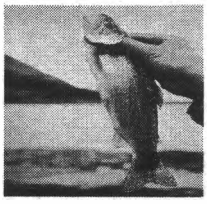
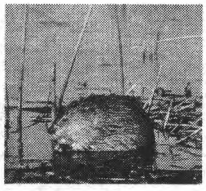
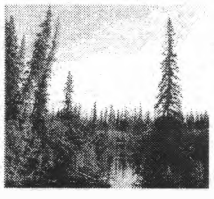
Canada Alberta Northwest Territories

Northern River Basins Study



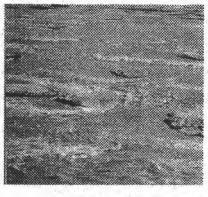


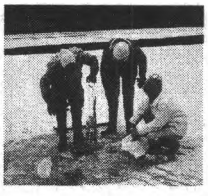
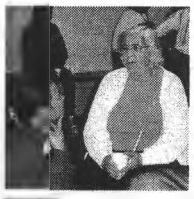




NORTHERN RIVER BASINS STUDY PROJECT REPORT NO. 100

SUITABILITY OF SMALL FISH SPECIES FOR MONITORING THE EFFECTS OF PULP MILL EFFLUENT ON FISH POPULATIONS, ATHABASCA RIVER, 1994 AND 1995



Prepared for the
Northern River Basins Study
under Projects 2353-D1 and 2353-E1

by

Wade Gibbons, Department of Biology, University of Waterloo
Kelly Munkittrick, Department of Fisheries and Oceans
William Taylor, Department of Biology, University of Waterloo

NORTHERN RIVER BASINS STUDY PROJECT REPORT NO. 100

SUITABILITY OF SMALL FISH SPECIES FOR MONITORING THE EFFECTS OF PULP MILL EFFLUENT ON FISH POPULATIONS, ATHABASCA RIVER, 1994 AND 1995

Published by the
Northern River Basins Study
Edmonton, Alberta
February, 1996

CANADIAN CATALOGUING IN PUBLICATION DATA

Gibbons, Wade N. (Wade Norman), 1963-

Suitability of small fish species for monitoring
the effects of pulp mill effluent on fish populations,
Athabasca River, 1994 and 1995

(Northern River Basins Study project report,
ISSN 1192-3571 ; no. 100)
Includes bibliographical references.
ISBN 0-662-24487-7
Cat. no. R71-49/3-100E

1. Fishes -- Effect of water pollution on -- Alberta --
Athabasca River.
2. Wood pulp industry -- Waste disposal -- Environmental
aspects -- Alberta -- Athabasca River.
3. Effluent quality -- Alberta -- Athabasca River.
I. Munkittrick, Kelly Roland L. H. (Kelly Roland Leslie Herbert)
II. Northern River Basins Study (Canada)
III. Title.
IV. Series.

TD899.W65G52 1996 597'.024 C96-980170-X

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
PROJECT REPORT RELEASE FORM

This publication may be cited as:

Gibbons, Wade, Munkittrick, Kelly, and Taylor, William. 1996. ***Northern River Basins Study Project Report No. 100, Suitability of Small Fish Species for Monitoring the Effects of Pulp Mill Effluent on Fish Populations, Athabasca River, 1994 and 1995,*** **Northern River Basins Study, Edmonton, Alberta.**

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.

(Dr. Fred J. Wrona, Science Director) — 4 Apr 96 (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

(Dr. P. A. Larkin, Ph.D., Chair) — 15 April/96 (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, Co-chair) — 21 April 1996 (Date)

(Robert McLeod, Co-chair) — 10 April 1996 (Date)

SUITABILITY OF SMALL FISH SPECIES FOR MONITORING THE EFFECTS OF PULP MILL EFFLUENT ON FISH POPULATIONS, ATHABASCA RIVER, 1994 AND 1995

STUDY PERSPECTIVE

The aquatic fauna of the Peace, Athabasca and Slave rivers are exposed to pulp mill effluent, and other types of industrial and municipal effluents. Previous NRBS projects documented that mountain whitefish and longnose suckers collected from the Athabasca River downstream of Hinton showed elevated liver mixed function oxygenase (MFO) activity, a detoxification response, and reduced levels of sex steroid hormones. These physiological responses in fish are consistent with similar studies done on bleached kraft pulp mills located elsewhere in Canada. Concerns that larger fish species may not be suitable as monitors of localized environments, because they are very mobile and capable of movement beyond effluent exposure areas, has resulted in new techniques for examining biochemical disruptions in smaller fish species. This project used these new methods to identify the potential of small fish species in monitoring the effects of pulp mill effluents on the Athabasca River.

Related Study Questions

1a)	*How has the aquatic ecosystem, including fish and/or other aquatic organisms been affected by exposure to organochlorines or other toxic compounds?*
4a)	*What are the contents and nature of the contaminants entering the system and what is their distribution and toxicity in the aquatic ecosystem with particular reference to water, sediments and biota?*
13a)	*What predictive tools are required to determine the cumulative effects of man-made discharges on the water and aquatic environment?*
13b)	*What are the cumulative effects of man-made discharges on the water and aquatic environment?*

The objectives of this project were addressed by first identifying common sentinel species immediately upstream and downstream of pulp mill effluents at Hinton and Whitecourt. Spoonhead sculpin and lake chub were identified as sentinel species because of their abundance in the Hinton and Whitecourt reaches of the river, respectively. These species are assumed to have limited mobility and a small home range. This project attempted to document the geographic extent of biochemical responses in fish subjected to prolonged exposures during low flow periods (i.e., fall and early spring). This was accomplished by conducting laboratory analyses on the fish tissues collected from the field to determine the potential for the pulp mill effluents to disrupt sex steroid levels and induce liver MFO activity.

Three field surveys were conducted; spring and fall 1994, and spring 1995. The biochemical responses of lake chub to effluent exposure at Whitecourt were low, and similar to fish collected at upstream reference sites. MFO data for spoonhead sculpin exposed to the combined effluent at Hinton confirmed exposure in near-field sites, and the response tended to persist to downstream far-field sites. In the fall, 1994, sculpins from the near-field sites at Hinton exhibited an increase in sex steroid hormone levels relative to reference fish. Overall, the most consistent general response shown by these two species downstream of all three pulp mills was an increase in body and organ size, suggesting that fish were responding to nutrient enrichment and increased food resources.

In addition to giving a direct assessment of pulp mill effects, results from this project will provide new information on monitoring protocols for pulp and paper mills. These results should be interpreted with some caution because, although the biochemical responses were typically low in these small fish species, they also are less likely to biomagnify contaminants as much as larger, predatory species. Nonetheless, this information will form critical linkages with other NRBS studies addressing biomonitoring, cumulative effects assessment, ecosystem health assessment and nutrient impact assessment.

REPORT SUMMARY

As part of the "Contaminants" component of the Northern River Basins Study (NRBS), effort was initiated to study the effects of pulp and paper effluents on the Athabasca River. One of the elements of the study included monitoring the effects of pulp mill effluent on resident fish populations of the Upper Athabasca River. Due to concerns regarding the extensive mobility of many larger fish species (i.e. beyond exposure areas), the emphasis of the project was to evaluate the suitability of small fish species as "sentinels" for monitoring effluent related effects in river environments.

Two study areas were selected from the general region of the Upper Athabasca River: 1) Hinton study area focussing on effluent from a kraft bleached pulp mill (mill A), and 2) Whitecourt study area focussing on two non-kraft mills (TMP-mill B, CTMP-mill C). For each study area, a sentinel species was selected based on non-migratory behaviour, small size (<15 cm), and capture efficiency. Responses of sentinel fish species were defined according to measurements describing body and organ metrics, reproductive parameters, age estimates, mixed function oxygenase activity (MFO, EROD activity) and *in vitro* steroid production by gonadal tissues. In addition, the basic biology of each sentinel species was described. The project was conducted over three field surveys during the spring of 1994, fall of 1994 and spring of 1995. During the fall 1994 and spring 1995 surveys water samples were collected at each sampling site for chemical analyses. As well, during each survey, habitat classification was conducted for each sampling site.

Hinton Study Area

Spoonhead sculpin (*Cottus ricei*) was the sentinel species selected for monitoring the mill at Hinton. Spoonhead sculpin were collected at night by electrofishing faster runs and riffles with cobble/boulder substrate. In general, spoonhead sculpin were effective at monitoring instream conditions downstream of the mill A outfall. Responses of sculpin exposed to mill effluent exhibited increased levels of energy expenditure and storage indicative of increased availability of food resources or enrichment. This response was found to persist downstream to the far-field sites.

During the fall 1994 survey, sufficient numbers of mature sculpin were collected at a reference site, near-field site and an additional site located across river from the effluent plume. The latter site was sampled to investigate the lateral mobility of spoonhead sculpin. Spoonhead sculpin from the near-field site were older, heavier, fatter and had larger gonad and liver weights relative to reference fish. The increased level of energy expenditure and storage was considered indicative of a response to increased food supply, or enrichment. Exposed sculpin also exhibited an increase in the production of testosterone and 17β-estradiol. MFO data confirmed that the fish at the near-field site were exposed to effluent. Spoonhead sculpin sampled across river from the effluent plume exhibited an intermediate response relative to reference and near-field fish. The results suggested that lateral and upstream/downstream movement of spoonhead sculpin was limited at these sites. Concentrations of chloride, sulphate and sodium were higher at the mill A near-field site further suggesting exposure to effluent.

During the spring 1995 survey, sculpin were collected from three reference sites (two on the Athabasca River and one on the North Saskatchewan River), as well as two near-field and far-field sites (21 km and 48 km from outfall). Differences in fish measurements between the Athabasca references sites, assuming no large differences in water quality, were considered representative of the natural variability in reference fish characteristics. The differences also supported the assumption of limited mobility. The two reference sites on the Athabasca River were pooled for subsequent comparisons between reference and exposed fish.

Similar to the fall survey, sculpin from the near-field zone were heavier, fatter and had larger liver weights than reference fish. Exposed female sculpin exhibited higher gonad weights and fecundity. This general response pattern again suggested that the fish were responding to an increase in food resource and were not negatively affected by effluent exposure. Significant EROD induction (4-fold) confirmed that sculpin from near-field site were exposed to mill effluent. However, gonadal tissues of sculpin from the near-field site exhibited similar *in vitro* production of testosterone and 17β-estradiol as tissues from reference sculpin. As in the fall survey, sculpin across river from the plume exhibited responses intermediate between the reference and near-field fish.

Sculpin from the far-field zone were compared with sculpin from the near-field and reference sites. Although some whole organism parameters were found to decrease downstream, many of the changes observed between reference and near-field fish had persisted, or become more pronounced. Hepatic EROD results indicated that sculpin at middle far-field site (21 km) were exposed to sufficient effluent concentrations to cause induction equal to that observed at the near-field site. There was no reduction in EROD activity until the furthest far-field site (48 km); however, EROD activity in male sculpin was still higher than reference levels. With the exception of male sculpin, there were no differences in *in vitro* steroid production among the near-field, far-field and reference sites. For male sculpin, testosterone production was depressed at the middle near-field site and stimulated at furthest far-field site relative to near-field and reference values. Levels at the further far-field site may have been higher because males at that site were guarding nests with fertilized eggs and at a different reproductive stage.

There were significant differences in some body/organ metrics, MFO activity and *in vitro* steroid production between the Athabasca and North Saskatchewan reference sites. The observed differences suggest that sculpin collected at the North Saskatchewan River did not accurately reflect the status of reference sculpin in the Athabasca River. In addition, had the North Saskatchewan site been used as the reference in this survey, some of the conclusions regarding exposed fish would have been altered and more negative. It was unclear whether the North Saskatchewan River site represented the upper range of the normal performance of spoonhead sculpin, or whether these fish were responding to fluctuations in water levels associated with the Big Horn Dam.

Chloride data indicated that effluent concentrations were approximately 5% at the near-field site, 4% at the middle far-field sites (22 km), and 3.5 % at the furthest far-field site located 48 km downstream.

Whitecourt Study Area

Lake chub (*Couesius plumbeus*) was the sentinel species selected for monitoring mills in the Whitecourt area. Lake chub were captured by backpack electrofishing quiet, cobble margins of the river during the day. In general, there was little evidence to suggest that lake chub collected downstream of mill B and mill C were adversely affected by effluent exposure. Although lake chub were effective at monitoring instream conditions, the absence of significant responses in chub was not surprising given that both mills produce chlorine free pulp, low effluent volumes and achieve high effluent dilution.

During the spring 1994 survey, sufficient numbers of mature chub were collected at the reference site (Windfall Bridge), mill B near-field site and mill C near-field site to conduct site comparisons. From the preliminary comparisons of body size, organ metrics and age of lake chub, there was little evidence suggesting that fish were responding to effluent from below mill B or mill C. Only fecundity of exposed chub was found to be different (lower among pooled mill B/C females). EROD activity in lake chub collected downstream of either outfall was not significantly induced relative to reference chub. The absence of significant EROD induction has also been documented in rainbow trout during laboratory exposures to 100% effluent from both mill facilities (Munkittrick *et al.*, unpublished data). As well, *in vitro* production of testosterone by follicles from female chub was not significantly different among fish from the reference, mill A and mill B sites.

During the fall 1994 survey lake chub were collected from an additional reference site located approximately 16 km downstream of the original reference site. Site differences were observed in age of male chub and body/organ metrics of female and immature chub. In the absence of anthropogenic stressors, it was concluded the differences probably represented the natural variability in fish characteristics within the reference zone. Subsequent comparisons between reference and exposed fish were conducted using data pooled from the two reference sites.

Adult lake chub downstream of the mill C outfall exhibited increased condition relative to mill B and reference fish, without concomitant increases in organ size or individual body size estimates. Immature lake chub from the mill B site exhibited reduced condition relative to mill C fish, but were similar to reference fish. As well, the mean liver size of exposed males was larger than reference males. Altered changes in condition without concomitant changes in other parameters did not represent a major concern. Similarly, decreased liver size without alterations in other metrics was not considered a dramatic change. There was a tendency towards increased production of testosterone by follicles of lake chub exposed to mill B and mill C effluent. Human chorionic gonadotropin stimulated reference production of 17β-estradiol, but had no effect on follicles exposed to mill B and C effluent. The absence of increased levels of 17β-estradiol from hCG mediated follicles of exposed females may be considered a response to effluent exposure. MFO data indicated that exposure to effluent was low (assuming the presence of an inducer) probably resulting from low effluent discharge and high effluent dilution.

During the fall survey, water samples collected at each site were analyzed for major ions (Cl, Na, K, SO_4, SIO_2) and adsorbable organic halide (AOX). Water chemistry data indicated that the near-field sites for each mill were exposed to mill effluent. This was supported by increased levels of sodium below both mills and increased concentrations of potassium and silicate below mill C.

Conclusions

Based on the three surveys, the potential to use small fish species is very high for the purpose of monitoring downstream of pulp mill outfalls. In particular, the abundance and distribution of resident forage species facilitates sampling several sites (fish populations) within a reference, near-field area or far-field area. In addition, the probable stationary behaviour of some small species (e.g., spoonhead sculpin), especially in large rivers, greatly improves the probability that the observed fish responses reflect the local environment. As well, typical measurements made on larger fish species were also possible using smaller species, including: body and organ metrics, reproductive parameters, age estimates, mixed function oxygenase activity, and *in vitro* steroid production. Information regarding the basic biology of spoonhead sculpin and lake chub was described for future studies.

To further improve our understanding of the responses of small sentinel fish species to mill effluents, several studies were recommended:

- Collect baseline data on life history characteristics of small fish species to improve our knowledge of growth rates, reproductive strategies and sampling requirements.

- Increase efforts towards establishing the full range of variability associated with reference fish; both within a monitoring system and among a variety of similar aquatic systems.

- Further evaluate the degree and pattern of mobility, size of home range and habitat requirements of smaller fish species.

- Compare the consistency and sensitivity of responses between small species and larger fish species of restricted movement (by habitat or man-made barriers) residing in the same monitoring system.

- Repeat laboratory evaluations of the potential of Athabasca effluents to disrupt steroids and induce MFO activity. This information would be valuable to evaluate whether effluents show the potential to induce the physiological changes. Also, the information would assist in evaluating the relative contribution of various mills, and the potential for mills further downstream to alter the biochemical performance of fish.

ACKNOWLEDGMENTS

This report was prepared by Wade Gibbons, Kelly Munkittrick and William Taylor. Field work was conducted by Wade Gibbons, Dana Boyter, Len Eklund and Kelly Munkittrick. Steroid assays were done by Janet Jardine and mixed function oxidase analyses were conducted by Bev Blunt. Fish ageing and fecundity estimates were completed by Dana Boyter. AOX analyses were done by Waste Water Technology of Burlington. Water Quality Branch of Environment Canada, Burlington provided analyses for major ions. Ruth Burr assisted in word processing the report.

We wish to thank Don Cadden (BC Ministry of Lands and Parks, Prince George) for providing fish sampling equipment during the field surveys, as well as Greg Wagner and Richard Chabaylo (Alberta Environment, Edmonton) for their assistance with the project. We would also like to thank Len Eklund for providing jet boat services, Linda Gysbers (Environment Canada, Burlington) for her assistance with financial matters of the project and Glen Van Der Kraak (University of Guelph) for his assistance regarding the steroid procedures and interpretation of the steroid data.

Thanks also to mill personnel for their cooperation and assistance during the field surveys and laboratory studies.

TABLE OF CONTENTS

LIST OF TABLES

Tables - Cont'd

Tables - Cont'd

LIST OF FIGURES

Figures - Cont'd

Figures - Cont'd

1.0 INTRODUCTION

As part of the "Contaminants" component of the Northern River Basins Study (NRBS), effort was initiated to study the effects of pulp and paper effluents on the Athabasca River. One of the elements of the study included monitoring the effects of pulp mill effluent on resident fish populations of the Upper Athabasca River. The emphasis of the project was to evaluate the suitability of small fish species as "sentinels" for monitoring effluent-related effects in river environments.

1.1 BACKGROUND TO FISH MONITORING STUDY

Monitoring fish populations to assess the effects of pulp mill effluents on receiving waters is an important part of the Environmental Effects Monitoring (EEM) program for Canada's pulp and paper industry (Environment Canada and Fisheries & Oceans, 1992). Evaluation of the significance of effects has historically been difficult, but considerable success has been achieved in demonstrating responses in wild fish populations. For this reason, the EEM program has included a detailed fish population assessment using a sentinel fish species to determine the biological significance of effluent effects. The framework of the assessment is a comparison of fish populations exposed to effluent (e.g., downstream of a mill outfall), with a comparable reference or control population (e.g., upstream of the outfall).

An assumption to the sentinel monitoring program is that fish collected at the respective sites show responses reflecting their local environment. Examples of fish species used as sentinel monitors include longnose sucker (e.g., Gibbons *et al.*, 1991; Gibbons *et al.*, 1992; Swanson *et al.*, 1992), white sucker (e.g., Munkittrick *et al.*, 1991; McMaster *et al.*, 1992a), lake whitefish (e.g., Munkittrick *et al.*, 1992), and mountain whitefish (e.g., Munkittrick *et al.*, 1990; Kilgour and Gibbons, 1991; Swanson *et al.*, 1992). There has been recent concern that larger fish species may not be suitable as monitors of localized environments in open river systems because they are very mobile and capable of extensive movement beyond effluent exposure areas. Successful demonstration of responses of wild fish has been seen in Central Canada, but predominantly in environments where movement of fish has been restricted by habitat (e.g., Munkittrick *et al.*, 1991) or man-made barriers (e.g., Hodson *et al.*, 1992).

There is a need to evaluate the suitability of fish species for monitoring this type of environment. Smaller fish species, such as cyprinids and cottids, have been advocated as possible sentinel species because they may have limited mobility (relative to larger species) and typically possess a small home range (e.g., Gerking, 1959; Greenburg and Holtzman, 1987; Hill and Grossman, 1987). These characteristics make them ideal for monitoring because they are more likely to be exposed to mill effluent for a majority of their life cycle and show responses reflective of the localized conditions than larger, mobile species. The objective of this study was to assess the suitability of smaller fish species for monitoring receiving environments. In particular: 1) did small fish species show responses to effluent?; and, 2) were the responses reflective of localized environmental conditions.

The project was applicable to NRBS board questions: (1-a) determining whether pulp mill discharges have affected fish, (4-a) what is the distribution of toxicity (if any is present), (13-a) the development of predictive tools for assessing cumulative effects, and (13-b) assessing the cumulative effects.

1.2 PROJECT OBJECTIVES

Work on the Athabasca River consisted of three field components: 1) pilot field survey (spring, 1994), 2) fall field survey (1994); and, 3) spring field survey (1995) .

The pilot survey was conducted in spring, 1994 in an effort to familiarize ourselves with the study area, and to address the following objectives:

- identify potential sentinel species for study
- determine the best method for collecting sentinel species
- select reference and exposure study sites
- collect preliminary data on sentinel fish characteristics exposed to pulp mill effluent (physiological and whole organism)

The fall field survey was a continuation of the field work initiated during the spring. In particular, the fall survey was conducted to:

- finalize sentinel species selection for the Hinton area
- collect greater numbers of sexually mature sentinel fish to facilitate the analyses of whole organism parameters, MFO activity and *in vitro* steroid responses
- evaluate responses of sentinel fish species and verify preliminary results observed during the pilot survey
- conduct water analyses for the purpose of confirming exposure zones
- record general habitat characteristics of each intensive fish collection site

A final survey was conducted during the spring, 1995. This survey focussed only on the sentinel species in the Hinton area (mill A). The survey was initiated to:

- collect sexually mature sentinel fish at sites within the reference, near-field and far-field zones to investigate the geographical extent of responses (whole organism, physiological) downstream of the mill A outfall
- further evaluate the *in vitro* steroid responses of the sentinel fish species following a prolonged period of high effluent exposure associated with winter low-flow conditions.
- improve our knowledge base on the basic biology and life history of the sentinel species
- further assess the mobility of the sentinel species
- conduct water analyses for the purpose of confirming exposure zones
- record general habitat characteristics of each intensive fish collection site

As well, although not described in this document, an ongoing component of the project included laboratory exposures of fish to mill effluent. The laboratory tests were conducted to investigate whether effluents from mills in Hinton and Whitecourt had the potential to elicit responses (steroid depression, induced MFO activity) in laboratory fish under worst-case conditions (100% effluent, no dilution). The study was part of an ongoing Fisheries & Oceans project to develop a laboratory assay capable of screening effluents based on the degree of steroid responses (if any)(K.R. Munkittrick and L.H. McCarthy, unpublished data).

1.3 STUDY AREA AND MILL CHARACTERISTICS

The upper Athabasca River was selected as the study area because pulp mills contribute a substantial proportion of the industrial effluent discharged into this section of the Athabasca River (one mill near Hinton and two mills in the vicinity of Whitecourt) (Figure 1). In addition, there has been concern expressed regarding the potential effects of mill effluent on resident fish populations.

For the purposes of our research, the study area was confined to the receiving waters of the mills at Hinton (Figure 2a) and Whitecourt (Figure 2c,d). As well, as reference zones were located upstream of Hinton (Figure 2a) and near Windfall Junction (Figure 2b) upstream of Whitecourt. During the spring 1995 survey, additional sites were sampled within the far-field zone of mill A ; downstream of the Obed Mountain Coal Ltd. conveyor road, and downstream of Emerson Bridge (Athabasca River crossing near Emerson Lakes Forest Recreation Area).

At the time of the project Mill A was a bleached kraft operation located in Hinton and produced approximately 1,100 ADMT/d of bleached kraft pulp (bleaching sequence: $OD_oE_{op}[DE_SD]$) (Rodden, 1995). Effluent discharge consisted of approximately 95% mill effluent and 5% municipal sewage for a total effluent discharge of 1.0 m^3/s (Noton and Shaw, 1989). Mill B was a thermomechanical pulp (TMP) and paper operation located 10 km west of Whitecourt. This mill produced 620 t/d of newsprint and discharged approximately 0.17 m^3 effluent/s (Sentar, 1994a). Mill C was a chemi-thermomechanical pulp and paper mill located in the town of Whitecourt. This mill produced approximately 575 ADMT/d of alkaline peroxide pulp and discharges 0.12 m^3 effluent/s (Sentar, 1994b). Mill B and C were totally chlorine-free; mill A used 100% chlorine dioxide substitution during the chlorination bleaching stage. All three mills utilized primary and secondary effluent treatment systems prior to discharging the effluent to the Athabasca River.

2.0 MATERIAL AND METHODS

2.1 PILOT STUDY: SPRING 1994 SURVEY

The pilot field trip to the Athabasca River was conducted from April 28 - May 16, 1994. The purpose of the trip was to identify sentinel fish species and study sites for intensive study. In addition, because fish capture success was sufficient in the Whitecourt study area, sentinel fish were collected for physiological, whole organism and chemical measurements. The specific study area included the near-field zones downstream of mills A, B and C, and reference zones located upstream

of mill A and mill B.

2.1.1 Sentinel Species and Site Selection

In the upper Athabasca River system, possible sentinel species included (Nelson and Paetz, 1992):

- longnose dace (*Rhinichthys cataractae*)
- pearl dace (*Margariscus margarita*)
- lake chub (*Couesius plumbeus*)
- fathead minnow (*Pimaphales promelas*)
- spottail shiner (*Notropis hudsonius*)
- trout-perch (*Percopsis omiscomaycus*)
- spoonhead sculpin (*Cottus ricei*)

These species represent small (max. adult total length < 15 cm), resident and non-migratory fish species which were assumed to exhibit relatively stationary behaviour and reduced longitudinal mobility as compared to larger species such as whitefish or sucker. Final selection of a sentinel species was evaluated based on the abundance and capture efficiency of each of the possible species.

Several habitat types (backwater, riffle, littoral zone, pools, runs, etc.) were sampled in an effort to collect any of the above listed species. Sampling occurred during both day and night (easily accessible sites) hours using a beach seine (30 m x 2.5 m, mesh size 6 mm) and backpack electrofisher (Smith-Root Type VII).

The *a priori* sampling design for the intensive sentinel fish study included at least one site within each reference zone and near-field zone downstream of mill A, B and C. Specific sites were selected from the numerous sites sampled within a zone during the sentinel species survey according to the following criteria:

- for reference sites, the immediate area was not exposed to mill effluent or other discharges which may confound future comparisons in fish characteristics
- for near-field sites, the immediate area was exposed to mill effluent (based on mill information on plume delineation), but with no other discharges or influences (e.g., habitat type) different from the associated reference site
- the selected sentinel species was present and occurred in adequate numbers for statistical analyses

2.2 FALL 1994 SURVEY

A second field trip to the upper Athabasca River was conducted from September 18 - October 6, 1994. The purpose of the trip was to: 1) determine whether spoonhead sculpin could be collected in sufficient numbers (i.e. adults) to be useful as a sentinel species for the Hinton study area, 2)

sample spoonhead sculpin across river from the effluent plume in the near-field zone as a simple test of mobility, 3) collect lake chub in the Whitecourt study area to validate the pilot survey results, and 4) sample lake chub at a second reference site to investigate possible differences in fish characteristics within the reference zone.

Hinton

In the Hinton study area, three sites were sampled for intensive study (Figure 3a). A reference site (Site HRL - Hinton reference, left upstream bank) was located immediately upstream of the mill pumphouse along the left upstream bank. The near-field exposure site (Site MAL - mill A, left upstream bank) was located along the left upstream bank of the river approximately 0.5 km downstream of the Helge-Nelson Bridge. An additional site was sampled along the right upstream bank (Site MAR) at the Helge-Nelson Bridge. This site was sampled to investigate whether fish captured across the river from the effluent plume exhibited characteristics similar to reference fish or exposed fish. It was hoped that the results from this site might provide some preliminary indication regarding the mobility of the sentinel species relative to the plume.

Sampling for spoonhead sculpin occurred during both day and night (easily accessible sites) hours; however, fishing during the evening (2000-0100 h) proved to be the best time to collect mature sculpin. Although a variety of habitats were sampled, greater success (especially capturing adults) was achieved when sampling faster runs and riffles (≈1.1-1.5 m/s) approximately 0.5-0.75 m deep with boulder/cobble substrates. The sampling technique consisted of holding a pole seine (2 m x 1.2 m, 6 mm mesh size) approximately 2 m downstream of a second researcher electrofishing amongst the large cobble/boulder substrate. Disrupted fish were shocked by the electrofisher and swept downstream by the current into the pole seine. A Smith-Root Type VII backpack electrofisher was used.

Whitecourt

In the Whitecourt study area, lake chub were collected from four sites. A reference site (Site WF) was located at the boat launch immediately downstream of the Windfall Junction Bridge along the left upstream bank (Figure 3d). A second reference site (Site R2) was located approximately 16 km downstream from the Windfall Junction Bridge (2 km upstream of the mill B outfall) along the right upstream bank (Figure 3e). A near-field exposure site was located approximately 3 km downstream of mill B outfall (Site MB) along the right upstream bank (Figure 3e). Another near-field exposure site was located 2.25 km downstream of mill C outfall (Site MC) along the left upstream bank (Figure 3f).

Lake chub were collected by electrofishing the quieter margins of the river during the day. A Smith-Root Type VII backpack electrofisher was used. Greatest success was achieved when sampling sites consisting of large cobble and boulder substrate piled one on top of another. The substrate was gently lifted and replaced while electrofishing and the shocked fish were captured with a small, long handled dip-net.

2.3 SPRING 1995 SURVEY, HINTON

.A third trip to the Athabasca River was conducted from April 05, 1995 - April 20, 1995. This trip focused on spoonhead sculpin in the vicinity of mill A , Hinton. The purpose of the trip was to: 1) evaluate *in vitro* steroid responses of spoonhead sculpin following prolonged high effluent exposure during winter low-flow conditions, 2) investigate the geographical extent of responses (whole organism, physiological) downstream of the mill A, 3) further assess the mobility of the spoonhead sculpin; and, 4) improve our knowledge of the basic biology and life history of the spoonhead sculpin.

Spoonhead sculpin were collected at a total of seven sites on the Athabasca River. Reference sites were located immediately upstream of the mill pumphouse along the left (Site HRL) and right (Site HRR) upstream bank (Figure 3a). These sites were chosen to further assess the lateral mobility of spoonhead sculpin, and increase the number of sampling sites within the reference zone. As in the fall survey, sculpin were again collected from near-field sites MAL and MAR (Figure 3a). A far-field site was located approximately 0.75 km downstream of the Obed Mountain Coal Ltd. conveyor road. Initially, the site was located along the left upstream bank (CL - coal road, left bank) of the river; however, poor capture success of sculpin necessitated sampling the right upstream bank as well (CR - coal road, right bank)(Figure 3b). A more distant far-field site was located approx. 0.75 km downstream of Emerson Bridge along the left upstream bank (Site E)(Figure 3c).

An additional reference site was located on the North Saskatchewan River (Site NS) approximately 25 km upstream of Rocky Mountain House, Alberta (Figure 3g). This river system has been used as a reference site in other studies monitoring the effects of pulp mill effluent on rivers in Alberta (e.g., Golder, 1994; Kloepper-Sams *et al.*, 1994). Spoonhead sculpin were collected from the North Saskatchewan River to compare whole organism and physiological measurements between reference fish from different river systems, and to assess the North Saskatchewan River as a reference system for the Upper Athabasca River.

Spoonhead sculpin were collected by procedures previously described for the fall, 1994 survey.

2.4 WHOLE ORGANISM FISH MEASUREMENTS

Each adult sentinel fish was rendered unconscious by concussion and total length (± 0.1 cm), fork length (± 0.1 cm - lake chub only), body weight (± 0.01 g), carcass weight (i.e. eviscerated)(± 0.01 g), gonad weight (± 0.001 g) and liver weight (± 0.001 g) were recorded.

Otoliths from spoonhead sculpin and scales and the left operculum from lake chub were removed from each fish for ageing (i.e. annuli count). Ageing measurements were obtained following procedures outlined in MacKay *et al.* (1990). Otoliths were cleaned in hot water, placed in propylene glycol for at least 24 h before reading under a dissecting microscope (reflective light). If annuli were difficult to count, the otoliths were ground thinner using silicon carbide grinding paper (grit # 400) until the annuli were visible. Opercular bones of lake chub were difficult to age

and scales were used instead. Scale reading was facilitated by making acetate impressions of 8-10 scales per fish and magnifying the impressions under a microfiche reader. All ageing structures were aged at least twice. The accuracy of ages from at least 10 % of all fish were verified by an independent researcher.

Following setup for *in vitro* steroid incubations (see below), the remaining ovarian tissue from mature females was frozen for fecundity analyses. In the laboratory, frozen ovarian tissue was thawed, blotted dry and reweighed (±0.001 g). The total number of eggs were counted and these results were used to estimate the total number of eggs per fish (total fecundity) and egg weight. As well, for each fish, the diameter of 10 eggs was determined as an alternate measure of egg size.

2.5 *IN VITRO* STEROID ANALYSES

During the spring (lake chub) and fall (lake chub and spoonhead sculpin) 1994 field surveys, *in vitro* steroid analyses were conducted on female fish only. Steroid analyses were conducted on both male and female spoonhead sculpin during the spring 1995 survey.

Gonadal tissues from adult sentinel fish were excised, weighed (± 0.001 g) and immediately placed in Medium 199 supplemented with 25 mM Hepes, 4.0 mM sodium bicarbonate, 0.01% streptomycin sulphate, and 0.1% serum albumin (pH 7.2) and stored at 4°C for < 2 h prior to incubation. Incubation of gonadal tissues were conducted according to procedures outlined in McMaster *et al.* (1995). During the spring and fall 1994 surveys, triplicate samples of 20 follicles were incubated in Medium 199, and Medium 199 supplemented with 10 IU/mL human chorionic gonadotropin (hCG) for 24 h. In many species, hCG acts as a gonadotropin (GtH) agonist resulting in an increase in steroid production. During the spring 1995 survey, only ten follicles per replicate were incubated because the eggs from prespawning sculpin were approximately twice as large as eggs from the previous fall. For male sculpin, 20 mg of testicular tissue per replicate was incubated. During the fall 1994 survey, hCG was not found to be an effective GtH agonist for spoonhead sculpin. Consequently, during the spring 1995 survey, hCG was replaced with 10 μM forskolin solubilized in ethanol. Forskolin activates adenylate cyclase, thereby mimicking GtH by bypassing the GtH receptor and increasing cyclic adenosine monophosphate (cAMP) production.

During the spring 1994 survey only production of testosterone was measured. Testosterone and 17β-estradiol (females only) production was measured during the fall 1994 and spring 1995 surveys. *In vitro* production of testosterone and 17β-estradiol released to the medium were quantified by radioimmunoassay procedures described in Van Der Kraak and Chang (1990) and Van Der Kraak *et al.* (1989), and further outlined in McMaster *et al.* (1995).

2.6 MIXED FUNCTION OXYGENASE ACTIVITY

During each field survey, whole livers were removed from each sentinel fish and placed in a cryovial and frozen immediately in liquid nitrogen. In the laboratory, liver samples were thawed

on ice and analysed for hepatic cytochrome P450IA-dependent MFO activity using the catabolism of ethoxyresorufin (EROD) as described in van den Heuvel *et al.* (1995). For the spring and fall 1994 field samples, all livers were homogenized and subsequently centrifuged at 10,000 x g for the purpose of isolating and extracting the microsomal fraction from the liver. However, low levels of EROD activity among reference and exposed fish suggested that the extraction of the microsomal fraction was incomplete, probably due to the small size of the individual livers (0.1-0.3 g). In an effort to ensure all microsomes were present in the sample, liver samples collected during the spring 1995 field trip were assayed using the whole homogenate, omitting the centrifugation procedure.

2.7 DATA ANALYSES

Means, standard errors and sample sizes were calculated for all fish measurements for each sampling zone. For presentation purposes, common fish indices describing relationships between body metrics also were calculated. These indices included:

Condition factor (k)=100(carcass weight/fork length^3)
Gonadosomatic Index (GSI)=100(gonad weight/carcass weight)
Liversomatic Index (LSI)=100(liver weight/carcass weight)

With the exception of immature fish (not dissected), carcass weight (i.e. eviscerated) was used in the above calculations because of possible differences in organ weight among sites. Using carcass weight instead of body weight eliminated possible confounding effects of altered organ weight (e.g. gonad weight, liver weight) on interpretation of variables related to body weight. Total body weight was used when calculating condition of immature fish. Spoonhead sculpin do not have a forked tail, therefore, total length was used instead of fork length when calculating condition factors.

The whole organism parameters analyzed are listed in Table 1. For spoonhead sculpin, total length was used instead of fork length. All parameters were regressions of one variable on another. In the case of liver weight, fecundity, egg size and gonad weight; carcass weight was used as a covariate to adjust for any differences in size and placed these variables on a relative scale. The basic design for the analysis of fish data was an Analysis of Covariance (ANCOVA) with site as a factor. An assumption of the ANCOVA model is that the slopes of the regression lines are equal among sites. Therefore, differences in slopes were tested prior to conducting the ANCOVA. Generally, ANCOVA is fairly robust even when slopes are not equal, so slopes were considered different when $p < 0.01$ (Hamilton *et al.*, 1993). Analysis of variance (ANOVA) was used to compare body size (body weight, length and carcass weight) and egg size (egg weight and diameter) estimates among sites. All data were $\log_{10}$ transformed and sexes were analyzed separately. Nonparametric Kruskal-Wallis tests were used to compare MFO activity and *in vitro* steroid levels between reference and exposed fish.

2.8 CHEMISTRY

To confirm that fish were being exposed to pulp mill effluent at the collection sites, samples were taken for chemical analyses on both water and fish tissue samples.

Water samples were collected in the vicinity of each fish collection site during the fall 1994 and spring 1995 surveys. At each sampling site,, water was collected in 3-125 mL Nalgene bottles for analyses of major ions (Cl, Na, K, SO_4, SiO_2). During the fall 1994 survey, water was also collected in 3-125 mL Nalgene bottles for AOX analysis. Water samples for AOX analyses were acidified (pH 2) with concentrated sulphuric acid. All samples were put on ice immediately after collection.

In addition, during each survey, 10-15 fish carcasses from each sampling site (reference, near-field, far-field zones) were placed in contaminant free polyethylene bags and archived frozen, pending possible future analyses for contaminants and lipids decided by the NRBS Science Directors.

2.9 HABITAT CLASSIFICATION

Major channel habitat types and bankside habitat classifications were documented at each fish collection site. The description was based on the NRBS habitat classification system outlined in the Terms of Reference (Appendix A). Black and white photographs of each site area were also taken.

3.0 RESULTS AND DISCUSSION

3.1 PILOT STUDY: SPRING FIELD SURVEY (1994)

3.1.1 Sentinel Species and Site Selection

A total of eleven sites in the Hinton study area, and nine sites in the Whitecourt study area were sampled for the purpose of collecting any of the potential sentinel species (Figure 4 a,b,c,d,e). For each site sampled, the specific location (latitude/longitude coordinates), general description and method of fishing is presented in Table 2.

In the vicinity of Hinton, seven taxa of fish were collected: mountain whitefish (*Prosopium williamsoni*), rainbow trout (*Oncorhynchus mykiss*), bull trout (*Salvelinus confluentus*), spoonhead sculpin (*Cottus ricei*), longnose dace (*Rhinichthys cataractae*), longnose sucker (*Catostomus catostomus*) and spottail shiner (*Notropis hudsonius*)(Table 3). Immature mountain whitefish were the most abundant and widely distributed fish species, followed by young-of-the-year sucker species. Of the possible sentinel species, small numbers of longnose dace and spoonhead sculpin were found. The majority of longnose dace captured were immature and attempts to collect adults (day and night hours) were unsuccessful. Similarly, most spoonhead sculpin captured were immature; however, collection of a few adults (1 male, 6 females) suggested that increased sampling effort could provide

greater numbers of mature male and female sculpin. It was difficult to select sampling sites for future study without first improving the capture success of adult individuals for this species. Based on abundance values observed during this survey (Table 5a), Site 1 (Hinton reference) and Site 2 (mill A near-field) represent tentative locations for future sampling. Unfortunately, additional collections of sculpin during the spring survey were not possible due to increasing water levels (low/high altitude melt) and loss of accessible sampling sites. Most sculpin were collected from habitats consisting of large cobble and boulder substrates using the backpack electrofisher.

In the vicinity of Whitecourt (including Windfall Junction), ten taxa of fish were collected: mountain whitefish, lake chub (*Couesius plumbeus*), trout-perch (*Percopsis omiscomaycus*), longnose dace, spottail shiner, spoonhead sculpin, white sucker (*Catostomus commersoni*), juvenile sucker species (*Catostomus* sp.), burbot (*Lota lota*) and northern pike (*Esox lucius*) (Table 4). Lake chub was the most abundant species collected, followed by juvenile sucker species. Lake chub was also the most abundant and widely distributed sentinel species for the Whitecourt area. Most chub were found along the quieter margins of the river consisting of large cobble and boulder substrates. Backpack electrofishing proved to be the most efficient method of capturing lake chub from these habitats.

Mature male and female lake chub were most abundant at Site 12 (Windfall Bridge reference - renamed Site WF), Site 13 (mill B near-field - renamed Site MB) and Site 14 (mill C near-field - renamed Site MC) (Table 5b). Higher numbers of lake chub were also captured at Site 18 (renamed site MCS); however, these fish were caught using a beach seine, whereas other sites were sampled using the electrofisher. These data were not included in subsequent analyses of fish responses.

3.1.2 Fish Measurements

Variations in body metrics for spoonhead sculpin and lake chub for each of the selected study sites are presented in Table 6 and Table 7, respectively. Because very little life history information is known for these species, part of the preliminary evaluation includes the development of sufficient background information that will facilitate and allow future assessment of species responses to effluent.

Spoonhead Sculpin

Numbers of sculpin were too low to discuss downstream trends in metrics. However, from the limited data it appeared that the size of mature sculpin was approximately 7-8 cm in total length and 3-5 g in body weight. Mean size of immature sculpin was less than 5.7 cm long and 1.82 g in body weight. Mean gonad weight for female sculpin collected from the reference site was 0.08 g and represented 1.58 % of the carcass weight. Prior to our collections, spoonhead sculpin were thought to spawn in April and May after the water temperature reached 6°C (Roberts, 1988). The spent condition of the ovaries from fish collected during this survey suggested that they had already spawned by May 5 (water temperature ≈ 9.5°C).

Lake Chub

Based on the reference site, mean sizes of mature males were similar to females (length, p=0.43; weight, p=0.25). Male and female chub were approximately 8-9 cm mean fork length and 5-8 g mean total body weight. Immature chub were found to be less than 6 cm fork length and 2.3 g body weight. Mature male and female chub were similar in age (p=0.26) and approximately 2-3 y old. Although the exact time of spawning for lake chub in the Whitecourt area is unknown, it has been suggested that lake chub spawn in late spring/early summer (Brown *et al.*, 1970). At the time of sampling (May 6-14, water temperature ≈ 14°C), lake chub had not yet spawned and the gonadosomatic index for prespawning males was approximately 2-2.5 %, and 13-15% for prespawning females. As well, the mean fecundity for reference females was 1848 eggs/female and the mean size of eggs were 0.38 mg in weight and 0.83 mm in diameter.

Sufficient numbers of lake chub allowed statistical comparisons of body size metrics among sites (i.e. Windfall Bridge, mill A near-field, mill B near-field). Estimates of fish parameters (i.e. regression of one variable onto another using ANCOVA) were also conducted for female and immature lake chub. Fish parameters were not calculated for male chub because sample sizes were not sufficient to confidently describe the bivariate relationships.

To determine whether lake chub collected downstream of mill C exhibited characteristics different from upstream conditions, comparisons were made with chub collected from the mill B near-field site. Univariate comparisons of body size indicated that there were no significant site differences in mature male (total weight, p=0.11; fork length, p=0.10), female (total weight, p=0.24; fork length, p=0.20) or immature lake chub (total weight, p=0.68; fork length, p=0.69). As well, there were no differences in mean ages of males (p=0.14) and females (p=0.70). Size-at-age relationships were also similar between sites for female chub (p=0.07). There were no significant differences in relationships describing condition (p=0.95), gonad size (p=0.14) and liver size (p=0.54) of female chub. Fecundity (p=0.43) and egg size (egg weight, p=0.12; egg diameter, p=0.46) were also similar between sites. Comparisons between condition of immature fish indicated a significant difference in the slopes of the regression lines between mill B and C fish (p=0.009). By calculating the separate regression lines for each site (Figure 5), it was apparent that:

1) the size range of immature fish collected at the mill B near-field site included individuals smaller (3-4 cm range) than collected from the mill C near-field site, and
2) immature fish from below mill B were slightly "fatter" at small lengths, but their weight gain per increase in length was lower than for fish captured below mill C until a fork length of 5.8-6.0 cm.

Because there were no statistical differences in body size and organ weights for male and female fish collected below mill B and C, these data were pooled for comparisons with reference fish. Immature fish were not pooled due to significant differences in condition. There were no differences in the univariate size estimates of mature male (total weight, p=0.08; fork length, p=0.10) or female lake chub (total weight, p=0.38; fork length, p=0.41) collected from the reference and exposed sites. As well, there were no differences in mean ages of males (p=0.36) and females

(p=0.71). Size-at-age relationships were also similar between sites for female chub (p=0.37). The pooled regression of size-at-age was significant (p=0.001); however, the correlation coefficient was low (i.e. r^2=0.35). There were no significant differences in condition (p=0.68), gonad weight (p=0.59) or liver weight (p=0.77) between reference and exposed female chub. Fecundity adjusted for body size was significantly higher (p=0.009) at the reference site; however, egg weight (adjusted for body size) was not different between sites (p=0.23). Egg diameter was not related to body size (p=0.42) and the univariate comparison of egg diameter indicated there was no difference between sites (p=0.82). Regression lines for size-at-age, condition, gonad weight and liver weight for female lake chub using data pooled among all sites are presented in Table 8.

Total body weight and fork length of immature chub from either mill B (total weight, p=0.71; fork length, p=0.73) or mill C near-field sites (total weight, p=0.30; fork length, p=0.33) were not different from immature fish collected from the reference site (Windfall Bridge). Similarly, there were no differences in condition of immature fish collected from either mill site (mill B, p=0.86; mill C, p=0.60) relative to reference fish.

From the preliminary site comparisons of body size, organ metrics and age of lake chub, there was little evidence suggesting alterations in these fish characteristics below mill B or mill C. Only fecundity was found to be different between reference and exposed fish (mill B + mill C near-field fish).

Mean hepatic EROD activity in male lake chub collected below mill B was 2.6-fold higher than reference males (Figure 6). However, variability among males from mill B was high and the difference relative to reference males was not found to be significant (p=0.75). EROD activity in male chub from the mill C was also not significantly different from reference males (p=0.22). Similarly, EROD activity in female lake chub collected downstream of either outfall was not significantly induced relative to reference females from Windfall Bridge (mill B, p=0.56; mill C, p=0.63) (Figure 6). Typically, fish exposed to pulp mill effluent (especially effluent from mills with kraft pulping) show increased levels of hepatic EROD activity relative to unexposed fish (e.g. Munkittrick *et al.*, 1994). The absence of induction in fish below mills B and C was likely influenced by the high level of effluent dilution even during low river flow conditions. Laboratory tests investigating the effluent thresholds for MFO responses indicate that induced MFO activity is observed at concentrations of 0.5-0.7% for some kraft mill effluents (Robinson *et al.*, 1994). Maximum effluent concentrations immediately below the mill B outfall during low flow conditions has been estimated to be approximately 0.15% (Sentar, 1994a). Maximum effluent concentrations within 155 m of the mill C outfall was estimated at 0.75%, and quickly dropped to 0.4 % approximately 1.5-1.7 km downstream (Sentar, 1994b). However, regardless of effluent dilution, the absence of significant EROD induction has also been documented in rainbow trout during laboratory exposures to 100% effluent from both mill B and C facilities (Munkittrick *et al.*, unpublished data).

In vitro production of testosterone by follicles from lake chub was not significantly different among fish from the reference, mill A and mill B sites (basal levels, p=0.37; hCG levels, p=0.33) (Figure 7). In addition, there was no significant difference between basal testosterone production and

follicles challenged with hCG (p=0.13). Based on this first survey, hCG did not appear to be a suitable GtH agonist for lake chub *in vitro* steroid tests. Human chorionic gonadotropin is not effective for all fish species (e.g., salmonids), but has been found to be suitable for several cyprinid species (McMaster *et al.*, 1995). As such, in the absence of specific information regarding steroid responses in lake chub, hCG seemed to be a reasonable choice to begin our investigation. Future surveys should use alternative agonists in an attempt to find one that is effective for lake chub. Several studies have documented depressed steroid production in fish exposed to bleached kraft mill effluent (McMaster *et al.*, 1991; Munkittrick *et al.*, 1991, 1992; Hodson *et al.*, 1992, Gagnon *et al.*, 1994). As well, reduced plasma steroid levels have been observed in fish exposed to effluents from a variety of pulp mill process types and treatment facilities (Munkittrick *et al.*, 1994). As with the MFO results, the high degree of effluent dilution for mill B and C, even during low flow conditions, minimized the likelihood of a steroid depression response in the exposed fish.

3.1.3 Summary of the Spring Pilot Survey (1994)

Data collected during the pilot survey provided specific information needed to design the intensive survey to be conducted the following fall. In particular, the following issues were addressed:

- identifying potential sentinel species for study

  Although limited collections were made, spoonhead sculpin represented the most likely sentinel fish species in the Hinton area. Further sampling should be conducted during the fall survey to confirm this opinion.

  Lake chub was selected as the sentinel fish species for mills in the Whitecourt area. Lake chub were sufficiently abundant and widely distributed within the study area.

- determining the best method for collecting sentinel species

  Although, both seining and electrofishing methods were used, backpack electrofishing was the easiest and most successful method of fish capture. This method also resulted in fewer incidental mortalities of fish.

- selecting reference and exposure study sites

  Based on fish capture success, sites for both the Hinton and Whitecourt study area were selected for future study. The site locations were tentative because it was recognized that the specific sites may not yield the same level of capture success during the fall season as they did during the spring season (i.e. possible seasonal variability in fish habitat selection).

- collecting preliminary data on sentinel fish characteristics exposed to pulp mill effluent (physiological and whole organism)

Sufficient numbers of lake chub were collected to conduct site comparisons of fish metrics, MFO activity and *in vitro* testosterone production. There was little evidence (with the exception of fecundity) to suggest that fish collected below the mill outfalls exhibited characteristics different from the reference fish. Data collected during the fall survey were used to further examine relationships.

3.2 FALL FIELD SURVEY (1994)

The exact location (latitude/longitude coordinates) and general description of each sampling site in the Hinton and Whitecourt study area are provided in Table 9.

In the vicinity of Hinton, six taxa of fish were collected by electrofishing: mountain whitefish (*Prosopium williamsoni*), rainbow trout (*Oncorhynchus mykiss*), bull trout (*Salvelinus confluentus*), longnose dace (*Rhinichthys cataractae*), spoonhead sculpin (*Cottus ricei*), and juvenile sucker species (*Catostomus* sp.) (Table 10). Sampling was biased towards sampling habitats appropriate for spoonhead sculpins (i.e. cobble/boulder riffle areas). Of all incidental species captured, immature mountain whitefish were the most numerous; reflecting the overlap in habitat preferences of the immature whitefish and adult sculpins. Abundance of male, female and immature spoonhead sculpin collected at the reference site (HRL), mill A near-field site (MAL) and a site located across-river from the effluent plume (MAR) are presented in Table 11a.

In the vicinity of Whitecourt (including Windfall Junction), seven taxa of fish were collected by electrofishing: mountain whitefish, lake chub (*Couesius plumbeus*), trout-perch (*Percopsis omiscomaycus*), longnose dace, spoonhead sculpin, burbot (*Lota lota*) and juvenile sucker species (Table 10). Abundance of male, female and immature lake chub collected at the reference sites (WF, R2), mill B near-field site (MB) and mill C near-field site (MC) are presented in Table 11b.

3.2.1 Fish Measurements

Variations in body metrics for spoonhead sculpin and lake chub for each of the selected study sites are presented in Table 12 and Table 13, respectively.

Spoonhead Sculpin

For mature female spoonhead sculpin, estimates of fecundity and egg size were limited. A large proportion of the larger, firm eggs were used for measuring *in vitro* steroid production. Many of the remaining eggs were smaller and broke easily when handled during counting and weighing. Univariate comparisons of fecundity and eggs size were conducted; however, bivariate relationships with carcass weight (i.e. ANCOVA) were not calculated because of insufficient sample sizes.

Based on data from the reference site, mean body size of mature male spoonhead sculpin was 8.7 cm total length and 6.6 g total weight. Females were similar to males in mean length ($p=0.12$) but

were slightly lighter (p=0.03) in total body weight (weight=5.4 g). Mature male and female sculpin were similar in mean age (p=0.59) and were approximately 3-3.5 y old. Immature sculpin were found to be less than 6.2 cm total length and 1.9 g body weight. The gonadosomatic indices (GSI) for males and females were 2.6% and 3.1%, respectively. These values were approximately twice the values reported during the spring survey, suggesting that a large part of gonadal development occurred during the summer and fall. The mean fecundity for reference females was 960 eggs/female and the mean size of eggs was 0.21 mg in weight and 0.66 mm in diameter.

Total body weight of female and male sculpin from the near-field site were greater than fish from the reference site (female, p=0.002; male, p=0.007). Similarly, total length of females was greater at the near-field site (p=0.01). Differences in total length for males were borderline (p=0.06). Univariate estimates of size for immature sculpin were not significantly different between the reference and near-field site (total length, p=0.90; total weight, p=0.49). Mean age of male sculpin from the near-field site was greater than for reference males (p=0.03). Differences in female age were marginal (p=0.06). Size-at-age relationships were not significantly different between sites for both males and females (Table 14). As well, univariate comparisons of fecundity (p=0.83) and egg diameter (p=0.12) did not indicate significant site differences; however the average egg weight at the near-field site was heavier (p=0.007). Condition factor, gonad weight and liver weight of male and female sculpin from the near-field site were significantly higher than values reported for the reference fish (Table 14). Condition factor for immature sculpin was also higher at the near-field site.

To assess whether fish captured across the river from the effluent plume exhibited characteristics similar to reference fish or exposed fish, comparisons were made between: a) Site MAR and the near-field site (MAL), and b) Site MAR and the reference site (HRL).

Body size estimates for male (length, p=0.57; weight, p=0.77), female (length, p=0.95, weight, p=0.94) and immature (length, p=0.57, weight, p=0.93) sculpin were not significantly different between Site MAR and the near-field site. Mean ages (male, p=0.37; female, p=0.56) and size-at-age (Table 14) for male and female sculpin were also similar between sites. Condition factors for male, female and immature sculpin were also not significantly different (Table 14). Gonad weights for males and females from the near-field site were heavier (Table 14). There were no differences in fecundity (p=0.68) or egg size (weight, p=0.24; diameter, p=0.31). In addition, there was no difference in female liver weight. For male liver weight, the slopes of the regression lines (liver weight. *vs* carcass weight) were significantly different between sites MAL and MAR (Table 14). It was apparent for the individual site regression lines (Figure 8), that for most of the range in carcass weight, the near-field males had smaller liver weights than Site MAR males. This relationship reversed at a carcass weight of about 9.5 g (i.e large males).

Length and weight estimates for male (length, p=0.006; weight, p=0.002) and female (length, p=0.01, weight, p=0.002) sculpin from Site MAR were significantly higher relative to reference fish. Body size of immature fish was not different between sites (length, p=0.46; weight, p=0.21). Mean ages of males (p<0.001) and females (p=0.01) were significantly higher at site MAR, although there were no differences in size-at-age (Table 14). Bivariate relationships of condition, gonad weight

and liver weight for males and females were not different between sites (Table 14). As well, there was no difference in condition of immature fish from the reference site and Site MAR (Table 14). There were also no differences in fecundity (p=0.87) and egg size (weight, p=0.07; diameter, p=0.94) between sites.

Site differences in the bivariate fish parameters have been summarized in Table 15. Spoonhead sculpin collected from the near-field site were older than reference fish, yet with similar size-at-age (length vs age) relationships for both males and females. This suggested that the fish at the near-field site were longer because they were older, not because of increased growth in length. Near-field fish were also heavier, fatter and had larger gonad and liver weights relative to reference fish of similar size (i.e. carcass weight). The increased level of energy expenditure and storage was indicative of fish responding to increased food supply (Gibbons and Munkittrick, 1994). Previous work on benthic communities attributed an increase in invertebrate populations downstream of the Hinton mill to mild enrichment (Anderson, 1989). Effluent from mill A represents a combination of treated wastewater from the mill and municipal sewage from of the town of Hinton. As such, the observed responses of spoonhead sculpins downstream of the mill A outfall may be related to eutrophication associated with the discharged effluent.

Studies conducted in Eastern Canada (e.g. McMaster *et al.*, 1991, 1992a; Munkittrick *et al.*, 1991) assessing the effects of bleached kraft mill effluent on white sucker and lake whitefish populations, demonstrated delayed sexual maturity, smaller gonads, reduced body size and increased liver size at some sites. This response was generally associated with some form of metabolic disruption and resulted in a negative effect on the fish population. Spoonhead sculpin were exhibiting signs of growth (weight and girth not length) and increased energy storage and did not appear to be negatively affected by the exposure to mill A effluent.

Sculpin from Site MAR were similar in age, size-at-age and condition to fish from the near-field site but had smaller gonads and liver weights (with the exception of females). Conversely, length, weight and mean age of sculpin from Site MAR were greater than reference fish and size-at-age, condition, gonad weight and liver weights were similar. Sculpin from Site MAR appeared intermediate in fish characteristics relative to fish from the reference and near-field sites (see Table 15). In particular, differences between Site MAR and near-field responses suggested that sculpin did not undergo extensive lateral movement across the river and in and out of the effluent plume. Similarly, differences in responses observed between Site MAR and reference fish suggested that longitudinal movement up and down the river was limited. Additional sampling on opposites sides of the river at multiple locations along the river would facilitate confirmation of these results.

In vitro production of testosterone (Figure 9a) and 17β-estradiol (Figure 9b) by follicles of sculpin from sites downstream of the mill A outfall were significantly higher than reference levels. Testosterone production at the near-field site was significantly higher than production at Site MAR, whereas, levels of 17β-estradiol were similar (Figure 9). There was no significant difference between basal production of 17β-estradiol and production by follicles challenged with hCG (p=0.40). As well, basal production of testosterone was significantly higher than levels produced by follicles treated with hCG (p=<0.001). Based on this survey, human chorionic gonadotropin did

not appear to be a suitable GtH agonist for spoonhead sculpin *in vitro* steroid production. Human chorionic gonadotropin is not effective for all fish species (e.g., salmonids), but has been found to be suitable for several cyprinid species (McMaster *et al.*, 1995). As such, in the absence of specific information regarding steroid responses in spoonhead sculpin, hCG seemed to be a reasonable choice (as with lake chub) to begin our investigation.

Follicles of fish exposed to BKME have shown reduced production of steroids relative to reference fish at a number of sites (Van Der Kraak *et al.*, 1992; Jardine, 1994; McMaster *et al.*, 1994). Depressed levels of steroids can potentially have serious negative effects on the reproductive capacity of some species of fish. Exposed spoonhead sculpin; however, exhibited an increase in steroid production. The increased steroid levels closely parallelled the observed trends in gonad weight and body size, and was perhaps part of a general response of exposed fish to an increase in food resource.

Mean hepatic EROD activity in male sculpin from the near-field site (MAL) was 2.6-fold higher than reference males ($p=0.03$), and 2.8-fold higher than males from Site MAR ($p=0.03$)(Figure 10). EROD activity in males from Site MAR was not significantly different from reference males ($p=0.51$). EROD activity in female spoonhead sculpin from the near-field site was 2.4-fold higher than reference females ($p=0.007$) and 1.5-fold higher than females from Site MAR ($p=0.03$). EROD activity in females from Site MAR were 1.6-fold higher than reference females, but the difference was not statistically significant ($p=0.20$).

