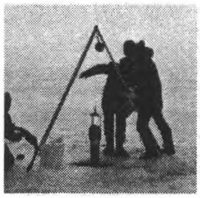
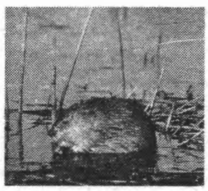
Canada Alberta Northwest Territories

Northern River Basins Study



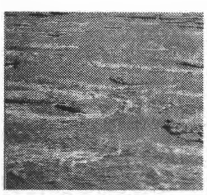




NORTHERN RIVER BASINS STUDY PROJECT REPORT NO. 118

LIFE HISTORY VARIATION OF INCONNU (*Stenodus Leucichthys*) AND BURBOT (*Lota lota*), LOWER SLAVE RIVER, JUNE TO DECEMBER, 1994



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by

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PREFACE:

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

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

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

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

F J Wrona ______ 14 May 96
(Dr. Fred J. Wrona, Science Director) (Date)

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

P. Larkin ______ 24 May /96
(Dr. P. A. Larkin, Ph.D., Chair) (Date)

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

Lucille Partington ______ May 29/96
(Lucille Partington, Co-chair) (Date)

Robert McLeod ______ May 21/96
(Robert McLeod, Co-chair) (Date)

LIFE HISTORY VARIATION OF INCONNU (*Stenodus leucichthys*) AND BURBOT (*Lota lota*), LOWER SLAVE RIVER, JUNE TO DECEMBER, 1994

STUDY PERSPECTIVE

To address cumulative environmental effects, the Northern River Basins Study Board identified fish distribution, abundance and movement as areas requiring further scientific investigation. Public input to the Board re-enforced this direction because, in many communities, fish remain peoples' most visible evidence on the health of the rivers. Except for short, isolated reaches of the Peace, Athabasca and Slave rivers, minimal information exists to assess the cumulative impacts of development on the fish community. The lower Slave River is one of these exceptions. In the early 1980's a comprehensive investigation of the fish community in the lower Slave River was completed. This database offered the Study an opportunity to assess possible changes.

The Slave River receives the combined flow of the Athabasca and Peace rivers, including the by-products of development discharged to their waters. The rapids at Fort Smith also serve to separate the fish community of the Slave in two; there is no evidence that fish downstream of the rapids have been able to move upstream into the Alberta portion of the Slave River. The fish community of the river reaches above and below the rapids are different. A number of the fish species are the basis of a domestic and commercial fishery on the Slave River and Great Slave Lake, respectively.

Related Study Questions

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

12) What traditional knowledge exists to enhance the physical science studies in all areas of enquiry?

13b) What are the cumulative effects of man-made discharges on the water and aquatic environment?

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

Under the auspices of the Food Chain Component, freshwater scientists developed a multi-faceted investigation into the movement, life history and diet of fish in the Northwest Territories portion of the Slave River, north of the 60oth parallel. The work was undertaken in such a manner that it could be compared to a mid-1980's investigations.

This project report describes the results of an investigation into the life cycle and population characteristics of two key harvested fishes, inconnu (*Stenodus leucichthys*) and burbot (*Lota lota*). The fish were monitored from June to December, 1994. Both species of fish are predators that feed on other fish. Consequently, they have the potential to biomagnify contaminants that may accumulate within fish tissue. They are also species likely to be the most vulnerable to change. Results indicated the inconnu that utilize the Slave River for spawning, generally show faster growth rates and mature at an earlier age than more northerly inconnu populations. The spawning population also tends to be younger with a more limited range in age structure. Conversely, burbot exhibited slower growth, later maturity and the population appeared to be relatively unexploited and unstressed. The project assessed inconnu as the species most vulnerable to environmental change due to the narrow range of its spawning year classes. Yet, burbot were considered the species most likely to bioaccumualte contaminants arising from localized pollution because of their restricted activity except during spawning.

The results of this project will be combined with the other complementary fish projects dealing with movement (Report # 117) and diet-food web investigations (Report # 119) in the form of a synthesis report that will compare current findings with those of the 1980's.

Report Summary

To determine the life cycle and demographic characteristics of the inconnu, *Stenodus leucichthys,* and burbot, *Lota lota* in the Slave River, Northwest Territories, we sampled between June and December, 1994. Inconnu are migratory utilizing the Slave River for spawning. They were most abundant in the river in late September and October. Based upon the gonadosomatic index, inconnu probably spawn in mid- to late-October in the Slave River. Burbot appear to be highly sedentary in the open water season because few were caught until December under ice cover. Inconnu had faster growth rates and earlier age-at-maturity (ages 5-7 for males and 7-9 for females) than more northerly inconnu populations. In contrast, burbot matured later (age 5) and grew more slowly than other populations. Inconnu mean fecundity-at-age was between 108,086 to 124,493 eggs per female. Based on the demographics of the two species in the Slave River, inconnu would be more vulnerable to environmental change.

Acknowledgements

George Low, Area Biologist and Fred Taptuna, Fisheries Technician, Department of Fisheries and Oceans, Hay River, provided invaluable advice, physical assistance and equipment for the project. They also provided considerable support in terms of setting up a joint contract with the Fort Smith band to hire local aboriginal assistants. Mr. Dale Archibald, Fishery Officer in charge at Hay River graciously allowed us to use the truck assigned to him for most of the study. The rest of the staff at the Hay River Office provided a base of support that made the study go much more smoothly. Mr. Kevin Antoniak of Arctic College in Fort Smith provided helpful advice and support as well as access to the college facilities. The Salt Plain First Nation of Fort Smith, in particular, Don Lapine, selected local helpers and administered a contract for their pay. The Deninu Kue First Nation of Fort Resolution also selected local helpers and administered a contract for their pay. Fred MacDonald, and Stewart Tourangeau of Fort Smith and Darwin and Tom Unka of Fort Resolution provided able field assistance. DFO research biologist F. Saurette coordinated the acquiring of equipment, ensuring that field equipment was delivered in a timely fashion and kept in good repair, handled financial records, and did just about everything else to ensure that field work and laboratory work went smoothly with continuity. Alison Little, Trevor Thera, Fern Saurette and Marc Lange provided professional direction in the field. Tom Mill, the food chain component leader provided much needed encouragement at the end of this study. Ken Crutchfield, the associate science director of the NRBS provided helpful feedback and direction regarding client-related issues in Fort Smith as well as good advice regarding record keeping requirements. Glen Hopky, Jim Reist and George Low of the Department of Fisheries and Oceans provided helpful reviews of earlier versions of the manuscript. Melanie Van Guerwen gave a final editorial check of the manuscript.

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1.0 INTRODUCTION

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 aquatic food chains. As such, they can be most severely affected by anthropogenic stresses, such as the bio-magnification of contaminants. These same species can also be important as food for humans. This can result in serious health concerns, especially for regular, long-term consumers of tainted fish (e.g., Jacobson et al. 1990). Toxicants can also affect fish populations, both via acute poisoning and chronic exposure (Coburn et al. 1993). 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. So, also are changes in the average size, flesh quality, condition and other indicators of sub-lethal effects of environmental changes.

The Slave River and its delta is the least studied of the three watersheds with major deltas in the Mackenzie River Basin (Tripp et al. 1981). Recently, Boag and Westworth (1993) studied the Alberta portion of the Slave River Alberta focussing mainly on fish inventory, especially on species considered important to sportfishing. They noted that the sportfish catches in this 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, nor were results of tagging in terms of movements mentioned in the report. There has been no recent assessment of the fish populations in the lower Slave River north of 60° latitude. 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 leuichthys*), lake whitefish (*Coregonus clupeaformis*), burbot (*Lota lota*) and walleye (*Stizostedion vitreum*) (Tripp et al. 1981). The abundance of highly palatable species provides the basis for commercial and subsistence fishing operations. The presence of spawning habitats of highly valued species downstream of proposed industrial developments to the south led Katapodis and Yaremchuk (1994) to designate the lower Slave River system as being highly vulnerable to resource development.

Fish have traditionally been an important source of food for the people of Fort Resolution, providing up to 40% of their own, and 100% of their dogs' food supply (Bodden 1980). Based on Bodden (1980) lake whitefish and inconnu were the most highly prized fish for both humans and dogs, followed by burbot, walleye and, to a lesser extent, northern pike and longnose sucker (*Catostomus catostomus*). A few people fish throughout the year in the Slave River Delta, but fishing intensity is generally greatest during the fall spawning migrations of the major species in the Slave Delta, in particular, lake whitefish, inconnu and burbot (Bodden 1980). Of an estimated 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).

A substantial fall subsistence fishery exists, also, in the vicinity of Fort Smith (McLeod *et al.* 1985). Inconnu contributed the greatest yield to the 1983-84 domestic catch (43.8% and 49.1% of the total catch by weight, respectively) although lake whitefish were numerically more abundant. A significant subsistence fishery for burbot, taking approximately 4408 kg in 1984-85 was recorded at the Cunningham Landing/Salt River area of the Lower Slave River (McLeod *et al.* 1985). MacDonald and Smith (1993) found that inconnu had the highest subsistence harvest, followed by lake whitefish and burbot during the early 1990's. They also identified additional key species to monitor: northern pike, walleye, goldeye, white sucker (*Catostomus commersoni*) and longnose sucker.

The Slave River is considered important to the commercial and subsistence fisheries in Great Slave Lake because many important species in the river and its delta spend part of the year or part of their lives in the lake environment (G. Low, Area Biologist, Hay River, Pers. comm.). 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 commercial species have been lake whitefish, inconnu, walleye and burbot (C. Day, Dept. of Fisheries and Oceans, Pers. Comm.).

Compounds such as organochlorines are susceptable to biomagnification (Begon et al. 1990). Biomagnification is an increasing concentration of toxicant at higher trophic levels, as a result of a repeated cycle of concentration of the insecticide in particular tissues in a lower trophic level, consumption by the trophic level above, further concentration, further consumption, and so on, until top predators suffer extraordinarily high doses (Begon et al. 1990). For example, contaminants may be absorbed by aquatic vegetation or be absorbed into detritus. These materials become food for the invertebrate community in the river which, in turn, are food for the forage fish. The smaller invertebrate feeding species are eaten by larger predators such as inconnu or burbot. At each step the toxin is not excreted and accumulates in the tissues.

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, since lake whitefish are not piscivores, they are less vulnerable to accumulation of toxic materials. Among the others species, lake trout does not occur in the Slave River and pike are less preferred for eating than the other species. Thus, inconnu, walleye and burbot are most suitable for detailed study because they are piscivorous throughout most of their lives, these species are abundant in the Slave River and they important for both commercial and aboriginal subsistence harvest. Of these three species, the least known are burbot and inconnu.

Inconnu is a top predator in the fish community of the Slave River, N.T. (Scott and

Crossman 1973). Therefore, if the Slave River system becomes affected by contaminants, the flesh of inconnu may accumulate high concentrations. In the Slave River, inconnu is the most heavily harvested species for subsistence by aboriginal and non-aboriginal fishermen (Tripp et al. 1981; Bodden 1980; Jalkotsky 1976); the Slave River stock is also thought to be the main source of fish for the second largest commercial fishery on Great Slave Lake (Day and Low 1995; Katapodis and Yaremchuk 1994). Burbot is also a principal predator in the fish community (Scott and Crossman 1973; Boag and Westworth 1993) and as such has the potential to accumulate high concentrations of toxicants. In the Slave River, burbot are harvested for subsistence and their livers are consumed by aboriginal people (MacDonald and Smith 1993). Ergo, contamination of either inconnu or burbot could have a significant impact on human health.

The impact that environmental stressors, including toxicants, has on the fish themselves depends upon how it affects their biological productivity parameters. The genetic basis of life history traits of each species which directly influence population demographics, such as size-at-age, age-at-maturity, age-structure, fecundity, and egg size are the products of evolution and the phenotypic expression of these will vary, also, in relation to the prevailing environment (and to each other). Therefore, the expression of these traits should integrate the effects of cumulative impacts of ecosystem stress on fish populations. For example, size-at-age is a key trait - any change in the environment that influences size-at-age (e.g., changes that result higher mortality based on size such as increased bio-concentration of contaminants, predator search behaviour or fishing) will likely cascade down to other traits such as age-at-maturity and fecundity. Smaller size-at-age may cause age-at-maturity to be delayed a year or more and age-specific fecundity (and therefore lifetime reproductive potential) to be greatly reduced. Thus, to understand the effects of ecosystem change on fish one must understand their demographics.

While there has been useful work on the fish populations of the Slave River, there is only limited information and analysis on demographic and life history traits of fish in the system. Some information is available on the life cycles (that is the general description of the important events and transitions in the life of the organism) of various species in the Slave River delta area (Tripp et al. 1981). However, the limited samples were taken . For example, a full analysis of life history traits (size at age, age-specific fecundity, egg size and maturity) was only achieved for nine inconnu. Growth information was provided for 143 burbot, but only 20 fish were analyzed fully. A later study provided some data, but no analysis was undertaken for growth rate and age-at-maturity of inconnu, lake whitefish and burbot (McLeod et al. 1985). No data were provided for age-specific fecundity or egg size. These life history traits are the keys to understanding population growth and mortality rates, and thus, stock productivity. Usually minimum sample sizes of 200 or more fish per stock per species are considered necessary for this type of analysis (S. Gavaris, Canadian Atlantic Fisheries Stock Assessment Chairman, DFO, St. Andrews, NB, pers. comm.).

In this report we characterize the variation in life history traits important to biological productivity in two of the key fish species in the Lower Slave River; inconnu and burbot -

more specifically we describe size at age, the seasonal pattern of sexual maturity development with time, age at maturity, size and age-specific fecundity and the population age structure of these species.

2.0 MATERIALS AND METHODS

2.1 Study Area

The Slave River is, by far, the largest tributary into Great Slave Lake (Figure 1). The Taltson River, the next largest river, contributes only approximately 1/20th as much water to Great Slave Lake. The Slave River, turbid and fast flowing, is connected to the Peace and Athabasca River systems to the south (Brunskill 1986). The main channel is up to one km across with depths ranging from less than a meter to 25 meters. The lower 300 km stretch between Fort Smith and the Slave River delta is relatively featureless. The 25 km stretch upstream and past Fort Smith, has many rapids and deep pools, whereas the Slave delta is a maze of variable-sized channels and islands with heavily vegetated banks. There is a diverse fish community in the river with up to 25 species having been recorded in the lower Slave River (McLeod et al 1985, Tripp et al 1981).

