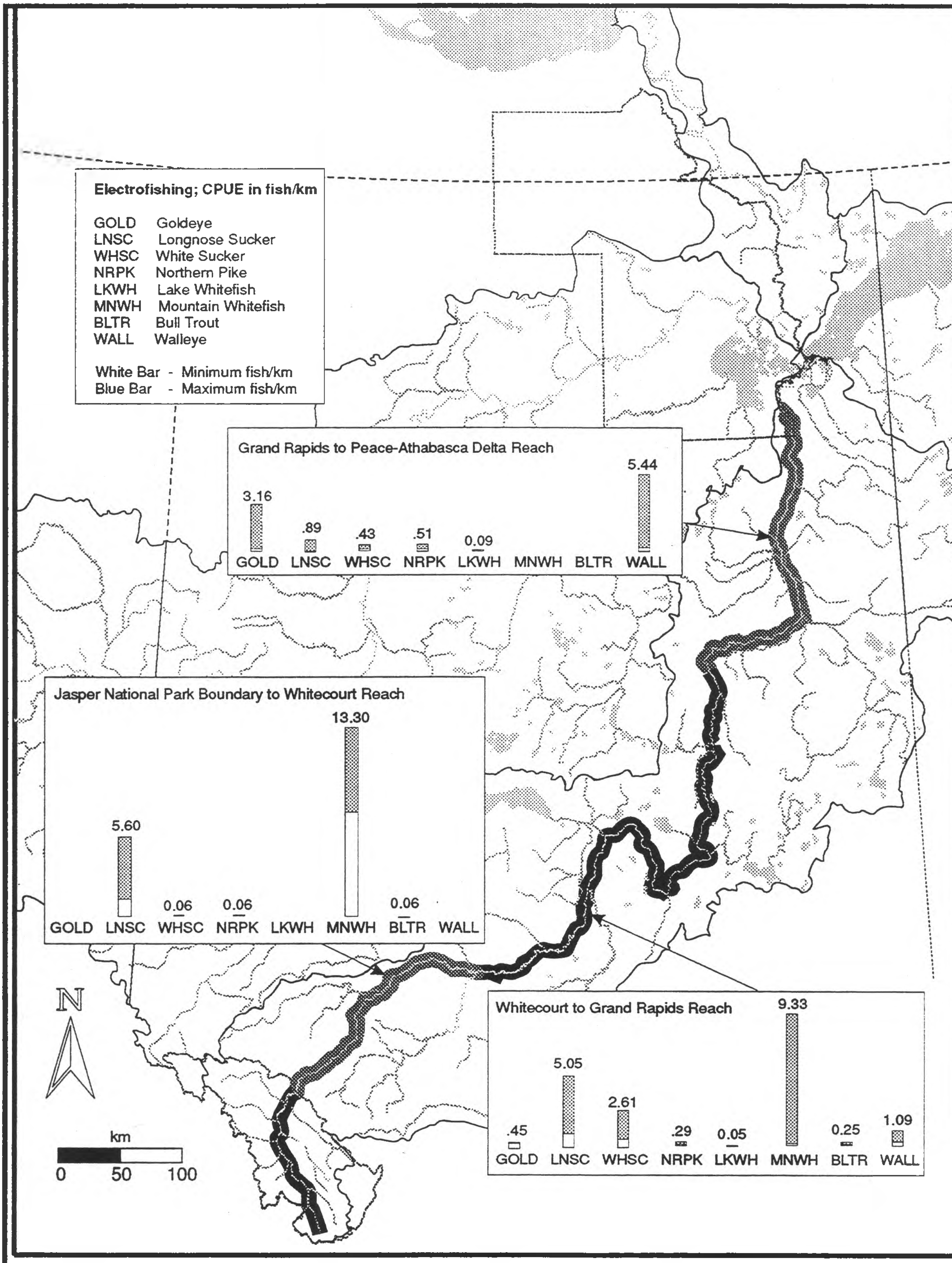

Figure 2. Athabasca River: Distribution and Relative Abundance of Key Fish Species Spring 1992 (Electrofishing Data)

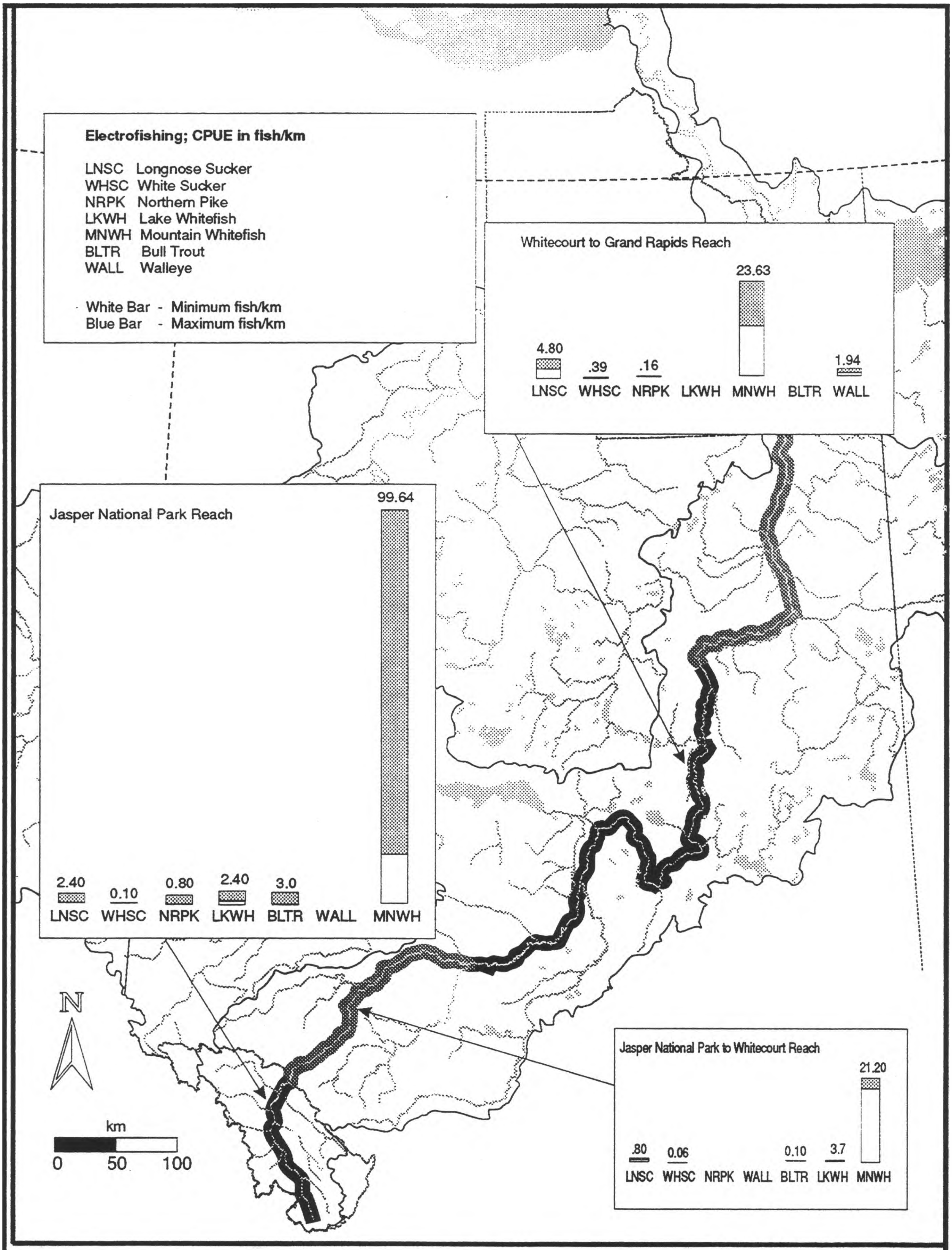

Figure 3. Athabasca River: Distribution and Relative Abundance of Key Fish Species
Fall 1992 - Electrofishing Data

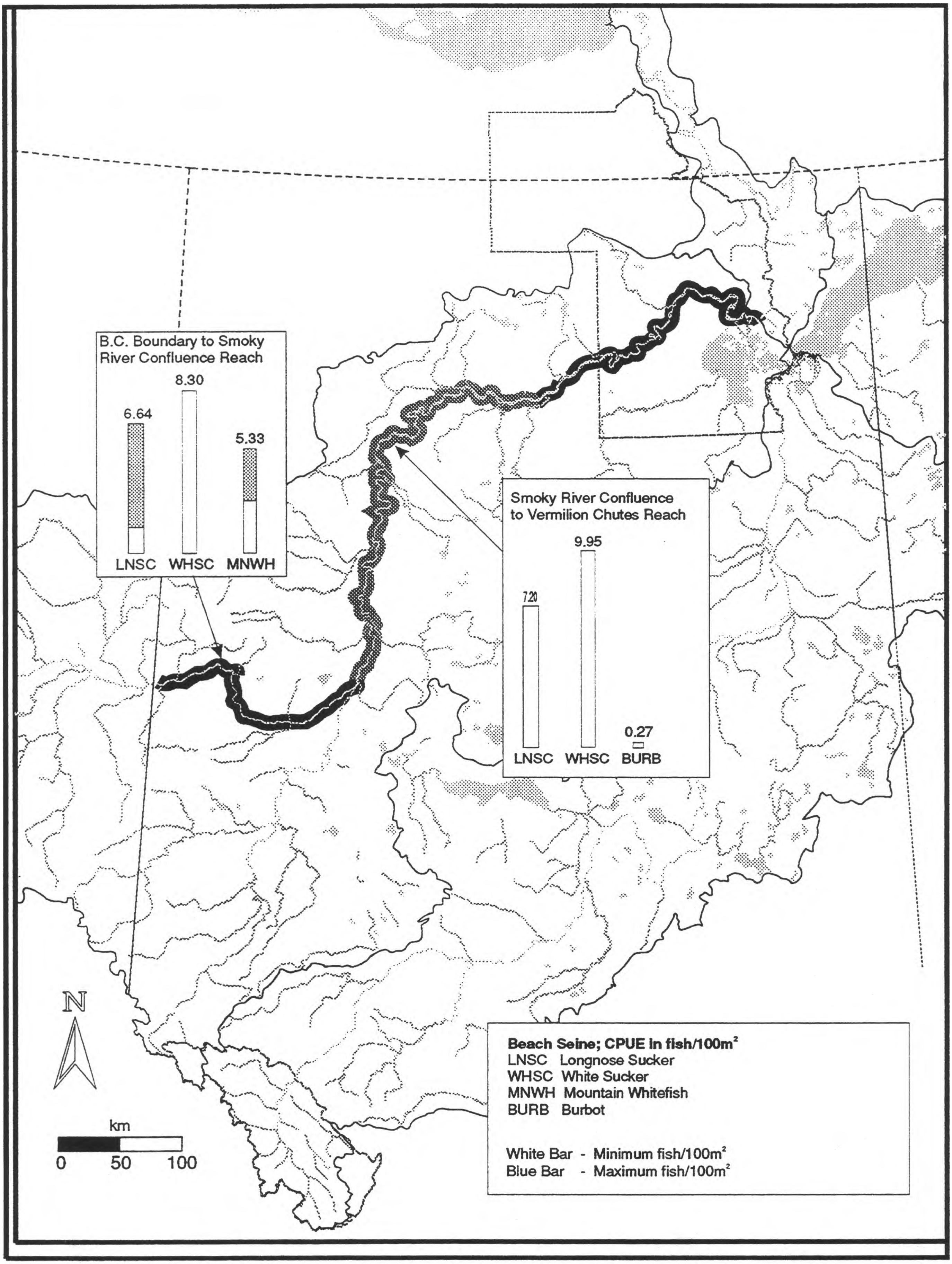

Figure 4. Peace River: Distribution and Relative Abundance of Key Fish Species Spring 1992 - Beach Seine Data