Fish exposed to kraft mill effluent often show increased levels of EROD activity. The increase in EROD activity in both male and female sculpin collected from Site MAL indicated probable exposure to effluent from mill A. The intermediate levels of activity observed at Site MAR suggested that fish were exposed to lower concentrations of effluent and parallelled the intermediate levels in fish parameters, steroids and water chemistry (cf Section 3.2.2)

Lake Chub

Based on data from the two reference sites (WF, R2), mean sizes of mature males were similar to females (length: Site WF $p=0.19$, Site R2, $p=0.86$; weight: Site WF $p=0.35$, Site R2 $p=0.91$). Mean sizes of mature male and female chub were approximately 8.8-9.4 cm fork length and 7.1-8.1 g total body weight. As well, the mean age of male and female chub was similar at both reference sites (Site WF, $p=0.61$; Site R2, $p=0.14$) and ranged from 1.2-1.8 y old. Immature chub were found to be less than 7.2 cm fork length and 3.5 g body weight. Gonadosomatic indices (GSI) were approximately 0.85-0.96% for males and 7.7-8.7% for females. These estimates of GSI were approximately half the values reported for prespawning lake chub during the spring survey. Reference females had mean fecundity estimates of 2394-2662 eggs/female, egg weights of 0.26-0.30 mg and egg diameters of 0.77-0.80 mm (Table 13).

Lake chub were collected from a second reference site (Site R2) located approximately 16 km downstream of the Windfall Bridge reference site (Site WF). A second reference site was sampled to investigate possible differences in fish characteristics among sites within the reference zone.

Total body weights of male and female lake chub were not significantly different between reference sites (male, p=0.98; female, p=0.47). Similarly, mean fork length of male chub was not significantly different (p=0.54). Differences in fork length for females were borderline (p=0.06). Both mean length and mean weight of immature chub were significantly higher at Site WF (fork length, p=0.046; total weight, p=0.006). The mean age of male chub was greater at Site WF (0.04); however, there was no difference in the age of female chub (p=0.16). Size-at-age for both sexes were not significantly different between sites (Table 16). Condition, gonad weight and liver weight for male chub were similar between reference sites (Table 16). Mean condition and liver weight of females, and condition of immatures, were higher at Site 5 (Table 16). Female gonad weight, fecundity, and egg size were similar between sites (Table 16).

From the above analyses, it is evident that there were differences in male age and body/organ metrics of female and immature chub within the reference zone. In the absence of anthropogenic stressors, it was likely that the observed differences represented the natural variability in fish characteristics within the reference zone. For comparisons between reference and exposed fish, reference sites WF and R2 were pooled. Although data are not generally pooled unless it has been demonstrated that there are no significant differences between sites, we wanted to ensure that the full extent of reference variability was included in reference/exposure comparisons. It was felt that this approach provided a more conservative test of exposure differences.

Males and females from the mill B near-field site (MB) were similar in length (male, p=0.34; female, p=0.92), weight (male, p=0.44; female, p=0.78) and mean age (male, p=0.14; female, p=0.59) to chub pooled over both reference sites (WF+R2). In addition, there were no differences in the size estimates of immature chub (length, p=0.86; weight, p=0.62). Size-at-age for both males and females were similar between sites (Table 16). Condition for male, female and immature chub were not different between the reference and exposed sites (Table 16). As well, there were no differences in gonad weight for both males and females. There was no difference in liver weight for males; however, female liver weight was greater at Site MB. Bivariate relationships of fecundity and egg size were not statistically different between sites (Table 16).

Pooled reference males and females were similar in length (male, p=0.60; female, p=0.14) and weight (male, p=0.15; female, p=0.47) to fish from the mill C site (MC); however, condition factor for reference male and female chub was significantly lower (Table 16). There were no differences in mean age (male, p=0.64; female, p=0.59) or size-at-age for male or female chub. In addition, gonad and liver weights for males and females were similar between sites (Table 16). Fecundity and egg size estimates were also similar (Table 16). There was no difference in length (p=0.41), weight (p=0.40) or condition of immature chub collected from the reference zone and Site MC.

Comparisons between fish from the mill B near-field site (MB) and mill C near-field site (MC) indicate that were no differences in fork length and body weight of male (length, p=0.72, weight, p=0.59), female (length, p=0.24, weight, p=0.69) or immature chub (length, p=0.89, weight, p=0.90). However, condition factors for males, females and immatures were significantly higher below the mill C outfall (Table 16). Mean age (male, p=0.07; female, p=0.90) and size-at-age of male and female chub (Table 16) were similar between sites. Male and female gonad weights were

also similar between the two near-field sites (Table 16). As well, there was no difference in fecundity (adjusted for size). Bivariate relationships between egg size and carcass weight were not significant (egg weight, p=0.34; egg diameter, p=0.11). Subsequent univariate comparisons of these parameters showed no differences between the exposure sites (egg weight, p=0.50, egg diameter, p=0.83). There were no differences in male and female liver weights between the near-field sites. For male chub, there was no relationship between liver and carcass weight pooled over sites (r^2=0.18) and the univariate comparison of liver weight did not indicate a difference between sites (p=0.19).

The observed differences in fish metrics between reference sites suggested that there was the potential for significant variability within a prescribed reference zone. It is necessary to consider this variability when designing impact monitoring studies. If possible, multiple reference populations within the reference zone should be sampled to acquire a representative description of reference fish. These reference sites should be as similar as possible to each other (and to the exposure sites, excluding effluent exposure) such that the variability in fish measurements represents natural variability in the reference zone, and not variability inflated by confounding factors.

Overall, there were no differences in length and weight of male, female or immature lake chub among the reference, mill B and mill C sites. As well, mean age among sites were similar, with the single exception of male chub being older at Site WF relative to Site R2. Site differences in the bivariate fish parameters have been summarized in Table 17.

Adult lake chub downstream of the mill C outfall exhibited increased condition relative to mill B and reference fish, without concomitant increases in organ size or individual body size estimates. An increase in condition factor is a common response to pulp mill effluent (e.g. McMaster *et al.*, 1991; Munkittrick *et al.*, 1991, Swanson *et al.*, 1994); however, unless coupled with other changes in size-at-age, gonad size, fecundity and liver weight, it probably represents a minor concern.

Immature lake chub from the mill B site exhibited reduced condition relative to mill C fish but were similar to reference fish. As well, liver sizes of exposed males were larger than reference males. Altered changes in condition without concomitant changes in other parameters does not represent a dramatic change. As well, borderline differences in liver size between reference and mill B males, without changes in other characteristics of male lake chub, is probably not a major concern. This is especially true when most fish populations exposed to pulp mill effluent exhibit an increase in liver size (Munkittrick *et al.*, 1994). The meaning of the change in liver size is unclear.

Basal levels of *in vitro* production of testosterone (Figure 11a) and 17β-estradiol (Figure 11b) by follicles of lake chub from the two reference sites (Sites WF and R2) were not significantly different. However, testosterone production by follicles challenged with hCG was different between reference sites. 17β-Estradiol production from follicles treated with hCG was also not different between reference sites (Figure 11b). For comparisons between reference and exposed *in vitro* steroid production, females from Site WF were pooled with Site R2 (i.e. WF+R2). Basal production of testosterone by follicles from mill B females was not significantly different from reference females. Follicles from mill C females; however, produced significantly more testosterone than

reference and mill B fish. When challenged with hCG, testosterone production was significantly higher by follicles of chub from both mill near-field sites (Figure 11a). There was no difference in basal levels of 17β-estradiol production among sites. However, when challenged with hCG, production of 17β-estradiol by follicles from both mill near-field sites were depressed relative to reference values. There was no significant effect of hCG on testosterone production of follicles from reference fish ($p=0.14$), but 17β-estradiol production was increased ($p=0.024$). Conversely, hCG increased production of testosterone in follicles of females from the mill exposure sites ($p<0.001$), but had no effect on 17β-estradiol ($p=0.17$).

There did not seem to be any negative effects (i.e. reduced production) of effluent exposure on basal and hCG mediated production of testosterone. Instead, there was a tendency towards increased production of testosterone by follicles of lake chub exposed to mill B and mill C effluent. Follicles from exposed fish produced lower mean basal levels of 17β-estradiol than reference fish; however, within-site variability was high and the levels were not statistically significant. Differences between reference and exposed follicle production of estradiol were amplified when challenged with hCG. Human chorionic gonadotropin successfully stimulated reference production of 17β-estradiol, but had no effect on follicles exposed to mill B and C effluent. The absence of increased levels of 17β-estradiol from hCG mediated follicles from exposed females can be considered a response to effluent exposure. It is also interesting that hCG stimulated testosterone production in exposed females, suggesting problems in the conversion of testosterone to 17β-estradiol. At this point this is speculative; however, levels of both testosterone and 17β-estradiol are typically high during vitellogenesis (McMaster *et al.*, 1995). Lake chub are spring/early summer spawners, and females collected during the fall survey would be in the mid-vitellogenic period.

Mean hepatic EROD activity in male lake chub was not significantly different between the two reference sites (WF and R2) (Figure 12). However, females from Site R2 were significantly induced relative to Site WF ($p=0.04$). Exposed female fish from the mill B and mill C near-field sites did not exhibit higher levels of EROD relative to the pooled reference females. Similarly, EROD activities in male lake chub collected from either near-field site were not significantly different from reference levels, although fish from mill C were induced relative to mill B (Figure 12). What this latter observation meant was uncertain given that these same fish had similar EROD levels to reference males. The absence of EROD induction in exposed fish relative to reference fish coincided with the results obtained during the spring 1994 survey. Water chemistry data collected during this survey (cf Section 3.2.2) indicated that fish at the mill B near-field sites were exposed to approximately 0.1-0.5 % effluent and to 0.4 % effluent at Site MC (i.e. downstream of mill B and C). Consequently, instream effluent concentrations were low during the survey and were probably lower during higher flow conditions of the spring/summer freshet period.

3.2.2 Chemistry

Adsorbable organic halide (AOX) was not detected in water samples collected from reference and exposure sites in the Hinton or Whitecourt study areas.

Concentrations of major ions (Cl, Na, K, SO_4, SIO_2) in water samples collected at each sampling site are presented in Table 18.

Hinton Area

Relative to the reference site, instream concentrations of chloride, sulphate and sodium were higher at the mill A near-field site (HRL), and suggested that the near-field site was exposed to mill effluent. Site MAR exhibited concentrations of chloride, sulphate, silicate and potassium similar to concentrations measured at the reference site. The concentration of sodium was moderately higher. This suggested that exposure of Site MAR to effluent was limited during the time of the fall survey. Recent plume delineation studies conducted by the mill (Golder, 1994) confirmed the results of the chemical analyses. The plume study indicated that, during low flow conditions in October, Site MAR was exposed to approximately 0.05-1% effluent and Site MAL (near-field site) was exposed to 2-2.5% effluent.

Whitecourt Area

Instream concentrations of major ions were similar between the two reference sites (WF & R2). Sodium was moderately higher at the mill B site (MB), and substantially higher at the mill C site (MC). Potassium and silicate were also higher at site MC. The mill C near-field site was influenced by discharges from mill C as well as the McLeod River. Water samples from the McLeod River were not collected; however, data from historical water quality surveys (Sentar, 1994b) indicated that the concentration of sodium in the McLeod River was approximately 2.5-3.3-fold higher than the concentration measured in the Athabasca River. Sodium from the McLeod River could explain the increased concentration at the mill C near-field site without factoring in contributions from the mill. The McLeod River was also found to contribute to concentrations of silicate and potassium. Plume delineation studies conducted for mill B (Sentar, 1994a) and mill C (Sentar, 1994b) indicated that the mill B and mill C near-field sites (this survey) were exposed to approximately 0.01-0.05% effluent and 0.4% effluent, respectively.

3.2.3 Summary of Fall Survey

The fall field survey was a continuation of the field work initiated during the spring, and was designed to evaluate the suitability of small fish species for monitoring. In particular, the fall survey addressed the following issues:

- finalizing sentinel species selection for the Hinton study area

  Sufficient numbers of male and female spoonhead sculpin were collected at both reference and near-field sites in the Hinton study area. All collections were conducted at night by electrofishing faster runs and riffles (≈ 1.1-1.5 m/s) approximately 0.5-0.75 m deep with boulder/cobble substrates.

- investigating lateral mobility of sentinel species by sampling fish across river from the effluent plume

  Spoonhead sculpins sampled across river from the effluent plume exhibited an intermediate response relative to reference and near-field fish. The results suggested that lateral and longitudinal (upstream/downstream) movement of spoonhead sculpin was limited.

- investigating whether there are differences in fish characteristics among sites within the reference zone

  Lake chub were collected from two reference sites located approximately 16 km from each other. Observed downstream changes in body and organ metrics of female and immature chub suggested that, in the absence of anthropogenic stressors, it was likely that the observed differences represent the natural variability in fish responses. As such, when comparing fish populations exposed to effluent with reference fish populations, care should be taken to adequately describe the natural variation in the reference zone (e.g. sample multiple reference sites within the reference zone that are as similar as possible to each other and the exposure site characteristics).

- evaluating responses of sentinel species

  Spoonhead sculpin (Hinton study area) and lake chub (Whitecourt study area) responses to pulp mill effluent were evaluated based on whole organism and physiological (MFO activity, *in vitro* steroid production) measurements.

  Spoonhead sculpin collected from the near-field site were older, heavier, fatter and had larger gonad and liver weights relative to reference fish. The increased level of energy expenditure and storage was probably indicative of fish responding to increased food supply, or enrichment. Exposed sculpin also exhibited an increase in the production of testosterone and 17β-estradiol. MFO data confirmed that the fish at the near-field site were exposed to effluent and that Site MAR represented an intermediate site of effluent exposure.

  Adult lake chub downstream of the mill C outfall exhibited increased condition relative to mill B and reference fish, without concomitant increases in organ size or individual body size estimates. Immature lake chub from the mill B site exhibited reduced condition relative to mill C fish but was similar to reference fish. As well, liver sizes of exposed males were larger than reference males. Altered changes in condition without concomitant changes in other parameters did not represent a major concern. Similarly, decreased liver size without alterations in other metrics was not considered a dramatic change. There was a tendency towards increased production of testosterone by follicles of lake chub exposed to mill B and mill C effluent. Human chorionic gonadotropin stimulated reference production of 17β-estradiol, but had no effect on follicles exposed to mill B and C effluent. The absence of increased levels of 17β-estradiol from hCG mediated follicles of exposed females may have been a response to effluent exposure. MFO data indicated that exposure to effluent was low

(assuming the presence of an inducer) probably resulting from low effluent discharge and high effluent dilution.

- conducting water analyses for the purpose of confirming exposure zones

  Water samples were collected at each site for AOX and major ion analyses. Instream concentration of AOX was not detectable at any sampling site. Concentrations of chloride, sulphate and sodium were higher at the mill A near-field site suggesting exposure to effluent. Sodium was moderately higher at the mill B site, and substantially higher at mill C site. Potassium and silicate were also higher at the mill C site. In general, it appeared from the water chemistry and plume delineation studies conducted by the mills, that the near-field site for each mill was exposed to mill effluent.

- recording general habitat characteristics of each intensive fish collection site

  Major channel habitat types and bankside habitat classifications were documented at each fish collection site. The description was based on the NRBS habitat classification system. Black and white photographs of each site were also taken. Summaries of this information are presented in Appendix C.

3.3 SPRING 1995 SURVEY, HINTON

The exact location (latitude/longitude coordinates), distance from the mill A outfall and a general description of each sampling site is provided in Table 19.

Among sites on the Athabasca River, seven taxa of fish were collected by electrofishing: mountain whitefish, rainbow trout, bull trout, spoonhead sculpin, longnose dace, northern pike and juvenile sucker species (Table 20). As in the fall, sampling was biased towards sampling habitats appropriate for spoonhead sculpins. Juvenile sucker species were the most abundant incidental catch, followed by mountain whitefish. Based on catch per unit effort estimates, fish were most abundant at Site MAR and least abundant at Site CL. However, spoonhead sculpin were most abundant at Site HRL and least abundant at Site E.

Total numbers of male, female (preovulatory and spent) and immature spoonhead sculpin collected from sampling sites on the Athabasca River and North Saskatchewan River are presented in Table 21. Limited numbers of male sculpin at Site CL and female sculpin at Site E prevented calculations of bivariate fish parameters. However, univariate comparisons of fish metrics could still be conducted. At some sites, both pre-ovulatory and spent females were collected. Although this had little bearing on sample sizes when calculating parameters such as size-at-age, condition and liver weight, sample sizes were reduced when calculating reproductive parameters (e.g. gonad weight, fecundity, egg size) of pre-ovulatory females. As such, numbers of pre-ovulatory fish at Sites MAR, CL, CR and E were limited, and site comparisons of reproductive parameters adjusted for carcass

weight (i.e. ANCOVA) were not conducted.

3.3.1 Fish Measurements

Variations in body metrics for spoonhead sculpin collected at each of the study sites on the Athabasca River and North Saskatchewan River are presented in Table 22a-c.

For simplicity sake, the current section describing fish measurements (body and organ metrics, steroids and MFO activity) was divided into four subsections:

1) General Biology -basic biology of spoonhead sculpin described using data collected from reference sites HRL and HRR.

2) Reference *vs* Near-Field - comparison of fish measurements between the reference (HRL + HRR) and near -field (MAL and MAR) sites.

3) Far-Field Effects - comparisons conducted to determine the geographical extent of fish responses.

4) Athabasca *vs* North Saskatchewan River - comparison of reference fish from the Athabasca and North Saskatchewan River.

3.3.1.1 General Biology

Metrics

Based on combined data from reference sites HRL and HRR, mature male sculpin were older ($p=0.004$), longer ($p<0.001$) and had heavier carcass weights ($p<0.001$) than mature female sculpin during the spawning period (Table 22a). The average reference male was 4 y old, 8.9 cm long, 7 g in total weight and 6.1 g in carcass weight. The average female sculpin was 3.6 y old, 8.2 cm long with a carcass weight of 3.5 g. Males also had significantly greater size-at-age, condition and liver weight relationships relative to females (Table 23). Spent female sculpin were similar in age to pre-ovulatory ("green") females ($p=0.13$); however, they were longer ($p<0.001$), heavier (carcass weight, $p<0.001$) and exhibited greater size-at-age (Table 23). Condition and liver weights were not different between the two groups of females (Table 23). A reference female (green) had an average gonad weight of 1.05 g, fecundity of 218 eggs/female, egg weight of 5.0 mg and egg diameter of 1.8 mm.

Mixed Function Oxygenase Activity

Mean mixed function oxygenase activity in preovulatory females was significantly lower ($p=0.04$) than observed in spent females (Table 24). EROD activity in male sculpin was higher than

preovulatory females (p=0.02), but similar to spent females (p=0.39) (Table 24), as should be expected. Decreased levels of EROD activity in prespawning females has also been observed in other studies monitoring white sucker (McMaster *et al.*, 1991; Munkittrick *et al.*, 1991; Gagnon *et al.*, 1994). Seasonal differences in EROD activity in female fish and gender differences in prespawning fish have suggested that gonadal steroids, particularly 17β-estradiol, depress total cytochrome P-450 activity. Förlin and Andersson (1984) found that juvenile rainbow trout administered with 17β-estradiol had decreased levels of MFO induction and that testosterone had no effect. Similarly, Stegeman (1982) and Pajor (1990) observed depressed MFO activity in immature brook trout administered with 17β-estradiol. However, contrary to the laboratory findings, Munkittrick *et al.* (1994) found no relationship between steroid levels and MFO activity in white sucker collected from reference and near-field sites associated with 8 Canadian pulp mills. The conclusion from their study was that steroid disruption and MFO induction were independent.

In vitro Steroids

Basal levels of *in vitro* production of testosterone for males was approximately 3.26 pg/mg tissue for male sculpin and 74.5 pg/10 follicles for preovulatory females. Incubation with 10 μM forskolin significantly increased *in vitro* testosterone production for male testicular tissue ($p<0.001$), but had no effect on female egg follicles (p=0.10). Mean basal levels of 17β-estradiol for preovulatory female sculpin was 20.3 pg/10 follicles. Forskolin increased mean production of 17β-estradiol two-fold relative to basal levels (Table 24); however, the difference was not found to be significant (p=0.56).

Using Site HRL as an example, when comparing *in vitro* testosterone production by spring prespawning follicles (13.8 pg/follicle) with follicle production measured during the fall (0.26 pg/follicle), it was clear that there was a substantial increase in steroid production by spoonhead sculpin just prior to spawning. Physiologically this was not surprising; however, it did emphasize that the *in vitro* steroid procedure was successful in demonstrating the natural seasonal increase in testosterone production in sculpin prior to spawning.

Time of Spawning

Looking at all sites sampled during the survey (reference, near-field and far-field), water temperatures ranged from 4.5°C to 7.0°C. Roberts (1988) suggested that spoonhead sculpin spawn during the spring at water temperatures around 6°C. Data from the Athabasca River generally supported this statement in that spent females were collected at sites exhibiting water temperatures between 4.5°C and 6.5 °C. The near-field site represented an anomaly to this trend where only preovulatory females were collected and the water temperature was approximately 7°C (influenced by mill effluent). However, the absence of spent females may not necessarily mean that sculpin at a particular site have not commenced spawning. For example, at the far-field Site E, water temperature was 4.5°C and it was not surprising that only preovulatory females were collected. However, it was soon recognized that males collected at this site were guarding egg masses affixed to the underside of cobble and boulders. Obviously, spawning had started at this site despite the cooler water temperature and the absence of spent females. It seems likely that spent females do

not occupy the same habitat as spawning females. In addition, given the observations at Site E, it is possible that: 1) water temperature may not be a dominant cue for spawning, 2) water temperature may not be the only cue for spawning; or, 3) spawning may start at temperatures $\leq 4.5°C$.

3.3.1.2 Reference vs Near-field

Reference Site Comparisons:

An additional reference site (Site HRR) was sampled across river from the original Site HRL in an effort to increase the number of sites within the reference zone. As well, additional information regarding the mobility of spoonhead sculpin was obtained by sampling sites on opposite sides of the river. A comparison between the reference areas was done prior to conducting reference/near-field comparisons. Body size estimates of male (length, p=0.34; carcass weight, p=0.11) and immature (length, p=0.49; total weight, p=0.67) sculpin were not significantly different between reference sites HRL and HRR. Female sculpin were longer and heavier at Site HRL (length, p=0.009; carcass weight, p=0.002). Male size-at-age was not significantly different; however, a difference in female size-at-age was borderline (Table 25). Male condition, gonad weight and liver weight were greater at Site HRL. Female condition was also greater at Site HRL; however, gonad weight was greater at Site HRR and there was no site difference in liver weight (Table 25). As well, there was no difference in fecundity between sites. Estimates of egg size were not related to carcass weight (egg weight, p=0.96; egg diameter, p=0.14), the univariate comparison of egg size between sites was not significant (egg weight, p=0.16; egg diameter, p=0.07). Condition of immature sculpin was similar between both reference sites.

Mixed function oxygenase(EROD) activity in male sculpin was significantly higher at Site HRR (Figure 13). However, there were no differences in EROD activity in preovulatory and spent (low sample size) female sculpin between reference sites (Figure 14a,b). Similarly, *in vitro* production of testosterone in male sculpin was lower at Site HRR (basal and forskolin levels)(Figure 15a,b), whereas, there was no site difference in production of testosterone (Figure 16a,b) or 17β-estradiol (Figure 17a,b) in female sculpin (basal and forskolin levels). For males, forskolin significantly increased *in vitro* production of testosterone at both sites (Site HRL and HRR, p<0.001); however, forskolin had no effect on production of testosterone (Site HRL, p=0.29; Site HRR, p=0.11) or 17β-estradiol (Site HRL, p=0.50; Site HRR, p=0.11) production in female sculpin. It was uncertain why male sculpin at Site HRR exhibited higher levels of MFO activity and depressed levels of *in vitro* testosterone relative to males at Site HRL, especially when no differences were observed among female sculpin. Regarding MFO activity, it was suspected that, despite the apparent induction, the level of activity was still low compared to downstream exposure sites (see reference/near-field comparison below), and that we were observing natural variability in EROD activity. The reason for depressed steroid production was unknown, unless it was related to differences in female size-at-age, condition and gonad size or water quality. Although it is difficult to speculate, it was interesting to note that there was no difference in egg size (which might be a contributing factor when measuring *in vitro* steroid production by follicles) between sites. Finally, it appeared from the reference data that forskolin was capable of stimulating steroid production in male gonadal

tissues, but was not successful in stimulating female follicles. In most cases, mean steroid production of testosterone and 17β-estradiol in females was actually higher when incubated with forskolin, but the sample variability was high and the differences were not significant. Conclusions regarding the success of forskolin should be delayed until results from other sites have been assessed.

The observed differences in fish measurements between Site HRL and HRR were surprising given their close proximity. Assuming no large differences in water quality (cf Section 3.3.2), nor the presence of some other anthropogenic modifying factor, it seemed likely the differences were representative of the natural variability in fish characteristics of reference fish. It also appeared that the lateral mobility of spoonhead sculpin was not so great as to eliminate these site differences, and supported the assumption of limited mobility. For comparisons between reference and exposed fish, reference sites HRL and HRR were pooled to ensure that the full extent of reference variability was included in reference/exposure comparisons. It was felt that this approach provided a more conservative test of exposure differences.

Pooled Reference vs. Site MAL vs. Site MAR:

Male and immature sculpin from the near-field site (Site MAL) were longer (male, $p<0.001$; immature, $p=0.003$) and heavier (male carcass wt, $p<0.001$, immature total weight, $p<0.001$) than reference fish. Similarly, females from Site MAL were heavier ($p=0.02$), but there were no differences in total length ($p=0.25$). Mean ages of male ($p=0.19$) and female ($p=0.20$) sculpin were similar between sites. There was no site difference in size-at-age for female fish; however, size-at-age of male sculpin was greater at the near-field site (Table 25). Condition of male, female and immature sculpin from the near-field site were significantly higher than values reported for reference fish. Similarly, liver weights for males and females were greater at the near-field site. Mean male gonad weight was similar between sites, but female gonad weight was greater at Site MAL. As well, fecundity was also higher at Site MAL (Table 25). Estimates of egg size were not different between sites (egg weight, $p=0.62$; egg diameter, $p=0.18$). As well, the relationship between egg diameter and carcass weight was borderline ($p= 0.06$), and both estimates of egg size were poorly correlated with carcass weight (egg weight, $r^2=0.20$; egg diameter, $r^2=0.10$).

As in the fall 1994 survey, fish were again collected across river from Site MAL and the effluent plume to assess whether fish from this site of intermediate exposure retained their intermediate responses observed during the fall survey. Mean length ($p=0.46$) and carcass weight ($p=0.79$) of female sculpin were not different between sites MAL and MAR. Body size estimates for male sculpin (length, $p=0.01$; carcass weight, $p=0.02$) were smaller at Site MAR. Immature sculpin were shorter at Site MAR ($p=0.04$), but were similar in total weight ($p=0.07$). The mean ages of both males and females were similar at both sites; however size-at-age for males was greater at the near-field site (Table 25). Male gonad weight was greater at the near-field site. Condition factors and liver weights of females were greater at the near-field site, but differences in these parameters were not found for male fish (Table 25). Condition of immature sculpin was not significantly different between sites. Bivariate descriptions of ovary weight, fecundity and egg size with body size were not possible due to insufficient numbers of pre-ovulatory females at Site MAR. Univariate

comparisons (i.e. not adjusted for body size) suggested that there were no differences in ovary weight (p=0.41), fecundity (p=0.98) or egg weight (p=0.13) between sites, but that egg diameter was greater at Site MAR (p=0.03). Unfortunately the effect of body size on these parameters could not be determined.

Comparisons of pooled reference fish with fish from Site MAR showed that there were no differences in univariate estimates of body size for male sculpin (length, p=0.92; carcass weight, p=0.28), but females from Site MAR were larger than reference females (length, p=0.009; carcass weight, p=0.001). Similarly, immature fish were longer (p=0.05) and heavier (total weight, p=0.007) at Site MAR. Mean ages of both males and females.(male, p=0.50; female, p=0.08) were similar between sites. Size-at-age for males was similar between sites, but was greater at Site MAR for female sculpin (Table 25). Condition of male, female and immature sculpin were greater at Site MAR relative to reference fish. Similarly, liver weights for both males and females were greater at Site MAR (Table 25). Male gonad weight was similar between sites. Ovary weight (p=0.02) and fecundity (p=0.002), unadjusted for body size (insufficient sample size), were greater at Site MAR than at the reference zone. Univariate comparisons of egg size did not show differences between sites (egg weight, p=0.41; egg diameter, p=0.17).

Differences in the bivariate fish parameters among Sites (HRL+HRR), MAL and MAR have been summarized in Table 26. Spoonhead sculpin collected from the near-field zone were heavier, fatter and had larger liver weights than reference fish. In addition, exposed female sculpin exhibited higher gonad weight and fecundity estimates. This general response pattern of increased energy expenditure and storage was also seen during the previous fall 1994 survey, and again suggested that the fish were responding to an increase in food resource (Gibbons and Munkittrick, 1994), and were not negatively affected by the exposure of mill A effluent. As in the fall survey, fish from Site MAR appeared to exhibit characteristics which were intermediate between reference and near-field sculpin. The intermediate responses of fish from Site MAR again suggested that spoonhead sculpin did not undergo extensive lateral movement across river (i.e. between Site MAR and MAL), nor longitudinal movement up and down the river (i.e between reference sites and Site MAR). However, sculpin from Site MAR collected during the spring survey exhibited more characteristics which were different from reference fish and more similar to near-field fish (see Table 15 *vs* Table 26) than observed during the fall 1994 survey. Perhaps this was because Site MAR experienced greater effluent concentrations during winter low-flow conditions such that differences in effluent exposure at Site MAL and Site MAR were minimized. Conversely, it was possible that ice cover and low-flow conditions during the winter reduced habitat availability (especially at Site MAR, wide/shallow habitat) displacing fish towards dominant flow areas of similar effluent exposure.

As in the previous surveys, hepatic EROD activity in this survey was used as an indication of effluent exposure. At Site MAL, EROD activity was approximately 4.3-fold higher in male sculpin and 4.2-fold higher in preovulatory female sculpin relative to reference fish. As well, at site MAR, MFO induction was 5-fold higher in males, 4.2-fold higher in preovulatory females and 2.5-fold higher in spent females relative to reference fish (Figure 13, 14). There were no significant differences in male or female EROD activity between sites MAL and MAR (Figure 13, 14). Significant EROD induction in both male and female sculpin from Site MAL and Site MAR

suggested that sculpin from both sites were exposed to mill effluent. In addition, the similarity in EROD activity between sites MAL and MAR further suggested that effluent exposure at each site was similar.

Comparisons of *in vitro* production of testosterone in males indicated that there was no difference in basal production between sites MAR and MAL (Figure 15a). However, forskolin-stimulated testosterone production was significantly higher (1.4-fold) at Site MAR relative to Site MAL. Basal levels of testosterone in males from either Sites MAL or MAR were not significantly different from reference males (Figure 15a). Testosterone production stimulated with forskolin at Site MAL was not significantly different from reference levels; however, stimulated production at Site MAR was significantly higher (1.5 times) than reference values (Figure 15b). There were no significant differences in basal or forskolin-stimulated levels of testosterone (Figure 16a,b) or 17β-estradiol (Figure 17a,b) production between females from Sites MAL and MAR. As well, there were no differences in basal production of testosterone and 17β-estradiol, or forskolin-stimulated production of 17β-estradiol, between reference females and females from either Sites MAR or MAL (Figure 16a; 17a,b). Forskolin-stimulated production of testosterone in females from Site MAR was significantly higher (5.4 times) than reference females (Figure 16b). At Site MAL and MAR forskolin was found to stimulate testosterone in male sculpin (for each site $p<0.001$); however, forskolin did not have any effect on testosterone (for each site $p>0.11$) or 17β-estradiol (for each site, $p>0.08$) production in female sculpin.

During the fall 1994 survey, follicles from exposed female sculpin exhibited greater *in vitro* production of testosterone and 17β-estradiol than follicles from reference females. However, during the spring 1995 survey, site differences in steroid levels for both male and female sculpin (with the exception of male/female forskolin-stimulated testosterone at Site MAR) disappeared. These results were especially interesting because spoonhead sculpin during the spring survey were collected: 1) during the prespawning stage at which time the steroid profiles were expected to be most developed, and 2) immediately following a prolonged period of high effluent exposure associated with winter low-flow conditions and at which time effects on steroids should be most noticeable. Although uncertain, an explanation may be related, as with other responses, to an increase in food resources. Higher levels of nutrients and food availability may have allowed sculpin at the near-field site to recover from spawning faster (i.e. recover energy losses) and start gonadal development slightly earlier than reference fish. Due to an earlier start, eggs from near-field fish collected in the following fall (fall 1994 survey) were at an advanced stage in development, relative to reference eggs, and were able to produce more steroids. However, once the following spring arrived, both reference and near-field fish had completed their gonadal development prior to spawning and exhibited similar levels of steroid production. Regardless of a possible time shift in gonadal development, it was recognized that mill A effluent did not appear to have a negative impact on *in vitro* production of steroids in exposed spoonhead sculpin.

3.3.1.3 Far-field Effects

Site CL vs CR

Although Site CR was sampled to increase the sample size initially collected at Site CL, it was necessary to confirm, where possible, that sculpin collected from sites CL and CR were similar and that it was reasonable to pool these sites.

Too few males were collected at Site CL to conduct ANCOVA analyses. As well, numbers of preovulatory females were insufficient at Site CL to conduct ANCOVA analyses of gonad weight, fecundity and egg size. Univariate estimates of body size of male (length, $p=0.93$; carcass weight, $p=0.99$), female (length, $p=0.43$; carcass weight, $p=0.81$) and immature sculpin (length, $p=0.44$; total weight, $p=0.99$) were not significantly different between sites CL and CR. Mean age of male ($p=0.73$) and female ($p=0.50$) sculpin were similar between sites, as well as size-at-age for female sculpin ($p=0.69$). Condition of female ($p=0.63$) and immature ($p=0.21$) sculpin were not significantly different between sites. As well, there was no site difference in liver weight of female sculpin ($p=0.26$).

EROD activity in male (Figure 13) and preovulatory female sculpin (Figure 14a) were not different between sites CL and CR. However, EROD activity of spent females at Site CL was 2.2-fold higher than site CR (Figure 14b, $p=0.04$). Basal and forskolin-stimulated *in vitro* production of testosterone from gonadal tissues of male (Figure 15a,b) and female (Figure 16a,b) sculpin were not significantly different between sites CL and CR. As well, no difference was found in the production of 17β-estradiol (Figure 17a,b).

With the exception of MFO activity in spent females, all comparisons of body and organ metrics, EROD activity and *in vitro* steroid production indicate that fish from sites CL and CR were similar. It was not surprising that fish from these sites were similar given their close proximity. As well, plume delineation studies conducted during August and October, 1993 indicated that complete vertical mixing of mill A effluent was achieved 100 m downstream of the diffuser, and complete lateral mixing of the effluent had occurred at about 10 km downstream of the diffuser (Golder, 1994). Sites CL and CR are approximately 21 km downstream of the diffuser. It is uncertain why MFO activity in spent females was higher at Site CL than Site CR. However, given the burden of evidence, and for the purpose of comparisons with reference sites, Site MAL and Site E, fish from sites CL and CR were pooled and referred to as Site C.

Geographical Extent of Responses

Sculpin were collected at sites C and E to investigate whether the responses observed at the near-field zone (specifically Site MAL) persisted downstream to the far-field exposure zone. Comparisons were made between Site MAL *vs* Site C, Site MAL *vs* Site E and Site C *vs* Site E. Total numbers of female and immature sculpin collected at Site E were limited. As such, site comparisons with Site E were not possible for immature sculpin, and only univariate comparisons could be conducted for female sculpin.

Univariate estimates of body size for male (length, p=0.36; carcass weight, p=0.41) and female (length, p=0.15; carcass weight, p=0.72) sculpin were not significantly different between Site MAL and Site C. Mean length of immature sculpin was also not different between sites MAL and C (p=0.35); however, total body weight was heavier at Site C (p=0.01). Mean ages of males (p=0.13) and females (p=0.89) were similar between sites, but there was a decline in size-at-age for males at Site C and an increase for females at Site C (Table 27). Condition of both males and females were similar between sites. Condition of immature sculpin was higher at Site C. Male gonad weight was smaller at Site C; however, female ovary weight was similar at both sites (Table 27). Liver weight in males increased at Site C, but female liver weight remained the same. Fecundity was higher at Site C than Site MAL, although egg weight was smaller (Table 27). There was no relationship between egg diameter and carcass weight (p=0.16); however, the univariate comparison of egg diameter indicated that egg diameter at Site C was greater than at Site MAL.

Male sculpin collected from Site E were greater in length (p=0.04), carcass weight (p=0.01) and mean age (p=0.01) relative to males from Site MAL. However, there were no differences in length (p=0.25), carcass weight (p=0.15) and mean age (p=0.30) of female sculpin between sites. Size-at-age of male sculpin was similar between sites (Table 27). Condition, gonad weight and liver weight of male sculpin were all significantly higher at Site E (Table 27). Univariate comparisons of gonad weight and fecundity, not adjusted for body size, indicated there were no differences in gonad weight (p=0.64), but fecundity was greater at Site E (p=0.02). Estimates of egg size (unadjusted for body size) were smaller at Site E than at Site MAL (egg weight, p=0.04; egg diameter, p=0.002).

There were no differences in length (p=0.43), carcass weight (p=0.18) or mean age (p=0.16) of female sculpin at Site E relative to females from Site C. Male sculpin were greater in length (p=0.01) and carcass weight (p=0.001) at Site E, but were similar in mean age (p=0.10) to males from Site C. Size-at-age, condition, gonad weight and liver weight of male sculpin were all significantly higher at Site E relative to Site C (Table 27). Univariate estimates of gonad weight and fecundity, unadjusted for body size, were not significantly different between sites (gonad weight, p=0.72; fecundity, p=0.22). Similarly, there were no differences in the univariate estimates of egg size between sites (egg weight, p=0.38; egg diameter, p=0.60).

From the above analyses, only four parameters at the far-field sites were reduced relative to observations from Site MAL: male size-at-age and gonad weight at Site C; and, female egg weight at Site C and Site E. As the response of sculpin from Site MAL suggested an overall increase in energy expenditure and storage, the fish parameters downstream of Site MAL were examined to determine if there was any "recovery" towards reference levels. Comparison of male size-at-age between Site C and pooled reference sites indicated a significant difference in the slopes of the regression lines between sites (p<0.001). By calculating the separate regression lines for each site (Figure 18), it was apparent that male sculpin from Site C were shorter than reference males at a given age until age 3-3.5 y (i.e. immature), after which males from Site C were longer at a given age than reference males. Therefore, although males from Site C were smaller at an early age relative to males from Site MAL, mature males were still larger at a given age than reference males. Similarly, although male gonad weight at Site C was smaller than at Site MAL, comparisons with reference males indicated that Site C gonad weight was significantly heavier than reference values

($p<0.001$). Comparisons of egg weight between Site C and pooled reference sites indicated that there was no relationship between egg weight and carcass weight ($p=0.13$). Subsequent comparisons of egg weight, unadjusted for body size, showed that egg weight was similar at both sites ($p=0.74$). As well, comparison of egg weight (unadjusted for body size) between Site E and the reference sites indicated that there was no difference in egg weight between sites ($p=0.13$). It appears that male size -at-age and gonad weight at Site C was still greater than reference males; however, female egg weight at Site C and Site E were smaller than near-field eggs and more similar to reference conditions.

Comparisons of the bivariate fish parameters among Sites MAL, C and E have been summarized in Table 28. In general, many of the changes in fish parameters observed between reference and the near-field fish had persisted, or were more pronounced, in sculpin resident to the far-field zone. If spoonhead sculpin were responding to an increase in food resource, as suggested at the near-field zone, then perhaps the enrichment effect extended beyond to the far-field zone. Recent studies also lent some support to this hypothesis. For example, a water quality survey conducted by mill A in January, 1992 indicated that total phosphorous concentrations were 0.02 mg/L upstream of mill, 0.70 mg/L at the near-field site and 0.31 mg/L at the Emerson Bridge site (i.e. Site E)(as seen in Sentar, 1994c). Similarly, results of recent (April, 1992) *in situ* work on the abundance of benthos and periphyton (as measured by chlorophyll *a* concentrations), indicated that both benthos abundance and chlorophyll *a* concentration increased substantially downstream of the mill A outfall and remained high until approximately 22 km downstream (i.e. Obed Mountain Coal Bridge, Site CR/CL), at which point values dropped to reference levels (TAEM, 1992). Results from both studies suggested that the far-field zone was also influenced by the enrichment effect of mill A effluent. This was probably particularly true during low-flow conditions as emphasized by effluent concentrations measured during this survey which found concentrations at the far-field sites to be 4.4 % at Site CL, 4.3 % at Site CR and 3.4 % at Site E (cf. Section 3.3.2).

Mean EROD activity of male and preovulatory female sculpin from Site C were not significantly different from sculpin from Site MAL; however, males were 4.5-fold induced and preovulatory females were 3.8-fold induced relative to reference fish (Figure 13, 14a). EROD activity in male sculpin at Site E was significantly less than either Site MAL or Site C, but was still induced 3-fold relative to reference males (Figure 13). Preovulatory females at Site E also exhibited EROD activity that was significantly less than Site C or Site MAL, and was similar to levels found at the reference sites (Figure 14a). Spent females were not collected at Site MAL or Site E. EROD activity of spent female sculpin at site C were induced 2.6-fold relative to reference levels ($p=0.02$)(Figure 14b). These results indicated that sculpin at Site C were exposed to sufficient concentrations of mill A effluent to cause induction equal to what was observed at Site MAL. Not until Site E did EROD activity decline; however, for male sculpin this was still higher than reference levels.

Basal *in vitro* production of testosterone in male sculpin at Site C was significantly lower than at Site MAL and the reference sites (Figure 15a). However, production of testosterone was significantly higher in males at Site E relative to Site MAL, Site C and the reference sites. Forskolin-stimulated production of testosterone in male sculpin was similar at Site MAL, Site C, Site E and the reference sites (Figure 15b). Basal *in vitro* production of testosterone and 17β-

estradiol by follicles were also similar among near-field, far-field and reference sites (Figure 16a; 17a). Follicles stimulated with forskolin produced similar levels of 17β-estradiol among sites MAL, C and E, but only levels produced by follicles from Site E were significantly higher than reference levels (Figure 17b). In addition, stimulated levels of testosterone produced by follicles from Site E were similar to levels at Site MAL, but significantly higher than levels at Site C and the reference sites (Figure 16b). Forskolin had a significant stimulating effect on male *in vitro* testosterone production at Site C ($p=<0.001$) and Site E ($p=0.05$), but had no effect on follicle production of testosterone production (Site C, $p=0.92$; Site E, $p=0.10$), or 17β-estradiol at Site E ($p=0.27$). Forskolin was also found to stimulate follicle production of 17β-estradiol at Site C ($p=0.02$).

For the most part, results of far-field *in vitro* steroid production in spoonhead sculpin suggested that there were no significant differences in steroid production among the near-field, far-field and reference sites. The dominant exception to this assessment was basal testosterone production of male gonadal tissue. For male sculpin, testosterone levels were depressed at Site C and stimulated at Site E relative to near-field and reference values. Levels at Site E may have been higher because males at that site were guarding nests with fertilized eggs and may have been at a different reproductive stage. This trend for males was also observed in female testosterone and 17β-estradiol production (especially forskolin-stimulated levels); however, high intra-site variability eliminated significant differences. It is uncertain why there was a tendency for lower mean steroid levels at Site C, given such a response was not observed at the near-field site where effluent concentrations were higher, and no other source of contamination was known to enter the river between Site MAL and Site C.

As described previously at other sites, forskolin was found to stimulate steroid production in male spoonhead sculpin at Site C and E, but was less successful stimulating follicle steroid production. Why forskolin stimulated male testicular tissue but not female follicles was uncertain; however, it was possible that female steroid production immediately prior to spawning was maximized such that forskolin had no observable effect (Van Der Kraak, pers. comm.).

3.3.1.4 Athabasca *vs* North Saskatchewan River

Data from the reference Sites HRL and HRR of the Athabasca River were pooled and compared with data from Site NS on the North Saskatchewan River.

Total length and carcass weight of both male (length, $p=0.002$; carcass weight, $p=0.005$) and female (length, $p<0.001$; carcass weight, $p<0.001$) spoonhead sculpin from Site NS were greater than Athabasca sculpin. Mean ages of male ($p=0.65$) and female ($p=0.30$) sculpin were similar between sites; however, size-at-age was greater at Site NS (Table 29). Male and female condition and liver weights were similar between sites (Table 29). Immature sculpin at Site NS had decreased condition relative to immatures from the Athabasca River (Table 29). Male gonad weight at Site NS was heavier than at the Athabasca reference sites; however, there was no difference in ovary weight between sites (Table 29). Fecundity was also not different between sites. Relationships between egg size were not related to carcass weight (egg weight, $p=0.88$; egg diameter, $p=0.63$). Univariate comparisons of egg size, unadjusted for body size, indicated that there were no differences in egg

size between sites (egg weight, p=0.79; egg diameter, p=0.90).

Comparisons of the bivariate fish parameters between reference sites of the Athabasca and North Saskatchewan River have been summarized in Table 30. Although most fish parameters were similar between sites, especially for female sculpin, both male and female sculpin at Site NS were longer at a given age than Athabasca River sculpin. As well, mean gonad weight for male sculpin at Site NS was heavier. If sculpin from Site NS had been used in comparisons with near-field and far-field sites instead of the Athabasca reference sites, results involving size-at-age and male gonad weight may have changed. For example, for comparisons with the near-field Site MAL, one would have concluded that size-at-age for males did not increase but stayed the same at Site MAL ($p<0.001$), that male gonad weight was not similar but had declined ($p<0.001$), and that female size-at-age was not similar but had also declined ($p=0.003$). It is unclear whether the North Saskatchewan River site represented the upper range of normal performance of spoonhead sculpin, or whether these fish were responding to fluctuations in water levels associated with the Big Horn Dam. Additional studies are needed to better quantify the normal range of variability among reference sites for these smaller fish species.

Hepatic EROD activity in male sculpin from Site NS was similar to activity found in males of the Athabasca reference sites (Figure 13). Preovulatory female sculpin from Site NS had significantly reduced EROD activity (⅓ the activity) relative to Athabasca females (Figure 14a). Although results concerning male sculpin would likely not have changed, induction at near-field and far-field sites would have been much more pronounced if Site NS was used as the reference site for comparisons of female EROD activity.

With the exception of basal production of male testosterone, *in vitro* production of steroids by gonadal tissues from sculpin collected from Site NS were significantly higher than levels measured at reference sites on the Athabasca River (Figure 15a,b; 16a,b; 17a,b). Basal production of male testosterone was similar between sites (Figure 15a). Because the *in vitro* steroid production was significantly higher at Site NS, comparisons with near-field and far-field sites would have indicated that steroid production downstream of the mill outfall was substantially depressed. As described previously, when the Athabasca reference data was used, this negative effect on steroid production was not evident.

Separate river systems are often used to collect reference data when it is difficult to find suitable reference habitat within the same river system receiving mill effluent. For the Athabasca River, this is not a concern because there is appropriate reference habitat upstream of the mill outfall for small species such as spoonhead sculpins. However, for researchers monitoring large and potentially mobile fish species, there is an additional concern that reference and exposure fish populations within the same river system may not be discrete and reflective of localized conditions. Therefore, to ensure that reference fish have not been exposed to mill effluent (i.e. the fish didn't just move upstream from the exposure zone), separate river systems, such as the North Saskatchewan River, have been used to assess the reference status of fish (NB however, this does not remove the possibility of collecting fish in the exposure area which have just moved downstream form an unexposed area). With this solution, an obvious (and untestable) assumption is that fish

collected at the North Saskatchewan River accurately reflects the status of reference fish in the Athabasca River. However, differences in whole organism and physiological measurements of spoonhead sculpin between Site NS and the Athabasca reference sites suggested that such an assumption may not be valid. In particular, had we used the North Saskatchewan site for comparisons with exposed sites downstream of the mill outfall, some conclusions would have been altered and more negative. Why differences existed between the reference populations was not investigated; however, it is probably related to natural differences in habitat characteristics. As well, Site NS experiences daily fluctuations in water discharge (water levels changed approx. 0.5-0.75 m at Site NS) due to regulation of the North Saskatchewan River by the Big Horn Dam. It is unknown how the variable discharge influences directly on fish populations, or indirectly on food resources and habitat quality and availability. Perhaps for larger fish species, this uncertainty is sufficient reason to consider a different river system from the North Saskatchewan River as a reference site for studies conducted on the Athabasca River.

For those monitoring mobile fish species there are few alternatives but to collect reference fish from different river systems. However, this problem does emphasize the benefit of monitoring small fish species, such as spoonhead sculpin, that are unlikely to exhibit large scale mobility between reference and exposure zones.

3.3.2 Water Chemistry

Concentrations of major ions (Cl, Na, K, SO_4, SiO_2) in water samples collected at each sampling site on the Athabasca River and North Saskatchewan River, as well as mill A effluent, are presented in Table 31.

With the exception of sulphate ($p=0.05$), concentrations of measured ions were similar between Site HRL and Site HRR (all ions, $p>0.14$). When pooled reference sites of the Athabasca River were compared with Site NS of the North Saskatchewan River, all ion concentrations were significantly higher at the Athabasca River reference sites (all ions, $p<0.001$). Although other parameters describing the chemical characteristics of the river were not measured (e.g., nutrients), the observed differences in major ions between the two river systems added to the concern that the North Saskatchewan River may not be a suitable reference site for the upper Athabasca River.

When pooled reference samples were compared with water chemistry downstream of the mill outfall (i.e. Site MAL), all ions except for silicate ($p=0.18$) had increased significantly (each ion, $p<0.001$). Relative to inputs of ions such as chloride or sodium, the concentration of silicate contributed by mill A effluent was limited. The increase in ion concentrations at Site MAL reaffirmed all indications that this site was exposed to mill effluent and was suitable as a near-field site. When ion concentrations between Site MAL and MAR were compared, all ions except silicate ($p=0.18$), were significantly higher at Site MAL (each ion, $p<0.001$). As well, ion concentrations at Site MAR were also greater than ion levels at the reference sites (SiO_2, $p=0.05$, remaining ions, $p<0.001$). The intermediate concentrations of ions at site MAR parallelled the whole organism and physiological responses of spoonhead sculpin discussed previously.

To investigate whether there was a downstream gradient in water chemistry, a linear contrast (-1 0 +1) was used to compare ion concentrations among Site MAL, Site C (i.e. CL+CR) and Site E. Concentrations of chloride, sulphate and sodium were found to decrease linearly (each ion, $p<0.001$) from Site MAL downstream to Site E (each ion, $p<0.001$). When the concentrations of these ions at Site E were compared with the reference sites, chloride ($p<0.001$) and sodium ($p=0.01$) were still higher than reference concentrations, and sulphate was lower than the reference level ($p<0.001$). There were no differences in silicate concentrations among the downstream sites ($p=0.06$). Differences in potassium occurred among the downstream sites ($p<0.001$); however, a quadratic ($p<0.001$) rather than a linear ($p=0.16$) contrast best described the downstream gradient. What this indicated was that potassium concentrations at Site MAL were similar to concentrations at Site E, but concentrations at Site C were significantly lower than either site. It was uncertain why the concentration of potassium dipped at Site C; however, the lower concentration was still higher than potassium levels measured at the reference sites ($p<0.001$).

Instream concentrations of chloride is commonly used as a chemical tracer for pulp mill effluents (mills with Cl bleaching). Because chloride does not degrade, it is possible to estimate the minimum concentration of effluent in receiving waters by instream concentrations of chloride. Chloride data from the spring 1995 survey suggested that effluent concentrations downstream of the mill A outfall were approximately 5.2 % at Site MAL and 0.8 % at Site MAR. Concentrations at the far-field sites were estimated to be 4.4 % at Site CL, 4.3 % at Site CR and 3.4 % at Site E. From these calculations, it was evident that all study sites were exposed to mill effluent and effluent concentrations remained substantial throughout the study area. Concentrations at the near-field site during the spring 1995 survey were approximately two times the concentrations measured during the October, 1993 plume delineation study. However, the flow rate of the Athabasca River during the October 1993 study was approximately 100 m^3/s, whereas during the spring 1995 survey (based on estimation from previous years) it was approximately 31 m^3/s (Water Survey of Canada, Calgary; unpublished data).

3.3.3 Summary of Spring 1995 Survey

The spring 1995 survey was a continuation of work conducted on spoonhead sculpin during the fall 1994 survey. The survey was designed to evaluate whole organism and physiological measurements of sculpin following winter low-flow conditions and prior to spring spawning. Specifically, the survey addressed the following issues:

- evaluating responses (body/organ metrics, *in vitro* steroids, MFO activity) of spoonhead sculpin at the near-field zone following a prolonged period of high effluent exposure

  Spoonhead sculpin collected from the near-field zone were heavier, fatter and had larger liver weights than reference fish. Exposed female sculpin exhibited higher gonad weights and fecundity estimates. This general response pattern of increased energy expenditure and storage was also seen during the previous fall 1994 survey, and again suggested that the fish were responding to an increase in food resource and were not negatively affected by

effluent. Significant EROD induction (4-fold) in both male and female sculpin from Site MAL confirmed that sculpin from near-field site were exposed to mill effluent. However, gonadal tissues of sculpin from the near-field site exhibited similar *in vitro* production of testosterone and 17β-estradiol as tissues from reference sculpin.

- investigating the geographical extent of responses downstream of the mill A diffuser

  Sculpin collected from the far-field zone were compared with sculpin from the near-field and reference sites. Although some whole organism parameters were found to decrease downstream (e.g., male size-at-age at Site C, egg weight at Site C and E), many of the changes observed between reference and near-field fish had persisted (e.g. male/female condition, female gonad/liver weight), or become more pronounced (e.g. male liver weight, immature condition, female size-at -age/fecundity). Of those parameters found to decrease downstream, only egg weight had returned to reference levels. Hepatic EROD results indicated that sculpin at Site C were exposed to sufficient effluent concentrations to cause induction equal to that observed at Site MAL. Not until Site E was there a reduction in EROD activity; however, for male sculpin activity was still higher than reference levels. With exception of male sculpin, there were no significant differences in *in vitro* steroid production among the near-field, far-field and reference sites. For male sculpin, testosterone production was depressed at Site C and stimulated at Site E relative to near-field and reference values. This general trend could also be seen for mean values of female testosterone and 17β-estradiol production (especially forskolin-stimulated levels); however, high intra-site variability eliminated significant differences.

- further assessing the mobility of spoonhead sculpin

  Sculpin collected from sites across river from Site HRL and Site MAL exhibited differences in body/organ metrics, MFO activity (Site HRL vs HRR) and *in vitro* steroid production. Given the close proximity of these sites, these differences suggested that spoonhead sculpin did not undergo extensive lateral movement across river. As in the fall 1994 survey, fish responses at Site MAR were intermediate between response observed at the reference and near-field sites. These results suggested that longitudinal movement up and down the river (i.e between reference sites and Site MAR) was also limited.

- improving our knowledge on the basic biology and life history of spoonhead sculpin

  Sampling sculpin immediately prior to spawning provided additional information on the basic biology of prespawning sculpin. In general, spawning occurred during the spring at water temperatures between 4.5°C and 7.0°C. Males at this time were found to be older, longer, heavier and fatter than preovulatory females (based on carcass weight). Females that had spawned early were similar in mean age and condition to preovulatory females, but were longer and heavier. EROD activity in males was characteristically higher than preovulatory females. Spent females also had higher EROD activity than preovulatory females. Baseline levels of *in vitro* steroid production for male and female gonadal tissues was also provided.

- comparing responses of reference fish from the Athabasca River and the North Saskatchewan River

  The North Saskatchewan River has been used as an alternative reference site for monitoring receiving environments of pulp mill effluent. When data from reference sites of the Athabasca River were compared with data from Site NS of the North Saskatchewan River significant differences in some body/organ metrics, MFO activity and *in vitro* steroid production were observed. The observed differences suggested that the assumption that fish collected at the North Saskatchewan River accurately reflected the status of reference fish in the Athabasca River may not be valid. If the North Saskatchewan site had been used as the reference site in this survey, some of the conclusions regarding exposed fish would have been altered and more negative. Use of the North Saskatchewan as a reference was further influenced by the occurrence of daily fluctuations in water discharge related to regulation by the Big Horn Dam.

- conducting water analyses for the purpose of confirming exposure zones

  Water samples were collected at each sampling site on the Athabasca River and North Saskatchewan River for analysis of major ions (Cl, Na, K, SO_4, SiO_2). With the exception of sulphate, concentrations of measured ions were similar between Athabasca reference sites. All ion concentrations were significantly higher at the Athabasca River reference sites relative to the North Saskatchewan River site. Ion concentrations, with the exception of sulphate, increased at the near-field site. Concentrations at Site MAR (across from the plume at Site MAL) were intermediate between reference and near-field values. Concentrations of chloride, sulphate and sodium decreased linearly from the near-field site to the furthest far-field site. Concentrations of chloride and sulphate at the furthest far-field site were still higher than reference concentrations; however, the concentration sulphate was lower than reference levels. Concentrations of silicate did not change among the downstream sites. Potassium concentrations were variable. Chloride data indicated that effluent concentrations were approximately 5% at the near-field site (Site MAL), 4% at the far-field sites located 21 km downstream of the diffuser, and 3.5 % at the furthest far-field site located 48 km downstream of the diffuser.

- recording general habitat characteristics of each fish collection site

  As in previous surveys, major channel types and bankside habitat classifications were documented for each fish collection site. The description was conducted according to the NRBS habitat classification system. Black and white photographs of each site area were also taken. All information was summarize in Appendix C.

4.0 CONCLUSION

The objective of the project on the Athabasca River was to assess the suitability of small, resident

fish species for monitoring receiving environments. In doing so, the impact of pulp mill effluent on exposed fish populations was to be assessed

Based on the three surveys, the potential to use small fish species is very high for the purpose of monitoring downstream of pulp mill outfalls. In particular, the abundance and distribution of resident forage species facilitates sampling several sites (fish populations) within a reference, near-field area or far-field area. In addition, the relatively stationary behaviour of most small species (e.g., spoonhead sculpin), especially in large rivers, greatly improves the probability that the observed fish responses reflect the local environment. As well, typical measurements made on larger fish species were also possible using smaller species, including: body and organ metrics, reproductive parameters, age estimates, mixed function oxygenase activity, and *in vitro* steroid production.

Prior to this survey, little information was available in the literature regarding the responses fish populations of the Athabasca River to pulp mill effluent. In addition, few studies described the general biology of smaller fish species which were not of recreational or commercial value. Consequently, the project also provided the opportunity to 1) determine whether small species such as spoonhead sculpin and lake chub exhibit responses reflective of local environmental conditions, 2) conduct an assessment of the effluent impacts on resident fish species of the Athabasca River, and 3) add to the knowledge base describing the basic biology of each sentinel species.

To further improve our understanding of the responses of small sentinel fish species to mill effluents discharged into the Athabasca River, there are several studies that could be conducted both in the field and laboratory:

- Very little information exists on the growth rates, reproductive strategies, or sampling requirements for using forage fish to monitor impacts of industrial discharges in large rivers. Baseline data on life history characteristics of these species needs to be collected. Greater knowledge of the general biology would also improve the capture efficiency of small species. Due to higher levels of abundance associated with many forage species, the collection of adequate sample sizes would become very cost-effective.

- The current report demonstrates that there can be substantial variability in whole organism responses among reference populations of small fish species (e.g., spoonhead sculpin, lake chub). More effort needs to be directed towards establishing the full range of variability associated with reference fish; both within a monitoring system and among a variety of similar aquatic systems.

- More information is needed to further evaluate the mobility of smaller fish species. Although small species are less likely to be as mobile as many of the large fish species, it is still necessary to increase our understanding of the degree and pattern of mobility, size of home range and habitat requirements associated with specific small species of interest.

- To further evaluate the suitability of small fish species, it would be of interest to compare

responses between small and large fish species of the same monitoring system. If possible, it would be advantageous to monitor a system possessing habitat or man-made barriers that would restrict the movement of the larger fish species. The comparison would examine the consistency of responses between species and investigate the relative sensitivity of each species.

- Laboratory evaluations of the potential of Athabasca effluents to disrupt steroids and induce MFO activity need to be repeated. Preliminary work was during the current project, but the steroid exposure protocol was still under development and has just been recently finalized. The exposures should be repeated using the final protocol. This information would be valuable to evaluate whether the effluents show the potential to induce the physiological changes. Also, the information would assist in evaluating the relative contribution of various mills, and the potential for mills further downstream (i.e. ALPAC, SLPC) to alter the biochemical performance of fish.

