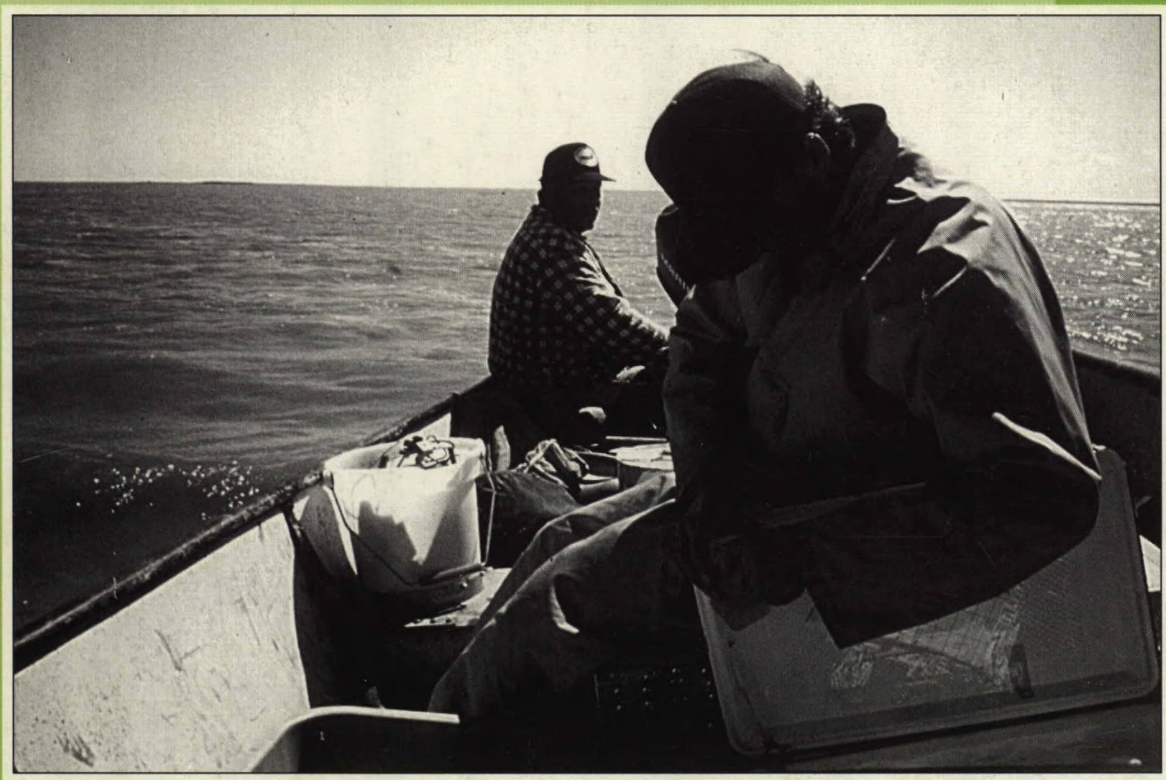
Synthesis of Fish Distribution, Movements, Critical Habitat and Food Web for the Lower Slave River North of the 60th Parallel: A Food Chain Perspective

13

Synthesis Report



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NORTHERN RIVER BASINS STUDY
SYNTHESIS REPORT NO. 13

SYNTHESIS OF FISH DISTRIBUTION, MOVEMENTS, CRITICAL HABITAT AND FOOD WEB FOR THE LOWER SLAVE RIVER NORTH OF THE 60TH PARALLEL: A FOOD CHAIN PERSPECTIVE

by

Ross F. Tallman
Department of Fisheries and Oceans,
Central and Arctic Region

Major Collaborators:

W. Tonn, K.J. Howland
Alison Little
Department of Biological Sciences
University of Alberta

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REPORT SUMMARY

This report brings together and synthesizes the available information on fish distribution, movements, critical habitat and food web for the lower Slave River north of the 60th parallel. The report is composed of seven major sections. The first section discusses background information, the original relevant questions posed by the NRBS, and three general models of the function of large rivers. The second section gives a description based on the literature of the environment in the lower Slave River including information on geography and surrounding habitat, climate, primary productivity and invertebrate faunal composition. The seasonal climatic variation is great and this results in striking changes in the primary productivity and invertebrate faunal composition.

The third section considers the distribution and abundance of fishes in time and space to provide a context for the interpretation of the findings of contaminants studies. Twenty-seven species of fish have been recorded to occur in the lower Slave River. The section provides a description from data gathered by the Northern Rivers Basin Study and previous studies of spatial distribution between the Slave River, Salt River and the Slave River Delta and of micro-habitat usage in the Delta. Seasonal and longer term variation in species composition are described. Fish species composition varies between the major areas of the lower Slave River and seasonally due to spawning migrations. The spring spawners such as goldeye, flathead chub and walleye dominate shortly after ice break-up. Fall spawners such as lake whitefish and inconnu become abundant during the months of September and October. Pike, flathead chub and goldeye remain relatively abundant throughout the open water season. Goldeye is the most abundant species of fish in the lower Slave River. Based on gillnet catches the diversity of major fish species has not changed to any recognizable degree from the late 1970's to the present.

Radio-telemetry and floy-tagging studies of harvested fish species, such as inconnu, burbot, lake whitefish, walleye are synthesized in section four to provide information on the range of movement in and out of the lower Slave River. Inconnu utilize the river for spawning in the fall but then return to Great Slave Lake for most of the rest of the year. Radio-telemetry and tagging results showed that inconnu migrate around much of the western basin of Great Slave Lake during the winter. They appear to travel along the southern shoreline during the summer and return to the Slave River by the fall. Lake whitefish also use the Slave River for spawning in the fall but may remain in the river until the next spring. Burbot appear to be sedentary most of the year but will undertake a winter spawning migration within the river to the Delta. Only limited information exists on pike and walleye movements. Walleye probably utilize Great Slave Lake for foraging while pike remain in the river and the Delta.

The demographic characteristics of inconnu, burbot, lake whitefish, lake cisco, goldeye, northern pike, flathead chub, longnose sucker and walleye are examined in section five.

Inconnu are fast growing and short lived in the Slave River compared to other locations. This may be due to exploitation or because they are at the southern end of their range. Their limited age structure makes them more vulnerable to the effects of changes in the environment. Burbot, on the other hand, are quite long lived in the lower Slave River. They appear to be relatively unstressed as a population at this time. Most of the other species do not show unusual patterns in their demographics compared to other conspecific populations or indications that they might be vulnerable to moderate environmental change.

Section six summarizes the available information on the diets of the major fish species in the Slave River and Delta in order to construct a piscine food web. The food web of the Slave River was highly dependent on the invertebrate community for its base. Foraging species, such as cyprinids, whitefish, suckers and goldeye, consumed invertebrates and were in turn consumed by top predators such as burbot, pike, walleye and inconnu. Three fish species, pike, goldeye and lake whitefish played dominant roles in that they could influence many other species of fish and invertebrates. These species, plus burbot, were also important in the food web of the Slave River delta. In general, the food webs are complex and may have predator-prey circularities where one species preys upon juveniles of another, while also being the prey to the adults.

Finally, section seven provides a summary of the major findings and knowledge gaps uncovered by the synthesis. There are 22 recommendations made for further work in the areas of biological monitoring, studies of habitat needs of fishes, and modelling. Monitoring requirements are divided into monitoring population function and species diversity. It is recommended that baseline data on the vital parameters of populations of goldeye and other forage species be gathered. As well, because of their vulnerability to change studies on the growth patterns of juvenile fishes should be done. Regular monitoring of the vital parameters of fishes is recommended. A quantitative model of the effects of environmental change on the life history trajectory should be developed. Regular monitoring of the diversity of fishes and invertebrates should be carried out.

To accurately determine the potential and actual consequences of environmental changes to fish populations a greater understanding of the distribution and movement patterns must be achieved. It is recommended that studies of distribution and movements under the ice, in the backwaters and tributaries of the lower Slave River and during the flood-pulse phase be undertaken. Quantitative models integrating distribution, movement patterns and the risk of exposure to environmental degradation, such as contaminants should be developed.

It is clear from this work that the lower Slave River is a unique part of the NRB. The biological community is relatively isolated from other communities upstream but it is probably vulnerable to perturbations further upriver.

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1.0 GENERAL INTRODUCTION TO FISH HABITAT STUDIES IN LARGE RIVERS

1.1 Background, General Questions and Prologue

The development of various industrial projects and increasing demands on use in northern Alberta river systems was a concern in the late 1980's and continues to be so. The Northern Rivers Basin Study (NRBS) was proposed in 1989 and culminated in a plan that addressed 10 intial questions. This plan was presented to the NRBS Board soon after the start of the Study on September 27, 1991. From this the Board developed sixteen guiding questions for the science program focussed on aquatic-ecosystem health and functioning in the major river systems that might be affected - the Peace, Athabasca and Slave Rivers. The Food Chain Component was formed to conduct studies to address questions about how industrial effluents affect fish. The NRBS Board posed the following questions related to fish:

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 are the distribution and movement of fish species in 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?

It was quickly recognized that there was an insufficient understanding of the fish community and the basic biology of fish species to allow interpretation of toxicological results in terms of exposure or to determine if the biota had been affected. As Prowse and Conly (1996) state "The range of potential studies (in hydrological impacts) was constrained by the lack of comprehensive understanding of the structure and function of the biotic environment of the affected river and delta systems. Knowledge of preferential use of fisheries habitat, for example was very limited". With this in mind, studies commenced on the Peace and Athabasca Rivers consisting of field surveys of fish movement, distribution and habitat and life history, field surveys and laboratory experiments of food sources and food chain pathways (Mill et al. 1996). Prior to 1994, studies on the Slave River were mainly confined to the portion of the river south of 60° N. latitude, at least partly because it was felt that more was known about the north of 60 portion of the Slave than the other parts of the study area. In late 1993, it was recognized that the Slave River north of 60° N latitude was probably a unique component of the system and deserved separate NRBS investigations of the biota as a contextual background to the findings of contaminants studies. Realizing that there was only one full open water season left for field work and that limited resources were available, the scientific program had to be directed towards what was tractable. It was decided to conduct studies in three areas: 1) Fish movements: using long-term radio telemetry studies of selected species and catch-per-unit-effort analysis of changes in abundance; 2) studies of vital rates (i.e. growth, age at maturity, fecundity and other parts of the life history trajectory) of key harvested species; 3) a direct study of the diets and food web in the fish community. The first study would characterize the habitat usage patterns of fish species in time and space in the system. The second would serve to give a baseline to assess changes in productivity within fish resources valued for their monetary or nutritional worth to man.. The third would provide a model of the configuration of the fish community and the interactions therein, defining trophic levels and the basis for fish productivity in the entire community. The first and third studies would be instrumental in developing a model to interpret the likelihood of exposure to contaminants and given the presence of contaminated fish, their probable fate and transport within the Slave River. The second allows assessment of sub-lethal effects on the fish themselves.

A synthesis of these studies and previous work related to fish communities in the Slave River north of 60^{o} (i.e. the lower Slave River) from the perspective of habitat requirements of fish in the lower Slave River was requested by the NRBS on December 22, 1995. Previous studies would provide information: on fish movements from floy tagging, radio-telemetry, catch effort analysis and traditional knowledge (Flett et al. 1995); to augment the available information on vital rates of fish community species; on the diet in selected areas such as the Slave River Delta. Combining the results and in some cases re-analyzing data from previous studies and the NRBS studies into a synthesis would give the most comprehensive picture of habitat requirements of fishes. One additional theme to those posed in the NRBS questions was: Has the fish community changed over the last 15 years?.

This report is broken into seven major sections: 1) A general overview perspective on defining habitat requirements in aquatic communities; 2) A description of the biotic and abiotic environment surrounding the lower Slave River fish community; 3) Distribution and abundance of fishes in time (seasonal and long-term) and space; 4) Geographic migratory patterns; 5) Demographic characteristics and vital rates of fish species; 6) Fish community and food web; 7) A summary of the major results and a compendium of the scientific recommendations for studies of the fish community in the future.

1.2 Aquatic communities, habitat requirements and probability of exposure

Fish communities in rivers have some unique features to their habitat which cannot be understood using concepts borrowed from studies of lake or stream communities (Johnson et al. 1995). Large rivers have been studied less than small streams and lakes, partly because they are more difficult to sample but also because there has been no clear theoretical basis for how large river ecosystems operate (Davies and Walker 1986). To discuss the habitat requirements of a community of fishes in a large river, such as the lower Slave River and relate them to the effect of anthropogenically driven changes, such as dams, mill effluents impacts of logging, is a formidable task. Recently, there have been three major theoretical models of large river function , the river continuum concept (Vannote et al. 1980) the flood-pulse concept (Bayley 1995, Junk et al. 1989) and the riverine productivity model (Thorpe and DeLong 1994), which are useful in inter-relating such elements as hydrology, contamination, fish movements and communities. Awareness of these concepts will place our studies on fish into a wider context of the entire aquatic ecosystem.

1.2.1 The River Continuum Concept

Rivers move. Fish move. Each of these can bring contaminants into an ecosystem. The River Continuum Concept focusses on the movement of the river. The concept states that forested river systems, such as the Slave River, have a longitudinal structure that results from a gradient of physical forces that change predictably along the length of the river. These forces produce a continuum of morphological, hydrological and biological features from the headwaters to the mouth. The unidirectional nature of water movement in the river means that anthropogenic effects may reach far downstream from their point source.

The river-continuum concept assumes that energy for biological production comes from three sources: local inputs of organic matter from terrestrial vegetation (allochthonous inputs), primary production within the stream (autochthonous production), and transport of organic material from upstream. The importance of these energy sources varies along the continuum (Figure 1).

The structure and function of the biotic communities along the river continuum is predicted to develop in dynamic equilibrium with the physical environment, and thus, it should be predictable based on the variability of the environment and the source of energy (Ward and Stanford 1983). For example, large rivers (those that are greater than sixth order - Strahler 1957) buffer temperature and flow variation compared to smaller systems. Leaf litter inputs are minor in large rivers and primary productivity is reduced due to turbidity. The main energy source is particulate organic matter transported downstream, thus collectors are the dominant invertebrate group (Johnson et al. 1995).

Thus, it is clear that disruption of the system upstream may have powerful effects downstream but the mechanism may not be immediately obvious. For example, contaminants or flow changes may affect fish populations downstream directly by being transported in the water column but they also might affect fish populations downstream by disrupting the physiology of decomposers of detritus (Less available decomposed food for invertebrates - less invertebrates for fish to feed upon) or by preventing the detritus energy source from reaching downstream.

1.2.2 The Flood Pulse Concept

The Flood-Pulse concept focusses, at least partly, on movement by fishes. The flood-pulse

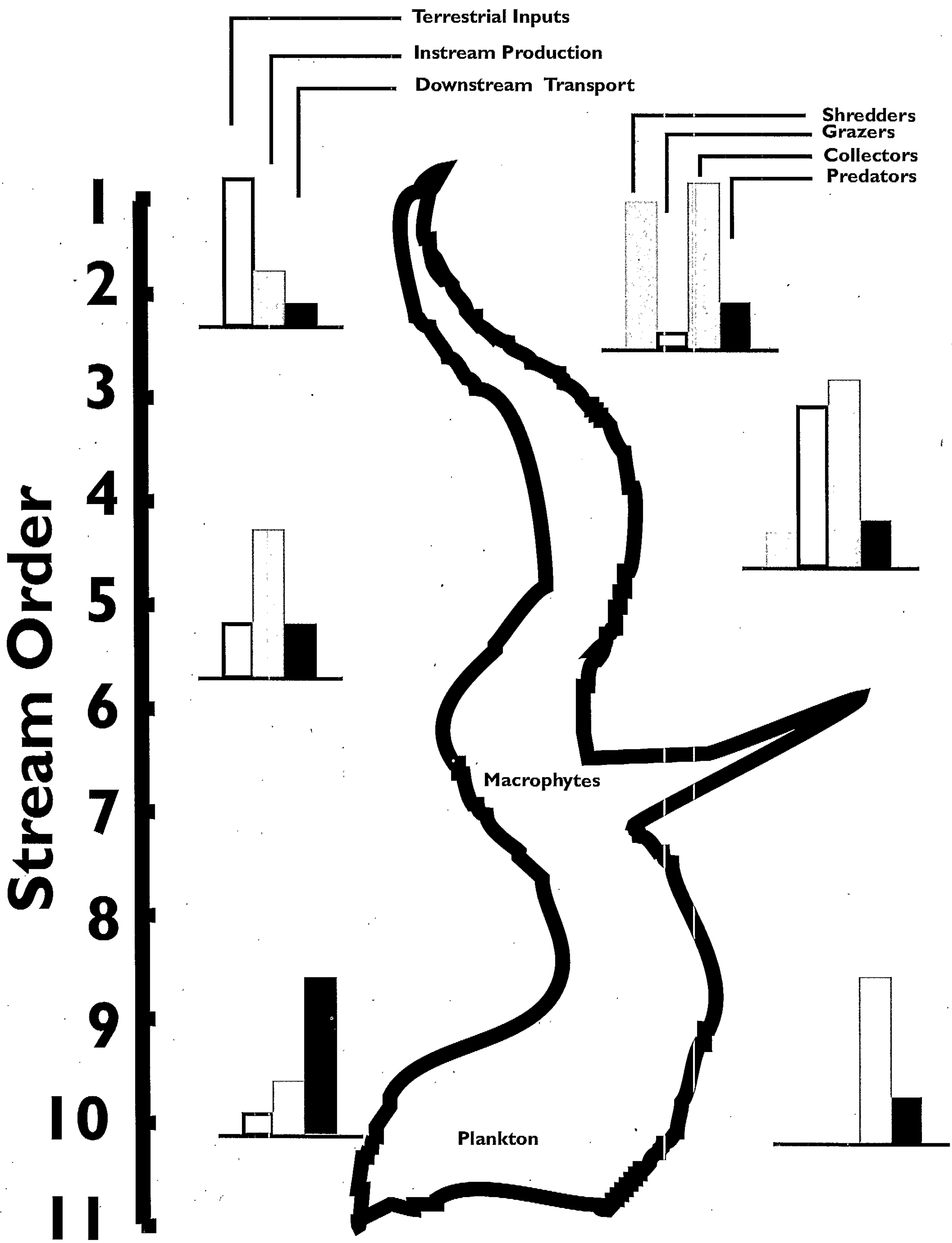

Figure 1. Schematic of the river-continuum concept depicting the river channel from first order to large river (After Johnson et al. 1995.

concept states that the most important hydrological feature of large rivers is the annual flood pulse, which extends the river onto the floodplain (Bayley 1995, Figure 2). Floodplains are highly productive and typically contain extensive riparian forest and a variety of aquatic habitats such as backwaters, marshes and lakes. During a flood the aquatic organisms migrate out of the channel and onto the floodplain to use newly available habitats and resources. As the flood waters recede nutrients and organic matter from the floodplain are funnelled back into the main channel, side channels and backwaters, along with newly produced biomass, such as young fish, invertebrates and waterfowl.

Under the flood-pulse concept, biotic communities should evolve adaptations to take advantage of the dynamic interaction between water and land. Thus, fish spawning time, juvenile and adult movements are all adapted to the opportunities that the flood pulse presents. The major zone of activity is the moving littoral (Junk et al.. 1989). which is an inshore zone from the water's edge to a few meters in depth. This zone traverses the floodplain as flooding and drawdown take place. High turnover rates of organic matter and nutrients are predicted to occur largely as a result of this movement. During flooding nutrients previously mineralized during the preceding dry phase are dissolved and enter the main river. The moving littoral provides an excellent nursery grounds for fish and near optimum environment for many invertebrates, especially those associated with macrophytes (Junk 1973). Fish need to grow quickly through the flood period to reach sufficient size to reduce predation losses when the water volume subsequently reduces to its minimum and to reduce overwinter mortality in temperate systems (Bayley 1995).

In general, river floodplain biota have high annual growth and mortality rates. They have evolved life-history strategies that enable then to quickly colonize large areas. They are therefore mobile active species that undergo aggregations and dispersions throughout the season. This ability helps them persist in the system over time because the flood pulse is variable in magnitude and different areas are available in different years.

The flood-pulse concept introduces a strong component of lateral movement to our view of the system. The critical habitat for fishes incorporates the surrounding areas of the channel. As well, it incorporates a powerful seasonal effect, which is clearly the case for sub-Arctic systems such as the Slave River. The habitat changes with the season and the necessary habitat for reproduction of a fish species may not be same as the appropriate rearing or feeding habitat - a diversity of species specific habitat usage and seasonal migratory patterns within the river result.

Thus, the perception of fish habitat requirements in large rivers must include not only a cartographic sense of the habitat as the main channel environment surrounding the fish populations of the lower Slave River but upstream areas, the moving littoral and areas lateral to the channel, and the seasonal dynamics upstream of, lateral to and within the channel itself. Preservation of habitat will maintain species diversity and enhance production of harvested fishes (Bayley 1995).

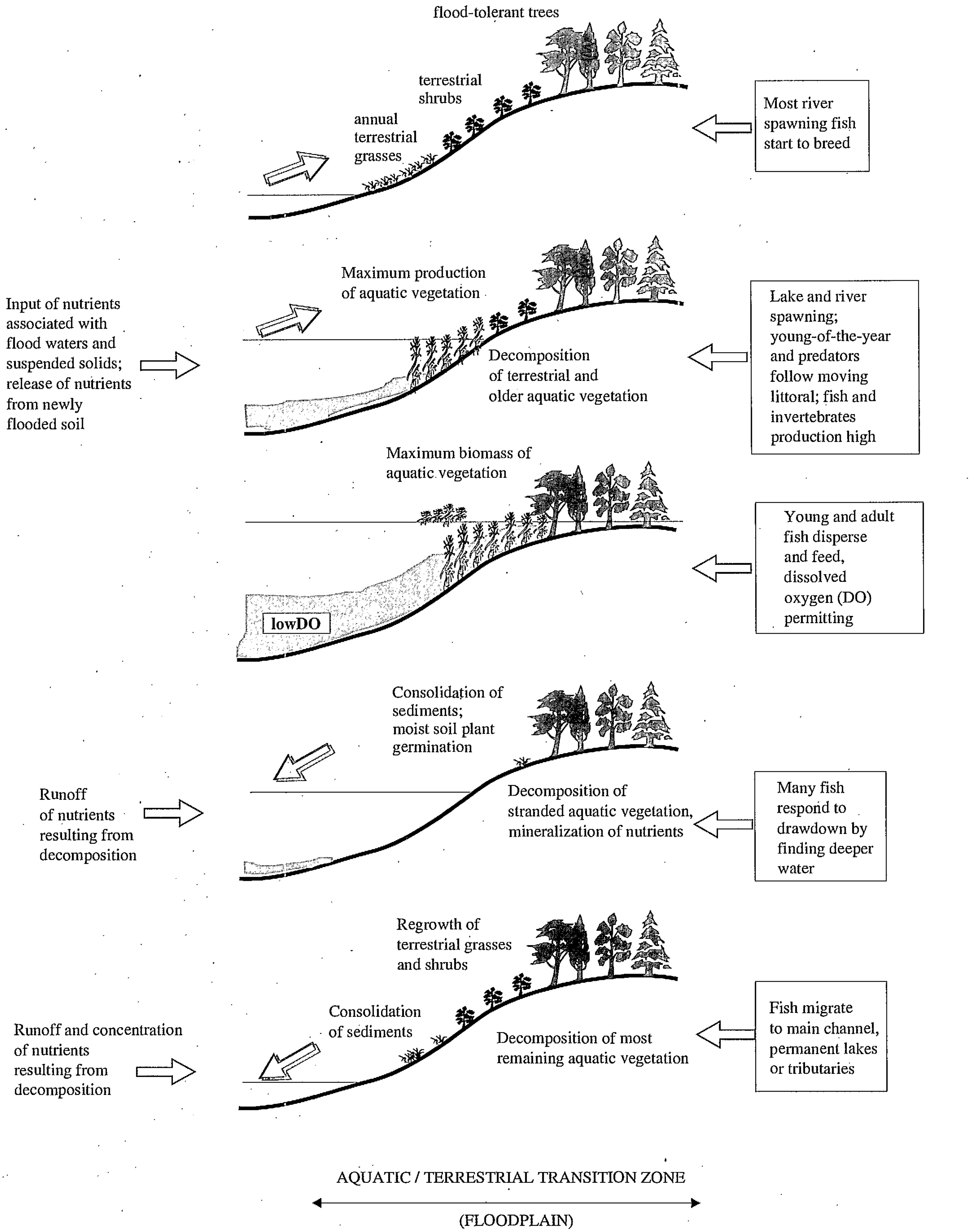

Figure 2. Diagram of flood-pulse concept showing five points in the hydrological cycle (After Bayley 1995).

While one logical approach is to study these systems from the bottom up, level by level starting with hydrology, Bayley (1995) connected the flood pulse effect to fish yield. Yield from multispecies fisheries can be regarded as integrating a variety of aquatic and terrestrial processes in the river-floodplain (Bayley 1995). All available data on riverine fisheries indicated that yields were higher on river-flood plains than one might expect from the increase in surface area alone in flooding.

If fish are integrators then we can benefit from studies of their vital rates which will presumably reflect all of the influences of the surrounding habitat throughout their lives. How fish use the environment in space and over the season can define key areas of habitat that must be preserved. Studies of the diet can give an indication of what are necessary items (such as key species of invertebrates) for their survival items. Keeping in mind that the riverine habitat is much greater than it superficially appears we can get some ideas regarding the likelihood of exposure to anthropogenic effects or given an exposure what might the pathway leading to the effect's arrival.

1.2.3 The Riverine Productivity Model (RPM)

The riverine productivity model assumes that a substantial portion of the organic carbon assimilated by animals comes from local plants (autochthonous production - phytoplankton, benthic algae, aquatic vascular plants and mosses) and direct inputs from the riparian zone (i.e leaves and other sources) throughout the open water season. Thorpe and DeLong (1994) hypothesized that food webs in large rivers characterized by a restricted channel and adequate firm substrate would be driven by the above two sources of organic carbon. Additionally, they proposed that primary productivity, especially from phytoplankton is a significant contributor to secondary productivity. The macroinvertebrate community will be dominated by grazers rather than filterers and gatherers. Thorpe and DeLong (1994) made no predictions regarding the fish community structure and therefore the applicability to our concerns may be limited.

Rather than challenging the concepts of earlier theories Thorpe and DeLong (1994) suggested that the applicability of the various hypotheses will vary depending on the river size and geomorphology. The river continuum concept is most appropriate for headwater streams and small rivers, whereas the flood pulse concept is limited to large floodplain rivers. The RPM is relevant to large rivers with constricted channels and firm substrates in the photic zone. The concepts are not mutually exclusive and rivers probably conform to varying degrees to all three.

1.2.4 Application to the Slave River

These theories give some context with which to consider the lower Slave River but as Davies and Walker (1986) state we do not really understand the ecology of large rivers. Large sub-Arctic river systems such as the lower Slave River are even less well understood because of their relative remoteness and generally poor models of the ecology of winter-bound systems. According to Barton (1986) no study has been designed to identify annual variations in species composition or production of the biota.

Water recognizes no political boundaries and therefore there is a need to acknowledge that the lower Slave River is connected (how connected is the question) to the Peace, Athabasca and upper Slave rivers and Great Slave Lake. What occurs in these systems could potentially affect the fauna of the lower Slave. Scientifically, we must recognize that rivers are unified in their ecology even if we must (for tractability) study them piecemeal.

The description of habitat requirements includes all factors that affect the survivorship and health of fishes both at an individual and population level. Thus, one must consider the abiotic factors in the environment such as water flow, discharge, temperature, other climatic factors, chemistry, and so on, and the biotic factors both autochthonous and allochthonous. The lower trophic levels, as well as the fish food web should be described. The purpose of this report is to focus on the fish community because that is where the environmental impacts of development that affect man will be observed. However, the ecosystem is an integrated entity and an understanding of the environment as perceived by the fish is essential to an appreciation of the cascading ecological consequences of environmental degradation. Thus, I will give a model of the habitat base via a synthesis of information from studies of other systems and the limited information available for the Slave River.

As another approach to the problem we might ask "how do communities respond to disturbances?". Krebs (1988) uses the analogy of imagining a community as a billiard ball rolling on a topography set by the environment. The ball comes to rest in a low spot in the topography and we can call the resting position the natural or original community. If we disturb the system by hitting the ball slightly - the way we would perturb a community with a small oil spill - the ball rolls uphill a ways and then returns to the original position - the system is locally stable. A major force (e.g. the Bennett dam) may move the ball to a new locally stable position on the topography, that is, the community does not return to its original configuration.

A change in configuration is defined as when the species present in the community and their abundances change dramatically. According to Krebs (1988) at present, we can measure changes to some of the common species in our communities, so we have only a crude ruler on which to measure biological disturbances. The configuration of a community is most clearly seen in the abundances of each species and in its food web. By comparing the results of previous studies such as Tripp et al. (1981) and McLeod et al. (1985) to our own we may be able to determine if the composition of the fish community has changed since 1978. As a baseline of the community configuration we also define the food web.

The major question in determining the food relations among members of a community is "who eats whom?" Food webs are organized by two major processes: "vertically" by predation and "horizontally" by competition. Because fishes grow through a large range of sizes during their lives, fish communities commonly have "circular" food webs where the adults of prey species may feed on the juveniles of their predators. For example, rainbow smelt live in the open waters of Lake Erie and are eaten by lake trout, lake whitefish, blue pike and sauger (Zaret 1980). As these species were reduced during the 1940's and 1950's, smelt increased in abundance. The "predator" species declined further because their young fry were fed upon by older smelt. The concept of "predator" and "prey" is reversible depending on the size of the fish, and the question of who eats whom results in a complex answer.

The response of fish communities to disturbances has been modelled successfully by Zaret (1980) based on the maximum size of a species, their life history and trophic position. Fish communities can be divided into three size related groups:

Large fishes: feed on fish, are highly predatory, often having low growth rates, and have older age at maturity, populations that are stable over time, and are highly desirable species for fisherman (e.g. inconnu, burbot).

Medium-sized fishes: feed on small fish, plankton and benthic invertebrates, exhibit moderate population fluctuation, and are desirable species for fishermen (e.g. walleye).

Small fishes: feed on plankton and benthic invertebrates, show high growth rates, and younger age-at-maturity, exhibit great population fluctuations, and not always desirable species for fishermen (e.g. flathead chub, goldeye).

As stress is applied to the fish community, larger forms fade away gradually and medium-sized forms collapse irregularly. The small fishes are the most resilient to stresses and tend to retain high but fluctuating abundance.

The habitat requirements for fishes are highly variable depending upon the species. Some fish may be adapted for high velocity water, others to withstand low oxygen. The species may use the system mainly for reproduction and appear only seasonally or may complete their entire life cycle within the system. To define habitat requirements comprehensively is therefore an enormous task. Given the limited amount of information on the Slave River it cannot be fully attained at this time. However, as a reasonable starting point we might attempt to characterize the use of the habitat in time and space by various fish species. In other words, what species are where and when. At least, then the potential impacts of development could be described in terms of what species might be affected. Ultimately, the impacts of development will most likely be recognized by the lowered abundance, productivity or extinction of fish species. These impacts cannot be measured without first, information on the temporal and spatial patterns and some information on fish productivity. Second, we should consider for the most important harvested species whether their vital rates make them vulnerable to environmental degradation. Following this we must consider if changes to the community composition and abundance of fishes has already taken place by examination of the available information and compare it to our results. Finally, we should consider the inter-relationships between species in terms of potential competition, predation and trophic pathways by which environmental degradation such as contaminants could work their way through the food chain. The last consideration will be particularly important to consumers of fish from the area since most harvested species are piscivorous predators near the top of the fish food web and therefore are likely to concentrate contaminants in their flesh.

The key concept in this work is to develop an ecological context with which to interpret the effects of contaminants and other anthropogenic impacts. Because fish species in a community occupy different niches and therefore have different movement patterns and trophic relationships with other species they will vary in their probability of exposure to anthropogenic effects (R. Hesslein, DFO Central and Arctic Region, pers. comm.). We will endeavour to develop a model of movements in time and space coupled with the position of the species in the food web that can give an estimate of their likelihood of exposure.

Geology, climate and habitat types will determine the amount and distribution of primary and secondary productivity and hence will have a profound influence on the distribution of fishes.

1.3 Immediate Background for Development of NRBS Slave River Studies

Impacts of development on aquatic systems are often most noticeable, especially to the public, in their effects on fish populations. Many fishes are top predators in the aquatic food chain. As such, they can be most severely affected by the bio-magnification of toxicants in the system. These same species can also be important as food for humans and as part of a traditional lifestyle for aboriginal peoples (Flett et al, 1995). For example, fishing was noted by Flett et al. (1995) as one of the most common traditional life skills maintained by the aboriginal population of the community of Fort Smith. Through fishing the public will monitor the health of a system by making personal observations on changes in numerical abundance, average size and condition of the animals that they catch. Because of their size and value fish are the most visible aquatic animals to the public. Fish kills are noticed.

For aboriginal peoples of communities such as Fort Smith, fishing continues to be an activity that most traditional resource users practice (Flett et al. 1975). Important riverine fish species harvested for human consumption and dog food are northern pike, lake whitefish, walleye, goldeye, burbot, sucker and inconnu (Flett et al. 1995). Flett et al. (1995) states that traditional users identified that there had been declines in the numbers available, size and flesh quality of fish in the area near Fort Smith.

The degree of accumulation and transport of toxicants in fish depend upon their concentration in the ecosystem and the behaviour and biology of the fish species. In particular, the patterns of movement and diet of a fish species will determine the extent to which it is affected. The life history traits of each species, such as size at age, age at maturity, age structure, fecundity, and egg size are considered to be optimized by evolution. These traits integrate the effects of cumulative impacts of ecosystem changes on the species in question through the individual fish and, ultimately, the population. To understand the effects of ecosystem change on fish one must understand their movement patterns in time and space, their dietary and trophic (foodweb) relationships and their demographics.

The Slave River and its delta has been the least studied of the three watersheds with major deltas in the Mackenzie River Basin (Tripp et al. 1981). McLeod et al.(1985) noted that 25 fish species occurred in the Slave River proper, with all except chum salmon (Oncorhynchus keta) and emerald shiner (Notropis atherinoides) also present in the delta. The river is considered to be an important area for spawning of species such as inconnu (Stenodus leucichthys), lake whitefish (Coregonus clupeaformis), burbot (Lota lota) and walleye (Stizostedion vitreum) (Tripp et al. 1981). According to traditional wisdom, riverine fish species that are most frequently used or observed by members of the Fort Smith community are northern pike, lake whitefish, walleye, goldeye, burbot, sucker, inconnu, mountain whitefish, rrainbow trout and chub (Flett et al. 1995). The Slave River system has been noted by Katapodis and Yaremchuk (1994) as being highly vulnerable to resource development.

Tripp et al. (1981) employed floy tags to mark 4044 fish (mostly goldeye) which included 334 lake whitefish, 495 burbot, 413 walleye but only 18 inconnu. From their results, Tripp et al. (1981) proposed that inconnu and lake whitefish migrate through the delta in late summer and early fall to spawn upstream (Figure 3). Large concentrations of both species have been observed in the vicinity of the rapids at Fort Smith during late fall. Tripp et al. (1981) also suggested that walleye move through the delta to spawn in the Slave River during the spring. Some return to feed in the delta shortly after spawning while others return in early fall to feed before continuing on to overwintering areas in Great Slave Lake. Burbot were reported to move into the delta area to spawn from late freeze-up to late December. Although it is likely that most return to Great Slave Lake, some burbot apparently move upstream as far as Fort Smith after spawning. Burbot, walleye and inconnu thus represent a range in expected migratory tendency from least migratory to most migratory, respectively. These piscivorous predators are all important for subsistence fishing with the best subsistence fishing areas located in the upper Slave River near Fort Smith (Tripp et al. 1981). These authors recommended that the movements in time and space of the inconnu and lake whitefish in the upper Slave River were the most important areas for further study. Such studies would provide the best opportunity to tag fish to assess the importance of the Slave River to commercial and subsistence fisheries in Great Slave Lake.

Floy tagging studies by Tripp et al. (1980, 1981) and Fuller (1947, 1955) indicated that inconnu began rapid upstream movement into the Slave River during mid-August with peak movements occurring near the end of August or early September. Radio-telemetry studies by McLeod et al. (1985) showed that the inconnu separated into upper river spawners (Cunningham Landing to Rapids of the Drowned) and mid-river spawners (Pointe Ennuyeuse to below Grand Detour). Rapid downstream (post-spawning) movement was recorded in mid-October. Fourty-six inconnu were fitted with radio-transmitters and movements

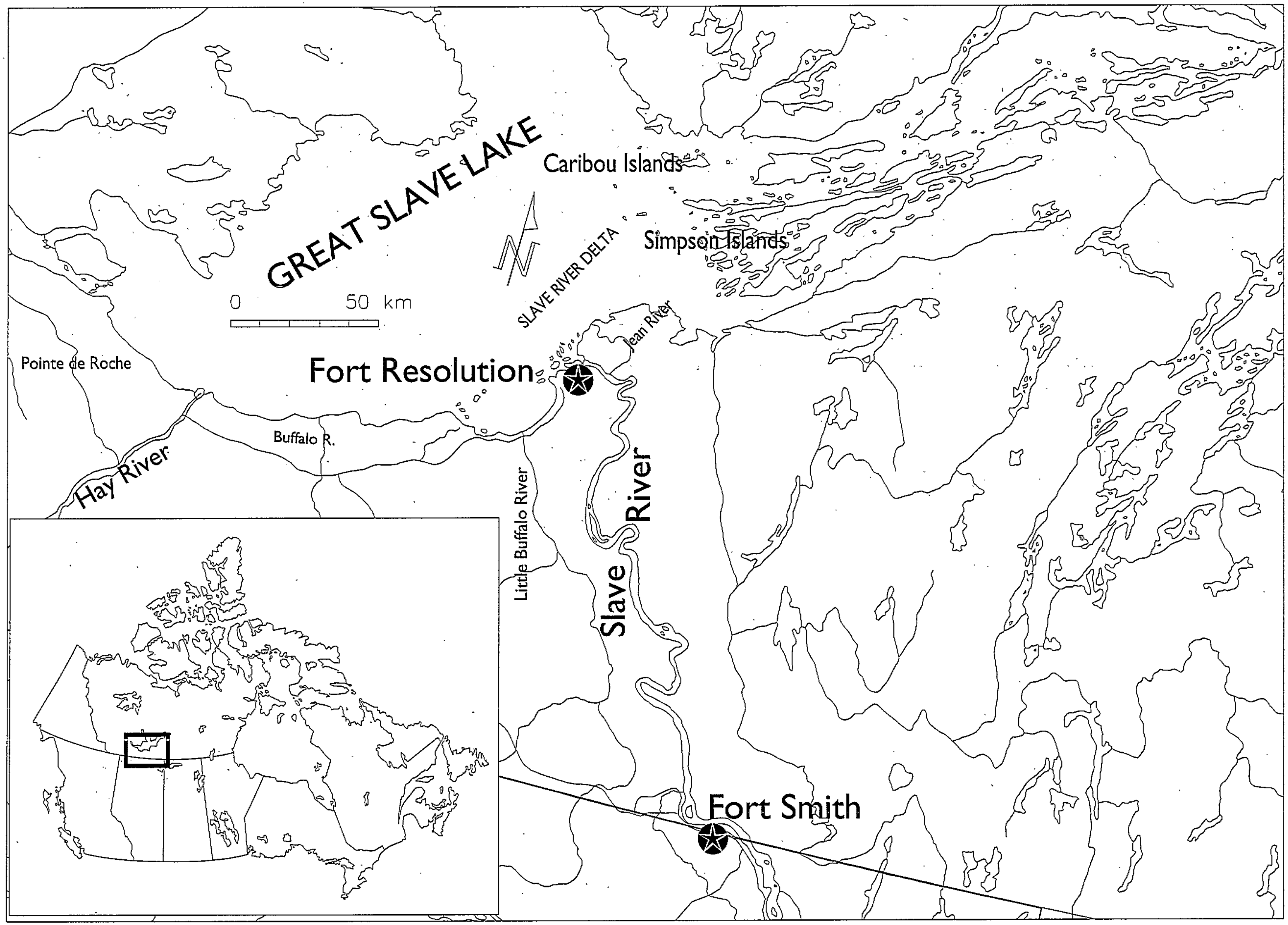

Figure 3. The study area showing the Slave River, Slave River Delta, Great Slave Lake, Fort Resolution and Fort Smith.

Figure 4. Detail of the Slave River Delta.

followed by aerial surveys. However, their studies did not commence until the spawning run was well underway and therefore could not characterize the earliest seasonal period of the migration. As well, since tags were inserted into the intestinal tract the inconnu could only be tracked during the period just prior to spawning when they were not feeding. Post-spawning and longer term movements would not have been possible to follow since the tags would prevent normal feeding activities.

McLeod et al. (1985), also, observed a well defined run of burbot in the Slave River delta after November 1, prior to freeze-up. However, radio-tagged fish movements did not follow a definable pattern. Most fish showed little movement. This may have been due to the effect of the tags on feeding.

Jalkotsky (1976) noted that the walleye run in the Slave River begins in the last week of May and continues until the second week in June. Average walleye size was from 0.7 to 0.9 kg. A fall run of walleye occurs from late September to freeze-up.
Tripp et al. (1981) provide some information on the life cycles of various species in the Slave River delta area. However, the samples taken were limited. For lake whitefish, a full analysis of life history traits (size at age, age specific fecundity, egg size and maturity) was only accomplished on 12 fish. For inconnu, age and growth characteristics were measured on only 26 fish with a full analysis on only 9 fish. There was growth information on 143 burbot but only 20 fish analyzed fully. Growth data were available for 240 walleye but only 4 fish were analyzed fully for life history traits. These traits are the keys to understanding population growth and mortality rates and thus stock productivity. Usually, a minimum sample size of 200 or more fish per stock per species are considered necessary for this type of analysis.

McLeod et al. (1985) provided some data but no analysis in their appendices on the growth rate, and age at maturity of inconnu, lake whitefish and burbot but did no work on age-specific fecundity or egg size.

Boag and Westworth (1993) studied the Slave River south of the Northwest Territorial Boundary focussing on species considered important to sportfishing. They noted that the sportfish catch in this southern section of the Slave river consisted of northern pike, (Esox lucius) goldeye, (Hiodon alosoides) walleye and burbot (most important to least important, respectively). No age specific information was generated in the study. Results of tagging in terms of movements were not noted in the report. The report focussed on fish inventory.

Analysis of dietary information and food web from diet is generally lacking. Tripp et al. (1981) record gut contents for a number of species but provide no synthesis of this information. There is no mention of it in the executive summary of their document. McLeod et al. (1985) and Boag and Westworth (1993) did not examine trophic relationships.