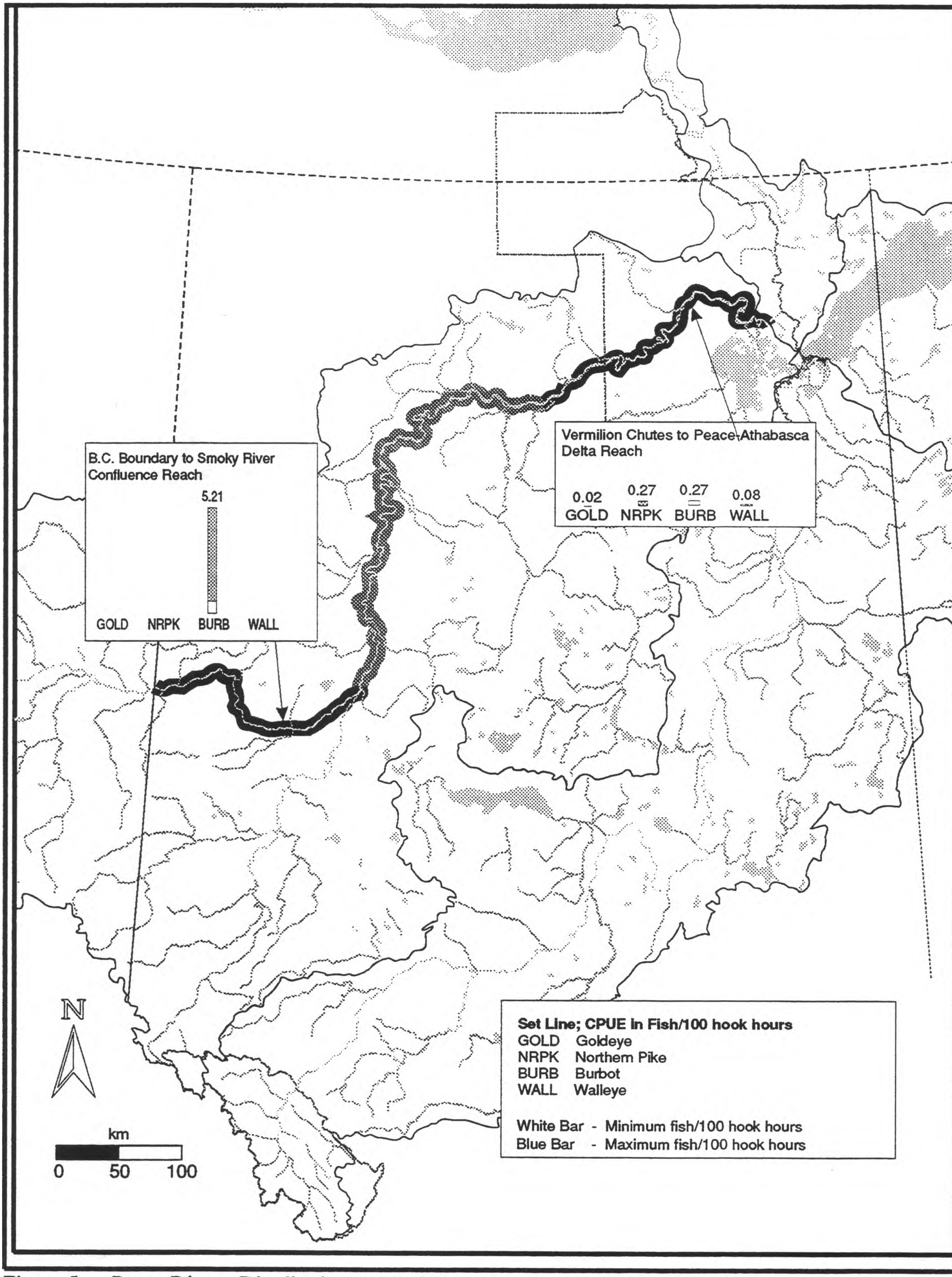

Figure 5. Peace River: Distribution and Relative Abundance of Key Fish Species Spring 1992 - Set Line Data

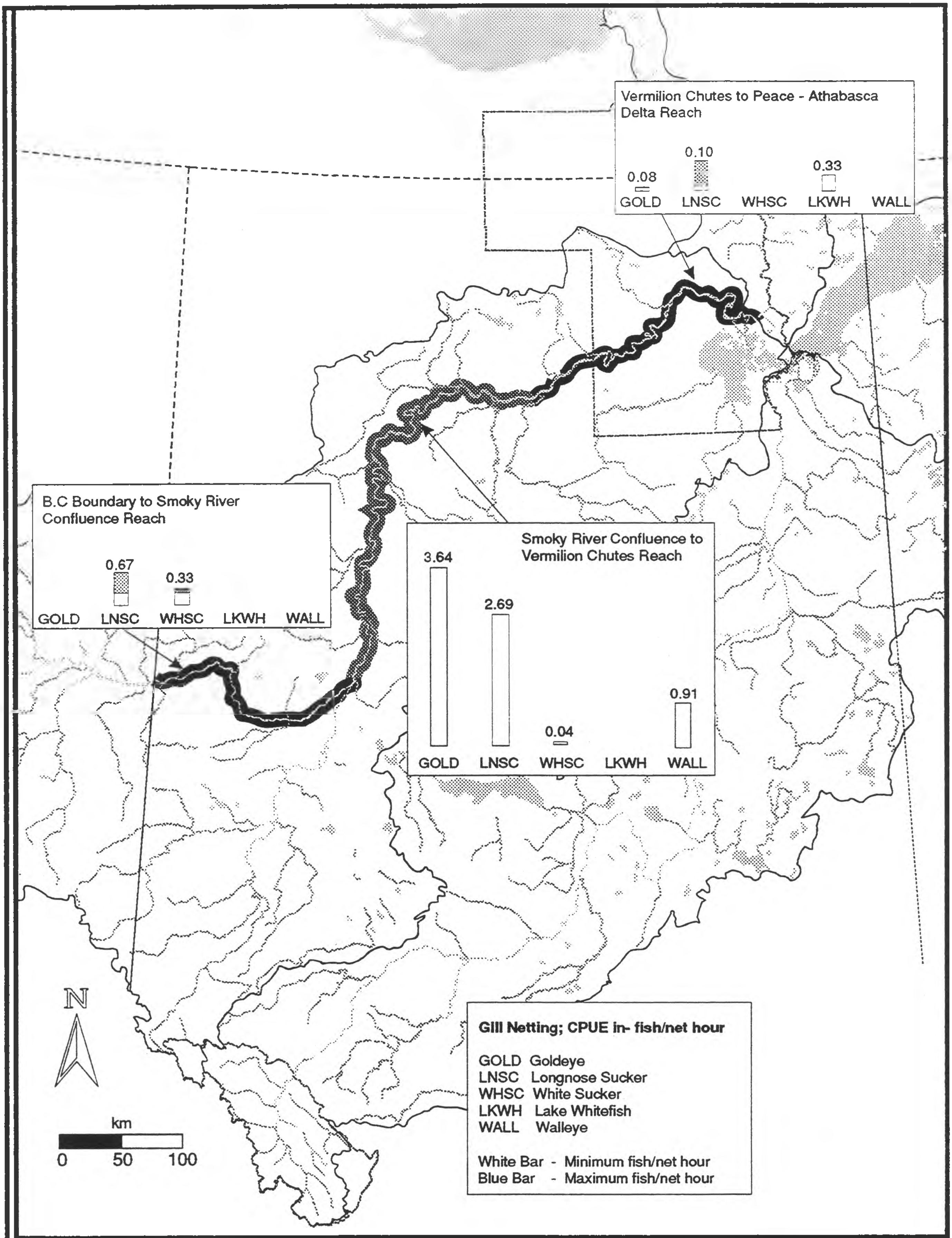

Figure 6. Peace River: Distribution and Relative Abundance of Key Fish Species Spring 1992 - Gill Net Data

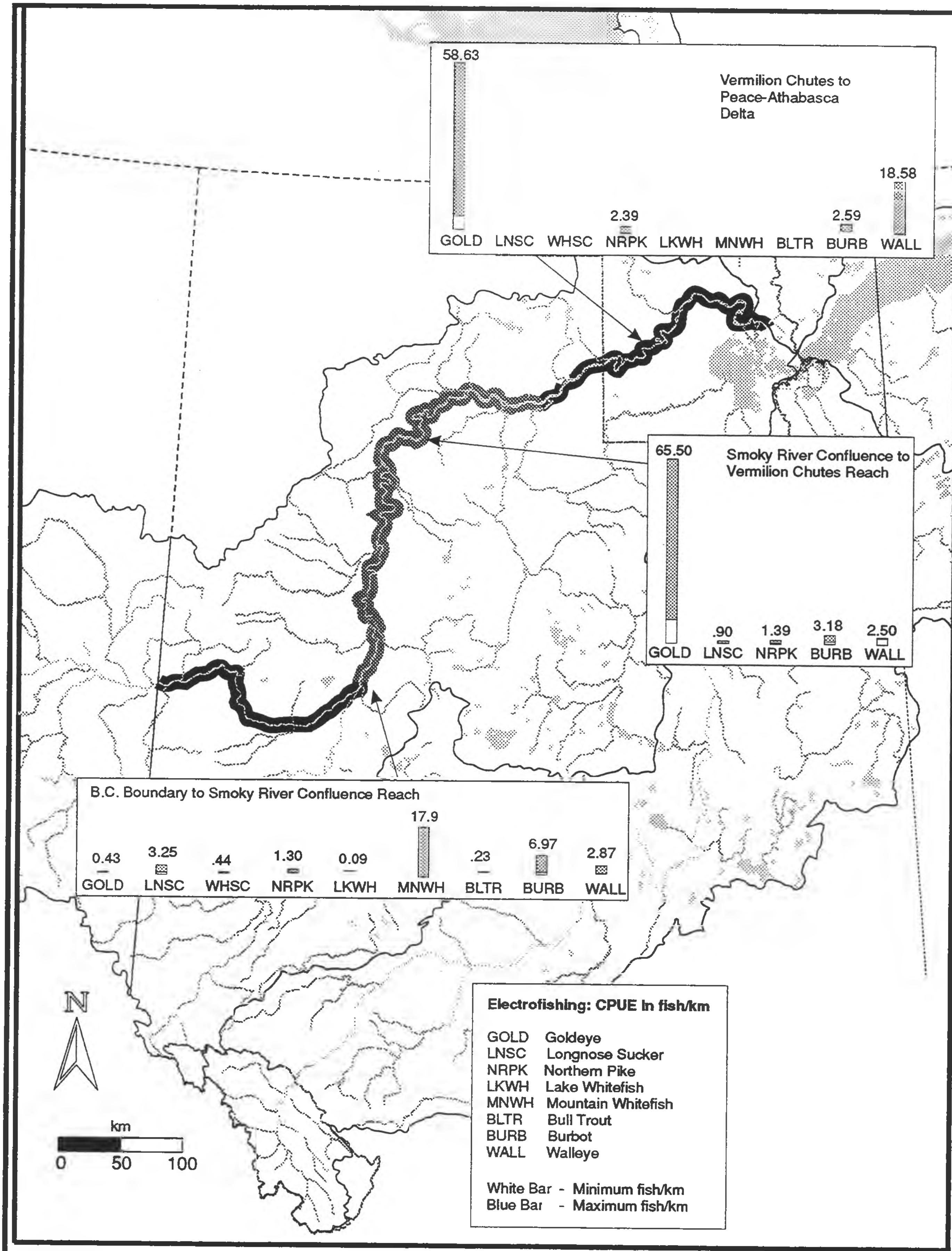

Figure 7. Peace River: Distribution and Relative Abundance of Key Fish Species
Spring 1992 - Electrofishing Data

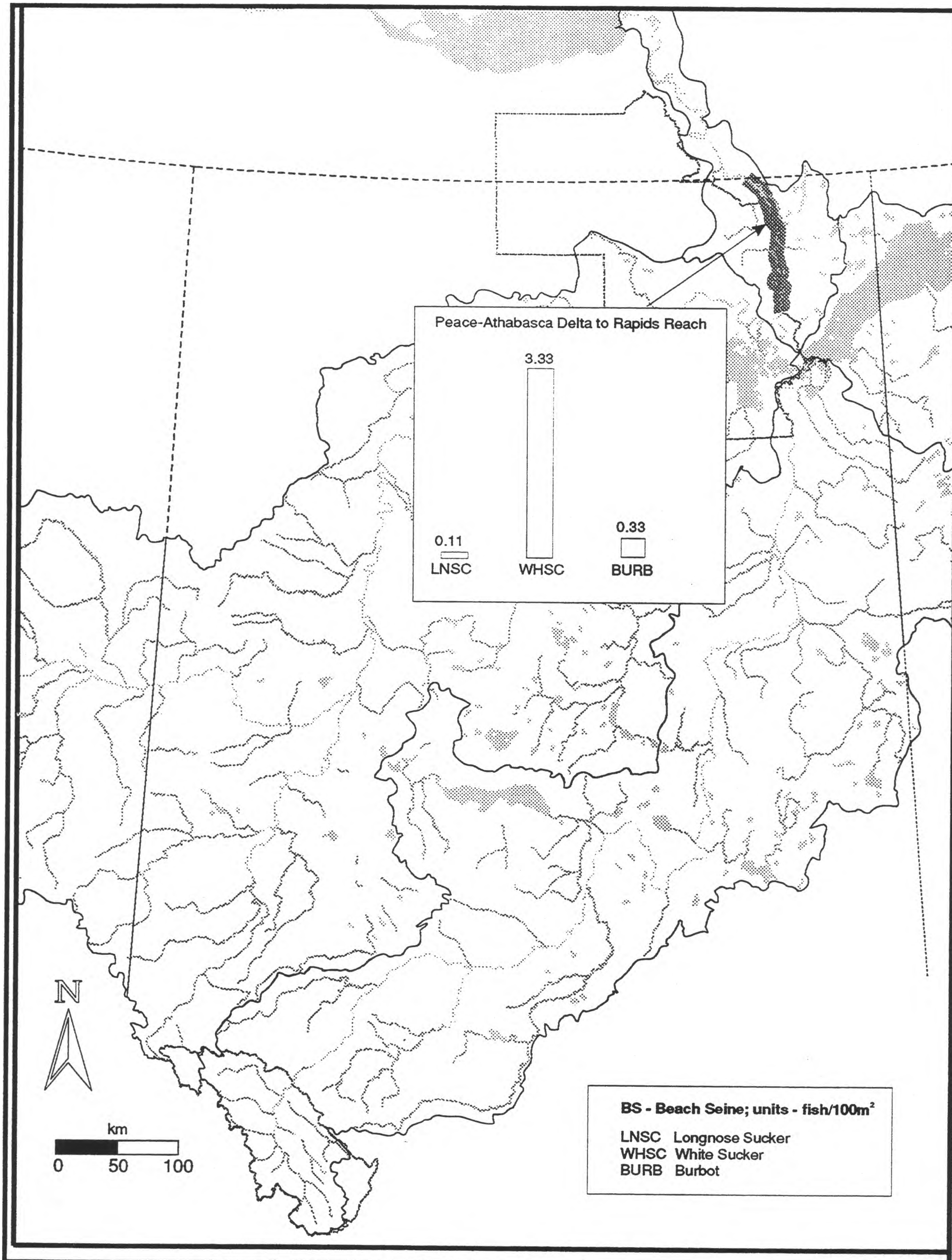

Figure 8. Slave River: Distribution and Relative Abundance of Key Fish Species Spring 1992 (Beach Seine Data)