The Slave River is divisible into three major sections: the river above the series of rapids between Fort Fitzgerald and Fort Smith ending in the Rapids of the Drowned, the lower Slave River and the Slave River Delta. The Rapids of the Drowned is important biologically because they likely are a barrier to the passage of fish species. For example, the Rapids of the Drowned are the furthest upstream occurrence of the inconnu which is primarily an arctic species.

2.2 Collection of fish:

To obtain samples of inconnu and burbot from the lower Slave River, nets were set for periods of 12 to 24 hours in 5 locations (Fig. 1): 1) Rapids of the Drowned (Fort Smith); 2) Cunningham Landing; 3) Salt River; 4) Buffalo crossing; and 5) Res-Delta Channel of the Slave River delta, during the summer, fall and winter of 1994. Exact sampling periods are listed in Appendix. Additional sampling for burbot using set lines was done at Fort Smith and the Slave River Delta during the week of December 10, 1994.

Netting was conducted using floating gillnets set in back-eddies of the river. Nets were 25 and 30 meters in length, 1.8 and 2.4 meters deep and of six mesh-size patterns: 1) 140mm stretch mesh (25 m); 2) 133mm stretch mesh (25 m); 3) 114mm stretch mesh (25m); 4) 102mm - 89mm - 76mm (3x10m); 5) 63.5mm - 51mm - 38mm (3x10m); 6) 102mm -89mm - 76mm - 63.5mm - 51mm - 38mm (6x10m).

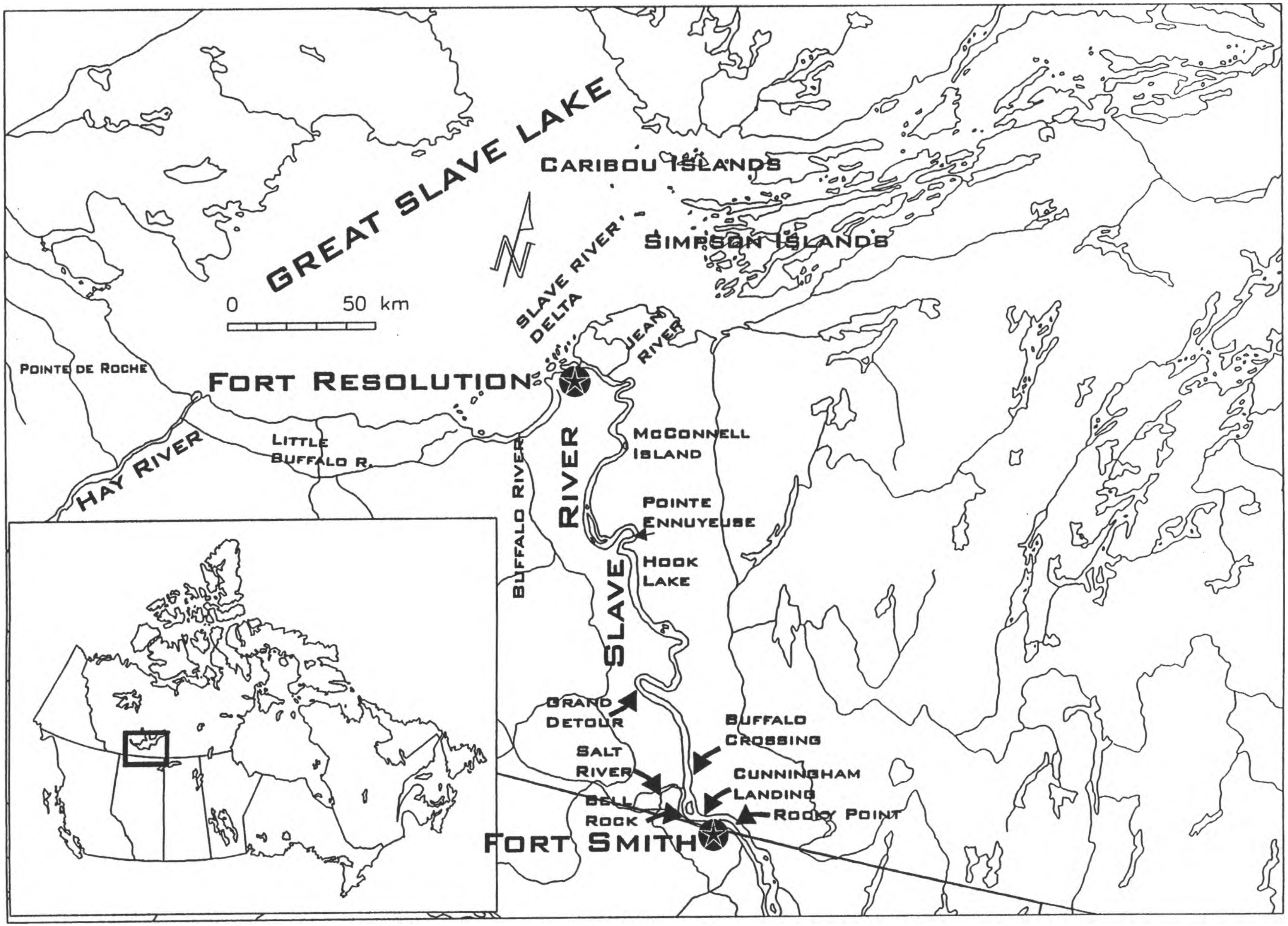

Figure 1. The study area showing the Slave River, Slave River Delta, Great Slave Lake, Fort Resolution and Fort Smith.

2.3 Determination of Catch-Per-Unit-Effort (CPUE)

To quantify the seasonal changes in abundance and thereby stratify our sampling and analysis appropriately, we calculated catch-per-unit-effort (CPUE). The netting periods were selected to permit an unbiased estimate of domestic catch of inconnu which exhibited a defined movement into and out of the area during the survey period. The CPUE was standardized to a 25 meter net length. Net length was standardized assuming a constant change in effort directly correlated to the net length. Thus, the catch for a set with a 30m net was multiplied by 25/30 to convert to 25m. Net depth was standardized in the same manner to 1.8 meter deep net. The catch/effort ratio was calculated for each set by dividing the standardized catch for that set by the soak time (in hours).

Results were analyzed using the following variables: netting periods, locations and mesh size. The netting periods were: 16-30 June, 16-31 July, 1-15 August, 16-31 August, 1-15 September, 16-30 September, 1-15 October, 15-31 October, November 1-15, November 16-30 and December 1-15. Where only a portion of days were covered in the time period (e.g. 16-30 June) the total was extrapolated assuming the sampling days could represent the pattern of variation for the entire time period. The net locations were: Area 1 Fort Smith - Rapids of the Drowned; Area 2 - Cunningham Landing; Area 3 - Salt River; Area 4 - Buffalo Crossing; and Area 5 - the Slave River delta (Fig. 1).

Results were analyzed using a factorial design analysis of variance (Kuttner *et al.*, 1989) with factors of netting period, net location, and mesh size as part of the model. The model was :

$$CE = \mu + TP + L + MS + TPxL + TPxMS + LxMS + TPxLxMS + E$$

where: CE = CPUE (unstandardized for mesh size)

μ = The overall mean CE

TP = the effect of Time Period

L = the effect of Location

MS = the effect of Mesh Size

TPxL = TP by L interaction

TPxMS = TP by MS interaction

LxMS = L by MS interaction

TPxLxMS = TP by L by MS interaction

E = the residual variance including unexpliained effects and error variation

To plot the CPUE, the catches were standardized to the most common mesh size - 140mm. Standardization was done by estimating for each mesh size the catchability of inconnu relative to the 140mm mesh size.

Physical factors that could potentially influence fish movements were systematically recorded at each study area during the 1994 open water study period. Water temperature was recorded at each sampling event and location (i.e. each net pull). Information on river levels and discharge for the Fort Smith area was obtained from the Water Survey of Canada Station at Fort Fitzgerald (Station 07NB001). We calculated the product-moment correlation (Sokal and Rohlf, 1981) between each of these environmental variables and the abundance of inconnu in the system. The formula for this calculation is as follows:

$$r_{jk} = \frac{\sum y_j y_k}{(n - 1) s_j s_k}$$

Where Y_j and Y_k are variables and s_j and s_k are the standard deviations about the mean of variables Y_j and Y_k, respectively.

2.4 Fish processing

The following biological data were collected from individual fish for determination of life history characteristics: fork length (nearest mm), total weight (nearest g), and gonad weight (nearest g) were measured; aging structures (scales, pectoral fin rays, and otoliths) were saved for later examination; sex and stage of maturity were qualitatively determined (see Appendix 2 for description), and ovaries of all mature females were preserved in 5% formalin for fecundity estimates.

2.5 Life History Characteristics

Inconnu - *Age determination*: Ages of inconnu were determined from a single reading of otoliths, prepared using the break-and-burn method (Chilton and Beamish 1982). An aging comparison has never been done for inconnu, however, comparisons of aging structures in broad whitefish (*Coregonus nasus*) (a member of the same sub-family as inconnu) suggest that otoliths can be read most accurately and require the least amount of preparation time before reading (J. Babaluk and R. Wastle, Freshwater Institute, pers. comm.).

Back-calculation of growth: Inconnu were collected within the Slave River itself, so the majority of fish captured were spawners migrating upstream to spawning sites. Consequently, there were no fish under six years of age. To construct complete growth curves of inconnu from the Slave River population, we back-calculated size-at-age of juveniles from otoliths, using the direct proportion method (Lea 1910; Schramm *et al.* 1992). An Optical Pattern Recognition System was used to measure growth increments on otoliths. The following equation was used to estimate, or "back-calculate", body size from growth increments on otoliths: $L_i = (O_i/O_c)(L_c)$, where L_i= back-calculated length at annulus i, O_i = size of otolith at annulus i, O_c=size of otolith at time of capture, L_c= length of fish at capture.

Fecundity and Egg Size: Fecundity was determined for 30 female inconnu collected in 1994. Inconnu are reported to have high fecundities, ranging from 130,000 to 400,000 eggs (Nikol'skii 1954; Alt 1977). We therefore chose to estimate fecundity by counting three sub-samples of 200 eggs each. Sub-samples and remaining eggs were air-dried to a constant weight. Fecundity was then determined by multiplying the ratio of total egg weight to sub-sample weight by the number of eggs in the subsample. Individual egg weight was determined by dividing the mean subsample weight by 200. Because most of the existing literature on inconnu reports egg diameter as a measure of egg size, we also measured diameter of preserved eggs in the lab by aligning ten eggs along a measuring trough (Morin et al. 1982). This was done four times for each fish. Egg diameter was measured in the field, prior to preservation, for 20 fish; this allowed us to calculate the amount of shrinkage that occurs with preservation.

Burbot - *Age determination*: Burbot ages were determined from a two readings of the broken surface of the otolith after burning. Burbot otoliths are very large like Atlantic cod (*Gadus morhua*) otoliths. They are relatively easy to read.

Fecundity and Egg Size: Fecundity was determined for 40 female burbot collected in 1994. Burbot fecundities have been reported to range from 45,600 to 1,326,000 eggs per female (Scott and Crossman 1973). We used the same protocol as for inconnu.

3.0 RESULTS

3.1 Life cycle - Inconnu

Pattern of migration - Inconnu first appeared in the Slave River near the beginning of August, 1994 (Table 1, Fig. 2). The run peaked between September 1 and September 15 and again between October 1 and 15, 1994. The run was estimated to have ended in the latter part of October. However, due to the formation of the ice few sets were made during this period. By October 21 most inconnu appeared to had left the Slave River.

Time period had a significant effect ($p = 0.0454$) on the CPUE while meshsize did not ($P = 0.1667$). All interactions (e.g. timeperiod by meshsize) were non-significant ($P = 0.7982$).

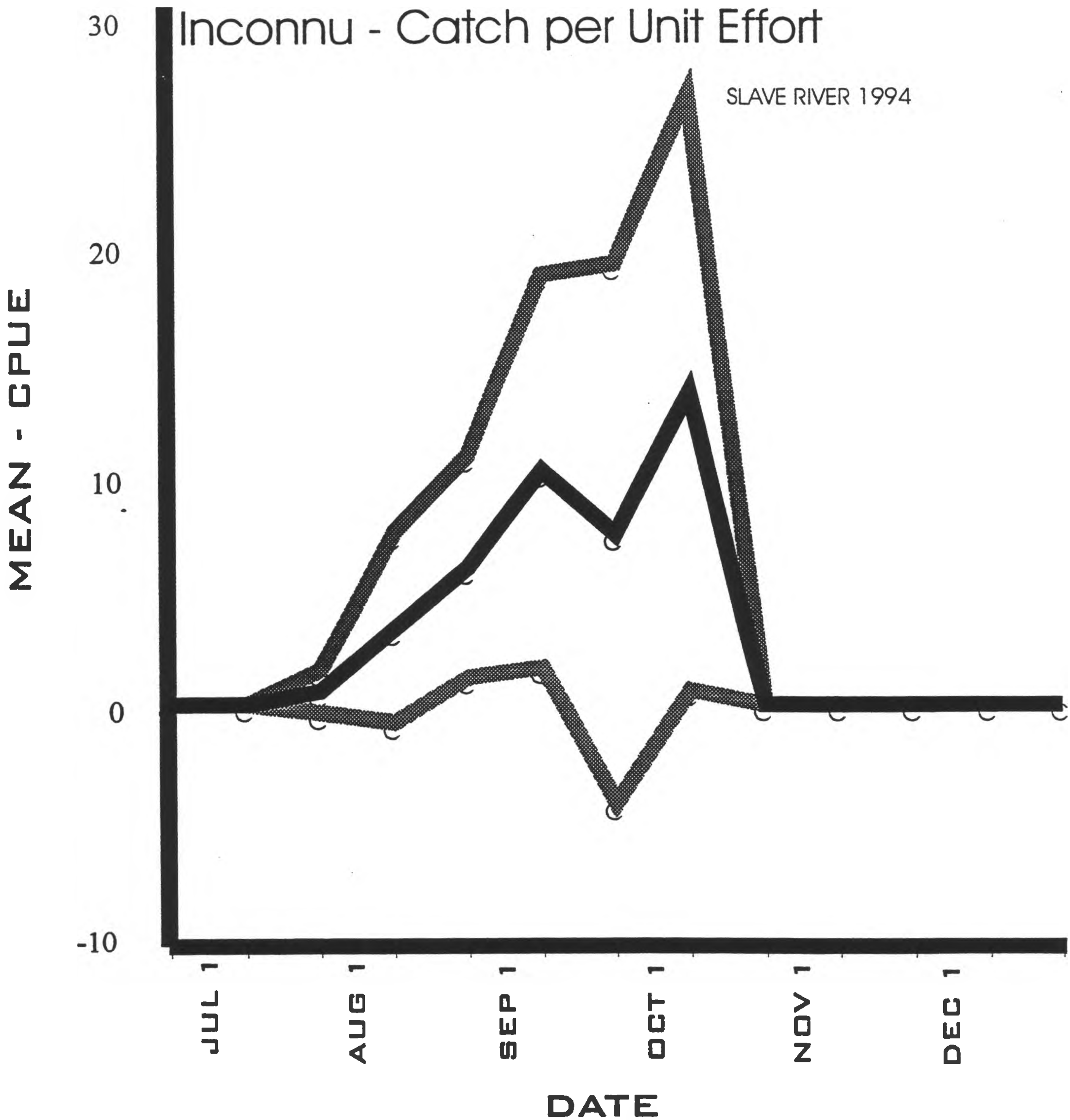

Figure 2. Catch-per-unit-effort (CPUE) (number of fish per hour for standardized net) of inconnu in the lower Slave River in 1994 against calendar date - Solid dark line is the mean CPUE - outside lighter lines are 2 standard errors from the mean.