According to Bodden (1980), fish have traditionally been an important source of food for the people of Fort Resolution, providing up to 40% of the food consumed by people and 100% of the food required to maintain sled dogs. Lake whitefish and inconnu are the most highly prized fish for both humans and dogs, followed by burbot, walleye and to a lesser extent by northern pike and longnose suckers (Catostomus catostomus). A few people fish throughout the year in the Slave River delta. Fishing intensity is generally greatest during the fall spawning migrations of the major species in the Slave Delta, especially lake whitefish, inconnu and burbot. Of 9715 fish taken in the Slave River delta during the 1976-77 season burbot were estimated to account for 45.3% of the total catch, followed by lake whitefish (25.7%), longnose sucker (10.8%), inconnu (9.4%), pike (7.9%), and walleye (0.9%) (Bodden 1980).

McLeod et al. (1985) recorded a substantial subsistence fishery in the vicinity of Fort Smith during the fall. Inconnu contributed the greatest yield to the domestic catch (43.8% and 49.1% of the total catch by weight in 1983 and 1984, respectively), although, lake whitefish was numerically most abundant. A significant subsistence fishery for burbot, taking roughly 4408 kg in 1984-85 occurred at the Cunningham Landing/Salt River area (McLeod et al. 1985)

MacDonald and Smith (MS, 1993) also noted the importance for subsistence of lake whitefish, inconnu and burbot in the Slave River basin. They noted that inconnu had the highest harvest followed by lake whitefish and burbot. They listed eight species as being key species to monitor : lake whitefish, inconnu, burbot, northern pike, walleye, goldeye, white sucker (Catostomus commersoni) and longnose sucker.

Historically, the lake whitefish has been the most important species for commercial harvest in the Great Slave Lake followed by lake trout, inconnu, northern pike and walleye (Tripp et al. 1981). More recently, the dominant species have been lake whitefish, inconnu, walleye and burbot (C. Day Dept of Fisheries and Oceans, Pers. Comm.). Although they do not use the delta extensively, large concentrations of lake whitefish are found in the Slave River near Fort Smith in the fall. However, because lake whitefish is not a piscivore, they would be less likely to accumulate toxic substances. Among the others, lake trout does not occur in the Slave River. Thus, inconnu, pike, walleye and burbot are most suitable for detailed study because they are piscivores throughout most of their lives, they are abundant in the Slave River and they are important for both commercial and aboriginal subsistence harvest. Of these, the least is known regarding the movements and life history variation of inconnu.

Prior to the NRBS there has been much useful work on the fish populations of the Slave River . However, work on movements was based on floy tagging studies with only one study using radio-tracking. The number of fish floy tagged has not generally been sufficient for inconnu. McLeod's radio-telemetry study is thorough but represented only a single year of effort and missed the early part of the migration and the longer term movements. There was no radio-tracking information examining inter-annual variation in fish movements. Only very limited information existed to understand and characterize the demographics and life history

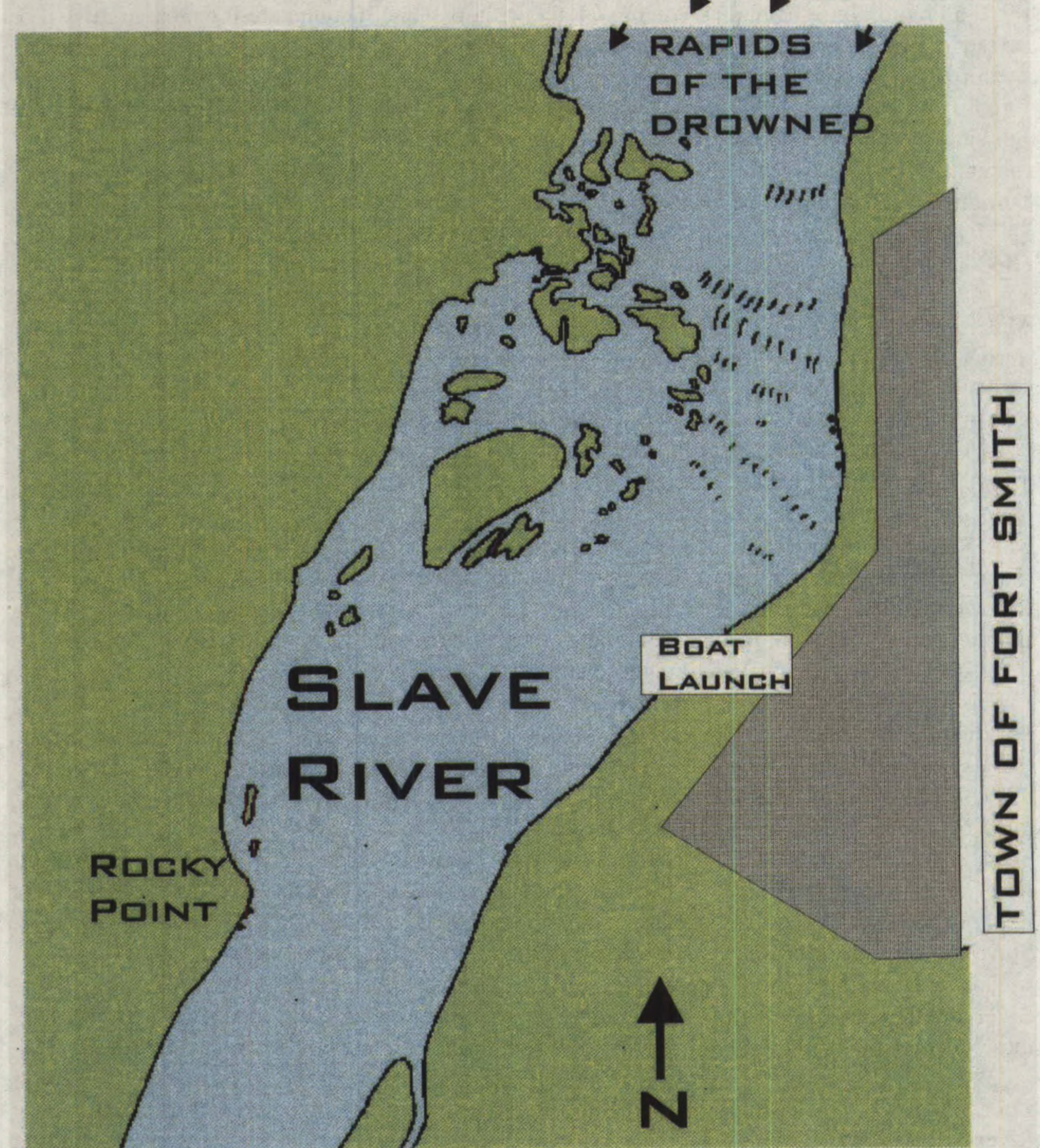

Figure 5 The lower Slave River at Fort Smith.

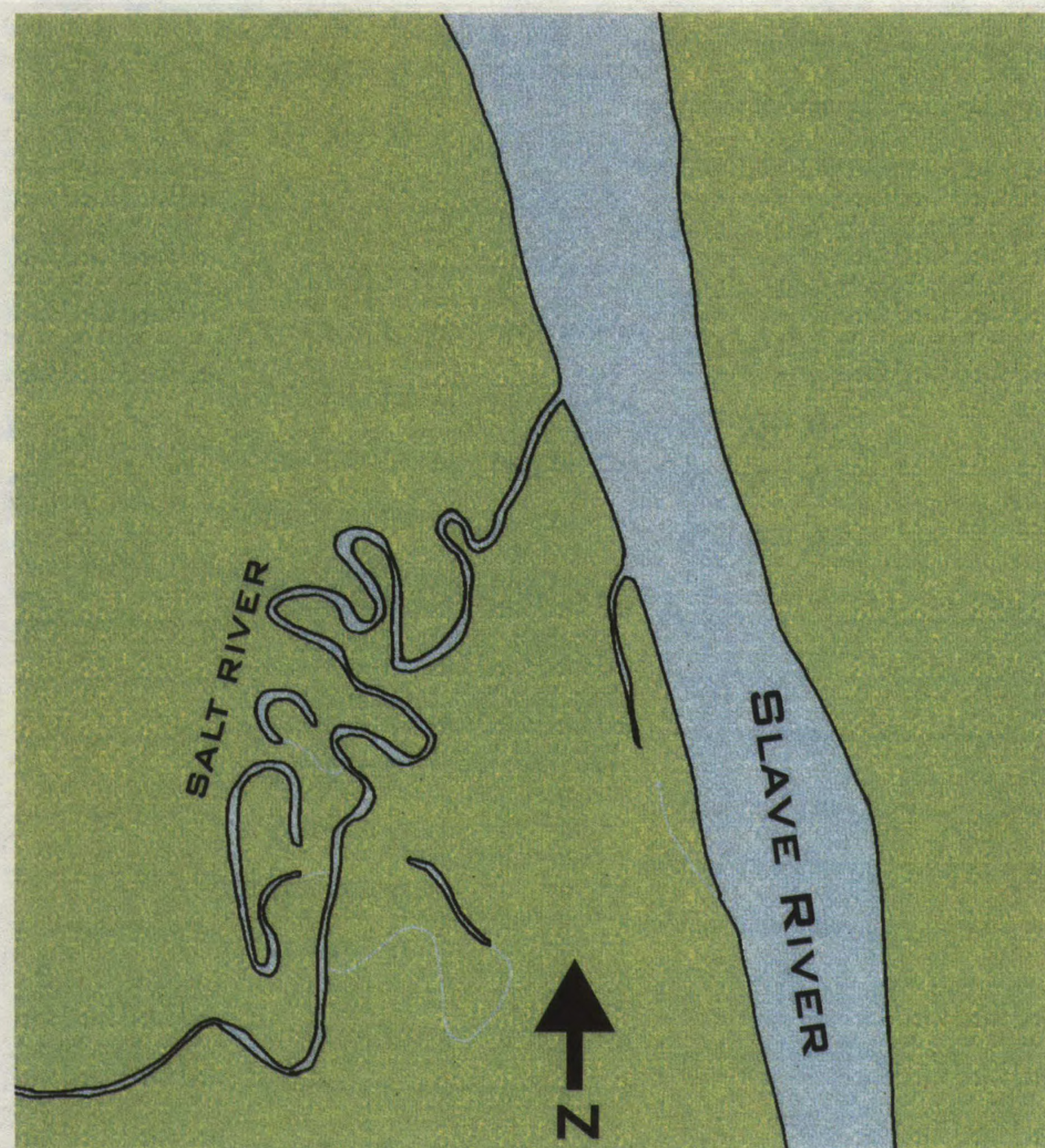

Figure 6. Detail of Salt River.

traits important to stock productivity of key species for human consumption. There was only spotty dietary information with no integration and synthesis nor was there any inter-annual comparisons of diet and trophic positions. Therefore, Tallman et al. (1996a, NRBS report # _) examined the migration of two species, inconnu and burbot, representing the expected extremes of migratory behaviour in the harvested species, using radio-telemetry techniques employing external tags. As well, they interpreted the movements of all fish species based on catch per unit effort analysis. Tallman et al. (1996b, NRBS report #_) examined the variation in life history traits important to productivity in inconnu and burbot - specifically size at age, age at maturity, age-specific fecundity, and egg size by collecting fish and analyzing appropriate samples. Finally, Tallman et al. (1996c, NRBS Report #_) conducted a thorough examination of the diets of species at all levels of the fish food web. This synthesis report describes the habitat requirements and probability of exposure of the fish community using the information from the NRBS reports and previously published studies on the Slave River system.

In this report I have tried to emphasize the community aspects of the fishes in the Slave River system . In spite of this, some areas such as vital rates are best represented on a species-by-species basis.

2.0 Description of the Slave River Environment - Background Synthesis

2.1 Study Areas

2.1.1Geography and Surrounding Habitat

The Slave River is, by far, the largest tributary of Great Slave Lake and divides the Interior Plain to the west and the Pre-Cambrian Shield to the east (Rosenberg and Barton 1986; Fig. 3). From the Rapids of the Drowned at Fort Smith, NWT, the river flows approximately 320 km to the Slave River Delta at Great Slave Lake. Three study areas were chosen for comparison: 1) the Slave River Delta, 2) the Slave River, immediately downstream of the Rapids of the Drowned near Fort Smith, NWT (60°00'N, 111°53'W) and 3) the lower Salt River.

Vegetation around the lower Slave River consists of boreal forest on the western side and sub-arctic forest on the eastern side (Brunskill 1986). There are grass-sedge-muskeg meadows, deciduous (trembling aspen, balsam, poplar, white birch) and coniferous trees(black and white spruce, tamarack, balsam fir, lodgepole and jack pine) (Brunskill 1986). The drainage area downstream Fort Fitzgerald (just south of Fort Smith) is about 606,000 km^2 (Brunskill 1986).

The Slave River Delta is located midway along the south shore of Great Slave Lake approximately 13 km north-east of Fort Resolution (61°10'N, 113°40'W). It covers an area of approximately 78 km^2 (English 1979). The delta is comprised of very diverse habitat types, compared with the main stem river proper, as a result of the numerous and variably sized channels. Landforms range from large mud flats on the outer edges of the Delta, to cut-bank levees ranging in height from 0.25 m to 3 m (English 1979). Shoreline habitat ranges from heavily vegetated shorelines on gently sloping banks to steeper banks with narrow littoral zones and little vegetation.

The delta consists of four main channels that connect the Slave River to Great Slave Lake: 1) Resdelta, 2) Middle Channel, 3) Old Steamboat Channel and 4) East Channel. Most delta sampling occurred along these channels (Figure 4). Resdelta Channel is the largest channel through the delta, accounting for 86% of the water flow (Tripp *et al.* 1981), with maximum depths ranging from 12 m to 32 m (Tripp *et al.* 1981; per. obs). The other main channels ranged from 5 m to 12 m deep and depths of 1 to 2 m occur in minor channels.

The delta of the Slave River is smaller and less complex than the Peace-Athabasca Delta (Tripp et al. 1981). It has been less closely studied although Kindle (1918) and Rawson (1950) recognized its importance to Great Slave Lake. According to Brunskill (1986) the active portion, with four major channels, is an arcuate 75 km^2 protruding into Great Slave Lake (Fig. 4). Twenty-six million tonnes of sediment per year on average pass through the delta and are deposited primarily in the large western basin of Great Slave Lake (Brunskill 1986). For further description of the Slave River delta refer to English (1996).

The lower Slave River near Fort Smith (Figure 5) is more homogenous with a maximum width of approximately 3 km (Vanderburgh and Smith, 1988). It is a mainstem habitat (Barton 1986) characterized by turbid, fast flowing water and steep river banks. It is strongly seasonal and both turbidity and discharge variations are significant. The steep banks reduce flooding but water levels and velocities fluctuate and the river bed is unstable. The bed of the lower Slave River bed is a patchwork of moving gravel, sand, silt and clay. The banks erode as water levels oscillate and a high concentration of suspended solids is maintained, so that light penetrates but a few centimetres during most of the open water season. The cut-bank levees can reach up to 35m high (Vanderburgh and Smith 1988) and, consequently, very narrow littoral zones result, deterring aquatic plant establishment .

The Salt River, is the largest tributary on the Slave River, located 25 km downstream of Fort Smith (Figure 6.). It is a meandering and narrow river, compared with the Slave River, with an average maximum depth of 1 to 2 m and a maximum width of about 60 m. It also differs from the Slave River in having greater amounts of aquatic vegetation present. The Salt River is a particularly important refuge area for migratory and feeding fishes.

Average annual discharge in the lower Slave River from Fort Fitzgerald is 110 km^2a-1 making it the largest river flowing northward in North America next to the Mackenzie River (Brunskill 1986). The total dissolved salts (TDS) average 120mg l^{-1}; conductivity - 253mS cm^{-1}. Like most of the Interior Plains rivers the pH is basic at 8.0 and other chemical characteristics are also typical of rivers of the region (See Brunskill 1986 for details). The

Slave River has the second highest levels of total dissolved phosphorous relative to other rivers in the Mackenzie River drainage basin (7.0 ppm; Brunskill 1986, second only to the Athabasca River at 13 ppm). Most other rivers in the Mackenzie River drainage have total dissolved phosphorous levels an order of magnitude less.

2.1.2 Climate

Winter (defined by average daily mean temperature below $0^{o}C$) lasts 175-200 days (Brunskill 1986). Mean daily temperatures are -20 to $-26^{o}C$ in January and $16\text{-}20^{o}C$ in July. Annual mean daily solar radiation is 275-300g cal cm^{-1} with extremes in December-January (25-75) and May-July (500-550).

2.1.3 Primary Productivity

Low-light penetration prevents the growth of macrophytes (although they are abundant in the Salt River) but the algal flora is rich. Blue-green alga dominate numerically during the cooler months but from June to August they are replaced by diatoms.

Autochthonous (i.e. within system) primary production is probably relatively unimportant in the trophic dynamics because light penetration is so limited - by suspensoids in summer and ice and snow in winter (Barton 1986). Microbial processing of allochthonous (i.e. originating externally) material is likely the dominant food base for macro-invertebrates based on the correspondence between bacterial and macro-invertebrate densities (Barton 1986).

Allochthonous inputs are substantial. Objects projecting from the river bed , such as logs or anchor lines, quickly accumulate debris that is colonized by invertebrates. According to Barton (1986) this offers attachment sites for filter-feeders such as *Simulium arcticum* (midges), *Brachycentrus* and hydropsychids, and food for shredders like *Pteronarcys dorsata* and surface scrapers like *Baetis*, *Heptagenia* and *Ephemerella inermis*. In turn, these are preyed upon by stoneflies.

2.1.4 Secondary Productivity - Invertebrate faunal composition, life cycle.

The faunal composition of the bedrock of the Slave River I infer from the study by Barton (1980) of the lower Athabasca. Trichoptera and *Ephemerella* spp. along with stoneflies were major components of the community. In the unstable sediments the community is dominated by chironomids and oligochaetes.

Tripp et al. (1981) collected invertebrates from the Slave River Delta using Ponar and Ekman grabs during September- November and May-June. In the main channels, standing stocks at less than 5-m depth were higher in autumn than spring (2031 vs 742 animals m^{-2}), but not in deeper water (88 vs 177 m^{-2}). The decline in abundance with depth was attributed to the increasing amount of sand towards the mid-channel. Sandy substrate supported mainly animals too small to be captured by 600mm sieves used in sampling.

At depths below 1m in the main channels, the dominant chironomids were *Chironomus* in autumn and *Polypedilum* in spring, whereas in deeper water *Procladius* was most abundant in both seasons (Tripp et al. 1981). *Chironomous* and *Procladius* were also the most abundant chironomids in minor channels, where the substratum was silty and depth rarely exceeded 2m. Other chironomids (e.g. *Tanytarsus*, *Pagastiella*), Oligochaeta, *Daphnia* and *Pisidium* were abundant, and the mean standing stock in the minor channels was similar to that of the most productive part of the main channel (c. 4900 animals m^{-2}). Over 90% of the invertebrates associated with macrophytes were Oligochaeta, Corixidae, Chironomidae and Gastropoda, in that order. Chironomid larvae were more abundant in shallow water, whereas snails were more abundant in deeper water.

Barton (1986) proposed that two factors were important in the ecology of delta lakes and ponds: high turbidity due to wind mixing in the shallow basins and annual flooding. Turbidity affords large zooplankters some protection from predators, but also limits phytoplankton productivity. Gallup et al. (1971) suggests that the principal energy source for these lakes is flood borne organic matter broken down by bacteria, especially in summer when the temperatures are high. Zooplankters use the combination of high temperatures, abundant bacteria and low visibility to reproduce throughout the summer and sustain high numbers despite heavy predation by fish.

There has been little direct study of the macrobenthos populations of the Slave River. Based mainly on studies at the Bigouray River, Barton (1986) proposed a general model of the seasonal patterns of the benthic invertebrate community for the Mackenzie River system including the Slave River. These animals are the major conduit of energy transfer from the rest of the biological community into the fish food chain.

During winter most flowing waters are ice-covered. Water temperatures remain near freezing and discharge is generally low. However, the lower Slave River has sections that are open well into the winter due to powerful flow patterns. Benthic community composition and abundance remains constant, although many slow-growing species are growing steadily, and fast-growing stoneflies are developing rapidly. Drift densities are minimal but benthic community concentrations are at a peak due to deep water aggregations of animals avoiding frozen areas of the river bed (Clifford 1978). Many first-order streams freeze into the substratum and activity ceases completely (Barton and Wallace 1980).

Spring starts with the disappearance of the winter ice and emergence of winter (fast-seasonal) stoneflies. Slow-seasonal mayflies resume rapid growth and maturation. Most nymphs of *Leptophlebia cupida* migrate into the surrounding marshes, where they emerge (Clifford et al.

1979), and adult corixids fly to muskeg pools where they breed (Barton and Wallace 1980). Water temperatures quickly rise to 15°C due to the long daylength and lack of shade from the undeveloped riparian vegetation. By the end of spring, over one-third of aquatic insects have begun their reproductive periods.

In summer temperatures rise to about 20°C and discharge declines in the latter half of the season (Clifford 1978). In early June, the chironomid standing stock is minimal, as the early species have emerged and the fast-seasonal summer generations are just beginning to be active. Most non-seasonal stoneflies emerge at this time. As the season progresses, the rapid growth, development and recruitment of many species cause standing stocks and composition to fluctuate more than in other seasons (Clifford 1978). Submerged vegetation provides more substrata for Corixidae, Ephemeroptera, Simuliidae and Chironomidae. By the end of August 85% of the insect taxa have completed reproduction (Clifford 1978).

The remaining species complete their reproduction in autumn as stream temperatures decline (Clifford 1978). The numerical standing stock reaches a maximum. Discharge continues to decline but rises abruptly when frost stops evapotranspiration by the muskeg vegetation. The macrophytes die and epiphytic invertebrates return to the sediments (Boerger 1981).

3.0 Distribution and abundance of fishes in time and space

3.1 Introduction

Although the Slave River system has been noted as being highly vulnerable to resource development (Katapodis and Yaremchuk 1994), the Slave River and its delta has been the least studied of the three watersheds having major deltas in the Mackenzie River Basin (Tripp et al. 1981). As many as 23 species occur in the Slave River proper, and it is also considered to be an important area for spawning of species such as inconnu (*Stenodus leucichthys*), lake whitefish (*Coregonus clupeaformis*), burbot (*Lota lota*) and walleye (*Stizostedion vitreum*) (Tripp et al. 1981).

Information on the changes in time and space can be broken down into studies of spatial distribution both on a macro and micro-scale and studies of temporal changes, either daily, seasonal or across years. Tripp et al. (1981) and Tallman et al. (1996c) provide information on the seasonal changes in the in time and space. Tripp et al. (1981), McLeod et al. (1985) and Tallman et al. (1996c) provide information on large scale spatial distribution and changes over long time scales. Tripp et al. (1981) is the only source for micro-habitat preference information from the lower Slave River. There is no available data on daily movements.

3.2 Fish species abundance changes in time and space over the annual cycle.

3.2.1 Spatial distribution large scale - Abundance variation between the Slave River delta, Slave and Salt rivers.

Three scientific studies of the Slave River fish fauna - - Tripp et al. (1981), McLeod et al. (1985) , and our study (Tallman et al. 1996a) can be used to generate a synthesis of the large scale spatial distribution of fishes in the Slave River, Salt River and Slave River Delta. As well, the NRB traditional knowledge study by Flett et al. (1995) may be used for verification of the spatail and temporal patterns of fishes' distribution. Knowledge of these patterns of will aid in assessment of the likelihood of exposure to water quality changes in the northern rivers basin. Sampling methods varied. Tripp et al. (1981) used more seine net and trap sampling than McLeod et al. (1985) or Tallman et al. (1996c). For the most part I have focussed on the major species - those vulnerable to gillnet sampling which was common to all programs. However, Tripp et al.'s seine catches provide useful information on forage species.

Lake whitefish were much less abundant in the Slave River Delta than in the Slave River near Fort Smith and the Salt River (Tripp et al. 1981, Tallman et al. 1996c, Table 1) For example, Tripp et al. (1981) noted that in early October, 1979 gillnet catches averaged 14.7 fish per hour compared to 0.7 fish per hour over the same period in the Delta. However, in the fall collections of McLeod et al. (1985, Appendix B) there were substantial numbers of lake whitefish in the Delta, the mid-river and near Fort Smith. In contrast, the three forms of ciscos recorded by Tripp et al. (1981) (*Coregonus artedii* and two other undefined forms) were found in the Delta and the Slave River channel just upstream but Tallman et al. (1996c) did not capture any in the Salt River or the Slave River near Fort Smith. McLeod et al. (1985, Appendix B) found the same result in the fall of 1983 and 1984.

Goldeye were the most abundant fish in both the Slave River and in the Delta (Tripp et al. 1981; Tallman et al. 1996c, McLeod et al. 1985 in Appendix B). Northern pike were also very abundant in the Delta (Tripp et al. 1981, McLeod et al. 1985, Appendix B) and moderately so in the Slave River near Fort Smith. Flett et al. (1995) recorded that pike were the most frequently utilized or encountered fish species by residents of Fort Smith. Juvenile pike were abundant in the Salt River mouth (Tallman et al. 1996c). Flathead chub were present but less abundant in the Slave River Delta than in the Slave River channel (Tripp et al. 1981, McLeod et al. 1985, Tallman et al. 1996c). Tripp et al. (1981) found trout-perch, *Percopsis omiscomaycus*, to be the most abundant small fish species in the Delta and the Slave River channel immediately upstream. Tallman et al. (1996c) found evidence of trout-perch in the stomachs of other species but did not capture any in the Slave River near Fort Smith. Burbot were present in low abundance in the Delta and throughout the Slave and Salt rivers (Tripp et al. 1981, Tallman et al. 1996c). Flett et al. (1995) noted that residents of Fort Smith described the Salt River as important habitat for burbot. Longnose sucker were present in low abundance in the Slave River and its Delta but not in the Salt River while the white sucker was only present in the Salt River. Flett et al. (1995) , also, identified the Salt River as an important area for sucker species. Walleye were moderately abundant throughout the Slave and Salt rivers (Tallman et al. 1996c). McLeod et al. (1985 in Appendix B) record that walleye abundance increased substantially in the fall in the Delta compared to the riverine habitats. Some smaller species (Arctic lamprey, *Lampetra japonica,* round whitefish, *Prosopium cylindraceum* , Arctic grayling, *Thymallus arcticus*, lake chub, *Couesius plumbeus*, emerald shiner, *Notropis atherinoides*, spottail shiner, *Notropis hudsonius,* pearl dace, *Semotilus margarita*, yellow perch. *Perca flavescens*, slimy sculpin, *Cottus cognatus*, spoonhead sculpin, *Cottus ricei*) inhabit the Delta and extreme lower reaches of the Slave River, only (Tripp et al. 1981, Tallman et al. 1996c). Of these it is doubtful that Arctic lamprey, Arctic grayling, and pearl dace are limited to this area because they are normally quite successful in river and stream environments (Scott and Crossman 1973). However, except in stomach contents, they have not been captured upstream of the area surveyed by Tripp et al. (1981).

3.2.2 Spatial variation small scale - Abundance variation by micro-habitat type

Tripp et al. (1981) measured seasonal variation in minnow seine catches for 11 species of fish in four different kinds of inshore habitat: shallow, vegetated areas with a low gradient; shallow unvegetated areas with a low gradient; deep, vegetated areas with a steep gradient; and deep unvegetated areas with a steep gradient. Overall, fish tended to be twice as abundant in shallow well vegetated areas as they were in the other three habitat types. Lake whitefish young-of-the-year, flathead chub, pearl dace, burbot young-of-the-year, trout-perch, *Percopsis omiscomaycus*, and spoonhead sculpin young-of-the-year preferred shallow well vegetated areas. On the other hand, northern pike and emerald shiners preferred vegetated areas regardless of depth, while young-of-the-year and small juveniles of longnose suckers preferred shallow water, regardless of the presence of vegetation. Lake chub and goldeye distributed themselves without regard to depth or vegetation (See Tripp et al. 1981 - Table 19.).

3.2.3 Seasonal Variation - Change in abundance and composition over the year.

Seasonal movements of fish will cause the community composition to change. As community composition changes the relative probability of exposure to water quality changes will change according to the species. Tripp et al. (1981) provides useful information on the pattern of seasonal movement in the Slave River Delta. McLeod et al. (1985) focussed on the fall period near Fort Smith and therefore cannot provide a complete picture of movement patterns in this area. Tallman et al. (1996a and 1996c) sampled throughout the season, including winter near Fort Smith. Thus, the data on changes in abundance and species composition in the delta and main part of the lower Slave River can be blended to give a more detailed picture of activities of fish species in the lower Slave River.

In the late May after ice break-up, the fish community in the Slave River was dominated by high numbers of flathead chub, *Platygobio gracilis,* walleye, *Stizostedion vitreum vitreum,* and goldeye, *Hiodon alosoides* (Tallman et al. 1996c) (Appendix 3). Goldeye were also abundant during the spring in the Slave River Delta in 1980 although they were not in 1979 (Tripp et al. 1981). Flathead chub were generally abundant in the Delta during the May (Tripp et al. 1981) . Juvenile pike, *Esox lucius,* are also present in certain areas near Fort Smith and in the Delta (Tripp et al. 1981; Tallman et al. 1996c) (Appendix 3). Tripp et al. (1981) proposed that adult pike overwinter in the Great Slave Lake or the Delta . After spring spawning near Fort Smith adult pike gradually moved into the Delta over the course of the season, presumably to feed (Tripp et al. 1981). The following year large numbers of pike in spawning condition were captured in the Delta demonstrating that in some years spawning probably occurs there (Tripp et al. 1981) . Traditional knowledge of the Fort Smith community supports the above in that whitefish, pike and goldeye are reported to be abundant in the spring after the ice goes out (Flett et al. 1995). Longnose sucker is also relatively abundant at the end of May near Fort Smith (Tallman et al. 1996c). (Appendix 3). Moderate numbers of lake whitefish were found by Tallman et al. (1996c) (Appendix 3). Tripp et al. (1981) also found an increase in the abundance of lake whitefish in the Slave River Delta after ice break-up but the numerical abundance was much lower than at Fort Smith. They attributed this to the general downstream movement by lake whitefish that stay and overwinter in the Slave River after spawning the previous fall. Absent near Fort Smith were burbot, inconnu, ciscos and white sucker (Tallman et al. 1996c(Appendix 3). Young of the year burbot were abundant in the Delta (Tripp et al. 1981).

I suspect that the high catches of chub, goldeye and walleye are due to aggregations for the purpose of spawning. If so we would place the spawning of these species in early spring shortly after river break-up. According to Scott and Crossman (1973) details of the spawning habits of flathead chub are unknown but available information indicates that spawning takes place in summer. Olund and Cross (1961) reported collections of males and females in spawning condition, taken in the Milk River in August 1955. However, McPhail and Lindsey (1970) reported the capture of females with large ovaries of almost free eggs, and one spent female in the Mackenzie River at 64° N, on June 27. Olund and Cross (1961) suggested that spawning occurred when water levels receded to the seasonal low during mid-summer. However, the seasonal low in the Slave River would be in fall. The nature of the Slave River may encourage spring spawning in this system. The biology of goldeye is well studied in Canada. In most locales spawning occurs in the spring from May to the first week of June starting just after the ice breaks and continuing over a period of 3-6 weeks (McPhail and Lindsey 1970, Battle and Sprules 1960, Kennedy and Sprules 1967, Pankhurst et al. 1986) . According to Scott and Crossman (1973) walleye spawning occurs in spring or early summer (early April in southwestern Ontario to the end of June in the far north) depending on the latitude and water temperature. Normally, spawning begins shortly after the ice breaks up at temperatures ranging from 5.6-11.1°C. Spawning grounds are commonly in rocky areas in white water below impassable falls in rivers. Tripp et al. (1981) found two major seasonal migrations of walleye through the Delta. The first was an upstream spawning migration starting in mid-April before spring breakup and continuing through most of May. The second migration is a downstream migration to Great Slave Lake that starts in late august and continues until freeze-up, and possibly later. Based on these criteria we suspect that the Rapids of the Drowned is the spawning area for walleye in the lower Slave River. On the other hand, Tripp et al. (1981) thought that the Salt River might be an important area. Pike are early spring spawners - probably so early here that there was no distinct evidence of a spawning aggregation. Spawning takes place immediately after the ice melts in April to early May when water temperatures 4.4 - 11.1°C. Pike also tend to spawn in small tributaries and therefore may have been massing elsewhere in the system. Since longnose suckers are recorded to spawn in the spring as soon as the water temperature exceeds 5° C (Harris 1962, Geen et al. 1966) I would expect that spawning had occurred around mid-May. What was observed in our work was the tail end of the aggregation. According to Geen et al. (1966) spawning takes place 152-279mm deep, with a current of 30 to 45 cm per second and a bottom gravel of 50-100mm in diameter. Tallman et al. (1996c) found that the high numbers of lake whitefish were due to the presence of juveniles near the Salt River area.. The Salt River may serve as a nursery area for this species. Whitefish may also have been attracted away from Great Slave Lake to take benefit from the more rapidly warming river. The absence of inconnu at this time is not surprising. In other studies inconnu have typically used certain rivers only for reproduction in the fall. Burbot were never very susceptible to the gear and thus may have been present in deeper areas or not been caught because they were relatively sedentary. White sucker were only found in the Salt River area.

In the early part of June the abundancies of the spring spawning species were tapering off but still generally high. Lake whitefish and northern pike juveniles were abundant at this time. The pike may have been attracted by the whitefish and chub concentrations. All nine major species (flathead chub, goldeye, burbot, inconnu, lake whitefish, walleye, northern pike, longnose and white sucker) were present near Fort Smith over the course of June and July but no major aggregations appeared to occur. In the Delta, Tripp et al. (1981) recorded peaks of abundance of longnose sucker in late June (1979) and early July. These fish were thought to be post-spawners from the spring spawning aggregation upstream.

In the latter part of August the fall spawning species such as inconnu and lake whitefish begin to increase in abundance (Flett et al 1995). Inconnu first appeared in the Slave River near the beginning of August (Tallman et al. 1996c)(Appendix 3). The run peaked between September 1 and September 15 and again between October 1 and 15 and was estimated to have ended in the latter part of October. By October 21 most inconnu seemed to have left the Slave River. However, due to the formation of the ice few sets were made during this period.

Little information exists on the biology of inconnu in Canada (Scott and Crossman 1973). Upstream runs into Great Slave Lake tributaries are protracted throughout the summer. Spawning is thought to occur in the early fall only every 2,3 or 4 years (Scott and Crossman 1973). However, Tallman et al. (1996c) placed spawning in the Slave River in mid-October and Tallman et al. (1996a) found that a male tagged on the spawning grounds returned to the Slave River the following season. Tripp et al. (1981) found two peaks of inconnu abundance in the fall in the Slave River delta - one as part of the upstream spawning run in late August and early September and the other as a concerted downstream run out of the system in late October. In contrast, McLeod et al. (1985, Appendix B) captured relatively few inconnu below the Rapid of the Drowned near Fort Smith. They were detected in low numbers during mid-September in 1983 and 1984. Regardless, radio telemetry by McLeod et al. (1985) suggested several areas near Fort Smith were inconnu spawning grounds in the fall. As well, mark-recapture experiments established that the inconnu run in 1984 was between 15,856 to 24,638 fish (95% confidence limit on the mean abundance - McLeod et al. 1985). McLeod et al. (1985, Appendix B) found that inconnu were abundant in the mid lower Slave River during the first two weeks of October . In the delta, inconnu showed two peaks of abundance in late August - early September and in the third week of October in 1983 and 1984 (McLeod et al. 1985, Appendix B). These probably represent the upstream run of pre-spawners and the downstream run of post-spawners, respectively.

Tallman et al. (1996c) recorded that lake whitefish became abundant in the Slave River during August and the CPUE steadily climbed to a peak in the first two weeks of October (Appendix 3). Tripp et al. (1981) noted a transient peak in abundance of lake whitefish in the Slave River Delta in late August, presumably from migrating pre-spawners. McLeod et al. (1985, Appendix B) , sampling from the second week in September onward, also, found that abundance below Rapids of the Drowned increased steadily to a peak in the first two weeks of October. In the Delta, McLeod et al (1985) observed a similar pattern in 1983 but with sampling prior to September in 1984 found that the highest CPUE was during mid to late August. According to Rawson (1947) spawning occurred in Great Slave Lake from late September to October. Therefore, the peak abundance in the Slave River is presumably a spawning run. Lawler (1965) suggested that spawning in Lake Erie was delayed until the temperature dropped to 7.8°C and below. This agrees well with the what was observed in the Slave River by Tallman et al. (1996c, Appendix 3). Tripp et al. (1981) proposed that the base of the rapids on the Slave River near Fort Smith was likely a major spawning area. They found that after October 10 water temperatures were 7.5°C and most of the males were running milt. In 1994, both sexes were ready to spawn by mid-October (Lange and Tallman, unpublished data). By the beginning of November lake whitefish appeared to have left the Slave River. However, due to the formation of the ice Tallman et al. (1996c) made few sets during this period. Floy tagging results of Tripp et al. . (1981) suggest that after spawning most adults return to Great Slave Lake. Nonetheless, a substantial proportion of adults and juveniles apparently over-wintered in the Slave River (Tripp et al. 1981).

Spawning usually occurs in shallow water at depth of less than 8m but spawning has been reported in deeper waters by Koelz (1929). It often takes place over a hard or stoney bottom but sometimes over sand. The Slave River has ample locations with this type of habitat. In northern waters individuals may spawn only every second year (Scott and Crossman 1973).

Burbot were only occasionally captured in the gillnets, thus, their apparent abundance was quite low (Tripp et al. 1981, McLeod et al. 1985, Tallman et al. 1996b) (Appendix 3). This might have reflected their lack of numbers or their lack of movement during most of the season. Tallman et al. (1996a) found that radio-tagged burbot were relatively sedentary, Tallman et al. (1996c) found goldeye were abundant with post-spawning peak catches occurring between August 1 and August 15 and October 15 and October 31, 1994 . They were undoubtably the most dominant fish in the Slave River system. McLeod et al. (1985, Appendix B) also recorded a peak in abundance around mid-October in the river. The peak in the late fall is possibly a preparatory phase for over-wintering. Reductions of the goldeye community from environmental changes would probably impact on the entire community of the Slave River including birds and mammals. On the other hand, Sandheinrich and Atchison (1986) show that anthropogenic changes such as those of the Missouri River could result in greater habitat for goldeye.

Except for May (noted above) longnose sucker were present in low numbers during the open water sampling period. (Appendix 3). Tripp et al. (1981) recorded a peak of abundance in the Slave River Delta in late September (1979) and late October (1980) which they attributed to downstream movements to over-wintering areas by fish that stayed upstream during the summer. White sucker only inhabited the Salt River (Appendix 3). Their abundance there was relatively low (Tallman et al. 1996c).

Northern pike, and walleye, and flathead chub are significant members of the Slave River fish community and were present in moderate abundance throughout the open water sampling period (Tallman et al. 1996c, Appendix 3). Juvenile pike were abundant in the Salt River. This tributary is likely a spawning area for pike. After the spring walleye had an aggregation in October in preparation for over-wintering.

The abundance of flathead chub may be important to monitor in the future because flathead chub are susceptible to flow changes in river systems. They are considered to be a specialized species for systems, such as the Slave River, characterized by high turbidity, wide seasonal fluctuations in flow and a wide channel that is in constant state of change (Pflieger and Grace 1987) Traditionally, the Slave delta showed about four year cycles of flooding and drying (Tom Unka, Fort Resolution Native Band Environmental Council). Since the construction of the Bennett Dam these cycles have been destroyed. Pflieger and Grace (1987) found that flathead chub declined in abundance to the point of extirpation after extensive man-made alterations to the Missouri River that restricted the river such that the turbidity and sediment load were reduced and the natural-flow regimen modified.

Minimal information is available regarding the species composition of the lower Slave River during the ice-covered winter season. Limited sampling using gillnets in 1994 and 1995 during December produced most of the major species except inconnu (Alison Little, Univ. Alta and Fernand Saurette, DFO, Wpg, pers. comm.). However, CPUE was low suggesting that the various species may use only restricted portions of the river for over-wintering or may have mostly left to over-winter in Great Slave Lake.

3.2.3.1 Relationship to temperature and flow patterns

According to Tallman et al. (1996c) inconnu first entered the Slave River in August when water temperatures were between 19 and 20° C and continued to enter throughout the fall period as temperatures declined to around 10° C (Appendix 3). They exited at much lower temperatures with the last fish leaving when the water temperature was around 5° C. Tallman et al. (1996c) found a significant negative correlation ($r = -.92893$) between the water temperature and the catch per unit effort of inconnu ($p = 0.0009$).

Inconnu enter the system when discharge levels are beginning to taper off but are still high (around 4000 to 5000 cubic meters per second) (Appendix 3). The discharge level fell steadily throughout the fall to a level of 2000 cubic meters per second. Tallman et al. (1996c) found no significant correlation between inconnu abundance and discharge level in the system ($r = -.009$, $p = 0.9765$)

In 1995, field workers observed that the early drop in temperatures in the system coincided with a slightly earlier spawning readiness in the inconnu than in 1994. Other authors (Alt 1987, Nikol'skii 1961) believe inconnu to have specific temperature requirements for spawning. The abundance of inconnu in the system was independent of water flow. Even so, alterations to the system that might increase or charge the temperature and discharge patterns in the system would presumably have detrimental effects on the inconnu reproduction.

In 1994, lake whitefish CPUE began increasing when water temperatures were between 19 and 20° C and they continued to enter throughout the fall period as temperatures declined to around 10° C (Tallman et al. 1996c). They exited at much lower temperatures with the last fish leaving when the water temperature was around 5° C. Tallman et al. (1996c) found a significant negative correlation ($r = -0.8668$) between the water temperature and the catch per unit effort of lake whitefish ($p = 0.0053$). Lake whitefish enter the system when discharge levels are beginning to taper off but are still high (around 4000 to 5000 cubic meters per second). The discharge level fell steadily throughout the fall to a level of 2000 cubic meters per second. Tallman et al. (1996c) found no significant correlation between lake whitefish abundance and discharge level in the system ($r = .1246$, $p = 0.6850$). Ciscos were not observed by Tallman et al. (1996c) but McLeod et al. (1985, Appendix B) and Tripp et al. (1981) found that they were abundant in the Slave River Delta from early October through to mid-November. At the end of October they were the most abundant fish. McLeod et al. (1985) proposed that they were spawning at this time in the Salt River or near Fort Smith.

Pike CPUE was highest when water temperatures were warmest in July (around 20° C). However, Tallman et al. (1996c) found no correlation between water temperature and abundance of pike ($r = -0.0224$, $p = 0.9580$). There was also no relationship between discharge and pike abundance (correlation = 0.2362, $p = 0.4371$).

There was no significant correlation (r = 0.0410) between the water temperature and the catch per unit effort of goldeye (p = 0.9232). There was no significant correlation between goldeye CPUE and discharge level in the system (r = 0.2725, p = 0.3678).