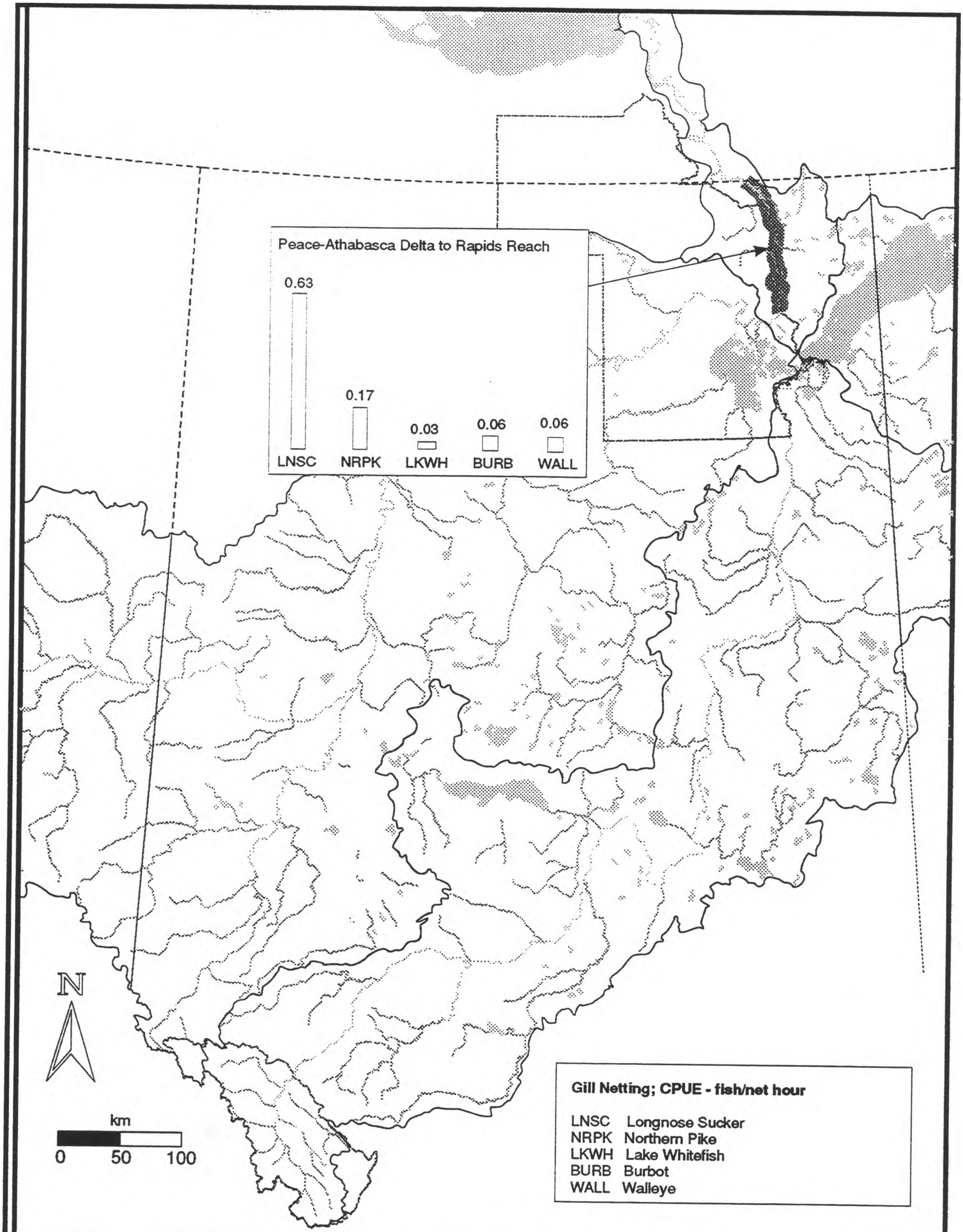

Figure 9. Slave River: Distribution and Relative Abundance of Key Fish Species Spring 1992 (Gill Net Data)

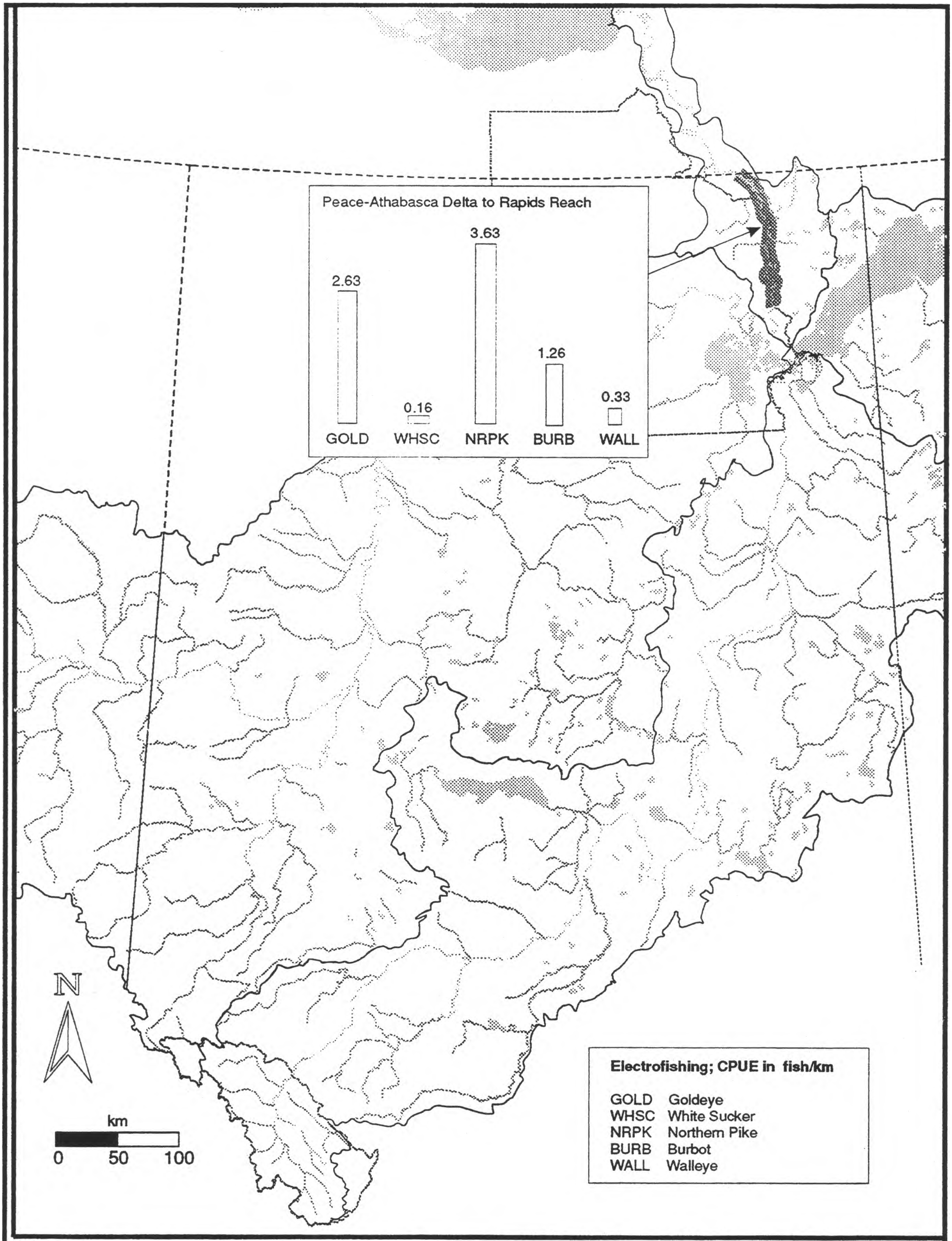

Figure 10. Slave River: Distribution and Relative Abundance of Key Fish Species
Spring 1992 - Electrofishing Data

Below are two tables that provide an index of fish movement studies in the Northern River Basins. For more detailed information on fish movement, the reader is encouraged to consult the sources listed in these tables. Fish movement literature is listed by author in Table 3 along with area sampled, the place where it's available (University of Alberta or Environmental Protection Library), when the work was done, and the client it was done for (what agency or study). A key to the abbreviations appears after the table.

Table 3. Fish Movement Studies in the Northern River Basins

Authors	Where Available				
	University of Alberta	Alberta Environmental Protection	Area Sampled (a)	When Done	Client (b)
Bidgood, 1966		X	PAD	May 1965	F&W
Bidgood, 1968		X	PAD	May 1967	F&W
Bidgood, 1971	X	X	PAD	May-June 1965-69	F&W
Bidgood, 1972		X	PAD	Mar.-June 1971-72	Delta
Boag, 1993	X	X	PCE/SLV	Apr.-June 1992	NRBS
Bond, 1980	X	X	L-ATH/PAD	Apr.-Nov. 1977-78	AOSERP
Bond & Berry, 1980a, 1980b	X	X	L/ATH/PAD	May 1976-Nov. 1977	AOSERP
Bond & Machniak, 1979		X	MUSKEG	Apr.-July 1976-77	AOSERP
Clayton & McLeod, 1994	X	X	U/ATH	May 1992-Mar. 1993	NRBS
Dietz, 1973		X	PAD	May-Aug. 1972	F&W
Donald & Kooyman, 1974		X	PAD	May-Nov. 1971-73	Delta
Donald & Kooyman, 1977		X	PAD	May-Nov. 1971-75	Delta
Golder Assoc., 1994	X	X	U/ATH	Oct. 1993	NRBS
Jones *et al.*, 1978	X	X	L-ATH/CLWR	Sept.-Nov. 1977	AOSERP
Kooyman, 1972	X		PAD	May 1971-Jan. 1972	CWS
Kristensen *et al.*, 1976	X	X	PAD	July-Sept. 1975	AOSERP
Kristensen, 1978	X		PAD	May-Aug. 1977	Delta

Authors	Where Available				
	University of Alberta	Alberta Environmental Protection	Area Sampled (a)	When Done	Client (b)
Kristensen, 1979	X		PAD	Apr.-June 1978	Gov. Can.
Kristensen & Parkinson, 1983		X	PAD	May & June 1980	AB. Env.
Kristensen & Summers, 1978		X	PAD	May-Oct. 1976	Gov. Can.
Machniak & Bond, 1979		X	STEEPBANK	Apr.-Oct 1977	AOSERP
Machniak *et al.*, 1980	X	X	MACKAY	Apr.-Oct. 1978	AOSERP
McCart *et al.*, 1977	X		L-ATH	Dec. 1974-Oct. 1975	Syncrude
McCart *et al.*, 1978a	X		SLV/SRD	Sept.-Nov. 1977	Mackenzie
McCart *et al.*, 1978b		X	MACKAY	May 1977-Jan. 1978	Syncrude
McCart *et al.*, 1982		X	PAD/L-ATH	Sept. 1980-Aug. 1981	AB Env.
Patalas, 1993	X	X	L-PCE	Oct. 1992	NRBS
RLL, 1982	X	X	SLV/L-PCE	May-Nov. 1980	AB Env.
RLL, 1983	X	X	SLV/L-PCE	Oct.-Nov. 1982	Transalta
RLL, 1994b	X	X	U-ATH/M-ATH	Oct. 1993	NRBS
RLL, 1995		X	U-ATH/M-ATH	May 1994	NRBS
RLL & AA Aquat., 1985		X	L-ATH	May-Sept. 1984	Syncrude
Shelast *et al.*, 1994			M-ATH	Apr. 1991-Oct. 1992	AL-PAC
Summers, 1978		X	PAD	Apr.-July 1977	AB Env.
Swanson, 1993	X	X	U-PCE	Oct. 1990-Oct. 1991	Weyer.
Tripp & McCart, 1979	X		L-ATH/CLWR	Apr.-June 1978	AOSERP
Tripp & Tsui, 1980	X		L-ATH/CLWR	May-Oct. 1978	AOSERP
Tripp *et al.*, 1981	X		SLV/SRD	Sept. 1978-Aug. 1980	Mackenzie

(a) CLWR=Clearwater River; L-ATH=lower Athabasca River (upstream from it's delta to the 22 base line); M-ATH=middle Athabasca River (from the 22 base line to the town of Athabasca); U-ATH=upper

Athabasca River (Town of Athabasca to source); L-PCE=lower Peace River (from the confluence with the Slave River to Fort Vermillion); U-PCE=upper Peace River (from Fort Vermillion to the B. C. Border); MACKAY =MacKay River; MUSKEG=Muskeg River; PAD=Peace-Athabasca Delta; SRD=Slave River Delta; STEEPBANK=Steepbank River.