Table 1. The mean catch per unit effort (CPUE = number of fish per hour per 25m length, 2 m deep net) of inconnu from the Slave River in 1994 by time period. N = number of sets, STE = Standard Error.

Time Period	DATES	Mean CPUE	N	STE
1	June 16 - June 30	0	5	0
2	July 1 - July 15	0	5	0
3	July 16 - July 31	0.591	42	0.4747
4	Aug. 1 - Aug. 15	3.368	37	2.0796
5	Aug. 16 - Aug. 31	6.027	63	2.4133
6	Sept. 1 - Sept. 15	10.171	49	4.2684
7	Sept. 16 - Sept. 30	7.452	26	5.8756
8	Oct. 1 - Oct. 15	13.568	32	6.4670
9	Oct. 16 - Oct. 31	0	2	0
10	Nov. 1 - Nov. 15	0	2	0
11	Nov. 16 - Nov. 30	0	4	0
12	Dec. 1 - Dec. 15	0	4	0
13	Dec. 16 - Dec. 30	0	4	0

Inconnu first entered the system 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 (Fig. 3). They exited at much lower temperatures with the last fish leaving when the water temperature was around 5° C. There was 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) (Fig. 4). The discharge level fell steadily throughout the fall to a level of 2000 cubic meters per second. There was no significant correlation between inconnu abundance and discharge level in the system (Pearson = -.009, $P = 0.9765$).

Pattern of gonad development - Gonadosomatic Index (GSI) values were calculated using the following equation: GSI = (Gonad weight/Body weight)* 100. The gonadosomatic index provides a quantitative measure of ovarian or testicular development, increasing as fish near the time of spawning and decreasing substantially after spawning. Changes are most pronounced in females. Inconnu female GSI increased throughout the summer and early fall prior to spawning (Fig. 5) . Male inconnu GSI, contrary to what would be expected, appears to decrease prior to spawning (Fig. 6). We offer two possible explanations for this: 1) Inconnu collected after September 2 were frozen and later sampled at the Freshwater Institute in Winnipeg - the testes may have shrunk proportionally more than the rest of the carcass during freezing, which could have resulted in lower GSI values for fish collected in the fall; 2) Males began to release milt before the main spawning event took place, resulting in weight loss of the testes. This latter possibility was based on observation that the male inconnu began releasing milt before the females were ripe when we held males and females in holding pens prior to spawning. This phenomenon was also observed among male coregonids in the Lower Mackenzie River, where males that arrived at spawning areas earlier than the females began releasing milt before females were ripe (R. Tallman and K. Howland, pers. observations). The reason for this behaviour is unknown.

3.2 Life cycle - Burbot

Pattern of migration - Burbot were only occasionally captured in the gillnets, thus, their apparent abundance was quite low (Fig. 7). This might have reflected their lack of numbers or their lack of movement during most of the season. Burbot were more readily caught using set lines which is the method is 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 for this species.

Pattern of gonad development - Gonadosomatic Index (GSI) values were calculated using the following equation: GSI = (Gonad weight/Body weight)* 100. Nearly all burbot were caught in December. Therefore, the seasonal development of the GSI can not be reported.

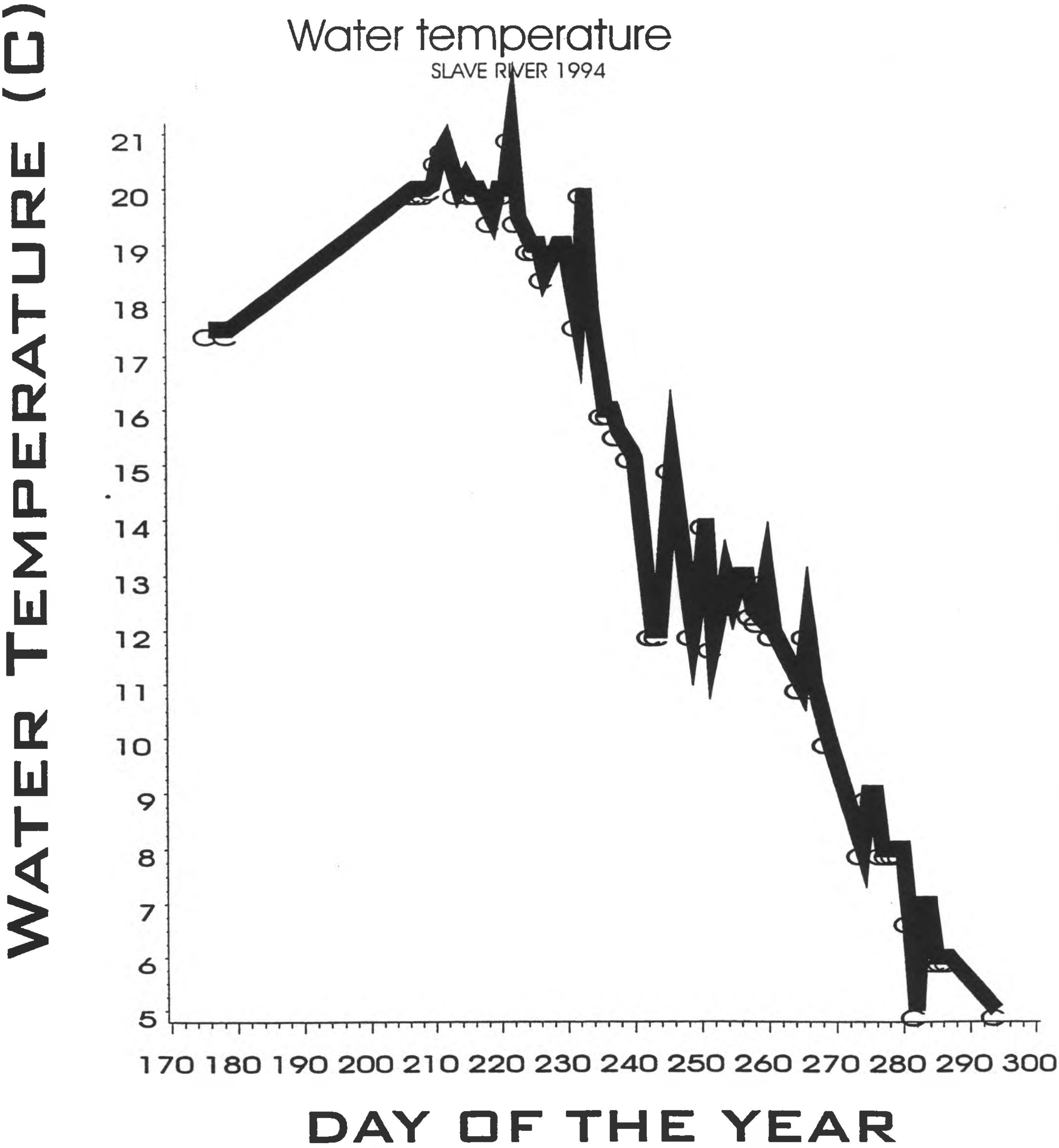

Figure 3. Water temperature (C - degrees Celsuis) against calendar date for the Slave River in 1994.

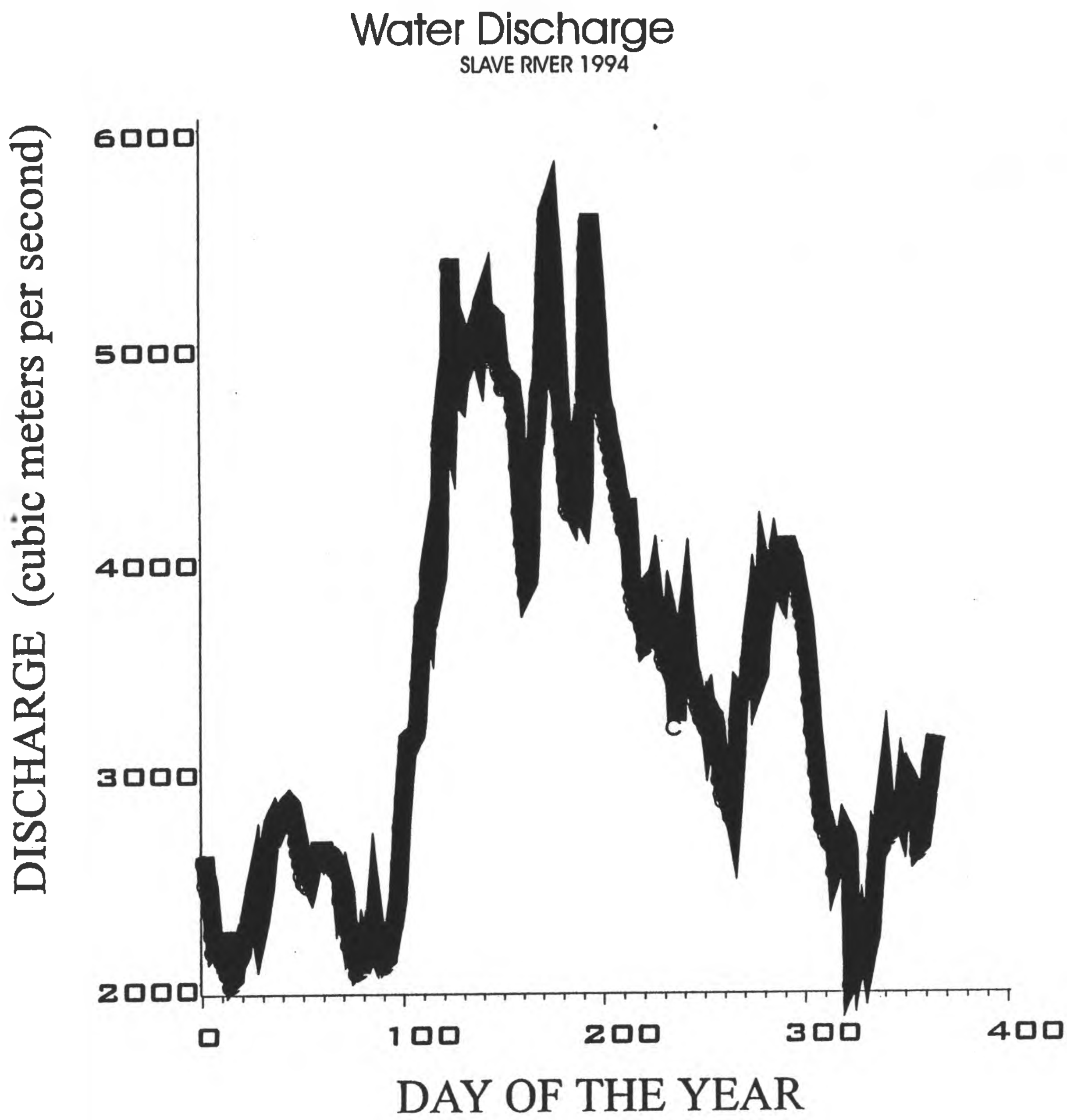

Figure 4. Water discharge in the lower Slave River in 1994.