Longnose sucker were present all the time and therefore there was no significant correlations between their CPUE and water temperature or discharge (r = -0.5966, -0.0142, respectively; p = 0.1184 and p = 0.9632, respectively)

Judging from the overall pattern from the two years walleye abundance fluctuated from May though to the end of October (Tallman et al 1996c). Not surprisingly, the CPUE was not significantly correlated with water temperature or discharge (r = -0.4283, p = 0.2898 and Correlation = 0.2839, p = 0.3472, respectively).

3.2.4 Summary of fish distribution

The main point of this section is that the Slave River serves a richly diverse and abundant fish community. Reproductive activities are probably taking place during at least 3 out of the four seasons of the year. Two major groups, the spring spawners including goldeye, walleye, northern pike, flathead chub and the suckers and fall spawning species, such as inconnu, lake whitefish and ciscos, use the river or its delta. The presence of juveniles and adults of some species outside of their particular spawning season suggests that the system also is an important area for feeding and rearing of fishes (Tallman et al. 1996c).

3.2.5 Evidence for changes in the fish community in the lower Slave River.

Resource users have stated that there have been declines in total numbers and individual fish size in recent years (Flett et al. 1995). In the past there were numerous burbot near Fort Smith and lake whitefish were available for harvest in the river for longer periods during the year (Flett et al 1995). The four major studies of the Slave River biota - Tripp et al. (1981), McLeod et al. (1985) , McCart (1986) and our study can be used to formulate some idea regarding whether there have been changes in the fish community over the last 15 years (Table 1). The fact that the W.A.C. Bennett dam was constructed on the Peace River gives one the opportunity to assess the long distance impacts of a major development upstream. In as much as the analysis of community changes could be confounded by differences in sampling regime I will describe the methodology used by each study and re-analyze using only data collected under a standardized protocol.

As a first attempt to answer the question of whether there has been changes in the Slave River community one can look at the total diversity of fishes captured by various research programs from 1971 to the present. Thirty species of fish have been reported from the Slave River, its tributaries and delta (Falk and Dalkhe 1975, Tripp et al. 1981, McLeod and O'Neill 1983, McLeod et al. 1985, McCart 1986, Tallman et al. 1996a,b,c, Table 1). Three of these, Dolly

Varden char, *Salvelinus malma*, mountain whitefish, *Prosopium williamsoni*, and longnose dace, *Rhynichthys cataractae*, are attributed to McCart (1986), only, who uses Falk and Dalkhe (1975), McLeod and O'Neill (1983) and McLeod et al. (1985) as sources. The other 27 species are recorded in Tripp et al. (1981), McLeod et al. (1985) or Tallman et al. (1996a,b,c). However, McLeod and O'Neill (1983) record only the occurrence of chinook salmon in the Liard River. Falk and Dalkhe (1975) report research catches in streams on the south side of Great Slave Lake from Hay River up to but not including the Slave River. McLeod et al. (1985) do not report catches of Dolly Varden, longnose dace or mountain whitefish and therefore it is difficult to determine the validity McCart's (1986) report that they occur in the lower Slave River. Twenty-three of the twenty-seven species are reported by Tripp et al. (1981) from collections made between 1978 and 1980. McLeod et al. (1985) sampling only in the fall of 1983 and 1984 found 18 species including 2 , rainbow trout, *Oncorhynchus mykiss* and lake char, *Salvelinus namaycush* not reported by Tripp et al. (1981). Discounting the three aforementioned species (Dolly Varden, mountain whitefish and longnose dace) then up to 25 species were present in the early 1980's. . Tallman et al. (1996c) report only 19 species and thus it superficially appears that there has been about a 20% drop in species abundance. The species not found were chum salmon, *Oncorhynchus keta*, lake cisco, *Coregonus artedii*, the small bodied cisco, *Coregonus spp*., round whitefish, *Prosopium cylindraceum*, pearl dace, *Semotilus margarita*, and the slimy sculpin, *Cottus cognatus*.. Tallman et al. . (1996c) reported both chinook and sockeye salmon (*Oncorhychus nerka*) not reported previously by neither Tripp et al. (1981) nor McLeod et al. (1985)

Table 1. List of scientific names, common names, and codes for fish species collected in the lower Slave River (SL), Slave River Delta (SLD) and Salt River (SALT), 1978-1995.

Family /Generic Name	Years	Common Name	Code	Location
Petromyzontidae				
Lampetra japonica	78-80,83,84,94,95	arctic lamprey [1,2,3]	ARLP	SL/ SLD
Salmonidae				
Oncorhychus keta	78-80	chum salmon [1]	CHUM	SLD
O. nerka	95	sockeye salmon [3]	SOCK	SL
O. tshawytsha	< 86,95	chinook salmon [3,4]	CHIN	SL
O. mykiss	83,84	rainbow trout [2]	RNTR	SL/SLD
Salvelinus namaycush	83,84,94.95	lake char [2,3]	LKTR	SLD
S. malma	< 86	Dolly Varden [4]	DVCR	SL
Coregonus clupeaformis	78-80,83,84,94.95	lake whitefish [1,2,3]	LKWT	SL/SLD/SALT
C. artedii	78-80,83,84	lake cisco [1,2]	LKCS	SLD
Coregonus spp.	78-80,83,84	small cisco [1,2,3]	SMCS	SLD
Stenodus leucichthys	78-80,83,84,94,95	inconnu [1,2,3]	INCO	SL/SLD
Prosopium cylindraceum	78-80,83,84	round whitefish [1,2]	RDWT	SLD
*Prosopium williamsoni**	< 86	mountain whitefish [4]	MTWT	SL
Esocidae				
Esox lucius	78-80,83,84,94,95	northern pike[1,2,3]	NTPK	SL/SLD/SALT
Hiodontidae				
Hiodon alosoides	78-80,83,84,94,95	goldeye [1,2,3]	GOLD	SL/SLD/SALT
Cyprinidae				
Couesius plumbeus	78-80,94,95	lake chub [1,3]	LKCB	SLD
Platygobio gracilis	78-80,83,84,94,95	flathead chub [1,2,3]	FHCB	SL/SLD/SALT
Notropis atherinoides	78-80,94,95	emerald shiner[1,3]	EMSH	SL/SLD/SALT
Notropis hudsonius	78-80,94,95	spottail shiner [1,3]	SPSH	SL/SLD/SALT
*Rhynichthys cataractae**	< 86	longnose dace [4]	LNDC	SL
Semotilus margarita	78-80	pearl dace [1]	PLDC	SL/SLD
Catostomidae				
Catostomus catostomus	78-80,83,84,94,95	longnose sucker [1,2,3]	LNSK	SL/SLD/SALT
Catostomus commersoni	78-80,83,84,94,95	white sucker [1,2,3]	WTSK	SALT
Gadidae				
Lota lota	78-80,83,84,94,95	burbot [1,2,3]	BRBT	SL/SLD/SALT
Gasterosteidae				
Pungitius pungitius	78-80,94,95	ninespine stickleback [1,3]	NSST	SL/SLD/SALT
Percopsidae				
Percopsis omiscomaycus	78-80,84,94,95	trout-perch [1,2,3]	TRPH	SL/SLD/SALT
Percidae				
Stizostedion vitreum vitreum	78-80,83,84,94,95	walleye [1,2,3]	WALL	SL/SLD/SALT
Perca flavescens	78-80,94,95	yellow perch [1,3]	YWPH	SL/SLD*
Cottidae				
Cottus cognatus	78-80	slimy sculpin [1]	SLSC	SLD
Cottus ricei	78-80,94,95	spoonhead sculpin [1,3]	SLSC	SL/SLD/SALT

[1] Tripp et al.(1981), [2] McLeod et al (1985), [3] Tallman et al (1996c), [4] McCart (1986)

Notwithstanding, each of the major studies (Tripp et al. 1981, McLeod et al. 1985 and Tallman et al. 1996c) emphasized somewhat different methods for capture and focussed on somewhat different portions of the Slave River. Tallman et al. (1996c) used mainly gillnets with occasional hand seining. Tripp et al. (1981) used a combination of gillnets, traps and hand seining. McLeod et al. (1985) used gillnets and hand seining. Tripp et al. (1981) also focussed on the Delta with some work in the Slave River channel. McLeod et al. (1985) sampled only in the fall and distributed effort over the Delta, mid-lower River and near Fort Smith. Tallman et al. (1996c) sampled extensively near Fort Smith in the Slave and Salt rivers and did about 20% of their sampling in the Slave River Delta.

If one examines only gillnet catches then Tripp et al. (1981), McLeod et al. (1985) and Tallman et al. (1996c) each captured only 14 species in total (Table 2). The species list for Tallman et al. (1996c) excludes only the ciscos captured by Tripp et al. (1981). These appeared very late in October almost exclusively in the Delta. At this time in 1994 and 1995 the river and delta were in transition from open water to ice cover and sampling could not be undertaken. If Tallman et al. (1996c) could have achieved the same level of coverage of the Delta as Tripp et al. (1981) it seems probable they would have caught the ciscos. McLeod et al. (1985) captured a couple of specimens identified as rainbow trout and round whitefish which neither Tripp et al. (1981) nor Tallman et al. (1996c) caught in gillnets. Similarly, while McLeod et al. (1985) failed to gillnet neither trout-perch nor yellow perch, Tripp et al. (1981) and Tallman et al. (1996c) caught only a few specimens of these species. Tallman et al. (1996c) caught one chinook and one sockeye salmon.

Table 2. List of fish species collected by gillnet in the lower Slave River , Slave River Delta and Salt River, 1981-1995 by various studies. X = captured; - = not captured.

Family /Generic Name	Tripp et al. (1981)	McLeod et al. (1985)	Tallman et al. (1996c)
Salmonidae			
Oncorhynchus nerka	-	-	X
O. tshawytsha	-	-	X
O. mykiss	-	X	-
Salvelinus namaycush	-	X	X
Coregonus clupeaformis	X	X	X
C. artedii	X	X	-
Coregonus spp.	X	X	-
Stenodus leucichthys	X	X	X
Prosopium cylindraceum	-	X	-
Esocidae			
Esox lucius	X	X	X
Hiodontidae			
Hiodon alosoides	X	X	X
Cyprinidae			
Platygobio gracilis	X	X	X
Catostomidae			
Catostomus catostomus	X	X	X
Catostomus commersoni	X	X	X
Gadidae			
Lota lota	X	X	X
Percopsidae			
Percopsis omiscomaycus	X	-	X
Percidae			
Stizostedion vitreum vitreum	X	X	X
Perca flavescens	X	-	X

To compare relative abundance estimates among Tripp et al. (1981), McLeod et al. . (1985) and Tallman et al. (1996c) I used the data from gillnet catches of major species : lake whitefish, inconnu, goldeye, northern pike, flathead chub, longnose sucker, white sucker, burbot and walleye. To make the data comparable between Tallman et al. (1996c) and McLeod et al. (1985) I combined the data for mid-River and Slave River near Fort Smith from McLeod et al. (1985) Tables 4.3 and 4.4 for both years and divided by number of sites represented (4 in total). Since other species were caught I then adjusted the totals to sum to 100%. To calculate an average percentage catch over 1994 and 1995 I used the data in Tables 2-10 from Tallman et al. (1996c) and averaged the CPUE over the entire sampling period to form the basis for calculating percentages.

There have been fluctuations in the relative abundance of these species between 1978 and 1995 (Table 3). Lake whitefish have remained relatively stable at between 5 and 10% of the catch. However, the observation from traditional knowledge that whitefish are available for less time during the year might be reflected in the drop in their percentage in the gillnet catch of McLeod et al. (1985) of around 10% to the 5% level recorded in Tallman et al.'s (1996c) data. Interestingly, inconnu have apparently increased steadily as a percentage of the total population since the early period. Historically, the subsistence fishery in the area has been much more intense than it is presently (Jalkotsky 1976, Bodden 1980, Tripp et al. 1981, MacDonald and Smith 1983, McLeod et al. 1985). During the last two years only one aboriginal fisherman was targeting inconnu in the Slave River near Fort Smith. As well, over the last few years, the Department of Fisheries and Oceans has progressively extended a spring conservation zone for inconnu in the nearshore areas along the south shore of Great Slave Lake (C. Day, DFO management biologist). The combination of much lower subsistence fishing in the river and more protection in Great Slave Lake may be resulting in an increase in the Slave River inconnu abundance. Goldeye have fluctuated greatly in percentage of the catch but overall they have been and continue to be the dominant species in the Slave River. Presently, they account for about half the catch by numbers of the major species in the river. Northern pike are also an abundant species although their relative importance may have waned somewhat since the late 1970's. One should note that Tripp et al. (1981) sampled more heavily in the lower end of the Slave River channel where the more sluggish flows would favour northern pike. Flathead chub represent a small component of the gillnet catch in these studies ranging from about 1 to 5%. White sucker are also present throughout but rather low in abundance contributing less than 1%. In contrast to inconnu the longnose sucker appears to be becoming less important with time. The relative contribution drops from almost 9% to about 1% of the catch. Similarly, burbot is also less evident now compared with in the late 1970's. This agrees well with the observations from traditional knowledge (Flett et al. 1995). Walleye is, also, an important fish in the system. The relative contribution to the catch has fluctuated from around 21% to 5% to 15%. The rather low value of 5% found by McLeod et al. (1985) is probably a result of not sampling at times other than the fall period. As we saw above, the composition of the community changes dramatically over season in relation to the influxes of spawners of different species. Therefore, McLeod et al.'s (1985) results may not be completely comparable to the others. Comparing only Tripp et al. (1981) and Tallman et al. (1996c) one can see that except for inconnu,burbot and longnose sucker the community composition has not changed much.

Table 3. Percentage of the gillnet catch for each species recorded by Tripp et al. (1981), McLeod et al. (1985) and Tallman et al. (1996c) for the Slave River Channel.

Species	Tripp et al. (1981)	McLeod et al. (1985)	Tallman et al. (1996c)
Lake whitefish	5.28%	9.32%	5.56%
Inconnu	1.26%	4.15%	9.30%
Goldeye	21.49%	64.87%	46.33%
Northern Pike	30.26%	12.51%	18.14%
Flathead Chub	2.07%	0.72%	4.50%
Longnose Sucker	8.90%	2.11%	1.06%
White Sucker	0.23%	0.15%	0.33%
Burbot	9.84%	1.68%	0.02%
Walleye	20.68%	4.51%	14.75%

4.0 Geographic migratory patterns

4.1 Introduction

To build a model of the expected likelihood of exposure of fishes to a source of contaminants or other anthropogenic effects on the Slave River it is necessary to understand their movement patterns throughout their lives. Some species are highly migratory and thus the possible interactions with anthropogenic effects are potentially complicated and have wide geographic implications. Other species are less mobile through their lives and therefore may be exposed intensely to local sources and those directly upstream but are unlikely to import or export a problem. For example, inconnu are thought to be highly migratory in other systems such as the lower Mackenzie River (K. Howland, unpublished data). Limited radio-tracking of fish tagged at the Slave River delta revealed that inconnu migrate to spawning areas upstream (McLeod et al. 1985). On the other hand, burbot are thought to be relatively sedentary most of the year with a spawning migration during the winter months (Scott and Crossman 1973). There is little scientific information on the longer term movements of burbot or inconnu in the system. The longer term movements could be important to the transport of contaminants to and from the system. Therefore, under the NRBS Tallman et al. (1996a) used regular sampling and radio-telemetry techniques to investigate the timing and extent of movements of inconnu and burbot in the lower Slave River. In addition, using literature directly concerned with the Slave River system and other species specific accounts I will attempt to describe the probable movement patterns throughout the life cycle of each of the major species in the Slave River that have been described in section 3.0.

4.2 Radio-telemetry Studies

Radio-telemetry is a specialized technique that allows detailed tracking of individual fish. Compared to floy tagging, radio-telemetry techniques have the advantage that one can detect an individual several times over the course of its migration as compared to usually only once when the fish is caught. On the other hand, radio-telemetry can only be done on a limited number of individuals at once (usually less than 50) whereas floy tagging can involve thousands of fish. McLeod et al. (1985) and Tallman et al. (1996a) did radio-telemetry on Slave River species. McLeod et al. (1985) followed species for a shorter time period but gave more detailed information on movements. Tallman et al. (1996a) were able to track fish for up to a year and thus give a more complete picture of the long term movements. I will discuss both studies below.

4.2.1 Tracking Methods

McLeod et al. (1985) tracked the movements of inconnu, lake whitefish and burbot using radio-tagging. Inconnu and lake whitefish were tagged in 1983; in 1984 the tagging effort concentrated on inconnu and burbot. They implanted Smith Root Incorporated model P-40-1000L-6V transmitters into the stomach of larger inconnu by insertion through the oesophagus. For smaller inconnu and lake whitefish a model p-40-500L-3V transmitter was attached , externally beside the dorsal fin. The expected life span of these transmitters was 180 and 150 days, respectively. Burbot had transmitters with life expectancies of 300-350 days were inserted into the stomach.

Aerial tracking surveys for inconnu and lake whitefish were conducted during September and October using low altitude passes (1300m) of the River. Tracking for burbot was done from late November, 1984 to March, 1985 at 250m altitude.

Tallman et al. (1996a) radio-tagged inconnu at the Ft. Smith Marina (Rapids of the Drowned) (N = 12) and at Buffalo Crossing (N = 4) between August 15, 1994 and September 01, 1994. These were thought to be aggregating pre-spawners. Nine more inconnu were tagged as spawners at Fort Smith Landing in the last week of September and first week of October, 1994. The tag used was an external radio-tag, model # 1035 available from Advanced Telemetry Systems 470-1st Ave. N., Box 398 Isanti, Minnesota, 55040. Each tag had a battery life-span of nine-months from the time of activation.

Fish were tracked using a radio-receiver mounted on an aircraft or hand-held receiver in a boat by Department of Fisheries and Oceans area office personnel from Hay River. The majority of tracking was conducted from a Cessna 185 plane using dual Larsen NMO-40 whip antenna attached to the wing struts. Tracking was done on a weekly basis after the initial tagging until December ;9, 1995 when most of the inconnu had cleared the system. Additional tracking was done January 9, 1995, January 27, 1995, January 31, 1995, and February 15, 1995 to confirm that inconnu had moved out of range into Great Slave Lake. The average altitude of the tracking aircraft was 1500 meters with two transects one upstream and one downstream.

Sixteen burbot were tagged at Bell Rock between November 25 and December 12, 1994 using the same type of tag as for the inconnu (Tallman et al. 1996a). Fish were tracked using a radio-receiver mounted on aircraft or hand-held receiver in a boat. Initial tracking was done after tagging on December 9, 1995. Additional tracking was done January 9, 1995, January 27, 1995, January 31, 1995, February 15, 1995 and twice during June, 1995 to confirm that burbot had moved out of range into Great Slave Lake. The average flying altitude of the tracking aircraft was 1500 meters.

4.2.2 Inconnu Movement

According to McLeod et al. (1985) most inconnu exhibited fallback (i.e. downstream movement likely related to handling stress) after radio tagging, before recommencing upstream migration. Some individuals dropped back to Great Slave Lake after tagging and in 1984, one such inconnu re-entered the Slave River via Jean River (which drains into the Great Slave Lake approximately 5 km east of the ResDelta Channel) rather than through the Delta channels. Factors such as high water temperatures during August of both years, holding, and handling stress also appeared to contribute to fallback after tagging and release. Inconnu may have been more susceptible to handling and fallback at spawning time (O'Neil et al. 1982). Delay in migration was most evident with early-run inconnu. During mid-August upstream movement was delayed about 12 days, while fish tagged in early September delayed only 5.4 days (McLeod et al. 1985).

Upon recommencing upstream migration, inconnu exhibited an average movement of 25.6 -

35.9 km/day (1984 - 1983, respectively) between the Delta and their spawning areas (McLeod et al. 1985). During the early portion of their migration, inconnu were often located in slow-flowing side-channel habitat; however after the third week in September they were rarely found in these areas, instead preferring main channel locations.

Several movement patterns were observed during radio tracking. After moving through the Delta, upstream migration of radio-tagged inconnu was rapid and continual over the lowermost 180 km of river, until reaching the vicinity of Brûlé Point. Upstream movement ended in this vicinity for some fish, with the remainder of the spawning population continuing to various points as far upstream as Rapids of the Drowned at Fort Smith. McLeod et al. (1985) found no inconnu located above Rapids of the Drowned in either year of the study. Upon reaching the upstream limit of migration, individuals either remained in the general vicinity until spawning occurred, or dropped back to downstream spawning locations. McLeod et al. (1985) concluded that the inconnu spawning population in the Slave River can be separated into two main groups: 1) Upper-River spawners, exhibiting movements consisting of: a) upstream migration to the base of Rapids of the Drowned followed by random movements and holding in the area, with spawning presumably occurring between 517 and 520 km downstream from the river origin; b) upstream migration to the Cunningham Landing area followed by short random movements until spawning occurred; and 2) mid-river spawners, exhibiting movements consisting of: a) upstream migration, occasionally as far as Cunningham Landing but often terminating below Grand Detour: dropping back to mid-river locations until spawning; b) upstream migration to mid-river with random movements and fallback to the area of Pointe Ennuyeuse where spawning occurred.

In 1983, post-spawning dispersal from suspected upstream spawning areas began during the period of October 3rd to October 6th with most fish having left by October 20 (McLeod et al. 1985). A defined and relatively brief post-spawning migration was recorded in the Delta between October 15 and October 25, 1983 (McLeod et al. 1985). In the initial part of the run the catch was made up of spent females whereas in the latter part spent males predominated. No inconnu were captured between October 28 and November 11 indicating that the spawning migration was probably over. In 1984, out-migration began on October 10 with most migrating between October 13 and October 20. All radio-tagged fish had reached Great Slave Lake by October 23. Tripp et al. (1983) recorded a brief out-migration of spent female inconnu in the lower Slave River between October 22 and October 24, 1979.

Table 4 shows the initial tagging date, recapture dates and locations for all inconnu tagged by Tallman et al. (1996a). Figure 7 shows the locations of tagging of inconnu in 1994. Figures 8, 9 and 10 show the geographic locations of recaptures of inconnu between August and October 15, 1994, October 15 and October 30, 1994, November 1, 1994 and July, 1995, respectively. Tallman et al. (1996a) detected inconnu in the Slave River up to October 25, 1994. After this point it was presumed that all fish were in Great Slave Lake. For example, tracking on January 9, 1995 revealed no inconnu in the river even though all burbot radio-tagged in December were detected. Fish numbers 3, 12, 13, 14, 23 and 24 were not seen again after initial tagging. Assuming that they did not expire they

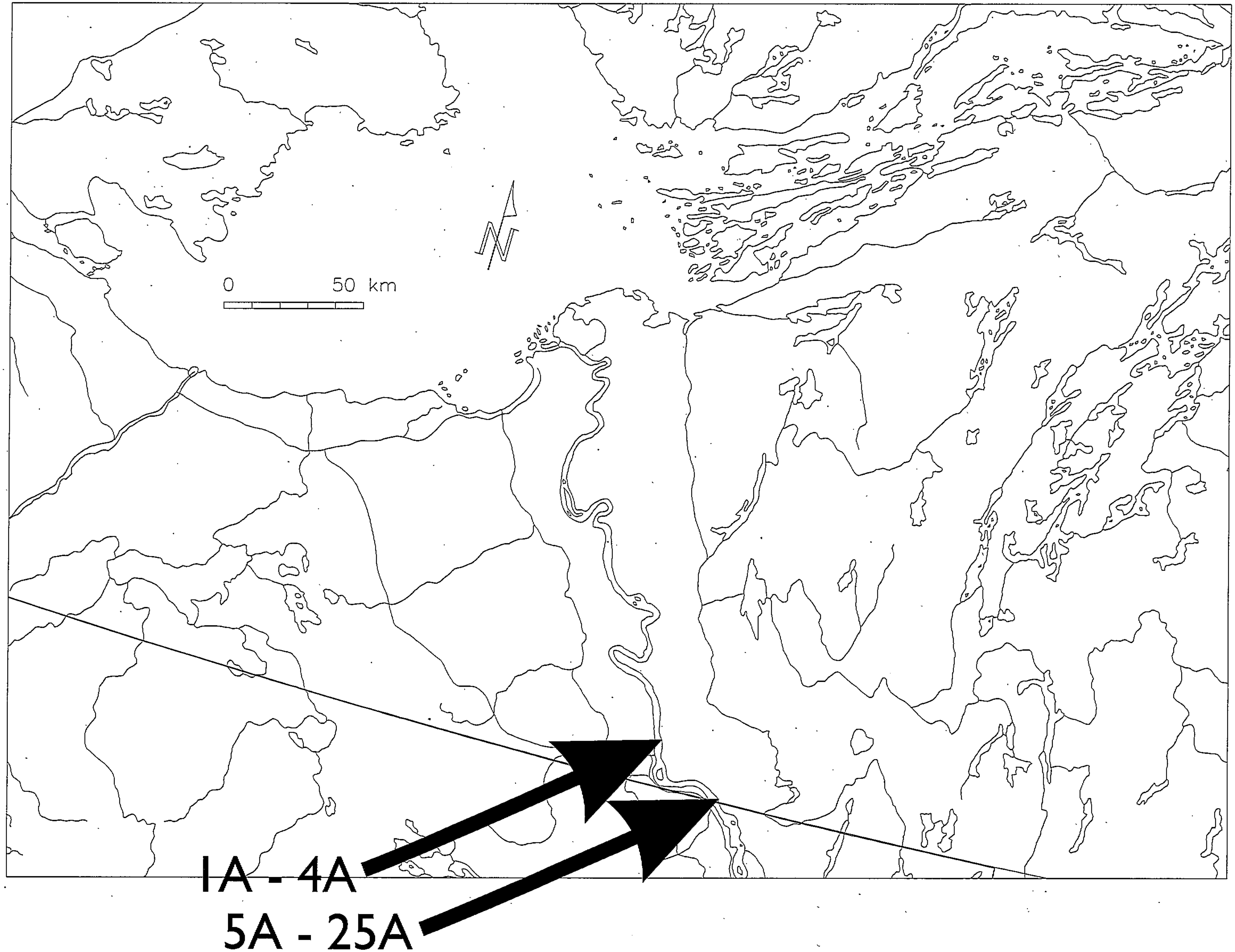

Figure 7. Tagging locations of inconnu in Slave River in 1994 during August and October. Letter-number codes correspond to individual fish and times. (See Table 2 for precise times and location per fish).

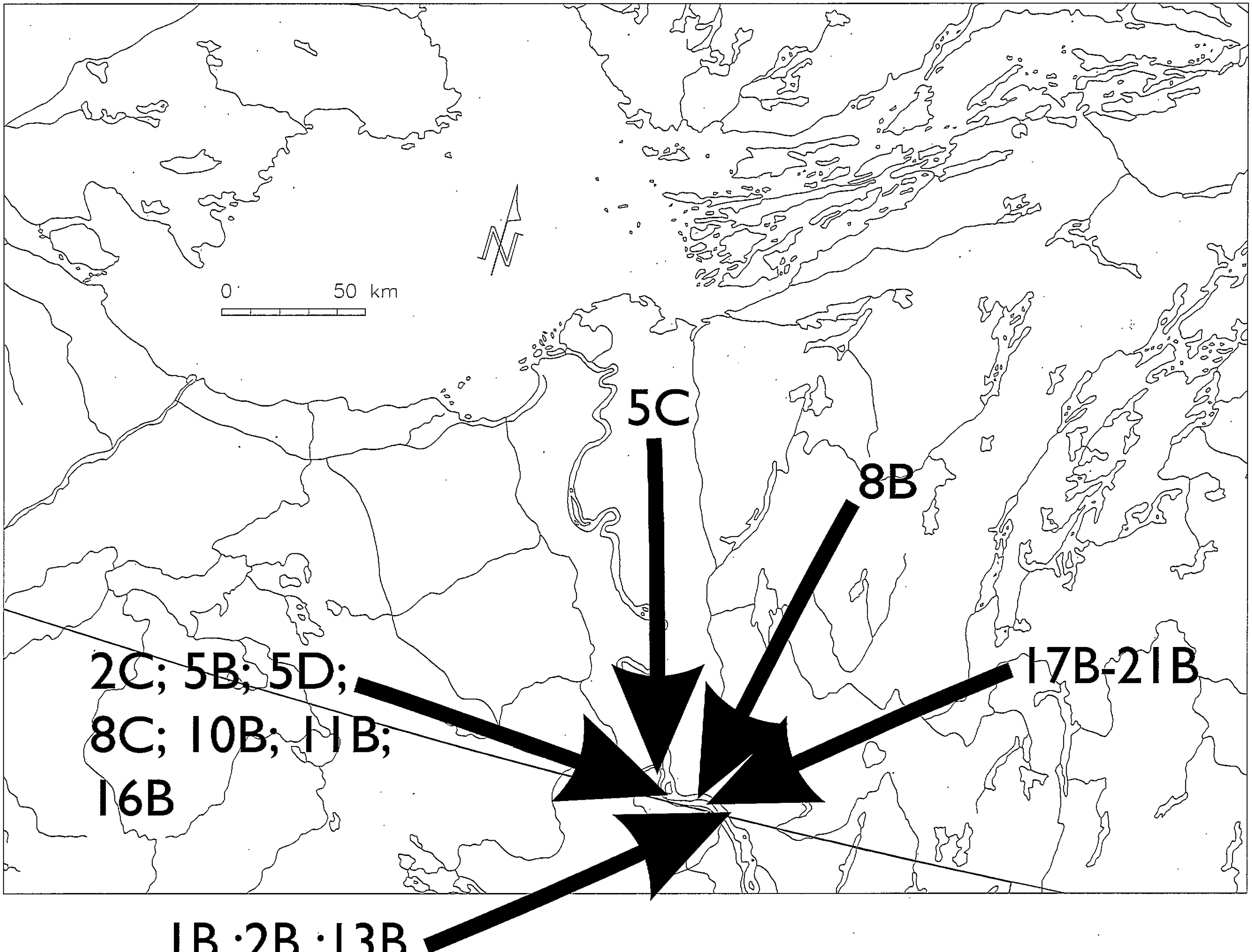

Figure 8. Re-capture and detection locations of inconnu in the Slave River and Great Slave Lake between August and October 15, 1994. Letter-number codes correspond to individual fish and times. (See Table 4 for precise times and locations per fish).

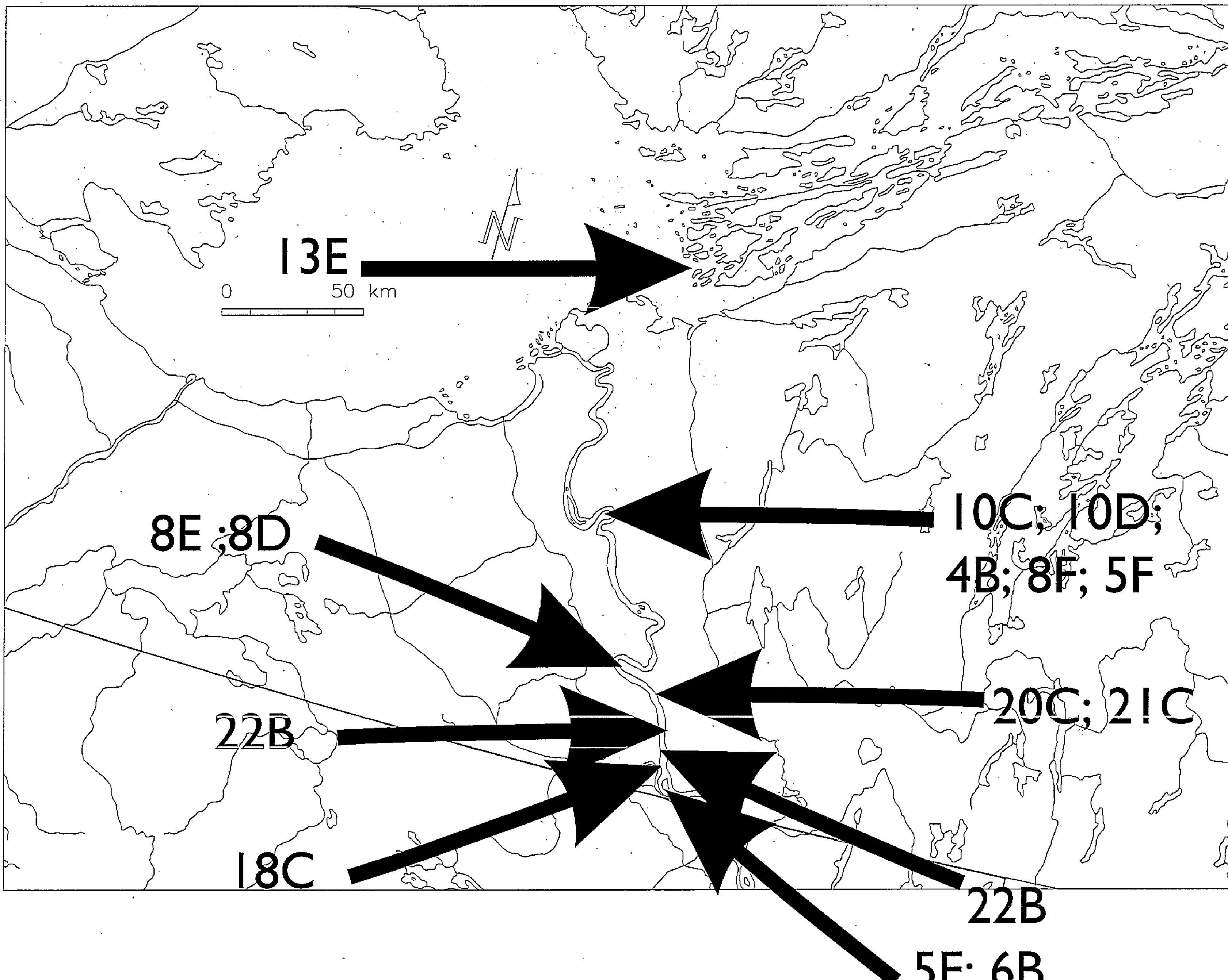

Figure 9. Re-capture and detection locations of inconnu in the Slave River and in Great Slave Lake between October 15 and October 30, 1994. Letter-number codes correspond to individual fish and times. (See Table 4 for precise times and locations per fish).

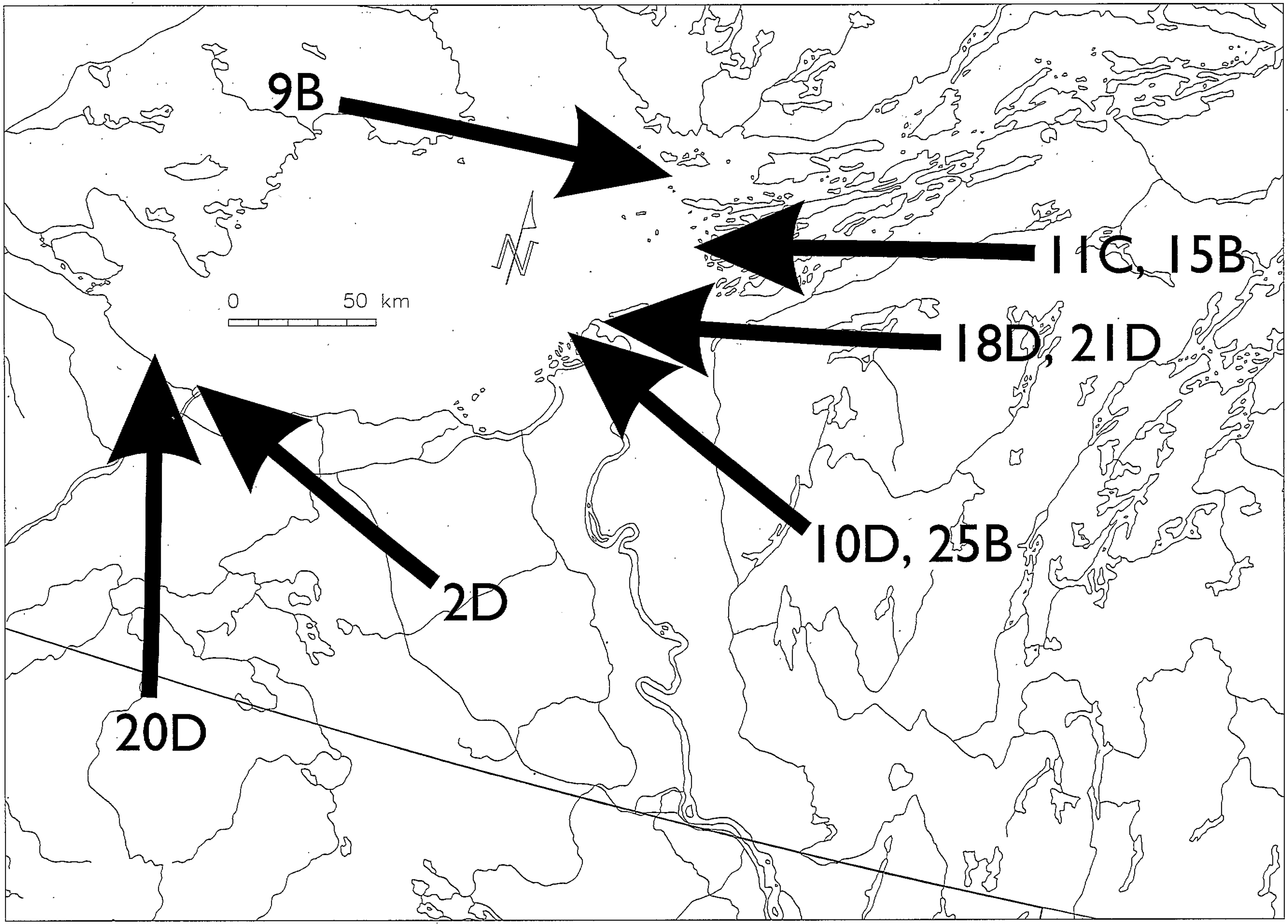

Figure 10. Re-capture and detection locations of inconnu in the Slave River and Great Slave Lake between November,1994 and July, 1995. Letter-number codes correspond to individual fish and times. (See Table 4 for precise times and locations per fish).

probably proceeded directly to Great Slave Lake. This seems reasonable because several fish were seen only as re-captures or detections in the Great Slave Lake between February and late June, 1995 (fish numbers 9, 10, 11, 15, 18, 20, 21, 25). These results suggest that fish could return to the lake as early as August 22 (fish number 3) . Other fish were detected several times proceeding down the river after tag and release (fish number 1, 2, 4, 5, 6, 8, 10, 11, 16, 17, 18, 19, 20, 21, 22). For example, fish number 5 was tagged on August 25, 1994 at Fort Smith Landing. The fish was detected at Cunningham Landing on October 9, 1994, at Salt River On October 11, Cunningham Landing on October 15, Bell Rock on October 18, and downstream of Pointe Ennuyeuse on October 25. Fish number 8, which was tagged at Fort Smith Landing on August 30, 1994, was detected upstream of Cunningham Landing on October 11, at Cunningham Landing on October 15, upstream of Grand Detour on October 18 (twice), downstream of Pointe Ennuyeuse on October 25 and then not detected after this point. Fish 10 was tagged August 31, 1994 moved to Cunningham Landing by October 6, Pointe Ennuyeuse by October 18 (twice) and was detected at MacConnell Island in the Res Delta Channel on June 9, 1995. Another fish (number 25) was detected close by near Steamboat channel on June 9, 1995. Two other fish (18 and 21) were detected near the mouth of the nearby Jean River on June 9, 1995, also. The others were probably out of range at this point. G. Low (DFO area biologist, pers comm.) has tracked inconnu from the Buffalo River into Great Slave Lake and suggested that once in the lake the inconnu swim at depths too deep for the signal to reach the receiver . If depth were a factor in radio transmission then this could account for some tracking problems in the Slave River, as well.

All inconnu that were detected or recaptured in 1995 were in Great Slave Lake except fish number 10 which was detected at McConnell Island in the Res Delta channel of the Slave River delta on June 9, 1995. Fish number 2 was captured near the mouth of Hay River, on the south shore of the lake well to the west of the Slave River, on July 11, 1995. Fish number 9 was captured on June 26, 1995 at Caribou Islands, in the northern part of the lake. Fish 11 was captured on February 1, 1995 at the Simpson Islands at the edge of the east arm of Great Slave Lake. Fish number 15 was captured on March 31, 1995 in the Simpson Islands, also. On June 9, Fish 18 and 21 were detected one km north of the mouth of the Jean River and fish 25 was detected 3 km north of Steamboat Channel. Re-captures are consistent with the radio-tracking. Three fish were re-captured in the river during the month of October. One fish with radio-tag was re-captured March 31, 1995 in the Eastern Arm of Great Slave Lake. Another fish (number 15) was also captured at Simpson Island on March 31, 1995. Fish numbers 18 and 21 were detected at 1km north of the mouth of the Jean River on June 9, 1995. Fish 20 was captured on June 21, 1995 at Pointe de Roche. Fish 25 was captured on June 9, 1995 3km north of Steamboat Channel. With the exception of fish number 9 all fish captured or detect in the warmer months were close to the shore or in the channels of river deltas. The fish detected or captured in the winter were in the deeper part of the lake. (Suggests two things: that it is possible for a fish to live some time with a radio-tag attached and that the inconnu go into the Great Slave Lake for the winter.

Based on the above the annual pattern of migration for adult inconnu can be summarized as follows: Inconnu begin migration into the Slave River in mid-summer, migrating upstream to spawning areas in the mid-river and below Rapids of the Drowned near Fort Smith. There they hold for several days to weeks until they spawn in the second to third week of October. The post-spawning migration to Great Slave Lake takes place over a few days to a couple of weeks and is completed by the end of October. During the winter the fish disperse through Great Slave Lake progressively moving around the western basin following a large counter-clockwise gyre present there. During the spring they begin to aggregate along the southern shore of the western basin and proceed towards the Slave River. Some will not enter the river and wait to spawn the following year but others will return the same year to enter the river in mid summer.

4.2.3 Lake Whitefish Movement

McLeod et al. (1985) fitted four lake whitefish with radio transmitters between October 1 and October 13, 1983. Only one individual was detected on a single occasion 813 km downstream from the place of tagging. One was recaptured by the commercial fishery in Great Lake the following June. McLeod et al. (1985) concluded that the whitefish moved down to Great Slave Lake after tagging.

4.2.4 Burbot Movement

McLeod et al. (1985) and Tallman et al. (1996a) attempted radio-telemetry studies of burbot movements. McLeod et al. (1985) tagged 12 burbot and followed them during the winter of 1984.

According to McLeod et al. (1985) movements of radio-tagged burbot did not follow a definable pattern. Of the fish located on two or more surveys, six exhibited distinct upstream movements ranging from 40 to 280 km from the release sites. The remaining six stayed in the same general area or exhibited fallback to a short distance downstream of the release site. Only one fish exhibited distinct upstream migratory behaviour - it moved 32 km by November 27 five days after release. It was not located again until March 25, 1985 upstream of Cunningham Landing. The five remaining burbot which moved upstream exhibited little movement until mid-January. McLeod et al. (1985) surmised that the active upstream movements represented a feeding or spawning-related activity in mid-winter. Robins and Deubler (1955) reported burbot in the Susquehanna River migrating downstream to spawn. MacCrimmon (1959) found that burbot took a post-spawning feeding run up tributary rivers of Lake Simcoe. Koops (1960 in Chen 1969) reported burbot in the Elbe River moved upstream from the lower reaches of the river to the upstream tributaries for spawning.