5.0 REFERENCES CITED

Anderson, A.M. 1989. An assessment of the effects of the combined pulp mill and municipal effluents at Hinton on the water quality and zoobenthos of the Athabasca River. Environmental Quality Monitoring Branch, Environmental Assessment Division, Alberta Environment, Edmonton.

Brown, J.H., U.T. Hammer and G.D. Koshinsky. 1970. Breeding biology of the lake chub, *Couesius plumbeus*, at Lac la Ronge, Saskatchewan. J. Fish. Res. Board Can. 27:1005-1015.

Environment Canada & Fisheries and Oceans. 1992. Aquatic environmental effects monitoring requirements, Annex 1. EPS 1/RM/18 27 pp.

Förlin, L. and T. Andersson. 1984. Influence of biological and environmental factors on hepatic steroid and xenobiotic metabolism in fish: Interaction with PCB and β-naphthoflavone. Mar. Environ. Res. 14:47-58.

Gagnon, M.M, J.J. Dodson, P.V. Hodson, G.Van Der Kraak and J.H. Carey. 1994. Seasonal effects of bleached kraft mill effluent on reproductive parameters of white sucker (*Catostomus commersoni*) populations of the St. Maurice River, Quebec, Canada. Can. J. Fish. Aquat. Sci. 51:337-347.

Gerking, S.C. 1959. The restricted movement of fish populations. Biol. Rev. 34:221-242.

Gibbons, W.N. and K.R. Munkittrick. 1994. A sentinel monitoring framework for identifying fish population responses to industrial discharges. J. Aquat. Eco. Health 3:227-237.

Gibbons, W.N., L.A. Dear, B.W. Kilgour and K.R. Munkittrick. 1991. Baseline environmental studies of the Pine River, B.C. Prepared for British Columbia Ministry of Environment by EVS Consultants, North Vancouver. 124 pp. + App.

Gibbons, W.N., M.D. Paine, W.M. Gibson, G.A. Vigers and K. Kingston. 1992. 1991 operational monitoring survey of the Lesser Slave River. Volume III. Prepared for Slave Lake Pulp Corporation, Edmonton, Alberta by EVS Consultants, North Vancouver, B.C. 63 pp. + Tables + Figures + App.

Golder and Associates. 1994. Environmental effects monitoring pre-design study report for Weldwood of Canada Limited Hinton bleached pulp mill. Prepared for Weldwood of Canada, Hinton, Alberta by Golder and Associates Ltd., Calgary, Alberta.

Greenberg, L.A. and D.A. Holtzman. 1987. Microhabitat utilization, feeding periodicity, home range and population size of the banded sculpin, *Cottus carolinae*. Copeia 1987(1):19-25.

Hamilton, H., M.D. Paine, W. Gibson and D. Conley. 1993. 1992 Operational monitoring survey of the Lesser Slave River. Volume VI. Prepared for the Slave Lake Pulp Corporation by EVS Environmental Consultants Ltd. 56 pp. + appendices.

Hill, J. and G.D. Grossman. 1987. Home range estimates for three North American stream fishes. Copeia 1987(2): 376-380.

Hodson, P.V., M. McWhirter, K. Ralph, B. Gray, D. Thivierge, J.H. Carey, G. Van Der Kraak, D.M. Whittle and M. Levesque. 1992. Effects of bleached kraft mill effluent on fish in the St. Maurice River, Quebec. Environ. Toxicol. Chem. 11:1635-1652.

Jardine, J.J. 1994. Impacts of physical stressors on physiological fitness of white sucker at a bleached kraft mill site. M.Sc. thesis, University of Guelph, Guelph, Ont. 92 pp.

Kilgour, B.W. and W.N. Gibbons. 1991. Baseline environmental studies of the Lesser Slave River. Volume II. Prepared for the Slave Lake Pulp Company, Edmonton, Alberta by EVS Consultants, North Vancouver, B.C. 103 pp. + App.

MacKay, W.C., G.R. Ash and H.J. Norris (eds). 1990. Fish ageing methods for Alberta. R.L.&L Environmental Services Ltd. in association with Alberta Fish and Wildlife Division and University of Alberta, Edmonton. 113 pp.

McMaster, M.E., G.J. Van Der Kraak, C.B. Portt, K.R. Munkittrick, P.K. Sibley, I.R. Smith and D.G. Dixon. 1991. Changes in hepatic mixed-function oxygenase (MFO) activity, plasma steroid levels and age at maturity of white sucker (*Catostomus commersoni*) population exposed to bleached kraft effluent. Aquat. Toxicol. 21:199-218.

McMaster, M.E., C.B. Portt, K.R. Munkittrick, and D.G. Dixon. 1992a. Milt characteristics, reproductive performance and larval survival and development of white sucker (*Catostomus commersoni*) exposed to bleached kraft mill effluent. Ecotox. Environ. Saf. 23:107-117.

McMaster, M.E., K.R. Munkittrick and G.J. Van Der Kraak. 1992b. Protocol for measuring circulating levels of gonadal sex steroids in fish. Can. Tech. Rept. Fish. Aquat. Sci. 1836:29 pp.

McMaster, M.E., G.J. Van Der Kraak and K.R. Munkittrick. 1994. Evaluation of the steroid biosynthetic capacity of ovarian follicles from white sucker exposed to bleached kraft mill effluent (BKME). Proc. 20th Aquatic Toxicity Workshop, October 17-21, 1993, Quebec City, Quebec. R.van Collie, Y. Roy, Y.Bios, P.G.C. Campbell, P. Lundahl, L. Martel, M. Michaud, P. Riebel and C. Thellan (eds.). Can. Tech. Rept. Fish. Aquat. Sci. 1989: 259.

McMaster, M.E., K.R. Munkittrick, J.J. Jardine, R.D. Robinson and G.J. Van Der Kraak. 1995. Protocol for measuring *in vitro* steroid production by fish gonadal tissue. Can. Tech. Rpt. Fish. Aquat. Sci. no. 1961. 78 pp.

Munkittrick, K.R. 1992. A review and evaluation of study design considerations for site-specifically assessing the health of fish populations. J. Aquat. Eco. Health (in press).

Munkittrick, K.R., B.W. Kilgour, W.N. Gibbons and W.M. Gibson. 1990. Baseline environmental studies of the Lesser Slave River. Volume 1. Prepared for Slave Lake Pulp Corporation, Edmonton by EVS Consultants, North Vancouver. 129 pp. + App.

Munkittrick, K.R., C.B. Portt, G.J. Van Der Kraak, I.R. Smith and D.A. Rokosh. 1991. Impact of bleached kraft mill effluent on population characteristics, liver MFO activity, and serum steroid levels of a Lake Superior white sucker (*Catostomus commersoni*) population. Can. J. Fish. Aquat. Sci. 48:1371-1380.

Munkittrick, K.R., M.E. McMaster, C.B. Portt, G.J. Van Der Kraak, I.R. Smith and D.G. Dixon. 1992. Changes in maturity, plasma sex steroid levels, hepatic mixed-function oxygenase activity, and the presence of external lesions in lake whitefish (*Coregonus clupeaformis*) exposed to bleached kraft mill effluent. Can. J. Fish. Aquat. Sci. 49:1560-1569.

Munkittrick, K.R., G.J. Van Der Kraak, M.E. McMaster, C.B. Portt, M.R. van den Heuvel and M.R. Servos. 1994. Survey of receiving-water environmental impacts associated with discharges from pulp mills. 2. Gonad size, liver size, hepatic EROD activity and plasma sex steroid levels in white sucker. Environ. Toxicol. Chem. 13:1089-1101.

Nelson, J.S. and M.J. Paetz. 1992. The fishes of Alberta. The University of Calgary Press, Calgary, AB. 437 pp.

Noton, L.R. and R.D. Shaw. 1989. Winter water quality in the Athabasca River system, 1988-1989. Prepared for Environmental Quality Monitoring Branch, Environmental Assessment Division, Environmental Protection Services, Alberta Environment, Edmonton.

Roberts, W.E. 1988. The sculpins of Alberta. Alberta Nat. 18:121-127.

Robinson, R.D., J.H. Carey, K.R. Solomon, I.R. Smith, M.R. Servos and K.R. Munkittrick. 1994. Survey of receiving water environmental impacts associated with discharges from pulp mills. I. Mill characteristics, receiving water chemical profiles and laboratory toxicity tests. Environ. Toxicol. Chem. 13:1075-1088.

Rodden, G. (ed). 1995. 1995 Pulp and paper annual and directory. Southam Magazine Group. 266 pp.

Pajor, A.M. J.J. Stegemen, P. Thomas and B. Woodin. 1990. Feminization of the hepatic microsomal cytochrome P-450 system in brook trout by estradiol, testosterone and pituatary factors. J. Exp. Zool. 253:51-60.

Schultz, L.P. 1935. The breeding activities of the little red fish, a landlocked form of the sockeye salmon *Oncorhynchus nerka*. J. Pan-Pac. Res. Inst. 10(1):67-77.

Sentar. 1994a. Pre-design study, environmental effects monitoring, Alberta Newsprint Company, Whitecourt, Alberta. Prepared for Alberta Newsprint Company, Whitecourt Alberta by Sentar Consultants Ltd., Calgary, Alberta. 107 pp. + appendices.

Sentar. 1994b. Pre-design study, environmental effects monitoring, Millar Western Pulp Ltd. Whitecourt, Alberta. Prepared for Millar Western Pulp Ltd., Whitecourt Alberta by Sentar Consultants Ltd., Calgary, Alberta. 117 pp. + appendices.

Sentar. 1994c. Nutrient loading on the Peace, Athabasca and Slave Rivers. Northern River Basins Study Project No. 28.

Stegeman, J.J., A.M. Pajor and P. Thomas. 1982. Influence of 17β-estradiol and testosterone on cytochrome P-450 monooxygenase activity in immature brook trout, *Salvelinus fontinalis*. Biochem. Pharmacol. 31:3979-3989.

Swanson, S.M. 1993. Wapiti/Smoky river ecosystem study. Prepared for Procter and Gamble Ltd./Weyerhaeuser Canada Ltd., Grand Prairie, AB by Sentar Consultants Ltd., Calgary, AB. 176 pp.

Swanson, S., R. Shelast, R. Schryer, P. Kloepper-Sams, T. Marchant, K. Kroeker, J. Bernstein and J.W. Owens. 1992. Fish populations and biomarker responses at a Canadian bleached kraft mill site. Tappi J. (1992):139-149.

Swanson, S.M., R. Schryer, R. Shelast, P.J. Kloepper-Sams and J.W. Owens. 1994. Exposure of fish to biologically treated bleached-kraft mill effluent. 3. Fish habitat and population assessment. Environ. Toxicol. Chem. 13: 1497-1507.

Terrestrial and Aquatic Environmental Managers (TAEM) Ltd. 1992. Biological and water quality survey of the Athabasca River, April 1992. TAEM Ltd., Saskatoon, Saskatchewan Monitoring.

van den Heuvel, M.R., K.R. Munkittrick, J.J. Stegeman and D.G. Dixon. 1995. Second-round interlaboratory comparison of hepatic ethoxyresorufin-o-deethylase activity in white sucker (*Catostomus commersoni*) exposed to bleached-kraft pulp mill effluent. Environ. Tox. Chem. :1513-1520.

Van Der Kraak, G., P.W. Sorensen, N.E. Stacey and J.G. Dulka. 1989. Periovulatory female goldfish release three potential pheromones: 17α,20β-dihydroxyprogesterone, 17α,20β-dihydroxyprogesterone glucuronide and 17α-hydroxyprogesterone. Gen. Comp. Endocrinol. 73:452-457.

Van Der Kraak, G. and J.P. Chang. 1990. Arachidonic acid stimulates steroidogenesis in goldfish preovulatory ovarian follicles. Gen. Comp. Endocrinol. 77:221-228.

Van Der Kraak, G.J. K.R. Munkittrick, M.E. McMaster, C.B. Portt and J.P Chang. 1992. Exposure to bleached kraft pulp mill effluent disrupts the pituitary gonadal axis of white sucker at multiple sites. Toxicol. Appl. Pharmacol. 115:224-233.

Tables

Table 1. Definition of fish parameters used in the spring and fall 1994 survey, and spring 1995 survey (taken from Gibbons *et al.*, 1992).

Parameter	Dependent Variable (Y)	Covariate (X)
Size-at-Age	Fork length (log)	Age (log)
Condition	Carcass weight (log)	Fork Length (log)
Gonad weight	Gonad weight (log)	Carcass weight (log)
Fecundity	Number of eggs/female (log)	Carcass weight (log)
Egg size	Egg size (log)	Carcass weight (log)
Liver weight	Liver weight (log)	Carcass weight (log)

Table 2. Location, general description and method of fishing for each site sampled for potential sentinel fish species during the spring 1994 survey, Athabasca River, Alberta. Abbreviations: LUB - left upstream bank; RUB - right upstream bank; E - electrofisher (backpack); S - beach seine.

Site	Location (latitude / longitude)	General Description	Fishing Method
Hinton Area			
1	N 53°24.25'/ W 117°35.49'	Immediately upstream of mill A pumphouse, LUB of river.	E
2	N 53°24.63'/ W 117°33.46'	Immediately downstream of Helge Nelson Bridge, LUB of river.	E,S
3	N 53°26.15'/ W 117°32.15'	First island downstream of bridge, LUB of island.	S
4	N 53°26.25'/ W 117°32.15'	First island downstream of bridge, RUB of island.	S
5	N 53°26.30'/ W 117°31.80'	First gravel bar downstream of previous island, LUB of bar.	S
6	N 53°26.30'/ W 117°31.80'	First gravel bar downstream of previous island, RUB of bar.	S
7	N 53°26.40'/ W 117°31.70'	Second island downstream of bridge, LUB of island.	E
8	N 53°26.02'/ W 117°31.95'	Downstream island, LUB of island.	S
9	N 53°26.02'/ W 117°31.95'	Downstream island, RUB of island.	S
10	N 53°26.65'/ W 117°31.15'	Small backwater area downstream of first island (Site 3,4), LUB of river.	S
11	N 53°42.10'/ W 117°09.80'	Upstream and downstream of Emerson Bridge, LUB/RUB of river.	E

Site	Location (latitude / longitude)	General Description	Fishing Method
Whitecourt Area			
12	N 54°12.16'/ W 116°04.15'	Immediately downstream of Windfall Bridge, LUB of river.	E
13	N 54°09.79'/ W 115°45.54'	Approx. 3.5 km downstream of mill B outfall, RUB of river.	E
14	N 54°09.95'/ W 115°40.10'	Approx. 2.25 km downstream of mill C outfall, LUB of river.	E,S
15	N 54°09.95'/ W 115°37.67'	Approx. 5.5 km downstream of mill C outfall, RUB of river.	E
16	N 54°09.61'/ W 115°36.50'	Approx. 6.1 km downstream of mill C outfall, LUB of river.	E
17	N 54°09.68'/ W 115°40.30'	Approx. 2 km downstream of mill C outfall near Site 14, RUB of river.	E
18	N 54°09.76'/ W 115°38.64'	Approx. 3.5 km downstream of mill C outfall, LUB of island across from unknown outfall pipe.	E,S
19	N 54°09.55'/ W 115°35.63'	Approx. 7.0 km downstream of mill C outfall, LUB of island.	E
20	N 54°09.53'/ W 115°35.30'	Approx. 7.5 km downstream of mill C outfall, LUB of gravel bar below site 19.	S

Table 3. Approximate number of each fish species caught at each site in the Hinton study area during the spring 1994 survey, Athabasca River, Alberta.

Species	Site											Total
	1	2	3	4	5	6	7	8	9	10	11	
Mountain Whitefish	6	65	15	96	123	31	26	53	145	52		612
Rainbow Trout	8	7						1				16
Bull Trout									2			2
Trout Perch												0
Lake Chub												0
Longnose Dace	1	18		1						1		21
Spottail Shiner		1										1
Spoonhead Sculpin	11	11		3			3		3	1	2	34
White Sucker												0
Longnose Sucker						4		1				5
sucker sp. (?)	>75	>75		1					27	182	>75	435
Burbot												0
Northern Pike												0
Total	101	177	15	101	123	35	29	55	177	236	77	1,126

Table 4. Approximate number of each fish species caught at each site in the Whitecourt study area during the spring 1994 field survey, Athabasca River, Alberta.

Species	Site									Total
	12	13	14	15	16	17	18	19	20	
Mountain Whitefish							7		5	12
Rainbow Trout										0
Bull Trout										0
Trout Perch	13	5	39	13					11	81
Lake Chub	69	56	86	4	9	7	47	>30	54	362
Longnose Dace	3	20	8		6	3				40
Spottail Shiner			2				3			5
Spoonhead Sculpin					2					2
White Sucker							1			1
Longnose Sucker										0
sucker sp. (?)	18		9	9		4	42		44	126
Burbot		3	2	1	1					7
Northern Pike							1			1
Total	103	84	146	27	18	14	101	30	114	637

Table 5. Abundance of male, female and immature a) spoonhead sculpin (*Cottus ricei*), and b) lake chub (*Couesius plumbeus*) at selected study sites during the spring 1994 survey, Athabasca River, Alberta.

a) Spoonhead Sculpin

Sex	Reference (pumphouse)	Mill A Near-field
Male	-	1
Female	3	1
Immature	8	9
Total	11	11

b) Lake Chub

Sex	Reference (Windfall Bridge)	Mill B Near-field	Mill C Near-field	Mill C Seine site*
Male	5	6	6	8
Female	10	14	15	7
Immature	54	36	66	19
Total	69	56	87	34

* seining site attempted within the mill C near-field zone (Site 18, cf. Table 2)

Table 6. Mean and SE (n) of body metrics for spoonhead sculpin (*Cottus ricei*) collected at selected sampling sites during the spring 1994 survey, Athabasca River, Hinton.

Sex	Reference (pumphouse)	Mill A Near-field
Male		
Total Length (cm)	-	7.0 (1)
Body Weight (g)	-	3.08 (1)
Carcass Weight (g)	-	2.66 (1)
Liver Weight (g)	-	0.07 (1)
Gonad Weight (g)	-	-
K	-	0.78 (1)
GSI (%)	-	-
LSI (%)	-	2.67 (1)
Female		
Total Length (cm)	8.07 ± 0.67 (3)	7.2 (1)
Body Weight (g)	5.08 ± 1.37 (3)	2.92 (1)
Carcass Weight (g)	4.45 ± 1.20 (3)	2.54 (1)
Liver	0.09 ± 0.03 (3)	0.07 (1)
Gonad Weight (g)	0.08 ± 0.03 (3)	0.02 (1)
K	0.80 ± 0.12 (3)	0.68 (1)
GSI (%)	1.58 ± 0.24 (3)	0.67 (1)
LSI (%)	2.08 ± 0.04 (3)	2.64 (1)
Immature		
Total Length (cm)	5.71 ± 0.41 (8)	4.8 ± 0.1 (9)
Body Weight (g)	1.82 ± 0.32 (8)	0.92 ± 0.05 (9)
K	0.90 ± 0.03 (8)	0.83 ± 0.03 (9)

Table 7. Mean and SE (n) of body metrics for lake chub (*Couesius plumbeus*) collected at selected sampling sites during the spring 1994 survey, Athabasca River, Whitecourt.

Sex	Reference (Windfall Bridge)	Mill B Near-field	Mill C Near-field	Mill C Seine site*
Male				
Total Length (cm)	9.1 ± 0.2 (5)	9.0 ± 0.2 (6)	9.7 ± 0.3 (6)	8.6 ± 0.2 (8)
Fork Length (cm)	8.4 ± 0.2 (5)	8.4 ± 0.2 (6)	9.1 ± 0.3 (6)	8.0 ± 0.2 (8)
Body Weight (g)	6.08 ± 0.36 (5)	5.95 ± 0.42 (6)	7.44 ± 0.63 (6)	5.25 ± 0.34 (8)
Carcass Weight (g)	4.80 ± 0.38 (5)	5.32 ± 0.41 (6)	6.74 ± 0.58 (6)	4.72 ± 0.30 (8)
Liver Weight (g)	0.11 ± 0.01 (5)	0.08 ± 0.01 (6)	0.08 ± 0.003 (6)	0.08 ± 0.01 (8)
Gonad Weight (g)	0.67 ± 0.09 (5)	0.13 ± 0.01 (6)	0.12 ± 0.02 (6)	0.08 ± 0.01 (8)
Age (y)	2.0 (5)	2.0 (6)	2.3 ± 0.21 (6)	2.1 ± 0.13 (8)
K	0.88 ± 0.02 (5)	0.89 ± 0.03 (6)	0.89 ± 0.02 (6)	0.91 ± 0.02 (8)
GSI (%)	2.02 ± 0.32 (5)	2.49 ± 0.21 (6)	1.75 ± 0.19 (6)	1.77 ± 0.18 (8)
LSI (%)	2.16 ± 0.14 (5)	1.50 ± 0.20 (6)	1.17 ± 0.13 (6)	1.59 ± 0.15 (8)
Female				
Total Length (cm)	9.1 ± 0.2 (10)	9.6 ± 0.3 (14)	9.1 ± 0.3 (15)	9.1 ± 0.3 (7)
Fork Length (cm)	8.4 ± 0.2 (10)	9.0 ± 0.2 (14)	8.5 ± 0.3 (15)	8.4 ± 0.3 (7)
Body Weight (g)	6.08 ± 0.36 (10)	7.77 ± 0.67 (14)	6.73 ± 0.73 (15)	6.18 ± 0.56 (7)
Carcass Weight (g)	4.92 ± 0.26 (10)	6.17 ± 0.47 (14)	5.32 ± 0.51 (15)	4.87 ± 0.40 (7)
Liver	0.11 ± 0.01 (10)	0.15 ± 0.02 (14)	0.12 ± 0.02 (15)	0.13 ± 0.02 (7)
Gonad Weight (g)	0.67 ± 0.09 (10)	0.99 ± 0.16 (14)	0.87 ± 0.17 (15)	0.77 ± 0.12 (7)
Fecundity (#eggs)	1848 ± 174 (9)	2792 ± 221 (7)	2156 ± 345 (7)	1867 ± 123 (6)
Egg weight (mg)	0.38 ± 0.03 (9)	0.53 ± 0.03 (7)	0.59 ± 0.05 (7)	0.44 ± 0.04 (6)
Egg diameter (mm)	0.83 ± 0.04 (9)	0.84 ± 0.03 (7)	0.88 ± 0.03 (7)	0.83 ± 0.02 (6)
Age (y)	2.3 ± 0.16 (8)	2.3 ± 0.13 (14)	2.4 ± 0.13 (14)	2.3 ± 0.16 (7)
K	0.83 ± 0.02 (10)	0.83 ± 0.01 (14)	0.84 ± 0.01 (15)	0.81 ± 0.02 (7)
GSI (%)	13.08 ± 1.27 (10)	14.82 ± 1.65 (14)	14.43 ± 1.69 (15)	15.20 ± 1.31 (7)
LSI (%)	2.16 ± 0.14 (10)	2.42 ± 0.17 (14)	2.21 ± 0.18 (15)	2.61 ± 0.23 (7)

Sex	Reference (Windfall Bridge)	Mill B Near-field	Mill C Near-field	Mill C Seine site*
Immature				
Total Length (cm)	6.4 ± 0.2 (54)	6.4 ± 0.2 (36)	6.2 ± 0.1 (66)	6.9 ± 0.2 (19)
Fork Length (cm)	6.0 ± 0.2 (54)	5.9 ± 0.2 (36)	5.8 ± 0.1 (66)	6.4 ± 0.2 (19)
Body Weight (g)	2.26 ± 0.17 (54)	2.18 ± 0.22 (36)	1.91 ± 0.09 (66)	2.63 ± 0.18 (19)
K	0.95 ± 0.01 (54)	0.95 ± 0.01 (36)	0.94 ± 0.01 (66)	0.99 ± 0.02 (19)

* seining site attempted within the mill C near-field zone (Site 18, cf. Table 2); data not included in analyses.

Table 8. Regression lines for condition, gonad weight and liver for female lake chub pooled over three sites sampled during the spring 1994 survey, Athabasca River, Whitecourt.

Parameter	Log_{10} Regression Line	Pearson r^2	*n*	p-value
Size-at-age	Log(fork length)= 0.38•Log(age) + 0.80	0.35	28	0.001
Condition	Log(carcass weight)= 2.91•Log(fork length) - 2.00	0.97	39	<0.001
Gonad weight	Log(gonad weight)= 2.04•Log(carcass weight) - 1.64	0.89	39	<0.001
Liver weight	Log(liver weight)= 1.15•Log(carcass weight) - 1.76	0.67	39	<0.001

Table 9. Location and general description of each site sampled for spoonhead sculpin (*Cottus ricei*) and lake chub (*Couesius plumbeus*) sentinel fish during the fall 1994 field survey, Athabasca River, Alberta. Abbreviations: LUB - left upstream bank; RUB - right upstream bank.

Site	Location (latitude / longitude)	General Description
Hinton Area		
HRL	N 53°24.25'/ W 117°35.49'	Reference site - immediately upstream of mill A pumphouse, LUB of river.
MAR	N 53°24.63'/ W 117°33.46'	Across river site - immediately downstream of Helge Nelson Bridge, LUB of river across from plume tracking.
MAL	N 53°25.73'/ W 117°33.17'	Mill A near-field site - approx. 0.25 km downstream of bridge, LUB of river.
Whitecourt Area		
WF	N 54°12.16'/ W 116°04.15'	Reference site - immediately downstream of Windfall Bridge, LUB of river.
R2	N 52°11.28'/ W 115°50.31'	2nd reference site - approx. 2 km upstream of Alberta Newsprint Co. outfall, RUB of river
MB	N 54°09.79'/ W 115°45.54'	Mill B near-field site - approx. 3.5 km downstream of mill B outfall, RUB of river.
MC	N 54°09.95'/ W 115°40.10'	Mill C near-field site - approx. 2.25 km downstream of mill C outfall, LUB of river.

Table 10. Approximate number of each fish species caught at each site in the Hinton and Whitecourt study areas during the fall 1994 field survey, Athabasca River, Alberta.

Species	Hinton Sites			Total	Whitecourt Sites				Total
	HRL	MAR	MAL		WF	R2	MB	MC	
Mountain Whitefish	20	52	66	138		1			1
Rainbow Trout		1		1					0
Bull Trout		1		1					0
Trout Perch					7	6	8	5	26
Lake Chub					57	45	33	28	163
Longnose Dace		2		2				4	4
Spoonhead Sculpin	79	57	57	193				13	13
sucker sp. (?)	20	10	22	52	5	2	7	3	17
Burbot					4	1	4	9	18
Total	119	123	145	387	73	55	52	62	242

Table 11. Abundance of male, female and immature a) spoonhead sculpin (*Cottus ricei*), and b) lake chub (*Couesius plumbeus*) at selected study sites during the fall 1994 survey, Athabasca River, Alberta.

a) Spoonhead Sculpin (Hinton study area)

Sex	Reference (Site HRL)	Across Plume (Site MAR)	Mill A near-field (Site MAL)
Male	26	14	13
Female	22	12	13
Immature	31	31	31
Total	79	57	57

b) Lake Chub (Whitecourt study area)

Sex	Reference (Site WF)	Reference 2 (Site R2)	Mill B near-field (Site MB)	Mill C near-field (Site MC)
Male	10	6	10	10
Female	16	13	15	7
Immature	30	26	7	10
Total	56	45	32	27

Table 12. Mean and SE (n) of body metrics for spoonhead sculpin (*Cottus ricei*) collected at each sampling site during the fall 1994 survey, Athabasca River, Hinton, Alberta.

Sex	Reference (Site HRL)	Across Plume (Site MAR)	Mill A near-field (Site MAL)
Male			
Total Length (cm)	8.7 ± 0.2 (26)	9.8 ± 0.3 (14)	9.5 ± 0.4 (13)
Body Weight (g)	6.61 ± 0.45 (26)	10.62 ± 1.24 (14)	10.03 ± 1.23 (13)
Carcass Weight (g)	5.87 ± 0.39 (26)	9.42 ± 1.09 (14)	8.91 ± 1.12 (13)
Liver Weight (g)	0.09 ± 0.01 (26)	0.19 ± 0.03 (14)	0.16 ± 0.02 (13)
Gonad Weight (g)	0.15 ± 0.01 (26)	0.24 ± 0.03 (14)	0.25 ± 0.03 (13)
Age (y)	3.4 ± 0.2 (25)	4.4 ± 0.2 (14)	4.2 ± 0.3 (13)
K	0.86 ± 0.02 (26)	0.95 ± 0.02 (14)	0.98 ± 0.03 (13)
GSI (%)	2.63 ± 0.10 (26)	2.53 ± 0.12 (14)	2.85 ± 0.08 (13)
LSI (%)	1.45 ± 0.07 (26)	1.82 ± 0.14 (14)	1.86 ± 0.07 (13)
Female			
Total Length (cm)	8.3 ± 0.2 (22)	9.5 ± 0.4 (12)	9.5 ± 0.4 (13)
Body Weight (g)	5.35 ± 0.45 (22)	9.32 ± 1.39 (12)	9.35 ± 1.32 (13)
Carcass Weight (g)	4.77 ± 0.40 (21)	8.0 ± 1.21 (12)	8.14 ± 1.18 (13)
Liver Weight (g)	0.11 ± 0.01 (22)	0.25 ± 0.05 (12)	0.25 ± 0.04 (13)
Gonad Weight (g)	0.15 ± 0.01 (22)	0.29 ± 0.05 (12)	0.34 ± 0.05 (13)
Fecundity (# eggs)	960 ± 229 (4)	1081 ± 292 (5)	872 ± 133 (6)
Egg Weight (mg)	0.21 ± 0.02 (4)	0.33 ± 0.05 (5)	0.43 ± 0.06 (6)
Egg diameter (mm)	0.66 ± 0.02 (5)	0.68 ± 0.06 (5)	0.73 ± 0.03 (7)
Age (y)	3.3± 0.2 (22)	4.2 ± 0.3 (9)	4.0 ± 0.3 (13)
K	0.79 ± 0.01 (22)	0.85 ± 0.03 (12)	0.87 ± 0.02 (13)
GSI (%)	3.08 ± 0.09 (22)	3.58 ± 0.22 (12)	4.23 ± 0.26 (13)
LSI (%)	2.28 ± 0.12 (22)	2.94 ± 0.15 (12)	2.98 ± 0.14 (13)

Sex	Reference (Site HRL)	Across Plume (Site MAR)	Mill A near-field (Site MAL)
Immature			
Total Length (cm)	6.2 ± 0.1 (31)	6.4 ± 0.1 (31)	6.2 ± 0.2 (31)
Body Weight (g)	1.94 ± 0.06 (31)	2.15 ± 0.11 (31)	2.25 ± 0.14 (31)
K	0.80 ± 0.01 (31)	0.83 ± 0.03 (31)	0.87 ± 0.02 (31)

Table 13. Mean and SE (n) of body metrics for lake chub (*Couesius plumbeus*) collected at each sampling site during the fall 1994 survey, Athabasca River, Whitecourt, AB.

Sex	Reference (SiteWF)	Reference 2 (Site R2)	Mill B near-field (Site MB)	Mill C near-field (Site MC)
Male				
Total Length (cm)	9.7 ± 0.2 (10)	9.5 ± 0.2 (6)	9.9 ± 0.3 (10)	9.7 ± 0.2 (10)
Fork Length (cm)	9.0 ± 0.2 (10)	8.8 ± 0.2 (6)	9.2 ± 0.3 (10)	9.0 ± 0.2 (10)
Body Weight (g)	7.15 ± 0.52 (10)	7.05 ± 0.53 (6)	7.68 ± 0.59 (10)	8.08 ± 0.53 (10)
Carcass Weight (g)	6.45 ± 0.46 (10)	6.37 ± 0.49 (6)	6.90 ± 0.52 (10)	7.33 ± 0.49 (10)
Liver Weight (g)	0.11 ± 0.02 (10)	0.10 ± 0.02 (6)	0.14 ± 0.01 (10)	0.12 ± 0.01 (10)
Gonad Weight (g)	0.06 ± 0.01 (10)	0.06 ± 0.01 (6)	0.16 ± 0.09 (10)	0.07 ± 0.01 (10)
Age (y)	1.7 ± 0.2 (10)	1.2 ± 0.2 (6)	1.8 ± 0.1 (10)	1.4 ± 0.2 (10)
K	0.88 ± 0.02 (10)	0.93 ± 0.03 (6)	0.89 ± 0.02 (10)	0.99 ± 0.02 (10)
GSI (%)	0.96 ± 0.07 (10)	0.85 ± 0.09 (6)	2.15 ± 1.15 (10)	0.91 ± 0.07 (10)
LSI (%)	1.60 ± 0.26 (10)	1.60 ± 0.18 (6)	2.02 ± 0.13 (10)	1.62 ± 0.16 (10)
Female				
Total Length (cm)	10.1 ± 0.2 (16)	9.5 ± 0.3 (13)	9.8 ± 0.3 (15)	9.3 ± 0.5 (7)
Fork Length (cm)	9.4 ± 0.2 (16)	8.8 ± 0.3 (13)	9.1 ± 0.3 (15)	8.5 ± 0.4 (7)
Body Weight (g)	8.10 ± 0.61 (16)	7.56 ± 0.83 (13)	7.73 ± 0.77 (15)	7.18 ± 0.94 (7)
Carcass Weight (g)	6.71 ± 0.48 (16)	6.08 ± 0.69 (12)	6.46 ± 0.62 (15)	5.91 ± 0.77 (7)
Liver Weight (g)	0.13 ± 0.01 (16)	0.16 ± 0.02 (13)	0.13 ± 0.01 (15)	0.14 ± 0.03 (7)
Gonad Weight (g)	0.61 ± 0.07 (16)	0.52 ± 0.09 (13)	0.56 ± 0.08 (15)	0.54 ± 0.09 (7)
Fecundity (# eggs)	2662 ± 391 (13)	2394 ± 267 (9)	2290 ± 288 (12)	2374 ± 290 (6)
Egg Weight (mg)	0.30 ± 0.02 (13)	0.26 ± 0.02 (9)	0.27 ± 0.02 (12)	0.25 ± 0.01 (6)
Egg Diameter (mm)	0.80 ± 0.02 (13)	0.77 ± 0.03 (9)	0.74 ± 0.02 (12)	0.73 ± 0.02 (6)
Age (y)	1.8 ± 0.1 (16)	1.5 ± 0.1 (13)	1.6 ± 0.1 (15)	1.6 ± 0.2 (7)
K	0.80 ± 0.01 (16)	0.89 ± 0.02 (12)	0.82 ± 0.01 (15)	0.92 ± 0.02 (7)
GSI (%)	8.67 ± 0.52 (16)	7.66 ± 0.70 (12)	8.07 ± 0.51 (15)	8.79 ± 0.64 (7)
LSI (%)	1.99 ± 0.11 (16)	2.39 ± 0.18 (12)	1.98 ± 0.09 (15)	2.30 ± 0.34 (7)

Sex	Reference (SiteWF)	Reference 2 (Site R2)	Mill B near-field (Site MB)	Mill C near-field (Site MC)
Immature				
Total Length (cm)	7.7 ± 0.1 (30)	7.2 ± 0.2 (26)	7.2 ± 0.4 (7)	7.0 ± 0.4 (10)
Fork Length (cm)	7.2 ± 0.1 (30)	6.7 ± 0.2 (26)	6.6 ± 0.3 (7)	6.6 ± 0.4 (10)
Body Weight (g)	3.54 ± 0.16 (30)	3.09 ± 0.23 (26)	2.84 ± 0.48 (7)	3.12 ± 0.56 (10)
K	0.93 ± 0.01 (30)	0.98 ± 0.01 (26)	0.92 ± 0.02 (7)	0.99 ± 0.02 (10)

Table 14. Site comparisons (ANCOVA) of size-at-age, condition, gonad weight and liver weight for male, female and immature spoonhead sculpin, fall 1994 survey, Athabasca River, Hinton. Abbreviations: I - intercept; S - slope; p - pooled over sites. Subscripts refer to site numbers. Interaction terms were considered significant at $p<0.01$.

Parameter	Sex	Probability value (p)		Log_{10} Mean Estimate
		Slope	Intercept	
Site HRL (reference) *vs* Site MAL (mill A near-field)				
Size-at-age	male	0.10	0.93	$S_p=0.35$, $I_p=0.76$
	female	0.13	0.09	$S_p=0.43$, $I_p=0.71$
Condition	male	0.53	0.001	$I_{hrl}=0.78$, $I_{mal}=0.83$
	female	0.25	0.009	$I_{hrl}=0.71$, $I_{mal}=0.75$
	immature	0.13	0.003	$I_{hrl}=0.28$, $I_{mal}=0.31$
Gonad vs. carcass wt.	male	0.94	0.002	$I_{hrl}=-0.806$, $I_{mal}=-0.715$
	female	0.21	<0.001	$I_{hrl}=-0.791$, $I_{mal}=-0.641$
Liver vs. carcass wt.	male	0.03	<0.001	$I_{hrl}=-1.062$, $I_{mal}=-0.914$
	female	0.32	0.05	$I_{hrl}=-0.915$, $I_{mal}=-0.829$
Site MAR (across river) *vs* Site MAL (mill A near-field)				
Size-at-age	male	0.63	0.83	$S_p=0.45$, $I_p=0.70$
	female	0.30	0.25	$S_p=0.52$, $I_p=0.66$
Condition	male	0.10	0.16	$S_p=3.35$, $I_p=-2.36$
	female	0.36	0.22	$S_p=3.39$, $I_p=-2.45$
	immature	0.02	0.17	$S_p=2.74$, $I_p=-1.87$
Gonad vs carcass wt.	male	0.55	0.03	$I_{mar}=-0.686$, $I_{mal}=-0.629$
	female	0.35	0.03	$I_{mar}=-0.605$, $I_{mal}=-0.523$
Liver vs. carcass wt.	male	0.002	-	$S_2=1.430$, $S_3=0.930$
	female	0.15	0.83	$S_p=1.182$, $I_p=-1.689$

Parameter	Sex	Probability value (p)		Log_{10} Mean Estimate
		Slope	Intercept	
Site HRL (reference) *vs* Site MAR (across river)				
Size-at-age	male	0.59	0.48	S_p=0.33, I_p=0.77
	female	0.08	0.63	S_p=0.42, I_p=0.71
Condition	male	0.035	0.08	S_p=3.38, I_p=-2.42
	female	0.08	0.39	S_p=3.33, I_p=-2.40
	immature	0.66	0.20	S_p=2.36, I_p=-1.59
Gonad vs carcass wt.	male	0.88	0.50	S_p=0.999, I_p=-1.593
	female	0.90	0.08	S_p=1.095, I_p=-1.561
Liver vs carcass wt	male	0.95	0.64	S_p=1.443, I_p=-2.176
	female	0.85	0.12	S_p=1.343, I_p=-1.861

Table 15. Summary of site comparisons for size-at-age, condition, gonad weight and liver weight of spoonhead sculpin (*Cottus ricei*), fall 1994 survey, Athabasca River, Hinton. Reference sites were set arbitrarily to a value of 100. Differences (and direction of difference) are represented by deviations from 100. Cells with two numbers indicate borderline differences (the left number refers to the comparison with the left adjacent cell; the right number refers to the comparison with the right adjacent cell).

Parameter	Site HRL (reference)	Site MAR (across river)	Site MAL (near-field)
Male			
Size-at-Age	100	100	100
Condition	100	**100/110**	**110**
Gonad *vs* carcass wt.	100	100	**110**
Liver *vs* carcass wt.	100	**100/110**	**110**
Female			
Size-at-age	100	100	100
Condition	100	**100/110**	**110**
Gonad *vs* carcass wt.	100	100	**110**
Liver *vs* carcass wt.	100	**100/110**	**110**
Immature			
Condition	100	**100/110**	**110**

Table 16. Site comparisons (ANCOVA) of size-at-age, condition, gonad weight, fecundity, egg size and liver weight for male, female and immature lake chub, fall 1994 survey, Athabasca River, Whitecourt. Abbreviations: I - intercept; S - slope; p - pooled over sites. Subscripts refer to site numbers. Interaction terms were considered significant at $p<0.01$.

Parameter	Sex	Probability value (p)		Log_{10} Mean Estimate
		Slope	Intercept	
SiteWF (reference 1) *vs* Site R2 (reference 2)				
Size-at-age	male	0.90	0.32	$S_p=0.11, I_p=0.93$
	female	0.76	0.13	$S_p=0.22, I_p=0.91$
Condition	male	0.55	0.08	$S_p=3.27, I_p=-2.31$
	female	0.59	<0.001	$I_{wf}=0.76, I_{r2}=0.82$
	immature	0.89	0.004	$I_{wf}=0.49, I_{r2}=0.51$
Gonad *vs* carcass wt.	male	0.92	0.40	$S_p=1.701, I_p=-2.613$
	female	0.94	0.49	$S_p=1.714, I_p=-1.669$
Liver *vs* carcass wt.	male	0.74	0.73	$S_p=1.737, I_p=-2.414$
	female	0.31	0.05	$I_{wf}=-0.929, I_{r2}=-0.841$
Fecundity *vs* carcass wt.	female	0.94	0.77	$S_p=0.90, I_p=2.62$
Egg wt. *vs* carcass wt.	female	0.70	0.15	$S_p=0.539, I_p=-1.015$
Egg dia. *vs* carcass wt.	female	0.33	0.46	$S_p=0.215, I_p=-0.285$
Site MB *vs* Site MC				
Size-at-age	male	0.50	0.38	$S_p=0.14, I_p=0.93$
	female	0.78	0.22	$S_p=0.16, I_p=0.92$
Condition	male	0.74	0.006	$I_{mb}=0.82, I_{mc}=0.86$
	female	0.92	0.005	$I_{mb}=0.75, I_{mc}=0.81$
	immature	0.29	0.02	$I_{mb}=0.41, I_{mc}=0.44$
Gonad *vs* carcass wt.	male	0.55	0.13	$S_p=1.364, I_p=-2.332$
	female	0.28	0.11	$S_p=1.471, I_p=-1.457$
Liver *vs* carcass wt.	male	0.27	0.08	$S_p=0.574^*, I_p=-1.398$
	female	0.16	0.35	$S_p=1.160, I_p=-1.819$
Fecundity *vs* carcass wt.	female	0.47	0.27	$S_p=1.20, I_p=2.37$

Parameter	Sex	Probability value (p)		Log_{10} Mean Estimate
		Slope	Intercept	
Site (WF+R2) *vs* Site MB				
Size-at-age	male	0.25	0.99	S_p=0.13, I_p=0.93
	female	0.41	0.70	S_p=0.19, I_p=0.92
Condition	male	0.10	0.67	S_p=2.86, I_p=-1.91
	female	0.93	0.32	S_p=2.97, I_p=-2.05
	immature	0.41	0.40	S_p=3.01, I_p=-2.04
Gonad *vs* carcass wt.	male	0.76	0.35	S_p=1.668, I_p=-2.572
	female	0.62	0.97	S_p=1.660, I_p=-1.626
Liver *vs* carcass wt	male	0.02	0.05	I_{wf+r2}=-1.014, I_{mb}=-0.896
	female	0.46	0.37	S_p=1.114, I_p=-1.780
Fecundity *vs* carcass wt.	female	0.28	0.82	S_p=1.0, I_p=2.53
Egg wt. *vs* carcass wt.	female	0.16	0.97	S_p=0.393, I_p=-0.893
Egg dia. *vs* carcass wt.	female	0.73	0.09	S_p=0.205, I_p=-0.285
Site (WF+R2) *vs* Site MC				
Size-at-age	male	0.75	0.30	S_p=0.11, I_p=0.94
	female	0.81	0.11	S_p=0.22, I_p=0.91
Condition	male	0.23	0.005	I_{wf+r2}=0.81, I_{mc}=0.84
	female	0.99	0.01	I_{wf+r2}=0.77, I_{mc}=0.81
	immature	0.55	0.91	S_p=2.933, I_p=-1.99
Gonad *vs* carcass wt.	male	0.40	0.51	S_p=1.465, I_p=-2.436
	female	0.24	0.19	S_p=1.578, I_p=-1.548
Liver *vs* carcass wt	male	0.28	0.89	S_p=1.408, I_p=-2.154
	female	0.40	0.67	S_p=1.256, I_p==1.877
Fecundity *vs* carcass wt.	female	0.17	0.39	S_p=0.90, I_p=2.57
Egg wt. *vs* carcass wt.	female	0.12	0.67	S_p=0.456, I_p=-0.949
Egg dia. *vs* carcass wt.	female	0.04	0.18	S_p=0.172, I_p=-0.255

* pooled liver weight vs carcass weight relationship was poor (r^2=0.181)

Table 17. Summary of site comparisons for size-at-age, condition, gonad weight, fecundity, egg size and liver weight of lake chub (*Couesius plumbeus*), fall 1994 survey, Athabasca River, Whitecourt. Reference sites were set arbitrarily to a value of 100. Differences (and direction of difference) are represented by deviations from 100. Cells with two numbers indicate borderline differences (the left number refers to the comparison with the left adjacent cell; the right number refers to the comparison with the right adjacent cell).

Parameter	Reference (WF+R2)	Mill B Near-field	Mill C Near-field
Male			
Size-at-Age	100	100	100
Condition	100	100	**110**
Gonad *vs* carcass wt.	100	100	100
Liver *vs* carcass wt.	100	**110/100**	100
Female			
Size-at-age	100	100	100
Condition	100	100	**110**
Gonad *vs* carcass wt.	100	100	100
Fecundity *vs* carcass wt.	100	100	100
Egg Weight *vs* carcass wt.	100	100	100
Egg Diameter *vs* carcass wt.	100	100	100
Liver *vs* carcass wt.	100	100	100
Immature			
Condition	100	**100/90**	100

Table 18. Mean ± SE (n=3) of major ion concentrations (mg/L) in water samples collected at each sampling site in the Hinton and Whitecourt study area, fall 1994 survey, Athabasca River, Alberta.

	Hinton Study Area			Whitecourt Study Area			
Ion	Site HRL	Site MAR	Site MAL	Site WF	Site R2	Site MB	Site MC
Cl	0.68 ± 0.04	0.69 ± 0.01	1.98 ± 0.02	1.63 ± 0.03	1.58 ± 0.04	1.63 ± 0.01	1.68 ± 0.01
SO_4	37.7 ± 0.2	37.6 ± 1.3	45.7 ± 0.4	38.4 ± 0.03	39.0 ± 0.2	39.7 ± 0.2	25.8 ± 0.1
Na	1.13 ± 0.01	1.20 ± 0.03	4.07 ± 0.02	4.03 ± 0.02	4.19 ± 0.01	4.32 ± 0.01	11.9 ± 0.1
SiO_2	2.5 ± 0.02	2.28	2.47 ± 0.01	3.75 ± 0.04	3.62 ± 0.06	3.78 ± 0.11	4.59 ± 0.02
K	0.40 ± 0.01	0.40 ± 0.003	0.47	0.52 ± 0.003	0.52 ± 0.003	0.54 ± 0.01	0.90 ± 0.003

Table 19. Location and general description of each site sampled for spoonhead sculpin (*Cottus ricei*) during the spring 1995 field survey, Athabasca River and North Saskatchewan River, Alberta. Abbreviations: LUB - left upstream bank; RUB - right upstream bank.

Site	Location (latitude / longitude)	General Description	River Distance from Outfall
Athabasca River			
HRL	N 53°24.25'/ W 117°35.49'	Reference site - immediately upstream of mill A pumphouse, LUB of river.	-0.50 km
HRR	N 53°24.34'/ W 117°35.56'	Reference site - across river from Site HRL, RUB of river.	-0.65 km
MAL	N 53°25.73'/ W 117°33.17'	Mill A near-field site - approx. 0.25 km downstream of bridge, LUB of river.	1.25 km
MAR	N 53°24.63'/ W 117°33.46'	Across river site - immediately downstream of Helge Nelson Bridge, LUB of river across from plume tracking.	1.0 km
CL	N 53°32.03'/ W 117°20.74'	Far-field site - approx. 0.75 km downstream of the Obed Mountain Coal Ltd conveyor road bridge, LUB of river.	21.25 km
CR	N 53°31.95'/ W 117°20.76'	Far-field site - approx. 0.75 km downstream of the conveyor road bridge, RUB of river across from Site CL.	21.25 km
E	N 53°42.46'/ W 117°10.13'	Far-field site - approx. 0.75 km downstream of Emerson Bridge, LUB of river.	47.5 km
North Saskatchewan River			
NS	N 52°23.60'/ W 115°18.64'	Alternative reference site on North Sask. River along LUB of island across from Horburg recreation area, Alberta Forest Service.	NA

Table 20. Numbers of fish caught per species by backpack electrofishing in the Athabasca River (near Hinton) and North Saskatchewan River, April 05-20, 1995.

Site	Species								Number Seconds Shocked*	Number Fish Caught per Minute	Number Sculpin Caught per Minute
	Mountain Whitefish	Rainbow Trout	Bull Trout	Spoonhead Sculpin	Longnose Dace	Sucker sp. (?)	Northern Pike	Total			
Athabasca River											
HRL	5	2		90	1	1		99	3448	1.72	1.57
HRR				56		16	1	72	3317	1.30	1.01
MAL	8	3	1	59		5		76	5681	0.80	0.62
MAR	2	4	1	91	15	13		126	3644	2.07	1.50
CL	3			34				37	4070	0.55	0.50
CR	3	2		52		9		66	2855	1.39	1.09
E				24		17		41	4004	0.61	0.36
Total	21	11	2	406	16	61	1	518			
North Saskatchewan River											
NS				46	20	6		72	6853	0.63	0.40

* refers to the total amount of time the shocker was active, not the total sampling time on the water.

Table 21. Abundance of male, female and immature spoonhead sculpin (*Cottus ricei*) collected at study sites during the spring 1995 survey, Athabasca River and North Saskatchewan River.

Sex	Reference			Near-field		Far-field		
	HRL	HRR	NS*	MAL	MAR	CL	CR	E
Male	32	22	8	19	15	4	26	15
Female	12	23	13	9	16	11	10	6
- preovulatory	10	17	13	9	5	3	5	6
- spent	2	6	-	-	11	8	5	-
Immature	63	13	25	32	59	22	16	3

* Alternate reference site located on the North Saskatchewan River, Alberta.

Table 22a. Mean and SE (n) of body metrics for spoonhead sculpin (*Cottus ricei*) collected at reference sites , spring 1995 survey, Athabasca / North Saskatchewan River[+], Alberta.

Sex	Reference zone		
	Site HRL	Site HRR	Site NS[+]
Male			
Total Length (cm)	9.0 ± 0.2 (32)	8.8 ± 0.2 (22)	10.1 ± 0.4 (8)
Body Weight (g)	7.90 ± 0.47 (32)	6.81 ± 0.43 (22)	11.08 ± 1.64 (8)
Carcass Weight (g)	6.81 ± 0.41 (32)	5.83 ± 0.37 (22)	9.39 ± 1.44 (8)
Liver Weight (g)	0.12 ± 0.01 (32)	0.09 ± 0.01 (22)	0.14 ± 0.02 (8)
Gonad Weight (g)	0.14 ± 0.01 (32)	0.08 ± 0.01 (22)	0.29 ± 0.05 (8)
Age (y)	4.1 ± 0.2 (32)	4.0 ± 0.2 (22)	4.3 ± 0.4 (8)
K	0.90 ± 0.01 (32)	0.84 ± 0.01 (22)	0.88 ± 0.02 (8)
GSI (%)	2.05 ± 0.08 (32)	1.40 ± 0.12 (22)	3.11 ± 0.13 (8)
LSI (%)	1.79 ± 0.08 (32)	1.54 ± 0.09 (22)	1.48 ± 0.06 (8)
Female			
Total Length (cm)	8.5 ± 0.2 (12)	8.0 ± 0.2 (23)	10.0 ± 0.4 (13)
Body Weight (g)	5.98 ± 0.46 (12)	4.79 ± 0.22 (23)	9.78 ± 0.98 (13)
Carcass Weight (g)	4.30 ± 0.40 (12)	3.37 ± 0.21 (23)	6.79 ± 0.73 (13)
Liver Weight (g)	0.12 ± 0.01 (12)	0.10 ± 0.02 (23)	0.19 ± 0.02 (13)
Gonad Weight (g)* [spent females]	1.09 ± 0.12 (10) [0.15 ± 0.02 (2)]	1.00 ± 0.06 (17) [0.14 ± 0.02 (6)]	1.94 ± 0.23 (13) [-]
Fecundity (# eggs)	243 ± 25 (9)	193 ± 11 (17)	357 ± 42 (12)
Egg Weight (mg)	4.69 ± 0.42 (9)	5.23 ± 0.25 (17)	4.93 ± 0.31 (12)
Egg Diameter (mm)	1.73 ± 0.08 (9)	1.86 ± 0.03 (17)	1.82 ± 0.04 (12)
Age (y)	3.6 ± 0.2 (12)	3.6 ± 0.10 (23)	4.1 ± 0.3 (13)
K	0.68 ± 0.02 (12)	0.63 ± 0.01 (23)	0.66 ± 0.01 (13)
GSI (%)* [spent females]	27.96 ± 1.57 (10) [2.32 ± 0.17 (2)]	33.84 ± 1.62 (16) [2.84 ± 0.33 (5)]	29.56 ± 2.47 (13) [-]
LSI (%)	2.97 ± 0.19 (12)	3.02 ± 0.14 (23)	2.83 ± 0.12 (13)
Immature			
Total Length (cm)	6.3 ± 0.1 (63)	6.5 ± 0.1 (13)	7.6 ± 0.1 (25)
Body Weight (g)	2.30 ± 0.09 (63)	2.32 ± 0.15 (13)	3.46 ± 0.23 (25)
K	0.89 ± 0.02 (63)	0.86 ± 0.02 (13)	0.77 ± 0.01 (25)

* refers to gonad weight and GSI from green or preovulatory females.

Table 22b. Mean and SE (n) of body metrics for spoonhead sculpin (*Cottus ricei*) collected at near-field sites during the spring 1995 survey, Athabasca River, Alberta.

Sex	Mill A near-field zone	
	Site MAL	Site MAR
Male		
Total Length (cm)	9.8 ± 0.2 (19)	8.9 ± 0.2 (15)
Body Weight (g)	10.84 ± 0.75 (19)	8.37 ± 0.70 (15)
Carcass Weight (g)	9.54 ± 0.66 (19)	7.08 ± 0.61 (15)
Liver Weight (g)	0.17 ± 0.01 (19)	0.16 ± 0.01 (15)
Gonad Weight (g)	0.14 ± 0.01 (19)	0.08 ± 0.01 (15)
Age (y)	3.8 ± 0.2 (19)	4.3 ± 0.3 (15)
K	1.00 ± 0.02 (19)	0.96 ± 0.04 (15)
GSI (%)	1.54 ± 0.11 (19)	1.19 ± 0.13 (15)
LSI (%)	1.83 ± 0.13 (19)	2.28 ± 0.17 (15)
Female		
Total Length (cm)	8.6 ± 0.4 (9)	9.0 ± 0.3 (16)
Body Weight (g)	8.25 ± 1.46 (9)	7.03 ± 0.67 (16)
Carcass Weight (g)	5.20 ± 0.89 (9)	5.36 ± 0.54 (16)
Liver Weight (g)	0.19 ± 0.02 (9)	0.17 ± 0.02 (16)
Gonad Weight (g)* [spent females]	2.18 ± 0.41 (9) [-]	1.73 ± 0.34 (5) [0.16 ± 0.03 (11)]
Fecundity (# eggs)	353 ± 38 (9)	356 ± 52 (5)
Egg Weight (mg)	5.91 ± 0.49 (9)	4.65 ± 0.55 (5)
Egg Diameter (mm)	1.96 ± 0.04 (9)	1.68 ± 0.14 (5)
Age (y)	3.7 ± 0.3 (9)	4.1 ± 0.3 (16)
K	0.76 ± 0.02 (9)	0.70 ± 0.01 (16)
GSI (%)* [spent females]	41.40 ± 1.26 (9) [-]	36.52 ± 3.54 (5) [2.74 ± 0.22 (11)]
LSI (%)	3.94 ± 0.29 (9)	3.20 ± 0.17 (16)
Immature		
Total Length (cm)	6.8 ± 0.1 (32)	6.6 ± 0.1 (59)
Body Weight (g)	2.88 ± 0.11 (32)	2.65 ± 0.10 (59)
K	0.92 ± 0.02 (32)	0.92 ± 0.01 (59)

* refers to gonad weight and GSI from green or preovulatory females.

Table 22c. Mean and SE (n) of body metrics for spoonhead sculpin (*Cottus ricei*) collected at far-field sites during the spring 1995 survey, Athabasca River, Alberta.

Sex	Mill A far-field zone		
	Site CL	Site CR	Site E
Male			
Total Length (cm)	9.5 ± 0.8 (4)	9.5 ± 0.2 (26)	10.6 ± 0.3 (15)
Body Weight (g)	10.42 ± 2.43 (4)	10.44 ± 0.78 (26)	16.31 ± 1.57 (15)
Carcass Weight (g)	8.98 ± 2.19 (4)	9.00 ± 0.71 (26)	14.01 ± 1.37(15)
Liver Weight (g)	0.24 ± 0.06 (4)	0.22 ± 0.01 (26)	0.36 ± 0.03 (15)
Gonad Weight (g)	0.08 ± 0.02 (4)	0.09 ± 0.01 (26)	0.32 ± 0.04 (15)
Age (y)	4.0 ± 0.4 (4)	4.2 ± 0.2 (26)	4.6 ± 0.3 (15)
K	1.01 ± 0.02 (4)	1.00 ± 0.02 (26)	1.12 ± 0.02 (15)
GSI (%)	0.93 ± 0.17 (4)	1.04 ± 0.08 (26)	2.37 ± 0.27 (15)
LSI (%)	2.69 ± 0.10 (4)	2.65 ± 0.17 (26)	2.78 ± 0.22 (15)
Female			
Total Length (cm)	9.0 ± 0.2 (11)	9.3 ± 0.3 (10)	9.5 ± 0.7 (6)
Body Weight (g)	7.44 ± 0.33 (11)	8.59 ± 0.71 (10)	11.97 ± 2.78 (6)
Carcass Weight (g	5.62 ± 0.29 (11)	6.17 ± 0.69 (10)	7.89 ± 1.81 (6)
Liver Weight (g)	0.24 ± 0.01 (11)	0.24 ± 0.02 (10)	0.34 ± 0.07 (6)
Gonad Weight (g)* [spent females]	1.94 ± 0.08 (3) [0.14 ± 0.02 (8)]	2.15 ± 0.11 (5) [0.19 ± 0.04 (5)]	2.64 ± 0.69 (6) [-]
Fecundity (# eggs)	477 ± 54 (3)	414 ± 34 (5)	568 ± 98 (6)
Egg Weight (mg)	4.14 ± 0.35 (3)	5.32 ± 0.44 (5)	4.35 ± 0.47 (6)
Egg Diameter (mm)	1.56 ± 0.02 (3)	1.71 ± 0.07 (5)	1.61 ± 0.09 (6)
Age (y)	3.6 ± 0.2 (11)	3.8 ± 0.3 (10)	4.2 ± 0.5 (6)
K	0.77 ± 0.02 (11)	0.76 ± 0.02 (10)	0.84 ± 0.03 (6)
GSI (%)* [spent females]	38.98 ± 1.35 (3) [2.30 ± 0.30 (8)]	42.50 ± 0.76 (5) [2.46 ± 0.19 (5)]	32.33 ± 1.88 (6) [-]
LSI (%)	4.21 ± 0.16 (11)	3.90 ± 0.19 (10)	4.45 ± 0.23 (6)
Immature			
Total Length (cm)	6.9 ± 0.1 (22)	6.8 ± 0.1 (16)	7.0 ± 0.3 (3)
Body Weight (g)	3.28 ± 0.15 (22)	3.25 ± 0.14 (16)	3.37 ± 0.39 (3)
K	0.97 ± 0.02 (22)	1.03 ± 0.03 (16)	0.96 ± 0.01 (3)

* refers to gonad weight and GSI from green or preovulatory females.

Table 23. Comparisons (ANCOVA) of size-at-age, condition, gonad weight and liver weight for male, female and immature spoonhead sculpin collected from reference sites HRL/HRR (combined), spring 1995 survey, Athabasca River, Hinton. Abbreviations: I - intercept; S - slope; p - pooled. Subscripts refer to site numbers. Interaction terms were considered significant at $p<0.01$.