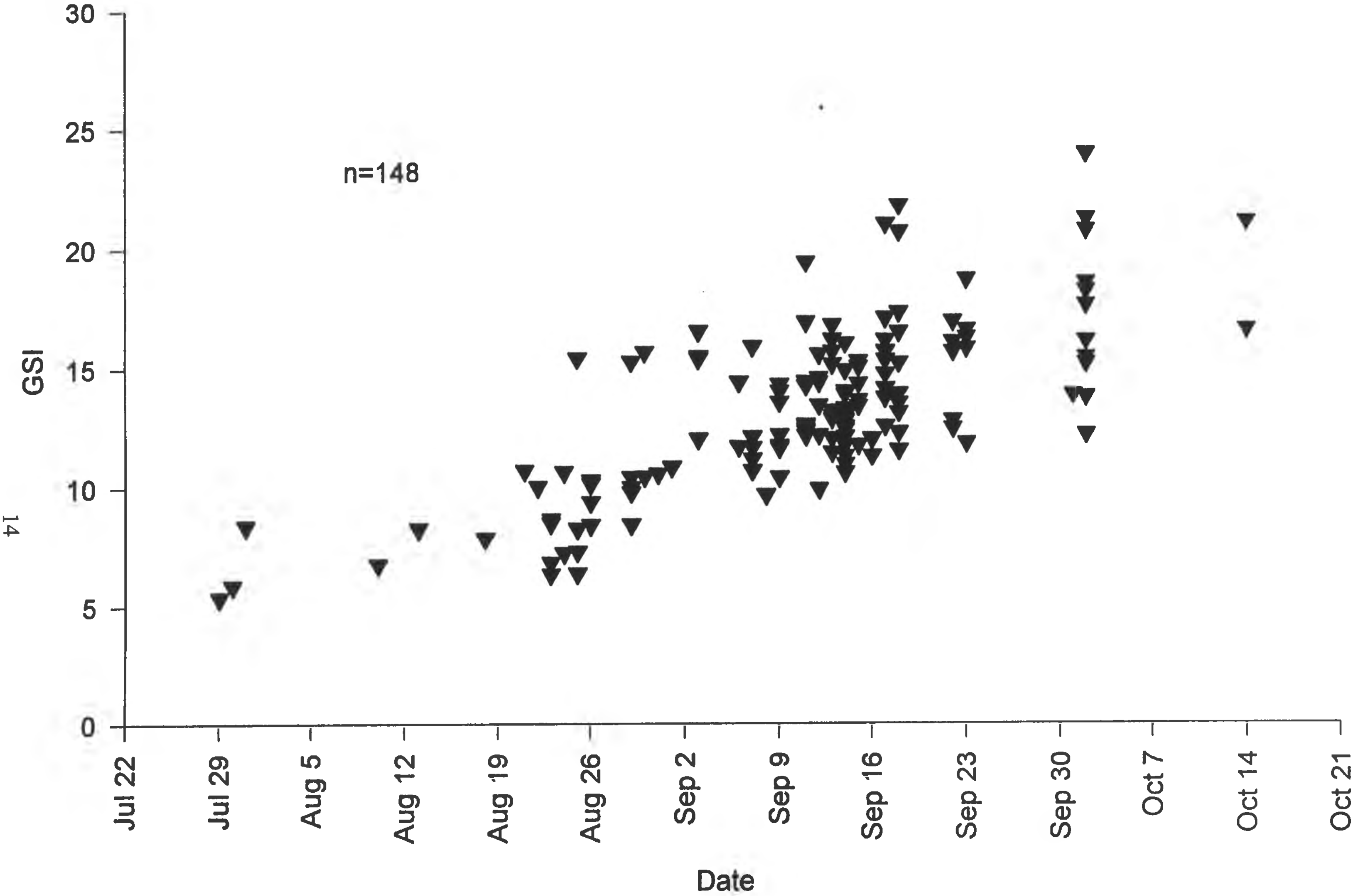

Figure 5. Seasonal pattern of gonad development in prespawning female inconnu collected in the Slave River in 1994.

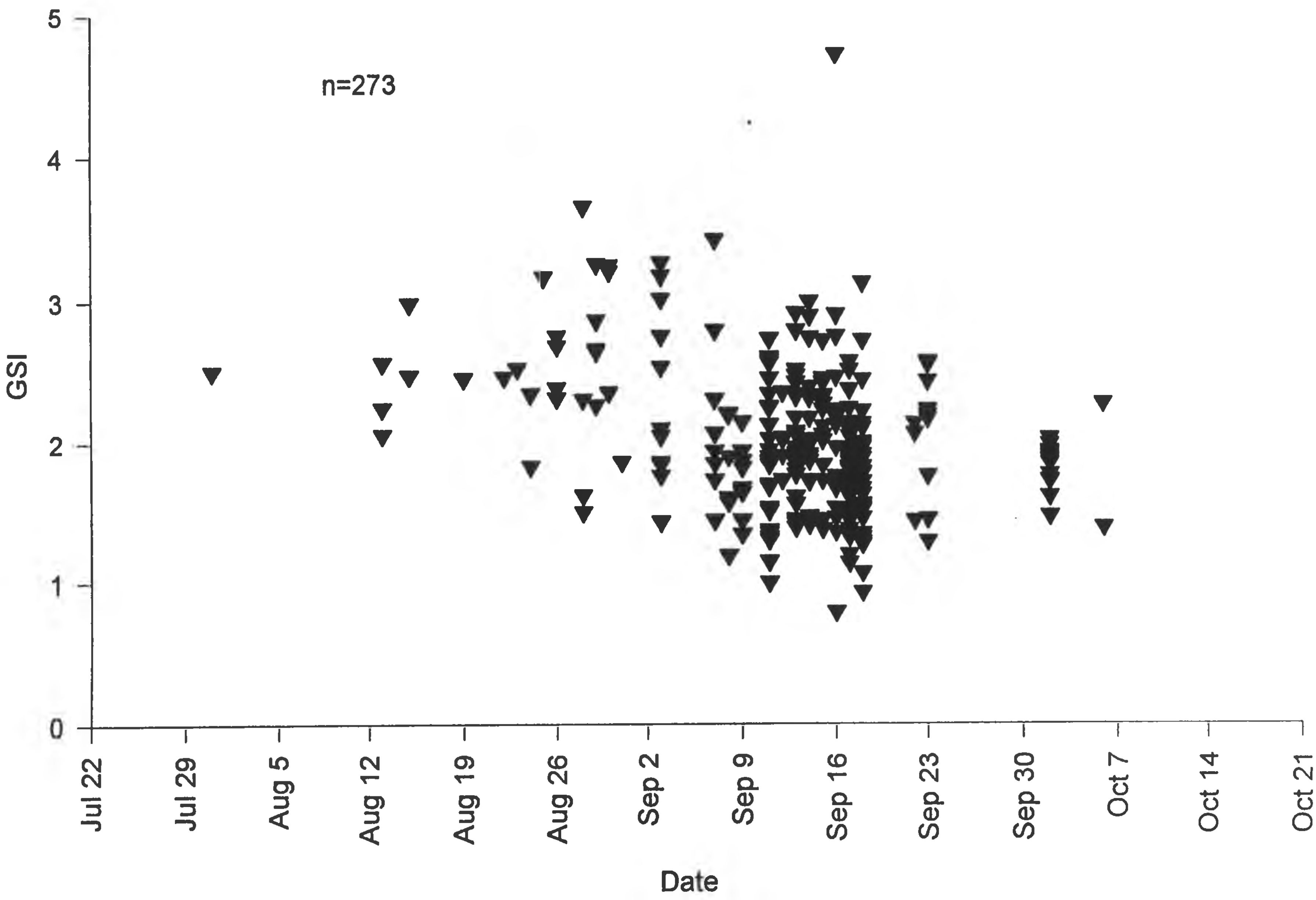

Figure 6. Seasonal pattern of gonad development for prespawning male inconnu collected in the Slave River in 1994.

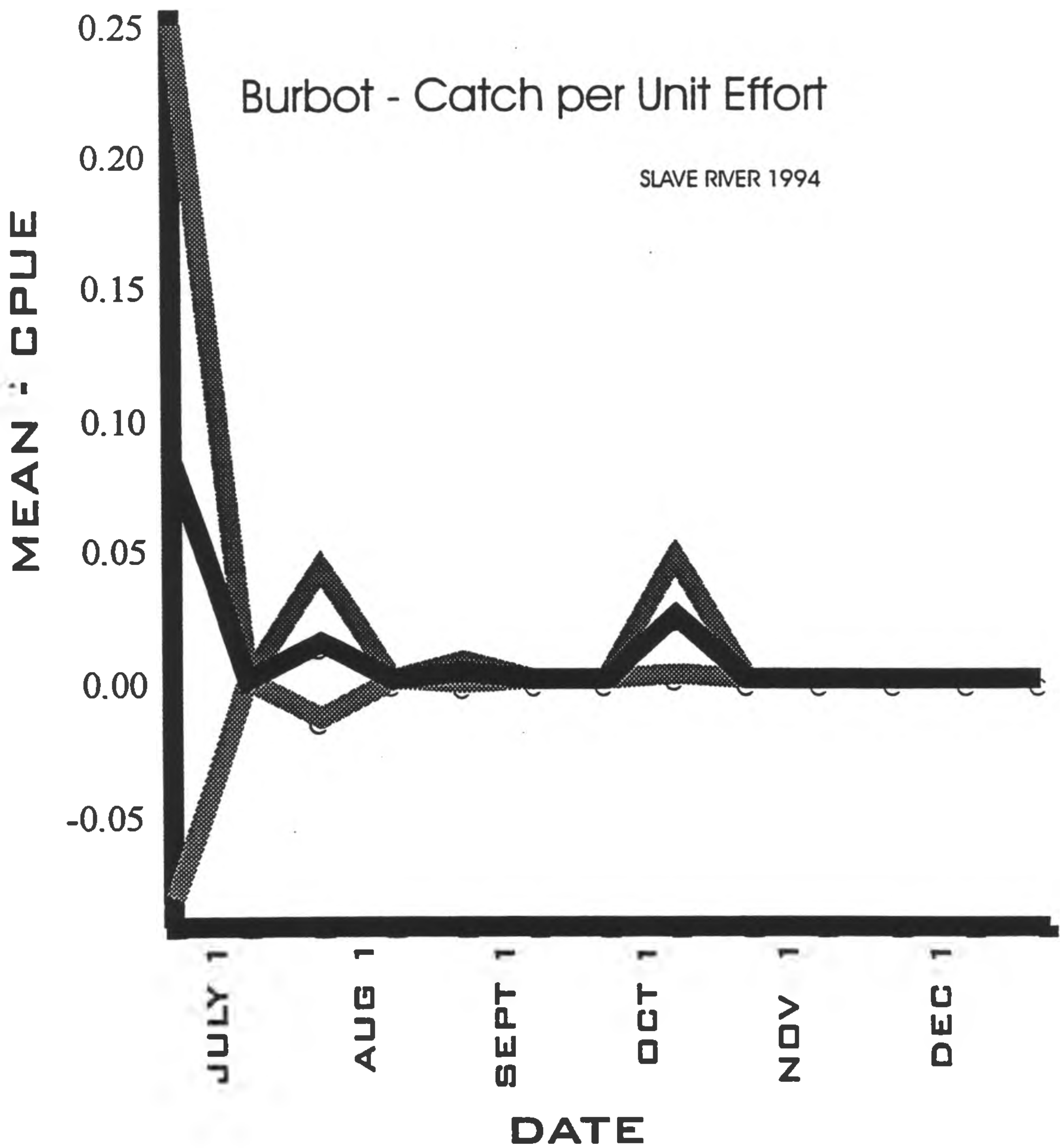

Figure 7. CPUE of burbot in the lower Slave River in 1994 against calendar date.

The GSI values plotted against age are shown in Figure 8. If we classified fish with less than 5% GSI as immature then it appears that burbot as young as age five can be sexually mature and that most fish are in pre-spawning condition in Decmber, between 10 to 15% GSI.

3.3 Life History Characteristics - Inconnu

Growth (length-at-age) - All inconnu captured during our 1994 sampling were mature fish associated with the fall spawning run. Mature females from this population reach a greater length at age than males. To provide a more complete range for length-at-age, we included data from a sample of 50 inconnu collected at the mouth of the Slave River by DFO Hay River personnel in the spring of 1993. This sample included juvenile fish under the age of six. To further increase the range for length-at-age we also included data from back-calculated lengths, the results of which are shown in Figures 9 (males), 10 (females) and 11 (both sexes). The complete growth curves (Fig. 11) 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.

Age-at-maturity - For northern fishes that do not spawn yearly 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). For this particular study the age-at-maturity was considered to be the age at which mature fish first showed up in the spawning population. The distribution of ages for mature inconnu (Fig. 12) 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; whereas, females first appear in the spawning population at age 7 and become most abundant at age 9.

Age structure - Age-frequency distributions of inconnu from the Slave River (Fig. 12) 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 for males, and 8 and 9 for females. Females appear to be longer-lived than males.

Fecundity - 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. 13A), but had no clear relationship with age (Fig. 13B). Mean and standard deviation for age-specific fecundities are listed in the Table 2. Both mean fecundity and the variation around the mean increased with age.

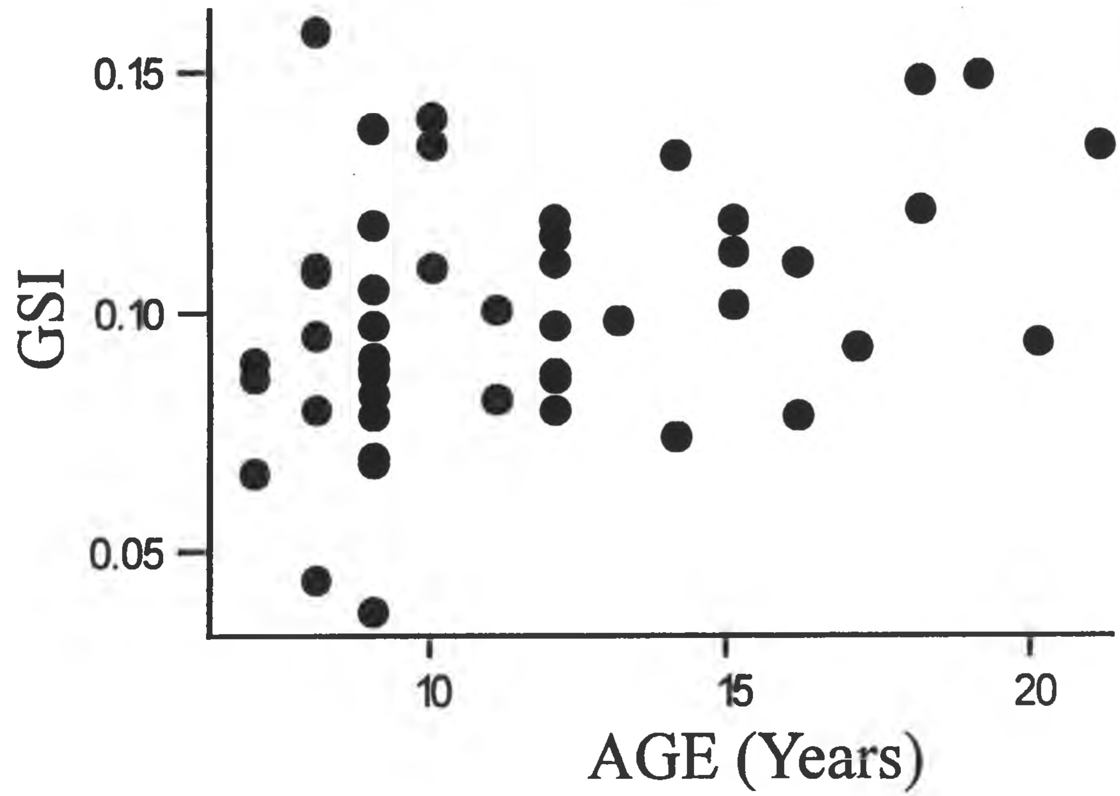

Figure 8. Gonadosomatic index (GSI) against age of female burbot collected in the lower Slave River in 1994.