Table 4 shows the initial tagging date, recapture dates and locations for all burbot tagged by Tallman et al. (1996a). Figure 11 shows the geographic locations and times of re-captures. Tallman detected burbot in the Slave River Fish on January 5, 1995 and January 31, 1995. Beyond this point there was no further detection and it was presumed that all fish were in Great Slave Lake. Interestingly, no fish were detected with land based reconnaissance on January 27, 1995. Fish number 29 was the only fish detected on January 31, 1995. Although tracking included the nearshore southern Great Slave Lake

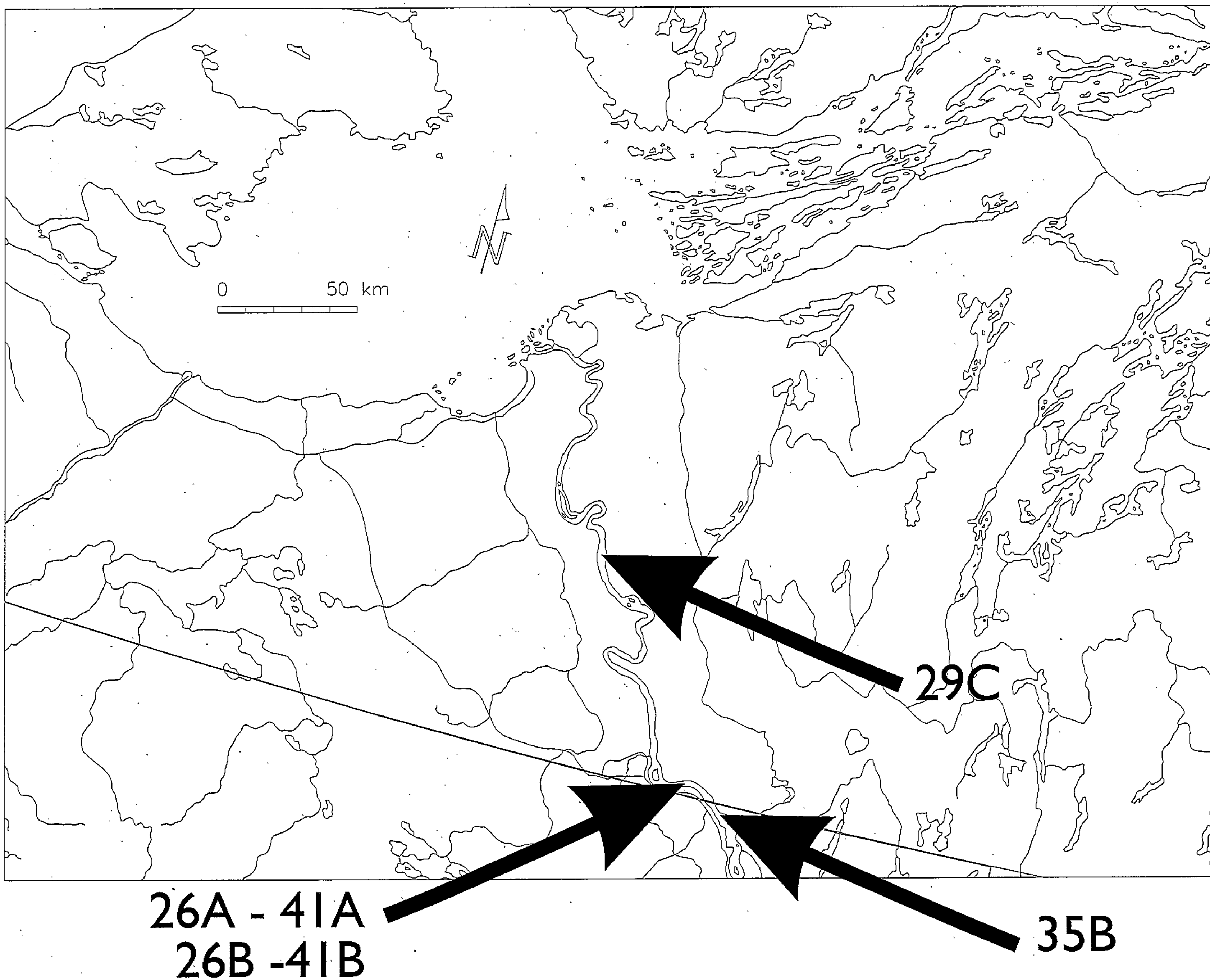

Figure 11. Tagging, re-capture and detection locations of burbot in the Slave River and Great Slave Lake between December, 1994 and July, 1995. Letter-number codes correspond to individual fish and times. (See Table 4 for precise times and locations per fish).

area from Hay River to the tip of the Slave Peninsula, no fish were detected. Tallman et al. (1996a) proposed that the benthic dwelling habit of the burbot meant that they were out of range for radio-telemetry. Fish that move in deeper water are less detectable. It is possible that the tags did not function well given that the fish were tagged under very cold conditions. They did not think that there was mortality or the tags failed because on January 9, 1995 they detected nearly all the fish and if the fish expired they might expect these the tags to continue transmitting from one fixed location. Similarly, if the tags worked initially as confirmed by the January 9 detections then they should not be affected by the temperature of the water. Assuming that the tags worked well, it appears that there was only slight movement of burbot from the initial site of capture. If there was directed movement in the river (suppose downstream to the delta) a larger percentage of the burbot would have been detected because there are unavoidable shallow areas. The most plausible explanation is that burbot had moved into deeper sections of the river and thereby escaped detection.

Table 4. Tagging, tracking and recapture dates and locations for radio-telemetry of inconnu and burbot on the Slave River and Great Slave Lake, 1994 and 1995.

Fish #	Species	Sex	Freq	Event	Date Tagged	Location	Coordinates	Tracking Mode
1A	Inconnu	M	49.170	Tagged	20-Aug-94	Buffalo Crossing	60-06-34N 112-14-04W	
-B				Detected	9-Oct-94	Ft. Smith Landing	60-01-05N 111-53-32W	Water
2A	Inconnu	F	49.350	Tagged	20-Aug-94	Buffalo Crossing	60-06-34N 112-14-04W	
-B				Detected	5-Oct-94	Ft. Smith Landing	60-01-05N 111-53-32W	Land
-C				Detected	15-Oct-94	Cunningham Landing	60-01-40N 112-07-33W	Water
-D				Captured*	11-Jul-95	Hay River	60-02-00N 115-45-00W	
3A	Inconnu		49.270	Tagged	22-Aug-94	Buffalo Crossing	60-06-34N 112-14-04W	
4A	Inconnu		49.230	Tagged	22-Aug-94	Buffalo Crossing	60-06-34N 112-14-04W	
-B				Detected	18-Oct-94	Pointe Ennuyeuse	60-49-00N 113-02-00W	Air
5A	Inconnu		49.190	Tagged	25-Aug-94	Ft. Smith Landing	60-01-05N 111-53-32W	
-B				Detected	9-Oct-94	Cunningham Landing	60-01-40N 112-07-33W	Water
-C				Detected	11-Oct-94	Salt River	60-06-13N 112-13-29W	Air
-D				Detected	15-Oct-94	Cunningham Landing	60-01-40N 112-07-33W	Water
-E				Detected	18-Oct-94	Bell Rock	60-01-20N 112-05-00W	Air
-F				Detected	25-Oct-94	Down Pté. Ennuyeuse	60-44-00N 112-10-00W	Air
6A	Inconnu		49.290	Tagged	28-Aug-94	Ft. Smith Landing	60-01-05N 111-53-32W	
-B				Detected	18-Oct-94	Up Cunningham Landing	60-02-30N 112-01-00W	Air
7A	Inconnu	M	49.210	Tagged	30-Aug-94	Ft. Smith Landing	60-01-05N 111-53-32W	
-B				Captured*	3-Oct-94	Ft. Smith Landing	60-01-05N 111-53-32W	
8A	Inconnu	M	49.330	Tagged	30-Aug-94	Ft. Smith Landing	60-01-05N 111-53-32W	
-B				Detected	11-Oct-94	Up Cunningham Landing	60-02-30N 112-01-00W	Air
-C				Detected	15-Oct-94	Cunningham Landing	60-01-40N 112-07-33W	Water
-D				Detected	18-Oct-94	Up Grand Detour	60-20-00N 112-34-00W	Air
-E				Detected	18-Oct-94	Up Grand Detour	60-21-00N 112-38-00W	Air
-F				Detected	25-Oct-94	Down Pte. Ennuyeuse	60-47-00N 113-49-00W	Air
9A	Inconnu	F	49.250	Tagged	30-Aug-94	Ft. Smith Landing	60-01-05N 111-53-32W	
-B				Captured*	26-June-95	Caribou Island	62-07-25N 113-49-00W	
10A	Inconnu	F	49.470	Tagged	31-Aug-94	Ft. Smith Landing	60-01-05N 111-53-32W	
-B				Detected	6-Oct-94	Cunningham Landing	60-01-40N 112-07-33W	Land
-C				Detected	18-Oct-94	Up Pointe Ennuyeuse	60-45-00N 112-58-30W	Air
-D				Detected	18-Oct-94	Up Pointe Ennuyeuse	60-45-00N 112-58-30W	Air
-E				Detected	9-June-1995	McConnell Island	60-48-00N 112-56-00W	Air
11A	Inconnu	M	49.120	Tagged	31-Aug-94	Ft. Smith Landing	60-01-05N 111-53-32W	
-B				Detected	9-Oct-94	Cunningham Landing	60-01-40N 112-07-33W	Water
-C				Captured*	1-Feb-95	Simpson Island (G.S.L.)	61-45-00N 113-00-00W	
12A	Inconnu	M	49.100	Tagged	31-Aug-94	Ft. Smith Landing	60-01-05N 111-53-32W	
13A	Inconnu	M	49.140	Tagged	31-Aug-94	Ft. Smith Landing	60-01-05N 111-53-32W	
-B				Detected	5-Oct-94	Ft. Smith Landing	60-01-05N 111-53-32W	Land
14A	Inconnu	F	49.570	Tagged	31-Aug-94	Ft. Smith Landing	60-01-05N 111-53-32W	
15A	Inconnu	M	49.550	Tagged	31-Aug-94	Ft. Smith Landing	60-01-05N 111-53-32W	
-B				Captured*	31-Mar-95	Simpson Island (G.S.L.)	61-45-00N 113-00-00W	
16A	Inconnu	F	49.590	Tagged	31-Aug-94	Ft. Smith Landing	60-01-05N 111-53-32W	
-B				Captured*	15-Oct-94	Cunningham Landing	60-01-05N 111-53-32W	
17A	Inconnu	M	49.750	Tagged-	12-Oct-94	Ft. Smith Landing	60-01-05N 111-53-32W	
-B				Detected	15-Oct-94	Rocky Point	60-02-14N 111-54-33W	Air
18A	Inconnu	M	49.630	Tagged	12-Oct-94	Ft. Smith Landing	60-01-05N 111-53-32W	
-B				Detected	15-Oct-94	Rocky Point	60-02-14N 111-54-33W	Water
-C				Detected	18-Oct-94	Up Salt R.	60-05-00N 112-14-00W	Air
-D				Detected	9-Jun-95	1km N. of mouth-Jean R.	61-25-00N 113-35-00W	Air
19A	Inconnu	M	49.910	Tagged	13-Oct-94	Ft. Smith Landing	60-01-05N 111-53-32W	
-B				Detected	15-Oct-94	Rocky Point	60-02-14N 111-54-33W	Air
20A	Inconnu	M	49.870	Tagged	13-Oct-94	Ft. Smith Landing	60-01-05N 111-53-32W	
-B				Detected	15-Oct-94	Rocky Point	60-02-14N 111-54-33W	Water
-C				Detected	18-Oct-94	Up Grand Detour	60-18-30N 112-25-00	Air
-D				Captured*	21-Jun-95	Point de Roche	60-54-00N 116-09-00W	
21A	Inconnu	M	49.790	Tagged	13-Oct-94	Ft. Smith Landing	60-01-05N 111-53-32W	
-B				Detected	15-Oct-94	Rocky Point	60-02-14N 111-54-33W	Water
-C				Detected	18-Oct-94	Up Grand Detour	60-16-00N 112-22-00W	Air
-D				Detected	9-Jun-95	1km N. of mouth-Jean R.	61-25-00N 113-35-00W	Air
22A	Inconnu	M	49.610	Tagged	13-Oct-94	Ft. Smith Landing	60-01-05N 111-53-32W	
-B				Detected	18-Oct-94	Buffalo Crossing	60-10-30N 112-16-04W	Air
23A	Inconnu	F	49.770	Tagged	13-Oct-94	Ft. Smith Landing	60-01-05N 111-53-32W	
24A	Inconnu	F	49.390	Tagged	13-Oct-94	Ft. Smith Landing	60-01-05N 111-53-32W	
25A	Inconnu	F	49.370	Tagged	13-Oct-94	Ft. Smith Landing	60-01-05N 111-53-32W	
-B				Detected	9-Jun-95	3km N of Steamboat Ch.	61-20-00N 113-45-00W	Air
26A	Burbot		49.490	Tagged	13-Dec-94	Bell Rock	60-01-20N 112-05-00W	
-B				Detected	9-Jan-95	Bell Rock/Salt River	60-01-35N 112-06-33W	Air
27A	Burbot		49.410	Tagged	13-Dec-94	Bell Rock	60-01-20N 112-05-00W	
-B				Detected	9-Jan-95	Bell Rock/Salt River	60-01-35N 112-02-55W	Air
28A	Burbot		49.080	Tagged	14-Dec-94	Bell Rock	60-01-20N 112-05-00W	
-B				Detected	9-Jan-95	Bell Rock/Salt River	60-01-08N 111-51-37W	Air
29A	Burbot		49.430	Tagged	14-Dec-94	Bell Rock	60-01-20N 112-05-00W	
-B				Detected	9-Jan-95	Bell Rock/Salt River	60-01-49N 111-54-34W	Air

-C			Detected	31-Jan-95	Hook Lake	60-42-65N 112-52-67W	Air
30A	Burbot	49.810	Tagged	14-Dec-94	Bell Rock	60-01-20N 112-05-00W	
-B			Detected	9-Jan-95	Bell Rock/Salt River	60-02-16N 112-00-02W	Air
31A	Burbot	49.890	Tagged	14-Dec-94	Bell Rock	60-01-20N 112-05-00W	
-B			Detected	9-Jan-95	Bell Rock	60-01-20N 112-05-00W	Air
32A	Burbot	49.830	Tagged	14-Dec-94	Bell Rock	60-01-35N 112-06-33W	
-B			Detected	9-Jan-95	Bell Rock/Salt River	60-02-47N 112-01-49W	Air
33A	Burbot	49.020	Tagged	15-Dec-94	Bell Rock	60-01-20N 112-05-00W	
-B			Detected	9-Jan-95	Bell Rock/Salt River	60-01-20N 112-04-12W	Air
34A	Burbot	49.510	Tagged	15-Dec-94	Bell Rock	60-01-20N 112-05-00W	
35A	Burbot	49.450	Tagged	15-Dec-94	Bell Rock	60-01-20N 112-05-00W	
-B			Detected	31-Jan-95	Up Fort Smith Landing	59-54.00N 111-43.50W	Air
36A	Burbot	49.040	Tagged	15-Dec-94	Bell Rock	60-01-20N 112-05-00W	
-B			Detected	9-Jan-95	Bell Rock/Salt River	60-01-58N 111-55-04W	Air
37A	Burbot	49.670	Tagged	16-Dec-94	Bell Rock	60-01-20N 112-05-00W	
38A	Burbot	49.710	Tagged	16-Dec-94	Bell Rock	60-01-20N 112-05-00W	
-B			Detected	9-Jan-95	Bell Rock/Salt River	60-01-49N 112-08-44W	Air
39A	Burbot	49.730	Tagged	16-Dec-94	Bell Rock	60-01-20N 112-05-00W	
-B			Detected	9-Jan-95	Bell Rock	60-02-09N 111-54-54W	Air
40A	Burbot	49.650	Tagged	16-Dec-94	Bell Rock	60-01-20N 112-05-00W	
-B			Detected	9-Jan-95	Bell Rock/Salt River	60-01-50N 111-54-02W	Air
41A	Burbot	49.690	Tagged	16-Dec-94	Bell Rock	60-01-20N 112-05-00W	
42	-	49.530	not used	.	.	42	49.530
43	-	49.060	not used	.	.	43	49.060
44	-	49.310	not used	.	.	44	49.310
45	-	49.850	not used	.	.	45	49.850

N.B. Tracking via aircraft on 01-Nov-94, via land on 27-Jan-95, but no hits recorded

* Commercial catch of Inconnu radio tag within Great Slave Lake.

Tallman et al. (1996a) radio-tracking results for burbot are consistent with the model that this species remains relatively sedentary until individuals begin their winter spawning migration. In conversations with the local fisherman it appears that spawning migration occurs in February, similar to most burbot populations (Scott and Crossman 1973). In the process of tagging during December, 1994, Tallman et al. (1996a) found no evidence that the fish were close to spawning. None had ripe eggs or running milt, for example. After spawning all burbot may return to Great Slave Lake perhaps to reside in off-shore areas or more likely to rest deep in the Slave River delta since tracking along the south shore and in the river in 1995 did not reveal any tagged burbot.

Radio-tracking of a bottom dwelling species such as burbot will not be very effective if the fish migrate to water greater than 5 meters in depth. Below this depth, it is thought that the radio signal attenuates and becomes hard to detect when tracking. In the Slave River and its delta there are many places with depths of up to 25 meters. Great Slave Lake, of course, has waters of great profundity. Thus, it was difficult to determine the exact fate of the radio-tagged burbot. Although such tags are not available at present, future studies could use tags with stronger batteries for multi-year tracking.

4.3 Floy Tagging Studies

McLeod et al. (1985) performed mark-recapture experiments using floy tags attached to inconnu, lake whitefish, burbot, northern pike, walleye, longnose sucker, goldeye and cisco. McLeod et al. (1985) did not report the sample sizes tagged of any species. Therefore, the following account gives information on the re-captures, only. Whether enough fish were tagged for an effective study cannot be assessed.

4.3.1 Inconnu

Eighty-two inconnu, tagged between August 15 and September 23 just downstream of the junction between the Slave River and Jean River were re-captured after 0 to 54 days at large (McLeod et al. 1985 - Appendix Table C3) . Only two fish did not exhibit upstream movement. One was caught four days after release 10 km downstream and the other showed no movement after 9 days. Since the rest were at large for longer periods these results probably reflect the short-term effects of post-tagging trauma. Most of the other 80 fish migrated 282 km upstream to be caught near Fort Smith. Six fish migrated 185 km to the mid-lower river area. Eight additional inconnu tagged in 1983 were recovered in the Slave River near Fort Smith during the fall of 1984. Since radio-tracking and catch per unit effort results indicate that the inconnu leave the Slave River for Great Slave Lake until the next spawning period these fish appear to be repeat spawners after only one year. It is also possible that the trauma of tagging prevented them from spawning in 1983 and they returned in 1984. McLeod et al. (1985) recorded other evidence of site fidelity. An inconnu tagged September 25, 1980 in the Slave River near Fort Smith was recovered in the river in October,1984 only 14 km downstream from its original tagging location (McLeod et al. 1985 - Table C7). Four inconnu tagged in the Slave River in between September 20 and October 23, 1983 were recaptured in Great Slave Lake (McLeod et al. 1985 - Appendix Table C10). One was captured in March, 1984 near Sulphur Point. Another was captured near the mouth of the Buffalo River July 5, 1984. The other two were captured on the 2nd and 3rd of September, 1984 at Grant Point.

4.3.2 Lake Whitefish

Twelve recaptured lake whitefish, tagged between September 10 and October 18, 1983 did not show a very consistent pattern (McLeod et al. 1985 - Appendix Table C4 and C5.) Six did not move at all. Four tagged near the Jean River junction move upstream 2 to 282 km. Two tagged in October near Fort Smith moved downstream 14 km. They were at large between 0 and 25 days. Recaptures from 1984 (McLeod et al. 1985 - Appendix Table C5) show a similar pattern Three fish tagged between August 17 and September 5 at the Jean River junction migrated upstream 282 km to near Fort Smith. Two tagged later on October 3rd and October 16th at Fort Smith moved 0 km and 2 km downstream. Overall there appears to be a migration upstream in late August through September to sites near Fort Smith and a downstream migration in October from near Fort Smith out of the system. Four lake whitefish were recovered after a year in the Slave River near Fort Smith (McLeod et al. 1985 - Appendix Table C6 and C7). Seven lake whitefish tagged in the Slave River in 1983 were recaptured in Great Slave Lake (McLeod et al. - Appendix Table C10). Three were recaptured near Dawson Landing in late July and early August. Two were captured near Sulphur Point, one at the Buffalo River mouth and one at Grant Point.

4.3.3 Burbot

Mark-recapture information for burbot show a highly sedentary animal in the fall compared to other species in the Slave River (McLeod et al. 1985). Of nine burbot tagged between September 24 and October 21, 1984 and recovered between September 30 and October 25, 1984 only one moved three km downstream. The other eight were caught in the same locations that they were released in.

4.3.4 Northern Pike

On the short term floy-tagged northern pike move little. Of 11 pike recaptured in 1983 between 2 and 46 days after tagging eight did not move at all, two moved 2 km and one went 175 km downstream (McLeod et al. 1985 - Appendix Table C8). On the longer term, out of four pike recaptured after 361 to 2147 days after tagging one went some distance (166 km downstream) while the others went 0, 6 and 14 km (McLeod et al. 1985 - Appendix Tables C8 and C9). In addition a pike tagged on September 9, 1983 was recaptured in Great Slave Lake on August 30, 1984 near Grant Point. Other than the three pike that travelled some distance downstream there was no consistent direction to movements(McLeod et al. 1985 - Appendix Tables C10).

4.3.5 Walleye

Floy-tagged walleye exhibited substantial movements both in the short and long term. A walleye tagged September 22, 1983 near Jean River junction was recaptured at Fort Smith , 282 km upstream, on November 11, 1983 (McLeod et al. . 1985 - Appendix Table C8). Five other walleye tagged in the Slave River were recaptured in 1984 near Fort Smith between 259 and 293 km upstream after being at large between 208 and 1851 days(McLeod et al. 1985 - Appendix Table C9). Two walleye tagged in the Slave River in the fall of 1983 were capture near Dawson Landing Great Slave Lake in the fall of 1984.

4.3.6 Goldeye, Cisco and Longnose Sucker

McLeod et al. (1985) records four tagging returns for goldeye. In all cases the goldeye appeared to have migrated downstream between 15 and 290 km. One was captured in Great Slave Lake at Dawson Landing.

One cisco was tagged and re-captured on the same day after no movement. One longnose sucker tagged in the Slave River was recovered in Great Slave Lake (McLeod et al. 1985).

4.4 Larval Drift Studies

Tripp et al. (1981) collected samples of the drift of young of the year of several species in the lower Slave River during the spring of 1979 and 1980. The earliest species to drift were coregonids possibly inconnu, lake whitefish or cisco in mid -May. Burbot and Arctic lamprey follow in the first two weeks of June. Longnose sucker appeared about 10 days after the burbot.

4.5 Species by species life-cycle model of seasonal movement patterns

(based on radio-tracking, floy tagging, CPUE studies, larval drift studies and general literature on each species)

Fish species migrate for three main reasons: 1) to seek suitable spawning habitat; 2) for feeding and rearing habitat; 3) to take refuge from unfavourable environmental conditions. From a survey of the literature , the information above and the catch per unit effort results of Tallman et al. (1996c, noted below)it is possible to construct a model of the general pattern of temporal and spatial migration over the course of the life cycle of each of the major species in the lower Slave River.

4.5.1 Inconnu Life Cycle

Inconnu spawn in the fall in the Slave River and the resulting zygotes incubate in the gravel until spring breakup when they are likely transported downstream into Great Slave Lake. The juveniles feed and rear in the lake for several years occupying nearshore areas early in the spring and the offshore areas the rest of the year . They likely follow a lake migration pattern around the western basin of Great Slave Lake swimming in the large count-clockwise gyre in the basin.

As they mature they begin to participate in the spawning runs in the tributaries of Great Slave Lake. Although, it has not been confirmed it is thought that inconnu stocks have natal site fidelity and therefore there is at least one distinct stock per spawning river. The rationale for this is that inconnu do not seem to be restricted by distance or geographic barriers from colonizing or re-colonizing any suitable spawning habitat yet successive spawning rivers have been depleted of inconnu without any recovery.
Inconnu first appeared in the Slave River near the end of July (Table A, Appendix 1) and the run peaked between September 1 and September 15. The end of the run was estimated to be in the latter part of October. By October 21 most inconnu had left the Slave River.

Radio tracking and floy tagging results suggest that the upstream migration of inconnu to their spawning sites probably occurs during August and September (McLeod et al. 1985, Tallman et al. 1996a). Inconnu may initially swim upstream until they reach a barrier (i.e Rapids of The Drowned). Some may spawn there but others move about in the reaches of the river just downstream of the rapids in search of suitable spawning sites. The radio-telemetry results of McLeod et al. (1985) and Tallman et al. (1996a) indicate that until mid-October the inconnu were still in close proximity to the tagging sites near Fort Smith. Therefore, spawning probably takes place in those first two weeks of October. Spawning takes place at two major locations: in the mid-river and near Fort Smith below Rapids of the Drowned. Between October 15th and 30th the fish begin to migrate downstream (Tallman et al. 1996a) . After this period all inconnu are presumably in Great Slave Lake, probably in off-shore areas (since tracking along the south shore and in the river did not reveal any tagged inconnu).. In 1995 all fish that were detected or re-captured were outside the river within Great Slave Lake (Tallman et al. 1996a).

After the winter period the inconnu become available to fisherman's nets in the areas closer to shore. Tallman et al. (1996a) found that inconnu from the Slave River use a large part of the lake basin in the course of a year.

Tallman et al. (1996a) observed a number of captures and detections of post-spawning radio-tagged inconnu in 1995 well to the west of the Slave River. The pattern in time and space of captures and detections in Great Slave Lake suggests that fish migrate throughout most of the lake basin and that there is a progressive movement in a counter-clockwise direction throughout the winter into the next summer. The limited floy tag re-captures from Great Slave Lake also support this assertion. This pattern follows the direction of current movement around the lake which proceeds in a large counter-clockwise gyre. Based on the changes in the geographical locations of catch of inconnu in the commercial fishery over the annual cycle, George Low (Department of Fisheries and Oceans, Hay River, pers comm.) has also suggested that the above pattern of movement occurs as the year progresses. If this is true, then any contaminants in the fish at Fort Smith would be transported throughout Great Slave Lake and into commercially sold fishes.

4.5.2 Burbot Life Cycle

In contrast to the inconnu burbot were remarkably sedentary. Burbot spawn during the mid-winter under the ice presumably in the Slave River delta and the Slave River channel just upstream (Tripp et al. 1981 - but see below for an alternate possibility of a spawning location). The eggs are semi-pelagic (Scott and Crossman 1973). The young of the year drift downstream a few weeks after ice break up. The rearing area of this species is probably the Delta or the bottom areas of Great Slave Lake.
At some point in their life it seems likely that the burbot establish a geographically limited feeding territory in the river and remain in this location except for spawning movements to and from the Slave River Delta. Floy tagged and radio-tagged adult burbot travelled almost no distance in most cases. Tallman et al. (1996c) proposed that during most of the warmer months burbot hold in small feeding territories along the river, delta and Great Slave Lake. Their lack of success in capturing burbot using gillnets during the summer months would corroborate this. On the other hand, it is possible that burbot are able to avoid capture by gillnets. Burbot are chiefly nocturnal animals and are well equipped to find their prey in the absence of visual stimuli (McCrimmon and Devitt 1954). Perhaps they can feel the gillnet and thereby avoid it.

Once mature burbot begin migrations within the Slave River to and from the spawning area in and near the Delta. Hewson (1955) noted that not all mature burbot spawn every year and thus some individuals may not move from their home territory. Burbot were more readily caught using set lines which is the method employed by local fishermen targeting burbot after freeze-up. The lack of abundance precluded meaningful statistical analyses of CPUE by time period, location and mesh size on this species (Table B, Appendix 1).

Burbot are thought to spawn in January or February in the Slave River (Fred MacDonald, Dene fisherman, Fort Smith, pers. comm.) On the other hand there has also been a run in late November reported (F. Saurette, DFO, pers. comm.). Spawning usually occurs in lakes in less than 2m of water over sand or gravel bottom in shallow bays or on gravel shoals between 2-3m deep (Scott and Crossman 1973). Water temperature during spawning is usually around 0.6 - 1.7°C. Based on the literature and their own results, McLeod et al. (1985) proposed the following behaviour and spawning pattern for burbot in the Slave River: 1) a pre-spawning feeding run occurs from Great Slave Lake into the Slave River Delta near or just after freeze-up. Some of these fish immediately migrate as far upstream as Rapids of the Drowned, while others likely remain in the Delta or lower river. Spawning by the latter group probably occurs in or immediately above the Delta; this is followed by an upstream post-spawning movement by some individuals.

2) A pre-spawning feeding run or concentration also occurs in the Cunningham Landing area during the early winter (late November to early January). Spawning also occurs in this vicinity.

Judging from the state of the gonads in December Tallman et al. (1996c) suggested that spawning probably occurs around February. Most burbot were around 10-15% GSI. Normally, GSI's must reach close to 25% at spawning. In this respect Slave River burbot would spawn at a similar time as most other Canadian populations (Scott and Crossman 1973).

4.5.3 Goldeye life cycle

Goldeye are the dominant species in the Slave River system (Tallman et al. 1996c). They spawn in the spring probably in early to late May shortly after the ice breaks up. However, spawning may continue for a period of 3 to 6 weeks while the water temperature is between 10.0 - 12.8 C° (Scott and Crossman 1973). Egg shedding takes place in pools in turbid rivers such as the Slave (Battle and Sprules 1960, Kennedy and Sprules 1967). The geographical location of spawning is in the Slave River is not known but Tripp et al. (1981) concluded that there was little evidence of spawning in the Delta. The high catches near Fort Smith suggest that spawning areas might be in pools below the Rapids of the Drowned (Table C, Appendix 1 , Tallman et al. 1996c).

The eggs are semi-buoyant and hatch in about two weeks (Battle and Sprules 1960). The larvae must be in habitats or have some behavioral adaptations where they are unlikely to drift because Tripp et al. (1981) recorded few in drift collections. Pulses of high abundance appear in the spring, August and in the fall suggesting that the distribution within the Slave River may shift depending on environmental conditions (Table C. Appendix 1) McLeod et al. (1985) also found a pulse of CPUE of goldeye late in the season. Possibly the fish are aggregating prior to over-wintering.

Because of its importance in the Slave River more information is needed regarding the habitat needs of this species.

4.5.4 Lake Whitefish Life Cycle

Lake whitefish spawn in the fall, probably below Rapids of the Drowned near Fort Smith, at Cunningham Landing and in other areas of the Slave River between these areas and Grand Detour (McLeod et al. . 1985). The eggs are deposited in relatively silt free substrates often situated on the outside perimeter of river meanders (McLeod et al. 1985). The eggs develop throughout the winter until pelagic larvae emerge around the time of ice break-up (Tripp et al. 1981). The larvae drift downstream with the current to Great Slave Lake. Presumably, some rearing takes place in Great Slave Lake. However, the juvenile whitefish were caught in large numbers at times in the river near Fort Smith and in the Slave River delta (Tallman et al. 1996c, Tripp et al. 1981). Therefore, some must remain in or migrate back into the Slave River. It is uncertain whether these remain permanent residents of the river until mature or whether at some size they also migrate into the Great Slave Lake.

The adult fish return to the river in the last two weeks of August and numbers continue to increase until October as the spawners aggregate. McLeod et al. (1985) placed spawning in late October but Tallman et al. (1996c) found that lake whitefish abundance had declined in the last two weeks of this month. Spawning probably occurs sometime in the middle of October (Table D, Appendix 1).
Neither Tallman et al. (1996c) nor McLeod et al. (1985) detected a defined post-spawning downstream migration. Mcleod et al. (1985) noted that CPUE increased in late October and early November and proposed that this might represent a post-spawning migration. Some out-migration to Great Slave Lake after freeze-up or during the following spring and early summer was noted by McLeod et al. (1985). It is presumed that all spawners do eventually return to Great Slave Lake to feed and recover before returning to spawn.

4.5.5 Northern Pike Life Cycle
Northern pike spawn in the early spring. Tripp et al. (1981) thought that northern pike probably moved to warmer areas upstream from the Delta to spawn, before the lower Slave River had cleared itself of ice in late May. Indirect evidence from the seasonal abundance of young-of-the-year supported this interpretation since it suggested that young-of-the-year migrated downstream late in the summer to rearing areas in the lower Slave River and Slave River Delta. As well, Tallman et al. (1996c) found that in early June there were large numbers of pike juveniles near the mouth of the Salt River in the upper part of the lower Slave River. While it has not been confirmed the shallow Salt River would probably warm quickly in the spring and make suitable habitat for northern pike spawning, In 1980, Tripp et al. (1981) found many pike in spawning condition in the Slave River delta and so they concluded that, in some years, spawning might occur in this area. They suggested that pike might be opportunistic regarding spawning site choosing the delta when conditions are favourable. According to Tripp et al. (1981) peak spawning occurred between May 4 to May 26 at water temperatures ranging from 5 to 14°C.

Eggs usually hatch after 12-14 days and young remain attached to aquatic vegetation for an additional 6-10 days (Scott and Crossman 1973). The requirement for vegetation to attach to also supports the idea that the Salt River may be the main spawning area because it is well vegetated. Once free-living growth is rapid and the juvenile pike start to re-distributed themselves into feeding territories. As noted above there is probably displacement of juveniles downstream in the early to late summer. The preferred habitat of pike is usually slow moving heavily vegetated areas (Scott and Crossman 1973). In general, once a feeding territory has been established pike are rather sedentary (Scott and Crossman 1973). This certainly seems to be the case for the Slave River population (McLeod et al. 1985).

Tallman et al. (1996c) found that northern pike were present in moderate abundance throughout the open water sampling period in 1994 (Table E, Appendix 1). In 1995 they were present in consistently higher numbers throughout the sampling period with substantial abundance recorded in the first two weeks of June and the last two weeks of August (Table E, Appendix 1). The increase in 1995 was probably due to better sampling coverage of the juvenile pike population in the area. More sampling was done in the Salt River area where juvenile pike were abundant.

4.5.6 Flathead chub life cycle

Both Tripp et al. (1981) and Tallman et al. (1996c) reported high CPUE of flathead chub in the spring suggesting aggregations for the purposes of spawning (Table F, Appendix 1). Tripp et al. (1981) found that small flathead chub were taken in minnow seines in the spring and early summer. However, the literature suggests that spawning occurs in the summer (Scott and Crossman 1973). Both Tallman et al. (1996c) and Tripp et al. (1981) found that CPUE results were fluctuating and no clear pattern emerged regarding seasonal movements. Tripp et al. (1981) hypothesized that flathead chub might overwinter in Great Slave Lake leaving the river entirely. Regardless, the biology of this species in the Slave River remains obscure and more work on its importance would be useful.

4.5.7 Walleye Life Cycle

Tallman et al. (1996c) found that walleye had two major periods of aggregation, in the spring and in the fall (Table G, Appendix 1). The spring aggregation is probably for spawning. Normally, walleye spawn shortly after spring breakup at temperatures ranging from 5.5 to 11.0°C (Scott and Crossman 1973). Preferred spawning areas are rocky areas in white water below falls or at the base of rapids. A likely spawning area is located at Rapids of the Drowned near Fort Smith. Tripp et al. (1981) thought that tributary streams such as the Salt River might be important, also. Tripp et al. (1981) concluded that there are two major migrations through the Delta. The first is an upstream spawning migration starting in mid-April before spring breakup and continuing through most of May. The second is a downstream migration to Great Slave lake that starts in late August and continues on at least freeze-up and possibly later. Tallman et al. (1996c) proposed aggregations in the fall were in preparation for over-wintering. The tagging results of Mcleod et al. . (1985) showing extensive downstream movements in the fall corroborate this interpretation. The walleye were found by Tripp et al. (1981), McLeod et al. (1985) and Tallman et al. (1996c) to be a significant part of the fish community in the Slave River during the open water season. The offspring must hold in the river during the summer and possibly remain there to rear until they become mature adults. The adults apparently over-winter in Great Slave Lake.

4.5.8 Lake Cisco Life Cycle

Cisco appear to utilize mainly the lower reaches of the Slave River near the Delta. Tallman et al. (1996c) failed to capture any cisco while Tripp et al. (1981) concentrating on the Delta area found them to be relatively abundant. The cisco appear to utilize the lower reaches of the river and Delta for spawning in late October and early November. The juveniles may rear in the outer Delta but more likely spend there rearing years in Great Slave Lake. The adults are only briefly present in the Slave River system.

4.5.9 Longnose Sucker Life Cycle

Longnose sucker is a spring spawner (Tripp et al. 1981). It was one of the most abundant species in the Delta but was present in low numbers upstream except in spring when spawning was occurring (Tripp et al. 1981, Tallman et al. 1996c Table H, Appendix 1). Spawning probably takes place in the Salt River area or areas of moderate flow. Tripp et al. (1981) found peaks of abundance in the Delta in late June and early July and interpreted this as indicative of a post-spawning downstream migration. Fish taken at this time were spent (Tripp et al.. 1981). The young suckers remain in the gravel for two weeks after hatching and emerge in June (Scott and Crossman 1973). The fry then begin feeding although it is unknown whether they remain in the river or migrate into Great Slave Lake. Adults appear to spend much of their time in Great Slave Lake or the Delta area migrating upstream in the spring for spawning.

4.5.10 Summary of migratory types in the Slave River

Overall, the Slave River appears to be home to four different migratory types of fish. 1) There are highly (i.e. long distance) migratory species such as inconnu and perhaps lake whitefish that are chiefly lake dwellers but use the Slave River for spawning in the fall. 2) There are other species who migrate moderate distances, that are spring or early summer spawners such as goldeye, flathead chub and northern pike and are moderately to highly abundant residents within the system. 3) There are species that are highly migratory spring spawners overwintering in the Delta or Great Slave Lake, such as walleye. 4) Finally, there is burbot and perhaps others which are sedentary in the system. This species apparently has low abundance yet can be readily caught using set lines during the winter and are also winter spawners.

5.0 Demographic characteristics and vital rates

5.1 Introduction

The intensity of the impact of contaminants and other anthropogenic effects can often be determined by the demographic characteristics of fish populations. Fishes that live a long time will have many more opportunities to accumulate the effects on the system. For example, a contaminant that enters transiently into the food chain will be more likely to be concentrated in a long lived animal than a short lived one. Furthermore, if the source persists then the longer lived animal will go through more annual cycles of exposure than a shorter lived animal.

The individual vital rates such as age at maturity,fecundity, growth rate and longevity determine the probability that a species or population will persist in the environment. For harvested fishes they also determine the potential yield and fishing rate that can be applied. For example, fishes that grow slowly, mature late and are not fecund cannot withstand the same level of exploitation as species that have high growth rates, earlier age at maturity and greater fecundity. Information on these traits is key to resource management.

Finally, the pattern or trajectory of vital rates - the life history trajectory of Stearns (1992 - integrates all the events that happen during a fish's life. Growth reflects the evolutionary trade-off between energy applied to maintenance of the individual (respiration, repairing injuries, avoiding predators, etc), reproduction and the accumulation of size. The trajectory evolves in the environment to sustain the maximum fitness in the organism. In evolutionary terms, anthropogenic effects are experienced by the fish as a change in the environment that the trajectory is adapted to. For example, a contaminant may interfere with metabolism causing increased energy to be expended on maintenance and less on growth, fecundity and early maturation. Or it may directly interfere with the development of sex products resulting in a rapid decline in the population through recruitment failure. An increase in flow might require greater energy resources to be used, again resulting in reduced growth and an altered life history trajectory.

In this section I will summarize the available information on the life history trajectories of fish species in the Slave River.

5.2 Inconnu Vital Rates

Tripp et al. (1981) sampled only 26 fish spread over 3 years for age and therefore many age-groups were missing from their results. As well, their samples were taken mainly in the Slave River delta and could have included resting fish from other stocks in Great Slave Lake. McLeod et al. (1985) collected information on age and length but it had to be converted into usable form. Therefore this analysis follows that of Tallman et al. (1996b) and the translated data of McLeod et al. (1985).

Growth curves (Fig. 12) show that male and female inconnu grow at similar rates up to age six. After this age, growth of the males slows down relative to females. Comparing inconnu collected in 1994 (Tallman et al. 1996b) to those collected in 1983-84 (McLeod et al. 1985) there appears to be no trend in size at age in that inconnu do not appear to be generally getting larger or smaller at age presently, compared to the mid-1980's(Table 5) . Growth appears to be somewhat slower in the initial ages in Tallman et al.'s (1996b) data and faster in the older ages.

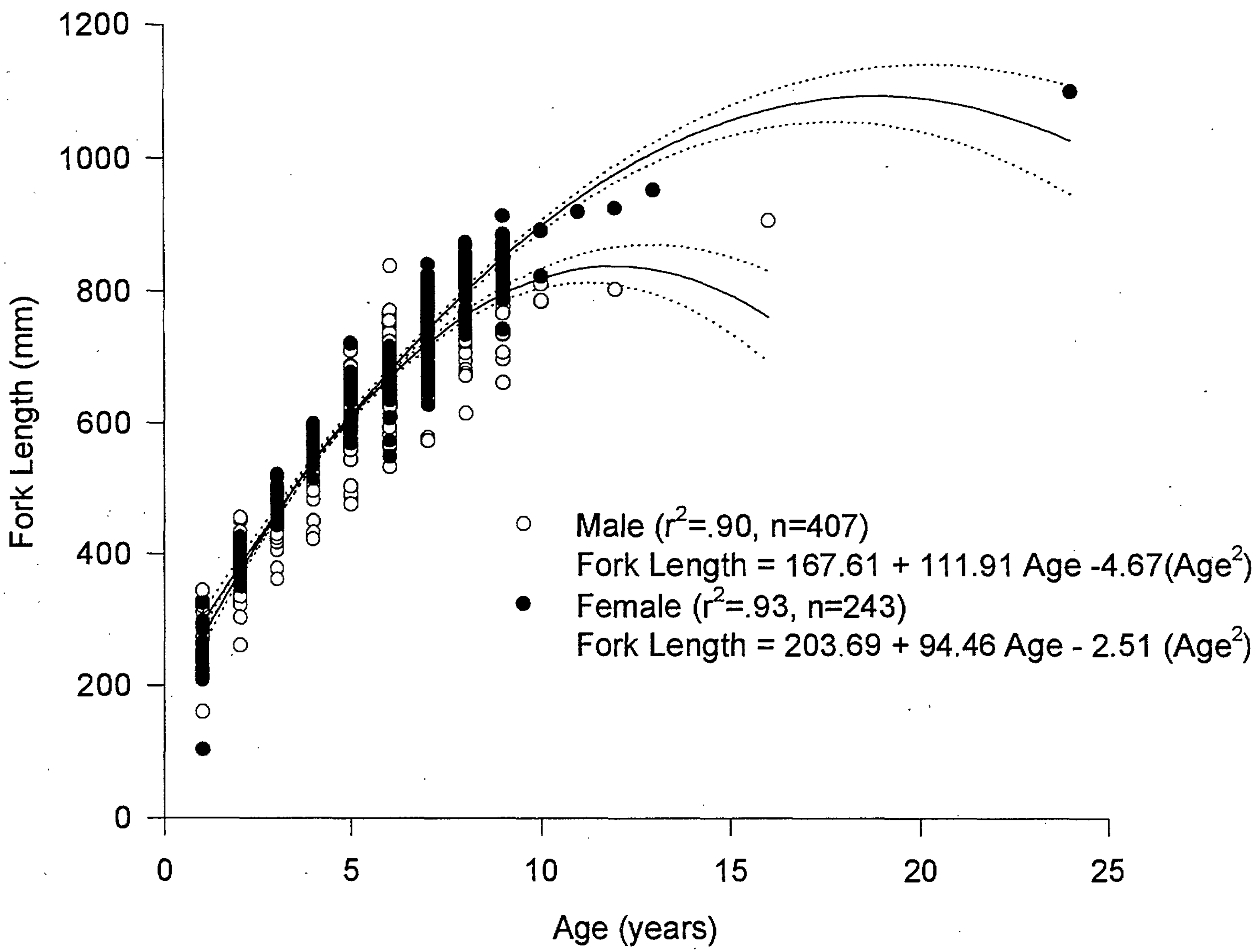

Fig. 12. Growth of inconnu collected from the Slave River in 1993 and 1994 (both original and back-calculated data are included in regressions).