(b) AOSERP=Alberta Oil Sands Environmental Research Program; AB Env.=Alberta Environment; AL-PAC=Alberta Pacific Forest Industries; CWS=Canadian Wildlife Service; Delta=Peace-Athabasca Delta Project; F&W=Alberta Fish & Wildlife Dept.; Gov. Can.=Government of Canada; Mackenzie=Mackenzie River Basin Study; NRBS=Northern River Basins Study; Transalta=Transalta Utilities Corp. & Alberta Power Ltd.; Weyer.=Weyerhaeuser Canada.

In table 4 the contribution of each report to our knowledge of fish movement is judged qualitatively by the amount of data it contributes to the overall understanding of one or more species' movement behaviour. This is a subjective measure for synthesizing an overall picture of the existing fish movement information.

Table 4. Summary of Fish Tagging Studies in the Northern River Basins

Authors	Number of Fish Tagged/Number of Fish Recaptured ("?" means authors gave no data; "X" indicates species studies but no tag data recorded; "{}" gives number radio tagged)							Contribution
	BLTR	BURB	GOLD	LKWH	MNWH	NRPK	WALL	
Bidgood, 1966				X			X	medium
Bidgood, 1968							508/23	high
Bidgood, 1971						X	756/101	high
Bidgood, 1972						X	2828/23	medium
Boag, 1993			?/7			1/?		low
Bond, 1980		48/1	3035/66	2389/70		939/83	959/83	high
Bond & Berry, 1980a, 1980b		48/1	3035/66	2389/65		939/96	959/82	high
Bond & Machniak, 1979				X	X	192/27	4/0	low
Clayton & McLeod, 1994	{9}	{5}		{1}	{17}			medium
Dietz, 1973							2893/290	medium
Donald & Kooyman, 1974			2825/167					high

Authors	Number of Fish Tagged/Number of Fish Recaptured ("?" means authors gave no data; "X" indicates species studies but no tag data recorded; "{}" gives number radio tagged)							Contri-bution
	BLTR	BURB	GOLD	LKWH	MNWH	NRPK	WALL	
Donald & Kooyman, 1977			4375/480					high
Golder Assoc., 1994		26/0		3/0	1626/42	159/12	3/0	low
Jones *et al.*, 1978			67/0	1275/12	X	14/0	11/0	high
Kooyman, 1972			X					medium
Kristensen *et al.*, 1976			X				X	low
Kristensen, 1978		43/0	5580/40	382/3		503/1	108/3	high
Kristensen, 1979		8/0	679/30	127/13		218/18	1035/56	high
Kristensen & Parkinson, 1983		47/1	3647/123	1093/15		3540/320	102/75	medium
Kristensen & Summers, 1978			16678/150	802/32		2143/32	346/15	medium
Machniak & Bond, 1979	1/0	25/0	2/1	1/0	9/2	162/40	133/53	medium
Machniak *et al.*, 1980		4/1	10/0	X		60/3	232/6	low
McCart *et al.*, 1977			X				X	low
McCart *et al.*, 1978a		173/5	24/0	5/0		81/1	7/0	medium
McCart *et al.*, 1978b			X				X	low
McCart *et al.*, 1982				16894/439				high
Patalas, 1993		23/0	274/3		1/0	37/1	66/2	low
RLL, 1982			?/7	?/3		?/2	X	low
RLL, 1983		23/0	274/3	X	1/0	37/1	66/2	low
RLL, 1994	24/2	1/0		29/0	420/5	24/0	14/0	low

Authors	Number of Fish Tagged/Number of Fish Recaptured ("?" means authors gave no data; "X" indicates species studies but no tag data recorded; "{}" gives number radio tagged)							Contri-bution
	BLTR	BURB	GOLD	LKWH	MNWH	NRPK	WALL	
RLL, 1995	17/0	12/0		22/0	623/9	10/2	14/0	low
RLL & AA Aquat., 1985			X	X	X		X	low
Shelast *et al.*, 1994		{3}	?/4		?/7 {15}	?/31	?/22 {19}	low
Summers, 1978							X	medium
Swanson, 1993			?/1		?/3 {19}	?/2	?/4	low
Tripp & McCart, 1979		X	X				X	low
Tripp & Tsui, 1980			X			X	X	low
Tripp *et al.*, 1981		495/6	639/3	334/46		509/27	413/33	medium

4.1 Summary of Movement Information for Key NRBS Species

4.1.1 Goldeye

Overview

Goldeye move widely within the northern rivers. Detailed tagging studies were completed in the Peace River and the Peace-Athabasca Delta, mainly during the 1970's, indicating that there are at least two distinct populations of goldeye in the Peace River basin. One exists upstream of the Vermilion Chutes on the Peace River and the second exists downstream of the Vermilion Chutes. They rarely occur together. Regular seasonal movements of several hundred kilometres are common in the mainstem rivers of the basin. Goldeye make long-distance movements occasionally, with one record of a fish that moved from the Peace-Athabasca Delta upstream in the Peace River as far as the town of Peace River (having passed through the Vermilion Chutes!). A review of tagging studies suggests that goldeye can move upstream at a rate of about 4 km per day, and downstream at least 8.5 km per day on average.

Spawning movements

In May, adult goldeye in the lower portion of the Peace River basin migrate to the Peace-Athabasca Delta, their only known major spawning area. Within the delta, they spawn in the area from the Chenal des Quatre Fourches to Lake Claire. Researchers suggest that goldeye home to the area of previous spawning, but not to the specific site, as salmonids do. Goldeye moving into the Peace-Athabasca Delta in spring use three channels: the Riviere des Rochers, Revillon Coupe, and Chenal des Quatre Fourches. Goldeye moving to spawn in the delta were observed to use Riviere des Rochers and Revillon Coupe three times more than Chenal des Quatre Fourches.

The frequency of spawning may vary in goldeye. Mature goldeye in the Slave River appear to spawn every year. However, goldeye in the Peace River upstream of Vermilion Chutes may not spawn every year.

Movement to summer feeding habitat
In May many immature goldeye move upstream into the Athabasca River drainage to feed for the summer. High catches of goldeye are found in the Athabasca River by April and the fish start moving into the tributaries of the Athabasca River, such as the Clearwater, Christina, and MacKay rivers where they spend the summer feeding. Juvenile goldeye also feed in the Peace-Athabasca Delta during summer. They migrate into the delta one or two weeks after adult spawning migrations. It is speculated that immature goldeye time upstream migrations into the Peace-Athabasca Delta around flow conditions. The goldeye movement seems to occur during the interval between two events—periods of ice jams on the Peace and Slave Rivers (April or May) and spring flood conditions in the Peace River (late June or July). Both events cause water to flow into the delta; at other times water flows out of the delta. Goldeye that spend the summer in the Peace-Athabasca Delta move frequently within the delta. However most goldeye that are in the Athabasca River for the summer move little.

Five goldeye were tagged in the Peace River between the towns of Peace River and Fort Vermillion. They moved approximately 135 km from spring to summer habitats. These fish travelled from river confluences (Cadotte/Peace, Notikewin/Peace) to other confluences (Heart/Peace) or tributary rivers (Little Smoky). Some also moved from tributary rivers (Wolverine) into the Peace River. Feeding at river confluences is a key life strategy of goldeye in summer, a fact well known by anglers.

Goldeye may not spend their summers in the same area every year. Several goldeye tagged in the Peace-Athabasca Delta have been recaptured in the Peace or Slave rivers in summer. Goldeye caught in the Athabasca River in spring have been located in the Slave River in following summers. Barriers to movement such as the Vermilion Chutes on the Peace River and the rapids on the Athabasca and Slave Rivers make much of these downstream movements into one-way dispersals.

Movements to winter habitat
Adult goldeye start migrating out of the Peace-Athabasca Delta in July. This migration peaks in late July to early August and is completed by October with most goldeye having moved out of the delta by the end of August. The reason for this movement is that most of the Lake Claire-Mamawi area of the delta freezes to the bottom and so is unavailable for overwintering of fish. Much of the rest of the delta that does not freeze solid (Prairie River, parts of the Chenal des Quatre Fourches, and parts of Lake Claire) has very little dissolved oxygen and provides poor overwintering habitat.

Goldeye move from the Peace-Athabasca Delta to overwinter in three areas: the lower Peace River; the upper Slave River; and even as far as the Slave River Delta. Goldeye tagged in the Peace-Athabasca Delta in spring have been recaptured in the fall as far upstream in the Peace River as Peace Point. While most goldeye leave the Peace-Athabasca Delta to overwinter, a few have been recaptured in the Birch River during February.

Juvenile and young-of-the-year goldeye move out of the Peace-Athabasca Delta before the adults do. The migration of juveniles to the Peace River begins in July and lasts until December. Young-of-the-year goldeye start moving out of the Peace-Athabasca Delta in late July, and continue until at least November.

Goldeye that are already in the Slave River may not move much from summer to fall. Two goldeye tagged in the June and early October (in the Fort Smith area) had both moved less than 25 km by late October. This is likely because they are already near overwintering areas. Juvenile goldeye move out of the Athabasca River and its tributaries (Clearwater, Christina, and MacKay rivers) in the summer or fall. Few were caught after mid-October.

Implications for Management

Goldeye were commercially harvested in the Peace-Athabasca Delta until 1966. They are still used domestically and as a sport fish throughout the Northern River Basins. Since goldeye may make extensive movements during spring, summer and fall, their migratory pathways should be kept clear of physical and chemical barriers. The channels leading to the Peace-Athabasca Delta should also be kept clear of barriers to movement, because goldeye migrate into spawning areas in the delta in May.

An effort should be made to maintain Peace-Athabasca Delta water levels within the range of natural variation, so that fish can move in and out of the delta for spawning and feeding. The fish habitat-related influence of the Bennett Dam in British Columbia is addressed in detail in the Hydrology/Hydraulics component of the Northern River Basins Study. Water levels in the Peace River may limit the movements of Goldeye. Residents of the area state that the lower water levels stop fish from moving past the Vermillion Chutes.

Sources: (Berry, 1986; Boag, 1993; Bond, 1980; Bond and Berry, 1980a & 1980b; Conly and Prowse, 1996; Donald and Kooyman, 1974; Donald and Kooyman, 1977; Jones *et al.,* 1978; Kooyman, 1972; Kristensen, 1978; Kristensen and Summers, 1978; Machniak *et al.,* 1980; McCart *et al.,* 1978a; R.L.&L., 1982, 1983, R.L.&L. and A.A., 1985; Tripp and McCart, 1979; Tripp and Tsui, 1980; Tripp *et al.,* 1981)

4.1.2 Northern Pike

Overview

Most northern pike in the study area do not make extensive movements. Of 48 northern pike tagged in the Peace-Athabasca Delta, 94% were recaptured within the delta (38% in the same waterbody), and only 3% were recaptured outside of the delta in the Slave or Athabasca Rivers. Similarly, most northern pike tagged in the Peace-Athabasca Delta in a 1983 study were also recaptured within the same water bodies of the delta. Only a small percentage of the recaptured northern pike in this study moved out of the delta into the Slave River, its tributaries, and the Athabasca River.

Spawning movements

Northern pike spawn in early spring, often before the ice has completely left lakes. They are known to make spawning movements into deltas, lakes, rivers and streams. In the Athabasca drainage, they may migrate into the Christina, Clearwater, Dunkirk, Gordon, Gregoire or Lac La Biche rivers. They may also migrate into lakes (such as Gregoire Lake) to spawn. In the Peace-Athabasca Delta, northern pike migrate up Maybelle River to spawn in May.

Movement to summer feeding habitat
In the Athabasca River basin, some northern pike move into tributaries of the Athabasca River in the spring, many of them probably after spawning. A lot of them spend at least part of the summer in tributaries such as the Steepbank, MacKay, and Muskeg rivers (not to be confused with the Muskeg River that is tributary to the upper Smoky River in the Peace River basin).