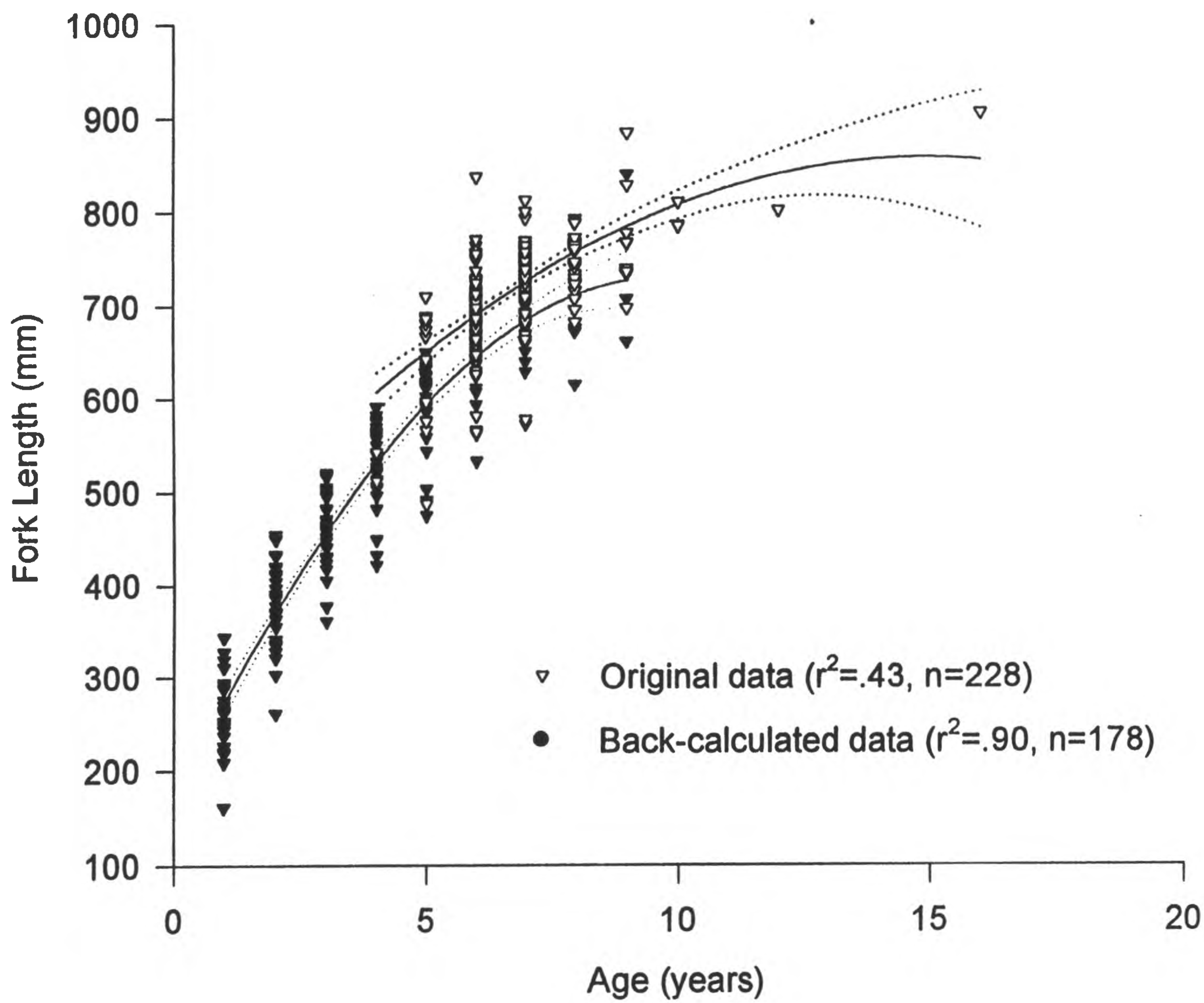

Fig. 9. Growth of male inconnu collected from the Slave River in 1993 and 1994 as determined from original and back-calculated fork lengths.

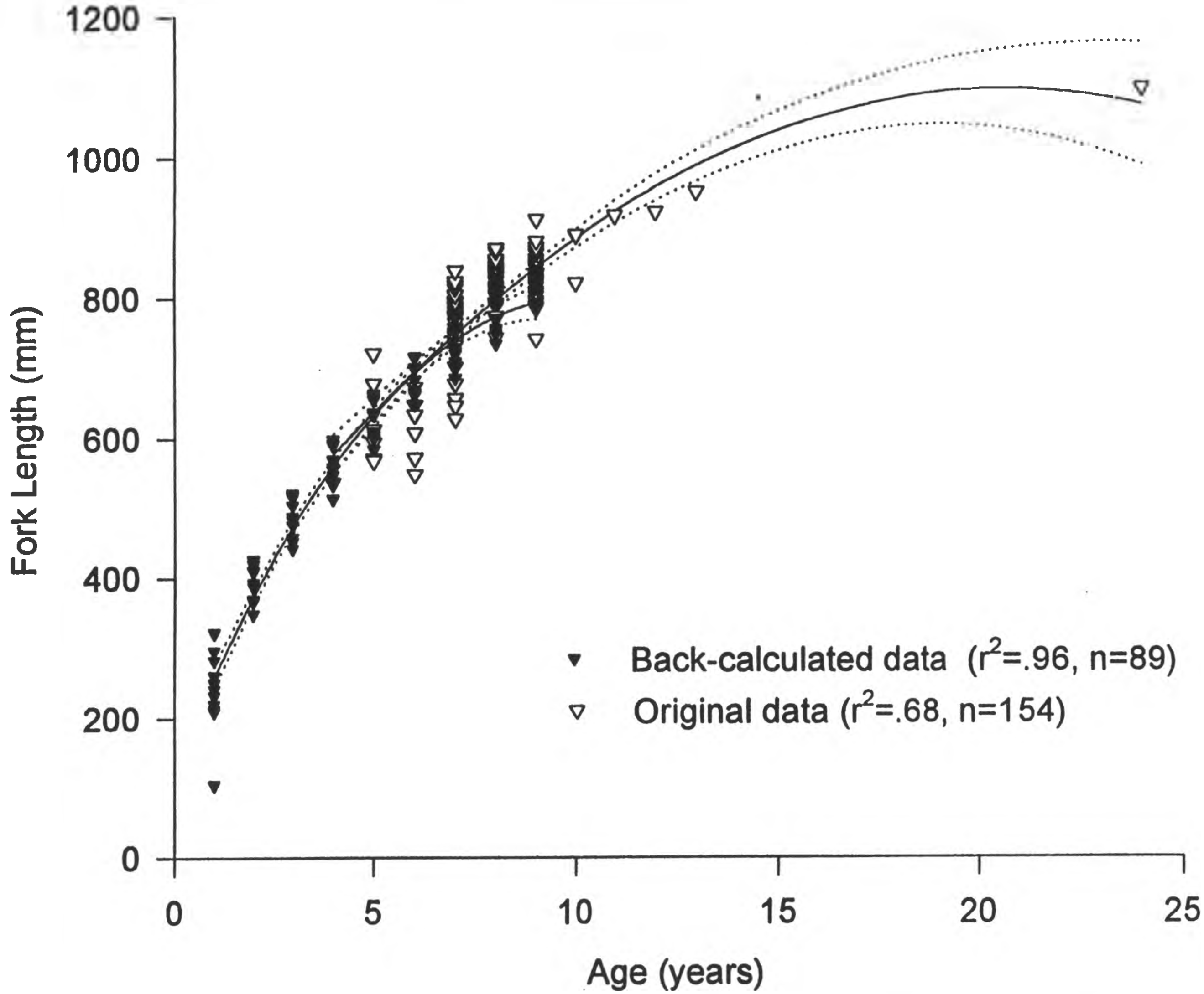

Figure 10. Growth of female inconnu collected from the Slave River in 1993 and 1994 as determined from original and back-calculated fork lengths.

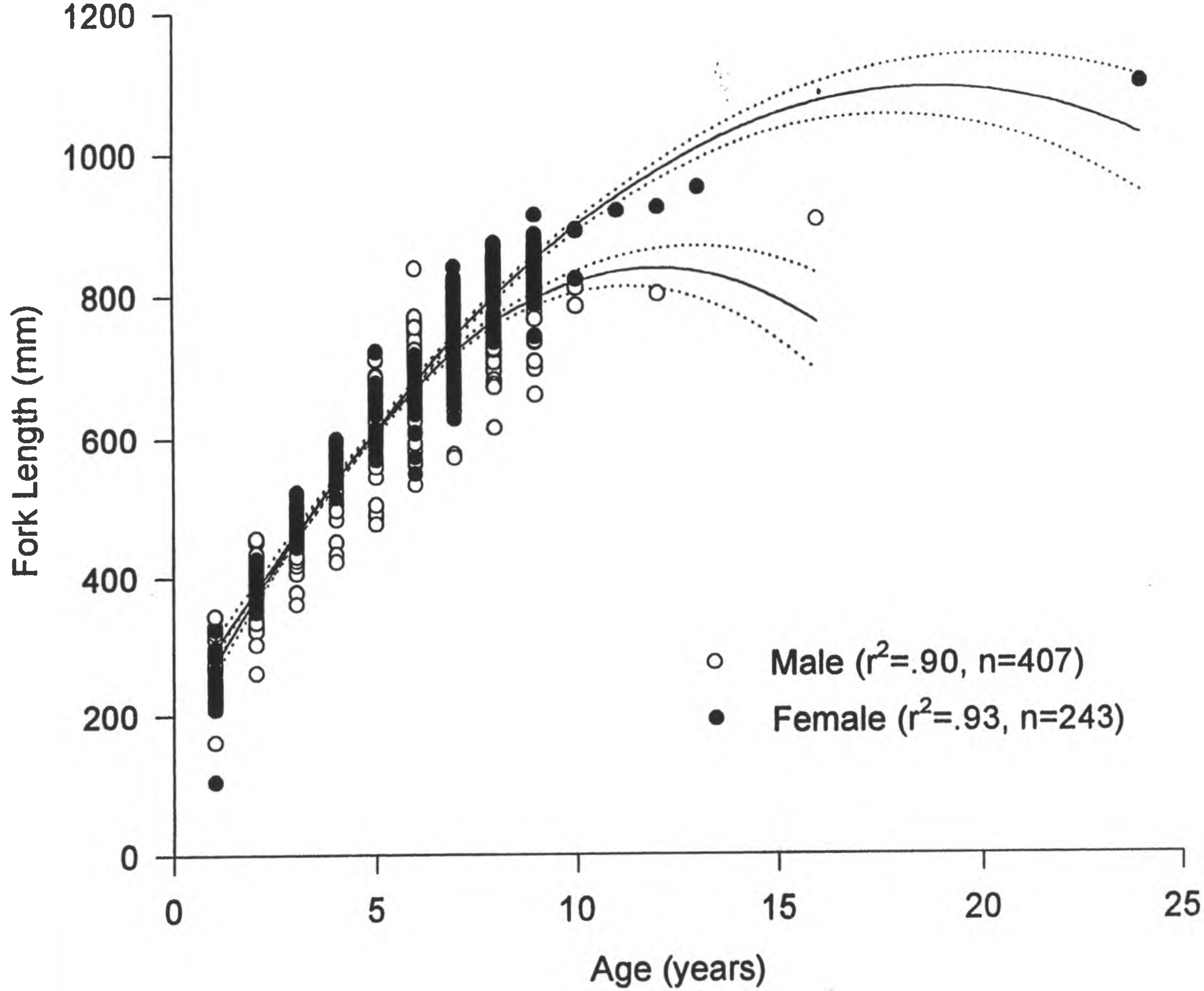

Figure 11. Growth of inconnu collected from the Slave River in 1993 and 1994 (both original and back-calculated data are included in regressions).