Table 5. The mean length at age for inconnu in the Slave River and Delta recorded by McLeod et al. (1985) and Tallman et al. (1996b).

Age	Mean Length (mm)/N McLeod et al. (1985)		Mean Length (mm)/N Tallman et al. (1996b)	
1			240.5	11
2			394.1	11
3			485.5	11
4			559.5	12
5	659.2	5	628.3	17
6	716.8	10	659.7	17
7	763.7	13	753.5	45
8	820.6	28	816.0	59
9	856.5	2	828.1	52
10	808.5	13	857.3	4
11	876.5	19	919.0	1
12	940.7	17	924.0	1
13	938.5	2	952.0	1
14	1037.0	2		
15				
16				
24			1100.0	1

For northern fishes that do not spawn annually there is no straight forward way of determining age at maturity. For these types of populations the proportion of mature fish typically increases with age, peaking at an age determined by spawning frequency, age at first maturity and mortality (Morin *et al.* 1982). Tallman et al. (1996b) considered age at maturity to be the age at which mature fish first showed up in the spawning population. The distribution of ages for mature inconnu (Fig. 13) suggests that females mature later than males for this population. Males from the Slave River are recruited into the spawning population between ages 5 and 6, but are most abundant at age 7, while females first appear in the spawning population at age 7 and become most abundant at age 9.Fecundity of inconnu from the Slave River ranged from 68,015 to 182,959, eggs per female.

Fecundity tended to increase with body size (Fig. 14), but had no clear relationship with age (Fig. 15). Mean and standard deviation for age-specific fecundities are listed in the table below. Both mean fecundity and the variation around the mean increased with age.

Age	Mean Fecundity	Standard Deviation	Sample Size
7	108,086	+ 16,023	6
8	114,532	+ 22,760	10
9	124,473	+ 33,443	13

Diameter of fresh eggs for spawning inconnu in the lower Slave River (Appendix 3) increased from 1.6 mm in mid-August to 2.5 mm in mid-October just prior to spawning. Individual dry weight (g) increased from 1.5 mg in mid-August to 4.3 mg in mid-October. Both egg diameter and egg weight show a similar pattern of increase over the prespawning period, suggesting that both measures of egg size work equally well.

Age-frequency distributions of inconnu from the Slave River (Fig. 13) show that the spawning component of this population has a very narrow age distribution. The most abundant age classes of mature fish from the Slave River population were age groups 6 and 7, and 8 and 9, for males and females, respectively. Females appear to be longer-lived than males. Comparing to McLeod et al's (1985) data (see Table 12 above) there is a noticeable truncation of the age structure. Ages 11 and 12 are much less frequent than 10-11 years before.

5.2.1 Conclusions

For a freshwater Arctic species, inconnu have exceptionally high growth rates; Tallman et al.'s (1996b) results show that the Slave River population has one of the highest growth rates among inconnu populations in North America. Slave River inconnu also mature early relative to other populations (Scott and Crossman 1973). They are probably capable of doing so because of their high rate of growth which enables them to reach the required physiological size for sexual maturation earlier than other slower-growing populations.

Differences between the sexes in growth and age at maturity were observed for inconnu from the Slave River. Males are capable of becoming sexually mature at a smaller size and younger age (age 5 to 6) than females. This difference in age at maturity is probably responsible for the divergence in growth rates of males and females at around age six. Fish are indeterminate growers, so once sexual maturity is reached, energy is diverted towards reproduction and growth slows down. Because females mature later than males they continue to grow at the faster rate for a longer period of time than males.

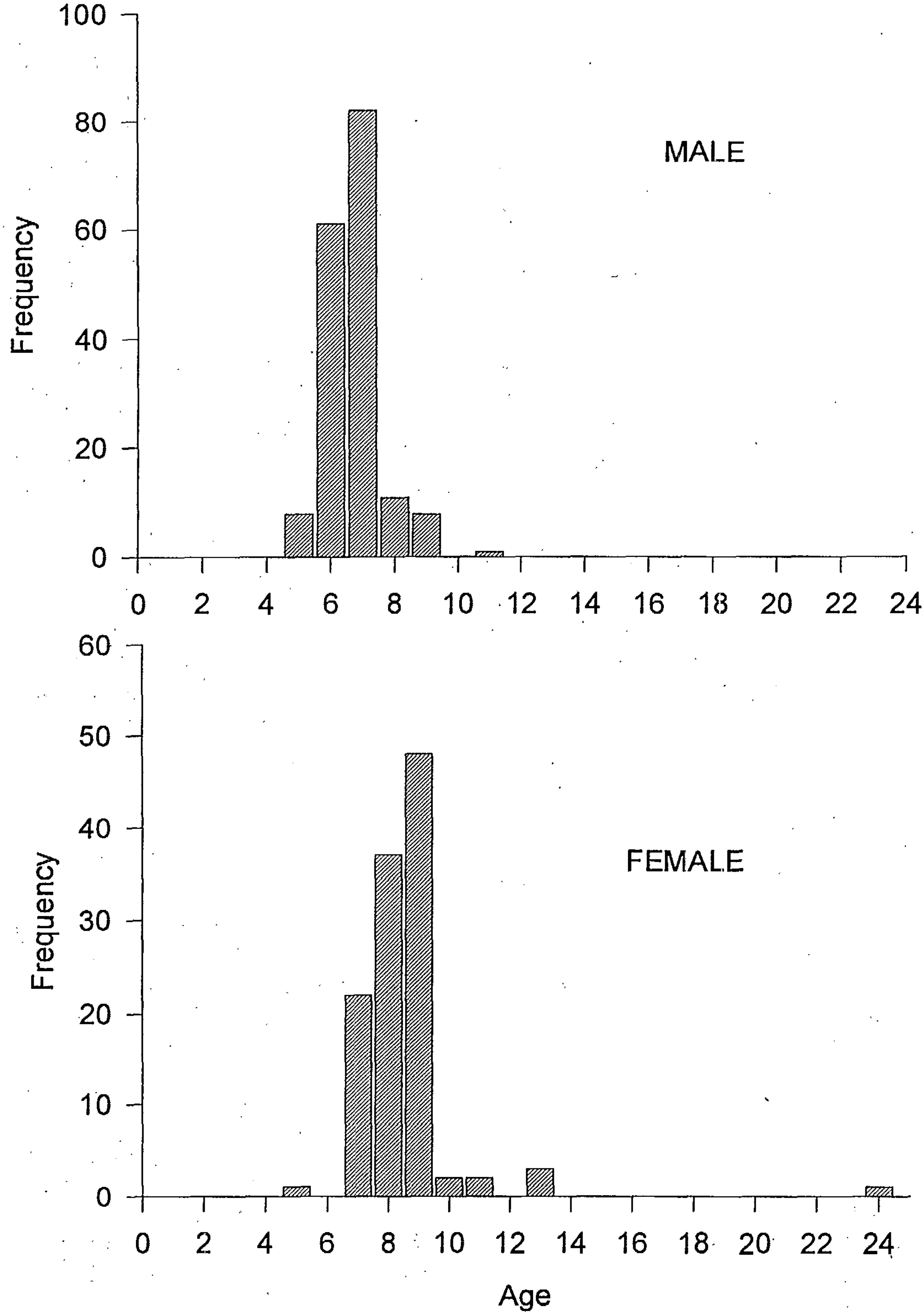

Fig. 13. Age frequency distributions for mature inconnu collected from the Slave River during 1994.

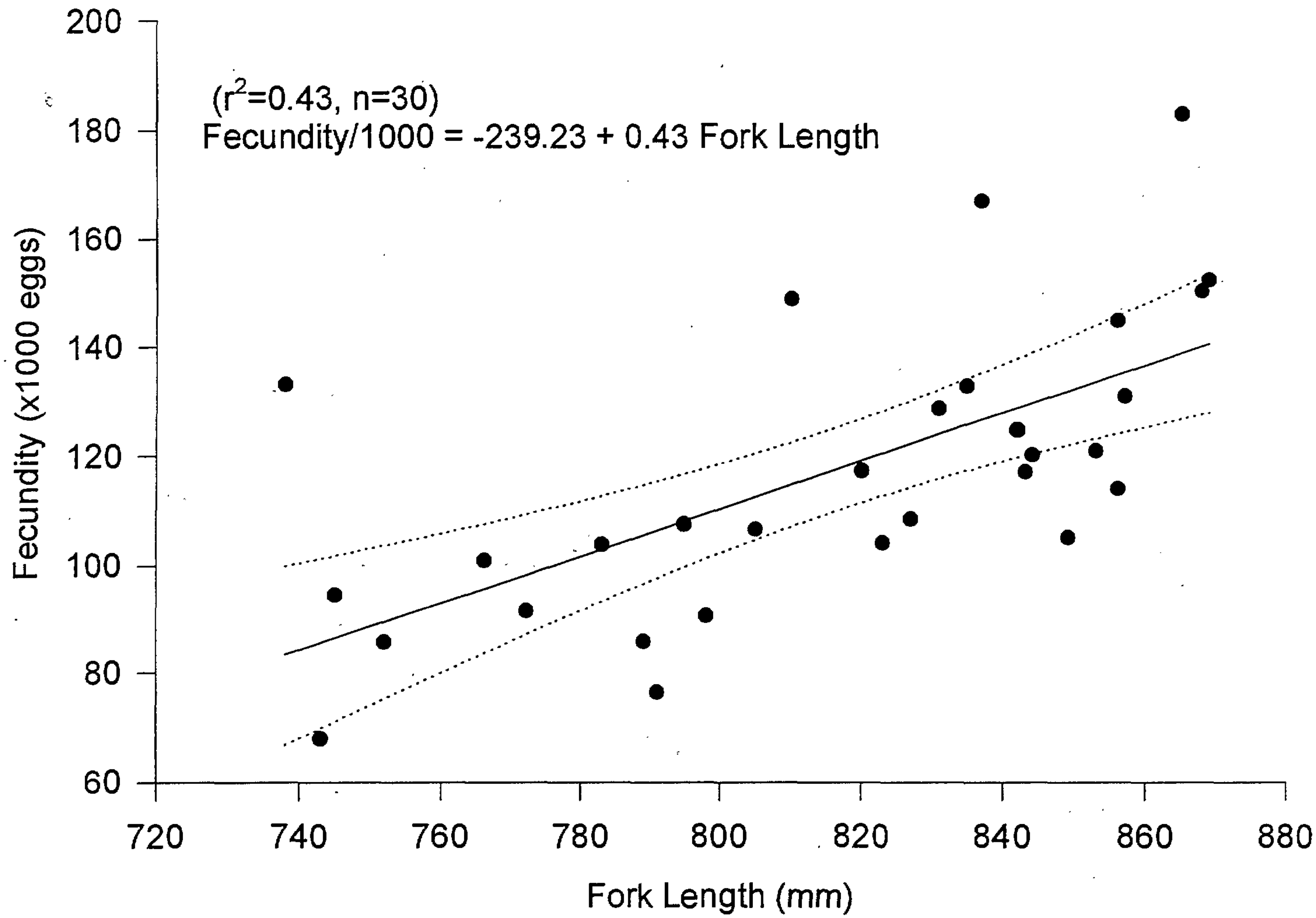

Fig. 14. Size specific fecundity of inconnu collected in the Slave River during 1994.

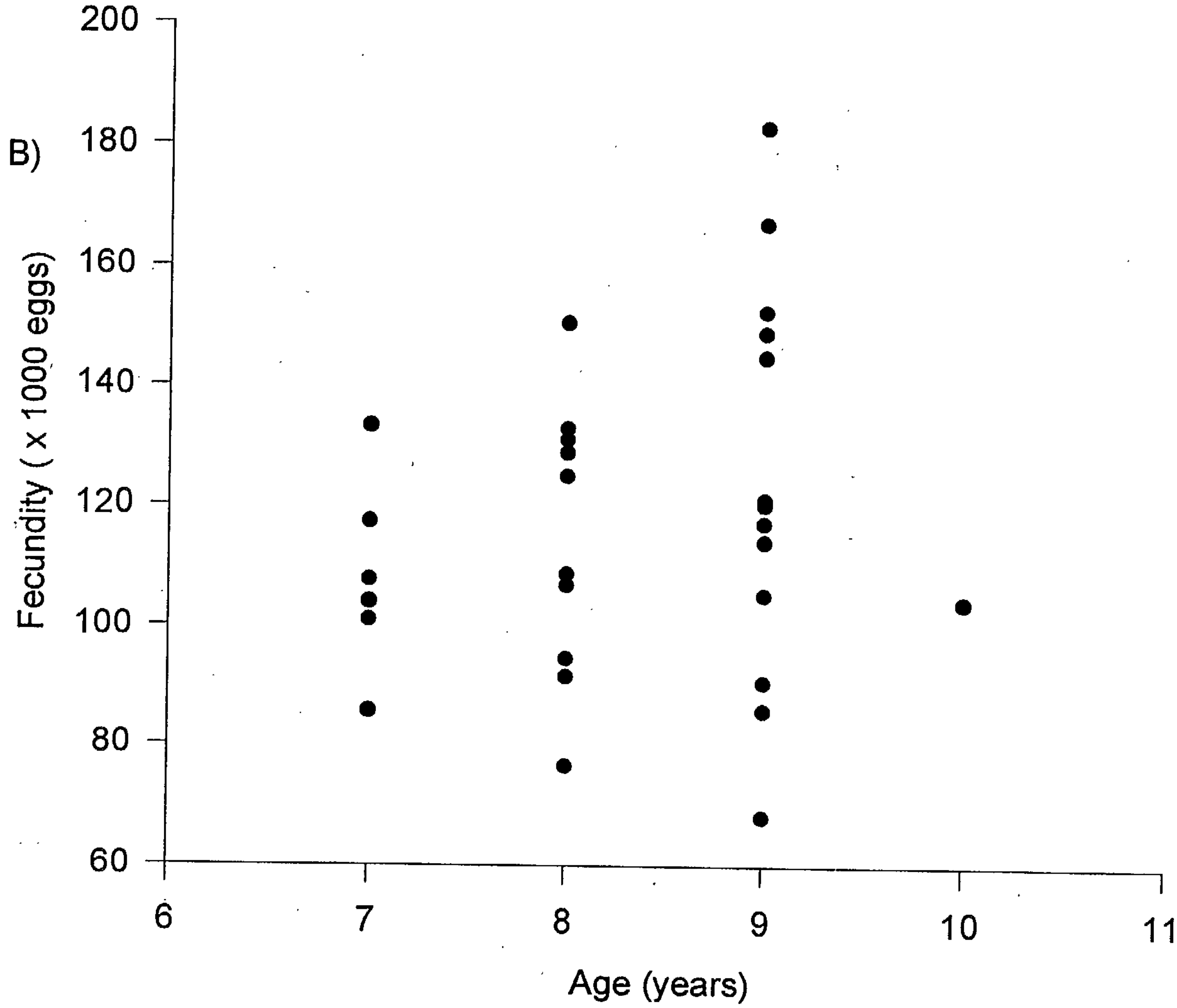

Fig. 15. Age specific fecundity of inconnu collected in the Slave River during 1994.

Inconnu, like other members of the coregonid family, are quite fecund, producing large numbers of small eggs. Nearly all of their reproductive effort is put into production of sexual products and the migration to spawning sites, unlike other species of fish that may produce fewer but larger eggs and invest more energy in care of their eggs and/or young. Fecundity of inconnu in the Slave River population is variable, but well within the range of fecundities reported for populations of inconnu in other locations such as Siberia (Nikol'skii 1954),Alaska (Alt 1977; Geiger 1969) and the Lower Mackenzie River (Howland and Tallman, unpublished). Egg sizes were also similar to those found for inconnu from Alaska (Geiger 1969) and the Lower Mackenzie (Howland and Tallman, unpublished).

Compared with other populations in the Canadian Arctic, inconnu from Slave River have a very narrow age structure (Scott and Crossman 1973). This is partly because we only sampled the spawning component of the population, but mainly a result of the short life span of individuals in this population - there are very few fish over the age of nine in the Slave River.

The most notable life history trait of the Slave River inconnu population is the extremely high growth rates and the consequently short life cycle (early maturation/short lifespan). Why does the Slave River population grow faster than other North American populations?
1) Latitude - the Slave River population is located further South than most other populations and may therefore have a longer growing season. This may have a particularly strong influence on juvenile growth which is highly temperature dependent.
2) Exploitation - Growth tends to increase with exploitation because remaining fish in the population are at lower densities and therefore have more resources available to them (Healey 1975). Inconnu in the Slave River have been subjected to both commercial and domestic fishing pressure for at least the last 50 years and as a result their life history characteristics may be changing
Inconnu in the Lower Slave River are characterized by a low age-at-maturity and rapid growth, with females maturing later and reaching a larger size at maturity than males. The inconnu population age structure is relatively narrow and young, while fecundity and egg size are comparable to other populations of inconnu for which these life history traits have been analyzed.

5.3 Burbot Vital Rates
Tripp et al. (1981) sampled 152 burbot from the Slave River delta for age and length. McLeod et al. (1985) sampled 69 burbot. Tallman et al. (1996b) also sampled in 1994. A comparison between the three studies is shown in table 6. The data of Tallman et al. (1996b) show much less of a change in size with age compared to Tripp et al. (1981) or McLeod et al. (1985).

Table 6. The mean length at age for burbot in the Slave River and Delta recorded by Tripp et. al. (1981), McLeod et al. (1985) and Tallman et al. (1996b).

Age	Mean Length (mm)/N Tripp et al. (1981)		Mean Length (mm)/N McLeod et al. (1985)		Mean Length (mm)/N Tallman et al. (1996b)	
1						
2						
3	223.7	1				
4	311.1	7				
5	358.9	22	327.0	5	560.0	2
6	406.1	27	411.0	1		
7	458.6	5	469.0	10	515.2	3
8	475.3	3	532.0	17	548.6	10
9	506.7	6	589.0	19	550.3	14
10	541.4	5	647.0	9	581.5	10
11	529.2	4	686.0	2	598.9	8
12	568.0	1	726.0	3	619.2	14
13	597.7	1	740.0	2	652.2	10
14	600.0	2	760.0	1	644.0	3
15					653.0	2
16						
17						
18	758.0	1				
19					733.5	3
20					608.0	6
21						
22						
23						

Burbot increase in length at age in a nearly linear manner(Table 13). For example, at age 8 the fork length ranges between 350 and 620 mm; age 13 between 470 and 730mm and age 20 between 650 to 870mm. The lower Slave River burbot appear to live longer and attain a larger individual size than in other burbot populations (Scott and Crossman 1973). This is perhaps not surprising since the second largest burbot recorded in North America has come from Great Slave Lake (937mm) (Scott and Crossman 1973 - Hopky and Ratynski 1983 recorded the largest at 995 mm length from the Tuktoyaktuk Harbour).

In most burbot populations individuals reach sexual maturity at age 3 or 4 and thus the Slave River population appears to delay sexual maturity somewhat by maturing at age 5.

Fecundity of burbot from the Slave River ranged from 282,556 to 2,800,960 , eggs per female. Fecundity tended to increase with body size and with age. Mean and standard deviation for age-specific fecundities are listed in table 7 below. Both mean fecundity and the variation around the mean increased with age.

GSI by age showed a slight increase but the highest GSI's were recorded in the intermediate ages. It is uncertain whether this represents the real pattern of reproductive effort or simply the a seasonal pattern of maturation. According to Scott and Crossman (1973) egg number increases from about 45,600 in a 343mm female to 1,326,000 in a 643mm female. Given that a substantial portion of Slave River burbot are above 600mm we expect the mean fecundity to be quite high in this population.

In contrast to inconnu, age-frequency distributions of burbot from the Slave River (Fig. 16) show a broad age structure ranging from age 3 to 20. Moreover, the older ages are well represented in the age frequency distribution. The dominant age classes in our samples are ages 8, 9 and 12. Age 11 is curiously under-represented. Alternatively, age 12 may be over-represented.

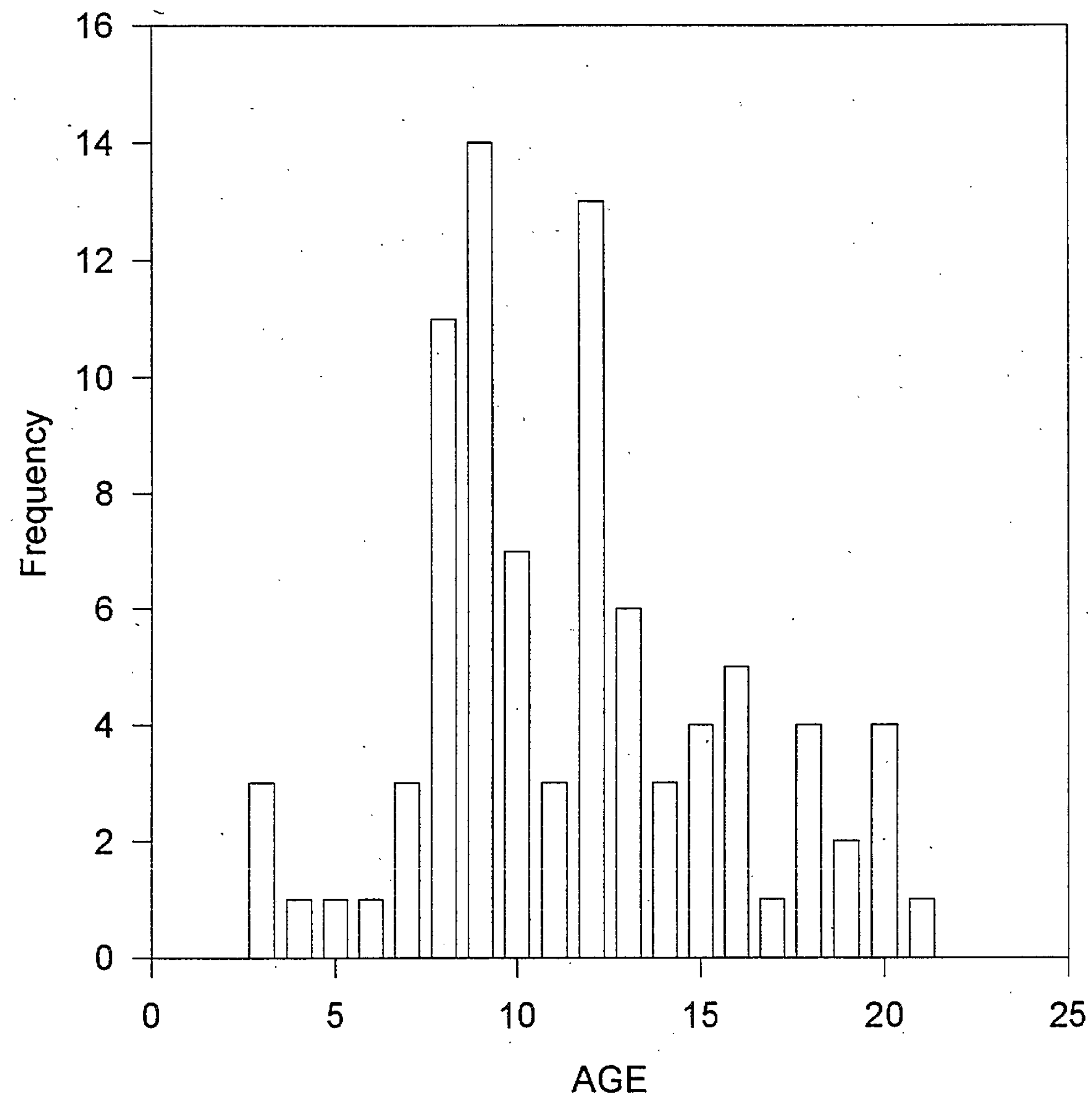

Figure 16. Frequency distribution of ages of burbot caught in the Slave River at Bell Rock, NWT.

Table 7. Fecundity of burbot collected from the Slave River in 1994.

Age	Sample Size	Mean Fecundity/Female	Standard Deviation
5-7	3	432689	49923
8-9	12	592994	300414
10-11	12	611083	353887
12-13	12	1176914	799535
14-20	8	1252151	544656

5.3.1 Conclusions

The Slave River burbot attain much older ages (up to age 21) than other populations. For example maximum ages from Manitoba and Ontario lakes typically range from 8 to 13 (Lawler 1963, McCrimmon and Devitt 1954, Clemens 1951). The broad age structure with strong age classes in the older ages suggests a relatively unexploited, unstressed population exists in the Slave River.

Growth appears to be slower than in some other systems. For example, Lake Simcoe burbot had reached an average total length of 837mm by age 13 (McCrimmon and Devitt 1954) whereas the average length of 13 year old burbot in our samples was around 600mm. On the other hand Heming Lake burbot were smaller at age 8 (465mm) than the Slave River burbot (490mm).

Burbot appear to have a relatively high age at maturity and grow more slowly compared to other populations. Burbot have a broad age frequency with many older ages and larger individuals represented.

5.4 Lake Whitefish Vital Rates

Lake whitefish in the Slave River grow more slowly than those in Great Slave Lake (Tripp et al. 1981) . Other river spawning populations in the region such as the Athabasca River and the Mackenzie River also show higher growth rates than the Slave River population (Tripp et al. 1981, Jones et al. 1978, Tripp and McCart 1980, Table 8).

Table 8. The mean length at age for lake whitefish in the Slave River and Delta recorded by Tripp et. al. (1981).

Age	Mean Length (mm)/N Tripp et al. (1981)	McLeod et al. (1985)
0	116.0 3	
1	106.0 1	
2	153.0 2	
3	182.4 10	
4	223.0 4	264.0 3
5	272.6 8	286.0 3
6	290.2 8	347.8 4
7	312.3 4	362.0 4
8	355.6 7	383.3 10
9	367.8 24	380.2 9
10	388.8 18	383.7 10
11	396.8 17	400.8 12
12	423.0 5	423.3 8
13	426.8 6	431.3 10
14	399.0 1	432.4 5
22	503.0 1	
23		

Tripp et al.'s (1981) data show that 50% of lake whitefish in the Slave River mature between the ages of 6 and 7.

Tripp et al. (1981) provides information on fecundity and egg size from 12 lake whitefish from the Slave River and Slave River delta. The mean age of the fish was 10.3 years. Mean fecundity was 23221 eggs per female with a range from 10643 to 36844. The average egg size ranged from 1.9 to 2.0 mm with a mean of 2.0 mm.

Lake whitefish in the Slave River range mainly from age 4 to 14 (Tripp et al. 1981, McLeod et al. 1985). It is possible that there are juveniles less than age 4, which were unavailable to the gear, rearing in the Salt River. The dominant age groups in the spawning population were ages 8-12. Although, growth rates were somewhat lower the number of age groups was similar to most lake whitefish populations in the region (Tripp et al. 1981)

5.4.1 Conclusions

The lake whitefish population in the Slave River has a slightly lower growth rate than other populations near Great Slave Lake. Otherwise, the population appears to be typical in many respects. The age range from 1-14 is similar to populations described by Scott and Crossman (1973) from more southern areas. Population fecundity is lower than most whitefish populations in the south which may have average fecundities ranging from 24000 to 80000 eggs/female (Scott and Crossman 1973). Thus, the lake whitefish population is probably not stressed by over-fishing or other perturbations but it likely does not have as great a potential sustainable yield as populations
to the south.

5.5 Lake Cisco Vital Rates

Tripp et al. (1981) found that there were two forms of "lake cisco" in the Slave River. The "white-finned form" ranged from 100 to 189 mm in length with most falling into the 130-149 mm range while the "black-finned form" ranged from 130 to 279 mm length with most falling into the 220 to 239 mm range. However, the combined growth curve was a relatively smooth uninterrupted line (Tripp et al. 1981). McLeod et al. (1985) also note that two size groups of cisco occurred in the Slave River Delta . Table 9 shows the relationship between size and age for both forms.

All of the ciscos sampled by Tripp et al. (1981) were mature. The white-finned form ranged from 1 to 11 years with most between 3 and 6 years of age. The black-finned form ranged from 4 to 13 years of age with most between 6 to 8 years. Therefore the white-finned form appears to have an earlier age at maturity than the black-finned.

Tripp et al. (1981) determined fecundities for 26 black-finned and 17 white-finned ciscos. Average fecundity for the black-finned form was 3843 eggs ranging from 708-10753 eggs per female. The gonad weight accounted for 11% of the total body weight.

The average fecundity of the white-finned form was 1357 eggs per female (range 506-2669). The total gonad weight accounted for 12.8% of the total body weight.

5.5.1 Conclusions

There appears to be two distinct forms of lake cisco utilizing the Slave River Delta. All aspects of the vital rates appear to be different with the white-finned form having lower fecundity, lower longevity, earlier age at maturity and slightly slower growth. It is uncertain whether these represent separate species or life history forms from the same species.

Table 9. The mean length at age for "lake cisco" in the Slave River Delta recorded by Tripp et. al. (1981).

Age	Mean Length (mm)/N white-finned		Mean Length (mm)/N black-finned		Mean Length (mm)/N combined	
1	104.0	1			104.0	1
2	112.0	3			112.0	3
3	124.8	43			124.8	43
4	139.9	52	151.5	13	142.2	65
5	149.5	18	159.6	11	153.3	29
6	151.4	20	184.7	32	171.9	52
7	162.0	7	200.0	51	195.4	58
8			211.7	56	211.7	56
9	166.0	1	227.3	13	222.9	14
10	173.0	1	257.8	6	245.7	7
11	170.0	1	254.2	5	240.2	6
12			254.5	2	254.5	2
13			273.0	1	273.0	1

5.6 Goldeye Vital Rates

Tripp et al. (1981) created an age-length key for goldeye from the Slave River Delta. Goldeye size age ranged from 64 mm at age 0 to 390 mm at age 18 (Ages ranged from 0 to 23 years). The data from Tripp et al. (1981) are shown in table 17. Compared to other goldeye populations, goldeye in the Slave River Delta grow more slowly and attain greater ages (Tripp et al. 1981). For example goldeye in Lake Claire reached only 10 to 13 years in age but attained a size of close to 350 mm by that point (Kristensen et al. 1976). In the Saskatchewan River Delta goldeye live to about age 12 and attain lengths over 350 mm (Kennedy and Sprules 1967). In contrast Tripp et al. (1981) recorded maximum ages of 23 years but average length at age 12 was only 337 mm

Tripp et al.'s (1981) data indicate that by age 3 over 50% of the males were mature. Females matured at age 5. However, Tripp et al. (1981) concluded that only a small percentage of goldeye were mature at age 5 and all were mature by age 9.

Tripp et al. (1981) made egg counts on eight goldeye from the Slave River Delta. Average fecundity of goldeye in the Slave River Delta ranged from 1999 to 16345 with a mean of 9205 eggs per female (Tripp et al. 1981). Average egg size was 1.6 mm and total gonad weight was 7.3% of the total body weight. There was a positive correlation between body size and egg number (Tripp et al. 1981).

Ages 0 to 23 were represented in the catch. The presence of the juveniles to age 0 suggest that the Delta may be important in rearing of goldeye. As stated before, the age range exceeds many other North American populations (Scott and Crossman 1973). Possibly this is an adaptation to the environmental uncertainty in the system. If goldeye are not able to reproduce each year or juvenile survivorship is erratic then a wider age range would allow for more population stability (Stearns 1992).

Table 10. The mean length at age for goldeye in the Slave River Delta recorded by Tripp et. al. (1981).

Age	Mean Length (mm)/N	
0	67.0	3
1		
2		
3	191.0	5
4	228.6	8
5	247.8	26
6	268.6	37
7	278.5	36
8	292.1	38
9	322.4	8
10		
11	337.0	3
12	330.3	4
13	373.0	1
14	335.5	2
15	335.0	1
16	369.5	2
17	361.0	3
18	380.6	5
19	367.0	1
20	381.0	1
21	373.3	3
22	368.0	1
23	350.0	1

5.6.1 Conclusions

Goldeye in the Slave River are characterized as slow growing, late maturing and long lived. As such, they may be more able to maintain an abundant population in the system with less inter-annual fluctuation. However, living to an old age may result in greater bio-concentration of contaminants. The lower growth rate may mean that the goldeye population would be slower to recover from heavy fishing than other populations.

5.7 Northern Pike Vital Rates

Tripp et al. (1981) recorded ages and length for pike in the Slave River Delta. Pike ranged from 0 to 15 years of age and from 134 to 998 mm in fork length. Few fish exceeded 8 years of age or a fork length of 670 mm. Tripp et al. (1981) noted that generally the oldest and largest fish were females although because of sample sizes no significant differences could be demonstrated. Pike in the Athabasca River grow at a faster rate than those in the Slave River Delta but do not attain as great an age or size (Bond 1980). Athabasca River fish only lived to age 7 and maximum sizes around 700 mm whereas the Slave River pike attained sizes of close to meter in length and lived to 15 years of age. On the other hand pike from the Kakisa River a tributary of Great Slave Lake lived to 17 years and grew more slowly than Slave River pike (Falk and Dalkhe 1975). The age-length data for pike are shown in Table 11.

Table 11. The mean length at age for northern pike in the Slave River Delta recorded by Tripp et. al. (1981).

Age	Mean Length (mm)/N	
0	152.0	11
1	221.9	19
2	272.3	27
3	394.5	21
4	439.4	25
5	514.6	23
6	553.9	29
7	610.7	25
8	646.9	19
9	723.0	7
10	710.7	6
11	804.3	7
12	823.3	4
13	782.0	2
14	936.0	1
15	994.0	3

Both males and females begin to mature at age 1 (Tripp et al. 1981). Most females are mature by age 3 and all are mature by age 8. Males are all mature by age 6.

Tripp et al. (1981) made egg counts on 18 pike ranging from 422-920 mm in fork length. Average fecundity was 41,589 eggs with a range from 7079 to 214600 eggs per female. Egg diameter averaged 1.4 mm. There was a positive correlation between body size and egg number (Tripp et al. 1981).

Ages 0 to 15 were represented in the catch. The presence of the juveniles to age 0 suggest that the Delta may be important in rearing of pike. Pike from the Slave River are somewhat older than the average in populations much further south (Scott and Crossman 1973). Their age structure appears to be in the middle range for the geographic area they are in.

5.7.1 Conclusions

Pike in the Slave River Delta appear to have a wide range of ages suggesting that they are not much affected by anthropogenic activities. However, because they are a long lived top predator they are vulnerable. The later age at maturity and generally larger size of the females make pike more vulnerable to depletion of the reproductive base through fishing. The Slave River Delta is an important area for all stages of pike from young-of the-year to the largest adults.

5.8 Flathead Chub Vital Rates

Flathead chub are rather low in the trophic chain and are unlikely to be consumed by people of the area. However, they are an important part of the biota of many large turbid rivers such as the Slave River. In spite of, or perhaps because of, this their biology is poorly known (Scott and Crossman 1973). Tripp et al. (1981) provided valuable data on their vital rates which is presented here.

Tripp et al. (1981) found that the length-frequency distribution of flathead chub to be distinctly bi-modal. They attributed this to the sampling methodology - chub from 250 to 299 mm were vulnerable to gillnets while most chub taken in minnow seines were under 50 mm. Based on 58 specimens Tripp et al. (1981) found that the age ranged from 4 to 14 and fork length from 133 mm to 315 mm. Presumably the 50 mm chub were fish < 4 years in age (probably young-of-the-year). Flathead chub grew rapidly from age 4 to age 8 and then seemed to reach an asymptotic value (Table 12). Growth was similar to that reported for flathead chub in the Athabasca River but was consistently faster than reported for the Mackenzie River (McCart et al. 1977, Tripp et al. 1981, Hatfield et al. 1972, Stein et al. 1973). The age-length data for flathead chub are shown in Table 12.

Females start to mature by age 5 and according to Tripp et al. (1981) spawn every year. Tripp et al. (1981) rarely encountered males and therefore gave no information on their age at maturity.

No information exists on the fecundity or egg size of flathead chub.

The age range of this species is quite broad for a cyprinid species and for a smaller species in the community. This does not appear to be unique to the Slave River population. It suggests that age specific mortality rates are low which is also unusual for a smaller species. Perhaps, predation pressure is low.

Table 12. The mean length at age for flathead chub in the Slave River Delta recorded by Tripp et. al. (1981).

Age	Mean Length (mm)/N gillnet catches	
0		
1		
2		
3		
4	181.7	3
5	198.0	2
6	242.3	3
7	247.5	6
8	277.3	9
9	288.6	9
10	285.8	12
11	302.7	4
12	314.0	3
13	303.7	4
14	299.0	3
15		

5.8.1 Conclusions

Flathead chub are interesting because they are one of the smaller species in the fish community and yet one of the largest representatives of their taxonomic family, the cyprinidae. Most smaller species have rather r-selected life histories but flathead chub mature relatively late and maintain a large number of age groups in the population for a cyprinid species. The population of the Slave River appears to be similar in this respect to other populations in the area. Interesting, also is the apparently strongly biased sex-ratio (towards females) observed by Tripp et al. (1981), McCart et al. (1977) in the Athabasca River and Hatfield et al. (1972) in the Mackenzie River. I am uncertain what this means. It could be that the males are substantially smaller than the females and therefore may have not been recruited to the gear used. On the other hand, perhaps the males occupy different environments than the females and have a somewhat different life cycle.

5.9 Longnose Sucker Vital Rates

Longnose sucker ranged in length from 105 to 574 mm in length and age from age 2 to 28 (Tripp et al. 1981). Few fish exceeded 16 years in age Table 13.

Females start to mature by age 8 and by age 12 all were mature (Tripp et al. 1981). Male mature earlier, the youngest reaching maturity at age 6 and all reaching maturity by age 10 (Tripp et al. 1981).

Mean fecundity was 47269 eggs per female (N=8) with a range between 23558 and 68545. Total gonad weight was 9.7% of the body weight.

Longnose suckers are long-lived in the Slave River (up to 28 years).

Table 13. The mean length at age for longnose sucker in the Slave River Delta recorded by Tripp et. al. (1981).

Age	Mean Length (mm)/N seine catches	
0		
1		
2	107.5	2
3	137.7	4
4	184.8	5
5	229.9	9
6	263.3	16
7	273.9	21
8	350.3	17
9	396.7	16
10	411.1	13
11	423.9	15
12	433.5	11
13	439.3	10
14	463.8	6
15	485.8	6
16		
17	512.7	3
18	500.5	2
19	478.7	3
20		
21	519.7	4
23	482.0	1
26	502.0	1
28	502.0	1

5.9.1 Conclusions

Longnose sucker have a wide range of ages in the Slave River Delta. They mature late and grow relatively slowly. They grow more slowly than longnose suckers in the Athabasca River (Bond 1974) up to age 8. They also grow more quickly than those in the upper Athabasca River (Tripp and McCart 1979).

5.10 Walleye Vital Rates

Walleye in the Slave River Delta ranged in fork length from 80 mm to 579 mm with most (80%) in the 280 to 479 mm fork length range. Three modal classes were present: 300 to 319 mm, 380 to 399 mm and 420 to 439 mm. There were no major differences in the length-frequency distribution of males and females, unlike those usually reported for more southerly populations where females typically predominate in the larger size classes (Scott and Crossman, 1973). Walleye ranged from 0 to 18 years of age and between 80 to 537 mm in fork length (table 14). Slave River walleye grew at similar rates to those in the Hay River a tributary of Great Slave Lake (Falk and Dalkhe 1975). Walleye growth in the Athabasca River and Lake Athabasca was faster than the Slave River walleye (McCart et al. 1977*, Bond and Berry 1980*).

According to Tripp et al. (1981) walleye in the Slave River Delta are slow to mature. Females start to mature by age 9 and by age 13 all were mature (Tripp et al. 1981). Male mature earlier, the youngest reaching maturity at age 6 and all reaching maturity by age 9 (Tripp et al. 1981). Tripp et al. (1981) proposed that once mature walleye spawn every year.
Tripp et al. (1981) counted eggs from only four walleye. Mean fecundity was 91615 eggs per female with a range between 69228 and 113414.

Walleye in the Slave River are long lived compared to other populations. For example, Athabasca Hay and Mackay River populations live to age 14 (McCart et al. 1977, Bond and Berry 1980, Falk and Dalkhe 1975) lived up to 12 to 14 years compared to the Slave River Delta population living to 18 years of age.

5.10.1 Conclusions

The wide range of ages in the Slave River suggest that little impact has occurred from anthropogenic sources. Walleye grow slowly and mature late compared to other populations and therefore could be slow to recover from disturbance in the system.

Table 14. The mean length at age for walleye in the Slave River Delta recorded by Tripp et. al. (1981).

Age	Mean Length (mm)/N	
0	95.4	7
1	145.5	4
2	201.2	6
3	260.6	15
4	263.9	37
5	279.1	21
6	339.7	14
7	358.7	30
8	385.4	23
9	413.1	13
10	436.1	15
11	445.3	9
12	450.9	14
13	446.7	9
14	463.1	7
15	467.0	6
16	483.0	7
17	519.0	1
18	454.5	2

5.11 General Conclusions on Vital Rates

Most fishes in the Slave River demonstrate life history trajectories that are within the norm for their species. Many species have broad age structures associated with fish populations that have not been impacted much by human activities. Some species worth monitoring are: inconnu because it possesses a narrow age structure suggesting that the population is already under stress, probably from exploitation pressure; flathead chub because it is a species that is especially adapted to large turbid rivers and is also sensitive to changes in water quality; goldeye due to its abundance and apparently unusually broad age structure compared to other conspecific populations.