Some northern pike do not move long distances from spawning to summer habitat. Nine northern pike recaptured in summer moved a mean of 18 km from their spring tagging location in the Steepbank River. Most (56%) of them moved downstream. Other northern pike, however, move greater distances from spring to summer locations. Eight fish were tagged at the confluence of the Athabasca and La Biche Rivers in late April or early May. Six of these moved upstream about 70 km to stream confluences near the town of Athabasca. One fish was recaptured in mid-May, four were recaptured in June, and one in October. One fish tagged in the same spot moved into Lac La Biche by the end of May. One northern pike, tagged in the Peace-Athabasca Delta in May, was recaptured in the Salt River (a tributary of the Slave River) the next July. It appears to have moved downstream after spawning in the delta. Another was tagged in the delta in summer, and recaptured in the Salt River in the summer four years later.

Movements to winter habitat
Northern pike move out of tributaries and back into the Athabasca River in September and October. Five northern pike recaptured in fall moved a mean of 13 km from their spring tagging location in the Steepbank River.

Implications for Management
Northern pike are a popular game fish. They are also used by domestic and commercial fisherman. Since many northern pike do not move far during the year, point source pollution may have a larger effect on them than on more migratory species. Because some pike make extensive spring movements in the middle and lower parts of drainages these sections should not be blocked to movement. Water levels in the Peace River may limit the movements of northern pike. Residents of the area state that the lower water levels stop fish from moving past the Vermillion Chutes.

Sources: (Bidgood, 1971; Bidgood, 1972; Bond, 1980; Bond and Berry, 1980a, 1980b; Kristensen, 1978; Kristensen and Parkinson, 1983; Kristensen and Summers, 1978; Machniak *et al.,* 1980; Machniak and Bond, 1979; Nelson and Paetz, 1992; Shelast *et al.,* 1994; Tripp and Tsui, 1980)

4.1.3 Lake Whitefish

Overview
There appears to be at least two life history types of lake whitefish—a river spawning population and a lake spawning population. The river spawners spawn in the Athabasca River; for example near Fort

McMurray. They grow fast, mature early and live to about 19 years. The lake spawners spawn in Lake Athabasca, grow slower, mature later, and live longer (the oldest found being 27 years). The complex results of movement studies on lake whitefish suggest that there may also be life history types that: spend most of their life in rivers, and spawn in lakes; spawn and overwinter in rivers, but feed in lakes during summer; or spend one fall spawning, while feeding the next fall (thus spawning every second year).

Spawning movements

Lake whitefish start to migrate upstream into the Athabasca River from the Peace-Athabasca Delta in late August and early September. Spawning likely occurs from mid-October to early November in the Mountain and Cascade Rapids area, near Fort McMurray. Some lake whitefish also move into the Christina or Clearwater rivers to spawn although the number moving into this area is likely small. One radio tagged lake whitefish in the upper Athabasca River moved upstream about 40 kilometres in September.

Lake whitefish are also abundant in the channels of the Peace Athabasca Delta in September and October. They migrate through the Riviere des Rochers more often than the Revillon Coupe and the Chenal des Quatre Fourches. The lake whitefish probably use the channels to make spawning movements from the Peace and Slave Rivers to Lake Athabasca or Flett Lake.

Lake whitefish are thought to move upstream from the lower Peace River or the Peace-Athabasca Delta to spawn below the Vermillion Chutes. However, it is probably a minor migration since during the spawning period below Vermilion Chutes in 1993 NRBS scientists caught only 15 lake whitefish and another study in 1990 caught just 18.

Movement to summer feeding habitat

During spring, small numbers of lake whitefish move into the Athabasca River and its tributaries (especially the Steepbank and MacKay Rivers) to feed. These fish may be moving upstream from Lake Athabasca. During summer 1994 one lake whitefish was tracked by radio telemetry in the upper Athabasca River. It moved little, if at all, from June 24 to Sept. 8.

There are few juvenile or adult lake whitefish found in the Athabasca River between May and August. However, young-of-the-year whitefish were caught in the Athabasca River in mid-June. They are thought to move quickly downstream to the Peace-Athabasca Delta, from areas where they were spawned the previous fall.

Movements to winter habitat

After spawning, lake whitefish appear to move out of the Athabasca River in late October and early November. Some make a rapid migration downstream to Lake Athabasca and the Peace-Athabasca Delta soon after spawning. Others may overwinter in the Athabasca River.

Implications for Management
Lake whitefish move up and down the Athabasca River, and spawn near Fort McMurray. Therefore, anything affecting fish in the river, such as dams and ice control weirs, could have adverse effects on the populations in Lake Athabasca (mostly in the western part of the lake). This would decrease the domestic fisheries in the Peace-Athabasca Delta, and at various locations along the Athabasca River where spawning fish are caught during their migrations.

Blockages in the channels of the Peace-Athabasca Delta in the fall would also cause problems, since the delta is used by lake whitefish moving to lakes in the area. Moreover, the Athabasca River downstream of the Mountain and Cascade Rapids should not be blocked during this time. This is because young lake whitefish are migrating down the Athabasca River starting in mid-June, and many adults move through the river on their way to and from spawning areas from August to November.

Seasonal influences arising from lowered DO concentrations (typically under ice-cover during winter) combined with effluent-sourced contaminants may affect spawning success, egg incubation and early larval success.

If major disturbances are to be made in any of these areas, the best time may be after the end of November. At this time, most major movements of lake whitefish appear to be concluded.

Sources: (Bond, 1980; Bond and Berry, 1980a; Chambers and Mill, 1996; Clayton and McCleod, 1994; Jones *et al.,* 1978; Kristensen, 1978; Kristensen and Summers, 1978; Machniak and Bond, 1979; Machniak *et al.*, 1980; McCart *et al.*, 1982; Nelson and Paetz, 1992; Parrott *et al.,* 1996; Patalas, 1993; R.L.&L., 1983; Tripp *et al.*, 1981)

4.1.4 Mountain Whitefish
Overview
Like the lake whitefish, there appear to be distinctions among mountain whitefish populations discernable from their life history strategies. Some mountain whitefish spend their entire lives in lakes, others spend their entire lives in headwater streams, and some live in both rivers and lakes.

Spawning movements
In the study area, mountain whitefish spawn from late September to early November. Some move from the Athabasca River into its tributaries to spawn. One mountain whitefish was recaptured, apparently spawning, in Snake Indian River (Jasper National Park) almost two years after its tagging at the confluence of the Athabasca and Lac La Biche Rivers. That was an upstream movement of 656 km. This is an extreme example and is not representative of the species.

NRBS scientists radio tagged several mountain whitefish in the Athabasca River near Hinton in the fall of 1994. They obtained data during the spawning period from six of them. Three of these fish appeared to make distinct spawning movements. They all moved upstream, a mean distance of 94 km, from Sept. 23 to Nov. 2. Two of these fish are suspected of spawning in the Athabasca River, and the other of spawning in the Rocky River. Another three fish did not make any obvious spawning movements. They may have spawned in the Athabasca River near their summer habitat, or they may not have spawned that year.

A non-NRBS study radio-tagged eleven mountain whitefish during October, 1994 in the Athabasca River, between the town of Athabasca and its confluence with the Pelican River. The fish moved a mean of 67 km from their release points to their last locations in spring. The mean total distance they moved was 85 km. It is important to note that this figure represents the mean of the starting and ending points measured in the study. During the period of the study many fish moved much greater total distances within the area of their initial and final measured locations. All but one fish ended up downstream of its tagging location. Since the dates when movements occurred are not available, it is not known whether these were spawning, overwintering, or spring movements.

Another non-NRBS study tagged 12 mountain whitefish with radio transmitters in early October 1990 in the Wapiti River. Seven of the 12 fish made sudden downstream movements after tagging, while the other 5 moved less than 10 km from tagging sites. The fish could have been moving downstream to spawning areas, or making long downstream movements after spawning. Another interpretation is that the fish reacted poorly to the transmitter tagging procedure.

Movement to summer feeding habitat

In spring, many mountain whitefish move into tributaries of the Athabasca River. They move into the Steepbank and Muskeg Rivers, in late April and early May. Others move into the MacKay River during spring and summer.

In the Bow River drainage of Alberta mountain whitefish have been noted moving upstream into tributaries in July. In Idaho, they have also been documented moving upstream a mean of 83 km from late May and early June to July. During the summer, mountain whitefish may move from tributaries of the Athabasca River back downstream to the mainstem river. In Idaho, mountain whitefish movement apparently stops in the summer.

A private sector study tagged four mountain whitefish with radio transmitters during spring in the Athabasca River, between the town of Athabasca and the confluence with the Pelican River. These fish moved a mean of 40 km (minimum of 0 km, maximum of 83 km) from their points of tagging to their last locations in summer. It is not known whether these movements were from spring to summer habitat, or within summer habitat.

Movements to winter habitat

Some mountain whitefish move long distances to overwintering areas. One mountain whitefish moved downstream 228 km in 15 days after it was tagged, on October 4, 1994, in the Snake Indian River (where it is thought to have spawned).

In the Bow River drainage young-of-the-year mountain whitefish move downstream out of tributaries in early November. Adults also move downstream after spawning.

Management Implications
The mountain whitefish is a highly prized recreational fish species in Alberta. It is widely distributed in the upper mainstems and tributary systems of both the Peace and Athabasca Rivers. Mountain whitefish are subject to restrictive fish consumption guidelines in both the upper Peace and Athabasca River basins as a result of contamination with dioxins and furans from kraft pulp mills. Their complex movement patterns make it extremely difficult to define localized contaminant exposure and subsequent fish distribution patterns. Consequently, there is a clear need to maintain the present trend to reduce the input of chlorinated organic compounds in industrial effluents emptying into these rivers.

Reduced winter DO concentrations may affect early life stage success. Efforts to reduce man-induced winter DO concentration sags downstream of industrial or municipal effluent sites are required.

Sources: (Alberta Environmental Protection, 1994; Bond and Machniak, 1979; Davies and Thompson, 1976; Giles and Van der Zweep, in sub. to NRBS; Hagen, 1970; Machniak and Bond, 1979; Nelson and Paetz, 1992; Pettit and Wallace, 1975; R.L.&L., 1994b; R. L. & L. and AA, 1985; Shelast *et al.*, 1994; Swanson, 1993)

4.1.5 Bull Trout

Overview
Resident populations of bull trout live in the headwaters of the Peace and Athabasca river basins and move little during the year. Migratory populations live in the further downstream portions of the mainstems of these rivers and migrate into tributary streams to spawn during the fall.

Spawning movements
NRBS scientists tracked four bull trout implanted with radio transmitters in the upper Athabasca River. They found that bull trout start to move upstream to spawning areas as early as June 24. The four fish moved upstream a mean of 68 km, into either the Rocky River or Snake Indian River between July 29 and Sept. 8. They spent from 9 to 42 days in these tributaries of the Athabasca River, staying there from July 29 until Sept. 23.

Work done outside of the Northern River Basins Study area shows that migratory bull trout start spawning migrations in April. They slowly move upstream as much as 250 km to spawning areas Spawners stay at the mouths of spawning tributaries 2-4 weeks, entering the tributaries from July to September. They usually spend a month in the tributaries before spawning in September and early October. After spawning, migratory fish move out of tributaries back to lakes or rivers.

Summer movements
Work done elsewhere suggests juvenile bull trout with a migratory life history stay in tributary streams (where they were hatched) for 1-3 years. They then migrate into rivers from June to August.

Movements to winter habitat
Data from three bull trout tagged in 1994 suggest that they move little during October or over the winter. In the Athabasca River, two bull trout moved less than 5 km from where they were tagged (October 4-7)

in the Jasper National Park reach to where they were recaptured (October 19-30). A third bull trout, tagged on October 7 in the same reach, moved less than five kilometers by March 8.

The mean distance four radio tagged bull trout moved from spawning areas to overwintering areas in the upper Athabasca River was 81 km. Bull trout reached their overwintering areas between September 23 and October 28. These areas were located a mean of 16 km upstream from the summer tagging location in the upper Athabasca River.

In other areas, bull trout also move little in late fall and winter. Fall and winter movements of resident bull trout in Montana were studied using radiotelemetry. Some bull trout made two stage movements from fall to winter habitats. Whether spawning or not, bull trout made limited (< 2 km) downstream movements from mid-September to early November, before ice formation. Many bull trout made a second movement (all < 2 km) after ice affected their habitat, and were mostly sedentary for the rest of the winter.

Implications for Management
All life stages of bull trout are sensitive to environmental disturbances. Since some bull trout populations occupy a small home range, they are very vulnerable to local disturbances. Migratory bull trout can be impacted by the blockage of migratory routes in rivers and small tributaries from April to November. Migrations occur mostly in upper and middle portions of drainage basins.

A fish consumption advisory is in effect for bull trout upstream of Whitecourt because of dioxin and furan contamination. Consequently, there is a clear need to maintain the present trend to reduce the input of chlorinated organic compounds in industrial effluents emptying into these rivers.