Parameter	Probability value (p)		Log_{10} Mean Estimate
	Slope	Intercept	
Male *vs* Female (preovulatory) Spoonhead Sculpin			
Size-at-age	0.60	0.01	I_m=0.94, I_f=0.92
Condition	0.07	<0.001	I_m=0.74, I_f=0.62
Liver vs. carcass wt.	0.87	<0.001	I_m=-1.076, I_f=-0.879
Preovulatory *vs* Spent Female Spoonhead Sculpin			
Size-at-age	0.44	<0.001	I_{pre}=0.90, I_{sp}=0.96
Condition	0.10	0.17	S_p=3.04, I_p=0.-2.22
Liver vs. carcass wt.	0.77	0.21	S_p=0.761, I_p=-1.402

Table 24. Mean and SE (n) of hepatic EROD activity and *in vitro* production of testosterone and 17β-estradiol in spoonhead sculpin (*Cottus ricei*) collected from reference sites HRL/HRR, Athabasca River, Alberta, during the Spring 1995 survey.

Parameter	Sex	Estimate
EROD activity (pmol/mg protein/minute)		
	Male	4.2 ± 0.5 (53)
	Female- preovulatory	2.3 ± 0.4 (28)
	- spent	7.0 ± 2.8 (7)
Testosterone (♂: pg/mg testicular tissue, ♀: pg/10 follicles)		
Basal levels	Male	3.26 ± 0.36 (28)
	Female	74.5 ± 32.4 (23)
Forskolin levels	Male	6.96 ± 0.59 (28)
	Female	59.4 ± 20.0 (24)
17β-estradiol (pg/10 follicles)		
Basal levels	Female	20.3 ± 8.3 (23)
Forskolin levels	Female	42.5 ± 15.9 (25)

Table 25. Comparison (ANCOVA) of size-at-age, condition, gonad weight and liver weight for male, female and immature spoonhead sculpin at Sites (HRL+HRR), MAL and MAR, spring 1995 survey, Athabasca River, Hinton. Abbreviations: I - intercept; S - slope; p - pooled over sites. Subscripts refer to sites. Interaction terms were considered significant at $p<0.01$.

Parameter	Sex	Probability value (p)		Log_{10} Mean Estimate
		Slope	Intercept	
Site HRL *vs* Site HRR (reference sites)				
Size-at-age	male	0.28	0.37	$S_p=0.31$, $I_p=0.76$
	female	0.23	0.06	$I_{hrl}=0.93$, $I_{hrr}=0.90$
Condition	male	0.13	0.003	$I_{hrl}=0.80$, $I_{hrr}=0.77$
	female	0.81	0.01	$I_{hrl}=0.57$, $I_{hrr}=0.54$
	immature	0.91	0.47	$S_p=2.81$, $I_p=-1.90$
Gonad *vs* carcass wt.	male	0.12	<0.001	$I_{hrl}=-0.906$, $I_{hrr}=-1.119$
	female	0.65	0.01	$I_{hrl}=-0.076$, $I_{hrr}=0.038$
Liver *vs* carcass wt.	male	0.53	0.01	$I_{hrl}=-0.969$, $I_{hrr}=-1.061$
	female	0.16	0.62	$S_p=0.761$, $I_p=-1.402$
Fecundity *vs* carcass wt.	female	0.50	0.40	$S_p=0.94$, $I_p=1.80$
Site (HRL+HRR) (pooled reference) *vs* Site MAL (mill A near-field)				
Size-at-age	male	0.98	<0.001	$I_{ref}=0.95$, $I_{mal}=0.99$
	female	0.14	0.18	$S_p=0.35$, $I_p=0.72$
Condition	male	0.42	<0.001	$I_{ref}=0.82$, $I_{mal}=0.86$
	female	0.76	<0.001	$I_{ref}=0.56$, $I_{mal}=0.63$
	immature	0.71	0.03	$I_{ref}=0.36$, $I_{mal}=0.39$
Gonad *vs* carcass wt.	male	0.41	0.67	$S_p=0.747$, $I_p=-1.583$
	female	0.62	0.002	$I_{ref}=0.039$, $I_{mal}=0.163$
Liver *vs* carcass wt.	male	0.39	0.02	$I_{ref}=-0.976$, $I_{mal}=-0.885$
	female	0.61	<0.001	$I_{ref}=-0.967$, $I_{mal}=-0.813$
Fecundity *vs* carcass wt.	female	0.11	0.02	$I_{ref}=2.33$ $I_{mal}=2.44$

Parameter	Sex	Probability value (p)		Log_{10} Mean Estimate
		Slope	Intercept	
Site MAR (across river) *vs* Site MAL				
Size-at-age	male	0.99	<0.001	I_{mar}=0.94, I_{mal}=0.99
	female	0.55	0.95	S_p=0.45, I_p=0.68
Condition	male	0.78	0.57	S_p=3.28, I_p=-2.28
	female	0.65	0.01	I_{mar}=0.68, I_{mal}=0.71
	immature	0.05	0.75	S_p=3.09, I_p=-2.12
Gonad vs carcass wt.	male	0.34	0.002	I_{mar}=-1.106, I_{mal}=-0.902
	female	-	-	unavailable
Liver vs. carcass wt.	male	0.50	0.32	S_p=0.540, I_p=-1.280
	female	0.62	0.02	I_{mar}=0.154, I_{mal}=0.187
Site (HRL+HRR) *vs* Site MAR				
Size-at-age	male	0.95	0.61	S_p=0.31, I_p=0.76
	female	0.22	0.05	I_{ref}=0.92, I_{mar}=0.94
Condition	male	0.83	<0.001	I_{ref}=0.79, I_{mar}=0.83
	female	0.87	0.003	I_{ref}=0.58, I_{mar}=0.62
	immature	0.03	0.01	I_{ref}=0.36, I_{mar}=0.38
Gonad vs carcass wt.	male	0.07	0.001	I_{ref}=-0.986, I_{mar}=-1.158
	female	-	-	unavailable
Liver vs carcass wt	male	0.97	0.002	I_{ref}=-1.0, I_{mar}=-0.856
	female	0.96	0.02	I_{ref}=-0.950, I_{mar}=-0.885

Table 26. Summary of site comparisons for size-at-age, condition, gonad weight, fecundity and liver weight of spoonhead sculpin (*Cottus ricei*), spring 1995 survey, Athabasca River, Hinton. Reference sites were set arbitrarily to a value of 100. Differences (and direction of difference) are represented by deviations from 100. Cells with two numbers indicate borderline differences (the left number refers to the comparison with the left adjacent cell; the right number refers to the comparison with the right adjacent cell).

Parameter	Site (HRL+HRR) (reference)	Site MAR (across river)	Site MAL (near-field)
Male			
Size-at-Age	100	100	**110**
Condition	100	**110**	**110**
Gonad *vs* carcass wt.	100	**90**	100
Liver *vs* carcass wt.	100	**110**	**110**
Female			
Size-at-age	100	**110/100**	100
Condition	100	**110**	**120**
Gonad *vs* carcass wt.	100	NA	**110**
Fecundity *vs* carcass wt.	100	NA	**110**
Liver *vs* carcass wt.	100	**110**	**110**
Immature			
Condition	100	**110**	**110**

Table 27. Comparison (ANCOVA) of size-at-age, condition, gonad weight, fecundity, egg size and liver weight for spoonhead sculpin at Sites MAL, C and E, spring 1995 survey, Athabasca River, Hinton. Abbreviations: I - intercept; S - slope; p - pooled over sites. Subscripts refer to sites. Interaction terms were considered significant at $p<0.01$.

Parameter	Sex	Probability value (p)		Log_{10} Mean Estimate
		Slope	Intercept	
Site MAL (near-field) *vs* Site C (far-field)				
Size-at-age	male	0.02	<0.001	$I_{mal}=1.0, I_{-}=0.97$
	female	0.14	0.03	$I_{mal}=0.93, I_{-}=0.96$
Condition	male	0.65	0.65	$S_{p}=3.24, I_{p}=-2.24$
	female	0.64	0.73	$S_{p}=2.91, I_{p}=-2.04$
	immature	0.70	<0.001	$I_{mal}=0.46, I_{-}=0.50$
Gonad *vs* carcass wt.	male	0.64	<0.001	$I_{mal}=-0.896, I_{-}=-1.085$
	female	0.52	0.89	$S_{p}=1.037, I_{p}=-0.411$
Liver *vs* carcass wt.	male	0.78	<0.001	$I_{mal}=-0.812, I_{-}=-0.668$
	female	0.53	0.12	$S_{p}=0.748, I_{p}=-1.216$
Fecundity *vs* carcass wt.	female	0.99	0.03	$I_{mal}=2.54, I_{-}=2.63$
Egg wt. *vs* carcass wt.	female	0.77	0.02	$I_{mal}=0.76, I_{-}=0.67$
Site MAL *vs* Site E (farther-field) - males only				
Size-at-age	male	0.36	0.82	$S_{p}=0.40, I_{p}=0.76$
Condition	male	0.89	0.002	$I_{mal}=1.01, I_{-}=1.05$
Gonad *vs* carcass wt.	male	0.54	<0.001	$I_{mal}=-0.832, I_{-}=-0.602$
Liver *vs* carcass wt.	male	0.97	<0.001	$I_{mal}=-0.763, I_{-}=-0.503$
Site C *vs* Site E - males only				
Size-at-age	male	0.19	0.01	$I_{-}=0.98, I_{-}=1.01$
Condition	male	0.50	<0.001	$I_{-}=0.97, I_{-}=1.01$
Gonad vs carcass wt.	male	0.76	<0.001	$I_{-}=-1.047, I_{-}=-0.637$
Liver vs. carcass wt.	male	0.71	0.004	$I_{-}=-0.641, I_{-}=-0.531$

Table 28. Summary of site comparisons for size-at-age, condition, gonad weight, fecundity, egg size and liver weight of spoonhead sculpin (*Cottus ricei*), spring 1995 survey, Athabasca River, Hinton. Site MAL was set arbitrarily to a value of 100. Differences (and direction of difference) are represented by deviations from 100.

Parameter	Site MAL (near-field)	Site C (far-field)	Site E (farther-field)
Male			
Size-at-Age	100	**90**	100
Condition	100	100	**110**
Gonad *vs* carcass wt.	100	**90**	**110**
Liver *vs* carcass wt.	100	**110**	**120**
Female			
Size-at-age	100	**110**	NA
Condition	100	100	NA
Gonad *vs* carcass wt.	100	100	NA
Fecundity *vs* carcass wt.	100	**110**	NA
Egg wt. *vs* carcass wt.	100	**90**	NA
Liver *vs* carcass wt.	100	100	NA
Immature			
Condition	100	**110**	NA

Table 29. Comparison (ANCOVA) of size-at-age, condition, gonad weight, fecundity and liver weight for spoonhead sculpin between reference sites on the Athabasca River (HRL+HRR) and North Saskatchewan River (NS), spring 1995 survey. Abbreviations: I - intercept; S - slope; p - pooled over sites. Subscripts refer to sites. Interaction terms were considered significant at $p<0.01$.

Parameter	Sex	Probability value (p)		Log_{10} Mean Estimate
		Slope	Intercept	
Site (HRL+HRL) *vs* Site NS				
Size-at-age	male	0.24	<0.001	$I_{(hrl+hrr)}=0.95$, $I_{ns}=1.0$
	female	0.19	<0.001	$I_{(hrl+hrr)}=0.91$, $I_{ns}=0.99$
Condition	male	0.95	0.21	$S_p=3.31$, $I_p=-2.35$
	female	0.85	0.64	$S_p=3.05$, $I_p=-2.24$
	immature	0.11	<0.001	$I_{(hrl+hrr)}=0.39$, $I_{ns}=0.35$
Gonad *vs* carcass wt.	male	0.66	<0.001	$I_{(hrl+hrr)}=-0.974$, $I_p=-0.691$
	female	0.48	0.78	$S_p=0.848$, $I_p=-0.429$
Liver *vs* carcass wt.	male	0.28	0.91	$S_p=0.779$, $I_p=-1.619$
	female	0.92	0.22	$S_p=0.823$, $I_p=-1.429$
Fecundity *vs* carcass wt.	female	0.51	0.81	$S_p=0.781$, $I_p=1.91$

Table 30. Summary of comparisons for size-at-age, condition, gonad weight, fecundity and liver weight of spoonhead sculpin (*Cottus ricei*) between reference sites on the Athabasca River and North Saskatchewan River (NS), spring 1995 survey. The Athabasca River site (HRL+HRR) was set arbitrarily to a value of 100. Differences (and direction of difference) are represented by deviations from 100.

Parameter	Site(HRL+HRR)	Site NS
Male		
Size-at-Age	100	**110**
Condition	100	100
Gonad *vs* carcass wt.	100	**110**
Liver *vs* carcass wt.	100	100
Female		
Size-at-age	100	**110**
Condition	100	100
Gonad *vs* carcass wt.	100	100
Fecundity *vs* carcass wt.	100	100
Liver *vs* carcass wt.	100	100
Immature		
Condition	100	**110**

Table 31. Mean ± SE (n=3) of major ion concentrations (mg/L) in water samples collected at each sampling site on the Athabasca River, Alberta during the spring 1995 survey.

Ion	Reference Zone		
	Site HRL	Site HRR	Site NS*
Cl	1.33 ± 0.04	1.25 ± 0.01	0.54 ± 0.01
SO_4	100 ± 1	104 ± 1	45.5 ± 0.5
Na	2.54 ± 0.01	2.56 ± 0.01	1.26 ± 0.02
SiO_2	4.19 ± 0.01	4.19 ± 0.003	3.12 ± 0.003
K	0.54 ± 0.01	0.55 ± 0.003	0.42 ± 0.01

* Alternate reference site located on the North Saskatchewan River, Alberta

Ion	Mill A Effluent and Near-field Zone			Far-field Zone		
	Effluent	Site MAL	Site MAR*	Site CL	Site CR	Site E
Cl	134 ± 0.3	8.23 ± 0.02	2.37 ± 0.02	7.12 ± 0.05	6.99 ± 0.01	5.79 ± 0.08
SO_4	450 ± 9	121 ± 1	105 ± 1	111 ± 1	107	97.2 ± 0.5
Na	296 ± 2	17.8 ± 0.13	5.0 ± 0.02	14.2 ± 0.07	14.3	13.8 ± 0.1
SiO_2	6.05 ± 0.21	4.29 ± 0.1	4.12 ± 0.01	3.98 ± 0.01	4.16 ± 0.01	4.07 ± 0.04
K	9.98 ± 0.21	0.85 ± 0.01	0.6 ± 0.003	0.8 ± 0.01	0.78 ± 0.003	0.87 ± 0.01

* Site MAR is located across river from the main plume of mill A effluent.

Figures

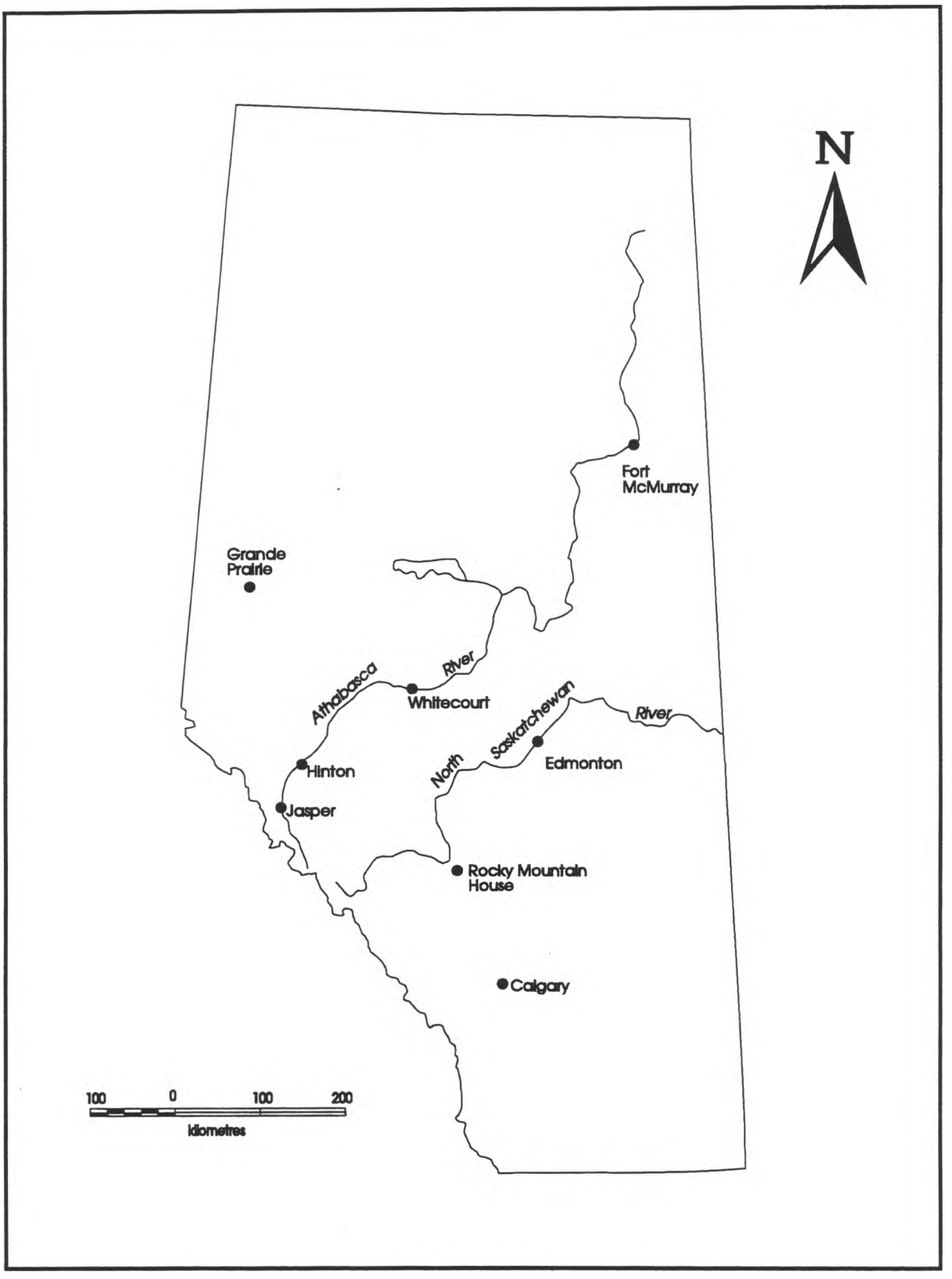


Figure 1. Schematic map of the Athabasca River and North Saskatchewan River, Alberta.

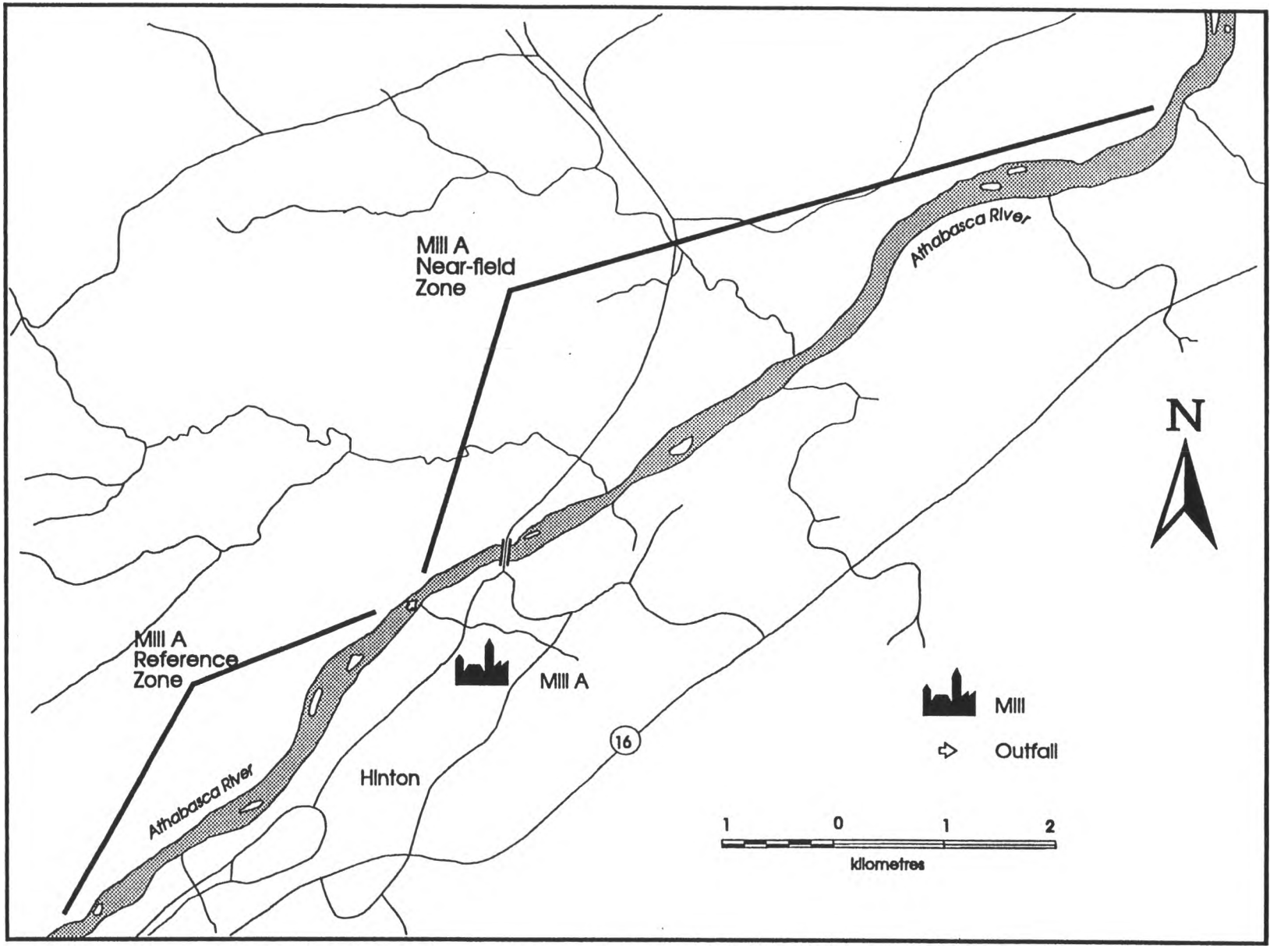


Figure 2a. Location of the mill A reference and near-field zones in the Hinton study area, Athabasca River, Alberta.

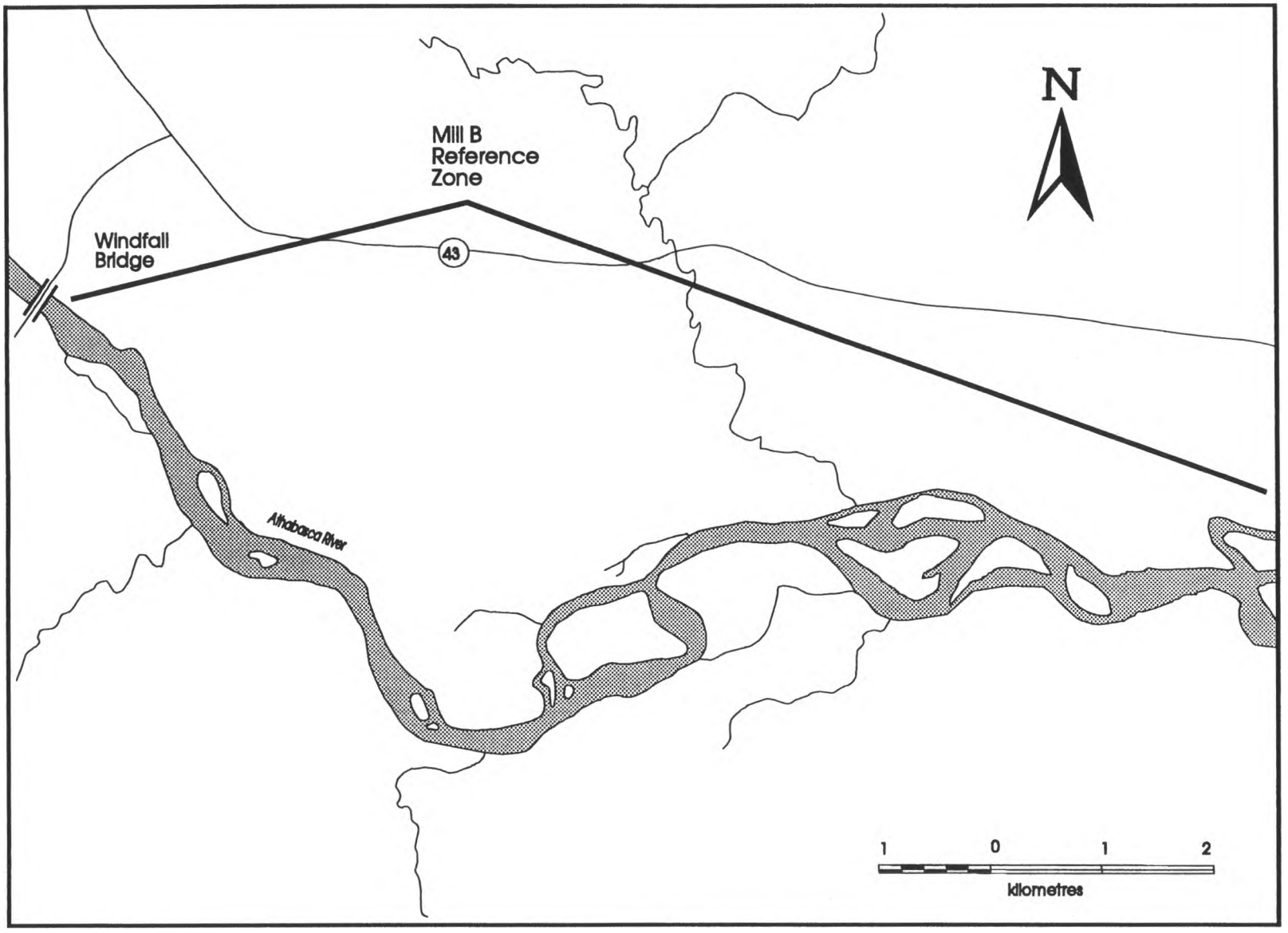


Figure 2b. Location of the mill B reference zone in the Whitecourt study area, Athabasca River, Alberta.

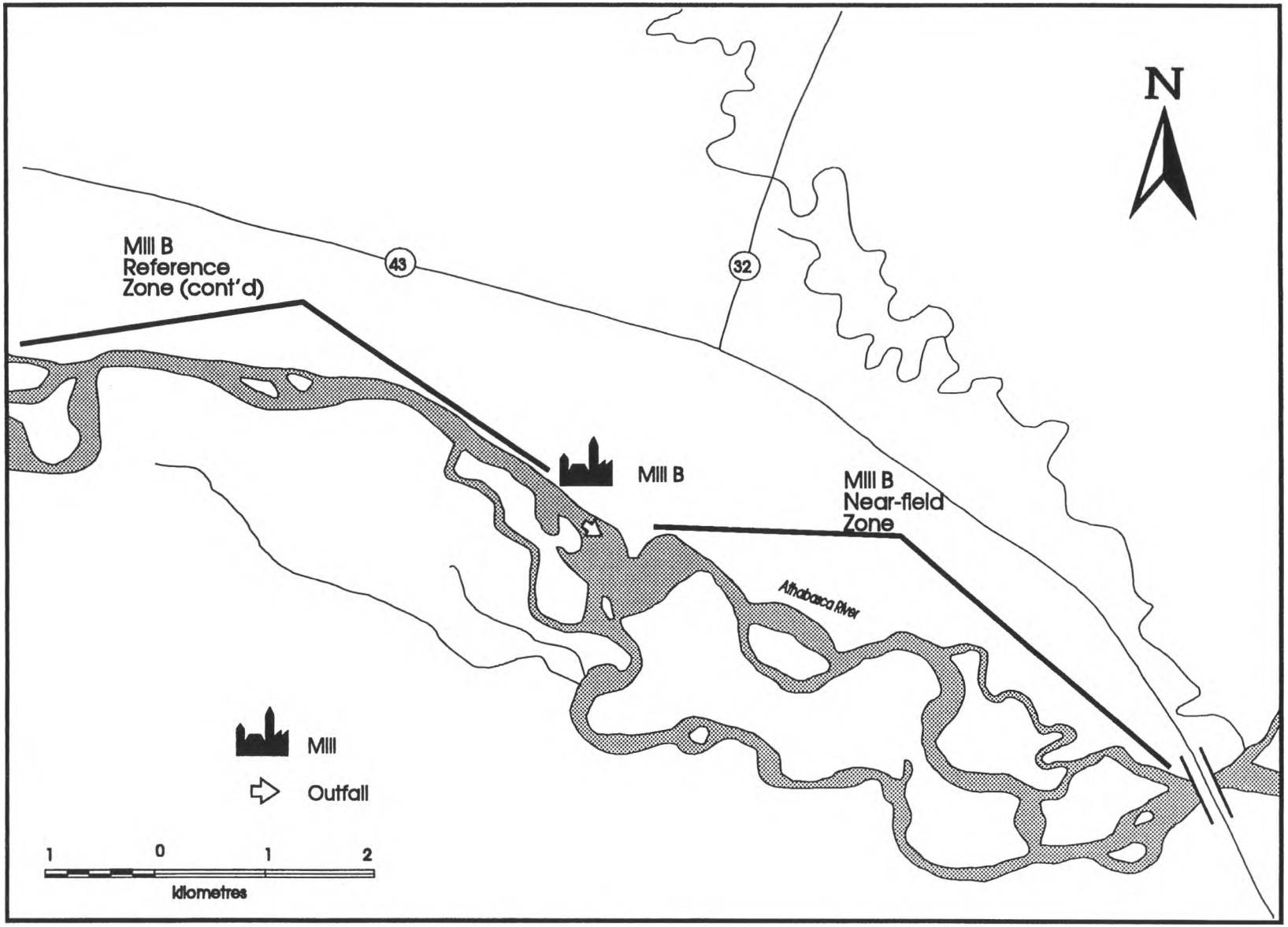


Figure 2c. Location of the mill B reference (continued) and near-field zones in the Whitecourt study area, Athabasca River, Alberta.

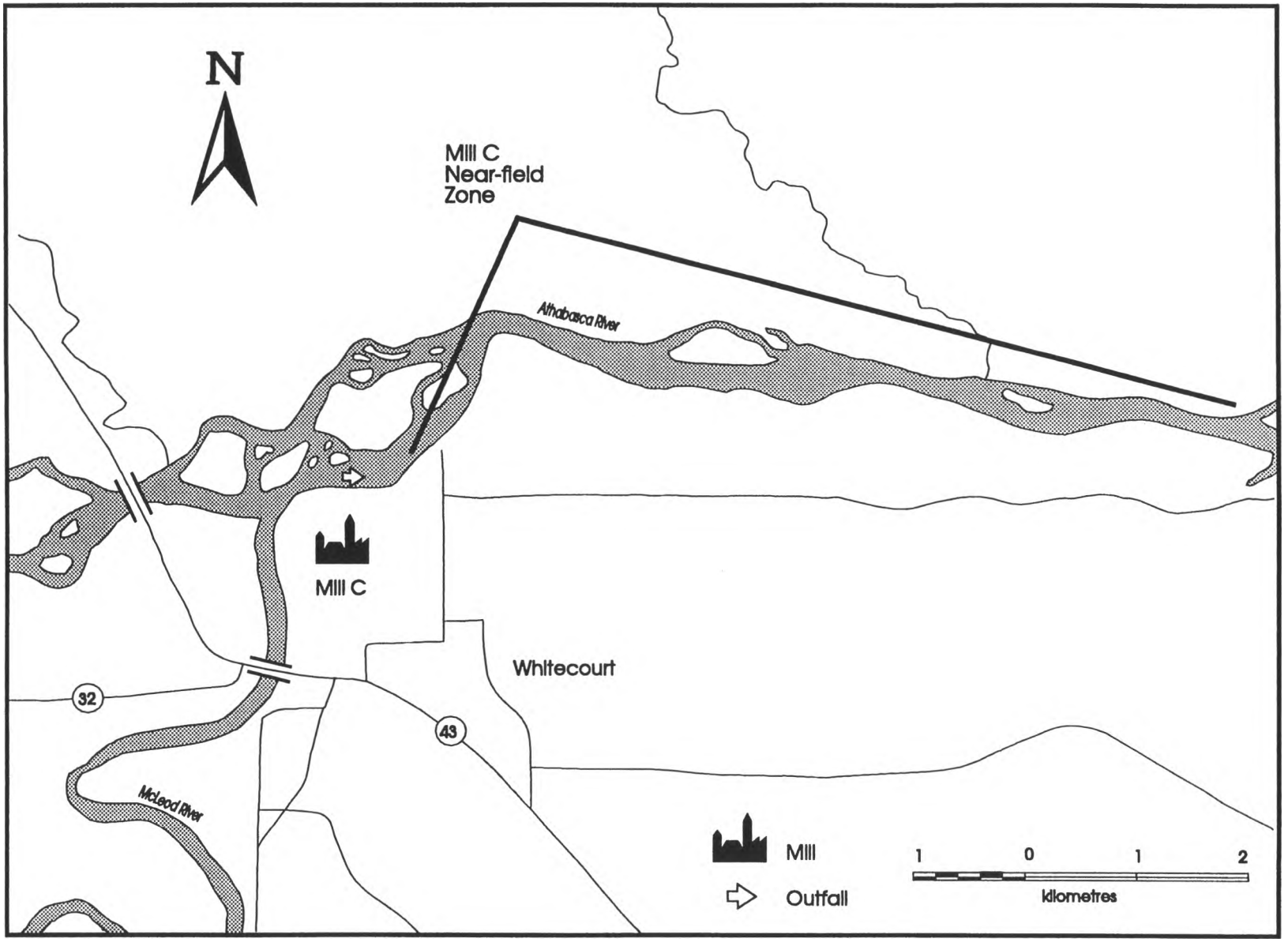


Figure 2d. Location of the mill C near-field zone in the Whitecourt study area, Athabasca River, Alberta.

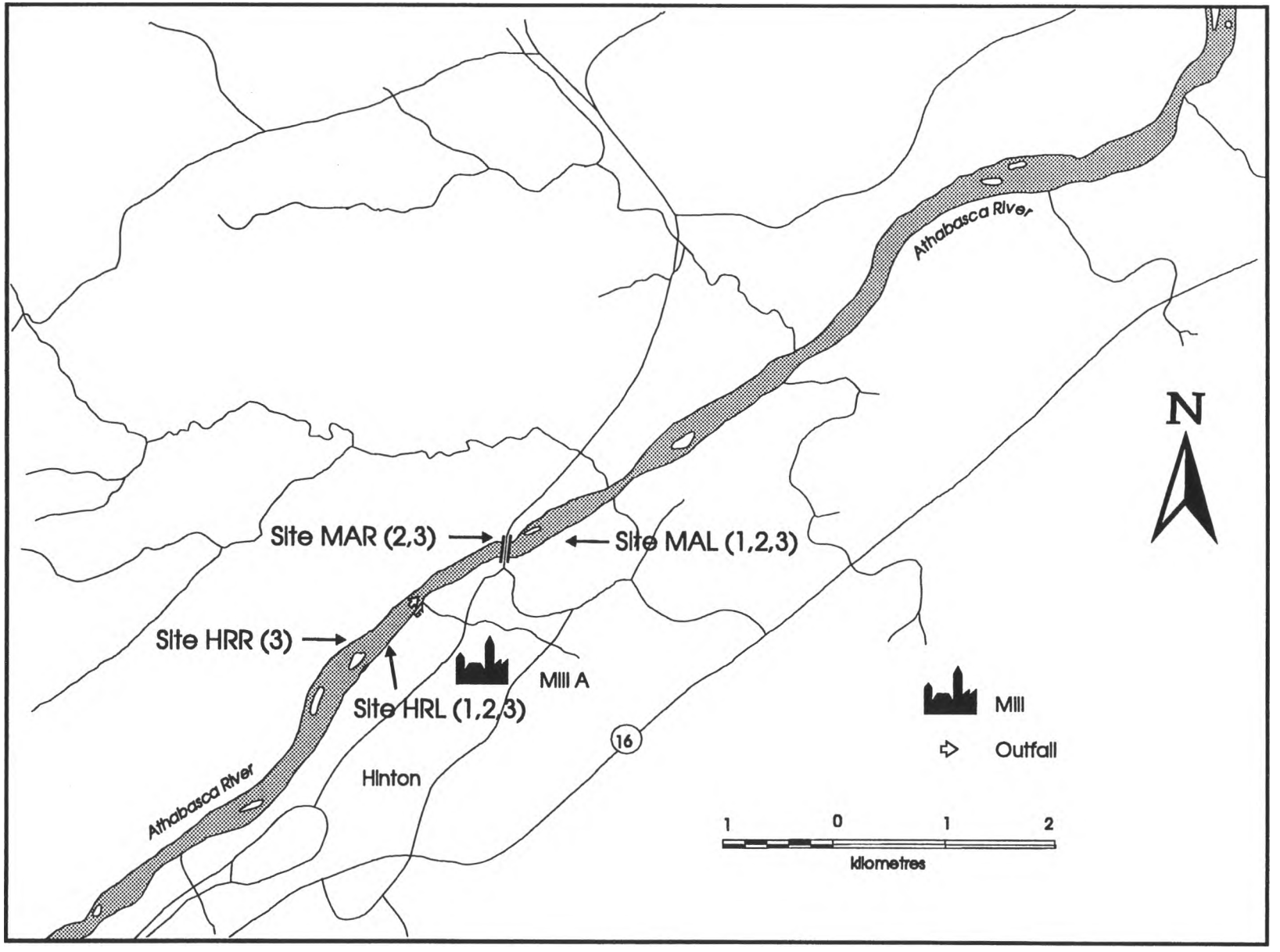


Figure 3a. Location of fish collection Site HRL, Site HRR, Site MAR, and Site MAL in the Hinton study area, Athabasca River, Alberta. Abbreviations: 1-spring 1994 survey, 2-fall 1994 survey, 3-spring 1995 survey.

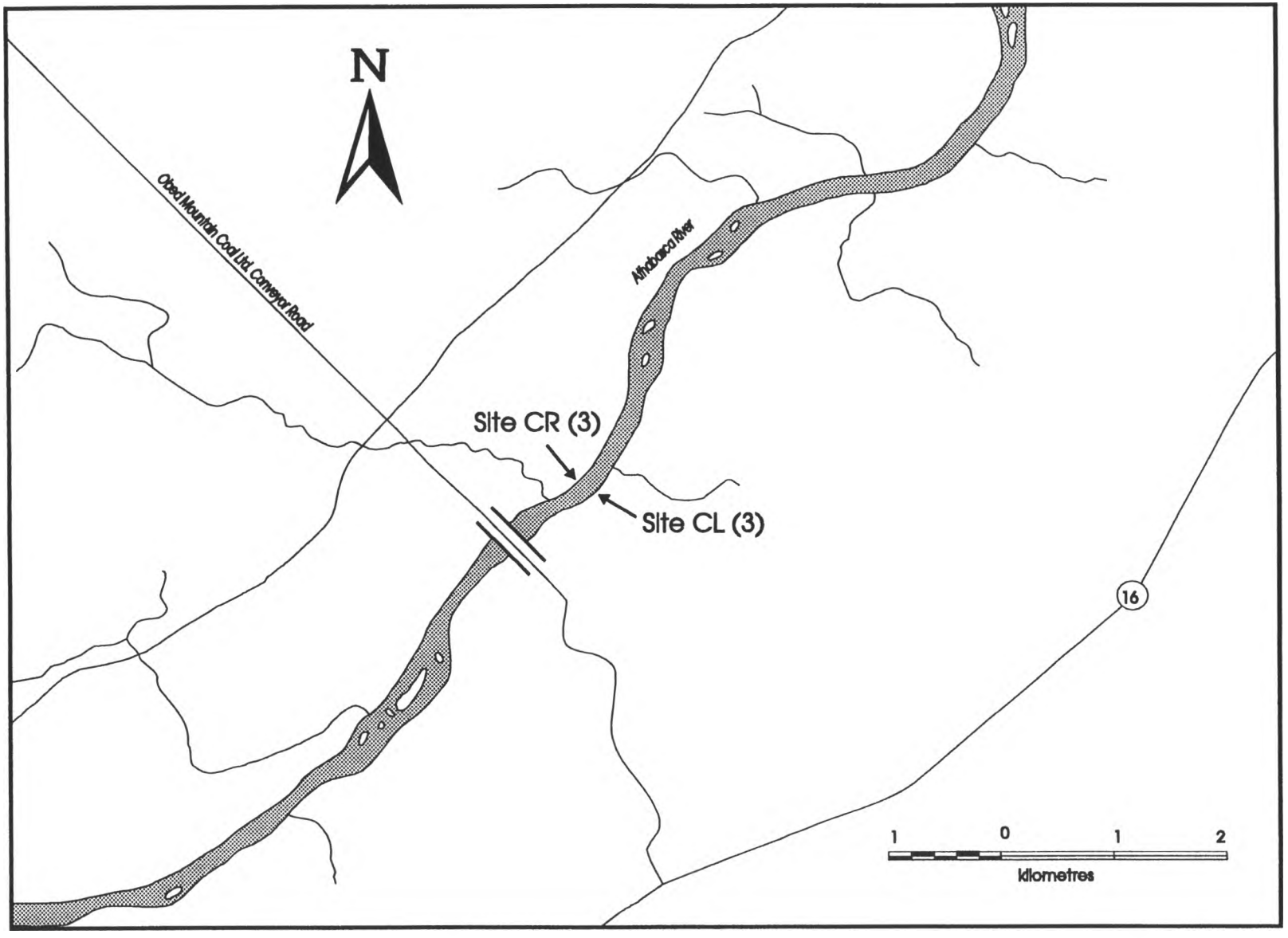


Figure 3b. Location of fish collection Site CL and Site CR in the Hinton study area near the Obed Mountain Coal Ltd. Bridge during the spring 1995 survey, Athabasca River, Alberta.

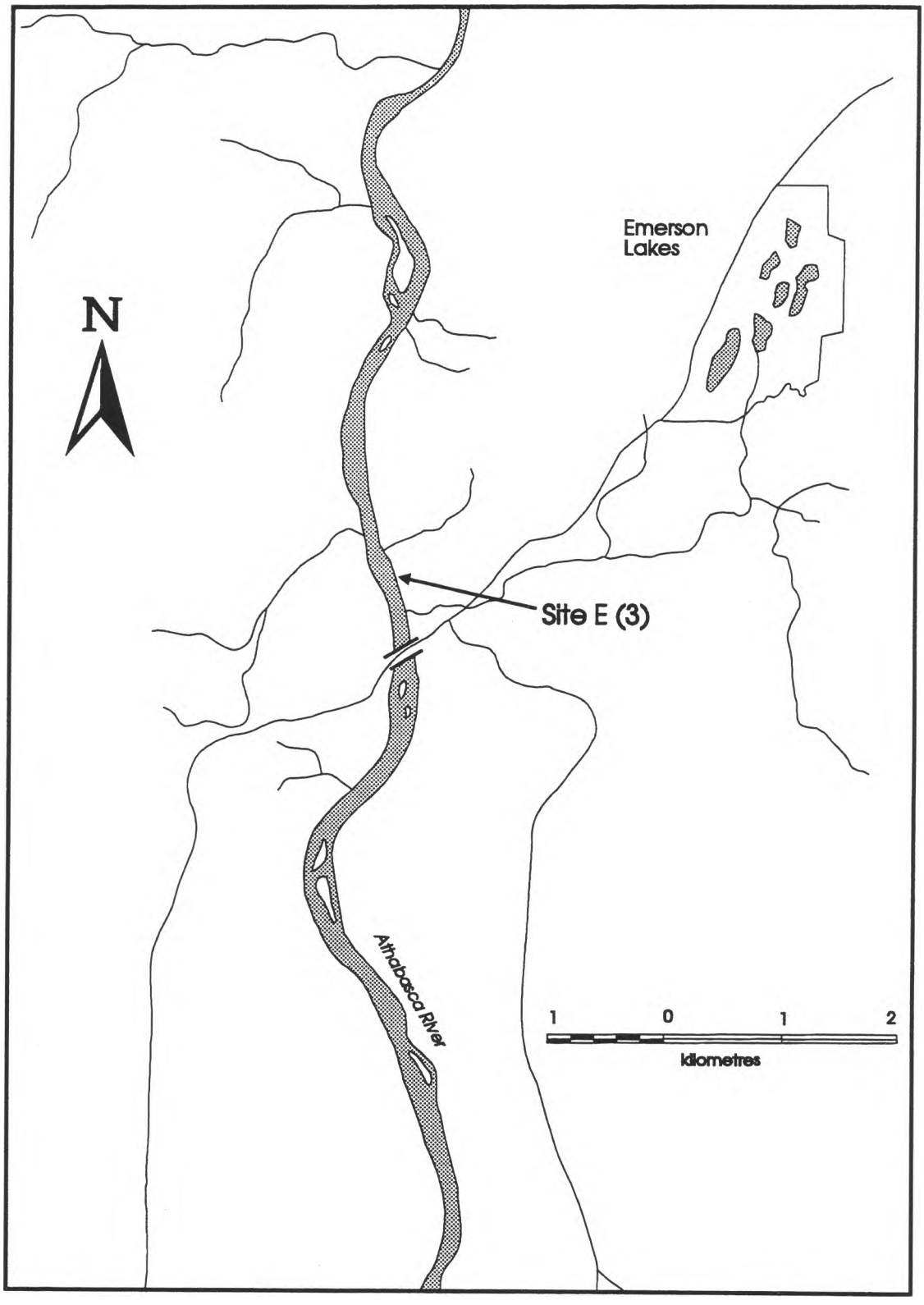


Figure 3c. Location of fish collection Site E in the Hinton study area (Emerson Bridge) during the spring 1995 survey, Athabasca River, Alberta.

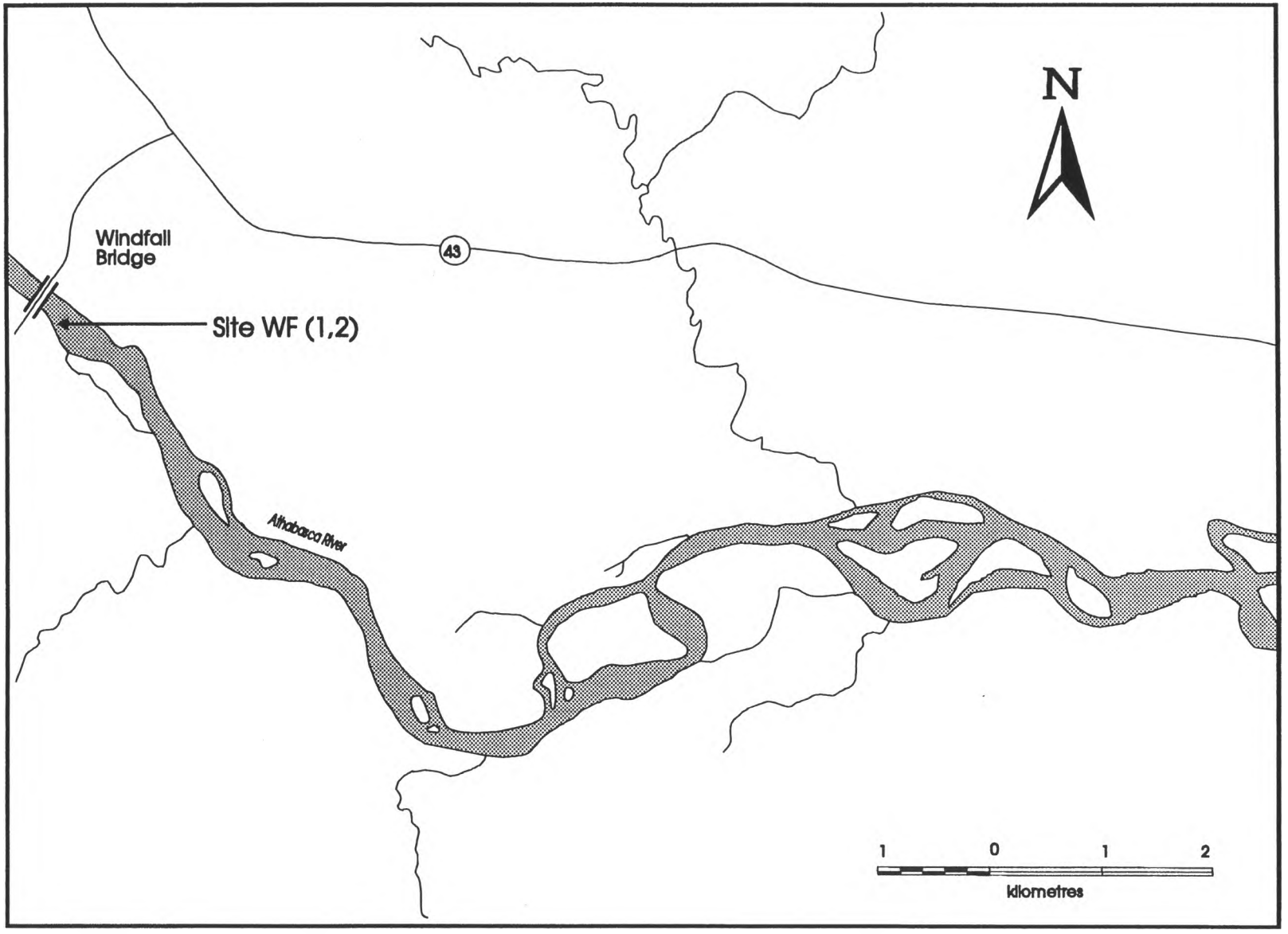


Figure 3d. Location of fish collection Sites WF in the Whitecourt study area during the fall 1994 survey, Athabasca River, Alberta. Abbreviations: 1-spring 1994 survey, 2-fall 1994 survey.

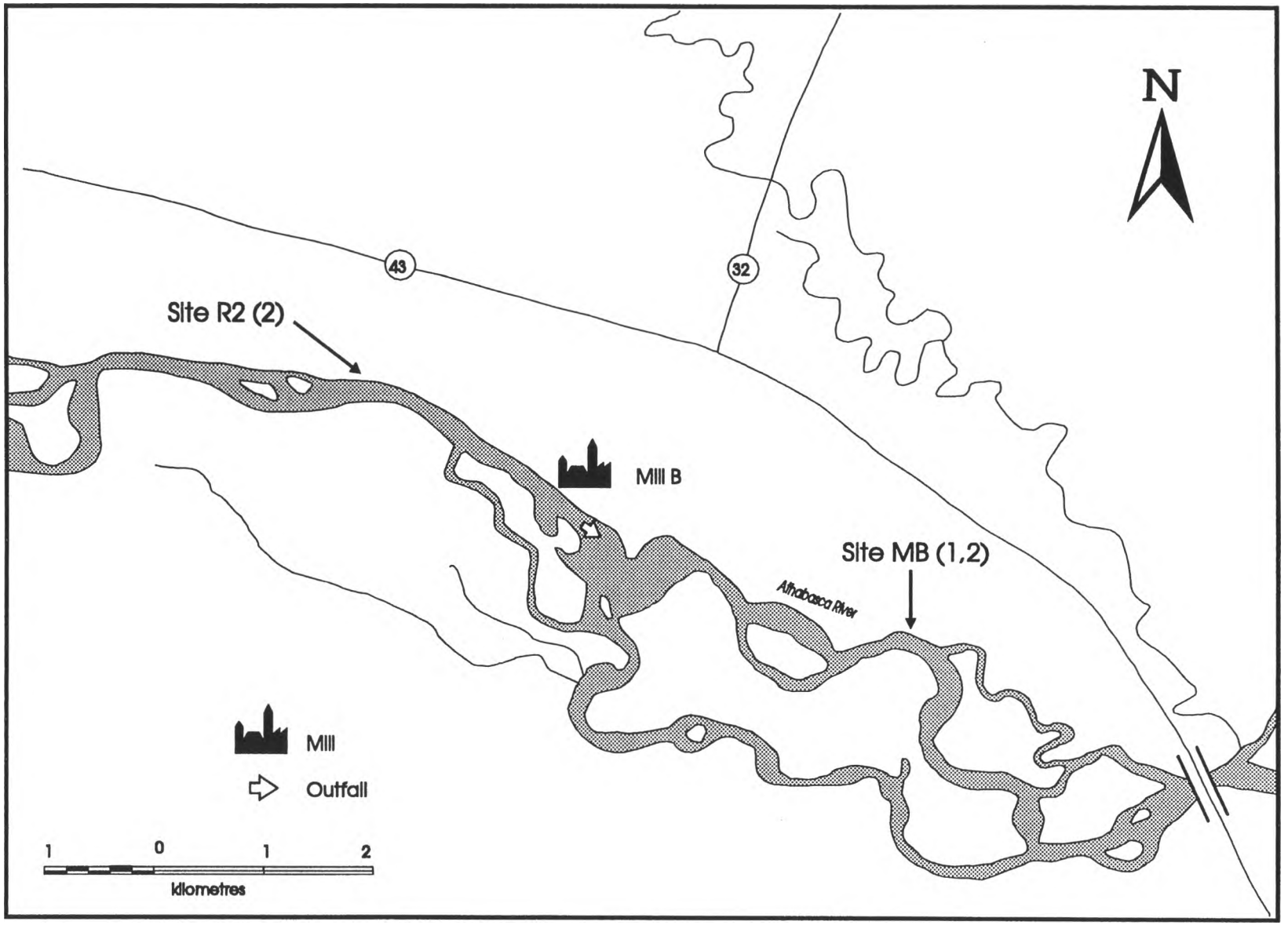


Figure 3e. Location of fish collection Site R2 and Site MB in the Whitecourt study area, Athabasca River, Alberta. Abbreviations: 1-spring 1994 survey, 2-fall 1994 survey.

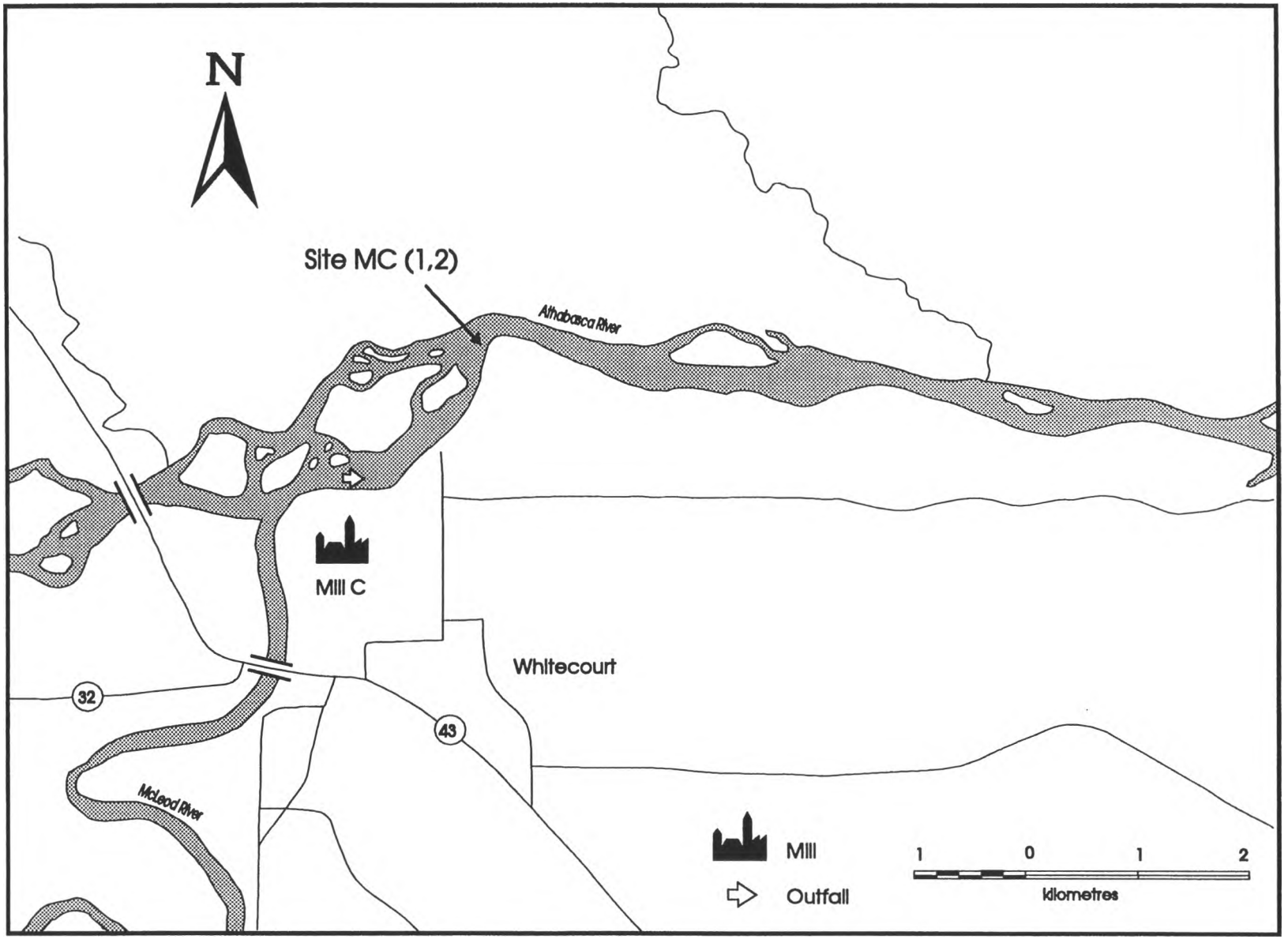


Figure 3f. Location of fish collection Site MC in the Whitecourt study area, Athabasca River, Alberta. Abbreviations: 1-spring 1994 survey, 2-fall 1994 survey.

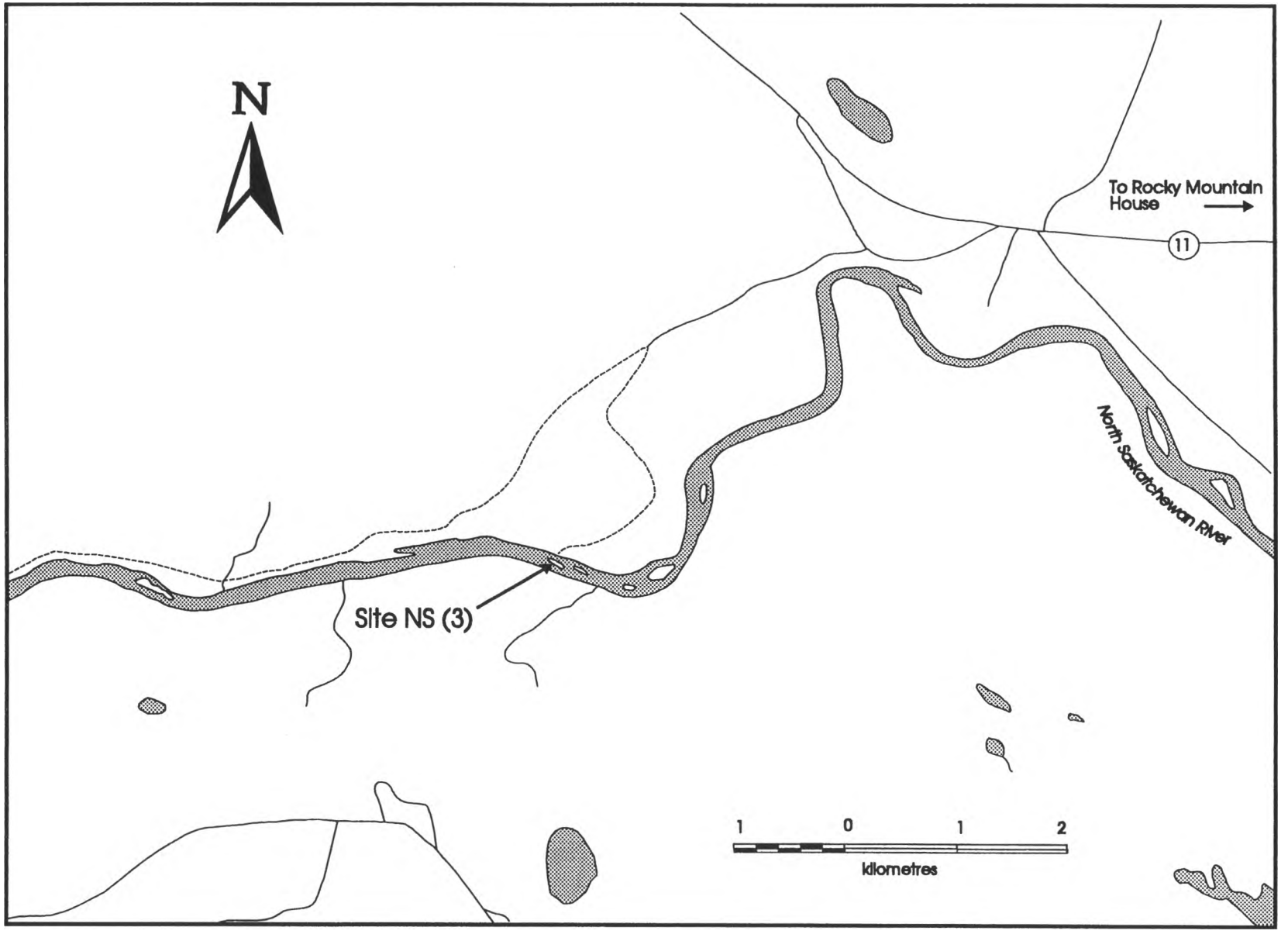


Figure 3g. Location of fish collection Site NS on the North Saskatchewan River during the spring 1995 survey, Alberta.