6.0 Piscine food web

6.1 Community and food web

A biological community can often bounce back from a disruption and come back to its starting configuration (Krebs 1988). But if the disturbance is sufficiently drastic the community may shift to a new configuration. The configuration of a community is most clearly seen in its food web. The organisms in a community can be classified into producers, consumers and decomposers. It is important to understand that the work here will mainly consider the secondary consumers of the piscine food web. A complete understanding of the food web must account for all of these groups. Regardless, a great deal of understanding can be achieved by determining who eats whom.

Two major processes organize food webs: predation and competition. Community structure is a summation of many species interacting through competition and predation. Descriptions of food webs can be complex even if only the major species are described.

The complexity of food web analysis is even greater with fishes because fish have relatively indeterminate growth and may over the course of their life pass through several different trophic levels. For example, a walleye may start out feeding on microscopic plankton, pass on to feeding on zooplankton such as *Daphnia*, move on to macro-benthic invertebrates, then small fish, and finally end up as mainly a piscivore - the top predator in the system. Where does one place walleye in a description of the food web? For much of its existence it is not a top predator but its greatest influence on the community may be from this position. In many cases top predators in the food chain are themselves subject to predation from their prey species during an earlier part of their life cycle. Thus, fish food webs are highly complex and the loss of one species can have a ripple effect at many levels.

Another aspect of food web configurations is seasonality. Several critical factors are often overlooked in studies of northern fish food webs. Because northern fishes are often opportunistic and generalist in their food preferences and community composition can change dramatically over the course of the season fishes diet may dramatically change during the course of the year. Description of diet based on samples over only short time periods cannot account for the great changes in diet over the course of the season. Therefore trophic relationships can be obscured. Fish, also, have the capability to stop feeding for long periods of time. Often species will stop feeding during spawning migrations and/or during the spawning period. Thus, the influx into a river of large numbers of a predatory species, such as inconnu, during their spawning migration may have little or no impact on the trophic dynamics in the system. Another time when fish may cease or reduce feeding is during the winter period. On the other hand, some species such as burbot may become more active during the winter (Scott and Crossman 1973) .

Large river food webs have not been studied extensively in Arctic Canada. Synthesis of dietary information and analysis of the Slave River food web are generally absent from previous studies; particularly lacking are studies of seasonal variation in the diets among fish in the lower Slave River. Tripp et al. (1981) recorded gut contents on a number of species but provided no synthesis of this information, whereas McLeod *et al.* (1985) and Boag and Westworth (1993) did not examine trophic relationships. Therefore, during 1994, we proposed to investigate the seasonal variation in the diets among fish in the lower Slave River at all levels of the food web. The following sections are extracted mainly from the results of Tripp et al (1981) for the Slave River Delta and our work (Tallman et al 1996c).

6.2 Slave River Food Web

There is no standard methodology for the analysis of stomach contents. Because of this it is important that I present the methodology used by the main studies discussed.

6.2.1 Diet Analysis - Slave River

To analyze stomach contents Tallman et al. (1996c) removed and froze the complete digestive tract, from the oesophagus to the anus,within 3 h after capture. In the laboratory, stomach contents were sorted into taxonomic categories, weighed and measured. Mass, total lengths and maximum body depths were measured for fish prey items. The frequency of occurrence, and the percentage composition of prey categories by number and by mass of all prey taxa found in fish stomachs were calculated for each fish species to estimate the relative importance of those food taxa in a species' diet (Hyslop 1980). The Relative Importance Index (George & Hadley 1979) is essentially a mean of the three diet measures for each food category (Wallace 1981):

$$AI = \%\ \text{frequency occurrence} + \%\ \text{total numbers} + \%\ \text{total weight},$$

$$RI = 100\ AI / \sum_{1}^{n} AI$$

where n = the number of different food types,

% frequency of occurrence = the percentage of all stomach containing food in which each food category occurred.

% total numbers = the percentage that each food category contributed to the total number of food items in all stomachs.

% total weight = the percentage that each food category contributed to the total weight of food in the stomach.

For stomach contents containing only digested remains of fish prey, diagnostic hard bone structures such as otoliths and pharyngeal arches were used to identify ingested prey items where possible.
Food relationships between species were calculated using the dietary overlap index of Schoener (1974):

$$a = 1 - 0.5\ (\sum |p_{xi} - p_{yi}|)$$

where a_{xy} is the overlap between species y and species x; p_{yi} is the proportion of food taxa i in the diet of species y; p_{xi} is the proportion of food taxa i in the diet of species x. The index ranges from 0 (no overlap) to 1 (complete overlap); an index value of 0.3 or less indicates little overlap in the diets; an index value of 0.7 or more indicates a high degree of overlap (Keast, 1978).

6.2.2 Diets of Slave River Fish Species

6.2.2.1 Northern Pike

Stomach content analysis was determined for 290 northern pike stomachs in 1994 and 1995. Only 102 stomachs (42%) were found to contain prey items.

General Description of Northern Pike diet: Prey items found are listed in Table 15 (Table A2, Appendix 2). A total of 21 different prey items were documented, 14 of which were fish species (37.5% total), 4 invertebrate orders (3.3%) and 3 vertebrate species (1.2%). The most common fish found in the stomachs were ninespine stickleback (6.7%), northern pike (4.6%), flathead chub (3.0%), arctic lamprey (3.0%), burbot (3.0%) and lake whitefish (3.0%) based on percent by absolute numbers of all prey items found in the diet (Figure 17). Prey items were also ranked by percent by weight and percent by frequency of occurrence. The Relative Importance Index (George & Hadley, 1979) was calculated for each prey item to reduce the biases of ranking by absolute numbers, by weight or by frequency of occurrence. The most important prey types as ranked by the Relative Importance Index were flathead chub, burbot, lake whitefish and northern pike, respectively .

The stomach content data was divided between the three sampling locations, the Slave Delta, the lower Slave River at Fort Smith and the Salt River (Figure 18). These 3 sampling locations were originally chosen since they represent three different types of habitat, and fish species composition varied among these sampling locations. For 1995, the Salt River had 15 different prey items found in northern pike stomachs, as compared to 10 prey items in the Slave River and 5 in the Slave Delta. The diets of northern pike caught in the Salt River had 9 different fish species, accounting for 46%, 3 invertebrate orders (9%), and 3 vertebrate species (3%). Ninespine sticklebacks and small lake whitefish were the most common prey items found. Of the northern pike caught in the Slave River, 8 of the 10 prey items found were fish species (38%) and 2 were invertebrate orders (3.5%). Arctic lamprey and flathead chub were by far the most common prey types found in adult pike stomachs from the Slave River near Fort Smith, accounting for 11.8% and 9.4% respectively. Results from the Slave Delta showed a total of 5 different prey types, 4 of which were fish (22%) and 1 vertebrate species, a rodent (2%). Burbot were the most common prey item eaten (8%), followed by lake whitefish (2%), lake cisco (2%) and lake chub (2%), while 76% of the stomachs analyzed were empty.

The stomach content data obtained for each of the 3 sampling locations, was divided into 2 seasonal time periods, May/June and July/ August (Figures 19 and 20). The significance of dividing the data in this manner, is that there are different species present in relatively higher abundance at different times of the year depending on their life histories and prey items found northern pike diets seem to be linked to the abundance and availability of prey in the environment (Christiansen, 1976; Scott and Crossman, 1973). Stomach contents of northern pike caught in the Salt River during May and June (Figure 19) showed 7 different prey items; 3 fish species (17%), 2 invertebrate orders (15%) and 2 vertebrate species (5%). Damselfly larvae, amphipods and smaller northern pike were the most common prey items. Also note here that a YOY burbot was found in the stomach contents. For the Slave River, stomachs contained 7 different prey items, 5 of which were fish species (45%) and 2 were invertebrate orders (7%). Arctic lamprey and flathead chub were by far the dominant prey types, each comprising 17%. Twenty-eight stomach samples were analyzed from the Delta, 21 of which were empty. Prey items found were burbot, lake whitefish, lake cisco, lake chub and rodent remains.

For the July and August sampling period, 11 different prey items were found in the northern pike stomachs caught in the Salt River; 8 fish species (67%), 2 invertebrate orders (5%), and 1 vertebrate (2%). Ninespine sticklebacks, lake whitefish and burbot were the most common prey types. Also found in the stomach contents was a YOY lake whitefish.
The stomach content data for the Slave River in Figure 20 showed a decrease in arctic lamprey, flathead chub and goldeye and an increase in smaller northern pike and walleye compared to the May/June period (Figure 19). The diversity in diet composition of fish caught in the Slave River during July and August increased compared to the May/June stomach contents. However, fish species found in the diet accounted for 35% in July/August and in May/June fish prey accounted for 45%. Finally, Figure 21 illustrates the differences found between 2 assigned size-classes. The criterion for determining the different size-classes was based on the average length of prey found in the diet. Two different size-classes were chosen based on prey length, less than 400mm fork length (<400mm) and greater than and equal to 400mm fork length (>400mm). 22 samples were analyzed for the <400mm category. Lengths of prey (excluding the invertebrates) ranged from 26mm to 100mm. For the >400mm size-class, prey lengths ranged from 30mm(EMSH) to 363mm (LKWT); a snake with a total length of 930mm was found in a 545 mm northern pike. Prey length varied from 7% to 43% of total predator length. Both assigned size-classes had invertebrates present.

6.2.2.2 Walleye

Stomach contents were determined for 197 walleye in 1994 and 1995. Only 59 stomachs (38%) were found to contain prey items. Walleye were noted to occasionally regurgitate their stomach contents when caught in gillnets.

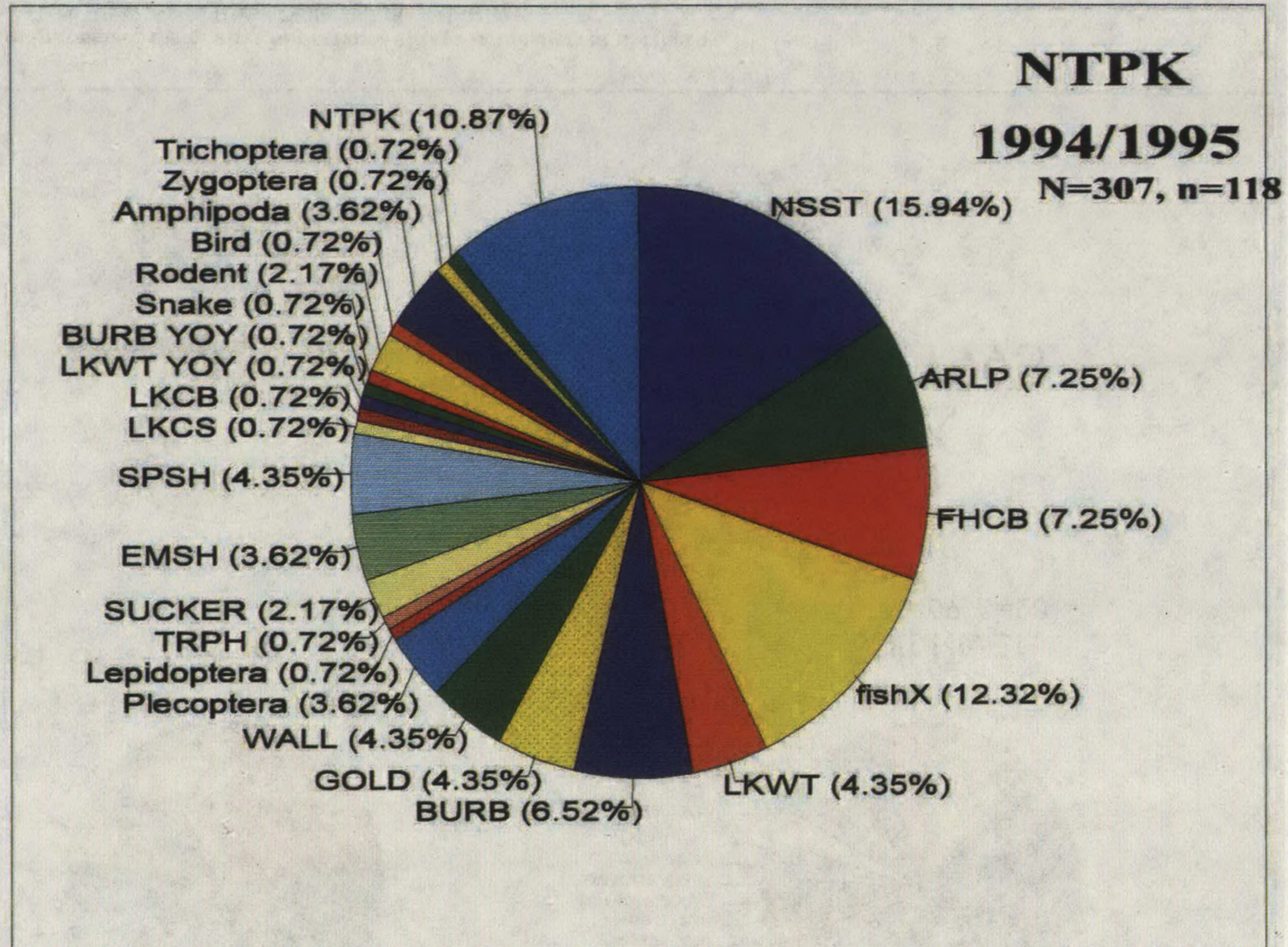

Figure 17 Pie chart showing the relative importance values of taxa in diet of northern pike from the lower Slave River.

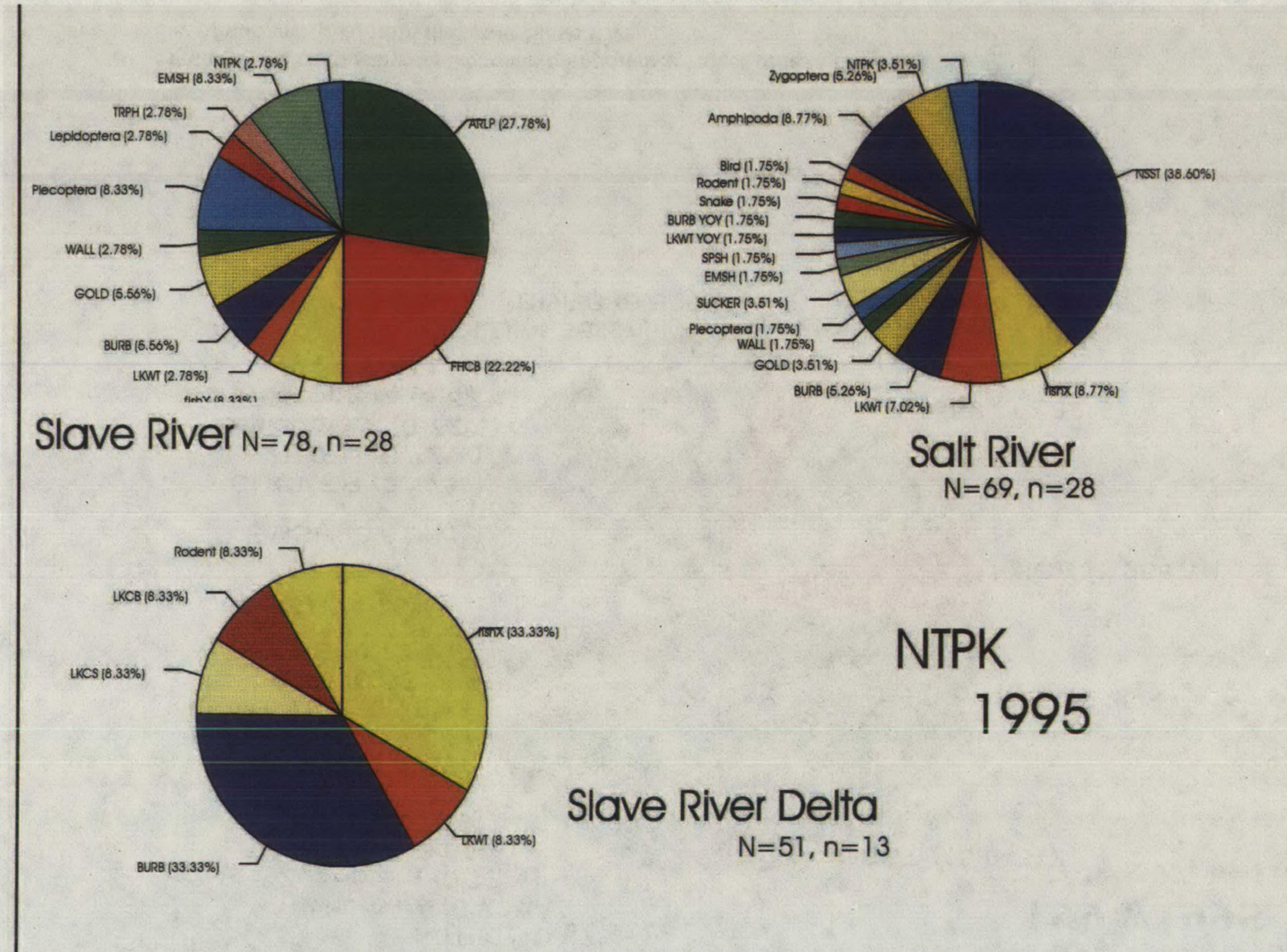

Figure 18. Comparison of the relative importance of taxa in the diets of northern pike from the Slave River, Slave River Delta and the Salt River.

Table 15. Prey items found in stomach contents of fish in the lower Slave River, NWT from Tallman et al. (1996c)

Prey Items	NTPK	WALL	INCO	BRBT	LKWT	GOLD	FHCB	LNSK*	WTSK*
FHCB	X	X	X						
NTPK	X	X	X						
ARLP	X	X							
BRBT	X								
LKWT	X		X	X					
GOLD	X			X					
NSST	X	X			X				
WALL	X	X	X						
EMSH	X	X							
SPSH	X	X							
TRPH	X	X	X						
LKCB	X								
LKSC	X								
SUCKER	X	X	X						
Rodents	X					X			
Snakes	X								
Birds	X								
Amphipoda	X				X	X			
Gastropoda					X		X		
Ostracoda					X				
Ephemeroptera			X			X	X		
Odonata	X	X			X	X			
Plecoptera	X	X				X			
Trichoptera		X			X	X			
Coleoptera						X	X		
Dytiscidae		X				X	X		
Corixidae					X	X	X		
Orthoptera							X		
Hymenoptera		X	X				X	X	
Diptera									
Chironomidae						X	X	X	
Tabanidae					X				
Ceratopogonidae						X		X	
Vegetation					X				
Oligochaeta					X				
Nematoda						X			

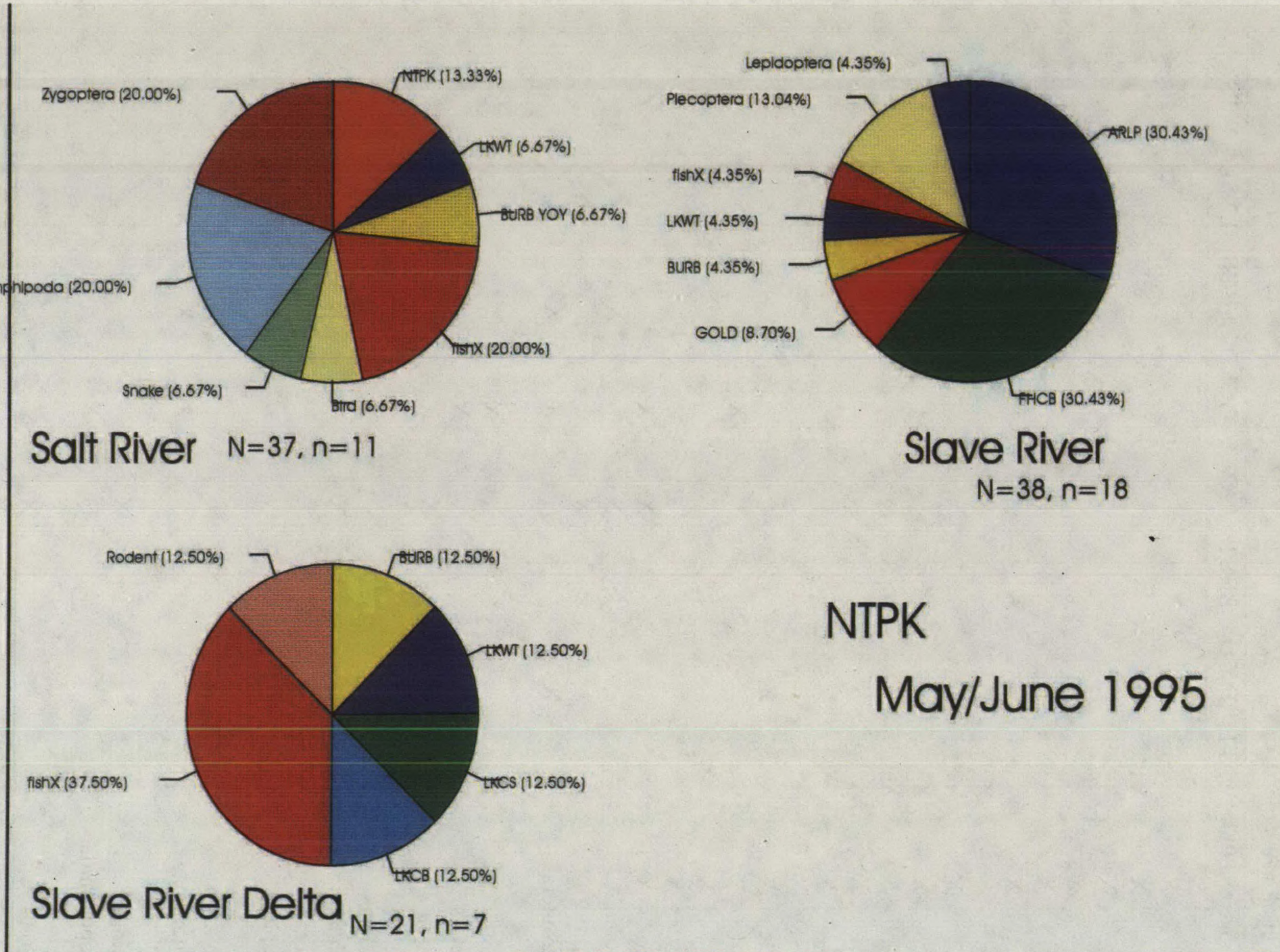

Figure 19. Relative importance of taxa in the diet of northern pike in the Slave River, Slave River Delta, and Salt River during May and June, 1995.

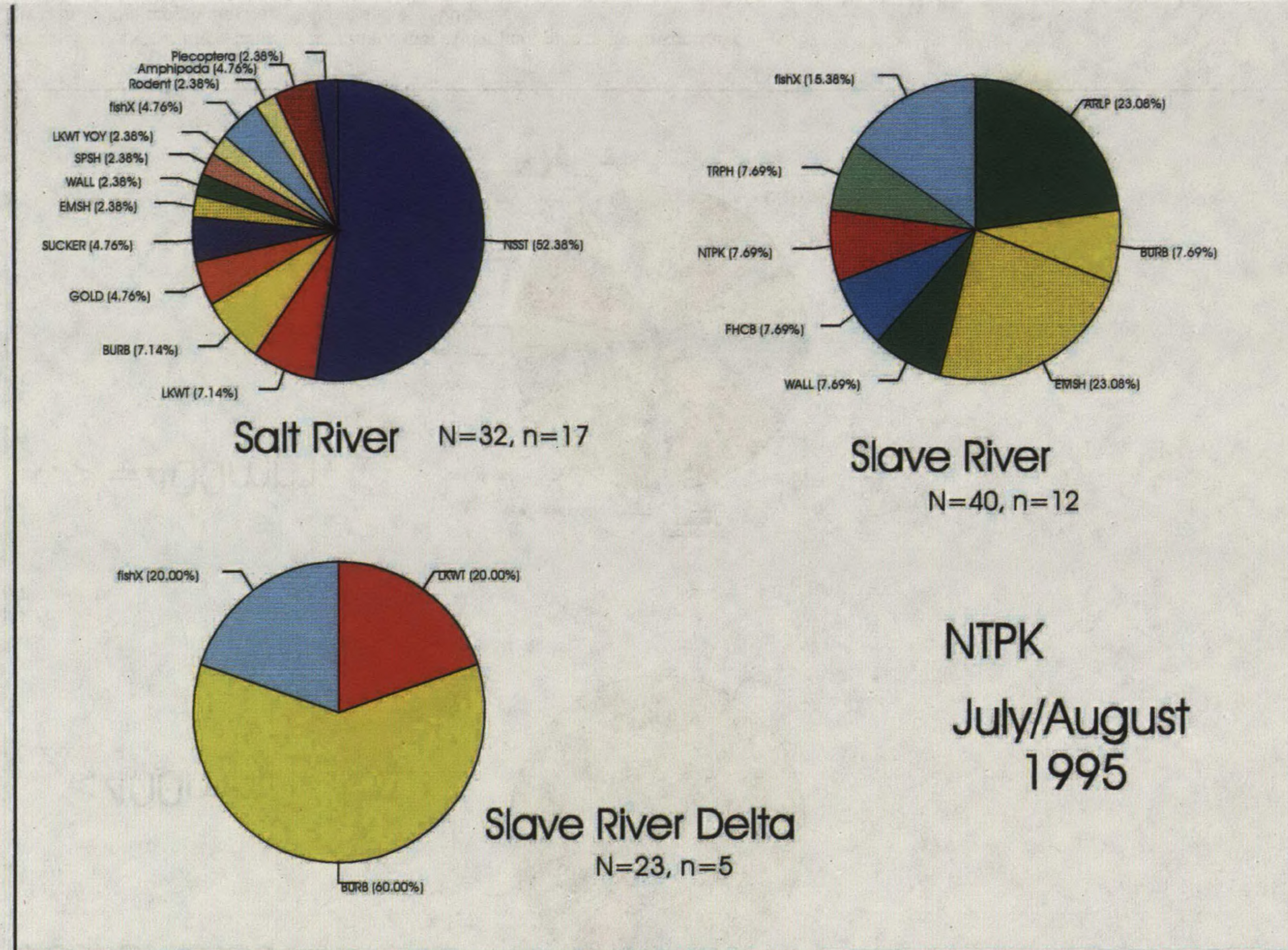

Figure 20 Relative importance of taxa in the diet of northern pike in the Slave River, Slave River Delta, and Salt River in the July and August, 1995.

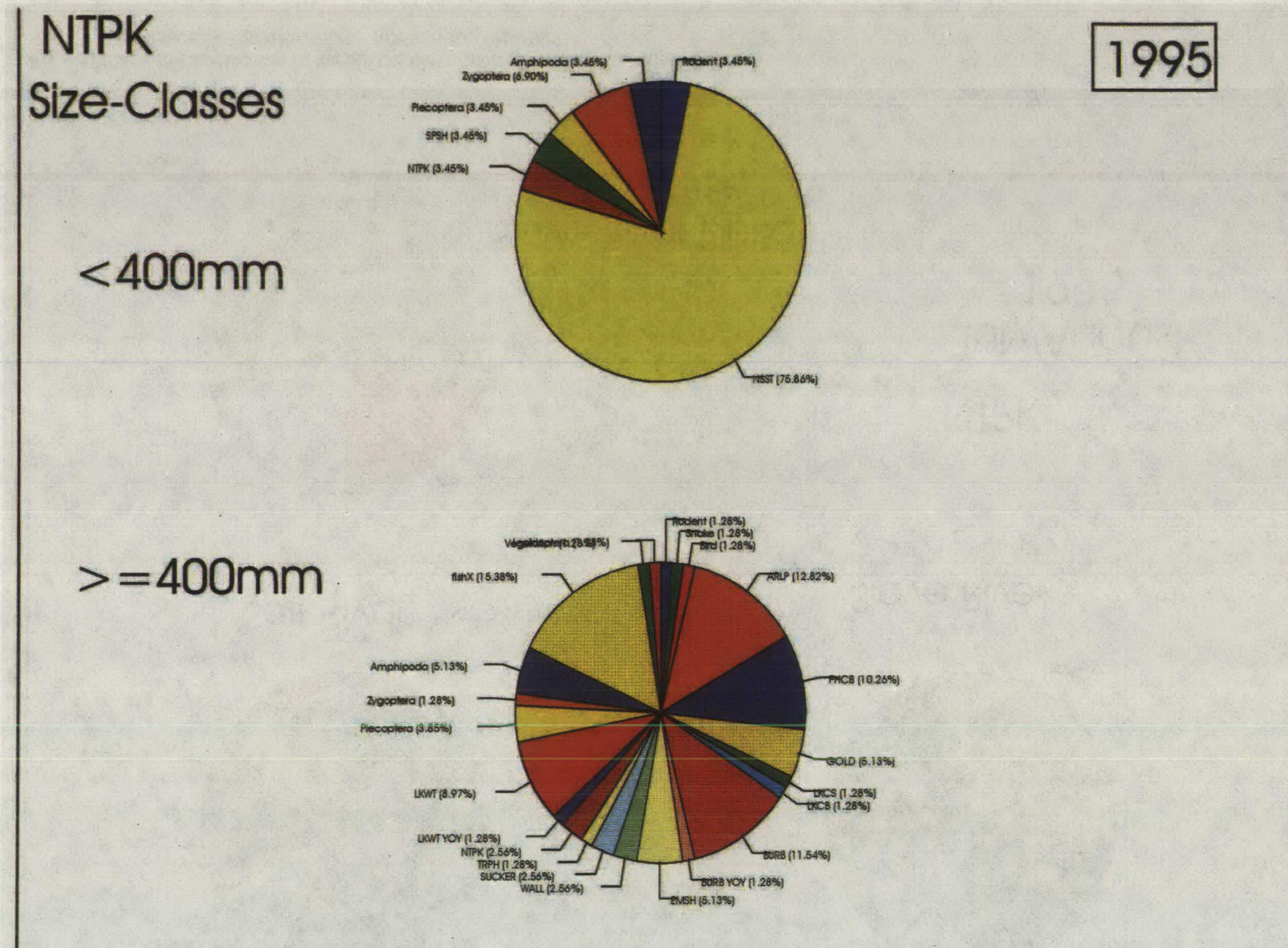

Figure 21. Relative importance of taxa in the diet of northern pike in the lower Slave River in 1995 - length classes < 400mm and >= 400mm.

General Description of Walleye diet: Prey items found are listed in Table 15. A total of 14 different prey items were documented, 8 of which were fish species and 6 were invertebrate categories (12%). The most common fish prey types were northern pike (5%), walleye (3%) and longnose sucker (3%) based on percent by absolute numbers of prey items found in the diet (Figure 22); using absolute numbers may over-emphasize the importance of invertebrates since more invertebrates can be consumed at a given time.. Prey items were also ranked by percent by weight and percent by frequency of occurrence in Table B2 (Appendix 2). The Relative Importance Index (George & Hadley, 1979) was calculated for each prey item to reduce the biases of ranking by absolute numbers, by weight or by frequency of occurrence. The most important prey types as ranked by the Relative Importance Index were northern pike, arctic lamprey, plecopterans and ephemeropterans, respectively. Aquatic invertebrates were found in walleye of a wide range of lengths, the largest being a 372mm fish.

The stomach content data obtained for each of the 3 sampling locations was divided into 2 seasonal time periods, May/June and July/August . The Salt River during May/June had 7 different prey items present, 2 of which were fish (9%). Plecopterans were the most commonly eaten prey item, accounting for 13% of total stomach contents. Walleye caught in the Salt River during July and August ate mostly fish prey (69%). For the walleye caught in the Slave River, the diversity of prey items was much lower in May/June compared to the July/August sampling period. Northern pike were the most common prey type in the July/August sampling period, accounting for 8% of the stomachs dissected. (for discussion: spawning, little feeding in May/early June). During the June sampling in the Slave Delta, only 4 walleye were caught, all with empty stomachs.

6.2.2.3 Inconnu

Stomach content analysis was determined for 110 inconnu stomachs in 1994 and 1995. Only 26 stomachs (24%) were found to contain prey items.

General Description of Inconnu diet: Prey items found are shown in Figure 23. A total of 6 fish species were documented in the stomach contents; northern pike, trout-perch, longnose sucker, flathead chub, walleye and lake whitefish. The Relative Importance Index was calculated only for those prey items from which a suitable weight could be obtained. The results from the Relative Importance Index by George and Hadley, 1979 is shown below in Table C2 (Appendix 2). Trout-perch were ranked first, followed by northern pike, then longnose suckers. Although flathead chub, lake whitefish and walleye could not be included in this ranking, the resulting ranking shown in Figure 23 would be the most appropriate order of importance, regardless.

6.2.2.4 Burbot

Stomach content analysis was determined for 65 burbot stomachs in 1994 and 1995. I have divided the burbot stomach content data into 2 categories, those collected during the spawning season and those not collected during the spawning season.

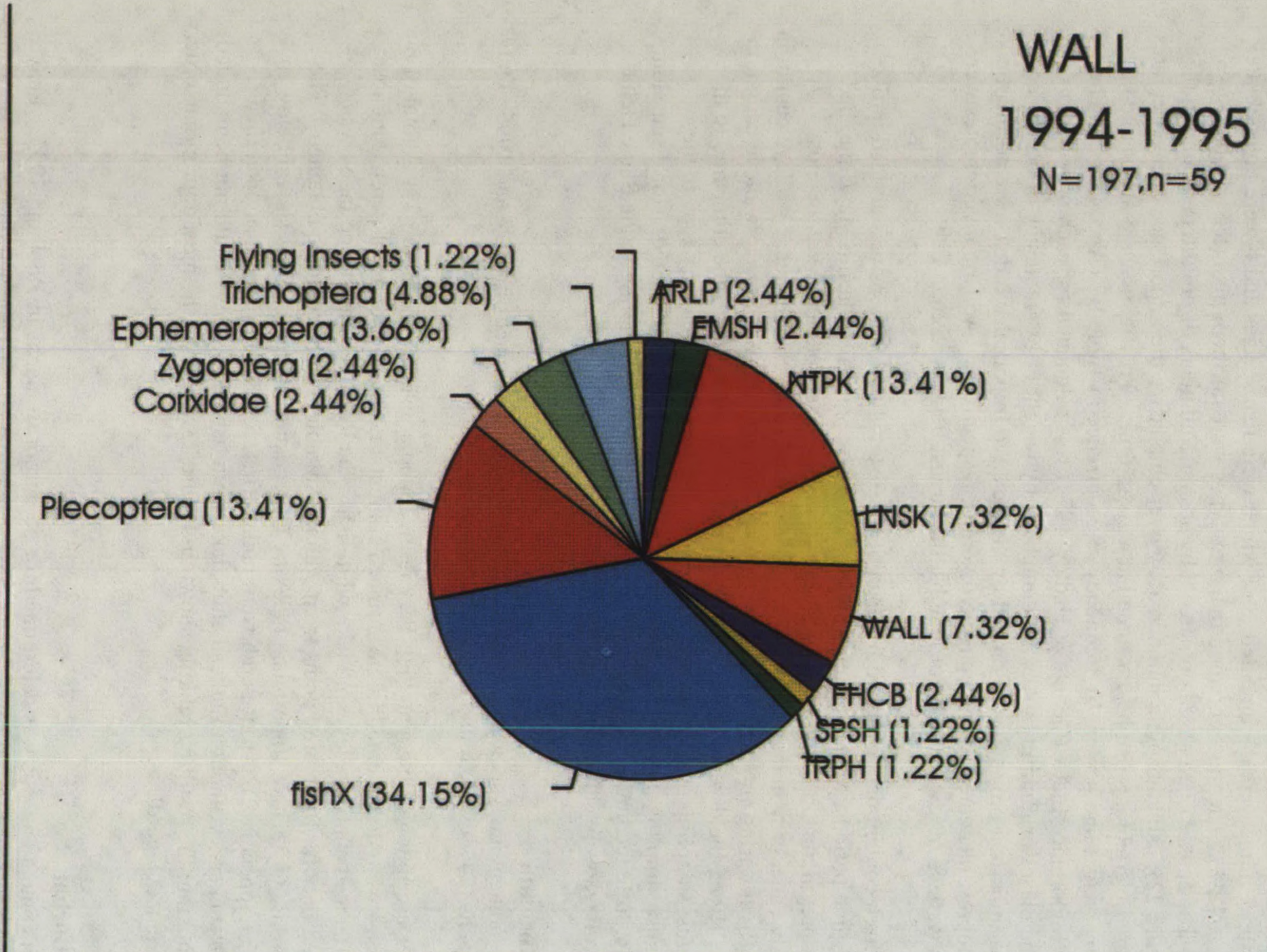

Figure 22. Relative importance of taxa in the diet of walleye in the lower Slave River during 1994 and 1995.

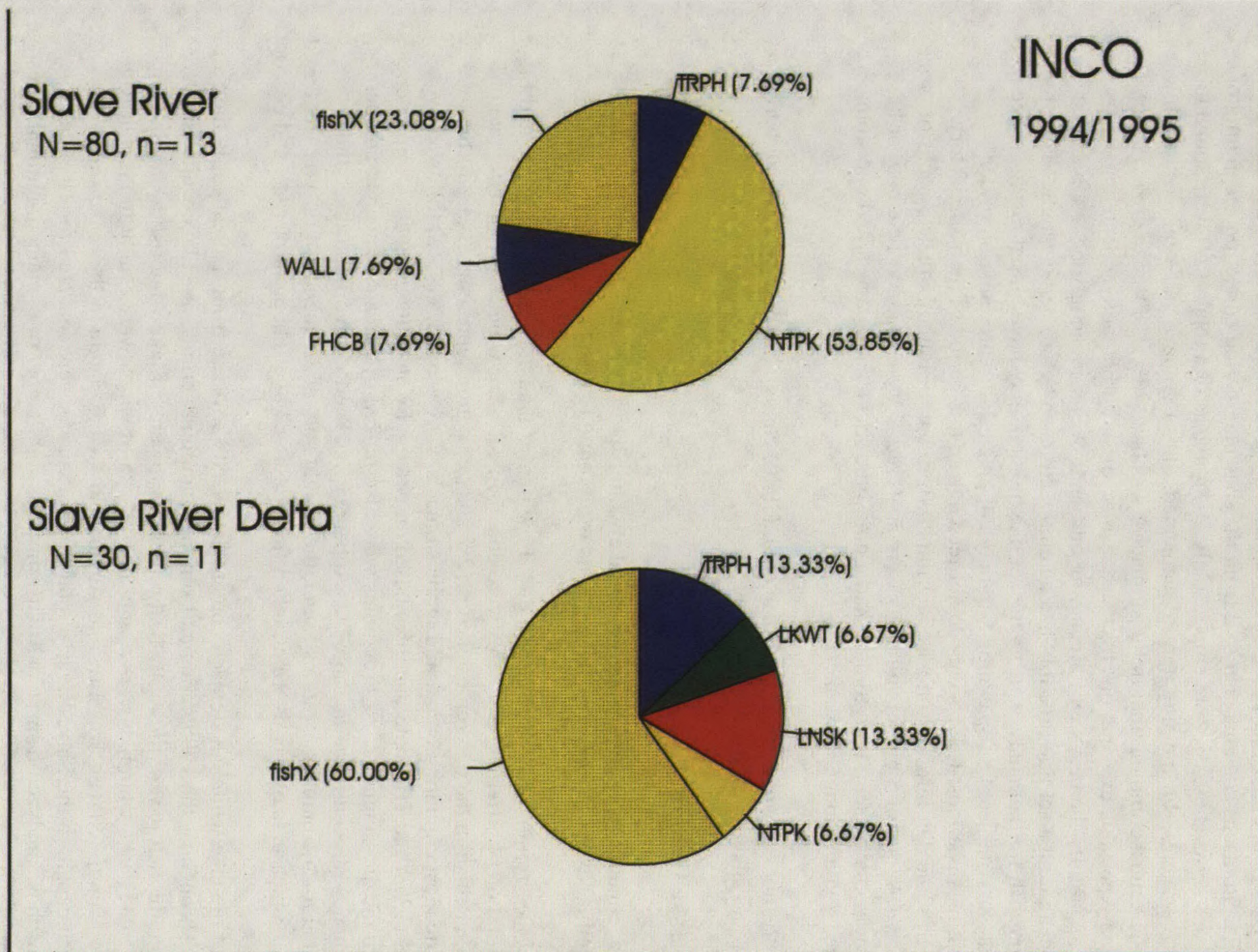

Figure 23. Relative importance of taxa in the diet of inconnu in the lower Slave River and Slave River Delta during 1994 and 1995.

General Description of Burbot diet: Prey items found are listed in Table 15 and shown in Figure 24. Stomachs contents analyzed from the spawning period collection (beginning of December), showed 69.5% were empty. Only 19 stomachs of a total of 60 were found to contain prey items. Of the prey items documented, only 1 goldeye and 1 lake whitefish was found. The most common item in the stomachs was bait (25%). Tallman et al (1996c) suggested 2 possible explanations for these results: first, burbot were collected using set lines. This is apparently the best way for catching burbot, however it can also be assumed that burbot caught on a set line probably had an empty stomach before being caught. Therefore, collecting fish for diet analysis using the set line method, may have biased results. Secondly, diet analysis completed on spawning fish may not give a full representation of diet composition since most fish species do not feed during this period of their life history. However, some diet information was determined from burbot found in the stomachs of other piscivores. A total of 5 burbot stomachs were analyzed; 3 were found to be empty or have digestive matter present; one stomach had a ninespine stickleback present and one stomach contained a young longnose sucker.

During the non-spawning period Tallman et al. (1996) captured only the occasional burbot and therefore no analysis of diet was performed.

6.2.2.5 Lake Whitefish

Stomach contents was determined for 69 lake whitefish in 1994 and 1995. 33 stomachs, representing 98.6% of total stomach contents were found to contain prey items.

General Description of Lake whitefish diet: Prey items found are listed in Table 15 and Figure 25. A total of 14 different prey items were documented, 12 of which were invertebrate orders (98% total); fish in the diet represented 0.12% and vegetation represented 0.3% of the total diet. The most common items found in the stomachs were ostracods (75%) followed by corixids (12%) and Trichopterans (6%) based on percent by absolute numbers of prey items found in the diet (Figure 25). Prey items were also ranked by percent by weight and percent by frequency of occurrence in Table D2 (Appendix 2). The Relative Importance Index accounted for the numbers of items found, the weight and the frequency of occurrence; based on those 3 measures ostracods were ranked first, followed by trichopteran larvae, and corixids.

Most of the lake whitefish stomach content data used above are from fish caught in the Salt River. Throughout the 1995 spring and summer sampling periods, most lake whitefish were caught in the Salt River. Figure 25 best represents the diet of lake whitefish in the Salt River. A total of 111 lake whitefish were caught in 1995, 85 of which were caught in the Salt River, 22 were from the Slave River near mid-August and 4 were caught in the Slave Delta. For lake whitefish caught in the Slave River, a total of 25 stomachs were analyzed for 1994 and 1995; 100% of those analyzed from mid-August onwards were empty or contained minimal digestive matter.