Sources: (Alberta Environmental Protection, 1994; Allan, 1980; Clayton and McLeod, 1994; Fraley and Shepard, 1989; Jakober, 1995; R.L.&L., 1994b)

4.1.6 Burbot

Overview
Research from Alaska shows that the distance burbot move depends on their stage of maturity. From September to July, the total distance immature burbot moved was smaller (mean 17 km) than that of mature burbot (mean 57 km). Mature burbot move most from November to March, during river freeze-up and break-up. They move least during the spawning period (mid-January to mid-February). These peaks are likely movements to and from spawning areas. Immature burbot, unlike adults, did not have any peaks in movement.

The very limited amount of tag and recapture data collected in the northern river basins to date suggests that burbot move little (less than 20 km) over the year. All three of the tagged and recaptured burbot moved less than 20 km from their tagging location. Two of these burbot were tagged in the spring in the Peace River. They were recaptured less than ten kilometers away two years later.

Spawning movements
In the study area burbot usually spawn in winter or early spring, usually February and March. Mature burbot may move to and from spawning during river freeze-up and break-up.

Movement to summer feeding habitat
Burbot have been caught while moving both in and out of the MacKay River in the spring. During summer, three radiotagged burbot moved less than six kilometers from where they were tagged in the upper Athabasca River.

Movements to winter habitat
Two burbot were radiotagged during the middle of June, 1994 in the upper Athabasca River. During fall and early winter, these two fish moved less than 20 kilometers from where they were tagged. One did not move more than a kilometer from the beginning of September to the end of December. The other made several movements during the fall and early winter. These two radio tagged burbot appeared to make distinct spawning movements during winter. One moved approximately 30 km upstream during January and February, while the other moved upstream about 6 km during early February. These mid-winter movements were probably to spawning areas, since in the study area burbot usually spawn in February and March.

Two burbot were tagged with radiotransmitters in August in the Athabasca River, between its confluence with the Calling River and with the Pelican River. This non-NRBS study recorded that the two fish moved six and zero kilometers from release points to their final locations in January.

Implications for Management
Indigenous and other people in northern Canada have long considered burbot (especially burbot liver) a culinary delicacy. However, due to contamination, they are not edible in some areas (eg. upstream of Iron Point on the Athabasca River and throughout the Smoky River and its tributaries in the upper Peace River basin). Consequently, there is a clear need to maintain the present trend to reduce the input of chlorinated organic compounds in industrial effluents emptying into these rivers. To understand where contamination affects burbot, further work is needed on their movements around point sources of pollution.

Since burbot move little during summer, they may be more affected by point source contaminants than more mobile species. Also, since they spawn in winter, their migrations may be affected by ice conditions in rivers. Open areas caused by warm water flowing into rivers or water flowing out of dams could lead to large amounts of frazil ice. This ice may build up to form anchor ice and ice dams, which could hamper winter migrations of burbot. Large amounts of frazil ice could also be a barrier to movement. If burbot passed water through their gills which contained frazil ice, it could damage their gills, or plug them, causing suffocation.

Sources: (Alberta Environmental Protection, 1994; Breeser *et al.*, 1988; Brown *et al.*, 1994; Clayton and McLeod, 1994; Evanson, 1993; Machniak *et al.*, 1980; Nelson and Paetz, 1992; R. L. & L. and EMA, 1985)

4.1.7 Walleye

Spawning movements

Walleye spawn in the spring, usually ending by mid-May. Walleye from Lake Athabasca move to several areas to spawn, including Lake Claire, Blanche Lake, Mamawi Lake and Richardson Lake; these spawning areas are all within the Peace-Athabasca Delta. The most intensive spawning of walleye from Lake Athabasca is found in Richardson Lake. They also spawn within Lake Athabasca.

A separate migration starts by mid-April and proceeds up the Athabasca River, to spawning areas north of Fort McMurray. Walleye also move from the Athabasca River into the MacKay River to spawn.

Movement to summer feeding habitat

After spawning takes place in May, walleye move into tributaries of the Athabasca River, such as the Steepbank and MacKay Rivers. Most of them are males, and likely return to the Athabasca River in late-spring or summer. Meanwhile, females leave the Fort McMurray/oil sands area of the Athabasca River immediately after spawning.

In the Peace River, five walleye were tagged between the town of Peace River and the Mikkwa River in late April to early May, 1992. They were recaptured in the summer after having moved an approximate mean of 45 km (maximum 70 km) from tagging sites. One was recaptured at its tagging location, three moved upstream and one moved downstream.

In the Athabasca drainage, some walleye move long distances from spring (spawning) to summer habitat. Eight walleye recaptured in the summer moved a mean of 71 km from their spring tagging location in the Steepbank River. Half of these fish moved upstream. In another study, ten walleye recaptured in the summer moved a mean of 193 km from their May tagging locations in the lower Athabasca River. Another walleye tagged in the Athabasca River made a very long movement. It was tagged in April at the confluence of the La Biche and Athabasca Rivers, and moved 340 km downstream. It was recaptured at the confluence of the Hangingstone and Clearwater Rivers (near Fort McMurray) in July.

Young-of-the-year walleye are active during summer. In the Athabasca River, they move downstream during late June and July, on their way to rearing areas in the Athabasca River or Lake Athabasca. Within the Peace-Athabasca Delta, young-of-the-year walleye start to move out of Richardson Lake through Jackfish Creek in June or July.

Three mature walleye were radio-tagged in the Athabasca River (near the town of Athabasca) during spring 1993 and tracked until summer. The three fish moved a mean of 10 km from their release sites. Walleye spawn in the spring, usually ending by mid-May, therefore these fish were probably finishing (or had just finished) spawning and were either at summer feeding areas or on their way to them.

Movements to winter habitat

In the Athabasca River walleye appear to start their winter migration in October. Four walleye were tagged during spring in the Steepbank River. They were recaptured in fall, having moved a mean of 129 km. All of them moved upstream.

Six walleye were tagged with radio transmitters in August, 1993 in the Athabasca River. Tagging took place between the Athabasca River's confluence with the La Biche River and its confluence with the House River. These fish were tracked through the fall and into the winter. They moved a mean total distance of 11 km, and a mean net of 3 km from their release points. In the same area, eight more fish were tagged with radio transmitters in October, 1993 and tracked until late winter. These fish moved much further than the ones tagged in August. They moved a mean total distance of 41 km, and a mean net distance of 33 km from their release points. These movements are movements from fall to winter, or movements during winter.

Implications for Management
Walleye are highly valued by domestic, sport, and commercial users. They may move long distances to spawning areas in the spring, to feeding habitat in the summer, and to overwintering habitat in the fall. Since this species is a target of commercial fishing, measures should be taken to insure that migrations are not overfished or blocked.

When the Bennett dam was built in British Columbia, there was concern that it would lower water levels in the Richardson Lake area, and interfere with spawning movements of walleye. This could present a problem, since the Richardson Lake area is important for the spawning of walleye from Lake Athabasca. However, the occurrence of breakup and access to Richardson Lake spawning grounds is apparently determined by water levels in the Athabasca River, not the Peace River.

Water levels in the Peace River may limit the movements of walleye. Residents of the area state that the lower water levels stop fish from moving upstream past the Vermillion Chutes.

It appears that most walleye in the Athabasca River do not move great distances between summer and winter habitats. Therefore they may be more vulnerable to point source pollution than more migratory species or other walleye populations that move downstream from the river mainstem into Lake Athabasca for the winter.

Sources: (Bidgood, 1968; Bidgood, 1972; Berry, 1986; Bond, 1980; Bond and Berry, 1980a, 1980b; Dietz, 1973; Kristensen *et al.,* 1976; Kristensen, 1979; Kristensen and Summers, 1978; Machniak *et al.,* 1980; Machniak and Bond, 1979; Nelson and Paetz, 1992; R.L.&L. and AA, 1985; Shelast *et al.,* 1994; Summers, 1978; Tripp *et al.,* 1981)

5.0 IMPLICATIONS OF MOVEMENTS FOR ECOSYSTEM MONITORING

It would be difficult to use mountain whitefish as an indicator of ecosystem health unless more is known about its complex life history. An unknown proportion move into tributaries during spring and spend all or part of their summer there. Mountain whitefish may also move long distances to tributaries to spawn. It is not know if they spawn yearly or less often. There are no data on their winter movements but they are assumed to move little.

The life history of burbot may also be complex. An unknown proportion move into tributaries during spring for an unknown length of time. There are few data on movements during summer but they are assumed to move little. During winter they may migrate to spawning areas. Data from radiotelemetry studies show mean winter movements ranging from 57 to 92 km for mature fish. Immature fish moved a mean of 17 km. It is not know if they spawn yearly or less often.

6.0 CRITICAL FISH HABITATS

In Canada fish habitat is defined as those parts of the environment "on which fish depend, directly or indirectly, in order to carry out their life processes" (DFO, 1986). NRBS board question number 6 specifically asks where are the important habitats of fish in the northern river basins. This requires us to focus our attention on those fish habitats that, in place or time, are known to be limiting to fish population viability. We typically consider these fish habitats in terms of their importance to specific life stages of fish and term these as *critical habitats*.

The term critical habitat implies habitat without which specific life stages of fish cannot carry on their life processes. Spawning, feeding, and overwintering habitat are commonly included in this approach to categorizing fish habitat. This is not to suggest that resting areas, protective cover or movement corridors are not also essential habitats for fish but that they are less limiting in that they are more available.

Critical habitats are not similar for all species, nor are they evenly distributed in the study area. The notion that there is a single location in the river for each of these life processes is too simplistic, however. Complex life history patterns such as that described for mountain whitefish lead us to conclude that the distribution of important habitats for this species is also complex. Evidence from our movement studies on key fish species in the study area leads to the conclusion that there are many patches of critical habitat, unique for each species, distributed within the river basins.

6.1 Spawning Habitat

To complete their life cycle, fish need spawning habitat. Their eggs need certain conditions to successfully incubate. Fish move to areas with those conditions to spawn. Scientists often find spawning areas by locating fish which hatched within the last year, called young-of-the-year.

The density or catch-per-unit-effort (number of fish caught per unit distance, time or area) for young-of-the-year can be used as an index of spawning habitat value. However, there may be limitations to using this as an index. Fish such as goldeye have semi-bouyant eggs. The young may be found long distances downstream of the actual spawning areas. Small fish of other species may also move long distances from spawning areas by fall or the next spring. So we often can only get a general idea of the area they came from. Also, young fish may have a patchy distribution. Not finding them in one location does not mean they may not have been found 100 m farther upstream.

Another way to locate spawning areas is by capturing fish in spawning condition. This may also only provide general spawning areas, since these mature fish can be very mobile. Some species, like walleye, may aggregate in one area for several days while fully ready to spawn. They then move quickly onto spawning grounds and complete their spawning in a few days.

6.2 Feeding Habitat

Feeding habitat is usually not considered critical habitat for fish over a year old. If food is not present in one area, they are mobile enough to move to an area where food is more abundant. However, young-of-the-year may not be mobile enough to move to better feeding habitat. They might perish on the way, because they have low energy reserves or because they expose themselves to heavy predation. Feeding habitat for young-of-the-year fish is generally referred to as rearing habitat. This habitat is generally located by capturing young-of-the-year-fish.

6.3 Overwintering Habitat

During winter, decreasing water temperatures slow the metabolism of fish. With a slower metabolism, fish cannot digest food as fast as during summer. It is no longer profitable for them to expend large amounts of energy collecting food. With falling winter water temperatures, fish shift into a strategy of conserving energy and finding protection from winter perils (Cunjak and Power, 1986) until water temperatures rise in spring.

If good overwintering habitat is limiting, some species assemble into large aggregations. The small amount of suitable habitat forces fish to squeeze into small amounts of good habitat (Hartman, 1965; Cunjak and Power, 1986; Heggenes *et al.*, 1993). However, if good overwintering habitat is not limiting, fish may remain more solitary (Brown and Mackay, 1995). Northern River Basins Study biologists have attempted to index the value of winter habitat by the presence of large groups of fish.

What about those areas where winter habitat is not limited? In the large rivers of the NRBS area, fish may not be spatially limited by habitat and may not aggregate. This would force us to find another way to put a value on overwintering habitat. At present, however, knowledge is too limited to allow us to do this.

Tables 5 to 7 show where spawning, rearing and overwintering habitat was found or thought to exist, and the evidence for these conclusions.