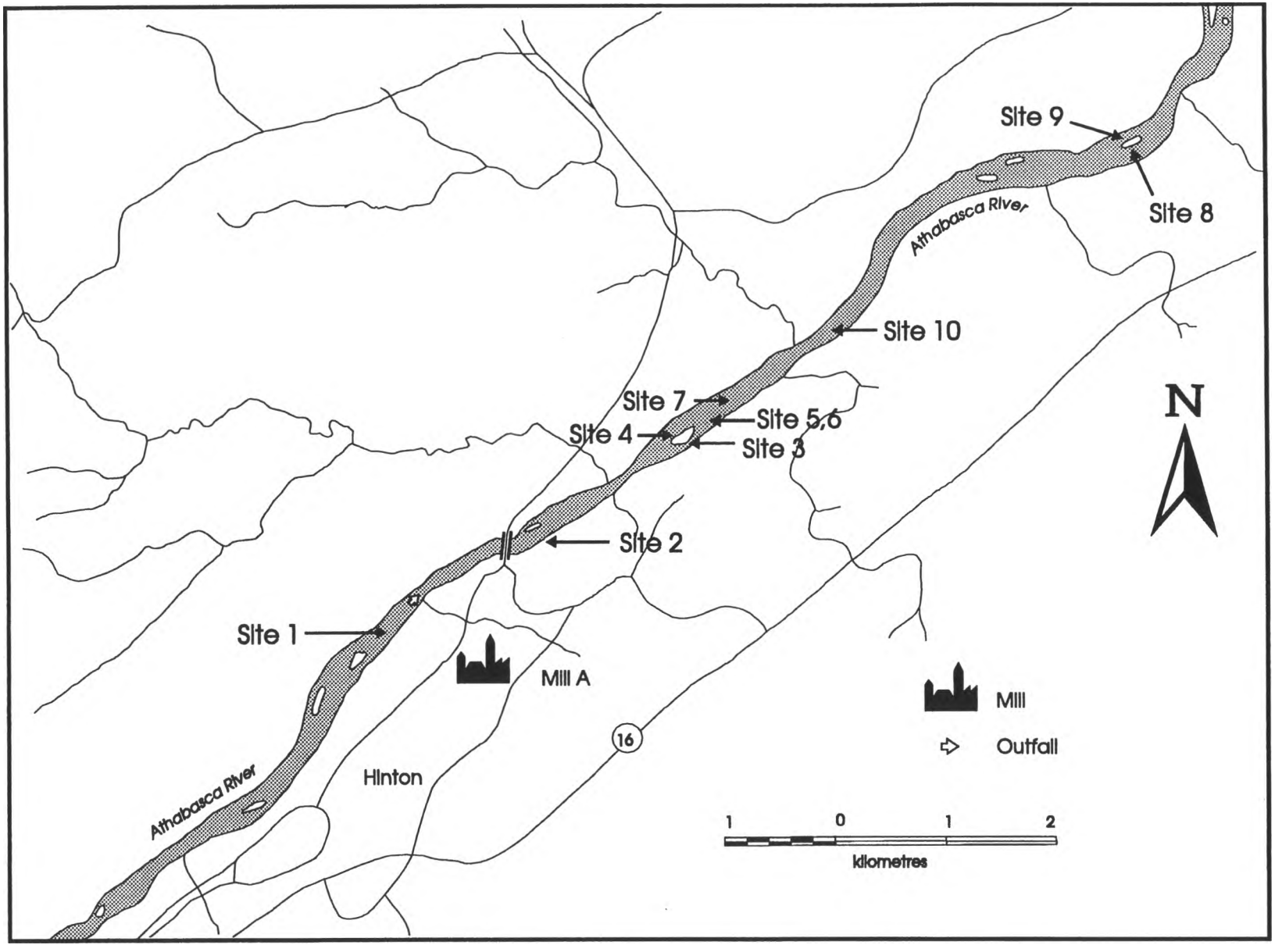


Figure 4a. Location of fish survey Sites 1-10 in the Hinton study area during the spring 1994 survey, Athabasca River, Alberta.

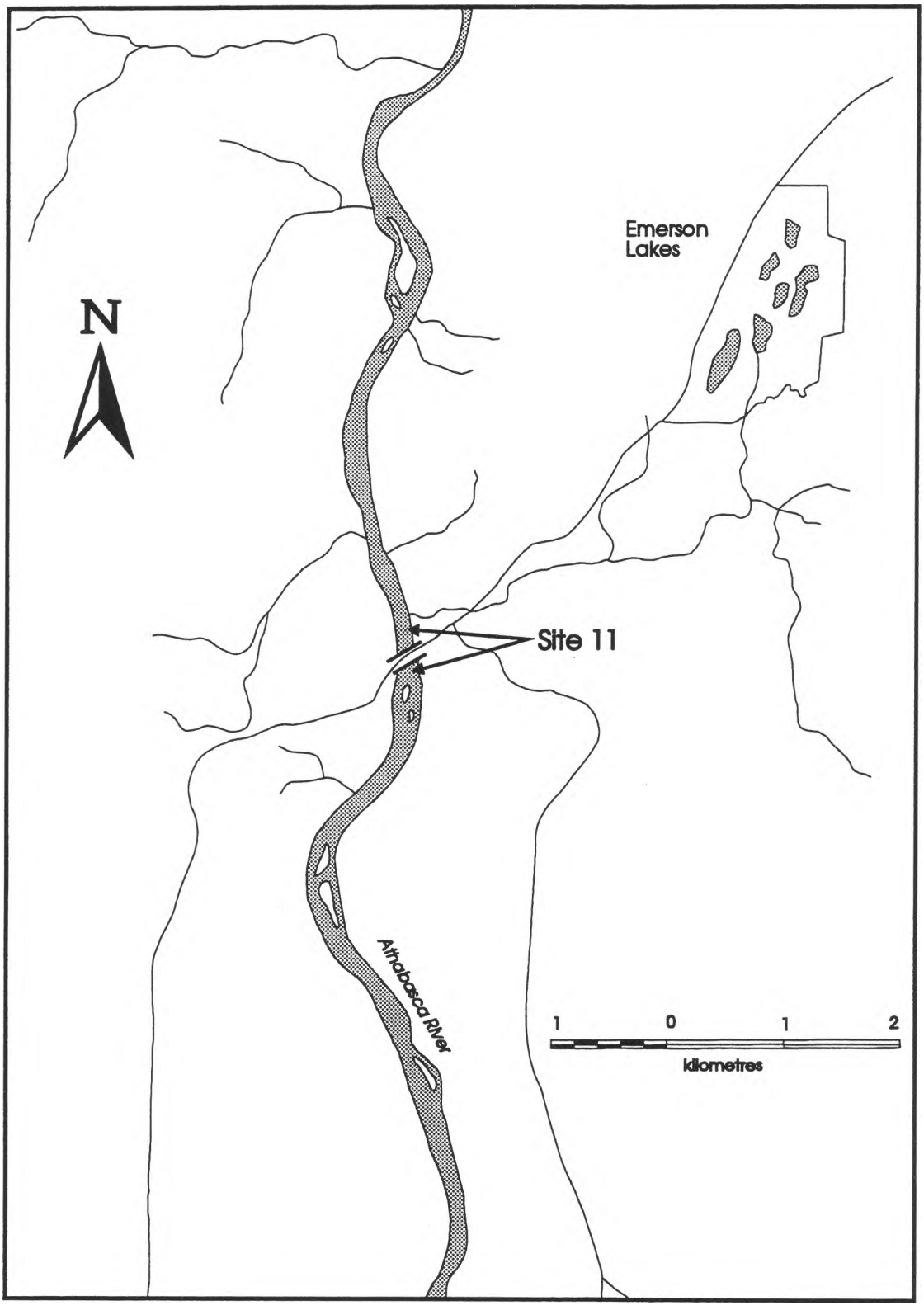


Figure 4b. Location of fish survey Site 11 in the Hinton study area (Emerson Lakes) during the spring 1994 survey, Athabasca River, Alberta.

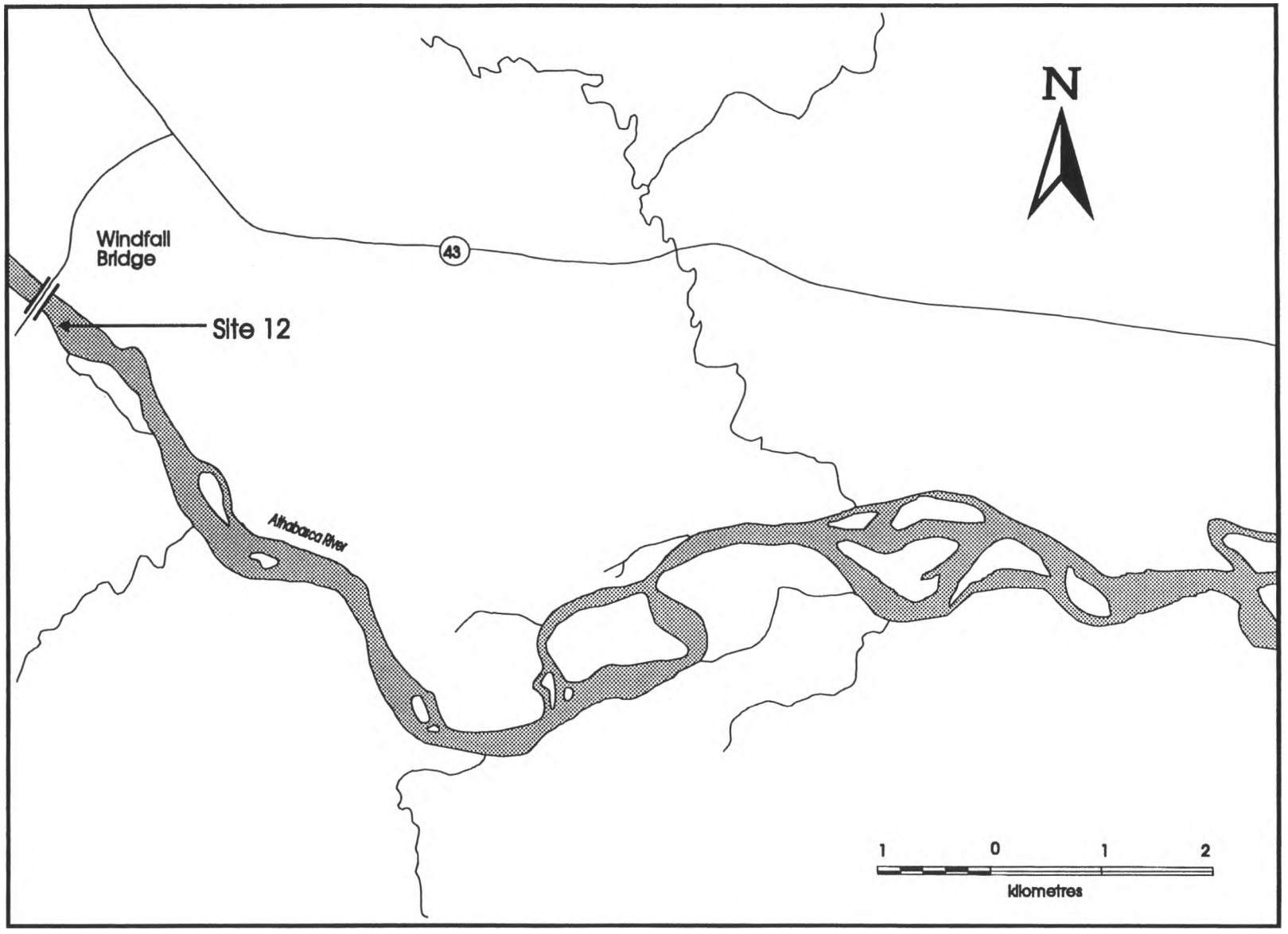


Figure 4c. Location of fish survey Site 12 in the Whitecourt study area during the spring 1994 survey, Athabasca River, Alberta.

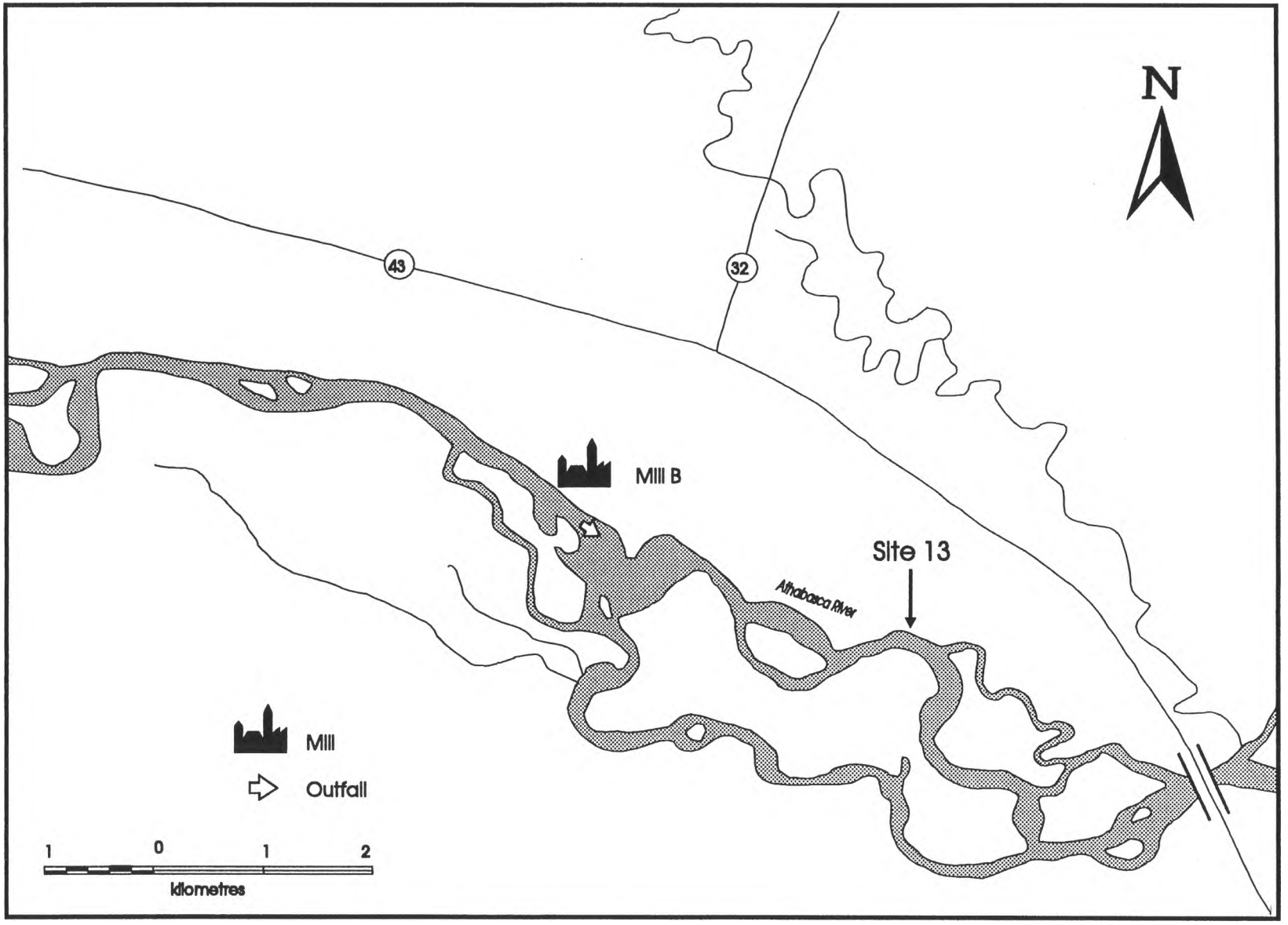


Figure 4d. Location of fish survey Site 13 in the Whitecourt study area during the spring 1994 survey, Athabasca River, Alberta.

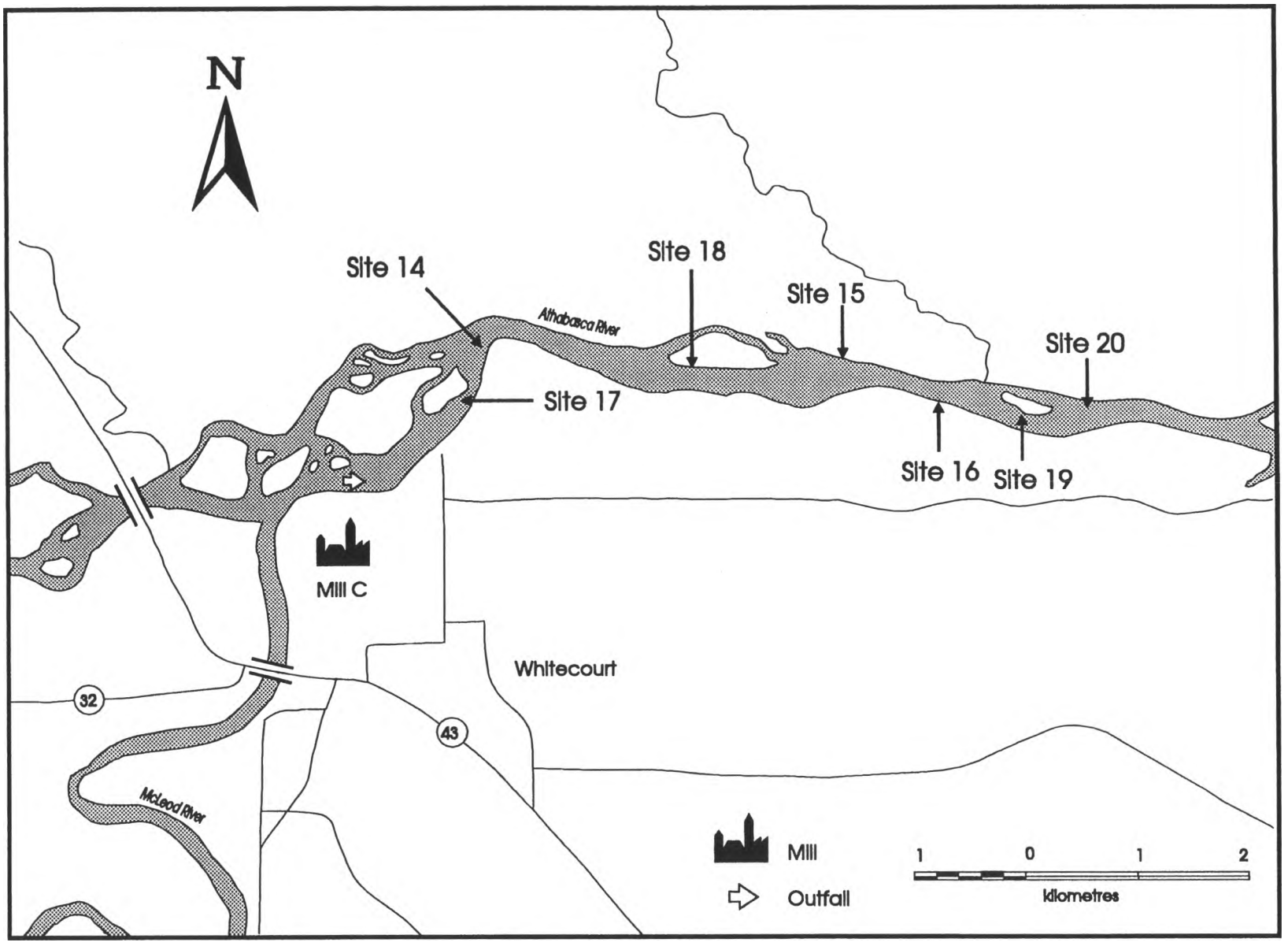


Figure 4e. Location of fish survey Sites 14-20 in the Whitecourt study area during the spring 1994 survey, Athabasca River, Alberta.

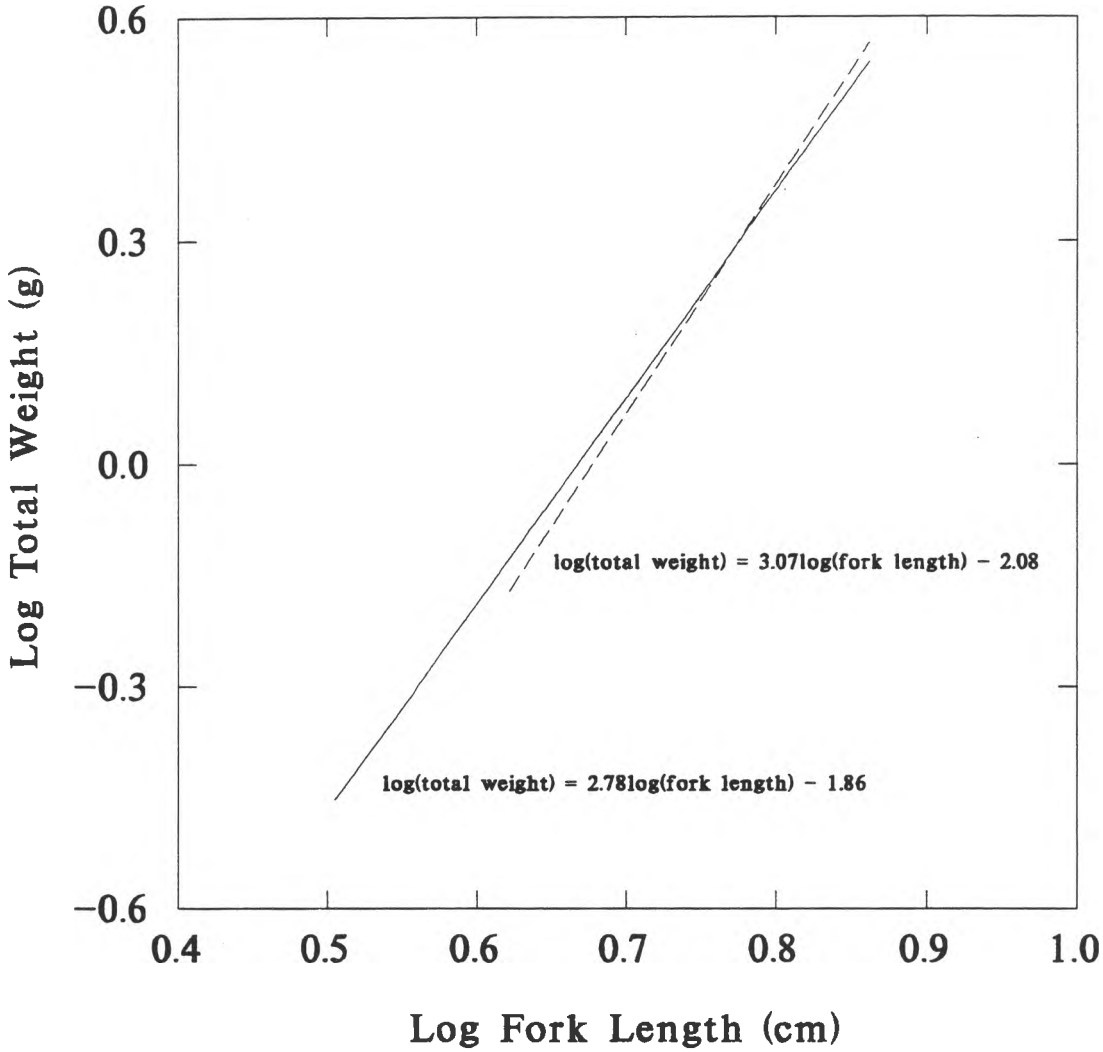


Figure 5. Regression lines of $\log_{10}$ total weight vs $\log_{10}$ fork length (condition) for immature lake chub (*Couesius plumbeus*) from the mill B (solid line, $p<0.001$, $r^2=0.981$.) and mill C (dashed line, $p<0.001$, $r^2=0.958$) near-field sites, spring 1994 survey, Athabasca River, Alberta.

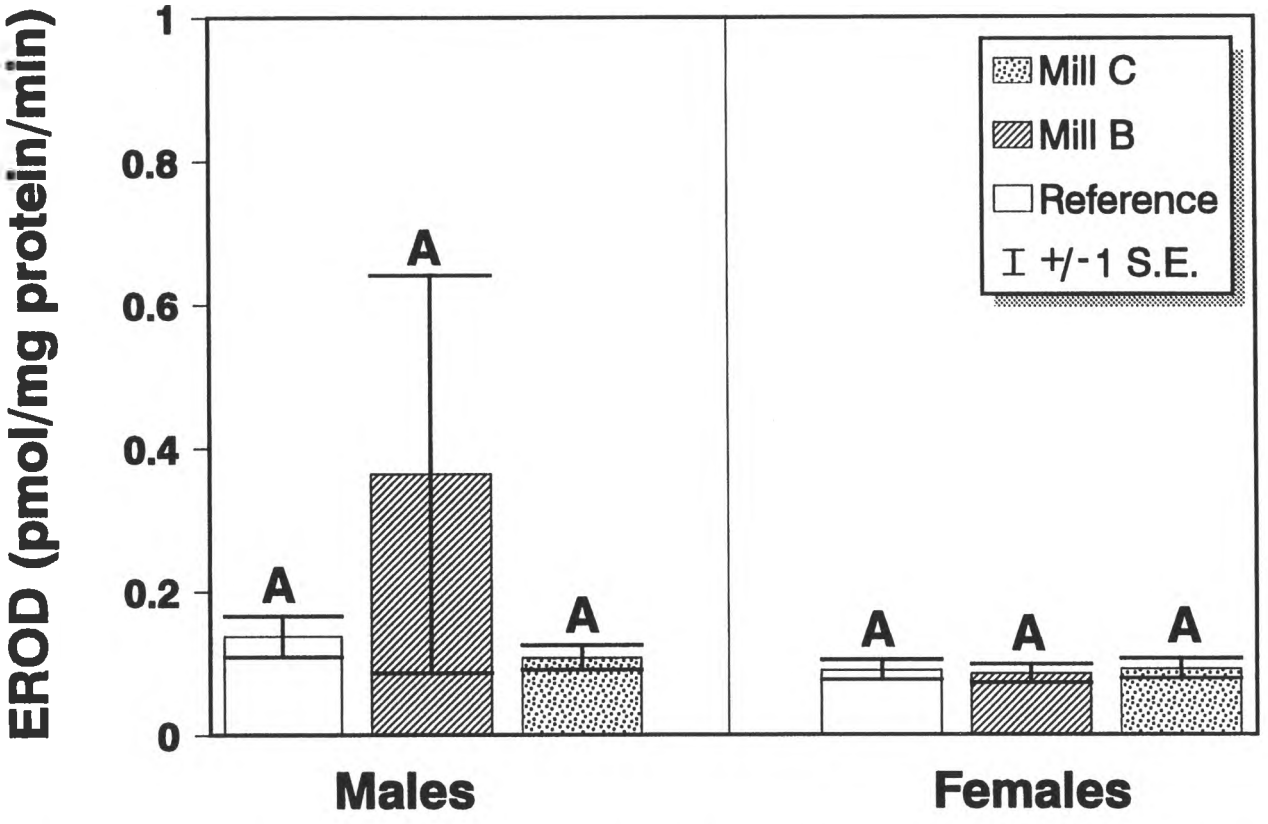


Figure 6. MFO activity in male and female lake chub (*Couesius plumbeus*) from reference, mill B near-field and mill C near-field sites in the Whitecourt study area, spring 1994 survey, Athabasca River, Alberta. Bars with different uppercase alphabetical superscripts are statistically ($p<0.05$) different from one another. Values represent the mean ± SE.

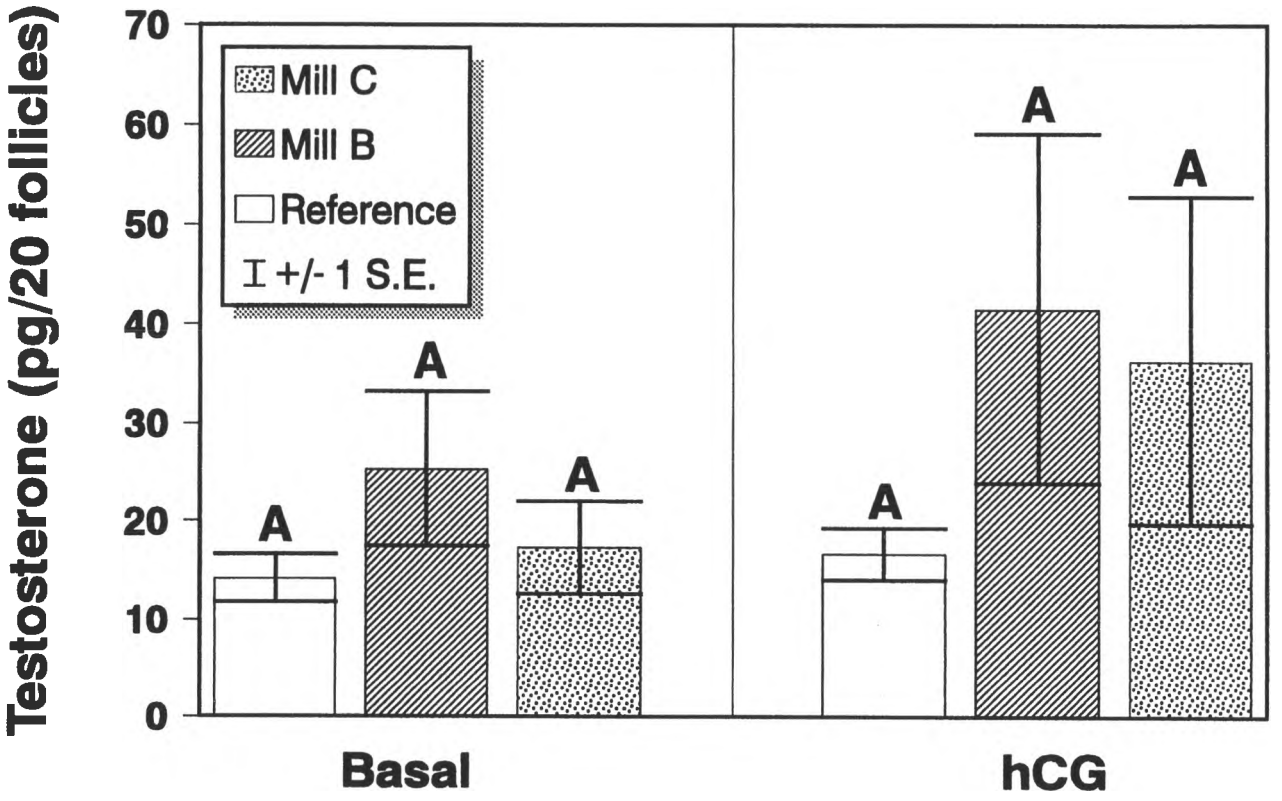


Figure 7. *In vitro* production (basal and hCG stimulated) of testosterone by follicles of female lake chub (*Couesius plumbeus*) from reference, mill B near-field and mill C near-field sites in the Whitecourt study area, spring 1994 survey, Athabasca River, Alberta. Bars with different uppercase alphabetical superscripts are statistically ($p<0.05$) different from one another. Values represent the mean ± SE.

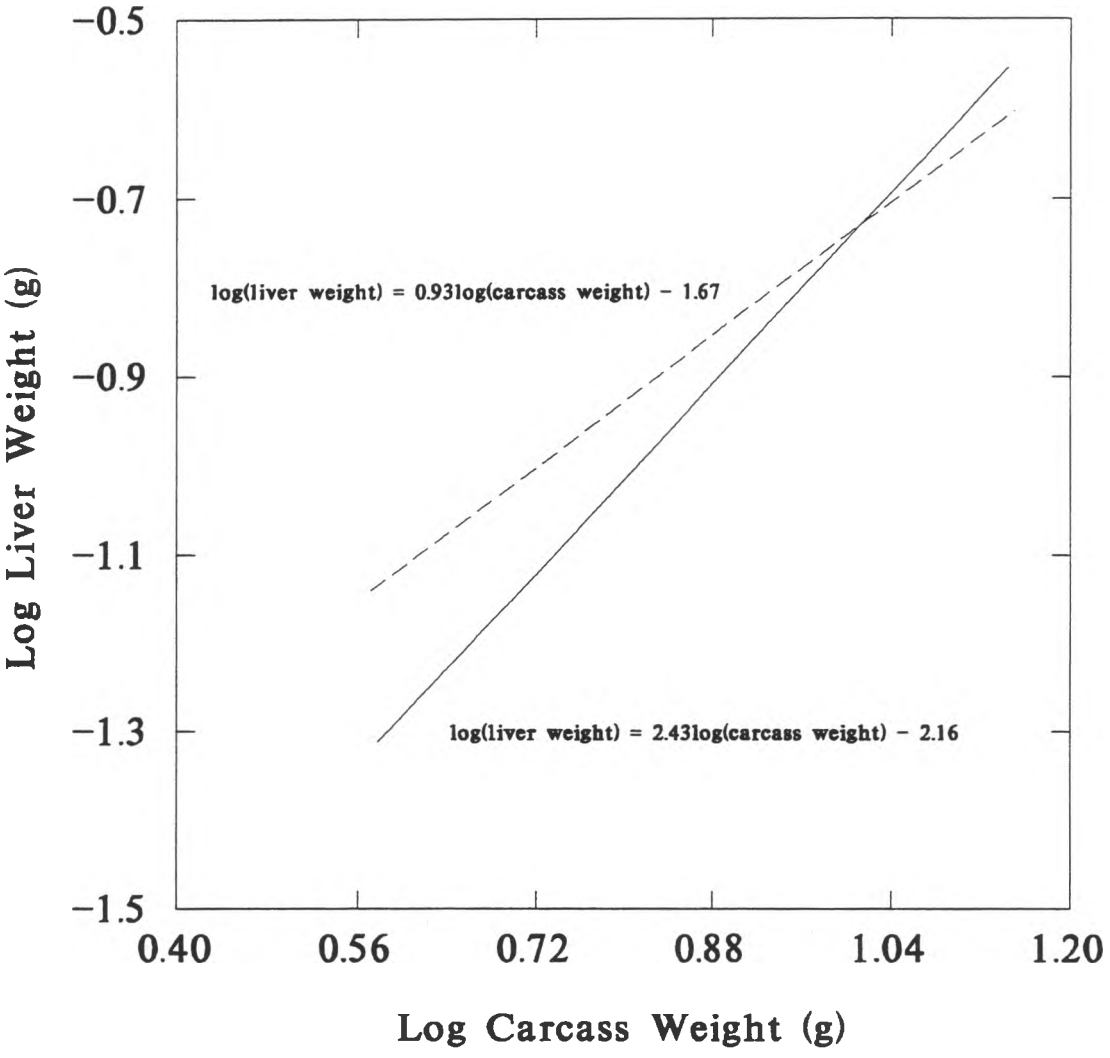


Figure 8. Regression lines of $\log_{10}$ liver weight *vs* $\log_{10}$ carcass weight (condition) for male spoonhead sculpin (*Cottus ricei*) from the mill A near-field site (solid line, r^2=0.93) and site MAR (dash line, r^2=0.93), fall 1994 survey, Athabasca River, Alberta.

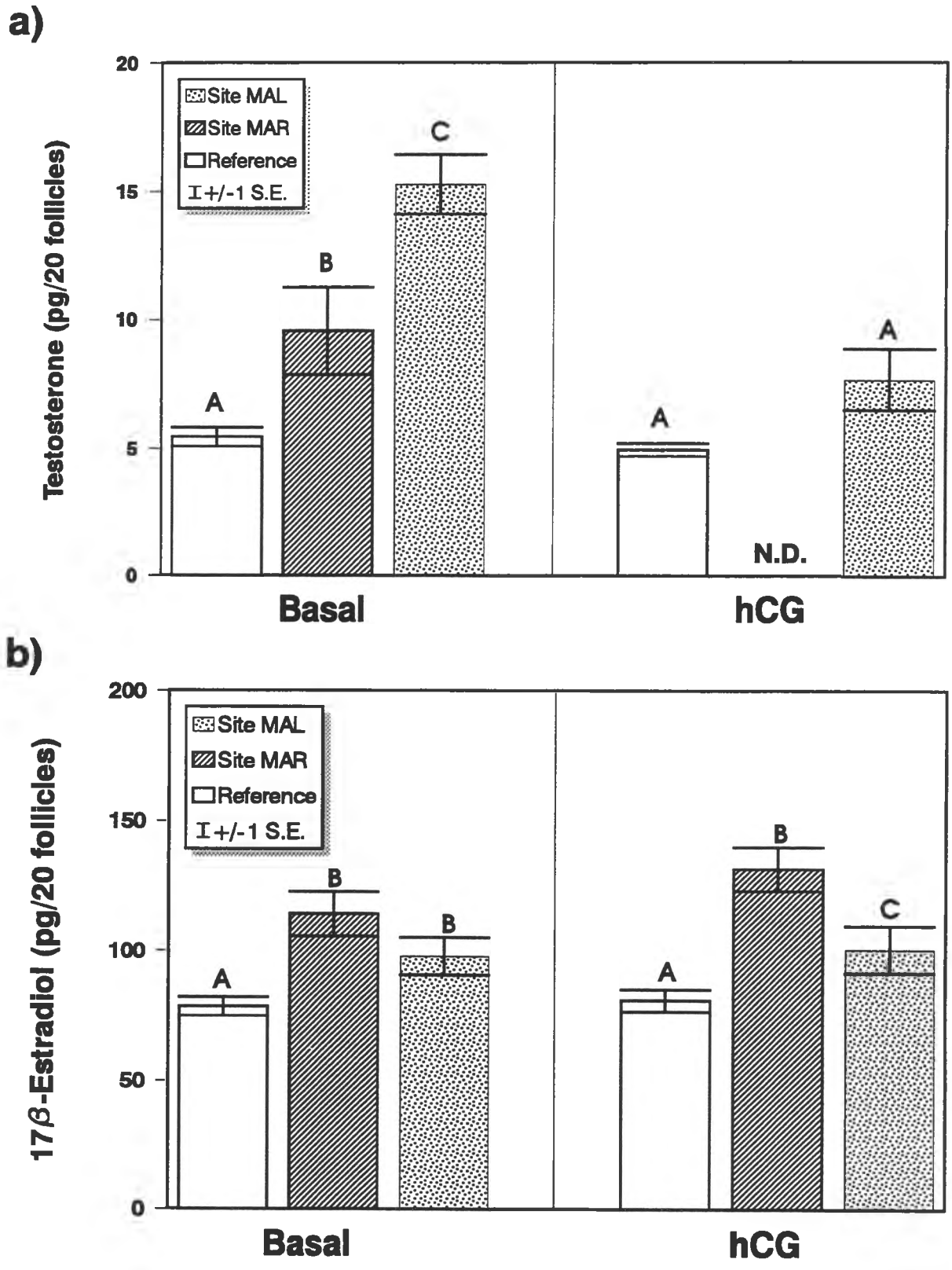


Figure 9. *In vitro* production (basal/hCG stimulated) of a) testosterone and b) 17 β-estradiol by ovarian follicles of female spoonhead sculpin (*Cottus ricei*) from the reference site, Site MAR and mill A near-field site in the Hinton study area, fall 1994 survey, Athabasca River, Alberta. Values represent the mean ± SE. Bars with different uppercase alphabetical superscripts are statistically ($p<0.05$) different from one another.

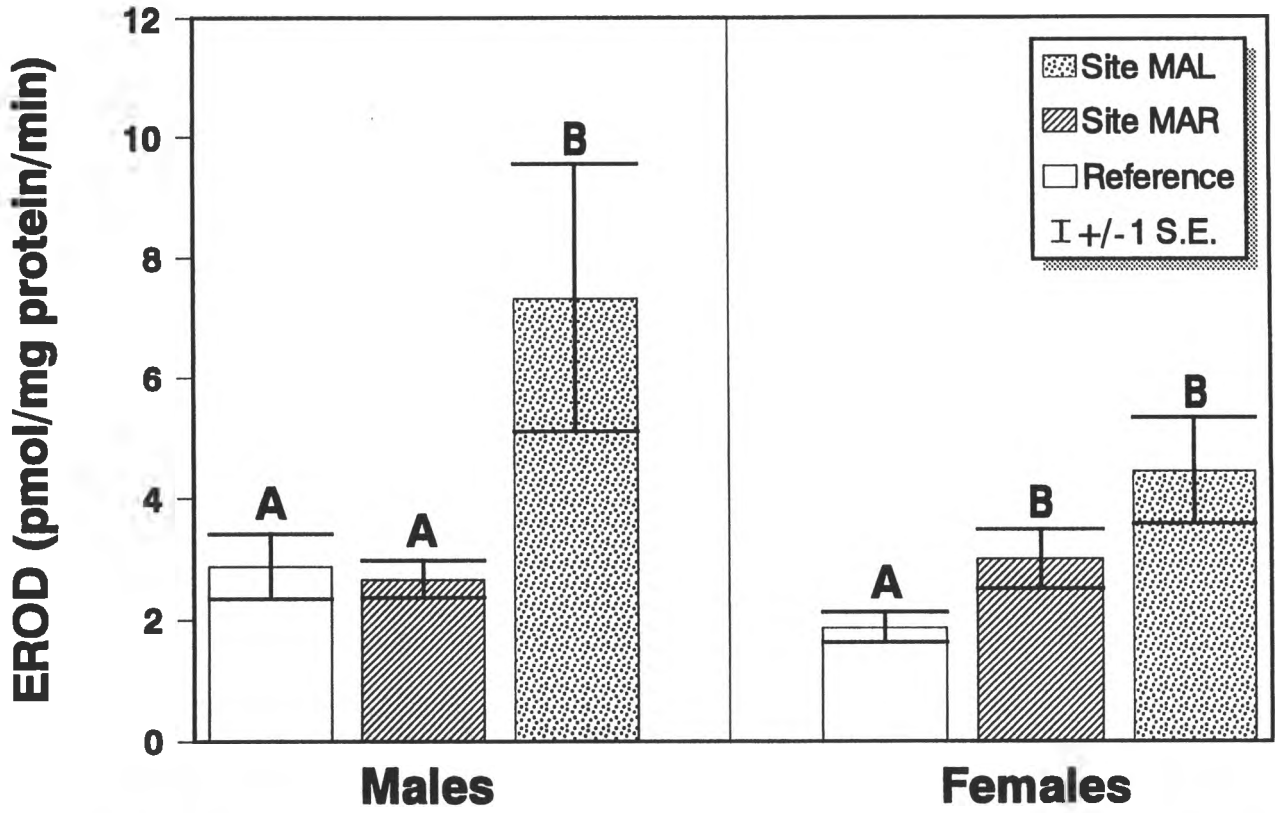


Figure 10. MFO activity in male and female spoonhead sculpin (*Cottus ricei*) from the reference site, Site MAR and mill A near-field site in the Hinton study area, fall 1994 survey, Athabasca River, Alberta. Values represent the mean ± SE. Bars with different uppercase alphabetical superscripts are statistically ($p<0.05$) different from one another.

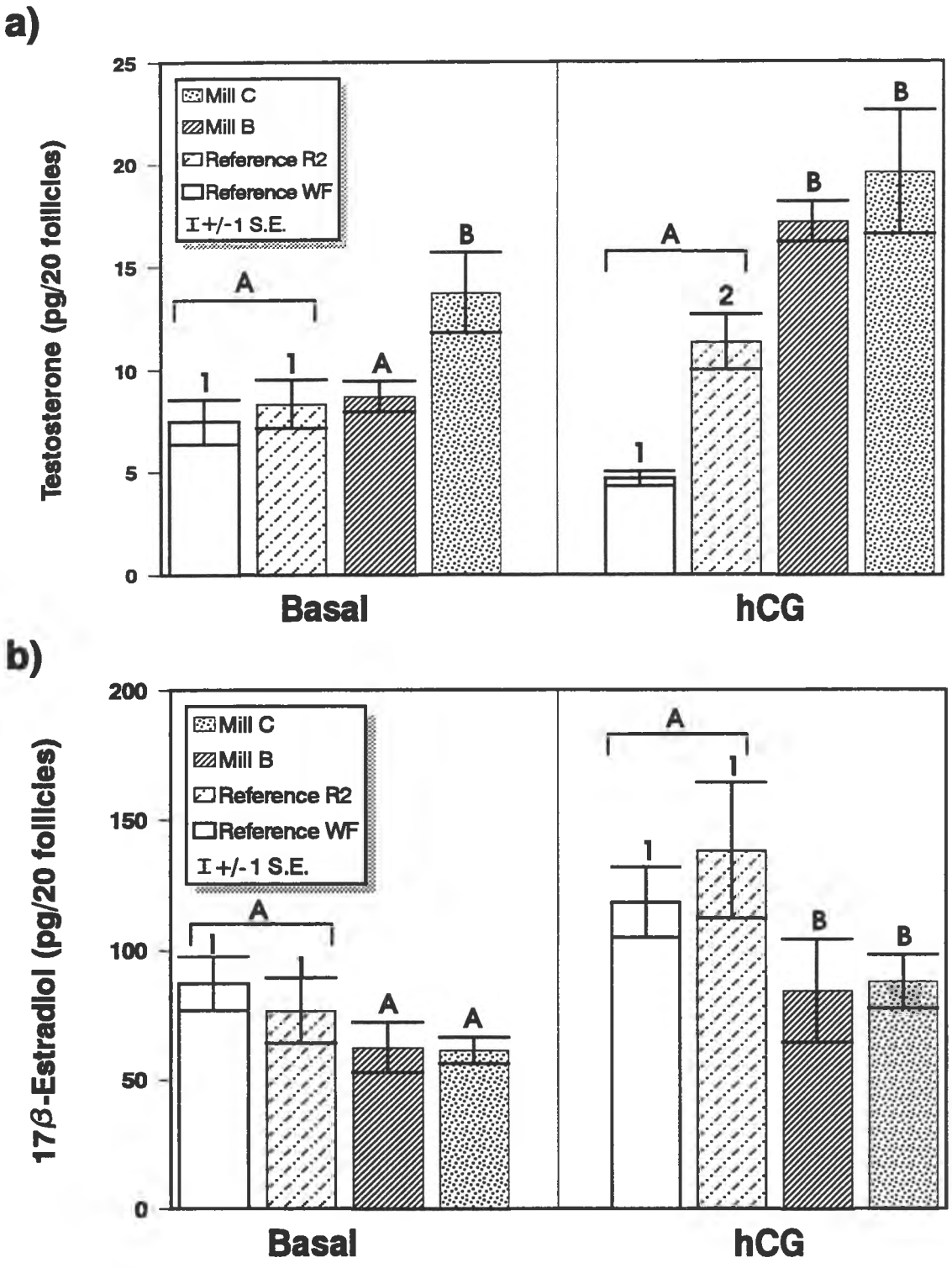


Figure 11. *In vitro* production (basal/hCG stimulated) of a) testosterone and b) 17 β-estradiol by follicles of female lake chub (*Couesius plumbeus*) from the reference sites, mill B near-field site and mill C near-field site in the Whitecourt study area, fall 1994 survey, Athabasca River, Alberta. Values represent the mean ± SE. Bars with different uppercase alphabetical superscripts are statistically ($p<0.05$) different from one another.

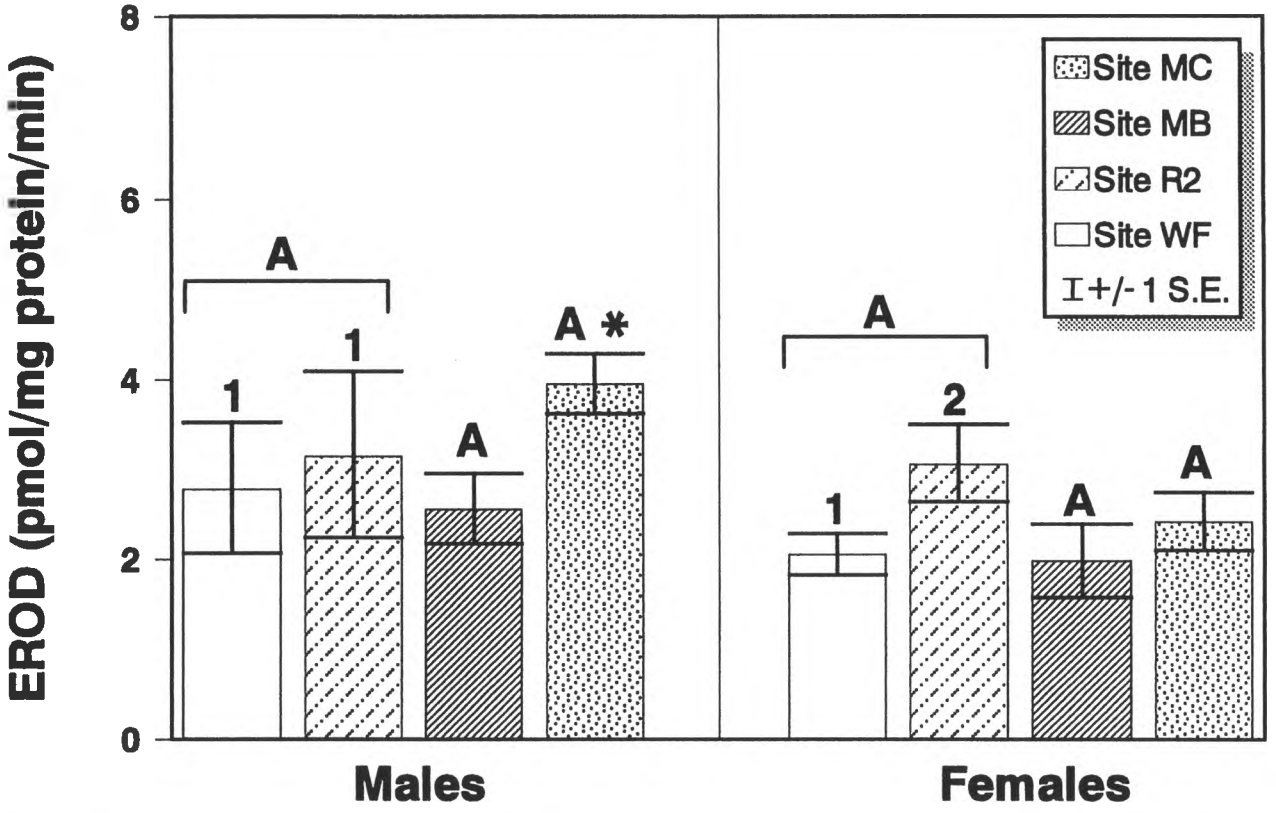


Figure 12. MFO activity in male and female lake chub (*Couesius plumbeus*) from the reference sites, mill B near-field site and mill C near-field site in the Whitecourt study area, fall 1994 survey, Athabasca River, Alberta. Values represent the mean ± SE. Bars with different uppercase alphabetical superscripts are statistically ($p<0.05$) different from one another. Significant ($p<0.05$) difference between exposure and sites is indicated with an asterisk.

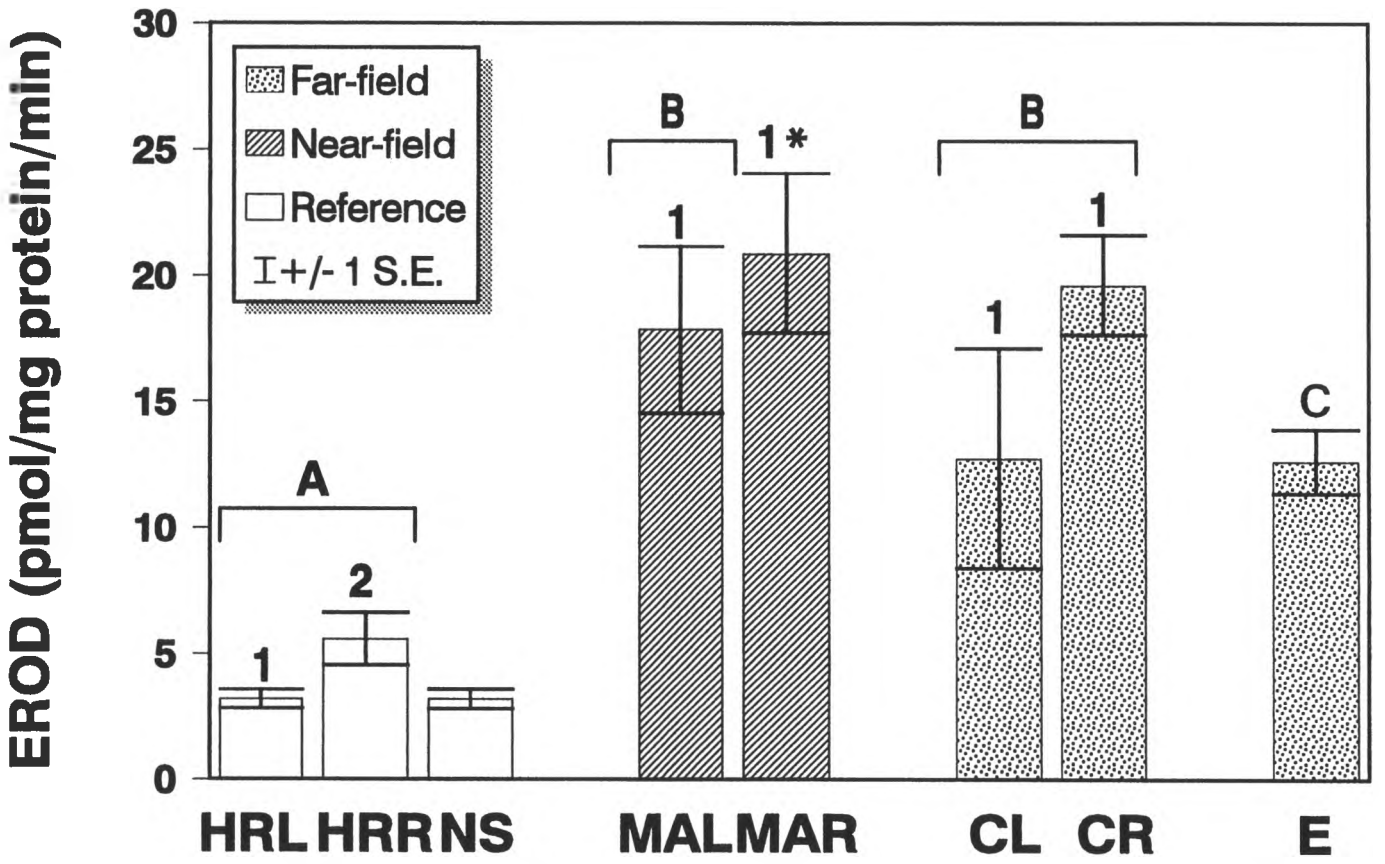


Figure 13. MFO activity in male spoonhead sculpin (*Cottus ricei*) from reference, near-field and far-field sites on the Athabasca River and North Saskatchewan River (NS), spring 1995 survey, Alberta. Values represent the mean ± SE. Bars with different alphabetical superscripts are statistically ($p<0.05$) different. Differences ($p<0.05$) between sites HRL *vs* HRR, MAL *vs* MAR, CL *vs* CR are denoted with different numerical superscripts. Differences ($p<0.05$) between Site MAR or NS and pooled reference sites are indicated with an asterisk (*).

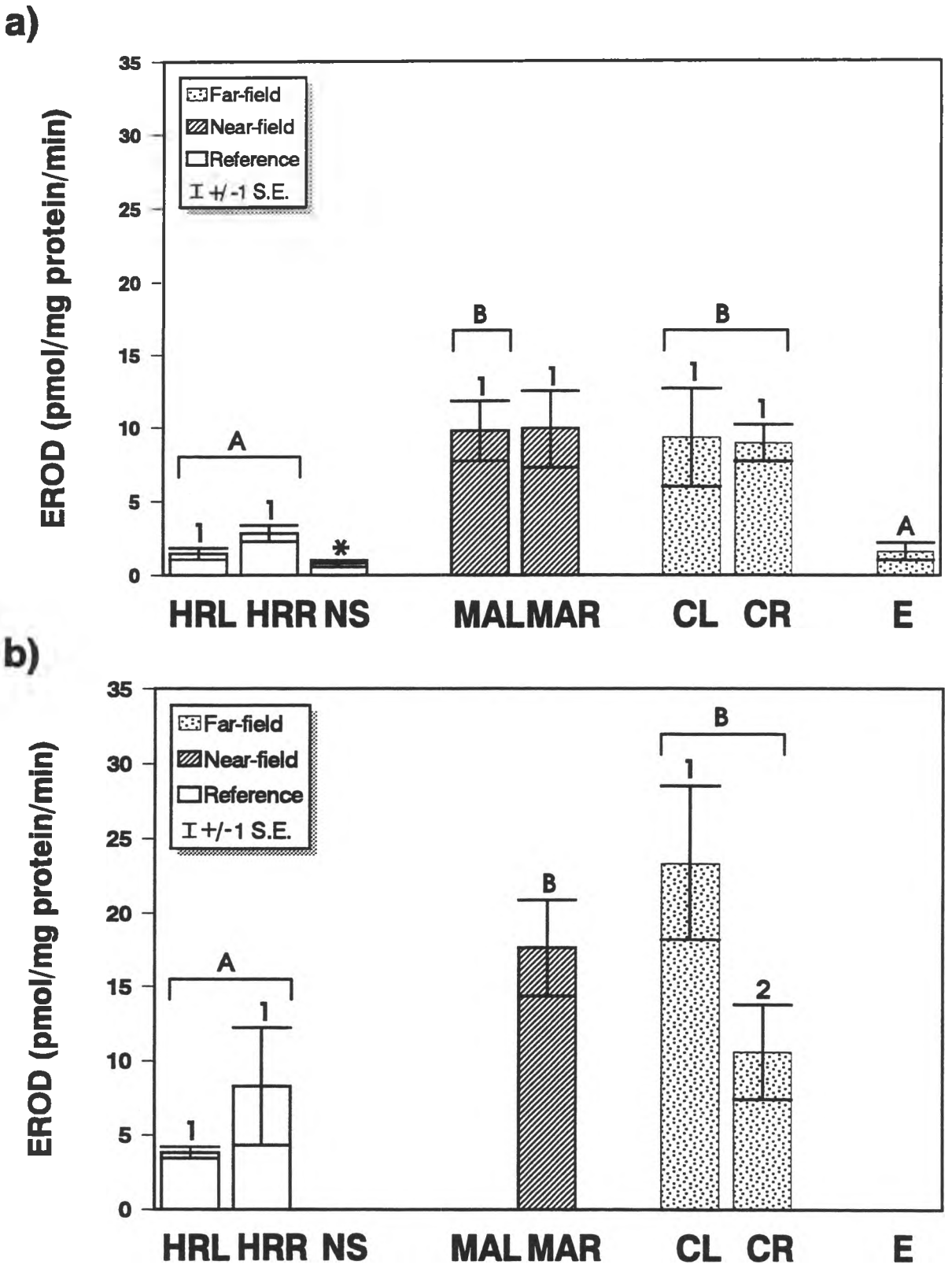


Figure 14. MFO activity in a) preovulatory and b) spent female spoonhead sculpin (*Cottus ricei*) from reference, near-field and far-field sites on the Athabasca River and North Saskatchewan River (NS), spring 1995 survey, Alberta. Values represent the mean ± SE. Bars with different alphabetical superscripts are statistically ($p<0.05$) different. Differences ($p<0.05$) between sites HRL *vs* HRR, MAL *vs* MAR, CL *vs* CR are denoted with different numerical superscripts. Differences ($p<0.05$) between Site MAR or NS and pooled reference sites are indicated with an asterisk (*).