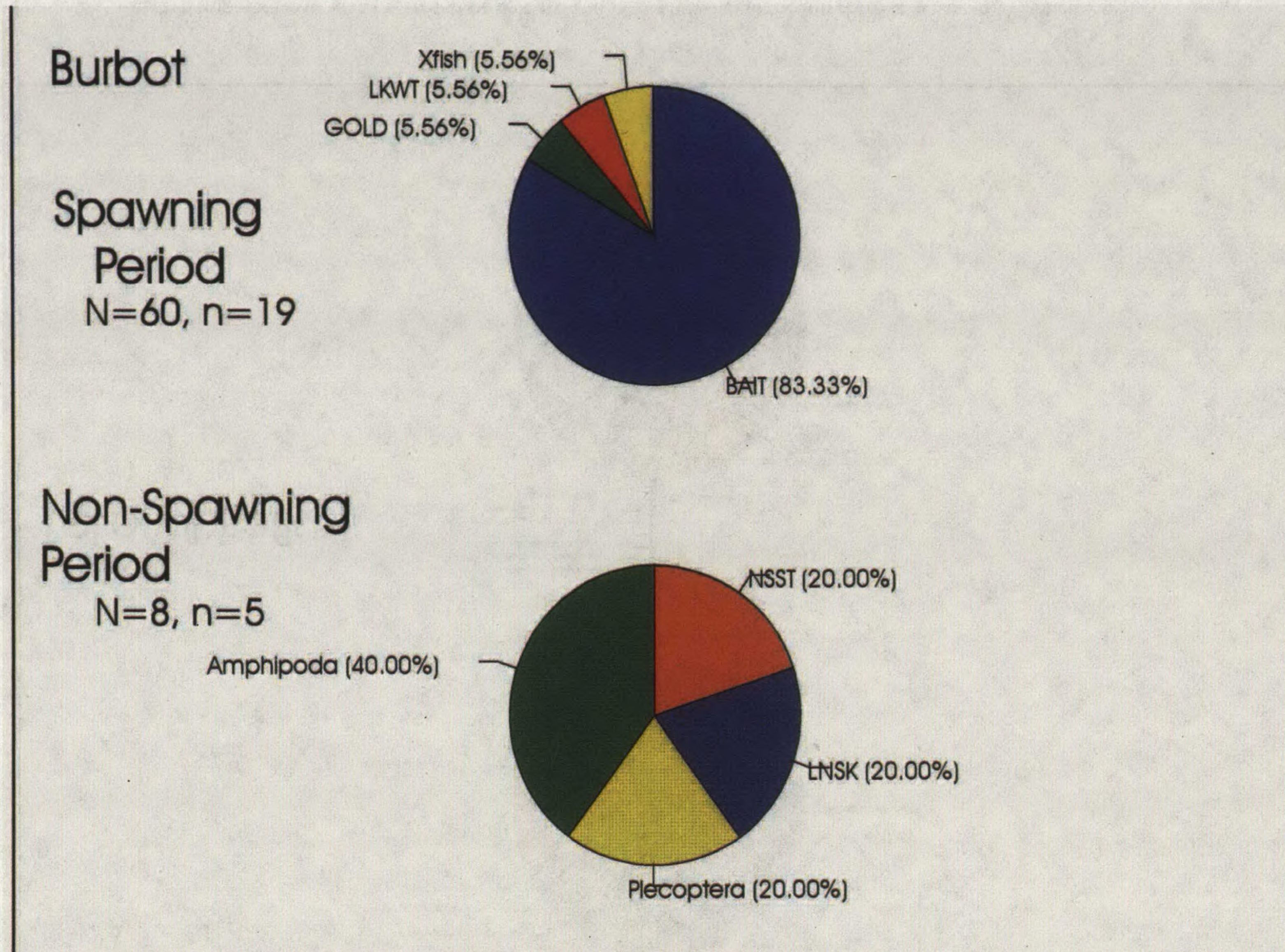

Figure 24. Relative importsnce of taxa in the diet of burbot in the lower Slave River in 1994.

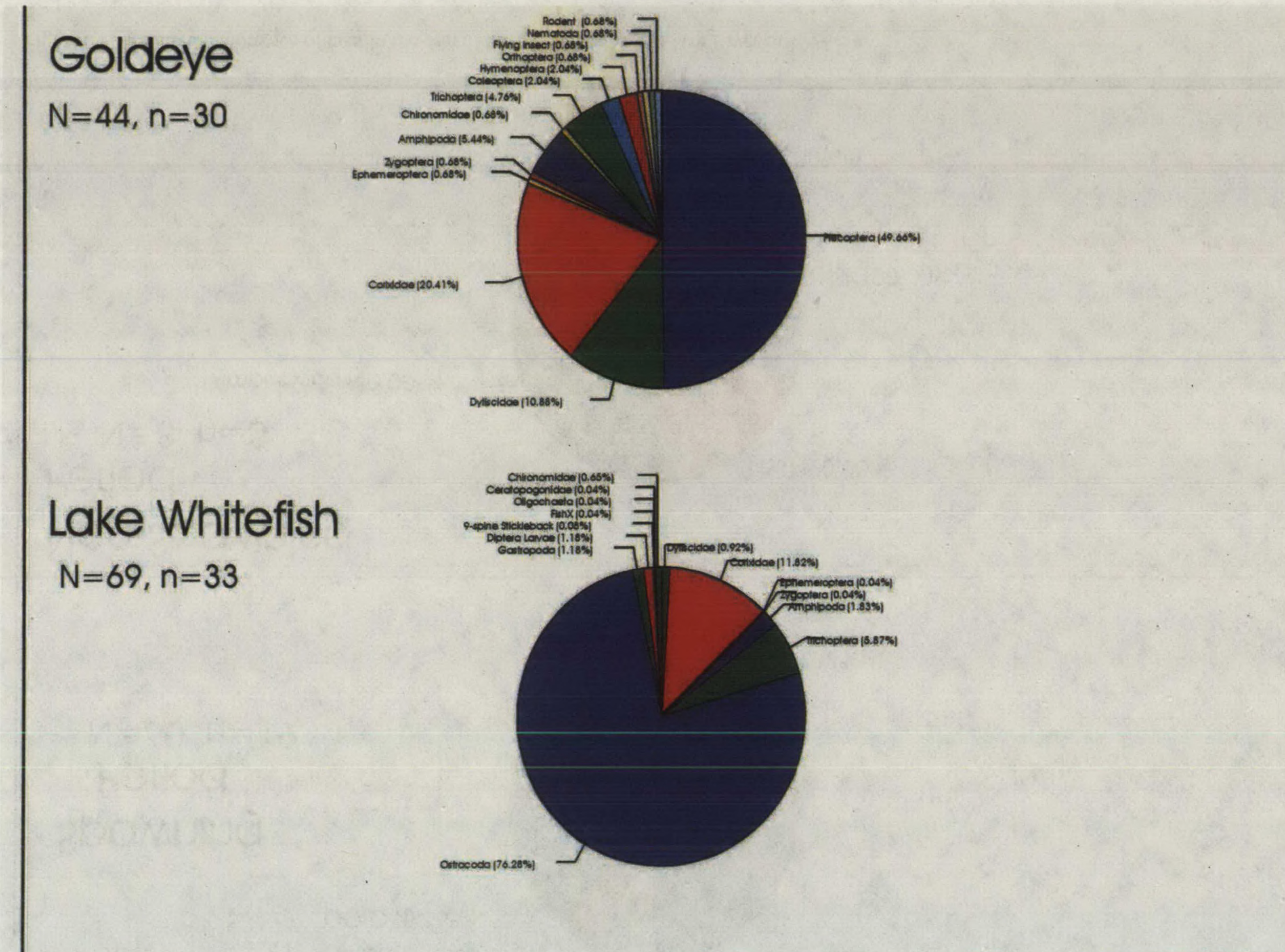

Figure 25. Relative importsnce of taxa in the diet of goldeye and lake whitefish in the lower Slave River in 1994 and 1995.

6.2.2.6 Goldeye

Stomach contents was determined for 43 goldeye in 1995. 30 stomachs, representing 92.5% of total stomach contents were found to contain prey items.

General Description of Goldeye diet: Prey items found are listed in Table 15. A total of 14 different prey items were documented; invertebrate orders represented 89.6% total contents, vegetation represented 1.7% and rodent remains represented 0.5% of total stomach contents analyzed (figure 38). Results from the Relative Importance Index (George & Hadley, 1979) are shown in Table E2 (Appendix 2) . The top four ranked prey items were as follows: plecoptera (31%), rodent remains (20.8%), Corixidae (14.4%), and Dytiscidae (11%).

6.2.2.7 Flathead Chub

Stomach content analysis was determined for 26 flathead chub stomachs in 1995, of which 8 contained prey items.

General Description of Flathead Chub diet: Prey items found are listed in Table 15. A total of 9 different prey items were documented; invertebrate orders represented 65% and vegetation represented 1.85% of total stomach contents analyzed (Figure 26). Gastropods and corixids were by far the most common prey item, representing 20.8% and 18.9% respectively. Chironomids represented 7.4% of the stomachs analyzed; also found were items belonging to the orders Hymenoptera, Coleoptera, Orthoptera, and the family Dytiscidae.

6.2.2.8 Longnose Sucker
Stomach content analysis was determined for 10 longnose sucker stomachs in 1995, of which 9 contained prey items.

General Description of Longnose sucker diet: Prey items found are listed in Table 15. A total of 8 different prey items were documented; invertebrate orders represented 57% and vegetation represented 4% of total stomach contents analyzed (Figure 27). Ostracods, plecopteran and trichopteran larvae were the most common prey item, representing 21.74%, 17.39% and 13.04% of the stomach contents, respectively. Amphipods represented 4.35% stomachs analyzed.

6.2.2.9 White sucker
Stomach content analysis was determined for 10 white sucker stomachs in 1995, of which all 10 contained prey items.

General Description of white sucker diet: Prey items found are listed in Table 15. Their diet was much broader than the longnose sucker with a total of 15 different prey items were

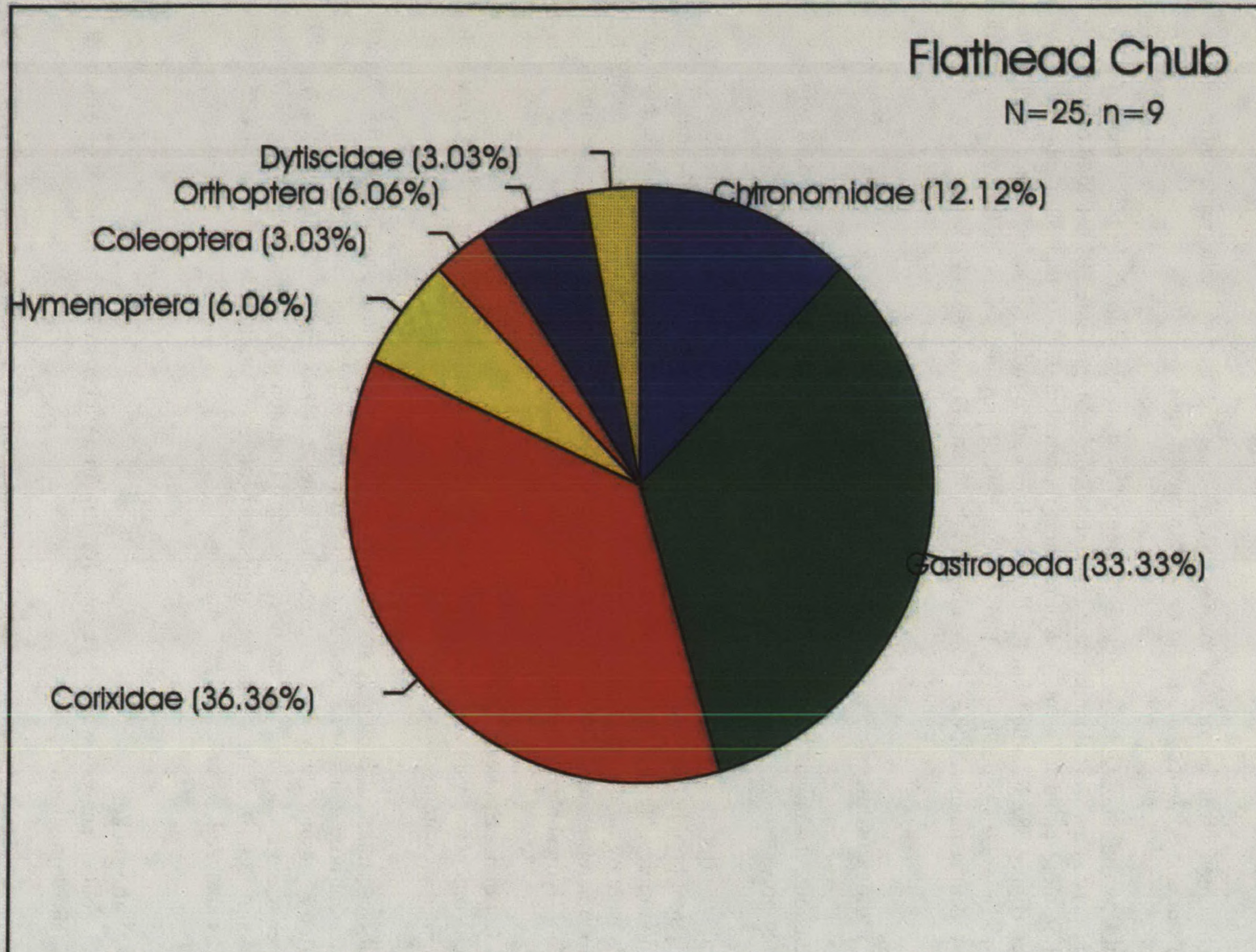

Figure 26. Relative importsnce of taxa in the diet of flathead chub in the lowerSlave River in 1994 and 1995.

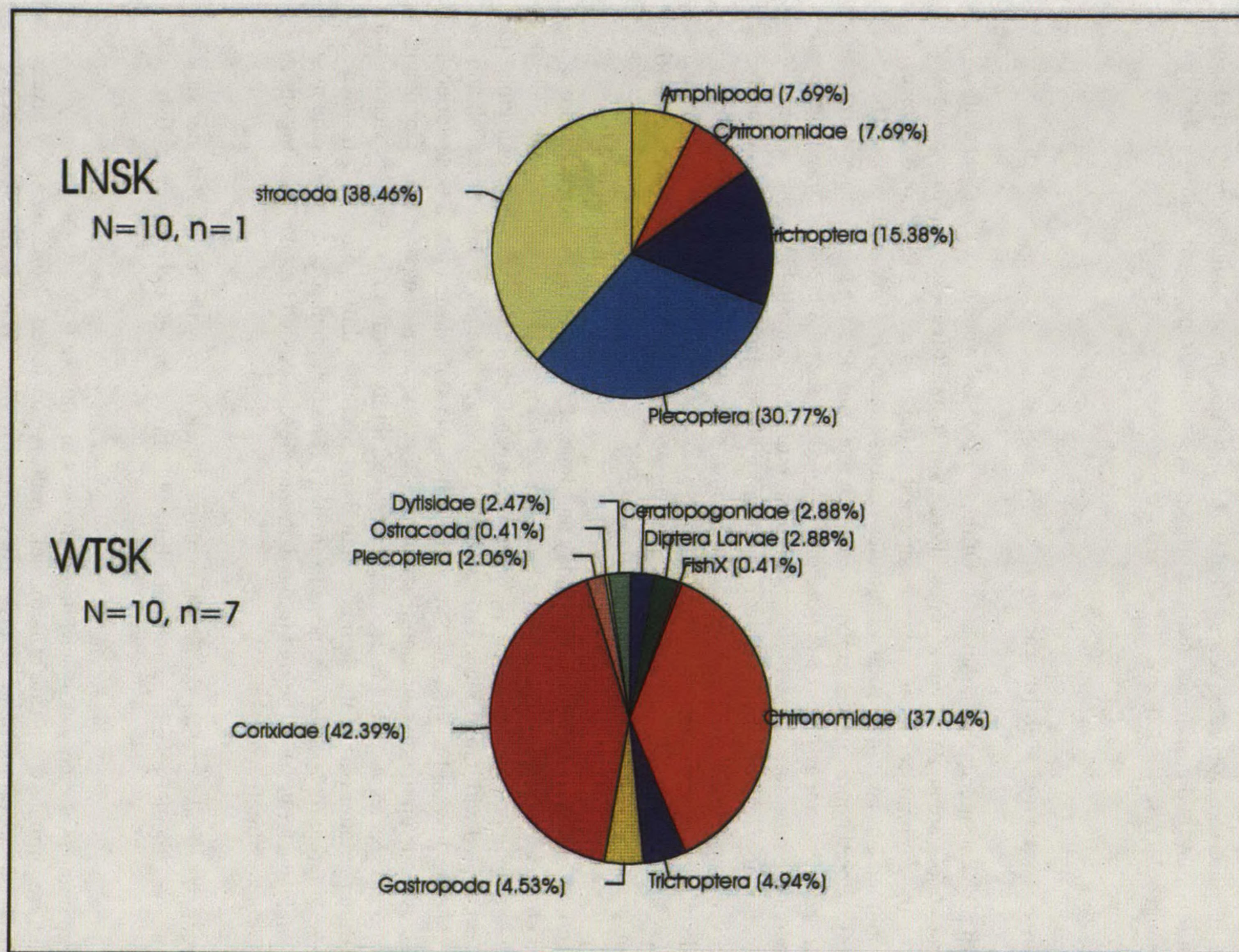

Figure 27. Relative importsnce of taxa in the diet of longnose sucker and white sucker in the lower Slave River in 1994 and 1995.

documented; invertebrate orders represented 98% of total stomach contents analyzed (Figure 27). Chironomids and corixiidae were the primary prey items, representing 38% and 43% of the stomach contents, respectively.

6.2.3 Slave River Food Web Interactions

Northern pike consumed 21 distinct taxa. Of these 14 are fish species, 3 are terrestrial vertebrates and 4 are aquatic invertebrates. Pike , as generalist feeders, therefore, have a wide impact on the community and are a key component in the food web. Pike not only take aquatic animals but large terrestrial vertebrates such as snakes, rodents and birds. Their versatility as predators is further emphasized when one considers the range of prey size against predator size. Prey ranged from 7 to 60% of the length of the pike predator body length. To some extent the pike diet can be used as an indicator of what is available in the system. For example, the stomachs of pike from the Salt River contained damselfly larvae whereas the Slave River proper and the Slave River delta did not. There were few flathead chub available in the Salt River and no Arctic lamprey. No white sucker were captured by pike in the Slave River. In general, the diet was quite different from pike captured in the Salt River, Slave River or Slave River delta (Figure 20)

Northern pike diet varied seasonally. In May and June Slave River pike concentrated on flathead chub (17% of stomachs examined) and Arctic lamprey (17%). Pike in the Salt River ate mainly amphipods and a variety of fish species, while those from the delta consumed fish species associated with Great Slave Lake such as lake chub, lake cisco, lake whitefish and burbot. During July and August the Slave River pike diet shifted such that a wide variety of fish species made up the diet with northern pike (9% of stomachs sampled) being dominant. The change in species probably reflected greater availability of migratory species such as lake whitefish in the latter part of the summer. Salt River pike also shifted more to fish species. Fish were found in 67% of the stomachs examined. The dominant food item was the nine-spined stickleback (39%). The diet in the delta remained focussed on lake dwelling species especially lake whitefish and burbot.

The larger size of pike greater than 400mm allowed them to prey upon a much wider variety of organisms. Smaller pike appeared to be limited to invertebrates and the smaller fish species.

The large number of empty stomachs in the analysis of walleye is due to the tendency of walleye to regurgitate when caught in the net. Walleye consumed 14 different prey taxa and appear to be an opportunistic generalist feeder similar to pike. Walleye rely about equally on invertebrates and fish species the most important being plecoptera and pike. Eight fish and 6 invertebrate species were noted.

Inconnu and burbot were exclusively piscivorous. In the Slave river inconnu concentrated on walleye, flathead chub, northern pike and trout perch. In the delta they consumed pike, longnose sucker, lake whitefish and trout perch. Burbot did not overlap with inconnu in the Slave River where they consumed lake whitefish and goldeye. In the delta they consumed longnose sucker and nine spined stickleback.

Goldeye, lake whitefish, flathead chub, longnose sucker and white sucker were almost exclusively invertebrate feeders consuming a wide variety of prey items. Goldeye concentrated on plecopteran larvae, dytiscids and corixids (42%, 9% and 17% of stomachs examined, respectively). Lake whitefish ate mainly ostracods (75%). Flathead chub concentrated on chironomid larvae, gastropods and corixidae (8%, 21% and 19%, respectively). Longnose sucker focussed on trichopteran larvae, plecopteran larvae and ostracods (13%, 17% and 22%, respectively). White sucker focussed on corixidae and chironomid larvae (43% and 38%, respectively) Thus, there were no species that focussed on exactly the same species although there were several cases of overlap in preferred prey items among the invertebrate feeders.

A schematic of the Slave River food web shows that three fish species, northern pike, goldeye and lake whitefish have the greatest number of interactions with others (Figure 28). Northern pike sample from most of the fish species available while goldeye and lake whitefish prey upon a great range of invertebrate taxa. Certain species such as goldeye, trout-perch and flathead chub serve as energy conduits between the lower trophic levels and the harvested fishes.

In conclusion, the piscine food web is layered into three major types of predator: 1) specialized fish only feeders such as inconnu and burbot; 2) generalized opportunistic predators such as pike and walleye that will take fish and invertebrates; and 3) invertebrate feeders such as lake whitefish, goldeye, flathead chub, longnose sucker and white sucker consuming a wide variety of prey items.

6.3 Slave River Delta Food Web

6.3.1 Diet Analysis

Tripp et al. (1981) estimated the percent fullness of stomachs visually and identified contents to major taxa (e.g. order, family) or other suitable category (e.g., insect parts, fish remains, vegetable matter, digested material) . The frequency of occurrence of each food type was recorded for major species. Tripp et al. (1981) did not calculate occurrence in the same manner as most researchers. They only reported the percentage of stomachs with food that had specified items. I have used this information to calculate occurrence in the usual manner.

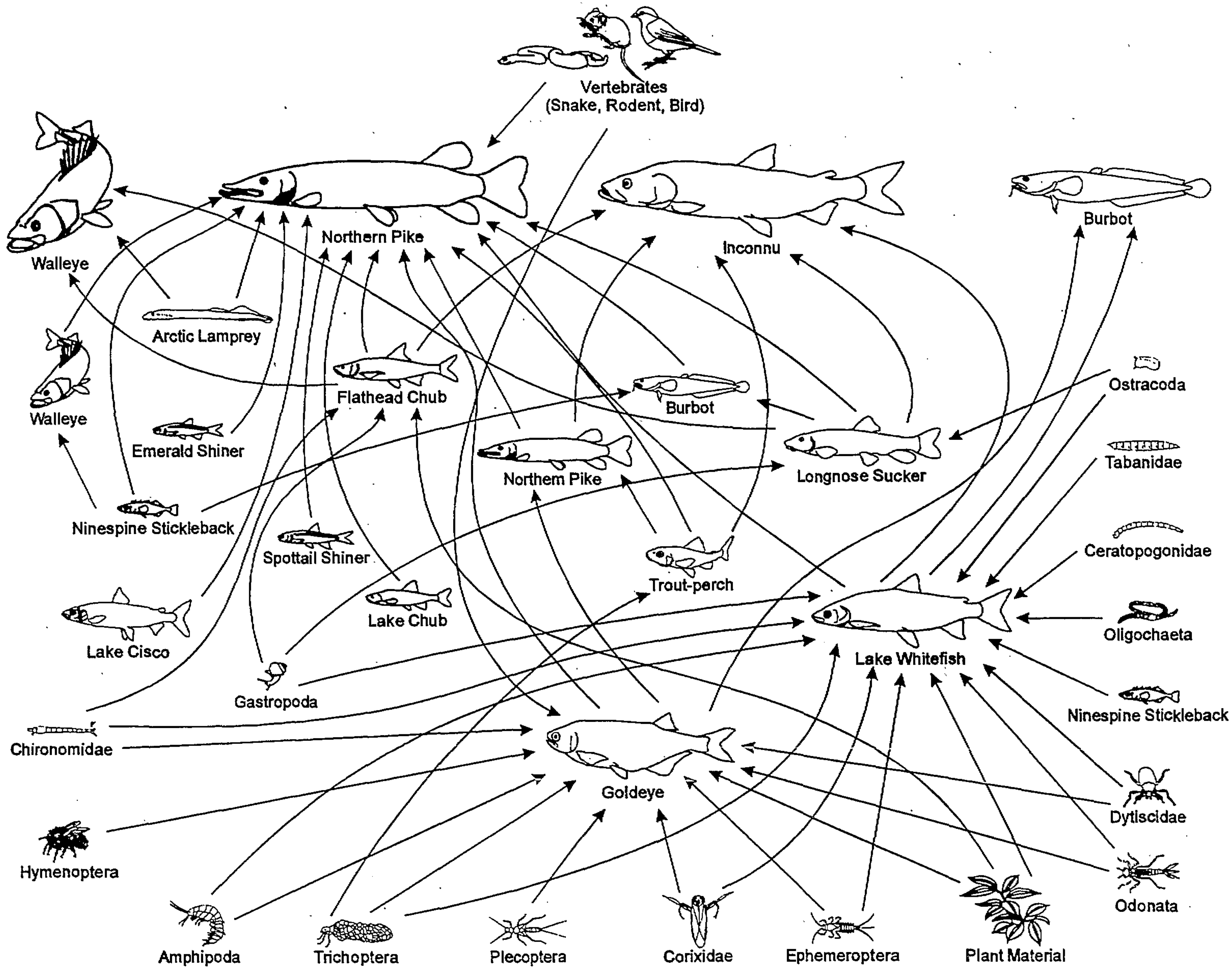

Figure 28. Slave River food web - arrows indicate the direction of predation.

6.3.2 Diets of Slave River Delta Fish Species

6.3.2.1 Lake Whitefish

Of 101 juvenile and adult lake whitefish stomachs examined, 72 were empty and only 29 contained recognizable food items. Most of the lake whitefish were taken during the course of migrations to and from the spawning grounds upriver when they appear to eat very little. Corixids were the major food item encountered followed by mollusca, chironomids, and trichoptera larvae (Table 16). Stomachs were contracted, with hick walls, and contained a relatively small volume of food in relation to the total size of the stomachs.

Table 16. Frequency of occurrence (Relative importance of food items in juvenile and adult lake whitefish in the Slave River Delta, 1978-80 (Data from Tripp et al. 1981).

Prey Items	% Frequency of Occurrence
Corixidae	47.63 (10)
Mollusca	42.86 (9)
Chironomidae	4.76 (1)
Trichoptera	4.76 (1)
	100

Of 46 young-of-the-year lake whitefish stomachs, 23 contained recognizable food items. Of these chironomid larvae were the most frequently encountered followed by copepods, mayflies nymphs, cladocerans and lepidopteran larvae (Table 17).

Table 17. Frequency of occurrence of food items in young-of-the-year lake whitefish in the Slave River Delta, 1978-80 (Data from Tripp et al. 1981).

Prey Items	% Frequency of Occurrence
Chironomidae	61.11 (22)
Copepodae	22.22 (8)
Ephemeroptera	8.33 (3)
Cladocera	5.56 (2)
Lepidoptera	2.78 (1)
	100

6.3.2.2 Lake Cisco

Of 29 stomachs examined 13 contained food. Chironomid larvae and mysids were the most common items, followed by corixids, cladocerans and amphipods (Table 18).

Table 18. Frequency of occurrence of food items in lake cisco in the Slave River Delta, 1978-80 (Data from Tripp et al. 1981).

Prey Items	% Frequency of Occurrence
Chironomidae	46.15 (6)
Mysids	23.08 (3)
Corixidae	7.69 (1)
Cladocera	7.69 (1)
Amphipoda	7.69 (1)
	100

6.3.2.3 Inconnu

Only 6 of 37 inconnu stomachs examined had food items. Fish remains were the only recognizable items including ciscos, northern pike and walleye.

6.3.2.4 Goldeye

Of 209 stomachs examined, 176 were found to contain food. Corixids were by far the most frequently consumed item followed by chironomid and caddisfly larvae, and allochthonous vegetable matter consisting of poplar seeds, twigs, spruce needles(Table 19). A wide variety of other items were consumed including other insects, amphipods, snails, fish and rodents.

Table 19. Frequency of occurrence of food items in adult and juvenile goldeye in the Slave River Delta, 1978-80 (Data from Tripp et al. 1981).

Prey Items	% Frequency of Occurrence	
Amphipoda	0.47	(1)
Ephemeroptera	1.40	(3)
Coleoptera	4.67	(10)
Corixidae	60.75	(130)
Trichoptera	10.28	(22)
Tipulidae	0.93	(2)
Chironomidae	10.75	(23)
Mollusca	1.40	(3)
LNSK	0.47	(1)
Rodent	0.47	(1)
Vegetable Matter	8.41	(18)

100

The diet of young-of-the-year goldeye was dominated by chironomid larvae and corixids (Table 20). Other items included mayfly larvae, stonefly nymphs, midge adults and butterfly larvae.0

Table 20. Frequency of occurrence of food items in young-of-the-year goldeye in the Slave River Delta, 1978-80 (Data from Tripp et al. 1981).

Prey Items	% Frequency of Occurrence	
Chironomidae	45.99	(86)
Plecoptera	2.67	(5)
Ephemeroptera	5,35	(10)
Corixidae	40.64	(76)
Diptera	5.35	(5)
Lepidoptera	5.35	(5)
		100

6.3.2.5 Northern Pike

Of 189 juvenile and adult pike stomachs examined, 104 were found to contain food. Pike were exclusively piscivorous the diet including all of the major fish species in the Delta except inconnu (Tripp et al. 1981). Ciscos were the most common item eaten, followed by smaller pike, burbot, longnose sucker, and walleye (Table 21).

Table 21. Frequency of occurrence of food items in juvenile and adult pike in the Slave River Delta, 1978-80 (Data from Tripp et al. 1981).

Prey Items	% Frequency of Occurrence	
LKCS	33.65	(35)
NTPK	10.58	(11)
BRBT	8.65	(9)
LNSK	6.73	(7)
WALL	5.77	(6)
Other Fish Spp	34.62	(36)

Young-of-the-year pike (N=66) contained fish remains and invertebrates such as amphipods, midge larvae, mayflies, corixids and beetles (Table 22).

Table 22. Frequency of occurrence of food items in young-of-the-year pike in the Slave River Delta, 1978-80 (Data from Tripp et al. 1981).

Prey Items	% Frequency of Occurrence
Amphipoda	27.66 (26)
Chironomidae	12.77 (12)
Ephemeroptera	11.70 (11
Corixidae	5.32 (5)
Coleoptera	2.13 (2)
Fish Remains	40.43 (38)

6.3.2.6 Flathead chub

Of 88 flathead chub stomachs examined, 53 were found to contain food. Corixids were the most frequently consumed food item, followed by chironomids, stonefly nymphs, caddisfly larvae, ceratopogonid larvae, snails and ostracods, mayfly nymphs, water beetles, clams, and oligochaetes (Table 23).

Table 23. Frequency of occurrence of food items in flathead chub in the Slave River Delta, 1978-80 (Data from Tripp et al. 1981).

Prey Items	% Frequency of Occurrence
Corixidae	42.42 (14)
Chironomidae	21.21 (7)
Ephemeroptera	6.06 (2)
Plecoptera	6.06 (2)
Ceratopogonids	6.06 (2)
Snails	6.06 (2)
Ostracods	3.03 (1)
Ephemeroptera	3.03 (1)
Clams	3.03 (1)
Oligochaetes	3.03 (1)

6.3.2.7 Longnose Sucker

Of 80 stomachs examined 51 were empty. Others contained unidentifiable digested matter. Of the identifiable remains chironomid larvae, copepods and corixids were important (Table 24).

Table 24. Frequency of occurrence of food items in juvenile and adult longnose sucker in the Slave River Delta, 1978-80 (Data from Tripp et al. 1981).

Prey Items	% Frequency of Occurrence
Chironomidae	50.00 (6)
Copepoda	41.67 (5)
Corixids	8.33 (1)

Young-of-the-year and yearling longnose sucker consumed chironomids, fingernail clams, snails, oligochaetes, amphipods, copepods, and fish eggs (Table 25).

Table 25. Frequency of occurrence of food items in young-of-the-year and yearling longnose sucker in the Slave River Delta, 1978-80 (Data from Tripp et al. 1981).

Prey Items	% Frequency of Occurrence
Chironomidae	56.62 (13)
Clams	13.04 (3)
Snails	13.04 (3)
Oligochaetes	4.35 (1)
Amphipods	4.35 (1)
Copepods	4.35 (1)
Fish eggs	4.35 (1)

6.3.2.8 Burbot

Of 77 stomachs of adult and juvenile burbot, 50 were found with food. Unfortunately, Tripp et al. (1981) does not give any numerical data which I could convert , perhaps because most items were partly digested by the time the fish were recovered. Fish remains, including ciscos, longnose suckers, other burbot, and stickleback was a major food item, followed by occasional occurrences of caddisfly larvae, corixids, cranefly larvae, midge larvae and amphipods.

Young-of-the-year burbot were dominated by midge larvae, copepods, mayfly larvae,stonefly larvae, amphipods and cladocerans (Table 26)

Table 26. Frequency of occurrence of food items in young-of-the-year burbot in the Slave River Delta, 1978-80 (Data from Tripp et al. 1981).

Prey Items	% Frequency of Occurrence
Chironomidae	55.06 (87)
Cladocera	3.16 (5)
Amphipoda	3.16 (5)
Copepoda	18.35 (29)
Ephemeroptera	16.46 (26
Plecoptera	3.80 (6)

6.3.2.9 Walleye

A total of 208 juvenile and adult walleye were sampled of which 97 had stomachs containing food. Tripp et al. (1981) did not provide data but stated that fish, including ciscos, pike, lake chub, longnose suckers, burbot and other walleye were the most common foods of walleye larger than 200 mm, while insects (mayflies, water beetles, midge larvae) were the most common foods consumed by walleye smaller than 200 mm.

6.3.2.10 Other Species

Tripp et al. (1981) provides data on the stomach contents of lake chub, emerald shiner, spottail shiner, pearl dace, trout-perch and spoonhead sculpin. Lake chub fed on a variety of invertebrates but especially corixids and chironomids, followed by plecoptera, gastropods, copepods, oligochaetes, pelecypods, trichoptera, ephemeroptera, and coleoptera (Table 27). Emerald Shiner consumed a wide variety of invertebrates - in order of importance: corixids, chironomids, ceratopogonidae, hymenopterans, cladocera, copepoda, plecoptera, and diptera. Spottail Shiner consumed mainly copepods and corixids plus small amounts of chironomid larvae and homeoptera. Pearl Dace had a rather restricted diet consisting mainly of copepods and corixidae. They also ate gastropods. Trout-perch preyed primarily on chironomids but also took mayflies, copepods, pelecypods, gastropods, trichopterans and corixids. Spoonhead sculpin preyed upon chironomids mainly but also took fish eggs, oligochaetes, mayflies, corixids and gastropods.

Table 27. Frequency of occurrence of food items of smaller species in the Slave River Delta, 1978-80 (converted to % occurrence using data from Tripp et al. 1981).

Prey Items	Lake Chub	Emerald Shiner	Spottail Shiner	Pearl Dace	Trout-Perch	Spoonhead Sculpin
Oligochaeta	3.16 (3)					
Pelecypoda	3.16 (3)				5.05 (5)	13.64 (21)
Gastropoda	6.32 (6)			10.00 (10)	3.03 (3)	2.60 (4)
Cladocera	5.26 (5)	4.00 (4)				
Amphipoda						
Copepoda		4.00 (4)	49.59 (61)	52.00 (52)	5.05 (5)	
Chironomidae	22.11 (21)	16.00 (16)	4.88 (6)		70.70 (70)	62.34 (96)
Ceratopogonids		16.00 (16)				
Trichoptera	2.11 (2)				3.03 (3)	
Ephemeroptera	2.11 (2)				10.10 (10)	5.19 (8)
Plecoptera	8.42 (8)	4.00 (4)				
Corixidae	45.26 (43)	40.00 (40)	40.65 (50)	38.00 (38)	3.03 (3)	5.19 (8)
Diptera		4.00 (4)				
Hymenoptera		8.00 (8)				
Lepidoptera						
Homeoptera			4.88 (6)			
Coleoptera	2.11 (2)	4.00 (4)				
Fish Eggs						11.04 (17)

6.3.3 Slave River Delta Food Web Interactions

Juvenile and adult northern pike consumed 10 distinct taxa and fed exclusively on fish in the Slave River delta. Thus, pike in the Delta, though not as generalistic in their food habits as in the river, still affected most of the fish species present. The most important fish species were cisco, followed by smaller northern pike, burbot, longnose sucker and walleye.

In contrast to the piscivorous diet of burbot in the river, burbot in the Delta consumed both fish and invertebrates. However, fish were the dominant food item.

Goldeye, lake whitefish, and flathead chub were almost exclusively invertebrate feeders consuming a wide variety of prey items. Goldeye ate a wide variety of invertebrates focussing on corixids, chironomids and trichoptera (61%, 11% and 10%, respectively). Lake whitefish ate mainly corixids and molluscs (48% and 43%). Flathead chub concentrated on chironomid larvae and corixidae (21% and 42%, respectively). In the Delta there was much overlap in food types with chironomids and corixids being preferred by the invertebrate feeding fishes.

A schematic of the Slave River Delta food web shows that the trophic separation is clear between the top predators, walleye, pike and burbot and the invertebrate foragers such as the cyprinids, goldeye, cisco, whitefish and suckers (Figure 29). Goldeye and lake whitefish are have the widest diet among the invertebrate feeders. Pike consumes the widest diversity of fish species.

Finally, a simple food web showing the young-of-the-year (Figure 30) emphasizes the importance of the invertebrate community to all species whether they are top predators or invertebrate foragers as adults.

In the delta food web pike appears to specialize on fish while burbot forages on both fish and invertebrates. This reversal of the pattern in the river may be related to depth. In the river, pike dwelling nearer to the surface have more opportunities to capture invertebrates than in the Delta. Contrastingly, burbot may encounter more invertebrates in the deep waters of the Delta. Overall the pattern remains quite similar to the river except that cisco are present and heavily utilized by pike.

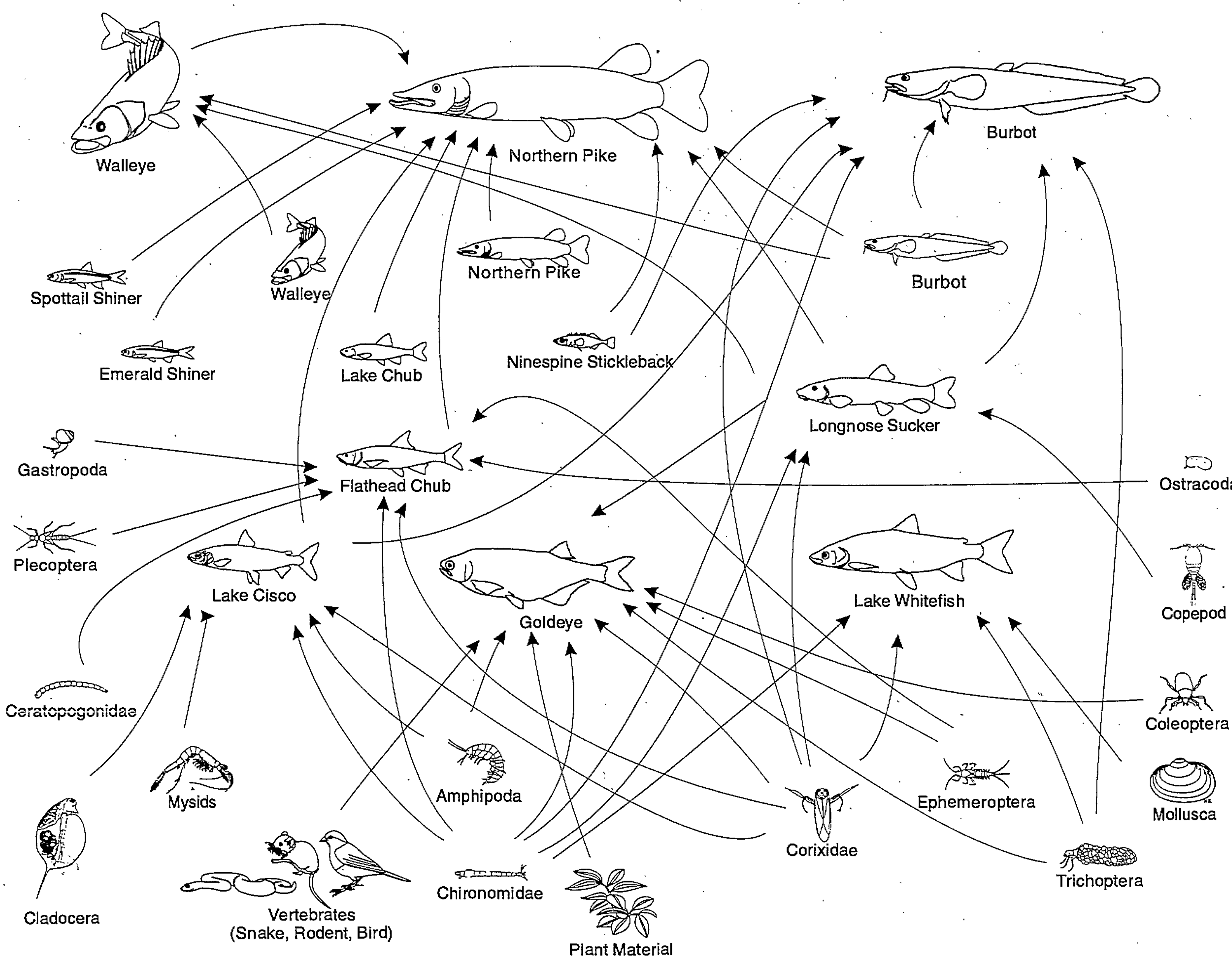

Figure 29. Food web in the Slave River Delta - arrows indicate the direction of predation.