Table 5. **Areas where fish are known, or suspected, to spawn in the Northern River Basins study area.**

Waterbody	YOY Caught	Ripe Fish Caught	Casual Observation
Athabasca River			
Reach 1 Mainstem	MNWH	NRPK, MNWH, LKWH	
Tributaries			
Miette River	MNWH	BLTR	
Snaring River	BLTR, MNWH	MNWH	
Rocky River		BLTR	
Snake Indian River	MNWH	BLTR, MNWH	
Fiddle River			BLTR, MNWH
Reach 2 Mainstem	MNWH	MNWH	
Tributaries			
McLeod River			WALL,MNWH
Reach 3 Mainstem	WALL, MNWH	WALL, GOLD, NRPK, MNWH	
Tributaries			
Pembina River			MNWH
Lesser Slave River		MNWH	
Reach 4 Mainstem	WALL, LKWH	WALL, GOLD, NRPK, LKWH	
Tributaries			
MacKay River			WALL
Peace River			
Reach 1 Mainstem	GOLD, MNWH	NRPK, MNWH	
Tributaries			
Pouce Coupe River	GOLD		
Clear River		WALL	
Smoky River			GOLD
Reach 2 Mainstem	WALL, GOLD, BURB	NRPK	
Tributaries			
Whitemud River			BURB
Cadotte River			WALL, GOLD
Notikewin River		WALL	
Keg River			WALL
Boyer River			WALL, GOLD
Wabasca River	WALL, GOLD	WALL	

Waterbody	YOY Caught	Ripe Fish Caught	Casual Observation
Reach 3 Mainstem	GOLD	WALL, LKWH	
Tributaries			
Mikkwa River	WALL	NRPK, WALL	WALL
Wentzel River		WALL	
Garden Creek		NRPK	
Jackfish River		WALL	
Slave River			
Reach 1 Mainstem		NRPK	
Tributaries			
Ryan Creek	NRPK	NRPK	
Hornady Creek		NRPK	WALL
Bocquene River		WALL, NRPK	
Dog River	NRPK	NRPK	
Bath Creek			NRPK

Sources: (Boag, 1993; Bond, 1980; Clayton and McLeod, 1994; Donald and Kooyman, 1974; EVS Consultants Ltd., 1991; Hildebrand, 1990; Kristensen, 1978; Patalas, 1993; RLL, 1982, 1994a, 1995)

Table 6. Areas where fish are known to, or suspected of, rearing (during their first year) in the Northern River Basins study area.

Waterbody	YOY Caught	Casual Observation
Athabasca River		
Reach 1 Mainstem	MNWH	
Tributaries		
Miette River	MNWH	
Snaring River	BLTR, MNWH	
Snake Indian River	MNWH	BLTR
Moosehorn River		BLTR, MNWH
Fiddle River		BLTR, MNWH
Reach 2 Mainstem	MNWH	
Tributaries		
Oldman Creek		BLTR, MNWH
Sakwatamau River		WALL, NRPK, MNWH, BURB
McLeod River		WALL, NRPK, MNWH, BURB

Waterbody	YOY Caught	Casual Observation
Reach 3 Mainstem	WALL, MNWH	
Tributaries		
Tawatinau River		WALL, NRPK, BURB
La Biche River		WALL, NRPK, BURB
Calling River		WALL, NRPK, BURB
Reach 4 Mainstem	WALL, LKWH	
Tributaries		
Little Fishery River		WALL, NRPK
Hangingstone River		WALL, NRPK
Clearwater RIver		WALL, NRPK
Muskeg River		WALL, NRPK
Firebag River		WALL, NRPK
Peace River		
Reach 1 Mainstem	GOLD, MNWH	
Tributaries		
Pouce Coupe River	GOLD	
Reach 2 Mainstem	WALL, GOLD, BURB	
Tributaries		
Wabasca River	WALL, GOLD	
Reach 3 Mainstem	GOLD	WALL, BURB
Tributaries		
Mikkwa River	WALL	
Slave River		
Reach 1 Mainstem		
Ryan Creek	NRPK	
Dog River	NRPK	

Sources: (Boag, 1993; Bond, 1980; Clayton and McLeod, 1994; Donald and Kooyman, 1974; EVS, 1991; Hildebrand, 1990; Kristensen, 1978; Patalas, 1993; RLL, 1982, 1994a and 1994b, 1995)

Table 7. Areas where fish are known to, or are suspected of, overwintering in the Northern River Basins study area.

Waterbody	Fish Caught	Casual Observation
Athabasca River		
Reach 1 Mainstem	BLTR, MNWH, BURB	
Reach 2 Mainstem		
Tributaries		
Soloman Creek		BLTR, MNWH
Maskuta Creek		BLTR, MNWH
Berland River		MNWH, BURB
Two Creeks		NRPK, BLTR, MNWH, BURB
Sakwatamau River		WALL,NRPK,MNWH, BURB
McLeod River		WALL,NRPK,MNWH, BURB
Reach 3 Mainstem	MNWH	WALL
Tributaries		
La Biche River		WALL, NRPK, BURB
Calling River		NRPK
Reach 4 Mainstem		NRPK, LKWH
Tributaries		
Clearwater River		WALL, NRPK
Steepbank River		WALL, NRPK
MacKay River		WALL, NRPK
Tar River		WALL, NRPK
Firebag River		WALL, NRPK
Grayling Creek		WALL, NRPK
Peace River		
Reach 1 Mainstem		MNWH, WALL, GOLD
Reach 2 Mainstem	NRPK	WALL, GOLD, BURB
Reach 3 Mainstem	LKWH	WALL, GOLD, NRPK
Slave River		
Reach 1 Mainstem		
Tributaries		
Ryan Creek		NRPK
Dog River		NRPK

Sources: (Boag, 1993; Donald and Kooyman, 1974; Hildebrand, 1990; Kristensen, 1978; Pattenden, 1993; RLL, 1982, 1994a; Shelast *et al.*, 1982)

6.4 Habitat Availability

Fish habitats must be available for use by fish when and where they are required to complete their life processes. Changes in water flow and water levels in rivers can alter the structure and amount of critical habitats and change the accessibility of these habitats (Conly and Prowse, 1996). The effects of flow variations on the structure, frequency and accessibility of fish habitats are described in the Hydrology Component synthesis report. In addition, changes in the ice regime of northern rivers has been shown to be an important determinant of fish habitat quantity and quality (Conly and Prowse, 1996). The conclusion of the study on effects of hydrological changes on fish is unclear because there are both positive and negative effects and because they influence different species in quite different ways.

7.0 FOOD CHAIN

A knowledge of the food chain in the northern river basins is important for understanding how contaminants move through the aquatic ecosystems. As organisms eat contaminated food, and are in turn eaten, the contaminants are passed up the food chain. These contaminants tend to become more concentrated in the animal tissues as they are passed up the food chain.

Northern River Basins Study data reported greater concentrations of contaminants in mountain whitefish than longnose sucker and northern pike collected downstream of a pulp mill. These differences in contaminant concentrations may be due to the different feeding habits of mountain whitefish and longnose sucker. Longnose sucker are bottom feeders. Mountain whitefish, although also classified as bottom feeders, often feed on organisms drifting through the water column. The accumulation of contaminants in the bodies of these fish may thus be a reflection of their different feeding strategies and different contaminant burdens in these food sources.

The Food Chain Component completed two stable isotope studies. Analyses of sulphur, carbon and nitrogen isotopes in aquatic organisms can improve our understanding of the food chain and help us speculate on the relationship between fish movements and contaminant accumulation. The sulphur isotope data were able to assign 12 of 85 mountain whitefish in the upper Athabasca River to a separate feeding group. This work confirmed our understanding that mountain whitefish's complex movement patterns were complicated further by differences in feeding patterns.

The sulphur and carbon isotope data lead us to consider different scenarios of feeding and movement by northern river basins fish. These scenarios are important considerations in our assessment of how fish are exposed to and accumulate contaminants. The understanding that the base of the food chain supporting many of the basin fish may be terrestrial material from the tributaries is important in considering contaminant pathways.

In one scenario, fish may move from the mainstem into the tributaries, feed there, then move back to the mainstem. These movements may be regular, seasonal patterns that revolve around physiological needs for specific kinds of habitat for spawning, feeding or overwintering. Alternately they may be opportunistic, responding to changes in habitat quality or food supply.

Another possible scenario is that the organic matter moves with the current down the tributaries and into the mainstem, where it is incorporated into the base of the food chain supporting the fish. This pathway would carry less contaminant burden upwards into the fish portion of the foodchain than if the organic material originated in the mainstem portions of the rivers where the contaminated effluents are introduced.

Some of our early contaminant information from samples of fish shows a wide variation in contaminant levels in species like mountain whitefish (Carey *et al.* 1996). The linkage between contaminant studies and food chain studies is an important part of our understanding of how fish become contaminated and provides a basis for providing public advice on consumption of fish and other aquatic resources from the northern river basins.

Predicting the timing and duration of exposure to contaminants of fish is a key requirement of the contaminant modelling. We understand from our fish movement studies that many fish species exhibit complex and variable movements that make predicting their contaminant exposure difficult. The stable isotope studies present a clearer picture of the food chain origins that complements our movement understanding. Of the nearly 280 fish that were analyzed for stable isotopes, 150 were also tested for dioxin and furan levels (2,3,7,8 TCDD and 2,3,7,8 TCDF). These fish were captured in the mainstems and tributaries of the northern rivers. Over 120 of these samples provided valid measures of dioxin and furan.

We divided the total sample into two, based on the sulphur isotope signatures for tributary versus mainstem food sources (Hesslein and Ramlal, 1993, 1995). The samples were tested for normality using a Lilliefors test. They were not normally distributed and so were subjected to a Mann-Whitney U Test to determine whether the two groups exhibited differences in levels of dioxin and furan. For all species combined, over all sampling locations, the tributary feeders showed a significantly ($P<0.01$) lower level of both dioxin and furan than fish that were mainstem feeders. Mean dioxin level for tributary feeders was 0.6 pg/gm (SD=1.5; N=37) while the mean for mainstem feeders was 4.5 pg/gm (SD=5.5; N=73). Mean furan level for tributary feeders was 1.3 pg/gm (SD=13.2; N=39) while the mean for mainstem feeders was 8.5 pg/gm (SD=9.6; N=80).

Insufficient samples were available to analyze for differences at the species level, except for mountain whitefish. Mountain whitefish with tributary food sources showed significantly ($P<0.01$) lower levels of both dioxin and furan than mountain whitefish with mainstem food sources. Mean dioxin level in tributary feeders was 1.3 pg/gm (SD=2.4; N=12) while the mean for mainstem feeders was 6.3 (SD=5.9; N=50). Similarly, the mean furan level for tributary feeders was 3.0 (SD=5.2; N=12) while the mean for mainstem feeders was 10.8 (SD=10.3; N=55).

It is very important to distinguish clearly what is meant by "mainstem feeder" or by "tributary feeder". We know from our movement studies that at least some mountain whitefish move into tributaries and feed there during some seasons. We also know that many of them remain in the mainstems, to feed, during part of the year. Others may remain in these separate locations for entire years. The complicating factor is that "mainstem feeders" will be ingesting a substantial portion of their food intake made up of tributary sourced organic matter that has drifted down from the tributaries into the mainstems. If the growth of organic matter was stimulated in the mainstem (eg. from nutrient enrichment and/or flow regulation causing changes in water turbidity), the picture might be quite different. This could open, or strengthen, a potential pathway for contaminants into the food chain. Organic matter growing in the mainstem could uptake contaminants, which could then be passed on up the food chain in different proportions to what we have observed.

8.0 ECOSYSTEM STRESSES - RESPONSES OF FISH TO CHANGES IN WATER QUALITY

8.1 Stresses on Fish and Fish Health

How are the fish populations in the northern river basins being affected by development? What kinds of stresses are there, and how are fish populations reacting? There are a number of potential stresses present, including industrial and municipal effluents, blockages to fish movement (eg., roads, weirs, dams), changes in dissolved oxygen levels and changes in water levels and flows. NRBS studies of fish responses to pulp mill effluents concentrated on measuring the effects of contaminants on fish physiology and health.

Ecosystem stresses can change the life history traits of fish populations (Brown *et al.,* 1996). Life history traits are characteristics like size at a given age, age at a given maturity level, fertility, and egg size. These traits vary in relation to environmental conditions. Life history traits are linked, so a change in one trait may cause changes in other traits. Analyses of the physiological responses of northern river basins fish to stresses is reported by Brown *et al.* (1993, 1996) and by Gibbons *et al.* (1995).

Brown *et al.* (1996) concluded that, while there were detectable reductions in the circulating levels of reproductive hormones in burbot and longnose suckers downstream of pulp mills, there were not observed impacts on gonadal growth and development. However, the high proportion of immature fish in the samples lead them to conclude that follow-up work was warranted. Similarly, Gibbons *et al.* (1996) found that spoonhead sculpins and lake chub exhibited evidence of exposure to pulp mill effluent in the upper Athabasca River (measured as mixed function oxidase activity, body and organ metrics and age) but that the principle response observed was increase in growth characteristics arising from nutrient enrichment rather than detrimental effects of effluent.

There are continued, consistent references to gross pathological changes in fish reported by the Traditional Knowledge study (Flett *et al.*, 1996) and by the Other Uses Component (MacLock and Thompson, 1996). MacLock and Thompson (1996) report that 14% of basin households surveyed that participate in water based recreation reported changes in fish populations, fish health and fish taste. This proportion rose to 17% among surveyed commercial fishermen. Health of fish populations was felt by survey respondents to be the second most important indicator of river health in the basins.