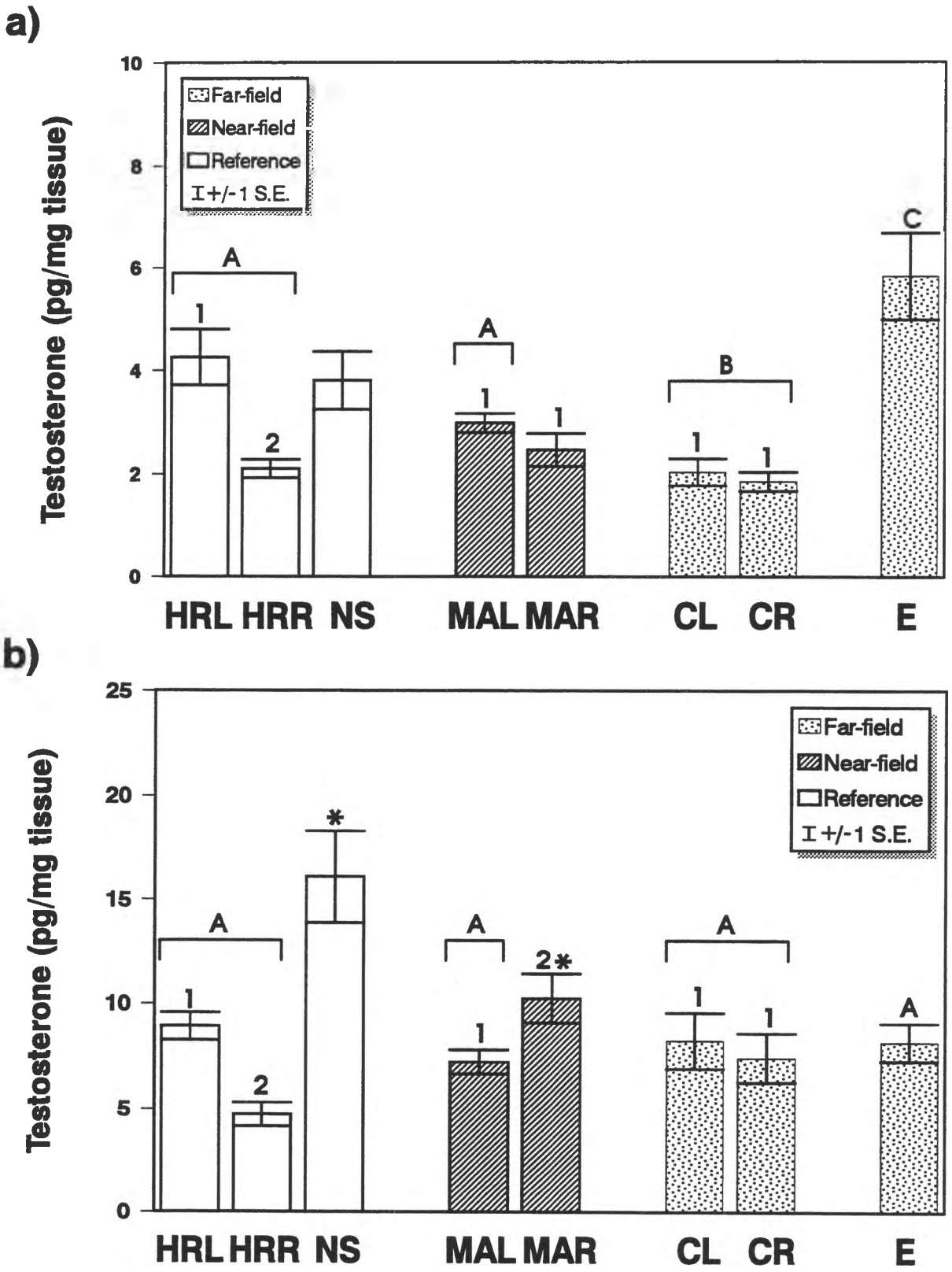


Figure 15. a) Basal and b) forskolin-stimulated *in vitro* production of testosterone by testicular tissue of male spoonhead sculpin (*Cottus ricei*) from reference, near-field and far-field sites on the Athabasca River and North Saskatchewan River (NS), spring 1995 survey, Alberta. Values represent the mean ± SE. Bars with different alphabetical superscripts are statistically ($p<0.05$) different. Differences ($p<0.05$) between sites HRL *vs* HRR, MAL *vs* MAR, CL *vs* CR are denoted with different numerical superscripts. Differences ($p<0.05$) between Site MAR or NS and pooled reference sites are indicated with an asterisk (*).

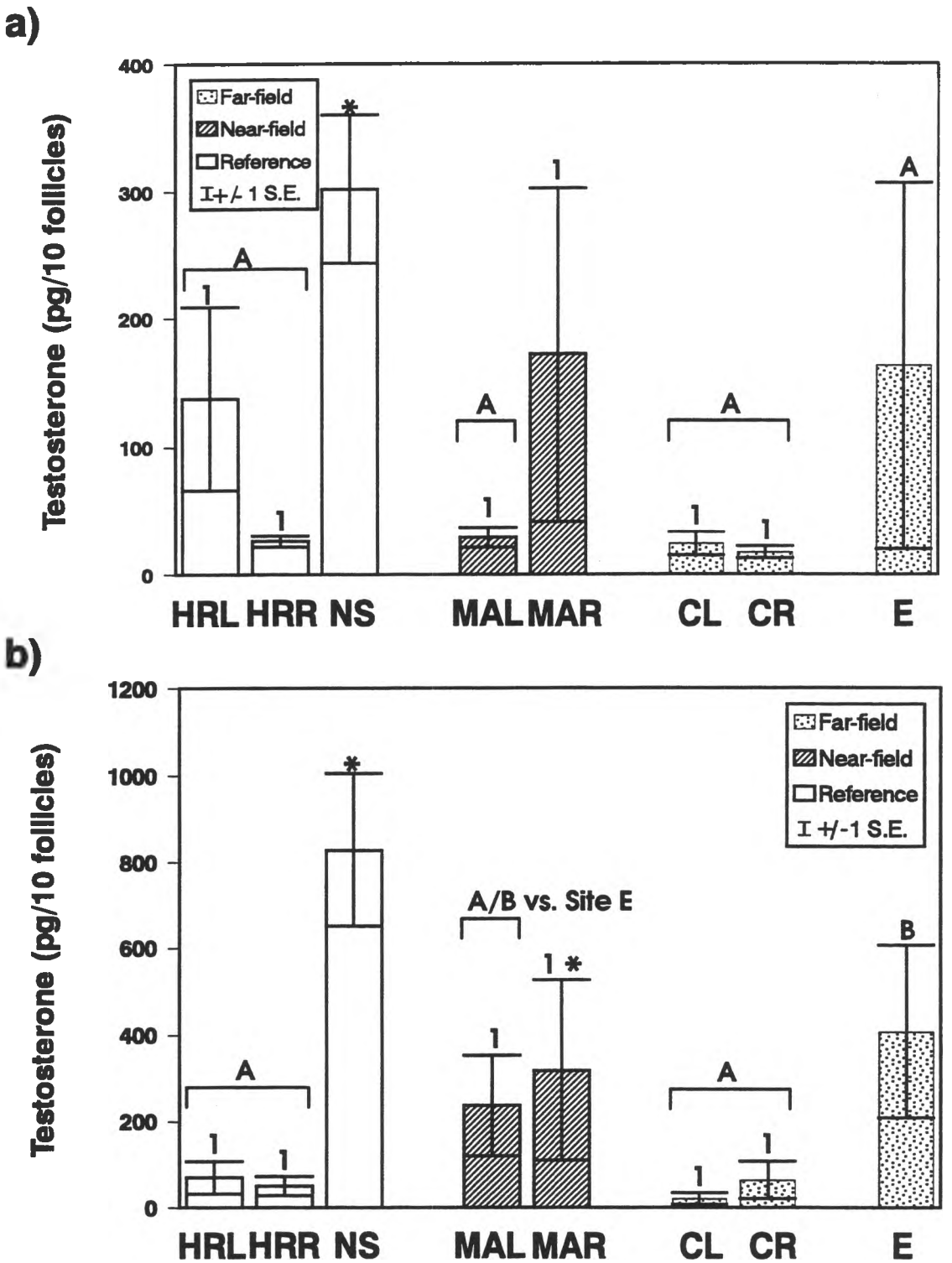


Figure 16. a) Basal and b) forskolin-stimulated *in vitro* production of testosterone by follicles of female spoonhead sculpin (*Cottus ricei*) from reference, near-field and far-field sites on the Athabasca River and North Saskatchewan River (NS), spring 1995 survey, Alberta. Values represent the mean ± SE. Bars with different alphabetical superscripts are statistically ($p<0.05$) different. Differences ($p<0.05$) between sites HRL *vs* HRR, MAL *vs* MAR, CL *vs* CR are denoted with different numerical superscripts. Differences ($p<0.05$) between Site MAR or NS and pooled reference sites are indicated with an asterisk (*).

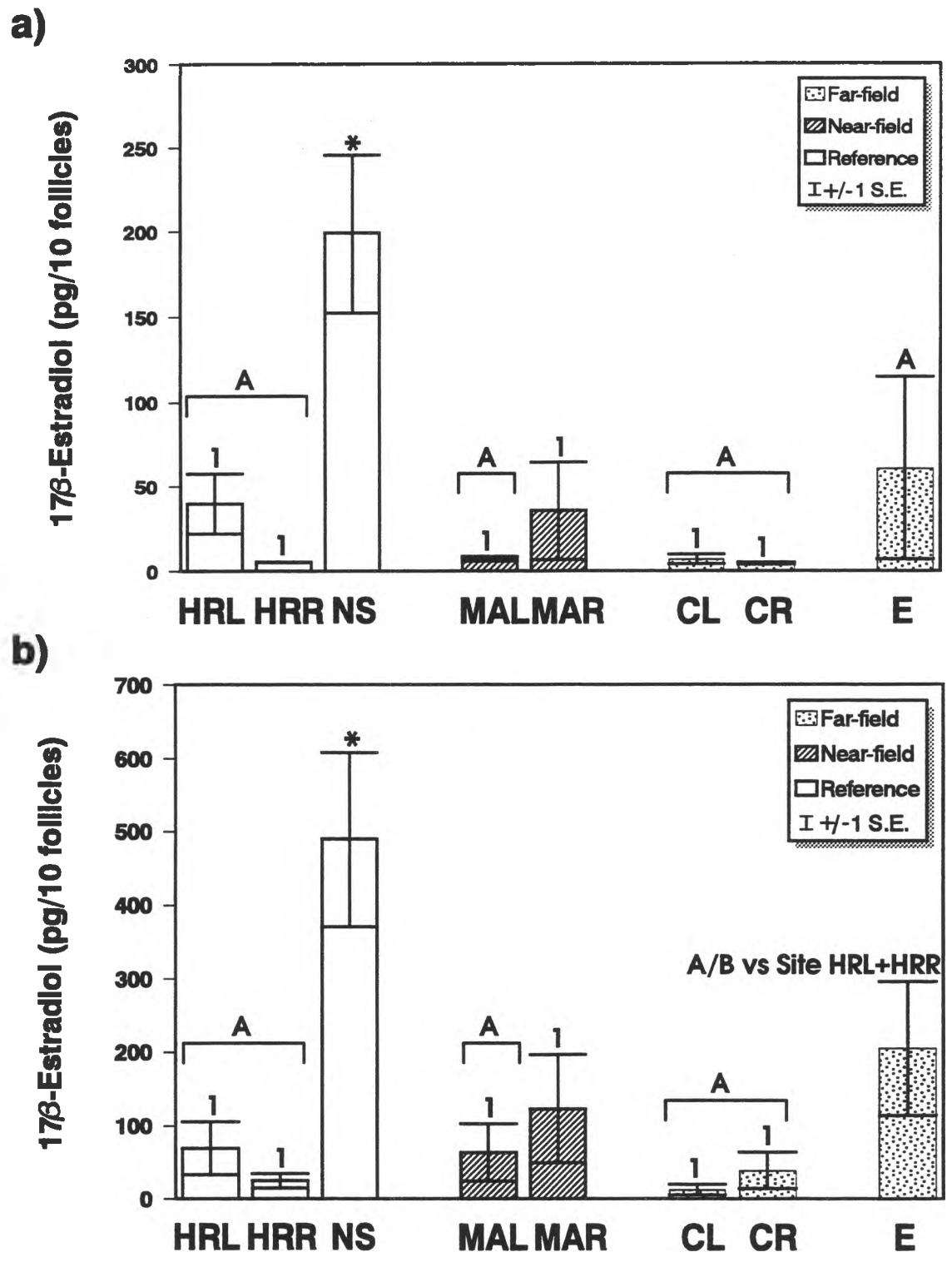


Figure 17. a) Basal and b) forskolin-stimulated *in vitro* production of 17 β-estradiol by follicles of female spoonhead sculpin (*Cottus ricei*) from reference, near-field and far-field sites on the Athabasca River and North Saskatchewan River (NS), spring 1995 survey, Alberta. Values represent the mean ± SE. Bars with different alphabetical superscripts are statistically ($p<0.05$) different. Differences ($p<0.05$) between sites HRL *vs* HRR, MAL *vs* MAR, CL *vs* CR are denoted with different numerical superscripts. Differences ($p<0.05$) between Site MAR or NS and pooled reference sites are indicated with an asterisk (*).

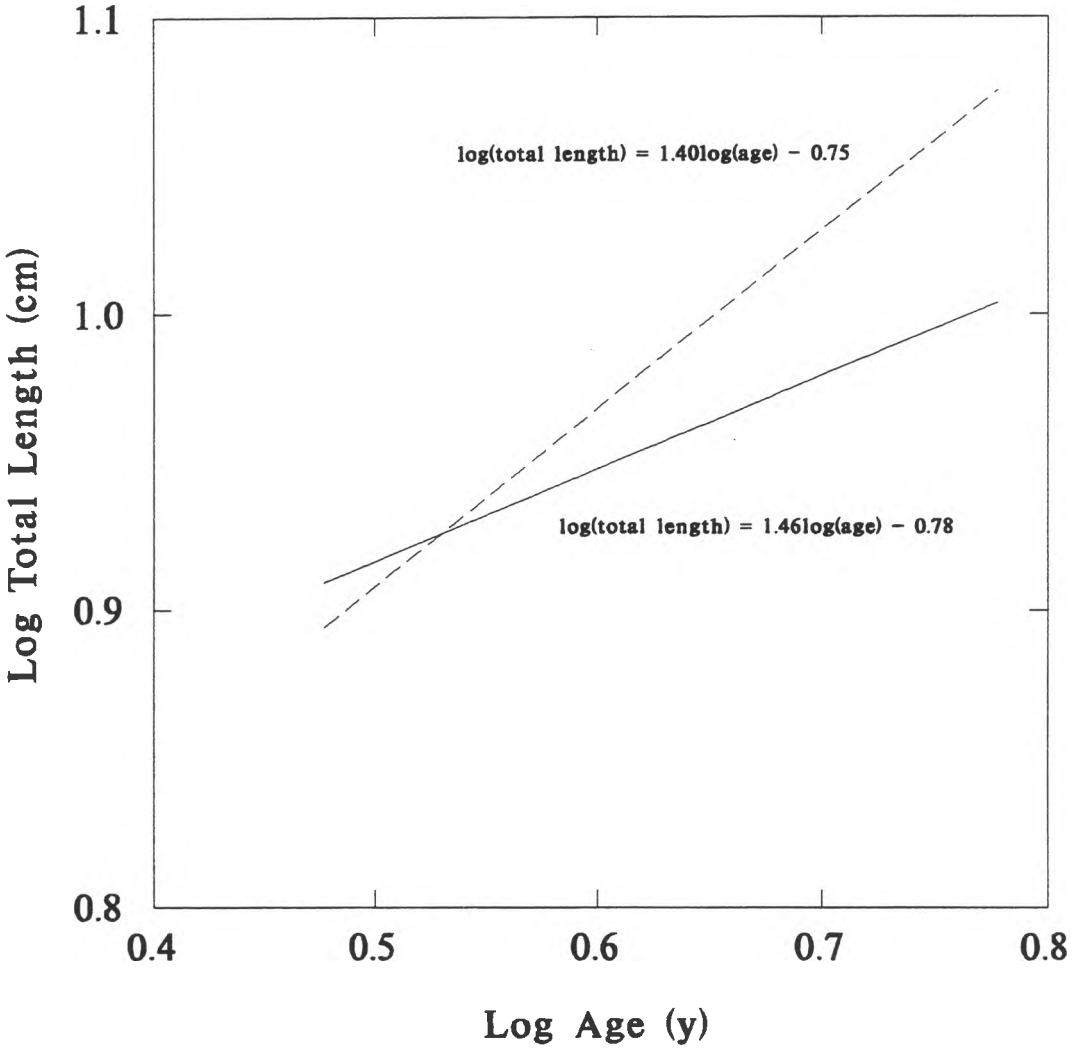


Figure 18. Regression lines of $\log_{10}$ total length *vs* $\log_{10}$ age (size-at-age) for male spoonhead sculpin (*Cottus ricei*) from the pooled reference sites (HRL+HRR) (solid line, r^2=0.46) and pooled far-field sites (CL+CR) (dashed line, r^2=0.84), spring 1995 survey, Athabasca River, Alberta.

APPENDIX A:

TERMS OF REFERENCE

Project 2353-D1: Monitoring Effects of Pulp Mill Effluents on Fish Populations

I. Background and Objectives

It has been demonstrated in eastern Canada that pulp mill effluents are associated with depressed levels of sex steroid hormones, as well as delayed maturity, reduced gonadal size and depressed secondary sexual characteristics in white sucker and lake whitefish. Similar biochemical disruptions have also been documented in goldfish, fathead minnow and longnose sucker exposed to pulp mill effluent. A previous NRBS study (Project 2352-B1) demonstrated that mountain whitefish and longnose sucker appear to have reduced sex steroid levels downstream of pulp mills on the Athabasca River (Brown *et al.* 1993). However, concerns have been raised that larger fish species may not be suitable as monitors of localized environments because they are very mobile and capable of movement beyond effluent exposure areas. To alleviate the problems associated with large, mobile fish species new techniques have recently been developed for examining biochemical disruptions in smaller fish species. These smaller species (eg., Cyprinidae, Cottidae) are assumed to have limited mobility with small home ranges, making them better indicators of environmental stressors in localized environments.

The purpose of this project is to: 1) evaluate the suitability of using small fish species for monitoring the effects of pulp mill discharges on the Athabasca River, and 2) evaluate the cumulative effects framework under development for its applicability to the Athabasca River ecosystem. This project would provide new information on monitoring protocols, as well as direct assessments of pulp mill effects. This study would support and receive benefits from ongoing studies documenting food chain effects, nutrient impacts and other studies within the contaminants section. This work would be directly applicable to study board questions aimed at determining whether pulp mill discharges have affected fish (Question 1a), what is the distribution and toxicity of contaminants in the aquatic environment (Question 4a) and the development of predictive tools for assessing cumulative effects (Questions 13a&b).

II. Requirements

A. April/May 1994 - Spring Field Trip

1) The contractor is to attempt to collect Cyprinidae and Cottidae fish species from locations upstream and downstream of the Hinton Combined Effluent and upstream and downstream of the town of Whitecourt on the Athabasca River. These fish are to be collected to identify a suitable sentinel fish species for biomonitoring.

2) Fish are to be collected for Mixed Function Oxygenase (MFO) and sex hormone assays. Collections methods may include backpack electrofishing, beach seines, minnow traps and, possibly, gill nets.

3) Sampling, handling, processing and shipping protocols for MFO and sex hormone assays are to follow those outlined in Hodson *et al.* (1991) and McMaster *et al.* (1992), respectively. To the extent possible, a minimum of 15 male and 15 female fish of each species are to be collected at each sampling location for MFO and sex hormone assays.

4) Up to 10 fish of each species are also to be collected and archived for possible future contaminant analyses. These fish are to be placed in contaminant-free bags after collection and placed in styrofoam or plastic coolers. The use of dry ice for initial freezing and shipping is the preferred method. However, ice packs or ice may be used as a secondary method. These fish are to be delivered to the Project Liaison Officer for archiving. The NRBS will provide the contractor with contaminant free bags.

5) Sample information is to be included with each specimen. Record date, species, sampling location, collector, total and fork length and sample number.

6) For each capture method employed, provide a measurement of Catch per Unit Effort for each species at each site.

7) For each specimen collected record information on gross pathology.

8) Record general habitat characteristics at each site sampled as outlined in Schedule A1. High contrast black and white photographs are to be taken of each site where sampling is attempted.

9) Utilizing Geographic Positioning System technology, record the latitude and longitude of each site where sampling is attempted.

10) Obtain water samples from all sites where fish are collected.

11) To the extent possible, all fish collected are to be aged using the methods outlined in McKay et al. (1990).

12) The contractor is responsible for obtaining all necessary collection permits from regulatory authorities.

B. June-September - Laboratory Analyses

1) Carry out EOX and, if required, other appropriate chemical analyses on water and fish samples collected in the spring to determine if the aquatic environment has been exposed to pulp mill effluents.

2) Carry out lipid analyses on fish (whole fish) samples.

3) Carry out MFO and sex steroid assays on fish tissues using the methods outlined in Hodson *et al.* (1991) and McMaster *et al.* (1992), respectively.

4) Carry out fecundity (eg., gonad weight), ageing measurements (weight and length at age) and other morphometric measurements (eg., liver weight) on the collected fish.

5) Review and summarize gross pathology information.

6) Tabulate and interpret data, utilizing statistical analyses as required.

C. September-October - Fall Field Trip

1) Based on the results of IIA and IIB, above, develop and carry out a fall field sampling program to 1) confirm the biochemical responses observed during the spring sampling and 2) refine the geographical extent of fish biochemical responses to pulp mill effluents.

2) The sampling methodology for the fall collection program is to conform to that outlined for the spring program under IIA, above.

D. October-March - Laboratory Analyses

1) Carry out EOX and, if required, other appropriate chemical analyses on water and fish samples collected in the fall and spring, as required, to determine if the aquatic environment has been exposed to pulp mill effluents.

2) Carry out lipid analyses on fish (whole fish) samples.

3) Carry out MFO and sex steroid assays on fish tissues using the methods outlined in Hodson *et al.* (1991) and McMaster *et al.* (1992), respectively.

4) Carry out fecundity (eg., gonad weight), ageing measurements (weight and length at age) and other morphometric measurements (eg., liver weight) on the collected fish.

5) Review and summarize gross pathology information.

6) Tabulate and interpret data, utilizing statistical analyses as required.

III. Reporting Requirements

1) Prepare an Interim Report documenting the findings of the spring and fall sampling programs and laboratory analyses. The report is to include discussion on the selection of a suitable sentinel species and outline the geographic extent of fish responses. The report is also to include a table documenting the geographic locations (latitude and longitude) of all sites where sampling was attempted. All fish collections are to be cross-referenced to a geographic location.

2) Ten copies of the Interim Report along with an electronic disk copy are to be submitted to the Project Liaison Officer by March 31, 1995. The style and format of the report is to follow that outlined in the NRBS Style Manual. A copy of the Style Manual will be supplied to the contractor by the NRBS.

3) The Interim 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 New Times 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 Interim 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.

IV. Deliverables

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. Project Administration

The Scientific Authority for this project is:

Dr. Kelly Munkittrick
Fisheries and Oceans Canada
867 Lakeshore Road
P. O. Box 5050
Burlington, Ontario L7R 4A6
phone: (905) 336-4864
fax: (905) 336-6437

Questions of a scientific nature should be directed to him.

The NRBS Study Office Project Liaison Officer for this project is:

Ken Crutchfield
Associate Science Director
Northern River Basins Study
690 Standard Life Centre
10405 Jasper Avenue
Edmonton, Alberta T5J 3N4
phone: (403) 427-1742
fax: (403) 422-3055

Administrative questions related to this project should be directed to him.

VI. Literature Cited

Brown, S. B., R. E. Evans, L. Vandenbyllaardt and A. Bordeleau. 1993. Analyses and Interpretation of Steroid Hormones and Gonad Morphology in Fish - Upper Athabasca River, 1992. Northern River Basins Study Project Report No. 13. Prepared by: Freshwater Institute, Fisheries and Oceans Canada, Winnipeg, Manitoba. Prepared for: Northern River Basins Study, Edmonton, Alberta. 82 pp.

Hodson, P. V., P. J. Kloepper-Sams, K. R. Munkittrick, W. L. Lockhart, D. A. Metner, P. L. Luxon, I. R. Smith, M. M. Gagnon, M. Servos and J. F. Payne. 1991. Protocols for Measuring Mixed Function Oxygenases of Fish Liver. Fisheries and Oceans Canada. Canadian Technical Report of Fisheries and Aquatic Sciences 1829.

MacKay, W. C., G. R. Ash and H. J. Norris (eds). 1990. Fish Ageing Methods for Alberta. R. L. & L. Environmental Services Ltd. in association with Alberta Fish and Wildlife Division and University of Alberta, Edmonton. 113 pp.

McMaster, M. E., K. R. Munkittrick and G. J. Van Der Kraak. 1992. Protocols for Measuring Circulating Levels of Gonadal Sex Steroids in Fish. Fisheries and Oceans Canada. Canadian Technical Report of Fisheries and Aquatic Sciences 1836.

HABITAT CLASSIFICATION AND DOCUMENTATION SYSTEM FOR USE IN FISHERIES SURVEYS CONDUCTED UNDER THE NORTHERN RIVER BASINS STUDY

1. CHANNEL TYPES

TYPE U - UNOBSTRUCTED CHANNEL

- only one main channel; permanent islands absent; side bars occasionally present with only limited development of exposed mid-channel bars during low flows.

TYPE S - SINGULAR ISLAND

- presence of two channels around single, permanent island; side bars and mid-channel bars often present at low flows.

TYPE M - MULTIPLE ISLAND

- more than two channels and permanent islands present; generally exhibit extensive side bar and mid-channel bar development during low flows.

TYPE F - FALLS

- a special channel type used to identify the unique habitat at Vermilion Falls.

2. SPECIAL HABITAT FEATURES

Tributary Confluences (TC)

- confluence area of tributary entering mainstem; classified according to flow at time of survey and wetted width at mouth

T1 - intermittent flow (dry/trickle); ephemeral stream
T2 - flowing; width at mouth <5.0 m
T3 - flowing; width at mouth 5-15 m
T4 - flowing; width at mouth 15-30 m
T5 - flowing; width at mouth 30-60 m
T6 - flowing; width at mouth >60 m

Shoal (SH)

- shallow (<1.0 m depth), submerged areas of coarse (SHC) or fine (SHF substrates generally found in mid-channel areas or associated with depositional areas around islands and side bars. Shoal boundaries are to be visually assessed and approximate locations mapped.

Backwater (BW)

- discrete, localized area of variable size, exhibiting a reversed flow direction relative to the main current; generally produced by bank irregularities; velocities variable but generally lower than in adjacent main flow; substrate similar to that in adjacent channel although usually with a higher percentage of fines. For the purposes of this study, only BW areas larger than 15 m in length and 10 m width are to be mapped; maximum depths will be determined by sonar along the eddy line between BW and mainstem flows.

Rapid (RA)

- area characterized by turbulent, broken surface (i.e., standing waves, chutes, whirlpools, etc.); water velocity high (greater than 1.5 $m \cdot s^{-1}$); substrates consist of large boulder or bedrock with low fines deposition.

Snye (SN)

- area characterized by a non-flowing body of water (generally within a side channel) which retains a connection to a flowing channel at its downstream end; most commonly associated with braided channel areas but also occur in singular channels in association with point or side-bar development; substrate mainly silt/sand maximum depth at the mouth to be recorded by sonar; depths within the snye proper to be recorded for snyes within fish sampling areas.

Slough (SL)

- a non-flowing body of water located in the flood plain but completely isolated from flowing waters except during annual or irregular flood events. Often exhibit more extensive littoral development in comparison to snye areas (dependant upon frequency of inundation); substrate of silt and organic material; water levels maintained by seepage, springs, precipitation, etc.; slough identification was based primarily on air photo interpretation.

The classification of major habitat units Type U, Type S, and Type M is to be based on field observations and air photo interpretation. For example, in instances where a single permanent island is present, but one of the channels around the island is dry, the habitat classification could be either Type U (Unobstructed channel) or Type S (Singular Island) depending on conditions within the dry channel. If the dry channel exhibits a low relief at the inlet and is devoid of permanent vegetation, suggesting it contained annual flows during some portion of the open water season (e.g., during spring run-off or freshet flows), the area is to be classed as Type S habitat. If, however, the entrance to the dry channel is at a level near the high water mark, well vegetated with either grasses or willows and appears to contain flows only during extreme flood events, the channel will be classed as Type U. These criteria are also to be used to differentiate between Type S and Type M channel habitats.

3. BANK HABITAT TYPES

Category	Code	Description
Armoured/Stable	A1	Banks generally stable and at repose with cobble/small boulder/gravel substrates predominating; uniform shoreline configuration with few/minor bank irregularities; velocities adjacent to bank generally low-moderate, instream cover limited to substrate roughness (i.e., cobble/small boulder interstices); overhead cover provided by turbidity.
	A2	Banks generally stable and at repose with cobble/small boulder and large boulder substrates predominating; irregular shoreline configuration generally consisting of a series of armoured cobble/boulder outcrops that produce Backwater habitats; velocities adjacent to bank generally moderate with low velocities provided in BW habitats; instream cover provided by BW areas and substrate roughness; overhead cover provided by depth and turbidity; occasionally associated with C1, E4, and E5 banks.
	A3	Similar to A2 in terms of bank configuration and composition although generally with higher composition of large boulders/bedrock fractures; very irregular shoreline produced by large boulders and bed rock outcrops; velocities adjacent to bank generally moderate to high; instream cover provided by numerous small BW areas, eddy pools behind submerged boulders, and substrate interstices; overhead cover provided by depth and turbidity; exhibits greater depths offshore than found in A1 or A2 banks; often associated with C1 banks.

Canyon	C1	Valley walls forming banks; bank substrate consists primarily of large cobble/boulder/bedrock fractures; generally stable at bank-water interface although on upper bank slumps/rock falls common; typically deep with high current velocities offshore; abundant velocity cover provided by substrate roughness and frequent bank irregularities.
	C2	Steep, stable bedrock banks associated with canyon cliffs or bedrock outcrops; deep to moderate depths offshore with generally moderate to fast current velocities; regular bank form; velocity cover occasionally provided by bedrock fractures in channel.
Depositional	D1	Low relief, gently sloping bank type with shallow water depths offshore; substrate consists predominantly of fines (i.e., sand/silt); low current velocities offshore; instream cover generally absent or, if present, consisting of shallow depressions produced by dune formation (i.e., in sand substrates) or embedded cobble or boulders and vegetative debris; this bank type is generally associated with bar formations.
	D2	Low relief, gently sloping bank type with shallow water depths offshore; substrate consists of coarse materials (i.e., gravels/cobbles); low-moderate current velocities offshore; areas with higher velocities usually producing riffle areas; overhead cover provided by surface turbidity or surface turbulence in riffle areas; instream cover provided by substrate roughness; often associated with bar formations; and shoal habitat.

Erosional	E1	High, steep, eroding banks often with terraced profile; banks unstable, frequently slumping and eroding; substrate consists of sand/silt materials; moderate to high off-shore current velocities; steep bank profile extends under water surface resulting in deep water immediately offshore; instream cover provided by abundant submerged bankside vegetation (i.e., trees, shrubs, root wads, etc.) that has fallen into the channel from the eroding bank crest; overhead cover provided by partially submerged vegetation, depth and turbidity.
	E2	Similar to A1 except without the high amount of instream vegetative debris (i.e., banks generally clean); depths offshore generally shallower than along E1 banks.
	E3	High, steep and eroding banks, substrate consists of loose till deposits (i.e., gravel/cobble/sand mixture); moderate to high current velocities offshore; moderate depths offshore; instream cover availability limited to substrate roughness; overhead cover provided by turbidity.
	E4	Steep, eroding or slumping highwall bank; substrates variable but primarily consisting of fines (i.e., clays/silts); moderate to high current velocities offshore; depths offshore generally moderate to deep; instream cover limited to occasional BW formed by bank irregularities; overhead cover provided by depth and turbidity.

		E5	Low, steep banks, often with terraced profile; predominantly composed of silt/sand substrates; generally low current velocities offshore; depths offshore variable but generally shallow to moderate; instream cover usually absent; this bank type is often associated with BW habitats in A1 and A2 bank types; overhead cover provided by turbidity.
Composite	e.g.,	A2/C2	These classifications are used in situations where the bank-water interface (i.e., nearshore bank) is predominantly one bank type but was still strongly influenced by the adjacent farshore bank (e.g., A2/C2 used where the nearshore bank is type A2 but was produced by active bedrock fracturing from the farshore bank type C2). In these composite bank types, the first bank type given is the dominant type at the bank-water interface.

4. SUBSTRATE ANALYSIS

Substrate Classes

Plant detritus/organic material
Mud/Soft Clay
Silt
Sand
Gravel (0.2 - 5.0 cm diameter)
Cobble (5.1 - 20.0 cm diameter)
Boulder (>20.0 cm diameter)
Bedrock

Where substrates can be visually identified, the percentage composition of each substrate type is to be estimated. In deeper areas, bottom type will be determined by "feeling" the bottom or from echo sounder tracing. Substrate classification in these areas will generally be limited to the identification of the dominant/co-dominant types (e.g., sand/silt, cobble or boulder etc.).

Project 2353-E1: Monitoring the Effects of Pulp Mill Effluents on Fish Populations

I. BACKGROUND & OBJECTIVES

It has been demonstrated in eastern Canada that pulp mill effluents are associated with depressed levels of sex steroid hormones, as well as delayed maturity, reduced gonadal size and depressed secondary sexual characteristics in white sucker and lake whitefish. Similar biochemical disruptions have also been documented in goldfish, fathead minnow and longnose sucker exposed to pulp mill effluent. A previous NRBS study (Project 2352-B1) demonstrated that mountain whitefish and longnose sucker appear to have reduced sex steroid levels downstream of pulp mills on the Athabasca River (Brown *et al.* 1993). However, concerns have been raised that larger fish species may not be suitable as monitors of localized environments because they are very mobile and capable of movement beyond effluent exposure areas. To alleviate the problems associated with large, mobile fish species new techniques have recently been developed for examining biochemical disruptions in smaller fish species. These smaller species (eg., Cyprinidae, Cottidae) are assumed to have limited mobility with small home ranges, making them better indicators of environmental stressors in localized environments.

The purpose of this project is to: 1) evaluate the suitability of using small fish species for monitoring the effects of pulp mill discharges on the Athabasca River, and 2) evaluate the cumulative effects framework under development for its applicability to the Athabasca River ecosystem. This project would provide new information on monitoring protocols, as well as direct assessments of pulp mill effects. This study would support and receive benefits from ongoing studies documenting food chain effects, nutrient impacts and other studies within the contaminants section. This work would be directly applicable to study board questions aimed at determining whether pulp mill discharges have affected fish (Question 1a), what is the distribution and toxicity of contaminants in the aquatic environment (Question 4a) and the development of predictive tools for assessing cumulative effects (Questions 13a&b).

II. GENERAL REQUIREMENTS

A. April/May 1995 - Spring Field Trip

1) The contractor is to attempt to collect Cottidae fish species from locations upstream and downstream of the Hinton Combined Effluent on the Athabasca River. These fish will be used to 1) confirm whole organism and biochemical responses observed during the fall 1994 survey, 2) evaluate mobility of sentinel species, and 3) refine geographical extent of responses to effluent.

2) Fish are to be collected for Mixed Function Oxygenase (MFO) and sex hormone assays. Collections methods may include backpack electrofishing, beach seines, minnow traps and, possibly, gill nets.

3) Sampling, handling, processing and shipping protocols for MFO and sex hormone assays are to follow those outlined in Hodson *et al.* (1991) and McMaster *et al.* (1992), respectively. To the extent possible, a minimum of 15 male and 15 female fish of each species are to be collected at each sampling location for MFO and sex hormone assays.

4) Up to 10 fish of each species are also to be collected and archived for possible future contaminant analyses. These fish are to be placed in contaminant-free bags after collection and placed in styrofoam or plastic coolers. The use of dry ice for initial freezing and shipping is the preferred method. However, ice packs or ice may be used as a secondary method. These fish are to be delivered to the Component Coordinator for archiving. The NRBS will provide the contractor with contaminant free bags.

5) Sample information is to be included with each specimen. Record date, species, sampling location, collector, total and fork length and sample number.

6) For each capture method employed, provide a measurement of Catch per Unit Effort for each species at each site.

7) For each specimen collected record information on gross pathology.

8) Record general habitat characteristics at each site sampled as outlined in Schedule A1. High contrast black and white photographs are to be taken of each site where sampling is attempted.

9) Using Geographic Positioning System technology, record the latitude and longitude of each site where sampling is attempted.

10) Obtain water samples from all sites where fish are collected.

11) To the extent possible, all fish collected are to be aged using the methods outlined in McKay et al. (1990).

12) The contractor is responsible for obtaining all necessary collection permits from regulatory authorities.

B. June-September - Laboratory Analyses

1) Carry out appropriate chemical analyses on water samples collected in the spring to determine if the aquatic environment has been exposed to pulp mill effluents.

2) Carry out MFO and sex steroid assays on fish tissues using the methods outlined in Hodson *et al.* (1991) and McMaster *et al.* (1992), respectively.

3) Carry out fecundity (eg., gonad weight), ageing measurements (weight and length at age) and other morphometric measurements (eg., liver weight) on the collected fish.

4) Review and summarize gross pathology information.

5) Tabulate and interpret data, utilizing statistical analyses as required.

III. REPORTING REQUIREMENTS

1. Prepare a report documenting the findings of the spring and fall 1994 sampling programs, the spring 1995 survey, and laboratory analyses. The report is to include discussion on the selection of a suitable sentinel species, biochemical and whole organism responses, and outline the geographic extent of fish responses. The report is also to include a table documenting the geographic locations (latitude and longitude) of all sites where sampling was attempted.

2. Ten copies of the Draft Report along with an electronic disk copy are to be submitted to the Component Coordinator by September 15, 1995.

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

4. The Contractor is to provide draft and final reports in the style and format outlined in the NRBS document, "A Guide for the Preparation of Reports," which will be supplied upon execution of the contract.

   The final report is to include the following: an acknowledgement section that indicates any local involvement in the project, Report 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.

5. 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.

6. 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).

7. A presentation package of 35 mm slides is to be included, comprising of one original and four duplicates of each slide.

IV. DELIVERABLES

1. Ten to tewnty-five 35 mm slides that can be used at public meetings to summarize the project, methods and key findings.

2. A Level II interpretive report due September 1995. The report will present information on the effects of pulp mill effluents on small fish species, particularly in relation to physiological response, and provide new information on biomonitoring protocols.

V. CONTRACT ADMINISTRATION

This project is proposed by the Contaminants Component of NRBS; Component Leader - Dr. John Carey, Rivers Research Branch, NWRI, Burlington.

The Scientific Authority for this project is:

Dr. Kelly Munkittrick
Fisheries and Oceans Canada
867 Lakeshore Road
P. O. Box 5050
Burlington, Ontario L7R 4A6
phone: (905) 336-4864
fax: (905) 336-6437

Questions of a technical nature should be directed to him.

The NRBS Study Component Coordinator for this project is:

Richard Chabaylo
Northern River Basins Study
690 Standard Life Centre
10405 Jasper Avenue
Edmonton, Alberta T5J 3N4
phone: (403) 427-1742
fax: (403) 422-3055

Questions of an administrative nature should be directed to him.

VI. LITERATURE CITED

Brown, S. B., R. E. Evans, L. Vandenbyllaardt and A. Bordeleau. 1993. Analyses and Interpretation of Steroid Hormones and Gonad Morphology in Fish - Upper Athabasca River, 1992. Northern River Basins Study Project Report No. 13. Prepared by: Freshwater Institute, Fisheries and Oceans Canada, Winnipeg, Manitoba. Prepared for: Northern River Basins Study, Edmonton, Alberta. 87 pp.

Hodson, P. V., D. J. Kloepper Sams, K. R. Munkittrick, W. L. Lockhart, B. A. Hellner, P. L. Luxon, I. R. Smith, M. M. Gagnon, M. Servos and J. F. Payne. 1991. Protocols for Measuring Mixed Function Oxygenases of Fish Liver. Fisheries and Oceans Canada. Canadian Technical Report of Fisheries and Aquatic Sciences 1829.

MacKay, W. C., G. R. Ash and H. J. Norris (eds). 1990. Fish Ageing Methods for Alberta. R. L. & L. Environmental Services Ltd. in association with Alberta Fish and Wildlife Division and University of Alberta, Edmonton. 113 pp.

McMaster, M. E., K. R. Munkittrick and G. J. Van Der Kraak. 1992. Protocols for Measuring Circulating Levels of Gonadal Sex Steroids in Fish. Fisheries and Oceans Canada. Canadian Technical Report of Fisheries and Aquatic Sciences 1836.

APPENDIX B:

RAW FISH DATA FOR SENTINEL SPECIES

Legend

Fish #: identification number and order of fish capture/dissection

Species:

SHS = Spoonhead sculpin (*Cottus ricei*)
LC = Lake chub (*Couesius plumbeus*)

Sex:

1 = male
2 = female
3 = immature

Site:

HRL - Hinton reference site, left upstream bank
HRR - Hinton reference site, right upstream bank
MAR - Mill A near-field, right upstream bank
MAL - Mill A near-field, left upstream bank
CL - far-field site near Obed Mountain Coal Ltd bridge, left upstream bank
CR - far-field site near Obed Mountain Coal Ltd bridge, right upstream bank
E - Farther-field site near Emerson Bridge
WF - Whitecourt reference site at Windfall Bridge
R2 - Second Whitecourt reference site just upstream of Mill B diffuser
MB - Mill B near-field site
MC - Mill C near-field site
NS - Reference site on the North Saskatchewan River

Carcass Weight: eviscerated (including the removal of liver and gonads) body weight

Female Gonad Condition:

1 = preovulatory or "green"
2 = spent or post-spawning

Treatment (*in vitro* steroid production):

basal = unstimulated basal production of steroids
hCG = incubated with 10 IU/mL human chorionic gonadotropin hormone
forskolin = incubated with 10μM forskolin

Spring 1994 Metric Data

Fish #	Species	Site	Sex	Age (y)	Total Length (cm)	Fork Length (cm)	Total Weight (g)	Carcass Weight (g)	Liver Weight (g)	Gonad Weight (g)	Total Fecundity (# / female)	Egg Weight (mg)	Egg Diameter (mm)
67	SHS	HRL	2		9		5.732	5.019	0.101	0.093			
71	SHS	HRL	2		6.7		2.447	2.152	0.045	0.024			
66	SHS	HRL	2		8.5		7.058	6.174	0.132	0.11			
73	SHS	HRL	3		6.5		2.768	2.403	0.032	0.009			
74	SHS	HRL	3		4.3		0.745						
70	SHS	HRL	3		6.6		2.298	1.972	0.036	0.004			
76	SHS	HRL	3		4.5		0.908						
69	SHS	HRL	3		6.4		2.211	1.892	0.016				
68	SHS	HRL	3		6.8		2.799	2.445	0.033				
72	SHS	HRL	3		6.4		2.186	1.931	0.031	0.011			
75	SHS	HRL	3		4.2		0.634						
6	SHS	MAL	1		7		3.076	2.661	0.071				
7	SHS	MAL	2		7.2		2.918	2.538	0.067	0.017			
12	SHS	MAL	3		4.8		0.798						
13	SHS	MAL	3		5		0.98						
11	SHS	MAL	3		5		1.001						
10	SHS	MAL	3		5.1		1.207						
16	SHS	MAL	3		4.3		0.76						
8	SHS	MAL	3		4.5		0.766	0.618	0.024				
9	SHS	MAL	3		5.2		1.098						
15	SHS	MAL	3		4.7		0.933						
14	SHS	MAL	3		4.7		0.776						
87	LC	WF	1	2	9	8.4	5.372	4.876	0.068	0.095			
84	LC	WF	1	2	8.8	8.2	4.972	4.584	0.053	0.031			
89	LC	WF	1	2	9.2	8.7	6.497	5.879	0.09	0.168			
95	LC	WF	1	2	7.9	7.3	3.943	3.516	0.03	0.091			
90	LC	WF	1	2	8.7	8.1	5.47	4.842	0.078	0.078			
86	LC	WF	1	2	9	8.2	5.358	4.907	0.056	0.054			
85	LC	WF	2	3	9.3	8.5	6.779	5.397	0.083	0.867	2076.1	0.4176	0.89
88	LC	WF	2	2	8.5	7.9	5.051	4.118	0.083	0.522	1494.0	0.3494	0.82
80	LC	WF	2	2	9.1	8.5	6.353	5.004	0.096	0.832	2853.2	0.2916	0.86

Fish #	Species	Site	Sex	Age (y)	Total Length (cm)	Fork Length (cm)	Total Weight (g)	Carcass Weight (g)	Liver Weight (g)	Gonad Weight (g)	Total Fecundity (# / female)	Egg Weight (mg)	Egg Diameter (mm)
60	LC	WF	2		9.4	8.4	7.025	5.501	0.103	0.729	2176.1	0.335	0.8
93	LC	WF	2	2	8.3	7.7	4.23	3.543	0.084	0.265			
91	LC	WF	2	2	8.4	7.9	5.028	4.187	0.126	0.389	1192.5	0.3262	0.86
78	LC	WF	2		9.8	9	7.524	5.923	0.107	1.132	2068.7	0.5472	1.03
82	LC	WF	2	2	9.1	8.6	6.404	5.604	0.128	0.675	1527.1	0.442	0.79
81	LC	WF	2	3	10.1	9.4	7.321	5.661	0.151	0.939	1944.1	0.483	0.82
79	LC	WF	2	2	8.6	8	5.43	4.234	0.101	0.178			
83	LC	WF	2	2	8.5	7.9	5.062	4.209	0.091	0.324	1302.8	0.2487	0.62
101	LC	WF	3		4	3.5	0.458						
99	LC	WF	3		6.4	5.8	1.818						
100	LC	WF	3		5	4.6	0.938						
103	LC	WF	3		5.5	5.2	1.278						
104	LC	WF	3		7.6	6.8	3.31						
98	LC	WF	3		7.5	6.9	3.242						
105	LC	WF	3		5.8	5.5	1.515						
102	LC	WF	3		8.5	8	4.112						
106	LC	WF	3		5.4	5.1	1.146						
94	LC	WF	3	2	8.4	7.8	4.355	4.09	0.034				
63	LC	WF	3		5.4	5.2	1.288						
62	LC	WF	3		4.6	4.3	0.965						
65	LC	WF	3		4.7	4.4	0.661						
64	LC	WF	3		6	5.5	1.74						
61	LC	WF	3		6	5.6	1.79						
143	LC	WF	3		6	5.7	1.957						
97	LC	WF	3		7.1	6.5	2.364						
92	LC	WF	3	2	8.6	8	4.762	4.382	0.071				
96	LC	WF	3	2	8	7.4	4.015	3.584	0.064				
107	LC	WF	3		7.4	6.8	3.17						
131	LC	WF	3		7.7	7.3	3.808						
130	LC	WF	3		6.1	5.7	1.824						
133	LC	WF	3		7.5	7.1	3.872						

Fish #	Species	Site	Sex	Age (y)	Total Length (cm)	Fork Length (cm)	Total Weight (g)	Carcass Weight (g)	Liver Weight (g)	Gonad Weight (g)	Total Fecundity (# / female)	Egg Weight (mg)	Egg Diameter (mm)
132	LC	WF	3		7.2	6.8	3.206						
127	LC	WF	3		7	6.6	2.804						
126	LC	WF	3		7	6.6	2.647						
129	LC	WF	3		4.7	4.4	0.761						
128	LC	WF	3		7.5	7.3	3.155						
134	LC	WF	3		5.8	5.5	1.518						
140	LC	WF	3		7.5	7.1	3.183						
139	LC	WF	3		7.2	6.9	3.23						
142	LC	WF	3		5.4	5.2	1.504						
141	LC	WF	3		7	6.7	2.511						
136	LC	WF	3		5.3	4.8	1.126						
135	LC	WF	3		6	5.7	1.734						
138	LC	WF	3		5.8	5.5	1.578						
137	LC	WF	3		5	4.7	0.887						
125	LC	WF	3		5.4	5.1	1.175						
113	LC	WF	3		4.7	4.4	0.842						
112	LC	WF	3		5.7	5.4	1.312						
115	LC	WF	3		7.9	7.4	3.664						
114	LC	WF	3		7.8	7	3.547						
109	LC	WF	3		6.5	6	1.769						
108	LC	WF	3		3.3	3.1	0.306						
111	LC	WF	3		5.8	5.5	1.511						
110	LC	WF	3		5.6	5.4	1.532						
116	LC	WF	3		6	5.6	1.702						
122	LC	WF	3		4.2	4	0.612						
121	LC	WF	3		5.5	5.2	1.349						
124	LC	WF	3		5	4.7	0.976						
123	LC	WF	3		5.4	5	1.082						
118	LC	WF	3		5.1	4.8	1.185						
117	LC	WF	3		5.7	5.4	1.616						
120	LC	WF	3		7.5	7	3.121						

Fish #	Species	Site	Sex	Age (y)	Total Length (cm)	Fork Length (cm)	Total Weight (g)	Carcass Weight (g)	Liver Weight (g)	Gonad Weight (g)	Total Fecundity (# / female)	Egg Weight (mg)	Egg Diameter (mm)
119	LC	WF	3		5.7	5.4	1.499						
162	LC	MB	1	2	8.5	8	5.406	4.763	0.104	0.101			
158	LC	MB	1	2	9.9	9.2	7.338	6.587	0.094	0.183			
154	LC	MB	1	2	9.3	8.8	6.994	6.433	0.058	0.121			
166	LC	MB	1	2	8.8	8.2	4.709	4.11	0.052	0.137			
163	LC	MB	1	2	8.6	8	5.402	4.774	0.057	0.111			
148	LC	MB	1	2	9	8.2	5.827	5.274	0.106	0.131			
151	LC	MB	1	2	9.8	9	6.898	6.194	0.053	0.052			
150	LC	MB	2	2	9.7	8.9	7.829	6.341	0.163	0.827			
147	LC	MB	2	2	9.7	9.2	8.304	6.341	0.199	1.183	3091.2	0.3827	0.84
164	LC	MB	2	2	8.2	7.5	4.107	3.381	0.096	0.286			
165	LC	MB	2	2	7.8	7.2	3.563	3.001	0.067	0.196			
152	LC	MB	2	2	10.4	9.6	9.44	7.476	0.201	1.696	3136.1	0.5408	0.84
146	LC	MB	2	3	10.5	9.8	9.218	7.043	0.171	1.401	2373.0	0.5904	0.86
159	LC	MB	2	2	9	8.5	5.895	5.032	0.084	0.445			
153	LC	MB	2	2	9.6	8.8	8.494	6.256	0.156	1.418	2493.4	0.5687	0.85
144	LC	MB	2	3	11	10.3	12.143	9.189	0.331	1.845	3476.5	0.5307	0.9
145	LC	MB	2	3	10.9	10.3	11.466	8.721	0.248	2.025	3164.1	0.64	0.68
149	LC	MB	2	2	10.1	9.4	8.921	7.309	0.108	0.875	1807.1	0.4842	0.9
157	LC	MB	2	2	9.5	8.8	6.574	5.625	0.109	0.462			
156	LC	MB	2	3	8.9	8.4	5.739	4.82	0.066	0.448			
155	LC	MB	2	2	9.5	8.8	7.128	5.794	0.153	0.809			
197	LC	MB	3		6.8	6.3	2.282						
181	LC	MB	3		5.6	5.3	1.437						
168	LC	MB	3		7.7	6.9	2.959						
167	LC	MB	3	2	7.8	7.3	3.468	3.129	0.028	0.082			
180	LC	MB	3		3.4	3.2	0.359						
170	LC	MB	3		6.6	6.3	2.401						
161	LC	MB	3	2	8.8	8.3	5.004	4.61	0.094	0.016			
173	LC	MB	3		6.2	5.8	1.68						
179	LC	MB	3		4.4	4.2	0.696						

Fish #	Species	Site	Sex	Age (y)	Total Length (cm)	Fork Length (cm)	Total Weight (g)	Carcass Weight (g)	Liver Weight (g)	Gonad Weight (g)	Total Fecundity (# / female)	Egg Weight (mg)	Egg Diameter (mm)
192	LC	MB	3		5.7	5.4	1.496						
191	LC	MB	3		7.7	7	3.205						
199	LC	MB	3		4	3.8	0.592						
160	LC	MB	3	2	9.6	8.8	5.534	5.007	0.08				
198	LC	MB	3		5	4.6	1.085						
190	LC	MB	3		5.5	5.2	1.354						
189	LC	MB	3		6.3	5.8	1.958						
194	LC	MB	3		6	5.6	1.507						
195	LC	MB	3		6	5.7	1.839						
182	LC	MB	3		5.4	5	1.171						
183	LC	MB	3		6.6	6.3	2.232						
196	LC	MB	3		5.7	5.4	1.304						
187	LC	MB	3		6.4	6	2.092						
186	LC	MB	3		5.8	5.4	1.41						
193	LC	MB	3		7.1	6.5	2.588						
184	LC	MB	3		5.9	5.5	1.536						
188	LC	MB	3		6.1	5.8	1.955						
172	LC	MB	3		6.5	6.1	2.187						
171	LC	MB	3		7	6.5	2.528						
169	LC	MB	3		6.9	6.4	2.729						
185	LC	MB	3		6.4	5.9	2.03						
174	LC	MB	3		6.8	6.3	2.207						
175	LC	MB	3		6.1	5.7	1.61						
178	LC	MB	3		6	5.4	1.739						
177	LC	MB	3		6.3	5.9	1.82						
176	LC	MB	3		5.8	5.4	1.563						
276	LC	MC	1	2	10	9.3	8.216	7.441	0.082	0.137			
274	LC	MC	1	2	10	9.4	8.327	7.485	0.067	0.156			
201	LC	MC	1	3	9.8	9.2	6.971	6.345	0.069	0.092	230.4	0.3993	0.96
278	LC	MC	1	2	8.3	7.7	4.472	4.026	0.073	0.046			
200	LC	MC	1	3	10.1	9.5	8.464	7.634	0.083	0.183			

Fish #	Species	Site	Sex	Age (y)	Total Length (cm)	Fork Length (cm)	Total Weight (g)	Carcass Weight (g)	Liver Weight (g)	Gonad Weight (g)	Total Fecundity (# / female)	Egg Weight (mg)	Egg Diameter (mm)
205	LC	MC	1	2	7.6	7.2	3.412	3.015	0.028	0.047			
275	LC	MC	1	2	10.1	9.2	8.175	7.534	0.076	0.119			
279	LC	MC	1	2	9.2	8.5	5.937	5.26	0.085	0.81			
253	LC	MC	1		8.8	8	6.121	5.156	0.151	0.257			
258	LC	MC	2	2	8.3	7.8	4.501	3.679	0.083	0.322			
203	LC	MC	2	2	7.8	7.2	3.739	3.208	0.048	0.238			
204	LC	MC	2	2	7.2	6.8	3.303	2.725	0.07	0.228			
259	LC	MC	2	2	8	7.5	4.085	3.484	0.078	0.355			
202	LC	MC	2	2	8.7	8.2	5.355	4.262	0.064	0.638			
290	LC	MC	2	3	11.3	10.3	12.347	8.92	0.286	2.396	2933.8	0.8167	0.97
277	LC	MC	2	3	10	9.3	8.256	6.354	0.142	1.211	2127.9	0.5691	0.83
255	LC	MC	2	3	10.3	9.6	9.918	7.163	0.14	1.845	2560.4	0.7206	0.87
256	LC	MC	2	2	9.4	8.7	6.931	5.878	0.082	0.504			
208	LC	MC	2	2	10.4	9.7	10.379	8.109	0.224	1.409	2751.4	0.5121	0.92
254	LC	MC	2	3	9.8	9.2	8.291	6.415	0.096	1.196	1960.7	0.61	0.82
260	LC	MC	2	2	7.3	6.8	3.323	2.823	0.062	0.196			
289	LC	MC	2	3	10.3	9.4	8.911	6.901	0.177	1.264	2527.5	0.5001	0.77
288	LC	MC	2	2	8.8	8.2	5.611	4.606	0.171	0.432			
227	LC	MC	3		6.2	5.8	1.966						
221	LC	MC	3		6.9	6.4	2.452						
222	LC	MC	3		6.6	6.3	2.226						
284	LC	MC	3		6.8	6.3	2.401						
283	LC	MC	3		7	6.4	2.642						
273	LC	MC	3		6	5.7	1.858						
285	LC	MC	3		7.4	6.8	3.242						
225	LC	MC	3		5.7	5.3	1.307						
226	LC	MC	3		6.5	6	2.246						
286	LC	MC	3		6.9	6.3	2.441						
236	LC	MC	3		6.4	5.9	2.035						
228	LC	MC	3		5.9	5.5	1.505						
237	LC	MC	3		6.6	6.2	2.315						

Fish #	Species	Site	Sex	Age (y)	Total Length (cm)	Fork Length (cm)	Total Weight (g)	Carcass Weight (g)	Liver Weight (g)	Gonad Weight (g)	Total Fecundity (# / female)	Egg Weight (mg)	Egg Diameter (mm)
261	LC	MC	3		6.4	6	1.921						
219	LC	MC	3		5.7	5.4	1.529						
241	LC	MC	3		6.9	6.4	2.568						
240	LC	MC	3		5.6	5.1	1.403						
218	LC	MC	3		5.2	4.9	1.166						
238	LC	MC	3		5.6	5.2	1.406						
239	LC	MC	3		6.6	6.1	1.971						
216	LC	MC	3		5.4	5.1	1.129						
223	LC	MC	3		7.2	6.7	2.864						
217	LC	MC	3		5.3	4.9	1.332						
215	LC	MC	3		6	5.6	1.615						
220	LC	MC	3		4.4	4.2	0.744						
242	LC	MC	3		5.6	5.4	1.289						
224	LC	MC	3		6.3	5.8	1.95						
262	LC	MC	3		7.1	6.6	2.96						
257	LC	MC	3	2	7.7	7.1	3.893	3.569	0.016				
263	LC	MC	3		5.3	5	1.153						
244	LC	MC	3		5.6	5.3	1.389						
212	LC	MC	3		5.8	5.5	1.571						
248	LC	MC	3		5.5	5.1	1.207						
243	LC	MC	3		6.4	6	1.783						
206	LC	MC	3	2	6.5	6.1	2.396	2.184	0.023				
210	LC	MC	3		7.2	6.7	2.753						
251	LC	MC	3		5.6	5.3	1.172						
211	LC	MC	3		6.7	6.3	2.533						
209	LC	MC	3		7.1	6.7	2.692						
245	LC	MC	3		6.4	6	1.83						
246	LC	MC	3		5.4	5	1.117						
265	LC	MC	3		6.9	6.3	2.699						
250	LC	MC	3		5.2	4.9	1.095						
266	LC	MC	3		5.9	5.5	1.403						

Fish #	Species	Site	Sex	Age (y)	Total Length (cm)	Fork Length (cm)	Total Weight (g)	Carcass Weight (g)	Liver Weight (g)	Gonad Weight (g)	Total Fecundity (# / female)	Egg Weight (mg)	Egg Diameter (mm)
268	LC	MC	3		7.3	6.8	2.917						
247	LC	MC	3		6.1	5.7	1.596						
249	LC	MC	3		6.3	5.9	1.984						
269	LC	MC	3		6	5.6	1.758						
264	LC	MC	3		6.2	5.8	1.646						
229	LC	MC	3		5.4	5	1.06						
232	LC	MC	3		6.8	6.4	2.42						
231	LC	MC	3		6	5.6	1.505						
235	LC	MC	3		5.7	5.3	1.458						
233	LC	MC	3		5.5	5.2	1.304						
271	LC	MC	3		6.2	5.8	1.725						
272	LC	MC	3		6.1	5.7	1.771						
234	LC	MC	3		6	5.5	1.656						
270	LC	MC	3		5.5	5.2	1.32						
230	LC	MC	3		4.6	4.4	0.785						
214	LC	MC	3		5.9	5.6	1.667						
207	LC	MC	3		6.8	6.4	2.389	2.03	0.026	0.111			
252	LC	MC	3		6	5.7	1.592						
213	LC	MC	3		5.5	5.2	1.276						
267	LC	MC	3		6.2	5.8	1.86						
280	LC	MC	3	2	7.7	7.2	3.748	3.384	0.052				
281	LC	MC	3	2	7.8	7.3	3.504	3.182	0.044				
282	LC	MC	3		7	6.5	2.455						
287	LC	MC	3		6.4	6	1.915						
300	LC	MCS	1	2	8	7.5	4.402	4.033	0.044	0.054			
306	LC	MCS	1	2	7.9	7.4	4.301	3.841	0.041	0.062			
304	LC	MCS	1	2	8.5	7.8	4.877	4.448	0.062	0.08			
296	LC	MCS	1	2	8.5	7.9	4.619	4.186	0.083	0.049			
298	LC	MCS	1	2	9	8.3	5.761	5.166	0.101	0.127			
301	LC	MCS	1	2	8.7	8.2	5.519	4.873	0.094	0.083			
305	LC	MCS	1	2	8.6	8.2	5.34	4.699	0.094	0.12			