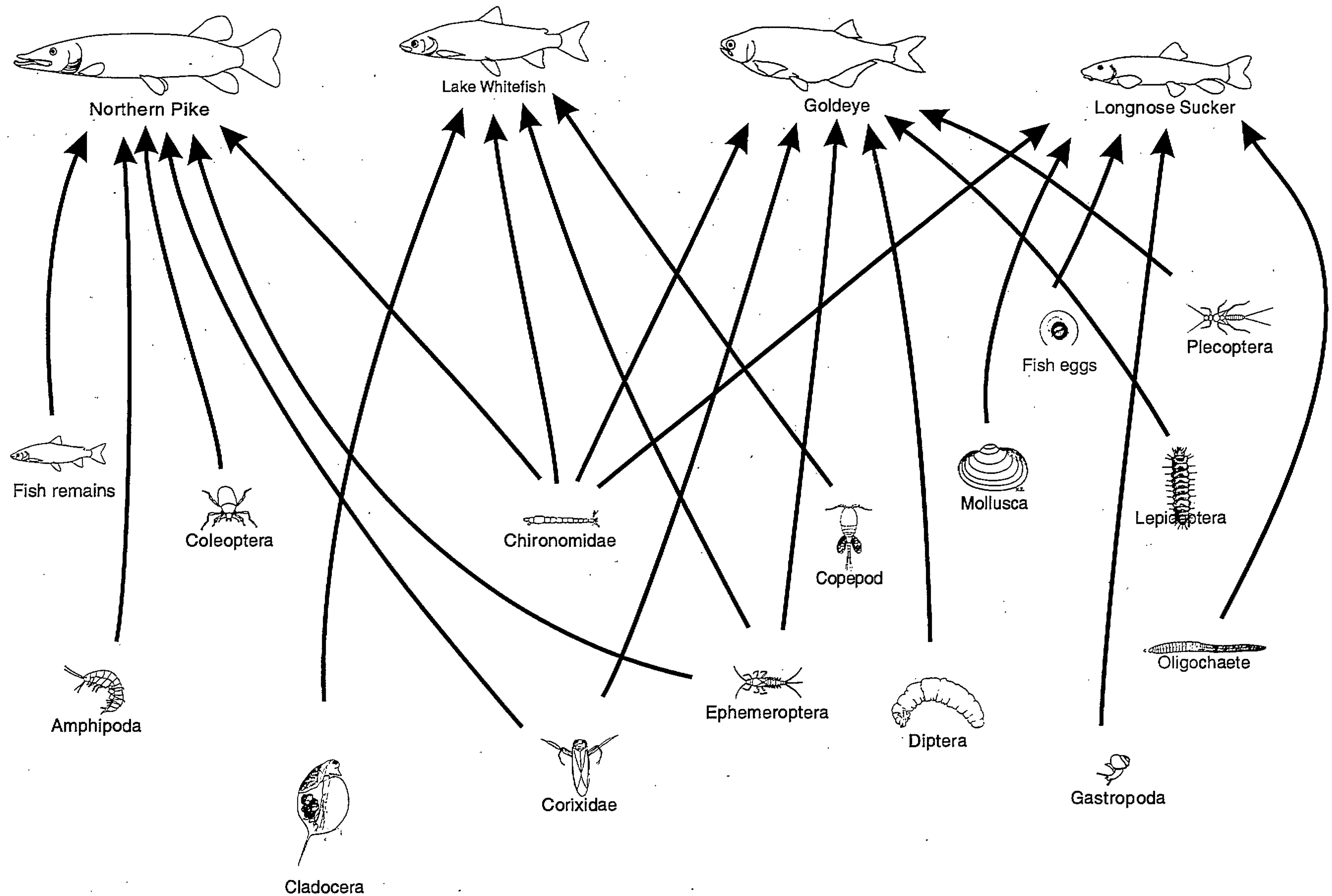

Figure 30. Schematic model of the young-of-the-year piscine food web in the Slave River Delta.

7.0 SUMMARY CONCLUSIONS AND RECOMMENDATIONS

The lower Slave River is a distinct habitat in the Northern Rivers Basin in that it is connected hydrologically and chemically to the upper part of the watershed but isolated at the level of the fish community. There is virtually no interaction between the fish communities upstream of Rapids of the Drowned and those in the lower Slave River. Habitat requirements for fishes are unique in the lower Slave River because of the life cycles of the species and the surrounding abiotic and biotic environment. Three guiding questions were posed by NRBS that are relevant to fish ecology: # 1a " How has the aquatic ecosystem including fish and\or other aquatic organisms been affected by exposure to organo-chlorines or other compounds?"; #6 "What are the distribution and movements of fish species in 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 by time and location?" To respond and/or provide supporting information to answer these questions I provided the following: 1) a review of the existing models for large rivers that could make predictions regarding the pathways contaminants and other anthropogenic effects might take to reach the fish food chain through hydrological regime and movements of the biota; 2) a general description of the major abiotic and biotic features of the environment surrounding the fish community in the lower Slave River; 3) a summary the available knowledge (including NRBS studies) on the community composition, distribution and abundance of the fishes in time and space in the lower Slave River; 4) a synthesis of the available knowledge of geographic migratory patterns of fishes of the lower Slave River; ; 5) a summary of vital rates of major species; 6) a description of the pathways in the fish food web.

7.0.1 Theoretical Models and the lower Slave River

Further research on the lower Slave River should be undertaken with a unifying theoretical model in mind. Such an approach will do more to preserve all ecosystem components than studies specializing in one or two species or aspects of fish biology in the river. On the other hand the present theoretical models which have been developed based on river sytems in the southern temperate and tropical regions may not be sufficient to describe the sub-Arctic Slave River. As stated before, the river continuum concept is most appropriate for headwater streams and small rivers, whereas the flood pulse concept is limited to large floodplain rivers and the RPM is relevant to large rivers with constricted channels and firm substrates in the photic zone. Where does the lower Slave River fit in? The original concern from NRBS was probably partly based on a river continuum model - that what happens upstream profoundly affects function downstream. This is undoubtably true. However, the lower Slave River seems to fit better between the flood pulse and riverine productivity models because there is certainly a flood pulse and yet much of the river is a restricted channel with productive tributaries. The recommendations that follow, therefore, keep in mind that much of the focus in the NRBS has been dealing with the linear nature of riverine systems and that research into lateral inputs and local productivity must be undertaken.

7.1 Effects on the fish community

Flow regulation from the Bennett Dam has produced a change to the seasonal hydrograph of the Slave River (Prowse and Conly 1996). By the lower Slave River the effects are diminished due to tributary flow becoming an increasing part of the total discharge. Contaminants have been found in some indicator fish (burbot) in the lower Slave River although at generally low levels (Brown 1996). The fish community could be affected by these changes in the environment in terms of vital rates, species composition and diversity.

7.1.1 Vital Rates

Vital rates respond to changes in the environment by re-partitioning energy between maintenance, growth and reproduction (Roff 1992). Growth and reproduction are the basis for productivity in fish populations. Unfortunately, there is no general model predicting precisely how vital rates will respond to changes in the abiotic environment. Presumably, the first level that the above changes might affect fish is to increase their maintenance costs with a trade-off in reduced growth, delayed age at maturity and/or reduced fecundity.

7.1.1.1 Growth

Ideally, one would like pre and post-impact information with which to judge, but this is not the case, in general. Inconnu, burbot and lake whitefish have data of this type for growth but the other species do not. Therefore, the information presented in the report on the other species serves only as a bench mark of productivity indices to judge further changes.

Inconnu in the lower Slave River has one of the highest growth rates in North America. The high growth rate is likely attributable to the normal response of the life history to fishing pressure and the fact that inconnu are at the southern end of their range. There appears to have been little change in growth patterns from 1983 to 1994. Burbot in the lower Slave grow more slowly than other populations but not substantially so. From the late 1970's to 1994 there may have been an increase in growth of the younger ages and a decrease in the growth rate of older ages. Based on data from the late 1970's and the early 1980's Slave River lake whitefish grow more slowly than surrounding populations. Between 1978 and 1984 there was little change in growth rate. Slave River goldeye also grow more slowly than other populations in the area whereas northern pike growth seems to be about average. Other than the changes observed in burbot there appears to be no unusual patterns in the growth of Slave River fishes that would suggest an impact. However, the conclusion is based on data on limited data.

7.1.1.2 Age at maturity

There is no information to check for changes in age at maturity among Slave River fishes. Therefore, the limited age at maturity data will be considered as a bench mark for future assessment of impacts. Some populations were distinct compared to conspecifics.

Inconnu had a low age at maturity compared to other North American populations. This is probably due to the rapid growth rate. Burbot in the lower Slave River matured about one year later than other burbot populations but this is not noticeably outside the inter-population variation one might expect. Lake whitefish and pike, age at maturities are similar to most other conspecific populations. Walleye, goldeye, and longnose sucker matured later than conspecific populations. Age at maturity does not appear to be outside the expected range for any of the major species in the Slave River.

7.1.1.3 Fecundity

There was no information available to determine if fecundity has changed in fishes in the Slave River.

Fecundity of inconnu, burbot and pike were comparable to other conspecific populations. Lake whitefish had a lower fecundity than most other lake whitefish populations. Fecundity levels were in the normal range and showed no evidence of impact.

7.1.1.4 Age Structure

Inconnu had a narrow age structure compared to other populations. Burbot, goldeye longnose sucker, lake whitefish, walleye, and pike had broad age structures suggesting little impact from anthropogenic activities. The narrow age structure of the inconnu would make it less able to adjust to environmental changes than the other species.

The major species are mainly in the two categories of large and medium sized fishes described which Zaret (1980) described as being most vulnerable to anthropogenic activities and therefore the first to show any effects. The vital rates of these species given no indication that contaminants or flow changes have affected the Slave River fish community to any appreciable degree. However, the data is not sufficient too make conclusive judgements.

RECOMMENDATION 1): Evaluating changes to the vital rates is limited by the lack of data prior to the construction of the Bennett Dam and other developments. Except for inconnu and burbot, most of the vital rates available are from 1978-79 collections by Tripp et al. (1981). Analysis of the current vital rates of other species should be undertaken - especially goldeye, northern pike, walleye and lake whitefish.

RECOMMENDATION 2): Future evaluations of the impact on fish productivity will require good data on vital rates. Key species, such as inconnu, northern pike, burbot, walleye and goldeye should be assessed on a regular basis. The Department of Fisheries and Oceans should continue collection and analysis of inconnu from the lower Slave River. Collections and analysis of the other key species should be made at least once every five years to assess changes in productivity.

RECOMMENDATION 3): There is little information on the growth patterns of juveniles of the major species in the lower Slave River. Impacts from environmental degradation will probably affect juvenile stages first. Projects that focus on factors important to juvenile life history should be encouraged.

RECOMMENDATION 4): There is almost no information on the vital rates of forage species such as emerald shiner, flathead chub, trout-perch . These species may be good indicators of changes that will ultimately affect the production of their predators, the harvested fish species. Studies that quantify the life history trajectory (growth, age at maturity, fecundity, longevity, mortality) of forage species in the lower Slave River should be undertaken.

RECOMMENDATION 5): There are no models that can be used to predict the response of the life history trajectory (hence how fishes are affected) to environmental degradation in the lower Slave River. Existing life history trajectory models relate to mortality factors such as fishing. Quantitative models of the potential consequences to vital rates of flow changes and/or contamination should be developed for the lower Slave River. Such models would allow more precise hypothesis testing and prediction of the effects of habitat change. This recommendation is key because it may help to priorize Recommendations 1-4 and others.

7.1.2 Fish Species Diversity

A major problem with environmental degradation is the permanent loss of species. Lowering the diversity of ecosystems makes them less stable and able to withstand further environmental impacts. A total of 30 species have been reported in the Slave River and its delta. Twenty-seven of these species are confirmed from collection records. The other three are only reported in McCart (1986) but the references he provided do not confirm actual collections of these species. Within the confirmed group the most important family is the Salmonidae with 10 members. The Cyprinidae (5 species) is next followed by Percidae (2), Catostomidae (2), Cottidae (2), Percopsidae (1), Petromyzontidae (1), Esocidae (1), Hiodontidae (1), Gadidae (1), and Gasterosteidae (1). In the late 1970's 23 species were captured in the system compared to 18 in the mid-1980's and 19 in 1994/95. Different fish species are more or less vulnerable to capture depending on the gear used. When considering only one gear type common to all studies (gillnet) then there was no change in the number of species recorded (14) from the 1978-80 period to 1994-95. The NRBS funded study added two species not collected before to the lower Slave River list - *Oncorhynchus nerka* and *O. tshawytsha.*

Overall, community composition differences were minor and are likely a result of chance in sampling. Therefore, there does not appear to be any affect of flow changes or contaminants on the fish species diversity in the lower Slave River.

RECOMMENDATION 6): Fish species diversity is a fundamental indicator of ecosystem health. Collections by gillnet and other means should be made at least once every 5 years over the entire season to determine if fish species diversity has changed.

RECOMMENDATION 7): A more formal analysis of the existing data using indexes of diversity should be undertaken.

7.1.3 Fish Species Abundance

While some species have been a relatively stable percentage of the community others have shown fluctuations in their relative abundance between 1978 and 1995. Lake whitefish, white sucker, northern pike, flathead chub and walleye have remained relatively constant. Inconnu appears to have increased, probably due to reductions in fishing pressure. Burbot and longnose sucker appear to have decreased somewhat. Some of the differences may be due to sampling location - the late 1970's samples were taken more heavily from the Slave River Delta than the recent samples.

RECOMMENDATION 8): To validate the catch per unit effort method of estimating abundance and to get a benchmark estimate of the numerical abundance of each species it is recommended that mark-recapture studies be undertaken for each species.

7.1.4 Invertebrate Diversity

In the flood-pulse and river continuum models all fish species in the Slave River would be considered predators. The basic medium of energy transfer is invertebrates. It is clear that maintenance of invertebrate populations is critical to the productivity of the fish populations. Effects of contaminants or flow changes may first affect the productivity of invertebrate populations.

RECOMMENDATION 9): Studies to determine the species diversity, habitat requirements and productivity of invertebrates in the lower Slave River should be undertaken.

7.2 Fish Distribution and Movement

The lower Slave River fish community is seasonally dynamic , constantly changing throughout the year. Fish movements vary according to species from extensive to limited. The lower

Slave River is an important habitat used for spawning, feeding, rearing of juveniles and for over-wintering of fishes and serves as a migratory corridor for all of these activities. All major species appeared to show seasonal aggregations and all seasons were important for spawning or feeding of at least one of the major species.

7.2.1 Distribution

7.2.1.1 Large Scale Patterns

Goldeye were abundant in the Slave River, Slave River Delta and Salt River. Inconnu could be found near the outer Slave River Delta in the spring but generally used the Slave River ,only, as a migration corridor and spawning area in the fall. Lake whitefish utilized the Slave River for feeding and spawning. The Salt River was an important nursery area for lake whitefish and juvenile pike. Northern pike adults were distributed throughout the system but were most abundant in the Slave River delta. Burbot were also widely distributed but had apparently much lower abundance. Longnose sucker inhabited the Delta and Slave River channel, while white sucker inhabited mainly the Salt River. Walleye had resident populations in the Salt and Slave rivers but also had spawning and over-wintering runs from and to Great Slave Lake in the spring and fall, respectively. Some species like flathead chub, preferred the Slave River channel. A large number of others (Arctic lamprey, pearl dace, lake chub, trout-perch, round whitefish, ciscos, Arctic grayling, emerald shiner, yellow perch, spoonhead sculpin and slimy sculpin) inhabit the Delta the extreme lower reaches of the Slave River channel.

7.2.1.2 Micro-habitat

Shallow, well vegetated areas were preferred by a greater diversity of species in greater numbers than other habitat types. However, the number of habitat types were limited to four defined by Tripp et al. (1981).

RECOMMENDATION 10): Field and simulation studies to characterize the differences in fish habitat among the major areas of the lower Slave River drainage should be undertaken to determine what are the habitat characteristics that separate species in these areas. Particular attention should be made to develop a detailed scale of micro-habitat types and the preferences of fish to each.

7.2.1.3 Seasonal Variation in Community Structure

The Slave River community changed greatly over the season. In the spring goldeye, flathead chub, walleye were numerically dominant. The high abundance was probably due to spawning aggregations. Longnose sucker, pike and lake whitefish were also present. Burbot and inconnu were absent. During the summer the community composition included most major species except inconnu. Goldeye was the most abundant but less so than in the spring. In the latter part of the summer the fall spawning species, inconnu and lake whitefish begin to dominate the biota. During the fall inconnu, lake whitefish and goldeye dominate but all species are present. Late in the fall ciscos enter the Delta in great numbers. In the winter there is a run of burbot downstream to spawn in the Delta.

RECOMMENDATION 11): Little is known regarding the seasonal distribution under ice. Field studies over the entire ice on period should be undertaken to determine the fish community composition in different parts of the lower Slave River drainage and over-wintering habitat of each species. Sampling would necessarily be limited to the gillnetting techniques used by local fishermen unless new methodologies could be developed.

RECOMMENDATION 12): Recognizing the seasonally dynamic nature of the Slave River fish community, geographic information system (GIS) analysis of relationship between probable point sources, fish distribution and contaminant concentrations in the fish over the seasonal cycle should be undertaken

7.2.1.4 Distribution in side channels, tributaries and on floodplain

Studies to date (including the NRBS) have focussed on the main channel or the Delta of the Slave River. Much of the productivity, including fish production, must take place in still side channels, tributaries such as the Salt River, quiet backwaters and seasonally on the floodplain of the river. There is no information available on the fish distribution in these areas. Therefore, the importance of these areas to fish as habitat and the probability that fish might be exposed to contaminants while in these areas cannot be determined. The effects of hydrological changes on these areas must be considered, especially in the Delta, where the Bennett Dam effects may be or are ongoing.

RECOMMENDATION 13): A study to determine the fish species composition in tributaries , backwaters and side channels throughout the season should be undertaken in the lower Slave River.

RECOMMENDATION 14): A study of the distribution and activities of both juvenile and adult fish during the flood-pulse on the lower Slave River should be undertaken.

7.2.2 Movements

The seasonally dynamic community composition in the Slave River is a result of fish migrations to feeding, spawning, rearing or over-wintering habitat. Movements can be extensive or limited depending on the season and species.

The annual movement patterns of the adults of one of the most important harvested fishes, inconnu can now be described in detail. Inconnu spawn in the Slave River at sites near Fort Smith and near Cunningham Landing. The offspring apparently migrate directly to Great Slave Lake where they spend five or more years in the case of the males and seen or more years in the case of the females until they are mature. Once mature inconnu return to the Slave River to spawn, entering the river in the late summer and proceeding up-river to their spawning site. They aggregate at the spawning grounds for several days to weeks until spawning occurs, usually around the third week of October. After spawning the return to Great Slave Lake is rapid occurring over less than a week. Within the lake migrations are geographically extensive. The inconnu migrate in a large counter-clockwise gyre in the western basin of the lake bounded by the south and north shores, the Simpson Islands and the Mackenzie River outlet. In the spring the inconnu are located in the open water near the outlets and deltas of rivers on the south shore. After this they proceed along the shore to the Slave River. Therefore, inconnu have great potential to transport contaminants from the northern river basins area into Great Slave Lake. Similarly, they could also import contaminants into the lower Slave River from sources around Great Slave Lake. On the other hand, as adults they are the top predator among fishes and thus contaminant transfer would not be to the fish food chain but mainly to the next level of dogs and humans.

In contrast, burbot migrate little, apparently holding small feeding territories in the river or delta. In the winter they migrate downstream in the Slave to spawn in the Delta probably in January or February and return back up river prior to the spring.

Lake whitefish appear to follow a similar migratory pattern both seasonally and geographically to inconnu except that at least some of their juveniles may rear in the river and not migrate to the lake until they mature. As well, some lake whitefish may over-winter in the lower river.

Goldeye, flathead chub and walleye migrate to the river near the Fort Smith area during the spring to spawn then disperse into the river for the rest of the year. Adult walleye may leave the river after spawning. Juveniles and some adult walleye remain in the river during the open water season. Lake ciscos migrate into the Slave River delta in late fall to spawn and spend the rest of the year in Great Slave Lake. Given the reliance of ciscos on the Delta for reproduction changes there may effect them the most. Northern pike, probably move into the Slave and Salt rivers from the Slave River delta to spawn in the early spring prior to the completion of ice-out. Pike then re-distribute themselves along the Slave River and the delta for the rest of the year. The seasonal movement patterns of longnose and white sucker are uncertain as there has only been limited data collected.

Most importantly, no fish have been observed to migrate above the Rapids of the Drowned . Thus, the lower Slave River populations are isolated from the conspecific populations upstream except when a fish slips downriver through the rapids.

7.2.3 Probability of exposure to water quality changes due to distribution and movements

If the flow and water quality changes are transported from upstream then fishes undergoing critical phases of their life cycle near Rapids of the Drowned would be at greatest risk. Thus, lake whitefish and inconnu during spawning in the fall; pike, goldeye, flathead chub and walleye spawning in the spring near Fort Smith would most likely be exposed. However, if the change in water quality is strong enough to be transmitted from a great distance it is unlikely to attenuate at Rapids of the Drowned. Thus, species that rear or are resident in the Slave River Slave River Delta, or even Great Slave Lake since 85% of the water entering it comes from the Slave River, such as northern pike, lake whitefish, walleye, flathead chub, goldeye, burbot and longnose sucker would be most vulnerable.

RECOMMENDATION 15): There is nearly no data on winter movements of fishes (inconnu movements in Great Slave Lake during winter are known) in the Slave River and delta. While it is assumed that most species are relatively inactive at this time it is not confirmed and remains a gap in the knowledge base. A study of winter ecology, including floy tagging and radio-tracking experiments on the major species excepting inconnu and ciscos should be undertaken.

RECOMMENDATION 16): Other than inconnu and burbot there is only limited knowledge of the details of movement patterns of major species, such as northern pike, goldeye, lake whitefish, and walleye, in the lower Slave River. Radio-telemetry studies of these species' movement patterns throughout the year should be undertaken in order to determine their probability of exposure to contaminants and other effects of environmental degradation.

RECOMMENDATION 17): There is almost no knowledge of the movements of forage species such as trout-perch, emerald shiner, lake chub, and flathead chub. The movement patterns of these species may determine whether or not contaminants enter the fish food chain. Studies of movement patterns using floy tags and dye markers should be encouraged.

RECOMMENDATION 18): Juvenile movements in the river have not been investigated to date. Studies of the movements of juvenile fish should be undertaken.

RECOMMENDATION 19): If, when and how fishes migrate onto the floodplain of the lower Slave River has not been studied. Studies to determine the degree of flooding during the spring pulse and the movement patterns of fishes should be undertaken. This is a key recommendation given the present Bennett Dam and future hydrological impacts.

RECOMMENDATION 20): A simulation model of the probable movement patterns of all species of fishes to feed, spawn, rear and over-winter should be constructed as a reference for habitat managers. The model could be checked against available data and modified as new data becomes available in the future. This is also key relative to assessing impacts from obstructions, such as dams.

7.3 Food Web

All fishes in the lower Slave River are carnivorous and would be classified as predators by general models of large rivers. Those lower in the food web, such as suckers, goldeye, lake whitefish, flathead chub and shiners concentrated on invertebrate prey. The top predators, such as inconnu, northern pike, walleye and burbot ate exclusively fish. Three species played key roles in the food web. Pike consumed all other major species of fish present except inconnu. Of the fish species occupying the lower part of the food web, goldeye and lake whitefish consumed the widest variety of invertebrates. Of the invertebrate fauna the most important by far were the chironomids, followed by the corixids.

In the Slave River delta the food web again revolved around pike, goldeye and lake whitefish. Corixids and chironomids were about equal in importance to invertebrate feeders and often composed 60 to 80% of the diet.

Because all fish in the lower Slave River and Slave River delta are predatory they are all at risk of bio-accumulation of toxicants through the food chain. Clearly, the fish predator group, including inconnu, northern pike, walleye, and burbot are the most likely to concentrate contaminants to a high level.

RECOMMENDATION 21): The importance of invertebrates to the productivity of the fish community and as potential conduits of contaminants is obvious. Detailed studies of the ecology and habitat requirements of the invertebrate community, especially the chironomids and corixids, should be undertaken in the lower Slave River.

RECOMMENDATION 22): To determine the organisms most at risk a bio-energetic model of the food web should be constructed.

7.4 Priorization of Recommendations

While all recommendations, above, should be carried out I believe it reasonable to emphasize some of the key ones in order to help researchers and habitat managers on the question of 'Where to proceed next?'. The key recommendations fall into three categories: critical gaps in the database, quantitative model development and long-term monitoring. There are serious knowledge gaps in the understanding of invertebrate ecology, winter ecology of the aquatic biota and the biological importance of side channels and the annual flood-pulse which are addressed in recommendations 13, 15, 19 and 21. Models to make predictions and quantitatively understand processes are completely lacking and therefore additional key recommendations are 5, 20 and 22. Finally, for the fish community there should be a monitoring effort that is ongoing, consistent and long-term in order to detect future changes, such as suggested in recommendation 6.

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Appendix 1: CPUE of Slave River Fishes (Frpm Tallman et al. 1996c).

Table A. The mean catch per unit effort of inconnu (CPUE - number of fish per hour per 25m length, 2 m deep net) by time period. N = number of sets, STE = standard error (From Tallman et al. 1996c).

Time Period	Year	DATES	Mean CPUE	N	STE
1	1994	June 16 -June 30	0	5	0
2	1994	July 1 - July 15	0	4	0
3	1994	July 16 - July 31	0.5906	42	0.4747
4	1994	Aug. 1 - Aug. 15	3.3676	37	2.0796
5	1994	Aug. 16 - Aug. 31	6.0273	63	2.4133
6	1994	Sept. 1 - Sept. 15	10.1719	49	4.2684
7	1994	Sept. 16 - Sept. 30	7.4523	26	5.8756
8	1994	Oct. 1 - Oct. 15	13.5683	32	6.4670
9	1994	Oct. 16 - Oct. 31	0	2	0
10	1994	Nov. 1 - Nov. 15	0	2	0
11	1994	Nov. 16 - Nov. 30	0	4	0
12	1994	Dec. 1 - Dec. 15	0	4	0
13	1994	Dec. 16 - Dec. 30	0	4	0
14	1995	May 16 - May 31	0	6	0
15	1995	June 1 - June 15	0	28	0
16	1995	June 16 - June 30	0.1863	20	0.1863
17	1995	July 1 - July 15	0	26	0
18	1995	July 16 - July 31	0.1547	39	0.1547
19	1995	Aug. 1 - Aug. 15	1.8027	36	0.8586
20	1995	Aug. 16 - Aug. 31	0.9932	5	0.4555

Table B. The mean catch per unit effort of burbot (CPUE - number of fish per hour per 25m length, 2 m deep net) by time period. N = number of sets, STE = standard error. (From Tallman et al. 1996c)

Time Period	Year	DATES	Mean CPUE	N	STE
1	1994	June 16 -June 30	0.083	5	0.083
2	1994	July 1 - July 15	0	4	0
3	1994	July 16 - July 31	0.014	42	0.014
4	1994	Aug. 1 - Aug. 15	0	37	0
5	1994	Aug. 16 - Aug. 31	0.0029	63	0.002
6	1994	Sept. 1 - Sept. 15	0	49	0
7	1994	Sept. 16 - Sept. 30	0	26	0
8	1994	Oct. 1 - Oct. 15	0.024	32	0.011
9	1994	Oct. 16 - Oct. 31	0	2	0
10	1994	Nov. 1 - Nov. 15	0	2	0
11	1994	Nov. 16 - Nov. 30	0	4	0
12	1994	Dec. 1 - Dec. 15	0	4	0
13	1994	Dec. 16 - Dec. 30	0	4	0
14	1995	May 16 - May 31	0	6	0
15	1995	June 1 - June 15	0	28	0
16	1995	June 16 - June 30	0	20	0
17	1995	July 1 - July 15	0	26	0
18	1995	July 16 - July 31	0	39	0
19	1995	Aug. 1 - Aug. 15	0	36	0
20	1995	Aug. 16 - Aug. 31	0	5	0

Table C. The mean catch per unit effort of goldeye (CPUE - number of fish per hour per 25m length, 2 m deep net) by time period. N = number of sets, STE = standard error (From Tallman et al. 1996c).

Time Period	Year	DATES	Mean CPUE	N	STE
1	1994	June 16 -June 30	1.1333	5	0.7599
2	1994	July 1 - July 15	0	4	0
3	1994	July 16 - July 31	6.7262	42	1.4310
4	1994	Aug. 1 - Aug. 15	24.9315	37	11.8838
5	1994	Aug. 16 - Aug. 31	7.7156	64	3.9302
6	1994	Sept. 1 - Sept. 15	0.9629	48	0.3831
7	1994	Sept. 16 - Sept. 30	1.7405	26	0.8851
8	1994	Oct. 1 - Oct. 15	5.9697	32	2.0492
9	1994	Oct. 16 - Oct. 31	10.5982	2	1.7094
10	1994	Nov. 1 - Nov. 15	0	4	0
11	1994	Nov. 16 - Nov. 30	0	4	0
12	1994	Dec. 1 - Dec. 15	0	4	0
13	1994	Dec. 16 - Dec. 30	0	2	0
14	1995	May 16 - May 31	89.6136	6	47.6936
15	1995	June 1 - June 15	56.9072	28	17.1527
16	1995	June 16 - June 30	5.2228	20	1.7876
17	1995	July 1 - July 15	3.0925	26	1.2278
18	1995	July 16 - July 31	4.5068	39	1.2827
19	1995	Aug. 1 - Aug. 15	4.9309	36	1.5801
20	1995	Aug. 16 - Aug. 31	3.4179	5	2.3099

Table D. The mean catch per unit effort of lake whitefish (CPUE - number of fish per hour per 25m length, 2 m deep net) by time period. N = number of sets, STE = standard error.

Time Period	Year	DATES	Mean CPUE	N	STE
1	1994	June 16 -June 30	0.0667	5	0.0667
2	1994	July 1 - July 15	0	4	0
3	1994	July 16 - July 31	0.6741	42	0.2318
4	1994	Aug. 1 - Aug. 15	1.9191	37	1.2318
5	1994	Aug. 16 - Aug. 31	1.4480	63	0.4311
6	1994	Sept. 1 - Sept. 15	2.0678	49	1.1239
7	1994	Sept. 16 - Sept. 30	1.9883	26	0.7369
8	1994	Oct. 1 - Oct. 15	5.5053	32	1.4251
9	1994	Oct. 16 - Oct. 31	1.5384	2	1.5384
10	1994	Nov. 1 - Nov. 15	0	2	0
11	1994	Nov. 16 - Nov. 30	0	4	0
12	1994	Dec. 1 - Dec. 15	0	4	0
13	1994	Dec. 16 - Dec. 30	0	4	0
14	1995	May 16 - May 31	1.2053	6	0.4272
15	1995	June 1 - June 15	4.7148	28	1.1577
16	1995	June 16 - June 30	0.7904	20	0.4716
17	1995	July 1 - July 15	0.7226	26	0.3664
18	1995	July 16 - July 31	0.5206	39	1.2036
19	1995	Aug. 1 - Aug. 15	0.6956	36	0.2552
20	1995	Aug. 16 - Aug. 31	2.6310	5	1.2855

Table E. The mean catch per unit effort of northern pike (CPUE - number of fish per hour per 25m length, 2 m deep net) by time period. N = number of sets, STE = standard error. (From Tallman et al. 1996c).

Time	Year	DATES	Mean CPUE	N	STE
1	1994	June 16 -June 30	0.1333	5	0.1333
2	1994	July 1 - July 15	0	4	0
3	1994	July 16 - July 31	0.9807	42	0.2582
4	1994	Aug. 1 - Aug. 15	3.3301	37	0.9698
5	1994	Aug. 16 - Aug. 31	1.3821	63	0.6205
6	1994	Sept. 1 - Sept. 15	0.3534	49	0.5888
7	1994	Sept. 16 - Sept. 30	0.8323	26	0.3516
8	1994	Oct. 1 - Oct. 15	0.7692	32	0.7692
9	1994	Oct. 16 - Oct. 31	0	2	0
10	1994	Nov. 1 - Nov. 15	0	2	0
11	1994	Nov. 16 - Nov. 30	0	4	0
12	1994	Dec. 1 - Dec. 15	0	4	0
13	1994	Dec. 16 - Dec. 30	0	4	0
14	1995	May 16 - May 31	5.9855	6	2.2829
15	1995	June 1 - June 15	13.0979	28	4.0086
16	1995	June 16 - June 30	4.8163	20	1.2979
17	1995	July 1 - July 15	5.0989	26	0.9140
18	1995	July 16 - July 31	5.5693	39	2.2850
19	1995	Aug. 1 - Aug. 15	5.0060	36	0.9140
20	1995	Aug. 16 - Aug. 31	39.0742	5	37.7009

Table F. The mean catch per unit effort of flathead chub (CPUE - number of fish per hour per 25m length, 2 m deep net) by time period. N = number of sets, STE = standard error (From Tallman et al. . 1996c).

Time Period	Year	DATES	Mean CPUE	N	STE
1	1994	June 16 -June 30	0.1667	5	0.1667
2	1994	July 1 - July 15	0	4	0
3	1994	July 16 - July 31	0.1303	42	0.0719
4	1994	Aug. 1 - Aug. 15	0.5985	37	0.2823
5	1994	Aug. 16 - Aug. 31	0.1433	63	0.0888
6	1994	Sept. 1 - Sept. 15	0.5775	49	0.3782
7	1994	Sept. 16 - Sept. 30	0.1282	26	0.1282
8	1994	Oct. 1 - Oct. 15	0.0343	32	0.0343
9	1994	Oct. 16 - Oct. 31	0	2	0
10	1994	Nov. 1 - Nov. 15	0	2	0
11	1994	Nov. 16 - Nov. 30	0	4	0
12	1994	Dec. 1 - Dec. 15	0	4	0
13	1994	Dec. 16 - Dec. 30	0	4	0
14	1995	May 16 - May 31	13.3333	6	10.4439
15	1995	June 1 - June 15	4.7499	28	2.2423
16	1995	June 16 - June 30	0	20	0
17	1995	July 1 - July 15	0.1357	26	0.0791
18	1995	July 16 - July 31	0.3718	39	0.2441
19	1995	Aug. 1 - Aug. 15	0.0579	36	0.0412
20	1995	Aug. 16 - Aug. 31	0.9932	5	0.4555

Table G. The mean catch per unit effort of walleye (CPUE - number of fish per hour per 25m length, 2 m deep net) by time period. N = number of sets, STE = standard error (From Tallman et al. 1996c).

Time	Year	DATES	Mean CPUE	N	STE
1	1994	June 16 -June 30	0.4667	5	0.3266
2	1994	July 1 - July 15	0	4	0
3	1994	July 16 - July 31	5.9717	42	3.4347
4	1994	Aug. 1 - Aug. 15	10.2595	37	5.6682
5	1994	Aug. 16 - Aug. 31	3.3641	64	1.9340
6	1994	Sept. 1 - Sept. 15	1.8372	48	1.1033
7	1994	Sept. 16 - Sept. 30	4.4416	26	2.6962
8	1994	Oct. 1 - Oct. 15	9.5987	32	3.2089
9	1994	Oct. 16 - Oct. 31	0.7906	2	0.2350
10	1994	Nov. 1 - Nov. 15	0	2	0
11	1994	Nov. 16 - Nov. 30	0	4	0
12	1994	Dec. 1 - Dec. 15	0	4	0
13	1994	Dec. 16 - Dec. 30	0	4	0
14	1995	May 16 - May 31	15.5617	6	2.5468
15	1995	June 1 - June 15	9.6955	28	2.4229
16	1995	June 16 - June 30	0.8153	20	0.4264
17	1995	July 1 - July 15	2.1602	26	0.3933
18	1995	July 16 - July 31	1.7502	39	0.4298
19	1995	Aug. 1 - Aug. 15	0.3139	36	0.1605
20	1995	Aug. 16 - Aug. 31	3.2351	5	2.6086

Table H. The mean catch per unit effort of longnose sucker (CPUE - number of fish per hour per 25m length, 2 m deep net) by time period. N = number of sets, STE = standard error (From Tallman et al. 1996c).

Time Period	Year	DATES	Mean CPUE	N	STE
1	1994	June 16 -June 30	0	5	0
2	1994	July 1 - July 15	0	4	0
3	1994	July 16 - July 31	0.0423	42	0.0367
4	1994	Aug. 1 - Aug. 15	0.3378	37	0.2490
5	1994	Aug. 16 - Aug. 31	0.1589	63	0.1410
6	1994	Sept. 1 - Sept. 15	0.0105	49	0.0051
7	1994	Sept. 16 - Sept. 30	0.5292	26	0.3446
8	1994	Oct. 1 - Oct. 15	0.2066	32	0.1118
9	1994	Oct. 16 - Oct. 31	0	2	0
10	1994	Nov. 1 - Nov. 15	0	2	0
11	1994	Nov. 16 - Nov. 30	0	4	0
12	1994	Dec. 1 - Dec. 15	0	4	0
13	1994	Dec. 16 - Dec. 30	0	4	0
14	1995	May 16 - May 31	3.1111	6	1.2779
15	1995	June 1 - June 15	0.4609	28	0.2162
16	1995	June 16 - June 30	0.0400	20	0.0400
17	1995	July 1 - July 15	0.0540	26	0.0374
18	1995	July 16 - July 31	0.0250	39	0.0250
19	1995	Aug. 1 - Aug. 15	0.0884	36	0.0884
20	1995	Aug. 16 - Aug. 31	0	5	0

Appendix 2: Importance Index of Diets (From Tallman et al. 1996c)

Table A2. Relative Importance Index (George & Hadley, 1979) for Northern Pike.

Prey Items	% Number n=105	% Weight	% Frequency of Occurrence	Weighted % Frequency n=65	Relative Importance (RI) of Occurrence
FHCB	8.6	24.3	13.9	12.2	15.0
BRBT	8.6	16.8	13.9	12.2	12.5
LKWT	5.7	21.3	9.2	8.1	11.7
NTPK	8.6	10.0	12.3	10.8	9.8
NSST	21.0	0.2	1.5	1.3	7.5
ARLP	8.6	3.8	9.2	8.1	6.8
Sucker	2.9	11.5	4.6	4.0	6.1
GOLD	4.8	2.9	7.7	6.8	4.8
Amphipod	5.7	.0075	6.2	5.5	3.7
EMSH	4.8	0.02	6.2	5.5	3.5
SPSH	5.7	0.3	4.6	4.0	3.3
WALL	1.9	3.8	3.1	2.7	2.8
Plecoptera	2.9	.0033	4.6	4.0	2.3
Snake	1.0	3.1	1.5	1.3	1.8
Rodent	1.9	0.6	3.1	2.7	1.7
Damselfly L.	1.9	.0014	3.1	2.7	1.5
LKCS	.95	0.5	1.5	1.3	0.9
Bird	.95	0.4	1.5	1.3	0.9
TRPH	.95	0.04	1.5	1.3	0.8
LKWT YOY	.95	0.04	1.5	1.3	0.8
BRBT YOY	.95	0.02	1.5	1.3	0.8
Flying Insect	.95	.0036	1.5	1.3	0.8

Note: ( ) = order in ranking scale.

Table B2. Relative Importance Index (George & Hadley, 1979) for Walleye.

Prey Items	% Number n=50	% Weight	% Freq. of Occurrence n=30	Weighted % Frequency of Occurrence	Relative Importance (RI)
NTPK	20.0	33.4	20.0	17.6	23.7
ARLP	4.0	38.1	6.7	5.9	16.0
Plecopteran	18.0	0.2	20.0	17.6	11.9
Ephemeroptera	22.0	0.2	10.0	8.8	10.3
EMSH	4.0	6.1	6.7	5.9	5.3
LNSK.	6.0	5.2	10.0	8.8	6.7
FHCB	4.0	4.2	6.7	5.9	4.7
WALL	4.0	3.4	6.7	5.9	4.4
SPSH	2.0	7.4	3.3	2.9	4.1
Zygoptera	4.0	0.08	6.7	5.9	3.3
Trichoptera	4.0	0.05	6.7	5.9	3.3
Corxiidae	4.0	.0092	3.3	2.9	2.3
TRPH	2.0	1.5	3.3	2.9	2.1
NSST	2.0	0.1	3.3	2.9	1.7

Note: ( ) = order in ranking scale.

Table C2. Relative Importance Index (George & Hadley, 1979) for Inconnu.

Prey Items	% Number	% Weight	% Freq.	Wt %	RI
TRPH	50	48.4	50	50	49.47
NTPK	33.3	48.0	33.3	33.3	38.2
LNSK	16.7	3.6	16.7	16.7	12.33

Note: ( ) = order in ranking scale.

Table D2. Relative Importance Index (George & Hadley, 1979) for Lake Whitefish.

Prey Items	% Number	% Weight Occurrence	% Freq. of Occurrence	Wt %	Relative Importance (RI)
Ostracoda	75.7	4.6	60.0	18.0	32.8
Trichoptera	5.8	39.3	68.0	20.5	21.9
Hemiptera					
Corixidae	11.7	22.5	76.0	22.9	19.0
Gastropoda	11.7	17.2	24.0	7.2	8.5
Amphipoda	1.8	5.7	28.0	8.4	5.3
Coleoptera					
Dytiscidae	0.9	3.6	24.0	7.2	3.9
Diptera					
Chironomidae	2.2	0.9	16.0	4.8	2.7
Ceratopogonidae	0.04	0.02	4.0	1.2	0.4
Tabanidae	0.4	3.7	12.0	3.6	2.6
NSST	0.08	1.2	8.0	2.4	1.2
Damselfly L	0.04	1.1	4.0	1.2	0.8
Ephemeroptera	0.04	0.04	4.0	1.2	0.5
Oligochaeta	0.04	0.04	4.0	1.2	0.4

Note: ( ) = order in ranking scale.

Table E2. Relative Importance Index (George & Hadley, 1979) for Goldeye.

Prey Items	% Number	% Weight	% Frequency of Occurrence	Wt % Occurrence	Relative Importance (RI)
Plecoptera	46.5	10.1	56.7	34.7	31.19
Rodent	0.6	71.6	3.33	2.0	20.80
Corixidae	23.3	2.4	26.67	16.3	14.39
Dytiscidae	11.3	12.2	16.67	10.2	11.07
Trichoptera	4.4	0.8	13.33	8.2	5.10
Plant Material	3.1	0.7	13.33	8.2	4.73
Amphipoda	5.7	1.5	6.67	4.1	3.81
Hymenoptera	1.9	0.1	10.00	6.1	3.31
Flying Insects	0.6	0.2	3.33	2.0	1.13
Damselfly L.	0.6	0.1	3.33	2.0	1.12
Driftwood	0.6	0.1	3.33	2.0	1.12
Ephemeroptera	0.6	0.05	3.33	2.0	1.10
Chironomidae	0.6	0.03	3.33	2.0	1.10

The Northern River Basins Study was established to examine the relationship between industrial, municipal, agricultural and other development and the Peace, Athabasca and Slave river basins.

Over four and one half years, about 150 projects, or "mini studies" were contracted by the Study under eight component categories including contaminants, drinking water, nutrients, traditional knowledge, hydrology/hydraulics, synthesis and modelling, food chain and other river uses. The results of these projects, and other work and analyses conducted by the Study are provided in a series of synthesis reports.

This Synthesis Report documents the scientific findings and scientific recommendations of one of these components groups. This Synthesis Report is one of a series of documents which make up the North River Basins Study's final report. A separate document, the Final Report, provides further discussion on a number of scientific and river management issues, and outlines the Study Board's recommendations to the Ministers. Project reports, synthesis reports, the Final Report and other NRBS documents are available to the public and to other interested parties.

Synthesis Report