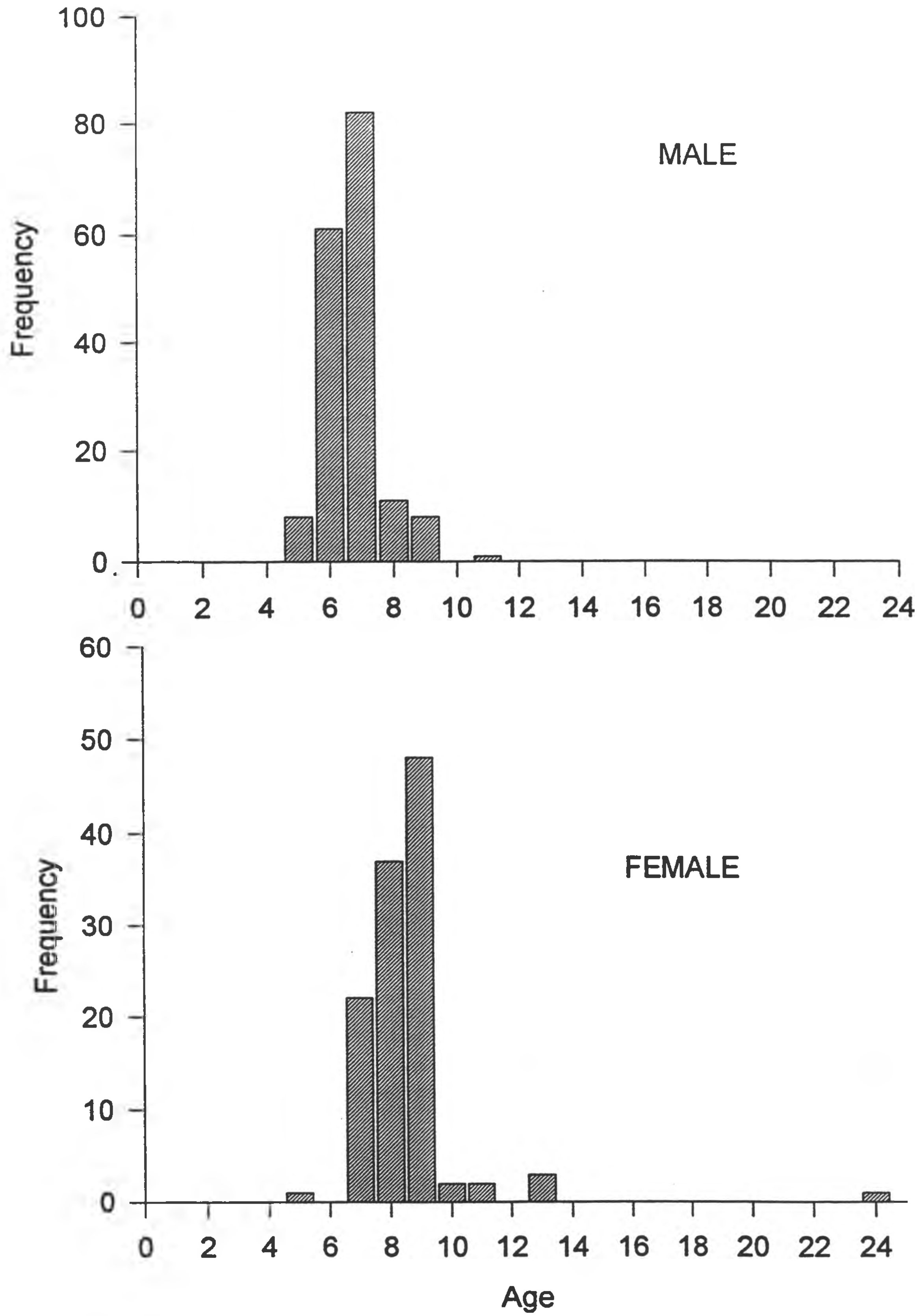

Figure 12. Age frequency distributions for mature inconnu collected from the Slave River during 1994.

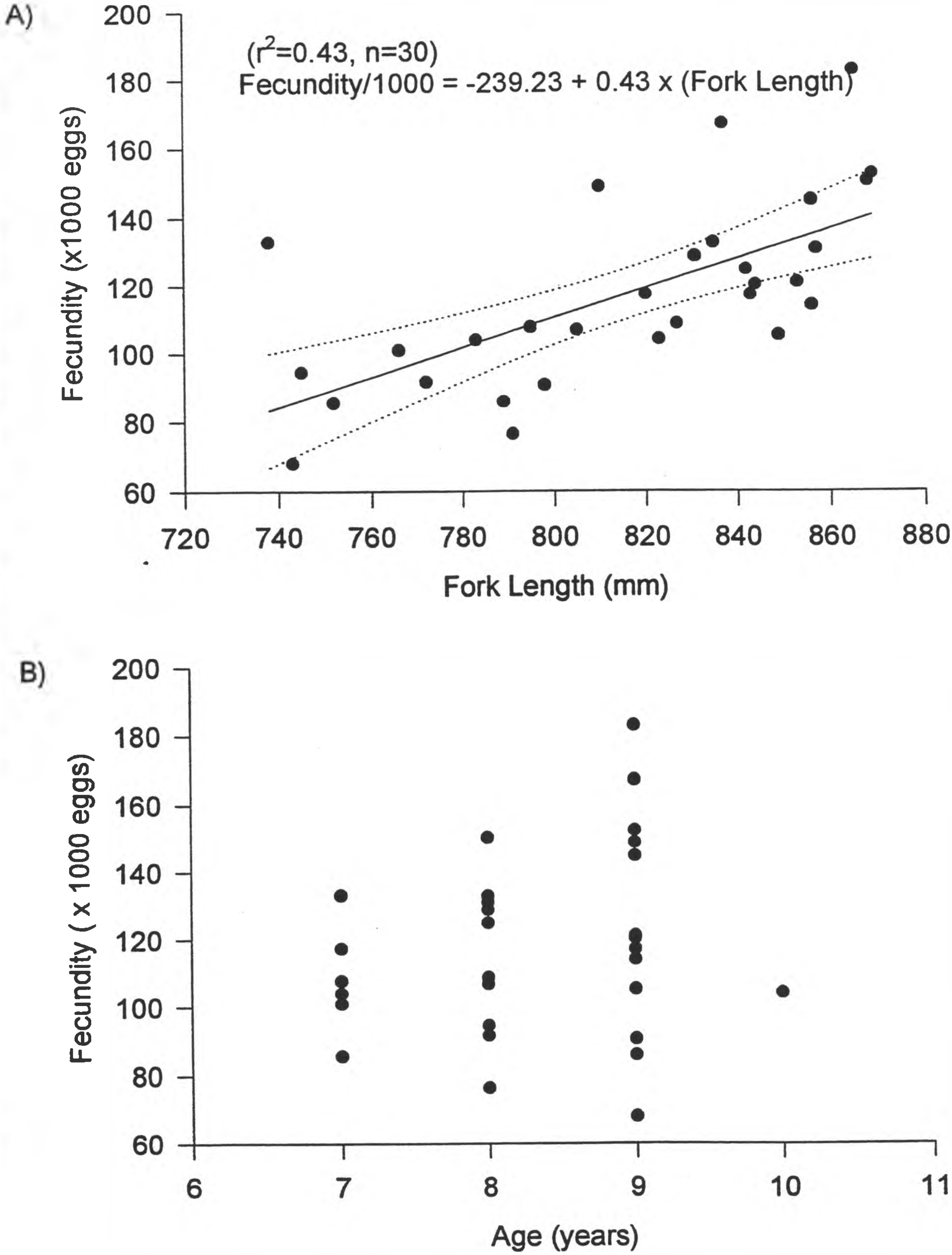

Figure 13. Size (A) and age (B) specific fecundity of inconnu collected in the Slave River during 1994.

Table 2. Age-specific fecundity of inconnu captured in the lower Slave River in 1994.

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

Egg Size - We found that egg diameter increased significantly with preservation ($p < 0.05$). Mean diameter of preserved eggs was 2.07 $\pm$ 0.138 mm (n=80 measurements), while fresh eggs were 1.92 $\pm$ 0.136 mm (n=76 measurements). This probably occurred due to uptake of fluids by the egg when immersed in the preserving solution. Fish eggs normally swell substantially when in contact with water. For samples where only preserved egg diameter was measured, fresh egg diameter was estimated using the following equation:

$$\text{Fresh egg diameter} = \frac{(1.92\ \text{mm})(\text{Preserved egg diameter})}{2.07\ \text{mm}}.$$

Diameter of fresh eggs for spawning inconnu in the lower Slave River (Fig. 14A) increased from 1.6 mm in mid-August to 2.5 mm in mid-October just prior to spawning. Individual dry weight g (Fig. 14B) increased from 1.5 mg in mid-August to 4.3 mg in mid-October. Both egg diameter and egg weight showed a similar pattern of increase over the prespawning period, suggesting that both measures of egg size worked equally well.

3.4 Life History Characteristics - Burbot

Length-at-age - Burbot increase in length-at-age in a nearly linear manner(Fig. 15). For example, at age 8 the fork length ranges between 350 and 620 mm, age 13 between 470 and 730mm, and at age 20 between 650 to 870mm. These burbot appear to live longer and attain a larger individual size than those from other burbot populations (Scott and Crossman 1973). This is perhaps not surprising since the largest burbot recorded in North America has come from Great Slave Lake (937mm) (Scott and Crossman 1973).

Age structure - In contrast to inconnu, age-frequency distributions of burbot from the Slave River (Fig. 16) showed a broad age structure ranging from age 3 to 21. Moreover, the older ages are well represented in the distribution. The dominant age classes in our samples are ages 8, 9 and 12. Age 11 is curiously under-represented and may represent a failed year class.

Fecundity - Fecundity of burbot from the Slave River ranged from 282,556 to 2,800,960 , eggs per female. Fecundity tended to increase with age. Mean and standard deviation for age-specific fecundities are listed in Table 3 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.

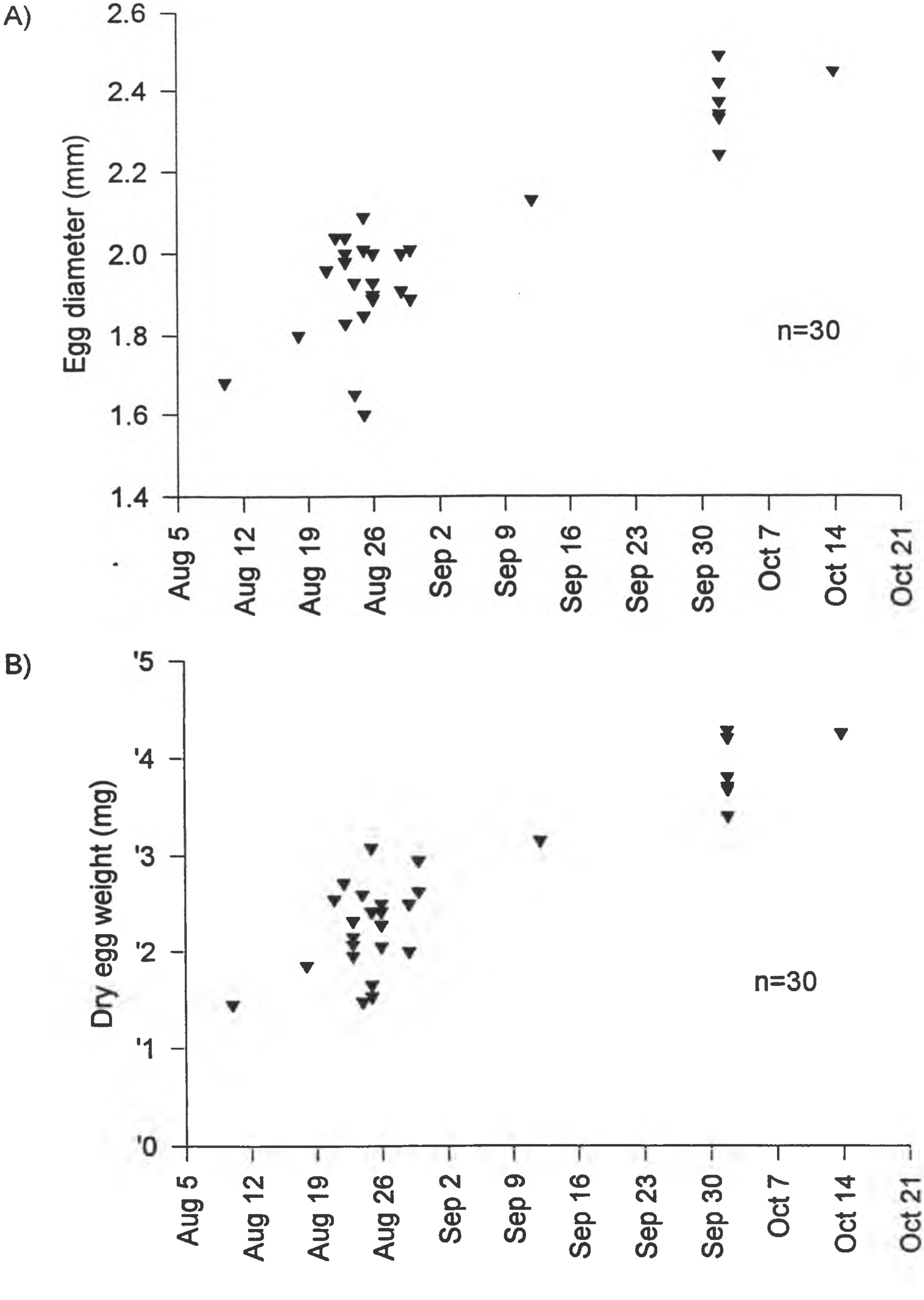

Fig. 14. Seasonal changes in egg diameter (A) and egg weight (B) of prespawning inconnu collected in the Slave River during 1994.