Fish #	Species	Site	Sex	Age (y)	Total Length (cm)	Fork Length (cm)	Total Weight (g)	Carcass Weight (g)	Liver Weight (g)	Gonad Weight (g)	Total Fecundity (# / female)	Egg Weight (mg)	Egg Diameter (mm)
297	LC	MCS	1	3	9.6	8.9	7.205	6.535	0.084	0.1			
302	LC	MCS	2	2	8.4	7.8	4.813	3.956	0.079	0.51	1763.5	0.2892	0.8
303	LC	MCS	2	2	8.7	8.1	5.648	4.597	0.117	0.629	1437.1	0.4377	0.84
299	LC	MCS	2	2	8.4	7.8	5.297	4.081	0.081	0.628	1778.0	0.3532	0.75
292	LC	MCS	2	3	9.5	8.9	7.422	5.553	0.199	1.112	1926.5	0.5772	0.86
294	LC	MCS	2	2	10	9.3	7.516	5.9	0.152	1.002	1940.4	0.5164	0.85
293	LC	MCS	2	3	8.6	7.9	4.605	3.805	0.06	0.154			
295	LC	MCS	2	2	8.2	7.6	4.438	3.641	0.119	0.35			
291	LC	MCS	2	2	10.2	9.3	8.148	6.325	0.147	1.126	2357.1	0.4777	0.87
310	LC	MCS	3		7.5	6.9	3.166						
319	LC	MCS	3		6.6	6.2	2.133						
320	LC	MCS	3		6.9	6.4	2.653						
311	LC	MCS	3		6.2	5.8	1.779						
321	LC	MCS	3		6.8	6.3	2.873						
317	LC	MCS	3		6.1	5.7	1.547						
315	LC	MCS	3		5.9	5.5	1.747						
312	LC	MCS	3		6.7	6.3	2.267						
323	LC	MCS	3		6.3	5.8	2.247						
324	LC	MCS	3		6	5.5	1.625						
316	LC	MCS	3		7.4	6.9	3.141						
318	LC	MCS	3		6.2	5.7	1.922						
308	LC	MCS	3	2	6.8	6.3	2.491	2.15	0.083				
307	LC	MCS	3	2	7.6	7	3.938	3.499	0.04	0.073			
309	LC	MCS	3	2	7.8	7.3	3.14	2.84	0.046				
322	LC	MCS	3		7	6.5	2.933						
313	LC	MCS	3		6.9	6.5	2.669						
314	LC	MCS	3		7.2	6.7	3.102						

Spring 1994 MFO Data

Fish #	Species	Site	Sex	EROD (pmol/mg protein/min)
90	LC	WF	1	0.126
87	LC	WF	1	0.246
89	LC	WF	1	0.097
84	LC	WF	1	0.104
95	LC	WF	1	0.115
93	LC	WF	2	0.131
91	LC	WF	2	0.107
81	LC	WF	2	0.079
60	LC	WF	2	0.024
82	LC	WF	2	0.129
88	LC	WF	2	0.071
85	LC	WF	2	0.098
96	LC	WF	3	0.283
92	LC	WF	3	0.013
148	LC	MB	1	0.039
158	LC	MB	1	0.166
162	LC	MB	1	0.039
166	LC	MB	1	1.467
154	LC	MB	1	0.111
156	LC	MB	2	0.069
164	LC	MB	2	0.045
159	LC	MB	2	0.182
155	LC	MB	2	0.073
144	LC	MB	2	0.088
146	LC	MB	2	0.083
145	LC	MB	2	0.061
152	LC	MB	2	0.083
149	LC	MB	2	0.043
147	LC	MB	2	0.135
167	LC	MB	3	0.012
161	LC	MB	3	0.062
275	LC	MC	1	0.095
278	LC	MC	1	0.160
201	LC	MC	1	0.099
274	LC	MC	1	0.082
258	LC	MC	2	0.072
260	LC	MC	2	0.109
259	LC	MC	2	0.093
256	LC	MC	2	0.192

Fish #	Species	Site	Sex	EROD (pmol/mg protein/min)
204	LC	MC	2	0.053
202	LC	MC	2	0.067
279	LC	MC	2	0.109
254	LC	MC	2	0.075
277	LC	MC	2	0.070
206	LC	MC	3	0.150
205	LC	MC	3	0.116
257	LC	MC	3	0.355
207	LC	MC	3	0.166

Spring 1994 *in vitro* Steroid Data

Fish #	Species	Site	Sex	Treatment	Testosterone (pg/20 follicles)
78	LC	WF	2	basal	14.160
78	LC	WF	2	hCG	23.183
79	LC	WF	2	basal	27.290
79	LC	WF	2	hCG	24.760
80	LC	WF	2	basal	19.323
80	LC	WF	2	hCG	16.708
81	LC	WF	2	basal	14.920
81	LC	WF	2	hCG	22.725
82	LC	WF	2	basal	20.930
82	LC	WF	2	hCG	25.875
83	LC	WF	2	basal	7.680
83	LC	WF	2	hCG	7.680
85	LC	WF	2	basal	7.680
85	LC	WF	2	hCG	7.680
88	LC	WF	2	basal	7.680
88	LC	WF	2	hCG	7.680
91	LC	WF	2	basal	7.680
91	LC	WF	2	hCG	13.503
144	LC	MB	2	basal	14.450
144	LC	MB	2	hCG	53.300
145	LC	MB	2	basal	14.083
145	LC	MB	2	hCG	32.018
146	LC	MB	2	basal	42.708
146	LC	MB	2	hCG	32.425
147	LC	MB	2	basal	17.723
147	LC	MB	2	hCG	10.100
149	LC	MB	2	basal	10.100
149	LC	MB	2	hCG	10.100
152	LC	MB	2	basal	19.070
152	LC	MB	2	hCG	24.605
153	LC	MB	2	basal	74.250
153	LC	MB	2	hCG	159.025
155	LC	MB	2	basal	10.100
155	LC	MB	2	hCG	10.100
202	LC	MC	2	basal	10.100
202	LC	MC	2	hCG	10.100
203	LC	MC	2	basal	10.100
203	LC	MC	2	hCG	10.100
204	LC	MC	2	basal	10.100

Fish #	Species	Site	Sex	Treatment	Testosterone (pg/20 follicles)
204	LC	MC	2	hCG	10.100
254	LC	MC	2	basal	10.100
254	LC	MC	2	hCG	21.763
255	LC	MC	2	basal	10.100
255	LC	MC	2	hCG	154.700
256	LC	MC	2	basal	10.100
256	LC	MC	2	hCG	10.100
258	LC	MC	2	basal	15.373
258	LC	MC	2	hCG	8.320
259	LC	MC	2	basal	28.093
259	LC	MC	2	hCG	22.648
277	LC	MC	2	basal	51.365
277	LC	MC	2	hCG	78.350

Fall 1994 Metric Data

Fish #	Species	Site	Sex	Age (y)	Total Length (cm)	Fork Length (cm)	Total Weight (g)	Carcass Weight (g)	Liver Weight (g)	Gonad Weight (g)	Total Fecundity (# / female)	Egg Weight (mg)	Egg Diameter (mm)
99	SHS	HRL	1	3	9.7		9.83	8.78	0.14	0.21			
100	SHS	HRL	1	4	9.3		9.74	8.69	0.14	0.2			
103	SHS	HRL	1	4	9.5		8.74	7.86	0.12	0.19			
104	SHS	HRL	1	3	9		7.02	6.15	0.11	0.18			
108	SHS	HRL	1	3	8.3		6.37	5.51	0.12	0.21			
109	SHS	HRL	1	4	9.7		7.72	6.55	0.1	0.13			
113	SHS	HRL	1	3	8.9		5.96	5.14	0.1	0.14			
114	SHS	HRL	1	3	9.3		6.98	6.28	0.09	0.14			
115	SHS	HRL	1	3	8.8		5.93	5.36	0.07	0.12			
116	SHS	HRL	1	2	8.1		5.27	4.74	0.07	0.11			
117	SHS	HRL	1	3	8.8		6.23	5.6	0.06	0.13			
119	SHS	HRL	1	3	8.2		4.93	4.41	0.06	0.15			
120	SHS	HRL	1	3	8.6		5.51	4.92	0.08	0.16			
128	SHS	HRL	1	2	6.7		3.02	2.74	0.03	0.06			
155	SHS	HRL	1	5	10.6		12.68	11.18	0.2	0.32			
156	SHS	HRL	1	5	9.9		10.53	9.4	0.19	0.24			
157	SHS	HRL	1	5	9.7		8.94	7.92	0.14	0.19			
159	SHS	HRL	1		8.7		6.2	5.54	0.07	0.18			
160	SHS	HRL	1	4	8.2		5.55	4.99	0.08	0.09			
161	SHS	HRL	1	4	8.3		5.76	5.11	0.05	0.17			
162	SHS	HRL	1	3	9		6.36	5.74	0.07	0.18			
163	SHS	HRL	1	3	8.2		5.11	4.53	0.04	0.13			
164	SHS	HRL	1	3	8		4.64	4.04	0.05	0.1			
166	SHS	HRL	1	4	7.7		4.43	3.9	0.05	0.1			
168	SHS	HRL	1	3	7.8		4.66	4.19	0.04	0.09			
169	SHS	HRL	1	3	7.2		3.77	3.36	0.04	0.08			
101	SHS	HRL	2	4	9.6		8.55	7.43	0.18	0.27	1237.4	0.2182	0.71
102	SHS	HRL	2	4	10		8.99	7.93	0.18	0.21			
105	SHS	HRL	2	4	9.5		8.01	6.94	0.25	0.21			
106	SHS	HRL	2	5	9.1		7.65	6.67	0.16	0.22	1415.7	0.1554	0.66
107	SHS	HRL	2	4	9.9		8.79	7.5	0.21	0.19			
110	SHS	HRL	2	3	9.1		6.52	5.69	0.12	0.19	784.8	0.2421	0.69

Fish #	Species	Site	Sex	Age (y)	Total Length (cm)	Fork Length (cm)	Total Weight (g)	Carcass Weight (g)	Liver Weight (g)	Gonad Weight (g)	Total Fecundity (# / female)	Egg Weight (mg)	Egg Diameter (mm)
111	SHS	HRL	2	3	9.1		5.96	5.28	0.14	0.19			
112	SHS	HRL	2	3	9.2		7.41	6.62	0.1	0.18			
118	SHS	HRL	2	3	8.3		5.06	4.45	0.1	0.13			
121	SHS	HRL	2	2	7.4		3.93	3.45	0.09	0.1			
122	SHS	HRL	2	3	7.9		4.04	3.5	0.08	0.12			0.68
123	SHS	HRL	2	3	7.4		3.32	2.97	0.06	0.1			
124	SHS	HRL	2	3	7.3		3.47		0.08	0.1			
125	SHS	HRL	2	4	7.4		4.04	3.62	0.07	0.1			
126	SHS	HRL	2	3	7.8		4.38	3.98	0.11	0.12			
130	SHS	HRL	2	2	6.9		2.99	2.59	0.02	0.07			
132	SHS	HRL	2	2	6.9		2.64	2.35	0.05	0.07			
158	SHS	HRL	2	4	9		6.35	5.51	0.13	0.19			
165	SHS	HRL	2	3	8.1		4.97	4.32	0.11	0.17			
167	SHS	HRL	2	3	7.7		4.25	3.77	0.07	0.12			
171	SHS	HRL	2	3	7.3		3.34	2.9	0.07	0.09	400	0.225	0.58
172	SHS	HRL	2	4	7.3		3.09	2.76	0.06	0.06			
127	SHS	HRL	3	3	6.5		2.33	2.12	0.05				
129	SHS	HRL	3	1	6.3		1.92	1.75	0.03				
131	SHS	HRL	3		6.5		2.3						
133	SHS	HRL	3	1	6.9		2.48	2.25	0.02				
134	SHS	HRL	3	2	6.7		2.31	2.08	0.04				
135	SHS	HRL	3		5.9		1.6						
136	SHS	HRL	3		6.1		1.93						
137	SHS	HRL	3		6.6		2.13						
138	SHS	HRL	3		6.6		2.02						
139	SHS	HRL	3		5.9		1.51						
140	SHS	HRL	3		5.5		1.54						
141	SHS	HRL	3		6.2		1.95						
142	SHS	HRL	3		6.2		1.95						
143	SHS	HRL	3		6.4		2.11						
144	SHS	HRL	3		6.2		1.63						
145	SHS	HRL	3		6.5		2.19						

Fish #	Species	Site	Sex	Age (y)	Total Length (cm)	Fork Length (cm)	Total Weight (g)	Carcass Weight (g)	Liver Weight (g)	Gonad Weight (g)	Total Fecundity (# / female)	Egg Weight (mg)	Egg Diameter (mm)
146	SHS	HRL	3		5.8		1.5						
147	SHS	HRL	3		6		1.71						
148	SHS	HRL	3		6		1.83						
149	SHS	HRL	3		6.2		2						
150	SHS	HRL	3		6		1.98						
151	SHS	HRL	3		5.9		1.63						
152	SHS	HRL	3		6.2		1.82						
153	SHS	HRL	3		6.4		2.41						
154	SHS	HRL	3		5.7		1.61						
170	SHS	HRL	3	3	7		2.69	2.46	0.02				
173	SHS	HRL	3	2	7.2		2.41	2.23	0.04				
174	SHS	HRL	3		5.6		1.32						
175	SHS	HRL	3		6.1		1.86						
176	SHS	HRL	3		6.1		1.82						
177	SHS	HRL	3		6		1.69						
2	SHS	MAR	1	5	10.3		11.13	9.89	0.22	0.2			
3	SHS	MAR	1	6	9.81		10.24	9.42	0.21	0.26			
4	SHS	MAR	1	5	11		15.02	13.4	0.21	0.3			
6	SHS	MAR	1	5	9		7.29	6.31	0.07	0.14			
7	SHS	MAR	1	3	7.9		4.34	3.79	0.05	0.11			
22	SHS	MAR	1	5	10.4		13.27	11.58	0.27	0.35			
24	SHS	MAR	1	4	11.1		15.88	13.98	0.33	0.47			
27	SHS	MAR	1	4	8.7		6.67	6.1	0.08	0.12			
29	SHS	MAR	1	4	7.5		4.38	3.87	0.06	0.1			
30	SHS	MAR	1	4	9.2		8.01	7.29	0.11	0.17			
32	SHS	MAR	1	4	8.6		5.71	5.08	0.07	0.13			
189	SHS	MAR	1	4	10.7		14.5	12.49	0.26	0.33			
190	SHS	MAR	1	5	11.5		18.69	16.42	0.47	0.47			
191	SHS	MAR	1	4	10.8		13.55	12.25	0.2	0.23			
1	SHS	MAR	2		10.5		11.26	9.86	0.29	0.36			
5	SHS	MAR	2		9.6		8.02	6.65	0.19	0.2			
8	SHS	MAR	2	3	8.1		4.88	4.16	0.1	0.14	562.5	0.24889	0.56

Fish #	Species	Site	Sex	Age (y)	Total Length (cm)	Fork Length (cm)	Total Weight (g)	Carcass Weight (g)	Liver Weight (g)	Gonad Weight (g)	Total Fecundity (# / female)	Egg Weight (mg)	Egg Diameter (mm)
9	SHS	MAR	2	3	6.9		2.86	2.56	0.07	0.07			
23	SHS	MAR	2	6	11.4		18.03	15.75	0.6	0.43			0.75
25	SHS	MAR	2	5	10.6		12.66	10.68	0.38	0.35			
26	SHS	MAR	2	5	10.9		14.06	12.37	0.45	0.37	1866.2	0.19826	0.57
28	SHS	MAR	2		8.9		5.83	4.99	0.13	0.2			
31	SHS	MAR	2	4	8.1		5.05	4.41	0.11	0.17	449.9	0.3778	
33	SHS	MAR	2	4	8.2		5.17	4.44	0.1	0.15			
192	SHS	MAR	2	4	11.1		14.81	12.62	0.43	0.62	1686.6	0.3676	0.64
193	SHS	MAR	2	4	9.8		9.25	7.49	0.19	0.38	839.65	0.45257	0.86
10	SHS	MAR	3	3	7		2.65	2.31	0.03				
11	SHS	MAR	3		6.8		2.63						
12	SHS	MAR	3		6.3		1.94						
13	SHS	MAR	3		6.4		2.38						
14	SHS	MAR	3		5.1		1.37						
17	SHS	MAR	3		6.7		2.44						
18	SHS	MAR	3		6.4		2.23						
19	SHS	MAR	3		5.9		1.64						
20	SHS	MAR	3		5.9		1.87						
21	SHS	MAR	3		6		1.54						
34	SHS	MAR	3		6.7		2.51	2.21	0.02				
35	SHS	MAR	3	3	7		3.11						
36	SHS	MAR	3		6.5		2.37						
37	SHS	MAR	3		6.7		1.86						
38	SHS	MAR	3		6.9		2.33						
39	SHS	MAR	3		5.6		1.19						
40	SHS	MAR	3		6.2		2.09						
41	SHS	MAR	3		5.9		1.57						
42	SHS	MAR	3		6.4		2.37						
43	SHS	MAR	3		6.2		1.71						
44	SHS	MAR	3		6.5		2.02						
45	SHS	MAR	3		6.8		2.21						
46	SHS	MAR	3		6.5		1.91						

Fish #	Species	Site	Sex	Age (y)	Total Length (cm)	Fork Length (cm)	Total Weight (g)	Carcass Weight (g)	Liver Weight (g)	Gonad Weight (g)	Total Fecundity (# / female)	Egg Weight (mg)	Egg Diameter (mm)
47	SHS	MAR	3		6.1		1.64						
48	SHS	MAR	3		4.6		1.41						
49	SHS	MAR	3		6.1		1.9						
50	SHS	MAR	3		5.3		1.3						
51	SHS	MAR	3		6.5		2.13						
52	SHS	MAR	3		7.4		2.96						
194	SHS	MAR	3	4	7.7		3.87	3.48	0.05				
195	SHS	MAR	3		7		3.37						
53	SHS	MAL	1	3	8.5		5.86	5.22	0.09	0.14			
54	SHS	MAL	1	3	8.6		6.24	5.48	0.1	0.17			
68	SHS	MAL	1	6	10.7		15.7	14.19	0.26	0.36			
69	SHS	MAL	1	5	11.3		15.53	13.81	0.2	0.48			
71	SHS	MAL	1	4	8.2		6.28	5.49	0.09	0.14			
73	SHS	MAL	1	5	10.6		12.03	10.79	0.22	0.3			
77	SHS	MAL	1		11		14.25	12.91	0.24	0.39			
78	SHS	MAL	1	3	8.5		6.61	5.93	0.09	0.17			
82	SHS	MAL	1	3	7.8		5.04	4.4	0.09	0.14			
179	SHS	MAL	1	5	9.5		10.14	8.73	0.17	0.25			
180	SHS	MAL	1	5	10.7		15.63	13.92	0.26	0.33			
181	SHS	MAL	1	5	10.5		12.73	11.17	0.22	0.3			
183	SHS	MAL	1	3	7.2		4.38	3.74	0.09	0.11			
67	SHS	MAL	2	5	12		18.23	16.4	0.41	0.72			
70	SHS	MAL	2	4	9.6		9.21	8.02	0.26	0.36	835.5	0.4309	0.61
72	SHS	MAL	2	5	10.8		14.12	12.46	0.37	0.41			
74	SHS	MAL	2	5	10.9		13.7	11.82	0.39	0.62	1206.9	0.5137	0.76
75	SHS	MAL	2	4	9.7		8.51	7.45	0.23	0.31	1103.2	0.281	0.65
76	SHS	MAL	2	3	8.1		5.45	4.68	0.14	0.2	292.1	0.6846	0.81
79	SHS	MAL	2	5	10.5		11.24	9.82	0.26	0.35	1012.7	0.3456	0.73
80	SHS	MAL	2	3	8.5		5.8	4.95	0.19	0.25			0.81
81	SHS	MAL	2	3	7.8		4.22	3.58	0.09	0.14			
178	SHS	MAL	2	6	11.3		15.34	13.1	0.49	0.47			
182	SHS	MAL	2	4	8.8		7.1	6.09	0.19	0.24	779.9	0.3077	0.76

Fish #	Species	Site	Sex	Age (y)	Total Length (cm)	Fork Length (cm)	Total Weight (g)	Carcass Weight (g)	Liver Weight (g)	Gonad Weight (g)	Total Fecundity (# / female)	Egg Weight (mg)	Egg Diameter (mm)
184	SHS	MAL	2	3	7.8		4.6	3.99	0.11	0.14			
185	SHS	MAL	2	2	7.4		4.04	3.39	0.07	0.23			
55	SHS	MAL	3	3	7		2.94	2.65	0.05				
56	SHS	MAL	3	3	6.9		2.81	2.52	0.04				
57	SHS	MAL	3		6.3		2.14						
58	SHS	MAL	3		6.5		2.14						
59	SHS	MAL	3		6.1		1.82						
60	SHS	MAL	3		4.3		0.63						
61	SHS	MAL	3		4.1		0.56						
62	SHS	MAL	3		6.7		2.09						
63	SHS	MAL	3		6.8		2.41						
64	SHS	MAL	3		6.8		1.96						
65	SHS	MAL	3		6.9		2.57						
66	SHS	MAL	3		6		1.75						
83	SHS	MAL	3	2	6.7		2.53	2.37	0.04				
84	SHS	MAL	3	3	7.1		3.46	3.09	0.08				
85	SHS	MAL	3	3	7.1		3.37	3.04	0.04				
86	SHS	MAL	3		6.8		2.86						
87	SHS	MAL	3		6.6		2.26						
88	SHS	MAL	3		6.6		2.44						
89	SHS	MAL	3		6.4		2.35						
90	SHS	MAL	3		6.9		3.18						
91	SHS	MAL	3		5.9		1.81						
92	SHS	MAL	3		4.3		0.8						
93	SHS	MAL	3		6.3		2.25						
94	SHS	MAL	3		3.7		0.48						
95	SHS	MAL	3		6.9		2.7						
96	SHS	MAL	3		6		1.99						
97	SHS	MAL	3		6.5		2.45						
98	SHS	MAL	3		6.5		3.02						
186	SHS	MAL	3	2	6.7		3.1	2.67	0.11				
187	SHS	MAL	3		6.5		2.51						

Fish #	Species	Site	Sex	Age (y)	Total Length (cm)	Fork Length (cm)	Total Weight (g)	Carcass Weight (g)	Liver Weight (g)	Gonad Weight (g)	Total Fecundity (# / female)	Egg Weight (mg)	Egg Diameter (mm)
188	SHS	MAL	3		6.6		2.4						
229	LC	WF	1	2	10.1	9.5	9.18	8.12	0.3	0.07			
231	LC	WF	1	2	10.5	9.8	9.7	8.71	0.16	0.09			
232	LC	WF	1	2	10.2	9.4	8.7	7.77	0.09	0.08			
233	LC	WF	1	2	10.3	9.6	7.98	7.29	0.08	0.09			
238	LC	WF	1	2	9.3	8.6	6.24	5.69	0.07	0.07			
239	LC	WF	1	2	9.7	8.9	6.92	6.22	0.12	0.06			
244	LC	WF	1	1	9.4	8.7	6.4	5.74	0.06	0.06			
246	LC	WF	1	2	9.3	8.6	6.2	5.6	0.09	0.05			
248	LC	WF	1	1	8.8	8.2	4.95	4.46	0.07	0.02			
249	LC	WF	1	1	9.1	8.3	5.25	4.86	0.04	0.04			
224	LC	WF	2	3					0.67	2.45	6820.7127	0.3592	0.85
225	LC	WF	2	2	11.5	10.7	12.11	9.89	0.17	1.05	2501.787	0.4197	0.82
226	LC	WF	2	2	11.4	10.6	12.11	9.88	0.2	0.92	3143.15	0.2927	0.84
227	LC	WF	2	2	11	10.1	10.7	8.73	0.2	0.98	3491.2718	0.2807	0.77
228	LC	WF	2	2	11.1	10.2	11.01	9.18	0.15	0.83	3274.1617	0.2535	0.84
230	LC	WF	2	2	10.5	9.7	10.01	8.3	0.18	0.77	2242.2831	0.3434	0.9
234	LC	WF	2	2	9.6	8.9	6.33	5.29	0.11	0.49	1751.877	0.2797	0.76
235	LC	WF	2	2	9.6	8.7	6.53	5.46	0.08	0.45			
236	LC	WF	2	2	10.1	9.8	7.84	6.63	0.1	0.54			
237	LC	WF	2	2	10.5	9.7	9.06	7.27	0.19	0.89	2595.5089	0.3429	0.74
240	LC	WF	2	2	9.6	8.9	7.03	5.74	0.14	0.59	2011.5922	0.2933	0.85
241	LC	WF	2	2	10	9.3	7.9	6.44	0.16	0.53	1830.7427	0.2895	0.77
242	LC	WF	2	2	10	9.3	6.99	5.81	0.1	0.44	1673.6402	0.2629	0.82
243	LC	WF	2	1	9.4	8.7	6.54	5.45	0.12	0.48	1554.4041	0.3088	0.75
245	LC	WF	2	1	8.8	8.2	4.98	4.22	0.11	0.29	1718.0095	0.1688	0.7
247	LC	WF	2	1	9.2	8.7	5.61	4.94	0.07	0.28			
250	LC	WF	2	1	8.9	8.2	4.85	4.15	0.06	0.16			
251	LC	WF	3	1	8.3	7.8	4.45	4.09	0.05				
252	LC	WF	3		8.7	7.9	4.22						
253	LC	WF	3		8.1	7.4	4.4						
254	LC	WF	3		7	6.6	2.76						

Fish #	Species	Site	Sex	Age (y)	Total Length (cm)	Fork Length (cm)	Total Weight (g)	Carcass Weight (g)	Liver Weight (g)	Gonad Weight (g)	Total Fecundity (# / female)	Egg Weight (mg)	Egg Diameter (mm)
255	LC	WF	3		8.9	8.2	5.13						
256	LC	WF	3		8.3	7.9	4.37						
257	LC	WF	3		7.7	7.3	3.56						
258	LC	WF	3		8.2	7.7	4.35						
259	LC	WF	3		7.6	7	3.24						
260	LC	WF	3		8	7.3	3.86						
261	LC	WF	3		7.7	7.2	3.59						
262	LC	WF	3		8.3	7.8	4.51						
263	LC	WF	3		8.4	7.9	4.73						
264	LC	WF	3		6.8	6.3	2.39						
265	LC	WF	3		6.9	6.4	2.25						
266	LC	WF	3		8.5	8	5.23						
267	LC	WF	3		8.1	7.5	3.82						
268	LC	WF	3		7.4	6.8	2.5						
269	LC	WF	3		7.6	7.2	3.58						
270	LC	WF	3		7.1	6.7	2.7						
271	LC	WF	3		8.4	7.9	3.61						
272	LC	WF	3		7.6	7.2	3.18						
273	LC	WF	3		6.7	6.4	2.49						
274	LC	WF	3		7.7	7.1	3.35						
275	LC	WF	3		7.5	7	3.03						
276	LC	WF	3		7.5	7.1	3.76						
277	LC	WF	3		7.2	6.7	2.99						
278	LC	WF	3		6.7	6.2	2						
279	LC	WF	3		7.4	6.9	2.92						
280	LC	WF	3		7.6	7.2	3.32						
316	LC	R2	1	2	10.1	9.4	9.55	8.67	0.16	0.09			
320	LC	R2	1	1	9.2	8.7	6.46	5.84	0.06	0.03			
321	LC	R2	1	1	9.8	9	7.22	6.59	0.09	0.05			
324	LC	R2	1	1	9.6	8.9	6.91	6.12	0.14	0.07			
325	LC	R2	1	1	9.3	8.6	6.26	5.58	0.08	0.04			
327	LC	R2	1	1	8.8	8.1	5.92	5.4	0.09	0.05			

Fish #	Species	Site	Sex	Age (y)	Total Length (cm)	Fork Length (cm)	Total Weight (g)	Carcass Weight (g)	Liver Weight (g)	Gonad Weight (g)	Total Fecundity (# / female)	Egg Weight (mg)	Egg Diameter (mm)
313	LC	R2	2	2	12	11	14.7	11.56	0.35	1.2	3445.3058	0.3483	0.89
314	LC	R2	2	2	11.1	10.2	11.94	9.95	0.22	0.95	2934.8162	0.3237	0.83
315	LC	R2	2	2	10.1	9.4	9.75		0.24	0.8	2781.7	0.28759	0.8
317	LC	R2	2	2	9.8	9.1	7.77	6.51	0.18	0.54	2968.6641	0.1819	0.78
318	LC	R2	2	2	9.2	8.5	7.61	6.08	0.16	0.68	3037.0701	0.2239	0.75
322	LC	R2	2	2	9.5	8.8	7.59	6.3	0.16	0.49	1609.7	0.30437	0.83
323	LC	R2	2	2	9.2	8.5	6.62	5.36	0.18	0.38			
326	LC	R2	2	1	8.9	8.2	6.08	5.08	0.09	0.4	1434.8	0.27878	0.82
328	LC	R2	2	1	9	8.3	6.03	5.03	0.13	0.36	2007.8081	0.1793	0.58
329	LC	R2	2	1	8.9	8.2	6.01	5.11	0.13	0.27	1326.1	0.20361	0.69
330	LC	R2	2	1	8.5	7.9	5.28	4.28	0.05	0.36			
331	LC	R2	2	1	8.3	7.8	4.63	4.09	0.1	0.08			
332	LC	R2	2	1	8.3	7.8	4.24	3.62	0.06	0.25			
319	LC	R2	3	1	9.1	8.4	6.07	5.36	0.16				
333	LC	R2	3		8.1	7.5	4.02						
334	LC	R2	3		8.3	7.8	4.78						
335	LC	R2	3		6.9	6.3	2.61						
336	LC	R2	3		7.9	7.4	4.32						
337	LC	R2	3		6.7	6.2	2.42						
338	LC	R2	3		8	7.4	4.19						
339	LC	R2	3		7.2	6.8	2.78						
340	LC	R2	3		7.7	7.2	3.56						
341	LC	R2	3		6	5.6	1.86						
342	LC	R2	3		8.4	7.9	4.39						
343	LC	R2	3		7.5	7	3.29						
344	LC	R2	3		6.3	5.9	1.83						
345	LC	R2	3		7.8	7.1	4.08						
346	LC	R2	3		8	7.4	3.84						
347	LC	R2	3		5.8	5.3	1.49						
348	LC	R2	3		7.5	7.1	3.73						
349	LC	R2	3		7.2	6.8	2.76						
350	LC	R2	3		5.7	5.4	1.36						

Fish #	Species	Site	Sex	Age (y)	Total Length (cm)	Fork Length (cm)	Total Weight (g)	Carcass Weight (g)	Liver Weight (g)	Gonad Weight (g)	Total Fecundity (# / female)	Egg Weight (mg)	Egg Diameter (mm)
351	LC	R2	3		6.2	5.8	1.86						
352	LC	R2	3		7.1	6.7	2.91						
353	LC	R2	3		7.5	7	3.46						
354	LC	R2	3		7.1	6.5	2.65						
355	LC	R2	3		5.5	5.1	1.28						
356	LC	R2	3		6.7	6.2	2.24						
357	LC	R2	3		6.9	6.4	2.62						
202	LC	MB	1	2	10.4	9.6	9.07	8.03	0.15	0.1			
203	LC	MB	1	2	11.2	10.3	10.49	9.41	0.13	0.12			
204	LC	MB	1	2	11	10.3	10.46	9.39	0.17	0.1			
206	LC	MB	1	2	10.4	9.6	8.24	7.32	0.14	0.07			
210	LC	MB	1	2	9.9	9.1	7.08	6.36	0.13	0.07			
211	LC	MB	1	2	9.6	8.9	6.88	6.15	0.16	0.05			
212	LC	MB	1	2	9.7	8.9	6.78	6.19	0.09	0.05			
286	LC	MB	1	2	9.2	8.5	7.06	6.4	0.14	0.08			
287	LC	MB	1	1	9.2	8.6	5.67	5.14	0.12	0.06			
288	LC	MB	1	1	8.4	7.8	5.03	4.6	0.12	0.03			
201	LC	MB	2	2	12.1	11.1	14.25	11.69	0.22	1.32	4327.8689	0.305	0.74
205	LC	MB	2	2	10	9.3	8.39	6.93	0.16	0.62	2158.7744	0.2872	0.78
207	LC	MB	2	2	10.7	10.1	9.24	7.78	0.17	0.65	1942.0376	0.3347	0.83
208	LC	MB	2	1	9.5	8.9	6.36	5.35	0.09	0.45	2123.6432	0.2119	0.71
209	LC	MB	2	2	9.3	8.6	6.2	5.19	0.14	0.42	1539.5894	0.2728	0.72
213	LC	MB	2	1	9	8.2	5.52	4.7	0.09	0.3	1113.9993	0.2693	0.74
214	LC	MB	2	2	9.1	8.4	5.75	4.75	0.11	0.35	1627.1502	0.2151	0.61
215	LC	MB	2	2	8.8	8.2	5.21	4.39	0.08	0.43	1404.7697	0.3061	0.68
216	LC	MB	2	1	8.8	8.1	4.5	3.97	0.07	0.14			
217	LC	MB	2	1	7.6	7	3.47	2.98	0.05	0.15			
281	LC	MB	2	2	11.7	11	12.86	10.67	0.17	1.09	3923.6861	0.2778	0.82
282	LC	MB	2	1	10.4	9.7	9.3	7.55	0.18	0.71	1874.34	0.3788	0.85
283	LC	MB	2	1	10.2	9.6	8.11	6.86	0.11	0.56	2365.864	0.2367	0.69
284	LC	MB	2	2	10.3	9.6	8.22	6.94	0.12	0.54			
285	LC	MB	2	2	10.1	9.2	8.55	7.19	0.15	0.59	3072.9167	0.192	0.73

Fish #	Species	Site	Sex	Age (y)	Total Length (cm)	Fork Length (cm)	Total Weight (g)	Carcass Weight (g)	Liver Weight (g)	Gonad Weight (g)	Total Fecundity (# / female)	Egg Weight (mg)	Egg Diameter (mm)
218	LC	MB	3	1	8.2	7.6	3.97	3.6	0.09				
219	LC	MB	3		6.9	6.4	2.33						
220	LC	MB	3		6.8	6.3	2.35						
221	LC	MB	3		6.5	5.9	1.79						
222	LC	MB	3		6	5.6	1.63						
223	LC	MB	3		7.2	6.6	2.65						
289	LC	MB	3	1	8.7	8	5.14	4.57	0.05				
290	LC	MC	1	1	10.7	9.9	10.65	9.7	0.15	0.09			
291	LC	MC	1	2	10.1	9.3	9.29	8.44	0.14	0.1			
293	LC	MC	1	2	10.2	9.4	9	8.27	0.09	0.05			
294	LC	MC	1	2	9.9	9.3	7.96	7.27	0.16	0.06			
296	LC	MC	1	1	8.5	7.9	5.68	5.1	0.11	0.03			
304	LC	MC	1	1	9.4	8.8	8.01	7.35	0.11	0.06			
305	LC	MC	1	2	10.8	10	10.01	9.1	0.13	0.1			
307	LC	MC	1	1	9.6	8.8	7.78	6.86	0.17	0.06			
308	LC	MC	1	1	9.3	8.7	6.2	5.64	0.06	0.07			
310	LC	MC	1	1	8.9	8.2	6.17	5.61	0.06	0.05			
197	LC	MC	2	2	11.3	9.8	10.29	8.8	0.13	0.74	3165.0984	0.2338	0.68
200	LC	MC	2	2	8.4	7.8	5.21	4.43	0.11	0.29	1053.3963	0.2753	0.72
292	LC	MC	2	2	9.7	9	8.92	7.06	0.25	0.68	2533.532	0.2684	0.67
295	LC	MC	2	2	9.9	9.3	8.29	6.55	0.21	0.74	2696.793	0.2744	0.74
298	LC	MC	2	1	7	6.5	2.96	2.49	0.03	0.17			
306	LC	MC	2	1	9.7	8.9	8.23	6.69	0.17	0.65	2492.3313	0.2608	0.79
309	LC	MC	2	1	9	8.3	6.36	5.37	0.09	0.49	2304.7977	0.2126	0.8
198	LC	MC	3	2	9.4	8.8	6.35	5.81	0.09				
199	LC	MC	3	1	8.8	8.1	5.61	5.09	0.05				
297	LC	MC	3	1	8.2	7.7	4.34	3.93	0.08				
299	LC	MC	3	1	6.4	6.3	2.58	2.27	0.05				
300	LC	MC	3		5.7	5.3	1.5	1.38					
301	LC	MC	3		7	6.5	2.87						
302	LC	MC	3		5.4	5.1	1.21						
303	LC	MC	3		5.7	5.4	1.63						

Fish #	Species	Site	Sex	Age (y)	Total Length (cm)	Fork Length (cm)	Total Weight (g)	Carcass Weight (g)	Liver Weight (g)	Gonad Weight (g)	Total Fecundity (# / female)	Egg Weight (mg)	Egg Diameter (mm)
311	LC	MC	3		7.2	6.8	2.9	2.55	0.05				
312	LC	MC	3		6.6	6.1	2.22	2.06	0.04				

Fall 1994 MFO Data

Fish #	Species	Site	Sex	EROD (pmol/mg protein/min)
103	SHS	HRL	1	2.265
104	SHS	HRL	1	6.77
120	SHS	HRL	1	0.818
100	SHS	HRL	1	3.889
108	SHS	HRL	1	4.715
109	SHS	HRL	1	1.62
115	SHS	HRL	1	0.90
114	SHS	HRL	1	1.23
113	SHS	HRL	1	3.37
119	SHS	HRL	1	1.85
117	SHS	HRL	1	0.69
116	SHS	HRL	1	4.550
169	SHS	HRL	1	12.541
161	SHS	HRL	1	5.79
160	SHS	HRL	1	1.376
159	SHS	HRL	1	2.92
164	SHS	HRL	1	3.855
163	SHS	HRL	1	1.826
162	SHS	HRL	1	0.510
155	SHS	HRL	1	2.40
99	SHS	HRL	1	1.047
168	SHS	HRL	1	-0.184
156	SHS	HRL	1	2.451
166	SHS	HRL	1	1.39
157	SHS	HRL	1	2.997
107	SHS	HRL	2	1.070
106	SHS	HRL	2	2.235
101	SHS	HRL	2	1.232
102	SHS	HRL	2	1.557
105	SHS	HRL	2	1.227
126	SHS	HRL	2	0.945
125	SHS	HRL	2	1.607
124	SHS	HRL	2	2.656
158	SHS	HRL	2	2.754
132	SHS	HRL	2	1.05
130	SHS	HRL	2	0.961
118	SHS	HRL	2	1.46
111	SHS	HRL	2	1.435
110	SHS	HRL	2	2.626

Fish #	Species	Site	Sex	EROD (pmol/mg protein/min)
123	SHS	HRL	2	3.63
122	SHS	HRL	2	1.172
121	SHS	HRL	2	0.897
165	SHS	HRL	2	5.149
171	SHS	HRL	2	2.837
172	SHS	HRL	2	2.30
167	SHS	HRL	2	0.217
134	SHS	HRL	3	8.00
129	SHS	HRL	3	1.469
127	SHS	HRL	3	1.856
170	SHS	HRL	3	4.685
173	SHS	HRL	3	-0.72
133	SHS	HRL	3	1.316
30	SHS	MAR	1	2.82
29	SHS	MAR	1	2.581
24	SHS	MAR	1	4.007
22	SHS	MAR	1	1.464
3	SHS	MAR	1	2.26
2	SHS	MAR	1	1.588
4	SHS	MAR	1	4.415
7	SHS	MAR	1	1.865
6	SHS	MAR	1	0.863
32	SHS	MAR	1	2.404
190	SHS	MAR	1	2.999
191	SHS	MAR	1	3.071
189	SHS	MAR	1	4.254
192	SHS	MAR	2	2.788
193	SHS	MAR	2	3.69
9	SHS	MAR	2	1.81
8	SHS	MAR	2	6.057
5	SHS	MAR	2	0.82
1	SHS	MAR	2	2.12
28	SHS	MAR	2	2.848
31	SHS	MAR	2	6.343
33	SHS	MAR	2	2.438
74	SHS	MAR	2	3.319
23	SHS	MAR	2	3.156
26	SHS	MAR	2	1.374
25	SHS	MAR	2	2.353

Fish #	Species	Site	Sex	EROD (pmol/mg protein/min)
13	SHS	MAR	3	8.42
194	SHS	MAR	3	0.787
34	SHS	MAR	3	0.271
10	SHS	MAR	3	1.54
183	SHS	MAL	1	26.102
179	SHS	MAL	1	14.688
181	SHS	MAL	1	8.281
180	SHS	MAL	1	6.746
68	SHS	MAL	1	4.96
77	SHS	MAL	1	7.41
69	SHS	MAL	1	2.985
82	SHS	MAL	1	3.69
54	SHS	MAL	1	0.442
53	SHS	MAL	1	4.71
71	SHS	MAL	1	0.595
70	SHS	MAL	2	2.34
182	SHS	MAL	2	8.216
67	SHS	MAL	2	6.539
185	SHS	MAL	2	0.084
184	SHS	MAL	2	5.249
79	SHS	MAL	2	1.425
80	SHS	MAL	2	10.108
81	SHS	MAL	2	1.500
72	SHS	MAL	2	4.139
178	SHS	MAL	2	3.216
75	SHS	MAL	2	7.121
55	SHS	MAL	3	2.291
84	SHS	MAL	3	7.196
85	SHS	MAL	3	0.230
186	SHS	MAL	3	14.978
83	SHS	MAL	3	3.503
56	SHS	MAL	3	5.20
233	LC	WF	1	1.063
238	LC	WF	1	1.26
232	LC	WF	1	4.677
229	LC	WF	1	2.089
231	LC	WF	1	2.615
248	LC	WF	1	6.975
249	LC	WF	1	0.94

Fish #	Species	Site	Sex	EROD (pmol/mg protein/min)
246	LC	WF	1	1.222
239	LC	WF	1	6.221
244	LC	WF	1	0.89
235	LC	WF	2	2.029
236	LC	WF	2	1.55
237	LC	WF	2	2.303
228	LC	WF	2	4.187
230	LC	WF	2	1.41
234	LC	WF	2	2.183
240	LC	WF	2	1.91
245	LC	WF	2	2.86
247	LC	WF	2	2.70
250	LC	WF	2	0.387
241	LC	WF	2	1.949
242	LC	WF	2	1.52
243	LC	WF	2	1.970
225	LC	WF	2	3.011
224	LC	WF	2	2.260
227	LC	WF	2	0.50
251	LC	WF	3	1.746
316	LC	R2	1	7.501
324	LC	R2	1	3.661
320	LC	R2	1	1.388
321	LC	R2	1	2.12
327	LC	R2	1	1.77
325	LC	R2	1	2.54
322	LC	R2	2	0.94
318	LC	R2	2	1.69
331	LC	R2	2	3.209
332	LC	R2	2	2.72
317	LC	R2	2	4.564
328	LC	R2	2	3.740
326	LC	R2	2	4.73
330	LC	R2	2	3.769
329	LC	R2	2	2.284
319	LC	R2	3	0.219
287	LC	MB	1	2.620
286	LC	MB	1	3.351
288	LC	MB	1	1.090

Fish #	Species	Site	Sex	EROD (pmol/mg protein/min)
203	LC	MB	1	3.581
204	LC	MB	1	4.08
206	LC	MB	1	0.04
202	LC	MB	1	3.60
210	LC	MB	1	2.060
211	LC	MB	1	3.182
212	LC	MB	1	2.08
201	LC	MB	2	3.695
207	LC	MB	2	2.372
215	LC	MB	2	1.279
217	LC	MB	2	1.059
214	LC	MB	2	2.699
208	LC	MB	2	1.322
205	LC	MB	2	1.816
283	LC	MB	2	5.311
282	LC	MB	2	0.944
284	LC	MB	2	2.251
216	LC	MB	2	0.287
281	LC	MB	2	0.71
218	LC	MB	3	2.054
308	LC	MC	1	5.165
310	LC	MC	1	5.85
293	LC	MC	1	4.34
294	LC	MC	1	3.216
290	LC	MC	1	2.309
291	LC	MC	1	4.520
296	LC	MC	1	3.450
305	LC	MC	1	3.36
307	LC	MC	1	3.95
304	LC	MC	1	3.354
200	LC	MC	2	1.99
197	LC	MC	2	2.053
298	LC	MC	2	2.744
306	LC	MC	2	1.02
292	LC	MC	2	2.13
295	LC	MC	2	1.239
314	LC	MC	2	3.628
315	LC	MC	2	4.543
309	LC	MC	2	2.250

Fish #	Species	Site	Sex	EROD (pmol/mg protein/min)
313	LC	MC	2	2.57
311	LC	MC	3	3.260
299	LC	MC	3	3.35
297	LC	MC	3	2.387
199	LC	MC	3	3.092
198	LC	MC	3	2.480
312	LC	MC	3	0.91

Fall 1994 *in vitro* Steroid Data for Spoonhead Sculpin

Fish #	Species	Site	Sex	Treatment	Estradiol (pg/20 follicles)	Testosterone (pg/20 follicles)
101	SHS	HRL	2	basal	87.183	4.440
101	SHS	HRL	2	hCG	79.300	4.405
102	SHS	HRL	2	basal	79.023	11.230
102	SHS	HRL	2	hCG	71.600	4.405
105	SHS	HRL	2	basal	107.367	4.440
105	SHS	HRL	2	hCG	123.983	6.277
106	SHS	HRL	2	basal	69.200	4.440
106	SHS	HRL	2	hCG	91.783	4.405
107	SHS	HRL	2	basal	84.983	4.440
107	SHS	HRL	2	hCG	64.567	4.405
110	SHS	HRL	2	basal	72.300	4.440
110	SHS	HRL	2	hCG	79.333	4.405
111	SHS	HRL	2	basal	89.517	4.440
111	SHS	HRL	2	hCG	85.700	4.405
112	SHS	HRL	2	basal	61.917	4.440
112	SHS	HRL	2	hCG	56.328	4.405
118	SHS	HRL	2	basal	83.250	4.440
118	SHS	HRL	2	hCG	95.700	8.935
121	SHS	HRL	2	basal	75.333	5.320
121	SHS	HRL	2	hCG	71.833	4.680
122	SHS	HRL	2	basal	62.983	5.760
122	SHS	HRL	2	hCG	63.050	4.818
123	SHS	HRL	2	basal	92.433	5.760
123	SHS	HRL	2	hCG	108.700	4.818
124	SHS	HRL	2	basal	55.183	5.760
124	SHS	HRL	2	hCG	55.613	4.818
158	SHS	HRL	2	basal	98.133	5.760
158	SHS	HRL	2	hCG	90.000	4.818
165	SHS	HRL	2	basal	60.017	5.760
165	SHS	HRL	2	hCG	68.900	4.818
167	SHS	HRL	2	basal	58.005	5.760
167	SHS	HRL	2	hCG	68.200	4.818
171	SHS	HRL	2	basal	93.067	5.760
171	SHS	HRL	2	hCG	87.625	4.818
172	SHS	HRL	2	basal	81.550	5.760
172	SHS	HRL	2	hCG	91.333	4.818
1	SHS	MAR	2	basal	92.167	24.457
1	SHS	MAR	2	hCG	110.425	5.640
5	SHS	MAR	2	basal	129.183	12.800

Fish #	Species	Site	Sex	Treatment	Estradiol (pg/20 follicles)	Testosterone (pg/20 follicles)
5	SHS	MAR	2	hCG	132.200	5.640
8	SHS	MAR	2	basal	94.683	6.328
8	SHS	MAR	2	hCG	117.100	5.640
9	SHS	MAR	2	basal	90.900	6.328
9	SHS	MAR	2	hCG	117.767	5.640
23	SHS	MAR	2	basal	120.700	6.328
23	SHS	MAR	2	hCG	135.150	5.640
25	SHS	MAR	2	basal	143.467	17.480
25	SHS	MAR	2	hCG	154.750	5.640
26	SHS	MAR	2	basal	102.600	9.400
26	SHS	MAR	2	hCG	144.350	5.640
28	SHS	MAR	2	basal	154.050	6.328
28	SHS	MAR	2	hCG	157.233	5.640
31	SHS	MAR	2	basal	139.567	6.328
31	SHS	MAR	2	hCG	179.300	5.640
33	SHS	MAR	2	basal	152.633	6.328
33	SHS	MAR	2	hCG	153.517	5.640
192	SHS	MAR	2	basal	83.700	6.328
192	SHS	MAR	2	hCG	102.600	5.640
193	SHS	MAR	2	basal	64.967	6.328
193	SHS	MAR	2	hCG	71.517	5.640
67	SHS	MAL	2	basal	105.067	12.218
67	SHS	MAL	2	hCG	121.483	9.165
70	SHS	MAL	2	basal	97.483	13.692
70	SHS	MAL	2	hCG	95.367	4.405
72	SHS	MAL	2	basal	84.333	11.548
72	SHS	MAL	2	hCG	84.017	6.512
74	SHS	MAL	2	basal	76.717	15.042
74	SHS	MAL	2	hCG	86.400	7.707
75	SHS	MAL	2	basal	60.833	22.497
75	SHS	MAL	2	hCG	49.882	16.680
76	SHS	MAL	2	basal	124.600	21.847
76	SHS	MAL	2	hCG	141.983	7.582
79	SHS	MAL	2	basal	98.083	17.635
79	SHS	MAL	2	hCG	89.633	12.395
80	SHS	MAL	2	basal	87.633	15.735
80	SHS	MAL	2	hCG	87.717	4.405
81	SHS	MAL	2	basal	97.533	12.143
81	SHS	MAL	2	hCG	94.050	6.590

Fish #	Species	Site	Sex	Treatment	Estradiol (pg/20 follicles)	Testosterone (pg/20 follicles)
178	SHS	MAL	2	basal	93.067	11.988
178	SHS	MAL	2	hCG	97.550	4.405
182	SHS	MAL	2	basal	150.550	13.463
182	SHS	MAL	2	hCG	159.050	4.405

Fall 1994 *in vitro* Steroid Data for Lake Chub

Fish #	Species	Site	Sex	Treatment	Estradiol (pg/20 follicles)	Testosterone (pg/20 follicles)
224	LC	WF	2	basal	157.367	15.567
224	LC	WF	2	hCG	163.450	4.188
225	LC	WF	2	basal	112.975	4.403
225	LC	WF	2	hCG	159.700	4.188
226	LC	WF	2	basal	75.833	13.520
226	LC	WF	2	hCG	90.800	4.188
227	LC	WF	2	basal	50.967	4.203
227	LC	WF	2	hCG	64.917	5.907
228	LC	WF	2	basal	53.895	4.203
228	LC	WF	2	hCG	90.550	8.572
230	LC	WF	2	basal	70.033	4.203
230	LC	WF	2	hCG	86.317	4.188
234	LC	WF	2	basal	90.950	6.787
234	LC	WF	2	hCG	130.583	4.188
236	LC	WF	2	basal	86.783	11.708
236	LC	WF	2	hCG	96.600	4.188
237	LC	WF	2	basal	60.083	7.369
237	LC	WF	2	hCG	143.733	4.188
240	LC	WF	2	basal	111.983	7.359
240	LC	WF	2	hCG	162.567	4.188
241	LC	WF	2	basal	21.418	4.203
241	LC	WF	2	hCG	18.798	4.188
243	LC	WF	2	basal	129.383	4.203
243	LC	WF	2	hCG	194.800	4.188
245	LC	WF	2	basal	113.300	9.103
245	LC	WF	2	hCG	135.983	4.188
313	LC	R2	2	basal	58.317	4.403
313	LC	R2	2	hCG	109.633	14.490
314	LC	R2	2	basal	117.283	12.613
314	LC	R2	2	hCG	174.367	15.430
315	LC	R2	2	basal	73.367	9.073
315	LC	R2	2	hCG	159.683	17.858
317	LC	R2	2	basal	48.315	13.182
317	LC	R2	2	hCG	85.917	11.270
318	LC	R2	2	basal	35.143	6.417
318	LC	R2	2	hCG	70.115	10.411
322	LC	R2	2	basal	84.983	9.053
322	LC	R2	2	hCG	129.650	11.540
326	LC	R2	2	basal	46.293	4.403

Fish #	Species	Site	Sex	Treatment	Estradiol (pg/20 follicles)	Testosterone (pg/20 follicles)
326	LC	R2	2	hCG	78.000	6.657
328	LC	R2	2	basal	75.733	4.403
328	LC	R2	2	hCG	113.538	5.702
329	LC	R2	2	basal	153.250	11.438
329	LC	R2	2	hCG	322.983	8.824
201	LC	MB	2	basal	69.183	9.192
201	LC	MB	2	hCG	67.400	19.788
205	LC	MB	2	basal	57.963	6.822
205	LC	MB	2	hCG	50.650	16.318
207	LC	MB	2	basal	47.737	5.728
207	LC	MB	2	hCG	56.023	16.257
208	LC	MB	2	basal	44.447	7.903
208	LC	MB	2	hCG	74.083	14.962
209	LC	MB	2	basal	74.850	3.790
209	LC	MB	2	hCG	96.400	16.010
213	LC	MB	2	basal	30.642	5.740
213	LC	MB	2	hCG	14.423	14.352
214	LC	MB	2	basal	78.367	9.713
214	LC	MB	2	hCG	226.483	19.788
215	LC	MB	2	basal	33.558	8.688
215	LC	MB	2	hCG	32.668	13.968
216	LC	MB	2	basal	1.425	8.942
216	LC	MB	2	hCG	1.884	16.588
281	LC	MB	2	basal	82.750	13.538
281	LC	MB	2	hCG	72.067	19.585
282	LC	MB	2	basal	148.683	10.003
282	LC	MB	2	hCG	234.150	14.410
283	LC	MB	2	basal	59.363	10.500
283	LC	MB	2	hCG	56.783	14.612
285	LC	MB	2	basal	81.683	12.490
285	LC	MB	2	hCG	113.967	26.520
197	LC	MC	2	basal	63.300	18.228
197	LC	MC	2	hCG	76.940	13.945
200	LC	MC	2	basal	84.933	9.363
200	LC	MC	2	hCG	138.533	12.663
292	LC	MC	2	basal	59.967	7.916
292	LC	MC	2	hCG	82.683	15.078
295	LC	MC	2	basal	49.062	11.262
295	LC	MC	2	hCG	71.217	29.502

Fish #	Species	Site	Sex	Treatment	Estradiol (pg/20 follicles)	Testosterone (pg/20 follicles)
306	LC	MC	2	basal	53.133	17.230
306	LC	MC	2	hCG	75.733	18.212
309	LC	MC	2	basal	57.347	18.392
309	LC	MC	2	hCG	83.192	28.047

Spring 1995 Metric Data

Fish #	Species	Site	Sex	Age (yr)	Total Length (cm)	Total Weight (g)	Carcass Weight (g)	Liver Weight (g)	Gonad Weight (g)	Female Gonad Condition	Total Fecundity (# /female)	Egg Weight (mg)	Egg Diameter (mm)
36	SHS	HRL	1	5	9.5	9.882	8.534	0.185	0.215				
35	SHS	HRL	1	6	10.0	10.663	9.576	0.155	0.177				
39	SHS	HRL	1	4	8.9	6.535	5.960	0.122	0.115				
37	SHS	HRL	1	4	9.2	8.477	7.458	0.137	0.197				
34	SHS	HRL	1	6	9.8	10.224	8.998	0.104	0.123				
30	SHS	HRL	1	5	10.3	12.601	11.002	0.178	0.204				
130	SHS	HRL	1	3	6.9	3.459	2.898	0.086	0.068				
32	SHS	HRL	1	4	9.5	9.261	8.062	0.187	0.162				
31	SHS	HRL	1	6	10.8	14.708	12.329	0.170	0.241				
47	SHS	HRL	1	3	8.8	6.184	5.587	0.086	0.098				
45	SHS	HRL	1	3	8.8	6.596	5.775	0.086	0.099				
50	SHS	HRL	1	3	8.4	5.721	5.059	0.063	0.113				
48	SHS	HRL	1	3	8.0	5.081	4.309	0.092	0.111				
44	SHS	HRL	1	3	8.7	6.201	5.472	0.090	0.143				
41	SHS	HRL	1	4	9.0	7.045	6.308	0.068	0.090				
40	SHS	HRL	1	4	9.0	7.286	6.292	0.143	0.093				
43	SHS	HRL	1	4	9.0	8.104	7.186	0.144	0.152				
42	SHS	HRL	1	4	9.2	6.803	5.995	0.100	0.155				
129	SHS	HRL	1	3	7.9	5.153	4.234	0.091	0.071				
115	SHS	HRL	1	4	8.7	6.504	5.443	0.118	0.114				
124	SHS	HRL	1	4	8.8	6.975	5.776	0.079	0.064				
127	SHS	HRL	1	4	8.5	5.860	4.914	0.105	0.131				
126	SHS	HRL	1	4	8.7	7.212	5.912	0.072	0.181				
117	SHS	HRL	1	4	9.2	8.291	7.099	0.146	0.179				
118	SHS	HRL	1	4	9.5	8.675	7.443	0.122	0.104				
120	SHS	HRL	1	4	8.2	6.143	5.146	0.106	0.115				
122	SHS	HRL	1	4	8.7	6.778	5.743	0.093	0.145				
121	SHS	HRL	1	4	8.9	7.777	6.240	0.094	0.114				
114	SHS	HRL	1	4	8.6	7.067	5.801	0.140	0.121				
112	SHS	HRL	1	6	10.6	14.179	12.000	0.180	0.220				
111	SHS	HRL	1	5	10.3	12.346	10.987	0.097	0.191				
128	SHS	HRL	1	4	7.8	5.061	4.221	0.094	0.081				

Fish #	Species	Site	Sex	Age (yr)	Total Length (cm)	Total Weight (g)	Carcass Weight (g)	Liver Weight (g)	Gonad Weight (g)	Female Gonad Condition	Total Fecundity (# /female)	Egg Weight (mg)	Egg Diameter (mm)
51	SHS	HRL	2	3	7.7	4.887	3.278	0.128	0.999	1			
54	SHS	HRL	2	3	7.4	4.347	2.848	0.099	0.913	1	185	4.95	1.57
53	SHS	HRL	2	3	7.7	3.772	2.795	0.090	0.517	1	103	5.00	1.97
113	SHS	HRL	2	5	10.1	9.041	7.561	0.166	0.163	2			
46	SHS	HRL	2	3	8.4	6.414	4.450	0.075	1.258	1	331	3.80	1.71
49	SHS	HRL	2	3	8.6	5.985	4.445	0.139	1.014	1	185	5.48	1.70
116	SHS	HRL	2	4	9.4	6.412	5.259	0.143	0.131	2			
119	SHS	HRL	2	3	8.2	4.816	3.306	0.112	0.956	1	252	3.80	1.87
33	SHS	HRL	2	4	9.7	8.674	5.860	0.137	1.863	1	252	7.40	2.12
125	SHS	HRL	2	4	8.5	5.806	3.911	0.136	0.941	1	271	3.47	1.56
38	SHS	HRL	2	4	8.6	5.999	4.318	0.150	1.192	1	343	3.48	1.34
123	SHS	HRL	2	4	7.9	5.591	3.580	0.093	1.258	1	263	4.79	1.71
76	SHS	HRL	3		7.0	2.558							
75	SHS	HRL	3		7.1	3.059							
77	SHS	HRL	3		6.2	1.752							
79	SHS	HRL	3		7.2	2.964							
78	SHS	HRL	3		4.4	0.596							
74	SHS	HRL	3		6.2	2.450							
70	SHS	HRL	3		6.5	2.251							
69	SHS	HRL	3		4.3	0.703							
71	SHS	HRL	3		5.1	2.059							
73	SHS	HRL	3		6.7	2.624							
72	SHS	HRL	3		5.2	1.143							
80	SHS	HRL	3		6.0	2.068							
86	SHS	HRL	3		6.2	1.890							
135	SHS	HRL	3		6.2	2.704							
85	SHS	HRL	3		7.1	3.223							
83	SHS	HRL	3		6.3	2.385							
84	SHS	HRL	3		7.3	3.396							
134	SHS	HRL	3		6.6	2.661							
131	SHS	HRL	3	3	7.1	3.021	2.610	0.047					
81	SHS	HRL	3		7.1	2.873							