The Traditional Knowledge synthesis report (Flett *et al.*, 1996) offers some insight into the views of traditional residents of the study area about how fish populations are reacting to stresses in their environment. Elders in the Little Red River First Nation frequently referred to "poisons" in the water.

This is an allusion to effluents from pulp mills and towns. Many say that fish populations have declined over the past twenty years or so. Others mention that fish in some areas are now thinner and more unhealthy than in the past. Some say fish do not taste the same anymore, or that the fish' livers are yellower in appearance. Other comments on fish health include the fact that some fish have sores and cysts.

9.0 GROSS PATHOLOGY OF NORTHERN RIVER BASINS STUDY FISH

The Northern River Basins Study provided an opportunity to collect detailed information about the health of fish. The study was designed to include specific measures of gross external and internal pathology. Over 30 000 fish were captured during the four years of field studies. Most of these fish were released alive after being measured and marked with tags.

Measures of gross pathology included external abnormalities like tumours, lesions, scars or injuries, skin discolouration, deformities and parasites. Some internal measures were taken when fish were sacrificed for chemical or physiological analyses. These measures included tumours, parasites, fat deposits and colouration of internal organs.

The record of external abnormalities provides a simple, mainly qualitative and observational database that can be analysed quantitatively. Nearly 23 000 fish (including most species found in the study area) were examined and reported upon for gross pathological abnormalities. Mountain whitefish, lake whitefish, northern pike, burbot, longnose suckers and white suckers were the main species for which gross pathological measures were recorded. This is mostly due to their prevalence in the sample collections which arises from their relative abundance in the fish community and the selectiveness of both fishing gear and study objectives to collect certain species for contaminant analyses.

The larger collections of several thousand fish, taken over long distances of river length, show relatively low overall levels of gross pathology. Pathological abnormalities for most species occurred in less than one percent of the fish in these large-scale collections. Occasional, very high frequencies of pathological abnormalities are reported (eg., 23 of 30 lake whitefish). These may be related to physiological and behavioural responses to spawning. Similarly, suckers (especially longnose suckers) appear to have occasional very high frequencies of pathological abnormalities. High frequencies of pathological abnormalities also appear in fish sampled near pulp mill effluents. Results in the upper Athabasca River show that detailed pathological studies of fish near pulp mill effluent sources is needed. Two field studies discovered more pathological abnormalities downstream of mill effluent sources than in the remainder of their Athabasca River study sections.

There is a slight indication of a pathological response in fish near the pulp mills in the upper Athabasca River and the Wapiti and Peace rivers. Swanson (1993) reported on gross pathological abnormalities in mountain whitefish and longnose suckers in the Smoky and Wapiti Rivers. She found no consistent, significant differences in any fish health parameters for these species between the Smoky-Wapiti River system and a control sample from the North Saskatchewan River. No tumours or pre-cancerous tissues were discovered during histopathological examinations of fish tissues. Swanson (1993) does report that

Smoky-Wapiti River fish show elevated EROD and Liver Somatic Index measures. This shows an exposure response but does not demonstrate effects. Further investigation into this response is needed.

Shelast *et al.* (1994) sampled over 7 500 fish during their 1991, 1992 and 1993 field seasons. Mountain whitefish, walleye, northern pike, goldeye, white suckers and longnose suckers were measured for external abnormalities, parasites and internal histopathologies. The fish were captured from the Athabasca River between Athabasca town and the Grand Rapids. External measures of "damage" (including scarring, lesions and tumours) ranged from 1.3% of 1 592 mountain whitefish sampled, to 9.0% of 301 northern pike sampled. The data are not directly comparable to Northern River Basins Study data because of the different recording and reporting approach taken. The overall trend is not inconsistent, however.

Table 8. Summary of Gross Pathology Records from Northern River Basins Study Fish Collections

Study Reference & Location	Season	Total Fish Sampled & No. of Species		Gross Pathology Observations (tumours, lesions, skin dis-coloration, injuries/scars, parasites)
R.L.&L., 1994a Athabasca River	April & May 1992	3522	20	All fish appear normal, no pathology forms completed
Boag , 1993 Peace & Slave Rivers	April to June 1992	7198	29	21 fish exhibited pathological abnormalities (0.3% of the total sample) 4 of these abnormalities were tumours (0.06% of the total sample)
Hvenegaard & Boag, 1993 Smoky, Wapiti & Peace Rivers	October & November 1992	185	4	52 of 157 burbot exhibited some abnormalities (33% of the total burbot sample) 5 of these abnormalities were tumours or lesions (3.2% of the total burbot sample)
Barton *et al.*, 1993 Athabasca River	May 1992	168	9	23 of 62 mountain whitefish exhibited external abnormalities (37% of the total mountain whitefish sample) 9 of these abnormalities were tumours (14.5% of the total mountain whitefish sample) 2 of 23 northern pike, 26 of 57 longnose suckers, and 13 of 26 white suckers exhibited abnormalities tumours or lesions accounted for 8.7, 10.5 and 7.7 percent of these abnormalities, respectively Fish in this sample were judged to be free of gross pathology, except for external measures Mountain whitefish were observed to carry a higher frequency of external abnormalities downstream from Hinton, compared to samples from upstream of Hinton

Study Reference & Location	Season	Total Fish Sampled & No. of Species		Gross Pathology Observations (tumours, lesions, skin dis-coloration, injuries/scars, parasites)
Patalas, 1993 Peace River	October 1992	465	11	2 of 15 lake whitefish examined exhibited abnormalities; one was scarred and one had red, circular lesions 1 northern pike had black spots, attributed to a strigeid fluke (*Uvulifer ambloplitis*)
R.L.&L. 1994b Athabasca River	October 1993	4792	16	67 fish had abnormalities (1.4% of total sample) tumours accounted for 0.06% of these abnormalities 29 of 3831 mountain whitefish had abnormalities (0.8% of mountain whitefish sampled) 3 of these abnormalities were tumours (0.08% of total mountain whitefish sampled) 23 of 30 lake whitefish sampled exhibited abnormalities (76.7% of total lake whitefish sampled, but these were mainly blisters)
Smithson, 1993 Lake Athabasca	February 1993	52	4	gross pathological abnormalities were observed to be consistent with previous samples from Northern Saskatchewan waters; mainly internal parasites: *Triaenophorus sp.*, and black spot (probably *Neascus sp.*)
Balagus *et al.*, 1993 Peace-Athabasca Delta	February 1993	239	6	1 of 105 lake whitefish had an abnormality (0.95% of the total lake whitefish sampled)
Jacobson, 1995 Peace, Athabasca & Slave Rivers	September October & mid-December 1994	535	13	84 fish had abnormalities (15.7% of the total sample) 42 of these abnormalities were tumours (7.9% of the total sample) nearly half of these abnormalities were observed in longnose suckers (40 of 84 abnormalities observed)
R.L.&L., 1995 Athabasca River	May 1994	3174		15 fish had external abnormalities (0.5% of the total sample) N.B. all of these fish were sampled in a 15 km section of the river immediately downstream of the confluence with the McLeod River
Golder & Associates, 1994 Athabasca River	October 1993	2630	10	124 of 2630 fish sampled exhibited abnormalities (4.7% of the total sample) 13 of these abnormalities were tumours (0.5% of the total sample) N.B. all of these fish were sampled within 10 km upstream and 20 km downstream of the confluence with the McLeod River

10.0 SUMMARY OF FINDINGS

This study has added to our knowledge of the fish distribution and movements in the basins. It has added to our knowledge of the spawning, early rearing and overwintering habitat use of several species:

- Observed movement patterns demonstrate that fish exposed to effluent plumes move elsewhere, both upstream and downstream of the effluent plumes. These movements vary according to species and in duration and timing.

- Complex and long-distance seasonal movements were demonstrated for mountain whitefish in the Athabasca River.

- Seasonal spawning movements of bull trout and mountain whitefish were described in the upper Athabasca River. Movement upstream in the Athabasca River mainstem into Jasper National Park was documented for both species. Evidence indicates that at least a portion of the population spawned in the tributary rivers to the Athabasca River, within Jasper National Park, but it is not clear what portion of these populations are involved in this spawning movement or where the remaining bull trout and mountain whitefish may spawn.

- Athabasca River tributaries in Jasper National Park were discovered to be important spawning, incubating and early rearing habitats for bull trout and mountain whitefish. Similarly, the upper Athabasca River contains important early rearing habitat for mountain whitefish along the mainstem river channel.

- The growth, feeding and early rearing life strategies of mountain whitefish in the upper Athabasca River were described.

- Extensive movements of goldeye were documented in the mainstem channel of the Peace River.
- Observations of the distribution of burbot in the Athabasca, Peace and Slave Rivers confirms its suitability as a basin-wide ecosystem monitoring species in the fish portion of the food chain.
- Stable isotope work has revealed that much of the food production entering the base of the fish food chain originates from the terrestrial environments of the tributary river systems. Analysis of contaminant loads of fish samples used in the stable isotope experiment indicates that the higher body burdens of contaminants occur in fish feeding on food that originates in the mainstem channel of the Athabasca River compared to fish feeding on food originating in the terrestrial environments of the Athabasca River tributaries.

- Gross pathology assessments demonstrate that most species exhibit low levels of gross, external pathology however there is evidence of increased incidence of pathology in the vicinity of pulp mill effluents.

10.1 Response to NRBS Board Questions

The central question supporting the Food Chain Component work is question number six relating to fish distribution, movement, exposure to changes in water quality and location of important habitats.

Most of the fish species in the basins are widely distributed. They make extensive use of the river mainstems and tributaries. Some species have localized, relatively sedentary populations (spoonhead sculpin); others are found in discrete, often highly mobile populations (goldeye); yet others occur in extremely complex population structures with equally complicated patterns of movement and habitat use (mountain whitefish). There are several species that are mainly restricted to headwater portions of the basins (bull trout); species like walleye and northern pike use mainly the larger, downstream mainstems and tributaries; others occur only very locally (pygmy whitefish); some frequent the entire study area (burbot). The Northern River Basins Study has added to the understanding of fish distribution in the northern river mainstems and we have made important gains in our knowledge of fish movement in the basins.

The issue the effects on northern river basins fish of exposure to water quality changes is less well understood. We know that some species like mountain whitefish experience complex patterns of exposure, reflected in their highly variable contaminant burdens. This species continues to be an important concern because of its frequent use as human food but we are not yet able to predict its exposure or to forecast its response to changes in water quality with any precision. This is attributable to the complex movement patterns seen in mountain whitefish and to their variable patterns of feeding. NRBS studies of 'small' fish species near pulp mill effluents leads to the conclusion that these fish may be better sentinels of water quality changes than many of the more commonly sampled fish species. Burbot continue to be relied upon as a basin-wide fish health indicator because of their relatively sedentary movement patterns, their wide distribution and top level trophic status.

Critical habitats for fish are widely dispersed throughout the river basins for most species. These habitats may be broken into many fragmented portions along the river mainstems or in the tributaries. For some species, like bull trout in the upper Athabasca River, spawning and early rearing habitats were discovered during the study.

Study Board questions numbers 1a and 8 relating to effects of exposure to contaminants and changes in these effects are mainly addressed in the reports of the Nutrients and Contaminants Components. Some important observations have arisen from the extensive fish collections that demonstrate locally higher levels of gross external abnormalities in the upper Athabasca River near Whitecourt. Fish appear not to be responding to water quality changes with reductions in key measures of overall population health; however, this was not a deliberate focus of the Food Chain Component studies. The trends observed by other study component scientists in water quality, nutrient and dissolved oxygen content, and contaminant burdens in fish all appear to reflect improvements in the health of the aquatic ecosystem. It is to be expected that these trends will be reflected, in diminishing levels of gross external abnormality also.

11.0 RECOMMENDATIONS

Several recommendations arise from the Food Chain Component studies for monitoring and further research.

- Radio telemetry studies of seasonal life history characteristics, habitat use and exposure to contaminant point sources should be conducted in the Athabasca River with bull trout, mountain whitefish and burbot to determine time and duration of exposure to contaminants.

- The fish inventory database needs to be subjected to detailed analyses to detect species, seasonal and basin specific trends in fish metrics (age, growth, maturity, etc.) that may exist at both the organism and population levels.

- A detailed field analysis of gross pathology should be conducted on the fish species in the upper Athabasca River.

- A long-term, periodic monitoring program should be implemented to follow trends in fish population-level effects of ecosystem change. Fisheries monitoring should include systematic recording and periodic assessment of the occurrence of gross pathology using standardized techniques to assess whether long-term trends in the health of fish are indicated.

- Further stable isotope work is needed for the tributary systems to refine our understanding of food production at the base of the fish portion of the food chain.

- In-situ bioassay studies with eggs of bull trout, mountain whitefish and burbot should be performed at key sites in the Athabasca River. This would allow us to assess the influence of natural conditions and the effects of contaminants and dissolved oxygen variation.

- Bull trout in the Athabasca and Peace Rivers and pygmy whitefish in the Athabasca River deserve additional species specific research and monitoring attention as fish species of concern.

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