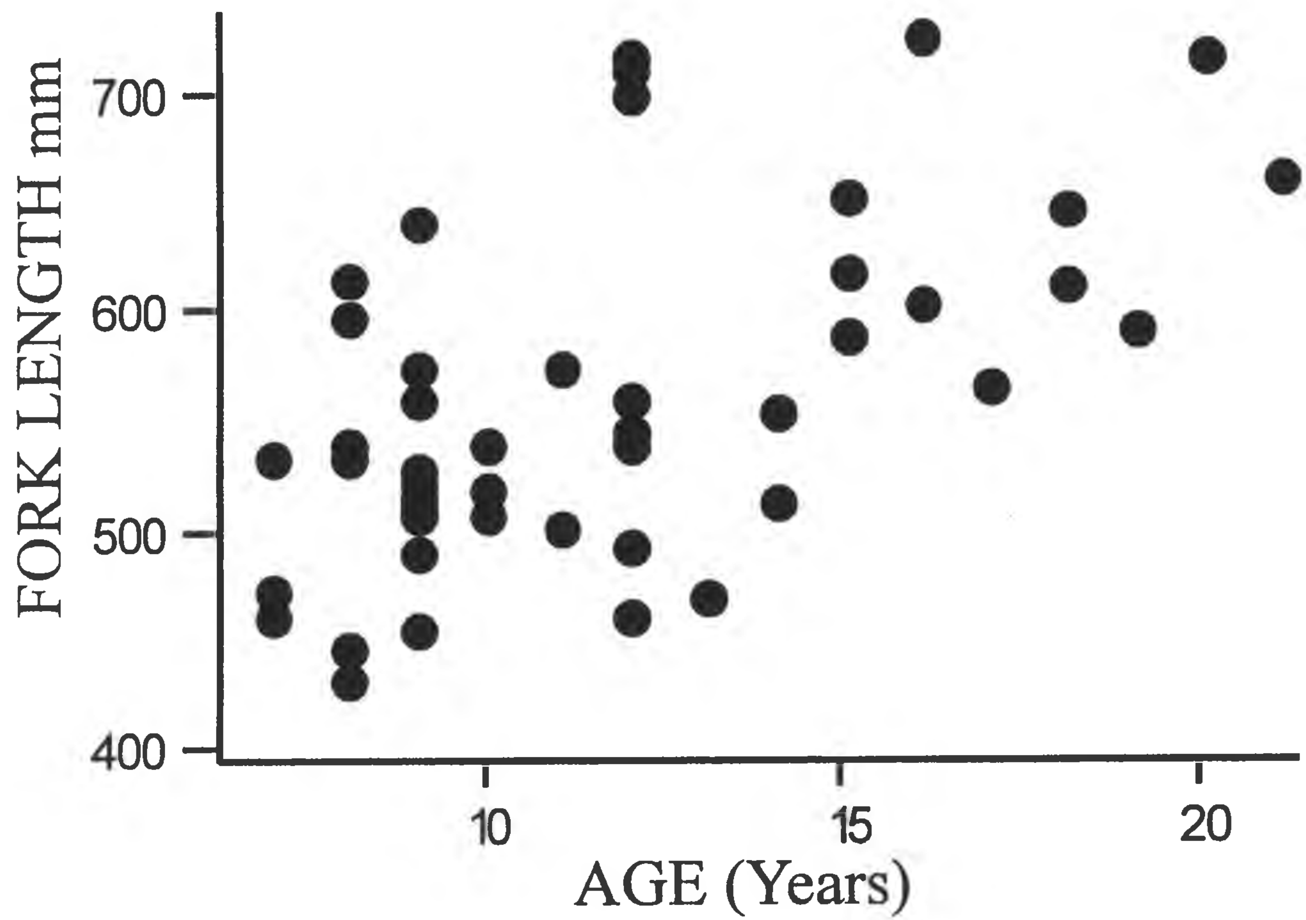

Figure 15. Fork length (mm) by age (years) for burbot collected in the lower Slave River in 1994.

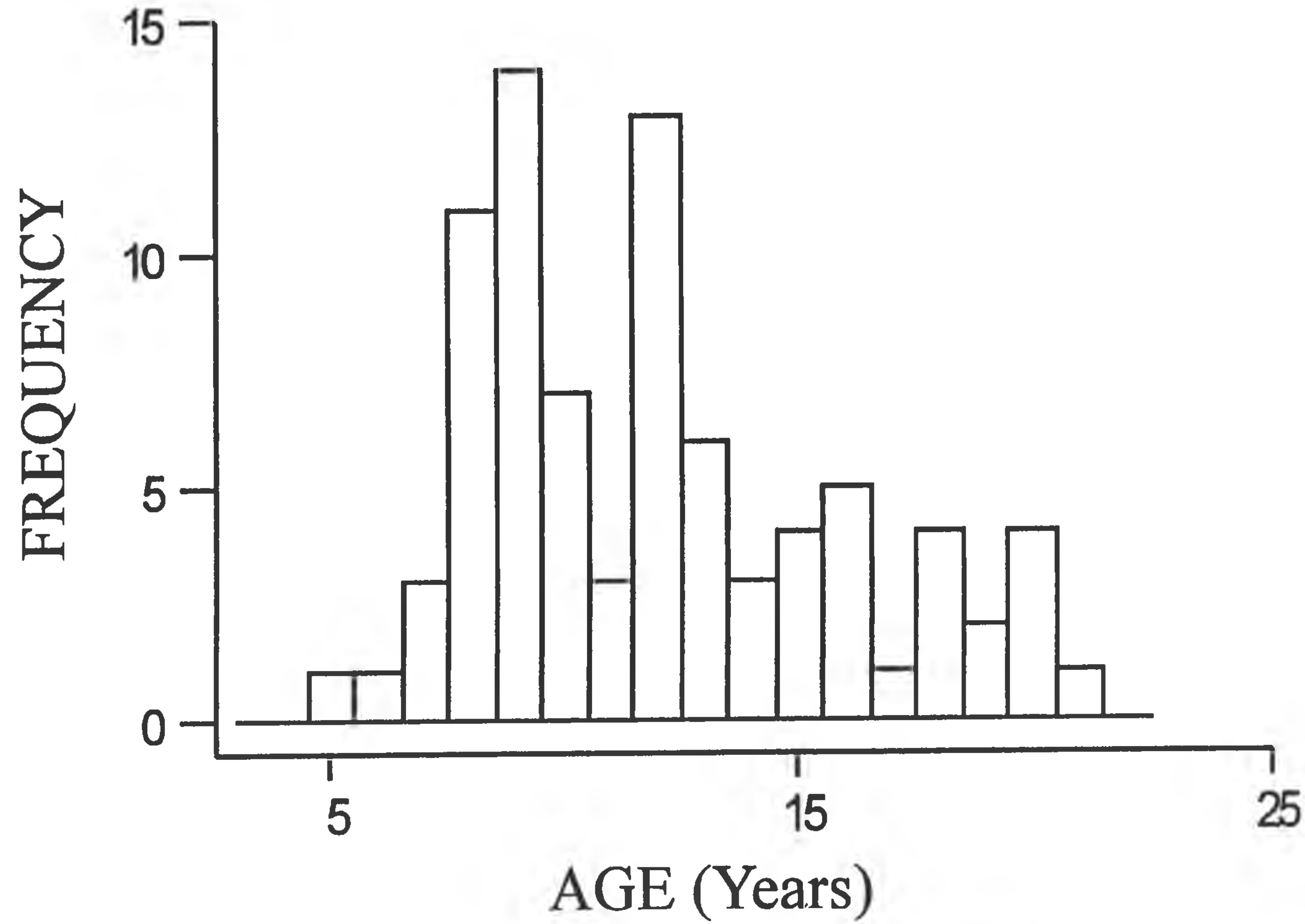

Figure 16. Age frequency of burbot collected in the lower Slave River in 1994.

Table 3. Fecundity of burbot collected from the Slave River in 1994. The regression equation describing the relationship is: Fecundity/1000 = -94.234 + 85.252 Age ($r^2 = 0.22$).

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

4.0 DISCUSSION

The information gathered in this study allowed us to describe several aspects of the life history of inconnu and burbot in the lower Slave River. 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. In contrast, burbot appear to have a relatively high age-at-maturity and grow more slowly compared to other populations (Scott and Crossman 1973). 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 (Scott and Crossman 1973, Alt 1977; Geiger 1969, Nikolsk'ii 1954, Howland and Tallman, unpublished data). In contrast, burbot have a broad age frequency with many older ages and larger individuals represented.

4.1 Inconnu Life Cycle

McLeod *et al.* (1985) conducted an environmental feasibility study related to hydroelectric development of the Slave River. The major objective of the study program was to survey fall-spawning fish populations and describe spawning habitat utilization. Studies focused on inconnu, lake whitefish, cisco, (*Coregonus* sp.), and chum salmon, (*Oncorhynchus keta*). The sub-objectives of the program were: 1) identification and mapping of spawning areas; 2) quantification of late summer and fall fishery resource use and 3) fish movement and tracking. The study was conducted between August 23, 1983 and November 10, 1983 and between August 6, 1984 and December 11, 1984. They were able to radio track inconnu for about six weeks each of these two years.

McLeod *et al.* (1985) concluded from their radio-telemetry studies that inconnu used the Slave River north of Fort Smith as a spawning area. From gillnetting results they observed a large increase of inconnu in the system around mid to late August and continuing into October (McLeod et al. 1985). Their radio-telemetry work revealed that inconnu have a rapid initial rate of upstream migration between mid-August and early September, followed by a holding pattern near the final point of upstream migration, or a fall-back to downstream locations in the Slave River. Based on gillnetting and, more precisely, on their radio-telemetry results, they estimated time of spawning to be between early and mid-October.

Our results are quite similar to those of McLeod et al. (1985) and complement their findings well. Our findings suggest that spawning probably occurs around mid-October. Our results show that inconnu only use the Slave River seasonally - spending the rest of their time in Great Slave Lake. The migration in and out of the system creates fishing opportunities for local aboriginal fishermen in the Fort Resolution, Salt River and Fort Smith areas. The abundance of inconnu in the system was independent of environmental variables but inconnu may require an upper maximum discharge level in order to migrate efficiently and are thought to have specific temperature requirements for spawning (Alt 1987, Nikol'skii 1954). Alterations to the system that might charge the temperature and discharge patterns in the system would presumably have detrimental effects on the inconnu reproduction.

Our results show that inconnu mainly utilize the Slave River for spawning, entering the river in mid-August and leaving by late October. These results corroborate those of McLeod *et al.* (1985) and Tripp *et al.* (1981) who indicated that the Slave was an important spawning river for species such as inconnu. As expected, female GSI increased steadily throughout the summer and fall until October 14 when the last inconnu were captured in the river. Due to logistical problems, no nets were set again until October 21 at which time no inconnu were captured. We believe that inconnu may have completed spawning and moved back downstream during that time. Although we were not able to sample the downstream migration of post-spawners to confirm this, the results of radio-tracking (Tallman et al. 1996a and the work of McLeod et al. 1985) indicate that spawning does take place around mid-October at which time spent inconnu then begin to move downstream towards Great Slave Lake (sometimes in as little as three days). Female GSI values (20-25) as well as egg size (2.2-2.5 mm) for inconnu captured during October, also suggest that these fish were close to spawning - Geiger (1969) reported that at the time of spawning, inconnu in Alaska had GSI's of between 20 and 25, and eggs were 2.5 mm in diameter.

All inconnu taken from the river in this study were mature spawners, as indicated by both the high GSI values as well as the qualitative visual assessment of maturity made at the time of fish processing. Although some individuals did appear to feed in the river during this period, feeding was restricted to the early stages of upstream migration. Migrating inconnu examined after August 30, 1994 had very little or no food in their guts, suggesting that inconnu cease feeding around this time (Tallman et al. 1996b). Consequently, the Slave River does not represent an important feeding area for inconnu during the spawning stage in their life history. This observation is supported by other studies that have found that inconnu stop feeding during spawning (Nikol'skii 1954; Howland and Tallman, unpublished). At other times during their life history, in particular at the resting and juvenile stages, inconnu congregate in the spring at the mouths of large rivers including the Slave (George Low, DFO Hay River, personal communication). These nutrient-rich zones are important feeding areas for non-spawning inconnu. These locationsd are, thus, potential areas where contaminants from the river enter the inconnu through their consumption of local prey.

Alt (1987) who has studied inconnu extensively in Alaska, suggested that availability of spawning habitat with the proper current, depth and substrate may be the most critical factor limiting inconnu distribution and abundance. Considering the importance of this fish to both subsistence and commercial use, and the fact that these fish are already under a considerable amount of fishing pressure, it is important that spawning rivers such spawning as the Slave River be maintained in order to ensure maximum recruitment to the existing population of inconnu in this area.

4.2 Life History Characteristics - Inconnu

Growth and Age-at-maturity - For a freshwater arctic species, inconnu have exceptionally high growth rates; our 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 and 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.

Population Age Structure - 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.

Fecundity and Egg Size - 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 River(Howland and Tallman, unpublished).

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? A number of possible explanations exist: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.

The life history traits of the inconnu of the lower Slave River suggest that it may be under more stress than other populations and have a lesser capacity to recover from disturbance. Therefore, the population may be more vulnerable than other species to anthropogenically induced changes. On the other hand, inconnu do most of their feeding in areas outside the immediate vicinity of the Slave River. Bio-magnification of contaminants through the Slave River food chain is less likely than for other species.

4.3 Burbot Life Cycle

The studies of Tripp et al. (1981) and McLeod et al. (1985) did not examine the migration and spawning of burbot. From our results we are confident that burbot make few if any directed movements in the Slave River between June and November. Judging from the state of the gonads in December, we suggest 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).

We suspect that during most of the warmer months burbot hold in small feeding territories along the river, delta and Great Slave Lake. Our 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.

4.4 Life History Characteristics - Burbot

The gonadosomatic index showed a slight increase with age 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 the high mean fecundity observed was expected.

In most burbot populations individuals reach sexual maturity at age three or four (Scott and Crossman 1973) and thus the Slave River population appears to delay sexual maturity somewhat by maturing at age five.

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 eight 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 140mm 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 eight (465mm) than the Slave River burbot (490mm).

The life history characteristics of inconnu and burbot in the Slave River contrast sharply. That inconnu are faster growing, and mature earlier than conspecific populations to the north might be expected in a species at the southern edge of its range. In comparison to other burbot populations, the characteristics of the Slave River burbot population of relatively slow growth, and late maturity might also be accounted for the northerly position of this population relative to the others in the range. On the other hand the demographics could reflect solely the intensity of fishing on each species with inconnu being highly migratory therefore more vulnerable to fishing. The more sedentary burbot may be relatively under-exploited in this area. Regardless of how the demographic patterns observed have come about it appears that inconnu might be considered as the more stressed population. It has fewer age classes to support reproduction and because it must migrate a good distance upriver to reproduce, any environmental change would have more immediate and serious consequences for the inconnu. As well, since inconnu are more widely sold for human consumption than burbot any bio-magnification would have larger scale human health consequences.

Thus, anthropogenic effects on the ecosystystem, such as flow changes and increases in contaminant concentrations would likely would likely be reflected more rapidly and profoundly in the inconnu population dynamics. Numerical declines such as those observed in species inhabiting the Great Lakes might follow (Scott and Crossman 1973). On the other hand, localized pollution would probably be concentrated more quickly in the flesh of burbot of the lower Slave River, even though their vital rates might remain relatively stable on the short term.

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APPENDIX A

TERMS OF REFERENCE

NORTHERN RIVER BASINS STUDY

SCHEDULE A - TERMS OF REFERENCE

Project: 3143-D2 LIFE HISTORY VARIATION OF HARVESTED FISHES

I. INTRODUCTION

A. Background

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. There have been numerous cases of human tragedy as a result of unknowing consumption of tainted fish. 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.

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. To understand the effects of ecosystem change on fish one must understand their movements 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 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 leuichthys), lake whitefish (Coregonus clupeaformis), burbot (Lota lota) and walleye (Stizostedion vitreum) (Tripp et al. 1981). 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 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. 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 followed by aerial surveys. However, their studies did not commence until the spawning run was well underway and therefore could characterize the earliest seasonal period of the migration. As well, since tags were inserted into the intestinal tract the inconnu could migrations could only be tracked during the period just prior to spawning when they were not feeding. In 1983, 16 inconnu were successfully tracked. Five inconnu were tracked for 38 days with rest being tracked for lesser periods down to one day, only. In 1984, 24 inconnu were tracked. One fish was followed for 47 days with the rest being followed for lesser time periods down to one day. 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.

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 achieved on 12 fish. For inconnu age and growth characteristics were achieved 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. These traits are the keys to understanding population growth and mortality rates and thus stock productivity. Usually, minimum sample sizes 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 focused on fish inventory.

Analysis of dietary information and food web from diet is generally lacking. Tripp et al. (1981) record gut contents on 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 their own and 100% of their dogs' food supply. 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 an estimated total 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 period. 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 longnosed 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, pike, lake trout, inconnu, and walleye (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 vulnerable to accumulations of toxic materials. Among the others, lake trout does not occur in the Slave River and pike are less preferred for eating than the other species. Thus, inconnu, 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 important for both commercial and aboriginal subsistence harvest. Of these the least is known regarding the movements and life history variation of inconnu.

While there has been useful work on the fish populations of the Slave River work on movements is based on floy tagging studies with one study using radio-tracking. The number of fish floy tagged has not generally been sufficient for inconnu. The radio-telemetry study is thorough but represented only a short season effort - missing the early part of the migration and the longer term movements. Only very limited information exists to understand and characterize the demographics and life history traits important to stock productivity of key species for human consumption. There is only spotty dietary information with no integration and synthesis nor is there any inter-annual comparisons of diet and trophic positions. Therefore, we propose to investigate the migration of two species, the inconnu and burbot using radio- telemetry techniques employing external tags. We will also examine the variation in life history traits important to productivity in these species - specifically size at age, age at maturity, age-specific fecundity and egg size by collecting fish and analyzing appropriate samples. Finally, we will conduct a thorough examination of the diets of species at all levels of the fish food web.
Study Board Concerns Considered:

Distribution and movement of fish species
- compile life histories of important species

When and where are fish "exposed" and where are important habitats
- Describe fish food-chain relationships

B. The Program

The program for the Slave River is a collaborative effort between the University of Alberta, the Department of Fisheries and Oceans and the Northern Rivers Basin Study Office. The project involves four components which that comprise an integrated whole to determine the movements and demographics of key harvested fish species and a description of the fish food web in the lower Slave River. It relates to the objectives (concerns) of the Northern Rivers Basin Study Board that deal with

1) Distribution and movement of fish species
   - compile life histories of important species

2) When and where are fish "exposed" and where are important habitats
   - Describe fish food-chain relationships

The four components are :

1) Movement of Harvested Fish

2) Life History Variation of Harvested Fishes

3) Diet of Fishes and Food Web

4) Fish Processing

The four components are inter-related so that each one supports and compliments the other. Two harvested fish species, the inconnu, Stenodus leucichthys, and the burbot, Lota lota are the focus. These are top predators, harvested heavily, with a body composition susceptible to the concentration of contaminants. Inconnu is highly important both in the commercial and aboriginal subsistence economy. Burbot is also important and is a focal species for studies basin wide including the Peace and Athabasca Rivers. They represent the extremes in migratory movement with burbot rather sedentary and inconnu highly migratory. The acquisition of samples will be rationalized for all programs by taking specimens for life history (demographic) and food web analysis while tagging fish. The life history component will serve to do the field specimen collection for both life history and food web. (There will, of course, be some requirement to make special collections for single a single purpose). Fish processing will support the life history and food web by sampling the largest suite of relevant variables possible per fish under ideal sampling conditions. This approach will minimize the costs while maximizing the information content.

The results of the study will put into ecological context the findings of some of the other components of the Northern Rivers Basin Study and other programs such as the Slave River Monitoring Program. The sampling may reduce some of the sample collection costs or enhance the volume of data available to other studies such as those on contaminant in fishes. Finally, the information gathered will be synthesized with other available information from parallel studies and from the historical studies in the Slave River area. The synthesis will allow a more comprehensive interpretation of the longer term events in the system and the significance of the results to the objectives of the Northern Rivers Basin Study.

II. PROJECT DESCRIPTION

The Northern Rivers Basins Study requires the contract laboratory to determine the demographic characteristics and life history variation of fishes caught for human consumption in the Slave River, N.W.T. such as inconnu, Stenodus leucichthys. and burbot, Lota lota. These will include variation in size and age structure of the population, age at maturity, size at age, age-specific fecundity and other characteristics relevant to stock productivity and resilience. The information gathered will also put the findings of other studies into an ecological context of the major features of the biology and the relative abundances of each species in the system. Ecological context will be essential for the interpretation of the findings of other projects on fish such as projects to measure contaminant levels.

III. TERMS OF REFERENCE

1. The contractor is required to obtain samples through a regular monitoring program on the Slave River from June to November, 1994.

    a. A survey of the Slave River to determine suitable sampling sites will be undertaken during June, 1994 or as soon as possible after ice- out on the river. Two and possibly three sampling sites will be determined. If the logistical problems can be solved it is expected that there will be at site near the town of Fort Smith, and a site upstream and downstream from this location.

    b. Sampling will commence by mid-June, 1994 with samples taken every two to four weeks until the end of November using large mesh (4-5.5 " stretch mesh) gillnets and multi-mesh (1.5 - 4.5 ") gangs of gillnets.

    c. For each fish caught the length of time that the net was set, the net mesh size, environmental conditions, fish species, fish length, Both fork length and total length, fish weight, and sex will be recorded. The fish will be dissected to determine the sexual maturity stage and gonad weight, and the gonads, otoliths, a pelvic fin ray, scales and stomach will be removed and preserved. Additional tissues will be removed as requested by other investigations such as the determination of stable isotope patterns, contaminant loading, bioenergetic investigation and genetic variation. Some fish will be sent to the FWISL laboratory for more detailed analysis.

    d. Gonads will be analyzed at the FWISL to verify the stage of sexual maturity and to estimate female fecundity. The otoliths, scales and finrays will be processed at the FWISL and used to determine fish age. The stomach contents will be analyzed to determine if the fish were feeding in the river and to determine the diet

    e. The data will be analyzed to determine length(fork and total) and weight at age, age at maturity, age-specific fecundity and if and when the species were spawning. The age determination will be made using the most reliable structure (Otolith, scale, fin ray or operculum). In addition, the data will provide estimates of relative abundance of each species.

f. All other species caught will be recorded and individual fish weight and length (fork and total) taken in the field. Apply Northern River Basins Study floy tags on fish specimens (inconnu, arctic grayling, northern pike, walleye, whitefish, bull trout, goldeye and burbot) greater than 250 mm. in length, unless the condition of fish and sampling circumstances permit the tagging of specimens less than 250 mm.

2. The contractor is requested to explore and implement, where practical, opportunities for community association/involvement with the project, e.g., South Slave Research Centre.

IV. REPORTING REQUIREMENTS

1. A progress report of field results to date will be submitted to the Northern River Basins Study office by March 31, 1995. Completion of the field work is anticipated by December 1994. Laboratory processing and analysis of samples is anticipated by March 31, 1995. Data entry and analysis of the data will be completed by June 30, 1995. A final report will be prepared on all results and submitted to the Study office by September 30, 1995.

2. The final report will include:

   a. a description of the methods utilized in the study including the details of gillnetting procedures, mesh sizes of nets, sampling times and locations,

   b. a determination of the catch per unit effort with time and location for each species, the pattern of maturity development with time for each species, the age-specific fecundity, age at maturity, length at age and population age structure of each species.

   c. a brief interpretation of the meaning of the results focussing on the ecological significance of the Slave River to these species (i.e. does it represent an area for feeding, spawning or refugium) and the significance of the life history trajectory with respect to the possible accumulation of toxicants in these species.

3. The raw data relating to field sampling and life history traits will be maintained in a data-base retained by the FWISL laboratory but will be made available to the Northern River Basins Study upon request.

   Identify to species and enumerate all fish captured. Record the general external conditions of "abnormal" fish using the Gross Pathology Form (Appendix 1). Compile a properly labelled colour photographic record of caught fish exhibiting "abnormalities". Labelling should permit cross referencing with fish data collection records.

Cross reference all fish sample data to:

a. sample number,
b. species,
c. reach,
d. date of capture,
e. kilometres from river mouth,
f. Universal Transverse Mercator coordinates for Zone 11,
g. capture method
h. abnormality

In addition to the above tagged fish, are to have the following data obtained:

i. total and fork length (mm.), weight (gms.),
j. life stage
k. tag number.

4. The Contractor is to provide draft and final reports in the style and format outlined in the NRBS Style Manual. A copy of the Style Manual entitled "A Guide for the Preparation of Reports" will be supplied to the contractor by the NRBS.

5. Ten copies of the Draft Report along with an electronic disk copy are to be submitted to the Project Liaison Officer by September 30, 1995.

   Three weeks after the receipt of review comments on the draft report, the Contractor is to provide the Project Liaison Officer with two unbound, camera ready copies and ten cerlox bound copies of the final report along with an electronic version.

6. The final report is to include the following: an acknowledgement section that indicates any local involvement in the project, Project Summary, Table of Contents, List of Tables, List of Figures and an Appendix with the Terms of Reference for this project.

   Text for the report should be set up in the following format:

   a) Times Roman 12 point (Pro) or Times New Roman (WPWIN60) font.
   b) margins; are 1" at top and bottom, 7/8" on left and right.
   c) Headings; in the report body are labelled with hierarchical decimal Arabic numbers.
   d) Text; is presented with full justification; that is, the text aligns on both left and right margins.
   e) Page numbers; are Arabic numerals for the body of the report, centred at the bottom of each page and bold.

- If photographs are to be included in the report text they should be high contrast black and white.
- All tables and figures in the report should be clearly reproducible by a black and white photocopier.
- Along with copies of the final report, the Contractor is to supply an electronic version of the report in Word Perfect 5.1 or Word Perfect for Windows Version 6.0 format.
- Electronic copies of tables, figures and data appendices in the report are also to be submitted to the Project Liaison Officer along with the final report. These should be submitted in a spreadsheet (Quattro Pro preferred, but also Excel or Lotus) or database (dBase IV) format. Where appropriate, data in tables, figures and appendices should be geo-referenced.

7. All figures and maps are to be delivered in both hard copy (paper) and digital formats. Acceptable formats include: DXF, uncompressed E00, VEC/VEH, Atlas and ISIF. All digital maps must be properly geo-referenced.

8. All sampling locations presented in report and electronic format should be geo-referenced. This is to include decimal latitudes and longitudes (to six decimal places) and UTM coordinates. The first field for decimal latitudes / longitudes should be latitudes (10 spaces wide). The second field should be longitude (11 spaces wide).

V. INTELLECTUAL PROPERTY

Upon completion or termination of this project, all data, documents, and materials which are acquired or produced under this project shall become the sole property of the Northern River Basins Study.

VI. PROJECT MANAGEMENT PLAN - DFO/Winnipeg laboratory

1. Survey of the river at first opportunity after ice-out (expected late May or early June 1994). Field sampling for inconnu and burbot during June to November 1994 on the Slave River. Laboratory analysis of samples will be from December, 1994 to March, 1995. Data analysis and write-up by September 30, 1995. All permits for the netting of fish and the transport of samples will be obtained by the Contractor.

2. The Northern Rivers Basins Study office will be informed at the earliest possible date of any impediments to the execution of this investigation such as difficulty acquiring fish.

VII. CONTRACT ADMINISTRATION

The Project Liaison Officer for this project is:

Ken Crutchfield
Associate Science Director
Northern River Basins Study
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10405 Jasper Avenue
Edmonton, Alberta T5J 3N4
Bus. Phone: (403) 427-1742
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This project is under the Food Chain Component of the NRBS led by:

Dr. Ray Hesslein
Research Scientist
Fisheries and Oceans Canada
Freshwater Institute
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Winnipeg, Manitoba R3T 2N6
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Questions of a scientific nature should be directed to him.

VIII. LITERATURE CITED

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NORTHERN RIVER BASINS STUDY

Appendix 1

EXAMINATION SHEETS
GROSS PATHOLOGY

DATE: ________

SAMPLE NO.: __________ **U.T.M. LOCATION:** ____________

SPECIES: __________ **CAPTURE METHOD:** ____________

CAPTURE TIME: _________ **EXAMINATION TIME:** ___________

GROSS EXTERNAL EXAMINATION

Skin: ( ) Normal ( ) Excessive mucus ( ) Abnormal Colour ________

( ) Lesions ( ) Single ( ) Multiple ( ) Closed

( ) Open ( ) Haemorrhagic ( ) Necrotic ( ) Ulcer

( ) Blister ( ) Tumour ( ) Lost Scales ( )Abrasions

Body Location: ________________________________

Eyes: ( ) Normal ( ) Exophthalmia ( ) Cataract ( ) Haemorrhagic

( ) Opaque cornea ( ) Lens lost ( ) Parasites ( ) Bilateral

Fins: ( ) Normal ( ) Frayed_________ ( ) Haemorrhagic

( ) Eroded __________ ( ) Deformed ____________

Gills: ( ) Normal ( ) Pale ( ) Mottled ( ) Haemorrhagic

( ) Necrotic ( ) Excessive mucus ( ) Hyperplasia

( ) Telangiectasia ( ) Gas emboli ( ) Cysts

( ) Large Parasites ___________ ( ) Fungus Visible

OTHER: ____

N.B. In the event that a significant number of specimens at any site have abnormalities, the contractor is asked to immediately notify the Project Liaison Officer.
Phone: 427-1742 or fab to 422-3055