Fish #	Species	Site	Sex	Age (yr)	Total Length (cm)	Total Weight (g)	Carcass Weight (g)	Liver Weight (g)	Gonad Weight (g)	Female Gonad Condition	Total Fecundity (# /female)	Egg Weight (mg)	Egg Diameter (mm)
132	SHS	HRL	3	3	7.2	3.375	2.712	0.072					
133	SHS	HRL	3		6.7	2.564							
82	SHS	HRL	3		6.6	2.367							
68	SHS	HRL	3		6.7	2.767							
148	SHS	HRL	3		7.0	3.195							
147	SHS	HRL	3		6.3	2.272							
150	SHS	HRL	3		6.3	2.269							
149	SHS	HRL	3		6.0	1.698							
146	SHS	HRL	3		6.4	2.130							
143	SHS	HRL	3		6.2	2.046							
142	SHS	HRL	3		6.7	2.486							
145	SHS	HRL	3		6.4	2.278							
144	SHS	HRL	3		5.6	1.853							
151	SHS	HRL	3		6.2	2.232							
158	SHS	HRL	3		6.6	2.707							
157	SHS	HRL	3		6.6	2.312							
160	SHS	HRL	3		6.7	2.042							
159	SHS	HRL	3		6.7	2.426							
156	SHS	HRL	3		4.4	0.959							
153	SHS	HRL	3		4.1	0.672							
152	SHS	HRL	3		6.3	2.110							
155	SHS	HRL	3		6.6	2.294							
154	SHS	HRL	3		6.7	2.413							
141	SHS	HRL	3		6.7	2.730							
61	SHS	HRL	3		6.0	1.753							
62	SHS	HRL	3		4.3	0.633							
59	SHS	HRL	3		6.8	2.967							
60	SHS	HRL	3		6.5	2.999							
63	SHS	HRL	3		5.4	1.422							
66	SHS	HRL	3		6.1	1.983							
67	SHS	HRL	3		6.3	2.453							
64	SHS	HRL	3		5.5	1.528							

Fish #	Species	Site	Sex	Age (yr)	Total Length (cm)	Total Weight (g)	Carcass Weight (g)	Liver Weight (g)	Gonad Weight (g)	Female Gonad Condition	Total Fecundity (# /female)	Egg Weight (mg)	Egg Diameter (mm)
65	SHS	HRL	3		6.6	2.530							
58	SHS	HRL	3		6.7	2.396							
138	SHS	HRL	3		6.1	1.907							
137	SHS	HRL	3		6.3	2.092							
140	SHS	HRL	3		6.0	1.478							
139	SHS	HRL	3		6.1	2.240							
136	SHS	HRL	3		6.6	2.853							
56	SHS	HRL	3	3	7.3	3.282	2.843	0.027					
57	SHS	HRL	3		6.5	2.571							
52	SHS	HRL	3	3	7.8	3.670	3.417	0.045					
55	SHS	HRL	3	3	7.2	3.700	3.106	0.024	0.035				
426	SHS	HRR	1	4	9.6	8.697	7.676	0.040	0.091				
427	SHS	HRR	1	4	8.1	5.579	4.734	0.086	0.076				
424	SHS	HRR	1	4	9.5	6.805	5.810	0.111	0.041				
425	SHS	HRR	1	4	9.0	6.808	6.201	0.121	0.042				
318	SHS	HRR	1	4	8.4	5.960	5.002	0.065	0.084				
300	SHS	HRR	1	5	10.4	11.744	10.206	0.131	0.060				
301	SHS	HRR	1	4	10.0	10.602	9.050	0.138	0.142				
320	SHS	HRR	1	5	9.0	8.268	6.838	0.142	0.047				
341	SHS	HRR	1	3	7.2	3.414	3.115	0.059	0.029				
334	SHS	HRR	1	3	8.2	5.135	4.388	0.070	0.075				
312	SHS	HRR	1	3	9.2	6.451	5.645	0.069	0.085				
315	SHS	HRR	1	4	9.1	7.395	6.214	0.152	0.097				
337	SHS	HRR	1	3	7.7	4.619	3.726	0.055	0.056				
316	SHS	HRR	1	4	8.7	6.609	5.506	0.050	0.128				
311	SHS	HRR	1	3	8.8	6.573	5.679	0.062	0.043				
325	SHS	HRR	1	4	8.3	5.693	4.596	0.080	0.072				
330	SHS	HRR	1	5	8.4	5.463	4.626	0.062	0.056				
328	SHS	HRR	1	5	8.6	5.665	5.051	0.076	0.097				
302	SHS	HRR	1	5	9.9	10.224	8.657	0.128	0.066				
303	SHS	HRR	1	4	8.6	6.662	5.765	0.112	0.086				
304	SHS	HRR	1	4	8.5	6.128	5.199	0.078	0.141				

Fish #	Species	Site	Sex	Age (yr)	Total Length (cm)	Total Weight (g)	Carcass Weight (g)	Liver Weight (g)	Gonad Weight (g)	Female Gonad Condition	Total Fecundity (# /female)	Egg Weight (mg)	Egg Diameter (mm)
323	SHS	HRR	1	4	8.1	5.267	4.593	0.057	0.101				
309	SHS	HRR	2	4	9.4	6.959	5.711	0.133	0.122	2			
310	SHS	HRR	2	4	9.7	6.955	5.812	0.149	0.222	2			
313	SHS	HRR	2	3	7.7	4.861	2.886	0.115	1.324	1	229	5.79	1.95
326	SHS	HRR	2	4	7.3	3.649	2.489	0.060	0.866	1	156	5.55	1.93
324	SHS	HRR	2	4	8.2	5.175	3.365	0.084	1.137	1	255	4.46	1.87
329	SHS	HRR	2	4	7.7	4.080	2.587	0.068	0.982	1	158	6.21	1.85
327	SHS	HRR	2	4	8.2	5.211	3.498	0.102	1.182	1	239	4.95	1.78
322	SHS	HRR	2	3	8.6	4.288	3.490	0.073	0.096	2			
317	SHS	HRR	2	3	7.7	4.510	2.846	0.087	1.133	1	212	5.35	1.86
314	SHS	HRR	2	4	8.1	4.591	3.031	0.086	1.053	1	213	4.94	1.79
321	SHS	HRR	2	4	8.0	5.180	3.541	0.141	1.005	1	246	4.08	1.89
319	SHS	HRR	2	3	8.8	5.091	4.178	0.140	0.140	2			
308	SHS	HRR	2	4	8.0	5.368	3.446	0.107	1.251	1	153	8.17	2.10
335	SHS	HRR	2	4	8.2	4.134	3.428	0.083	0.073	2			
333	SHS	HRR	2	4	7.5	4.295	2.631	0.079	1.102	1	228	4.84	1.77
336	SHS	HRR	2	3	7.1	3.536	2.428	0.083	0.675	1	131	5.16	1.97
339	SHS	HRR	2	3	7.0	2.874	1.985	0.073	0.385	1	104	3.69	1.45
338	SHS	HRR	2	3	7.1	3.554	2.416	0.052	0.716	1	146	4.89	1.75
306	SHS	HRR	2	3	8.0	5.152	3.243	0.095	1.193	1	242	4.92	1.87
307	SHS	HRR	2	4	9.5	6.474	5.231	0.148	0.177	2			
305	SHS	HRR	2	3	8.2	5.364	3.531	0.164	0.923	1	215	4.30	1.91
332	SHS	HRR	2	4	7.3	4.113	2.597	0.074	0.935	1	156	5.98	1.90
331	SHS	HRR	2	4	7.6	4.765	3.092	0.117	1.084	1	195	5.57	1.94
350	SHS	HRR	3		6.8	2.970							
349	SHS	HRR	3		6.2	1.968							
348	SHS	HRR	3		6.2	1.885							
428	SHS	HRR	3		5.9	1.812							
352	SHS	HRR	3		6.4	2.182							
351	SHS	HRR	3		5.8	1.649							
347	SHS	HRR	3		6.6	2.432							
343	SHS	HRR	3		6.2	1.872							

Fish #	Species	Site	Sex	Age (yr)	Total Length (cm)	Total Weight (g)	Carcass Weight (g)	Liver Weight (g)	Gonad Weight (g)	Female Gonad Condition	Total Fecundity (# /female)	Egg Weight (mg)	Egg Diameter (mm)
342	SHS	HRR	3	3	7.3	2.978	2.606	0.064					
345	SHS	HRR	3		6.2	1.972							
344	SHS	HRR	3		6.6	2.710							
346	SHS	HRR	3		6.2	2.365							
340	SHS	HRR	3	3	7.4	3.369	3.043	0.036					
176	SHS	MAR	1	3	7.9	4.956	4.186	0.084	0.062				
221	SHS	MAR	1	3	7.5	4.380	3.769	0.083	0.084				
358	SHS	MAR	1	5	9.5	9.102	7.181	0.167	0.041				
357	SHS	MAR	1	5	9.8	9.891	8.712	0.143	0.044				
353	SHS	MAR	1	6	10.6	13.103	11.187	0.198	0.063				
362	SHS	MAR	1	5	8.7	7.148	6.114	0.216	0.081				
361	SHS	MAR	1	4	8.0	5.543	4.551	0.139	0.061				
360	SHS	MAR	1	5	9.0	8.014	6.644	0.092	0.045				
166	SHS	MAR	1	4	9.0	8.119	6.757	0.128	0.081				
165	SHS	MAR	1	5	9.7	9.506	8.092	0.154	0.102				
163	SHS	MAR	1	4	8.8	8.498	6.993	0.234	0.111				
167	SHS	MAR	1	3	9.0	7.968	6.757	0.171	0.086				
168	SHS	MAR	1	4	8.8	8.579	7.363	0.222	0.139				
170	SHS	MAR	1	3	8.3	6.428	5.599	0.103	0.058				
161	SHS	MAR	1	5	9.5	14.297	12.312	0.207	0.115				
1	SHS	MAR	2	4	9.6	10.510	6.907	0.256	2.321	1	498	4.66	1.82
380	SHS	MAR	2	3	7.7	4.065	3.329	0.095	0.089	2			
363	SHS	MAR	2	3	8.2	4.324	3.448	0.099	0.071	2			
172	SHS	MAR	2	4	8.2	5.693	3.517	0.158	1.479	1	307	4.82	1.54
169	SHS	MAR	2	5	9.2	6.800	5.597	0.186	0.160	2			
175	SHS	MAR	2	3	8.6	5.089	4.128	0.125	0.104	2			
171	SHS	MAR	2	5	9.3	6.775	5.662	0.143	0.128	2			
173	SHS	MAR	2	3	8.6	5.606	4.504	0.117	0.186	2			
162	SHS	MAR	2	4	9.1	9.163	5.626	0.186	2.223	1	372	5.98	1.99
354	SHS	MAR	2	6	11.0	10.350	8.703	0.178	0.215	2			
356	SHS	MAR	2	5	10.8	10.929	8.931	0.294	0.183	2			
180	SHS	MAR	2	3	6.6	3.042	2.088	0.092	0.502	1	189	2.66	1.22

Fish #	Species	Site	Sex	Age (yr)	Total Length (cm)	Total Weight (g)	Carcass Weight (g)	Liver Weight (g)	Gonad Weight (g)	Female Gonad Condition	Total Fecundity (# /female)	Egg Weight (mg)	Egg Diameter (mm)
355	SHS	MAR	2	4	8.8	7.966	4.879	0.184	2.117	1	414	5.12	1.84
178	SHS	MAR	2	3	8.5	5.002	4.136	0.128	0.109	2			
164	SHS	MAR	2	6	10.8	11.417	9.515	0.249	0.392	2			
359	SHS	MAR	2	4	8.9	5.760	4.730	0.154	0.110	2			
378	SHS	MAR	3		5.5	1.469							
379	SHS	MAR	3		6.7	2.690							
218	SHS	MAR	3		6.1	2.268							
217	SHS	MAR	3		6.0	2.247							
220	SHS	MAR	3		6.0	1.739							
219	SHS	MAR	3		6.4	2.671							
377	SHS	MAR	3		6.3	2.345							
367	SHS	MAR	3		7.0	3.406							
368	SHS	MAR	3		6.4	2.043							
369	SHS	MAR	3		6.0	1.764							
364	SHS	MAR	3	3	7.1	3.411	3.058	0.096					
365	SHS	MAR	3		5.7	1.681							
366	SHS	MAR	3		6.4	2.508							
370	SHS	MAR	3		6.3	2.313							
374	SHS	MAR	3		6.6	2.717							
375	SHS	MAR	3		6.0	1.811							
376	SHS	MAR	3		6.4	2.476							
371	SHS	MAR	3		6.5	2.399							
372	SHS	MAR	3		6.3	2.048							
373	SHS	MAR	3		6.5	2.284							
197	SHS	MAR	3		6.5	2.988							
198	SHS	MAR	3		6.2	2.051							
199	SHS	MAR	3		6.5	2.652							
196	SHS	MAR	3		6.8	2.715							
193	SHS	MAR	3		5.9	1.944							
194	SHS	MAR	3		6.0	1.976							
195	SHS	MAR	3		6.5	3.064							
204	SHS	MAR	3		6.9	2.874							

Fish #	Species	Site	Sex	Age (yr)	Total Length (cm)	Total Weight (g)	Carcass Weight (g)	Liver Weight (g)	Gonad Weight (g)	Female Gonad Condition	Total Fecundity (# /female)	Egg Weight (mg)	Egg Diameter (mm)
205	SHS	MAR	3		7.0	3.337							
206	SHS	MAR	3		6.9	3.164							
203	SHS	MAR	3		6.3	2.718							
200	SHS	MAR	3		6.5	2.150							
201	SHS	MAR	3		7.0	2.983							
202	SHS	MAR	3		7.0	2.878							
183	SHS	MAR	3	2	7.6	4.386	3.578	0.170					
184	SHS	MAR	3	2	7.2	3.694	2.969	0.161					
185	SHS	MAR	3		6.2	1.961							
182	SHS	MAR	3	3	7.0	3.534	2.993	0.119					
177	SHS	MAR	3	3	8.2	5.491	4.327	0.271					
179	SHS	MAR	3	3	7.5	4.074	3.441	0.112					
181	SHS	MAR	3	3	6.9	2.995	2.395	0.080					
190	SHS	MAR	3		6.5	2.696							
191	SHS	MAR	3		7.0	3.426							
192	SHS	MAR	3		6.7	2.794							
189	SHS	MAR	3		6.8	3.020							
186	SHS	MAR	3		6.6	2.427							
187	SHS	MAR	3		5.5	1.667							
188	SHS	MAR	3		6.9	3.102							
211	SHS	MAR	3		6.6	2.365							
174	SHS	MAR	3	3	8.0	4.658	3.809	0.100	0.031				
209	SHS	MAR	3		6.2	1.913							
210	SHS	MAR	3		6.7	2.705							
212	SHS	MAR	3		6.4	2.277							
215	SHS	MAR	3		6.2	2.147							
216	SHS	MAR	3		6.5	2.465							
213	SHS	MAR	3		6.2	1.865							
214	SHS	MAR	3		6.3	2.541							
208	SHS	MAR	3		5.7	1.479							
207	SHS	MAR	3		7.0	2.972							
381	SHS	MAL	1	4	9.6	10.489	8.901	0.176	0.088				

Fish #	Species	Site	Sex	Age (yr)	Total Length (cm)	Total Weight (g)	Carcass Weight (g)	Liver Weight (g)	Gonad Weight (g)	Female Gonad Condition	Total Fecundity (# /female)	Egg Weight (mg)	Egg Diameter (mm)
87	SHS	MAL	1	4	10.1	12.076	10.578	0.228	0.195				
95	SHS	MAL	1	5	10.6	14.129	12.329	0.205	0.152				
90	SHS	MAL	1	4	8.6	6.745	6.132	0.140	0.142				
91	SHS	MAL	1	3	8.0	5.946	5.022	0.126	0.107				
382	SHS	MAL	1	3	9.7	10.350	9.083	0.150	0.048				
101	SHS	MAL	1	4	10.4	12.988	11.466	0.143	0.165				
99	SHS	MAL	1	4	11.7	18.104	15.970	0.221	0.173				
98	SHS	MAL	1	3	8.6	6.707	5.861	0.155	0.093				
96	SHS	MAL	1	4	10.5	11.675	10.689	0.133	0.096				
97	SHS	MAL	1	4	9.5	9.048	7.946	0.149	0.106				
102	SHS	MAL	1	4	10.7	14.828	13.091	0.205	0.183				
89	SHS	MAL	1	4	9.0	7.428	6.703	0.205	0.110				
6	SHS	MAL	1	3	8.7	6.518	5.714	0.059	0.104				
5	SHS	MAL	1	4	10.6	13.766	12.026	0.186	0.166				
7	SHS	MAL	1	4	10.6	12.750	11.440	0.116	0.188				
88	SHS	MAL	1	5	9.6	10.076	8.989	0.202	0.124				
8	SHS	MAL	1	3	9.1	10.295	9.130	0.161	0.209				
3	SHS	MAL	1	3	9.7	12.037	10.102	0.186	0.229				
12	SHS	MAL	2	3	7.4	5.122	3.294	0.167	1.448	1	320	4.52	1.88
10	SHS	MAL	2	4	7.8	5.518	3.583	0.185	1.369	1	238	5.74	1.85
11	SHS	MAL	2	3	7.7	5.046	3.261	0.120	1.387	1	312	4.44	2.00
9	SHS	MAL	2	4	9.4	11.085	6.971	0.266	2.590	1	361	7.18	2.14
100	SHS	MAL	2	3	8.7	7.698	4.678	0.171	2.224	1	339	6.55	1.91
103	SHS	MAL	2	3	7.8	5.373	3.535	0.173	1.301	1	267	4.87	1.78
4	SHS	MAL	2	4	10.0	10.360	6.598	0.198	2.709	1	355	7.63	2.11
2	SHS	MAL	2	6	11.2	18.149	11.247	0.328	5.120	1	640	8.00	2.04
105	SHS	MAL	2	3	7.7	5.852	3.652	0.119	1.454	1	346	4.20	1.93
27	SHS	MAL	3		6.5	2.291							
26	SHS	MAL	3		6.3	2.530							
28	SHS	MAL	3		6.9	3.134							
29	SHS	MAL	3		6.5	2.551							
25	SHS	MAL	3		6.3	2.236							

Fish #	Species	Site	Sex	Age (yr)	Total Length (cm)	Total Weight (g)	Carcass Weight (g)	Liver Weight (g)	Gonad Weight (g)	Female Gonad Condition	Total Fecundity (# /female)	Egg Weight (mg)	Egg Diameter (mm)
16	SHS	MAL	3		6.8	2.782							
17	SHS	MAL	3		6.7	2.597							
18	SHS	MAL	3		6.6	2.392							
13	SHS	MAL	3	3	7.9	4.190	3.703	0.081					
14	SHS	MAL	3	3	6.9	2.948	2.589	0.054					
15	SHS	MAL	3	2	7.3	3.573	3.017	0.108					
22	SHS	MAL	3		6.8	2.718							
23	SHS	MAL	3		6.9	3.004							
24	SHS	MAL	3		7.2	3.104							
19	SHS	MAL	3		6.5	2.223							
20	SHS	MAL	3		6.4	2.585							
21	SHS	MAL	3		6.3	2.615							
110	SHS	MAL	3		6.5	2.566							
383	SHS	MAL	3	3	7.0	3.515	2.943	0.142					
109	SHS	MAL	3		6.1	2.341							
107	SHS	MAL	3		7.1	2.784							
108	SHS	MAL	3		7.1	3.186							
387	SHS	MAL	3		5.8	1.892							
388	SHS	MAL	3		6.7	3.085							
386	SHS	MAL	3	3	7.2	4.191	3.460	0.176					
384	SHS	MAL	3		6.7	2.534							
385	SHS	MAL	3		6.5	2.829							
94	SHS	MAL	3		6.7	2.413							
93	SHS	MAL	3		6.7	2.523							
92	SHS	MAL	3	3	7.2	2.831	2.468	0.063					
104	SHS	MAL	3	3	7.9	4.834	3.977	0.109					
106	SHS	MAL	3	3	6.9	3.296	2.763	0.082					
287	SHS	CL	1	4	9.7	10.383	8.894	0.214	0.115				
228	SHS	CL	1	3	8.5	7.320	6.135	0.170	0.069				
286	SHS	CL	1	5	11.5	17.293	15.211	0.409	0.078				
290	SHS	CL	1	4	8.1	6.673	5.691	0.164	0.045				
226	SHS	CL	2	4	9.2	7.429	6.129	0.223	0.146	2			

Fish #	Species	Site	Sex	Age (yr)	Total Length (cm)	Total Weight (g)	Carcass Weight (g)	Liver Weight (g)	Gonad Weight (g)	Female Gonad Condition	Total Fecundity (# /female)	Egg Weight (mg)	Egg Diameter (mm)
223	SHS	CL	2	4	9.1	7.515	6.072	0.274	0.169	2			
225	SHS	CL	2	4	10.3	9.913	8.098	0.310	0.196	2			
222	SHS	CL	2	4	9.0	8.095	4.885	0.255	1.982	1	556	3.56	1.54
224	SHS	CL	2	3	8.7	8.118	5.127	0.188	2.054	1	502	4.09	1.60
227	SHS	CL	2	3	8.5	7.771	4.916	0.193	1.784	1	374	4.78	1.54
289	SHS	CL	2	4	9.2	7.197	5.739	0.235	0.175	2			
288	SHS	CL	2	4	9.5	7.286	5.845	0.258	0.149	2			
232	SHS	CL	2	3	8.2	6.418	5.162	0.257	0.017	2			
229	SHS	CL	2	3	8.5	6.040	4.771	0.208	0.126	2			
231	SHS	CL	2	3	8.6	6.010	5.085	0.189	0.116	2			
244	SHS	CL	3		6.3	2.191							
243	SHS	CL	3		6.7	2.625							
236	SHS	CL	3		7.2	3.573							
234	SHS	CL	3	3	7.8	4.670	3.748	0.140					
235	SHS	CL	3	3	7.0	3.923	2.963	0.208					
242	SHS	CL	3		6.7	3.058							
238	SHS	CL	3		6.6	2.668							
237	SHS	CL	3		7.2	3.296							
239	SHS	CL	3		6.7	3.395							
241	SHS	CL	3		6.7	2.524							
240	SHS	CL	3		7.3	3.125							
294	SHS	CL	3		6.5	2.878							
295	SHS	CL	3		6.6	2.909							
292	SHS	CL	3	2	7.4	3.872	3.226	0.098					
293	SHS	CL	3		6.4	3.006							
298	SHS	CL	3		6.8	3.064							
299	SHS	CL	3		6.7	2.957							
296	SHS	CL	3		7.0	2.972							
297	SHS	CL	3		6.3	2.232							
230	SHS	CL	3	3	7.7	4.831	4.004	0.202					
291	SHS	CL	3	3	7.2	4.067	3.076	0.157					
233	SHS	CL	3	2	7.6	4.241	3.316	0.121					

Fish #	Species	Site	Sex	Age (yr)	Total Length (cm)	Total Weight (g)	Carcass Weight (g)	Liver Weight (g)	Gonad Weight (g)	Female Gonad Condition	Total Fecundity (# /female)	Egg Weight (mg)	Egg Diameter (mm)
389	SHS	CR	1	5	10.9	15.999	14.270	0.330	0.079				
250	SHS	CR	1	4	9.9	11.046	9.648	0.208	0.088				
246	SHS	CR	1	5	10.5	13.787	11.917	0.216	0.093				
245	SHS	CR	1	6	11.5	19.945	17.565	0.397	0.116				
249	SHS	CR	1	4	10.0	12.662	10.847	0.310	0.183				
247	SHS	CR	1	5	11.2	17.562	15.478	0.259	0.177				
400	SHS	CR	1	4	9.1	9.002	7.730	0.220	0.080				
399	SHS	CR	1	4	9.7	10.080	8.552	0.233	0.086				
398	SHS	CR	1	4	9.7	10.503	9.121	0.234	0.084				
401	SHS	CR	1	3	7.9	6.517	5.379	0.220	0.047				
406	SHS	CR	1	3	7.6	5.008	3.906	0.196	0.029				
404	SHS	CR	1	4	9.2	8.355	7.127	0.221	0.049				
402	SHS	CR	1	4	9.3	9.947	8.839	0.207	0.056				
393	SHS	CR	1	5	10.0	10.819	9.684	0.158	0.076				
391	SHS	CR	1	5	10.6	13.312	11.729	0.267	0.075				
390	SHS	CR	1	5	10.9	15.654	13.439	0.269	0.116				
394	SHS	CR	1	4	8.7	6.799	5.774	0.091	0.074				
397	SHS	CR	1	4	9.0	8.197	6.820	0.198	0.072				
396	SHS	CR	1	5	10.5	13.185	11.256	0.374	0.084				
395	SHS	CR	1	4	8.6	7.111	6.172	0.159	0.065				
252	SHS	CR	1	4	9.7	10.374	9.064	0.197	0.116				
262	SHS	CR	1	3	7.7	5.194	4.144	0.155	0.063				
255	SHS	CR	1	4	9.5	9.683	8.219	0.172	0.152				
254	SHS	CR	1	4	9.5	10.524	8.709	0.116	0.182				
260	SHS	CR	1	3	7.6	5.267	4.318	0.177	0.054				
261	SHS	CR	1	3	7.8	4.887	4.206	0.139	0.046				
405	SHS	CR	2	3	8.9	6.164	4.706	0.236	0.089	2			
403	SHS	CR	2	4	9.0	6.018	4.950	0.155	0.113	2			
392	SHS	CR	2	4	10.3	10.184	8.269	0.336	0.195	2			
259	SHS	CR	2	3	8.8	8.049	5.207	0.219	2.121	1	431	4.93	1.82
253	SHS	CR	2	4	10.0	8.946	7.157	0.226	0.209	2			
251	SHS	CR	2	4	9.0	10.123	6.230	0.275	2.571	1	463	5.55	1.51

Fish #	Species	Site	Sex	Age (yr)	Total Length (cm)	Total Weight (g)	Carcass Weight (g)	Liver Weight (g)	Gonad Weight (g)	Female Gonad Condition	Total Fecundity (# /female)	Egg Weight (mg)	Egg Diameter (mm)
248	SHS	CR	2	6	11.0	13.533	11.198	0.366	0.317	2			
257	SHS	CR	2	4	8.5	7.374	4.680	0.195	1.992	1	290	6.87	1.72
256	SHS	CR	2	3	8.7	7.648	4.714	0.169	2.018	1	401	5.03	1.87
258	SHS	CR	2	3	8.3	7.824	4.545	0.181	2.050	1	484	4.23	1.61
407	SHS	CR	3	3	7.2	3.353	2.822	0.106					
409	SHS	CR	3		6.4	3.014							
408	SHS	CR	3	3	7.4	4.054	3.232	0.116					
414	SHS	CR	3		6.2	2.264							
413	SHS	CR	3		7.0	3.402							
412	SHS	CR	3		6.9	2.987							
415	SHS	CR	3		6.5	3.185							
265	SHS	CR	3		6.9	3.040							
266	SHS	CR	3		7.5	3.828							
263	SHS	CR	3	3	7.2	3.583	2.999	0.090					
264	SHS	CR	3	3	7.7	4.688	3.946	0.128					
267	SHS	CR	3		6.5	2.865							
411	SHS	CR	3		6.2	3.075							
410	SHS	CR	3		6.3	2.995							
268	SHS	CR	3		6.5	2.766							
269	SHS	CR	3		6.6	2.841							
422	SHS	E	1	4	9.0	8.109	6.935	0.258	0.145				
281	SHS	E	1	4	9.8	11.534	9.679	0.274	0.289				
282	SHS	E	1	4	10.5	14.598	11.886	0.250	0.594				
421	SHS	E	1	4	11.2	17.465	15.482	0.259	0.241				
418	SHS	E	1	3	8.7	9.025	7.812	0.300	0.127				
419	SHS	E	1	4	10.2	13.685	11.732	0.330	0.230				
420	SHS	E	1	5	12.0	19.622	17.222	0.351	0.257				
276	SHS	E	1	4	10.0	12.938	11.085	0.332	0.300				
271	SHS	E	1	7	12.3	25.987	22.006	0.710	0.378				
273	SHS	E	1	6	11.5	21.388	18.406	0.440	0.413				
274	SHS	E	1	5	11.0	19.367	16.574	0.352	0.349				
270	SHS	E	1	5	12.8	26.518	23.152	0.495	0.383				

Fish #	Species	Site	Sex	Age (yr)	Total Length (cm)	Total Weight (g)	Carcass Weight (g)	Liver Weight (g)	Gonad Weight (g)	Female Gonad Condition	Total Fecundity (# /female)	Egg Weight (mg)	Egg Diameter (mm)
279	SHS	E	1	5	11.4	21.973	19.059	0.473	0.365				
280	SHS	E	1	5	10.4	14.847	12.672	0.303	0.556				
277	SHS	E	1	4	8.3	7.572	6.403	0.317	0.132				
283	SHS	E	2	3	7.9	6.412	4.364	0.224	1.230	1	436	2.82	1.21
272	SHS	E	2	6	11.2	19.813	12.874	0.582	4.681	1	861	5.43	1.86
416	SHS	E	2	4	9.3	9.235	5.968	0.224	2.281	1	444	5.14	1.70
278	SHS	E	2	5	11.7	21.420	14.150	0.556	4.858	1	893	5.44	1.69
417	SHS	E	2	3	8.0	6.446	4.235	0.211	1.259	1	386	3.26	1.71
275	SHS	E	2	4	9.1	8.504	5.720	0.250	1.553	1	386	4.02	1.47
285	SHS	E	3	3	6.6	2.758	2.297	0.089					
284	SHS	E	3	3	7.5	4.102	3.361	0.144					
423	SHS	E	3		7.0	3.249							
455	SHS	NS	1	4	9.9	9.852	8.066	0.128	0.194				
434	SHS	NS	1	5	11.1	14.914	12.772	0.220	0.446				
464	SHS	NS	1	3	8.7	7.262	6.105	0.092	0.162				
437	SHS	NS	1	4	9.2	7.686	6.445	0.082	0.247				
456	SHS	NS	1	5	10.3	11.663	9.883	0.158	0.357				
459	SHS	NS	1	3	8.9	6.700	5.625	0.075	0.165				
431	SHS	NS	1	6	12.3	20.461	17.701	0.230	0.498				
457	SHS	NS	1	4	10.1	10.062	8.597	0.133	0.268				
462	SHS	NS	2	3	9.1	7.011	5.004	0.134	1.055	1	213	4.95	1.63
463	SHS	NS	2	3	8.6	6.062	4.090	0.131	1.312	1	316	4.15	1.75
465	SHS	NS	2	3	7.8	4.997	3.189	0.115	1.344	1	294	4.57	1.79
458	SHS	NS	2	4	9.4	7.748	5.717	0.181	1.300	1	95	3.77	1.61
454	SHS	NS	2	4	10.2	9.356	6.522	0.155	1.628	1	331	4.92	1.80
460	SHS	NS	2	3	9.8	8.531	5.900	0.182	1.571	1	369	4.26	1.77
453	SHS	NS	2	5	11.0	13.043	7.932	0.189	3.875	1	564	6.87	2.05
433	SHS	NS	2	4	11.9	13.851	10.802	0.251	1.902	1	426	4.47	1.74
435	SHS	NS	2	3	9.2	6.826	4.764	0.153	1.303	1	209	6.22	1.97
436	SHS	NS	2	4	9.7	9.496	6.391	0.141	2.192	1	567	3.87	1.83
429	SHS	NS	2	5	10.6	12.850	8.559	0.232	3.046	1	453	6.72	2.09
430	SHS	NS	2	5	12.2	17.170	12.568	0.343	2.745	1			

Fish #	Species	Site	Sex	Age (yr)	Total Length (cm)	Total Weight (g)	Carcass Weight (g)	Liver Weight (g)	Gonad Weight (g)	Female Gonad Condition	Total Fecundity (# /female)	Egg Weight (mg)	Egg Diameter (mm)
432	SHS	NS	2	4	9.9	10.197	6.866	0.217	1.995	1	451	4.42	1.77
473	SHS	NS	3		6.7	2.340							
474	SHS	NS	3		7.3	2.936							
466	SHS	NS	3	3	8.3	4.457	3.665	0.044					
469	SHS	NS	3		7.4	3.159							
468	SHS	NS	3	2	7.5	3.265							
467	SHS	NS	3	3	8.0	3.986	3.382	0.052					
472	SHS	NS	3		7.4	2.753							
461	SHS	NS	3	3	8.7	5.215	4.467	0.098	0.060				
470	SHS	NS	3		7.2	2.741							
471	SHS	NS	3		7.6	3.820							
442	SHS	NS	3		7.0	2.334							
443	SHS	NS	3		7.7	3.564							
444	SHS	NS	3		6.7	2.211							
441	SHS	NS	3		6.7	2.506							
438	SHS	NS	3	4	8.6	5.561	4.682	0.131					
439	SHS	NS	3	3	9.1	6.158	5.243	0.052					
440	SHS	NS	3	3	8.8	5.028	4.284	0.063	0.063				
445	SHS	NS	3		7.3	2.951							
450	SHS	NS	3		6.7	2.135							
451	SHS	NS	3		7.0	2.359							
452	SHS	NS	3	4	8.3	4.667	4.135	0.061	0.030				
449	SHS	NS	3		7.1	2.580							
446	SHS	NS	3		7.4	3.124							
447	SHS	NS	3		8.0	3.587							
448	SHS	NS	3		7.0	3.094							

Spring 1995 MFO Data

Fish #	Species	Site	Sex	EROD (pmol/mg protein/min)
34	SHS	HRL	1	0.974
35	SHS	HRL	1	2.209
32	SHS	HRL	1	1.140
30	SHS	HRL	1	2.359
31	SHS	HRL	1	1.418
126	SHS	HRL	1	3.648
124	SHS	HRL	1	3.616
122	SHS	HRL	1	4.251
127	SHS	HRL	1	3.130
129	SHS	HRL	1	3.027
130	SHS	HRL	1	4.830
128	SHS	HRL	1	3.303
115	SHS	HRL	1	4.738
114	SHS	HRL	1	1.596
112	SHS	HRL	1	2.250
117	SHS	HRL	1	1.260
121	SHS	HRL	1	5.927
120	SHS	HRL	1	9.453
118	SHS	HRL	1	1.937
47	SHS	HRL	1	4.745
45	SHS	HRL	1	3.982
50	SHS	HRL	1	7.525
48	SHS	HRL	1	3.040
42	SHS	HRL	1	2.047
41	SHS	HRL	1	1.332
44	SHS	HRL	1	0.580
43	SHS	HRL	1	3.709
39	SHS	HRL	1	6.709
40	SHS	HRL	1	1.225
36	SHS	HRL	1	1.232
37	SHS	HRL	1	1.250
54	SHS	HRL	2	1.191
33	SHS	HRL	2	1.248
116	SHS	HRL	2	3.442
46	SHS	HRL	2	2.620
49	SHS	HRL	2	0.673
113	SHS	HRL	2	4.196
119	SHS	HRL	2	3.539
125	SHS	HRL	2	1.004

Fish #	Species	Site	Sex	EROD (pmol/mg protein/min)
38	SHS	HRL	2	0.386
53	SHS	HRL	2	0.450
51	SHS	HRL	2	0.191
123	SHS	HRL	2	3.211
55	SHS	HRL	3	5.027
132	SHS	HRL	3	19.438
131	SHS	HRL	3	35.123
56	SHS	HRL	3	4.834
315	SHS	HRR	1	2.525
302	SHS	HRR	1	3.750
323	SHS	HRR	1	5.140
427	SHS	HRR	1	8.937
320	SHS	HRR	1	2.488
316	SHS	HRR	1	19.288
301	SHS	HRR	1	1.025
300	SHS	HRR	1	5.007
312	SHS	HRR	1	3.296
318	SHS	HRR	1	8.206
303	SHS	HRR	1	3.959
341	SHS	HRR	1	18.644
304	SHS	HRR	1	5.726
424	SHS	HRR	1	3.263
337	SHS	HRR	1	1.985
425	SHS	HRR	1	0.000
311	SHS	HRR	1	4.759
328	SHS	HRR	1	3.929
325	SHS	HRR	1	1.797
330	SHS	HRR	1	8.979
426	SHS	HRR	1	3.220
334	SHS	HRR	1	1.791
313	SHS	HRR	2	2.209
336	SHS	HRR	2	4.277
339	SHS	HRR	2	0.703
338	SHS	HRR	2	1.048
335	SHS	HRR	2	0.206
331	SHS	HRR	2	3.072
327	SHS	HRR	2	3.448
329	SHS	HRR	2	2.076
314	SHS	HRR	2	10.112

Fish #	Species	Site	Sex	EROD (pmol/mg protein/min)
333	SHS	HRR	2	3.734
332	SHS	HRR	2	1.749
326	SHS	HRR	2	0.864
324	SHS	HRR	2	0.823
305	SHS	HRR	2	2.215
322	SHS	HRR	2	1.542
319	SHS	HRR	2	22.863
321	SHS	HRR	2	1.253
306	SHS	HRR	2	5.457
309	SHS	HRR	2	7.593
310	SHS	HRR	2	0.975
317	SHS	HRR	2	4.727
307	SHS	HRR	2	8.320
308	SHS	HRR	2	3.036
342	SHS	HRR	3	8.831
340	SHS	HRR	3	31.244
353	SHS	MAR	1	25.925
165	SHS	MAR	1	52.489
161	SHS	MAR	1	10.365
163	SHS	MAR	1	17.848
168	SHS	MAR	1	8.395
170	SHS	MAR	1	29.665
166	SHS	MAR	1	12.999
167	SHS	MAR	1	16.801
360	SHS	MAR	1	36.177
361	SHS	MAR	1	13.199
362	SHS	MAR	1	27.751
358	SHS	MAR	1	10.095
176	SHS	MAR	1	20.763
221	SHS	MAR	1	23.821
357	SHS	MAR	1	6.741
172	SHS	MAR	2	7.886
355	SHS	MAR	2	23.447
356	SHS	MAR	2	7.155
363	SHS	MAR	2	10.254
1	SHS	MAR	2	3.334
162	SHS	MAR	2	14.014
354	SHS	MAR	2	5.814
171	SHS	MAR	2	9.973

Fish #	Species	Site	Sex	EROD (pmol/mg protein/min)
180	SHS	MAR	2	14.439
359	SHS	MAR	2	24.730
173	SHS	MAR	2	19.260
380	SHS	MAR	2	13.266
175	SHS	MAR	2	29.018
164	SHS	MAR	2	1.680
178	SHS	MAR	2	28.376
169	SHS	MAR	2	38.735
184	SHS	MAR	3	35.963
182	SHS	MAR	3	26.431
183	SHS	MAR	3	47.239
364	SHS	MAR	3	44.452
177	SHS	MAR	3	69.508
174	SHS	MAR	3	51.022
179	SHS	MAR	3	54.495
8	SHS	MAL	1	28.295
98	SHS	MAL	1	0.605
7	SHS	MAL	1	25.890
95	SHS	MAL	1	13.106
96	SHS	MAL	1	12.148
90	SHS	MAL	1	25.254
111	SHS	MAL	1	3.095
88	SHS	MAL	1	4.335
381	SHS	MAL	1	20.680
89	SHS	MAL	1	14.318
91	SHS	MAL	1	28.446
87	SHS	MAL	1	11.220
382	SHS	MAL	1	31.234
97	SHS	MAL	1	7.662
99	SHS	MAL	1	9.309
6	SHS	MAL	1	67.474
5	SHS	MAL	1	16.860
101	SHS	MAL	1	6.327
102	SHS	MAL	1	21.990
3	SHS	MAL	1	8.595
10	SHS	MAL	2	14.482
12	SHS	MAL	2	3.976
100	SHS	MAL	2	15.309
105	SHS	MAL	2	18.929

Fish #	Species	Site	Sex	EROD (pmol/mg protein/min)
4	SHS	MAL	2	5.165
103	SHS	MAL	2	7.195
11	SHS	MAL	2	3.739
9	SHS	MAL	2	9.253
92	SHS	MAL	3	49.692
15	SHS	MAL	3	64.648
386	SHS	MAL	3	85.954
383	SHS	MAL	3	53.906
104	SHS	MAL	3	73.262
106	SHS	MAL	3	15.842
14	SHS	MAL	3	80.177
13	SHS	MAL	3	67.508
287	SHS	CL	1	14.133
290	SHS	CL	1	24.487
286	SHS	CL	1	6.402
228	SHS	CL	1	5.823
222	SHS	CL	2	4.287
227	SHS	CL	2	4.992
226	SHS	CL	2	19.091
231	SHS	CL	2	16.272
289	SHS	CL	2	16.175
225	SHS	CL	2	16.531
288	SHS	CL	2	18.812
223	SHS	CL	2	14.383
224	SHS	CL	2	9.179
229	SHS	CL	2	28.672
232	SHS	CL	2	52.320
233	SHS	CL	3	28.941
234	SHS	CL	3	66.001
235	SHS	CL	3	46.116
292	SHS	CL	3	64.491
291	SHS	CL	3	32.859
230	SHS	CL	3	82.039
245	SHS	CR	1	10.267
261	SHS	CR	1	25.496
250	SHS	CR	1	19.883
396	SHS	CR	1	14.059
399	SHS	CR	1	43.169
89	SHS	CR	1	13.250

Fish #	Species	Site	Sex	EROD (pmol/mg protein/min)
247	SHS	CR	1	13.836
246	SHS	CR	1	4.833
398	SHS	CR	1	10.768
249	SHS	CR	1	11.086
397	SHS	CR	1	10.890
255	SHS	CR	1	16.734
391	SHS	CR	1	45.709
395	SHS	CR	1	34.646
390	SHS	CR	1	20.097
254	SHS	CR	1	18.670
401	SHS	CR	1	22.816
394	SHS	CR	1	10.842
406	SHS	CR	1	25.684
260	SHS	CR	1	10.423
262	SHS	CR	1	26.518
393	SHS	CR	1	25.912
252	SHS	CR	1	5.209
404	SHS	CR	1	13.683
402	SHS	CR	1	20.491
389	SHS	CR	1	23.647
400	SHS	CR	1	30.861
258	SHS	CR	2	10.267
257	SHS	CR	2	10.591
256	SHS	CR	2	8.228
405	SHS	CR	2	2.053
403	SHS	CR	2	8.059
259	SHS	CR	2	4.401
251	SHS	CR	2	11.200
248	SHS	CR	2	7.949
253	SHS	CR	2	21.016
392	SHS	CR	2	13.821
264	SHS	CR	3	64.508
263	SHS	CR	3	35.900
408	SHS	CR	3	32.853
407	SHS	CR	3	19.229
420	SHS	E	1	3.747
419	SHS	E	1	8.731
422	SHS	E	1	19.370
421	SHS	E	1	9.808

Fish #	Species	Site	Sex	EROD (pmol/mg protein/min)
281	SHS	E	1	13.584
280	SHS	E	1	13.270
418	SHS	E	1	17.251
282	SHS	E	1	13.431
270	SHS	E	1	8.924
276	SHS	E	1	19.122
274	SHS	E	1	18.300
279	SHS	E	1	10.177
277	SHS	E	1	16.648
271	SHS	E	1	5.443
273	SHS	E	1	11.351
275	SHS	E	2	0.732
283	SHS	E	2	0.359
278	SHS	E	2	1.659
272	SHS	E	2	0.390
416	SHS	E	2	2.849
417	SHS	E	2	3.862
285	SHS	E	3	3.978
284	SHS	E	3	47.553
464	SHS	NS	1	1.451
431	SHS	NS	1	2.050
455	SHS	NS	1	4.036
434	SHS	NS	1	4.791
437	SHS	NS	1	2.578
459	SHS	NS	1	2.918
457	SHS	NS	1	3.913
456	SHS	NS	1	3.719
436	SHS	NS	2	2.987
429	SHS	NS	2	0.609
430	SHS	NS	2	0.141
454	SHS	NS	2	0.736
465	SHS	NS	2	0.447
463	SHS	NS	2	0.255
433	SHS	NS	2	0.305
458	SHS	NS	2	0.616
435	SHS	NS	2	0.548
453	SHS	NS	2	0.725
432	SHS	NS	2	0.609
462	SHS	NS	2	1.941

Fish #	Species	Site	Sex	EROD (pmol/mg protein/min)
460	SHS	NS	2	0.308
461	SHS	NS	3	1.960
467	SHS	NS	3	4.653
468	SHS	NS	3	3.713
452	SHS	NS	3	3.885
438	SHS	NS	3	2.023
439	SHS	NS	3	1.269
440	SHS	NS	3	10.685

Spring 1995 *in vitro* Testosterone Data

Fish #	Species	Site	Sex	Female Gonad Condition	Treatment	Testosterone (pg/ 20 mg testicular tissue or 10 ovarian follicles)
30	SHS	HRL	1		basal	2.98
30	SHS	HRL	1		forskolin	6.45
31	SHS	HRL	1		basal	3.17
31	SHS	HRL	1		forskolin	10.87
32	SHS	HRL	1		basal	7.71
32	SHS	HRL	1		forskolin	7.66
34	SHS	HRL	1		basal	3.72
34	SHS	HRL	1		forskolin	6.61
35	SHS	HRL	1		basal	2.88
35	SHS	HRL	1		forskolin	11.10
36	SHS	HRL	1		basal	3.28
36	SHS	HRL	1		forskolin	6.54
37	SHS	HRL	1		basal	3.12
37	SHS	HRL	1		forskolin	7.84
39	SHS	HRL	1		basal	5.09
39	SHS	HRL	1		forskolin	6.47
40	SHS	HRL	1		basal	2.71
40	SHS	HRL	1		forskolin	10.97
41	SHS	HRL	1		basal	3.93
41	SHS	HRL	1		forskolin	10.34
42	SHS	HRL	1		basal	5.84
42	SHS	HRL	1		forskolin	13.74
43	SHS	HRL	1		basal	10.03
43	SHS	HRL	1		forskolin	10.88
111	SHS	HRL	1		basal	3.60
111	SHS	HRL	1		forskolin	6.66
112	SHS	HRL	1		basal	3.03
112	SHS	HRL	1		forskolin	11.89
124	SHS	HRL	1		basal	2.81
124	SHS	HRL	1		forskolin	5.61
33	SHS	HRL	2	1	basal	27.14
33	SHS	HRL	2	1	forskolin	24.04
38	SHS	HRL	2	1	basal	238.95
38	SHS	HRL	2	1	forskolin	400.03
46	SHS	HRL	2	1	basal	138.34
46	SHS	HRL	2	1	forskolin	35.39
49	SHS	HRL	2	1	basal	44.55
49	SHS	HRL	2	1	forskolin	5.25

Fish #	Species	Site	Sex	Female Gonad Condition	Treatment	Testosterone (pg/ 20 mg testicular tissue or 10 ovarian follicles)
51	SHS	HRL	2	1	basal	747.00
51	SHS	HRL	2	1	forskolin	34.08
53	SHS	HRL	2	1	basal	22.23
53	SHS	HRL	2	1	forskolin	26.21
54	SHS	HRL	2	1	basal	79.67
54	SHS	HRL	2	1	forskolin	95.30
119	SHS	HRL	2	1	basal	12.03
119	SHS	HRL	2	1	forskolin	5.50
123	SHS	HRL	2	1	basal	12.87
123	SHS	HRL	2	1	forskolin	5.50
125	SHS	HRL	2	1	basal	53.78
125	SHS	HRL	2	1	forskolin	74.81
300	SHS	HRR	1		basal	2.29
300	SHS	HRR	1		forskolin	7.41
301	SHS	HRR	1		basal	3.33
301	SHS	HRR	1		forskolin	6.52
302	SHS	HRR	1		basal	2.37
302	SHS	HRR	1		forskolin	4.51
303	SHS	HRR	1		basal	2.42
303	SHS	HRR	1		forskolin	9.00
304	SHS	HRR	1		basal	1.67
304	SHS	HRR	1		forskolin	3.17
312	SHS	HRR	1		basal	1.39
312	SHS	HRR	1		forskolin	3.12
315	SHS	HRR	1		basal	1.90
315	SHS	HRR	1		forskolin	4.29
316	SHS	HRR	1		basal	3.24
316	SHS	HRR	1		forskolin	4.72
318	SHS	HRR	1		basal	2.11
318	SHS	HRR	1		forskolin	3.37
320	SHS	HRR	1		basal	1.35
320	SHS	HRR	1		forskolin	3.36
323	SHS	HRR	1		basal	2.08
323	SHS	HRR	1		forskolin	2.47
325	SHS	HRR	1		basal	1.56
325	SHS	HRR	1		forskolin	6.78
328	SHS	HRR	1		basal	1.56
328	SHS	HRR	1		forskolin	2.68

Fish #	Species	Site	Sex	Female Gonad Condition	Treatment	Testosterone (pg/ 20 mg testicular tissue or 10 ovarian follicles)
305	SHS	HRR	2	1	basal	36.14
305	SHS	HRR	2	1	forskolin	47.09
306	SHS	HRR	2	1	forskolin	253.80
307	SHS	HRR	2	2	basal	73.68
307	SHS	HRR	2	2	forskolin	55.81
309	SHS	HRR	2	2	basal	44.96
309	SHS	HRR	2	2	forskolin	39.47
310	SHS	HRR	2	2	basal	102.14
310	SHS	HRR	2	2	forskolin	103.68
313	SHS	HRR	2	1	basal	6.50
313	SHS	HRR	2	1	forskolin	7.37
314	SHS	HRR	2	1	basal	18.70
314	SHS	HRR	2	1	forskolin	9.42
317	SHS	HRR	2	1	basal	9.17
317	SHS	HRR	2	1	forskolin	8.25
319	SHS	HRR	2	2	basal	38.67
319	SHS	HRR	2	2	forskolin	110.70
321	SHS	HRR	2	1	basal	55.60
321	SHS	HRR	2	1	forskolin	159.87
322	SHS	HRR	2	2	basal	77.43
322	SHS	HRR	2	2	forskolin	122.23
324	SHS	HRR	2	1	basal	19.98
324	SHS	HRR	2	1	forskolin	5.50
326	SHS	HRR	2	1	basal	30.01
326	SHS	HRR	2	1	forskolin	12.00
327	SHS	HRR	2	1	basal	56.90
327	SHS	HRR	2	1	forskolin	185.42
329	SHS	HRR	2	1	basal	27.85
329	SHS	HRR	2	1	forskolin	5.50
331	SHS	HRR	2	1	basal	23.17
331	SHS	HRR	2	1	forskolin	7.68
332	SHS	HRR	2	1	basal	20.96
332	SHS	HRR	2	1	forskolin	7.60
333	SHS	HRR	2	1	basal	12.38
333	SHS	HRR	2	1	forskolin	5.50
336	SHS	HRR	2	1	basal	20.71
336	SHS	HRR	2	1	forskolin	5.50
161	SHS	MAR	1		basal	2.87

Fish #	Species	Site	Sex	Female Gonad Condition	Treatment	Testosterone (pg/ 20 mg testicular tissue or 10 ovarian follicles)
161	SHS	MAR	1		forskolin	10.81
163	SHS	MAR	1		basal	2.57
163	SHS	MAR	1		forskolin	7.20
165	SHS	MAR	1		basal	1.65
165	SHS	MAR	1		forskolin	7.62
166	SHS	MAR	1		basal	3.42
166	SHS	MAR	1		forskolin	4.73
167	SHS	MAR	1		basal	2.67
167	SHS	MAR	1		forskolin	9.64
168	SHS	MAR	1		basal	4.36
168	SHS	MAR	1		forskolin	6.53
221	SHS	MAR	1		basal	3.52
221	SHS	MAR	1		forskolin	11.84
353	SHS	MAR	1		basal	1.18
353	SHS	MAR	1		forskolin	11.11
357	SHS	MAR	1		basal	1.06
357	SHS	MAR	1		forskolin	9.84
361	SHS	MAR	1		basal	1.69
361	SHS	MAR	1		forskolin	17.57
362	SHS	MAR	1		basal	2.01
362	SHS	MAR	1		forskolin	15.85
1	SHS	MAR	2	1	basal	63.11
1	SHS	MAR	2	1	forskolin	73.23
162	SHS	MAR	2	1	basal	37.32
162	SHS	MAR	2	1	forskolin	116.70
172	SHS	MAR	2	1	basal	33.51
172	SHS	MAR	2	1	forskolin	240.30
180	SHS	MAR	2	1	basal	692.83
180	SHS	MAR	2	1	forskolin	1134.50
354	SHS	MAR	2	2	basal	105.28
354	SHS	MAR	2	2	forskolin	92.97
355	SHS	MAR	2	1	basal	32.23
355	SHS	MAR	2	1	forskolin	25.22
356	SHS	MAR	2	2	basal	89.85
356	SHS	MAR	2	2	forskolin	67.13
359	SHS	MAR	2	2	basal	56.63
359	SHS	MAR	2	2	forskolin	57.12
363	SHS	MAR	2	2	basal	94.80

Fish #	Species	Site	Sex	Female Gonad Condition	Treatment	Testosterone (pg/ 20 mg testicular tissue or 10 ovarian follicles)
380	SHS	MAR	2	2	basal	53.33
380	SHS	MAR	2	2	forskolin	57.38
3	SHS	MAL	1		basal	3.65
3	SHS	MAL	1		forskolin	5.38
5	SHS	MAL	1		basal	4.47
5	SHS	MAL	1		forskolin	9.25
6	SHS	MAL	1		basal	2.49
6	SHS	MAL	1		forskolin	8.36
7	SHS	MAL	1		basal	2.36
7	SHS	MAL	1		forskolin	5.41
8	SHS	MAL	1		basal	2.14
8	SHS	MAL	1		forskolin	10.00
87	SHS	MAL	1		basal	2.60
87	SHS	MAL	1		forskolin	6.35
88	SHS	MAL	1		basal	3.27
88	SHS	MAL	1		forskolin	9.06
89	SHS	MAL	1		basal	2.76
89	SHS	MAL	1		forskolin	10.99
90	SHS	MAL	1		basal	3.22
90	SHS	MAL	1		forskolin	4.50
91	SHS	MAL	1		basal	4.57
91	SHS	MAL	1		forskolin	8.32
95	SHS	MAL	1		basal	2.14
95	SHS	MAL	1		forskolin	7.42
96	SHS	MAL	1		basal	2.55
96	SHS	MAL	1		forskolin	4.11
97	SHS	MAL	1		basal	2.26
97	SHS	MAL	1		forskolin	6.80
98	SHS	MAL	1		basal	2.94
98	SHS	MAL	1		forskolin	11.04
99	SHS	MAL	1		basal	2.72
99	SHS	MAL	1		forskolin	4.27
101	SHS	MAL	1		basal	3.83
101	SHS	MAL	1		forskolin	4.59
102	SHS	MAL	1		basal	2.64
102	SHS	MAL	1		forskolin	6.88
2	SHS	MAL	2	1	basal	11.16
2	SHS	MAL	2	1	forskolin	12.01

Fish #	Species	Site	Sex	Female Gonad Condition	Treatment	Testosterone (pg/ 20 mg testicular tissue or 10 ovarian follicles)
4	SHS	MAL	2	1	basal	14.81
4	SHS	MAL	2	1	forskolin	11.82
9	SHS	MAL	2	1	basal	10.39
9	SHS	MAL	2	1	forskolin	17.83
10	SHS	MAL	2	1	basal	54.62
10	SHS	MAL	2	1	forskolin	686.67
11	SHS	MAL	2	1	basal	65.78
11	SHS	MAL	2	1	forskolin	289.07
12	SHS	MAL	2	1	basal	49.09
12	SHS	MAL	2	1	forskolin	122.08
100	SHS	MAL	2	1	basal	7.00
100	SHS	MAL	2	1	forskolin	32.01
103	SHS	MAL	2	1	basal	37.77
103	SHS	MAL	2	1	forskolin	950.00
105	SHS	MAL	2	1	basal	9.57
105	SHS	MAL	2	1	forskolin	5.50
228	SHS	CL	1		basal	2.53
228	SHS	CL	1		forskolin	10.27
286	SHS	CL	1		basal	1.84
287	SHS	CL	1		basal	2.36
287	SHS	CL	1		forskolin	5.72
290	SHS	CL	1		basal	1.39
290	SHS	CL	1		forskolin	8.71
222	SHS	CL	2	1	basal	42.39
222	SHS	CL	2	1	forskolin	49.09
224	SHS	CL	2	1	basal	14.84
224	SHS	CL	2	1	forskolin	10.16
225	SHS	CL	2	2	basal	87.68
225	SHS	CL	2	2	forskolin	106.77
226	SHS	CL	2	2	basal	68.32
226	SHS	CL	2	2	forskolin	92.22
227	SHS	CL	2	1	basal	14.69
227	SHS	CL	2	1	forskolin	5.50
229	SHS	CL	2	2	basal	41.42
229	SHS	CL	2	2	forskolin	56.38
231	SHS	CL	2	2	basal	121.10
231	SHS	CL	2	2	forskolin	110.62
232	SHS	CL	2	2	basal	69.40

Fish #	Species	Site	Sex	Female Gonad Condition	Treatment	Testosterone (pg/ 20 mg testicular tissue or 10 ovarian follicles)
232	SHS	CL	2	2	forskolin	73.63
288	SHS	CL	2	2	basal	68.93
288	SHS	CL	2	2	forskolin	65.42
289	SHS	CL	2	2	basal	91.37
289	SHS	CL	2	2	forskolin	97.87
245	SHS	CR	1		basal	1.85
245	SHS	CR	1		forskolin	7.38
246	SHS	CR	1		basal	2.36
246	SHS	CR	1		forskolin	13.28
247	SHS	CR	1		basal	2.17
247	SHS	CR	1		forskolin	3.92
249	SHS	CR	1		basal	2.15
249	SHS	CR	1		forskolin	4.13
250	SHS	CR	1		basal	1.74
250	SHS	CR	1		forskolin	6.20
252	SHS	CR	1		basal	2.21
252	SHS	CR	1		forskolin	11.09
254	SHS	CR	1		basal	1.71
254	SHS	CR	1		forskolin	1.48
255	SHS	CR	1		basal	2.37
255	SHS	CR	1		forskolin	4.10
260	SHS	CR	1		basal	2.17
260	SHS	CR	1		forskolin	8.67
261	SHS	CR	1		basal	2.74
261	SHS	CR	1		forskolin	15.49
262	SHS	CR	1		basal	2.77
262	SHS	CR	1		forskolin	15.89
389	SHS	CR	1		basal	1.02
389	SHS	CR	1		forskolin	4.69
390	SHS	CR	1		basal	1.24
390	SHS	CR	1		forskolin	4.65
391	SHS	CR	1		basal	1.02
391	SHS	CR	1		forskolin	6.11
393	SHS	CR	1		basal	6.00
393	SHS	CR	1		forskolin	4.41
248	SHS	CR	2	2	basal	57.57
248	SHS	CR	2	2	forskolin	66.53
251	SHS	CR	2	1	basal	17.96

Fish #	Species	Site	Sex	Female Gonad Condition	Treatment	Testosterone (pg/ 20 mg testicular tissue or 10 ovarian follicles)
251	SHS	CR	2	1	forskolin	10.03
253	SHS	CR	2	2	basal	29.68
253	SHS	CR	2	2	forskolin	61.20
256	SHS	CR	2	1	basal	9.98
256	SHS	CR	2	1	forskolin	9.15
257	SHS	CR	2	1	basal	5.00
257	SHS	CR	2	1	forskolin	9.14
258	SHS	CR	2	1	basal	24.03
258	SHS	CR	2	1	forskolin	64.13
259	SHS	CR	2	1	basal	30.61
259	SHS	CR	2	1	forskolin	233.45
392	SHS	CR	2	2	basal	38.37
392	SHS	CR	2	2	forskolin	46.67
403	SHS	CR	2	2	basal	6.75
403	SHS	CR	2	2	forskolin	36.22
405	SHS	CR	2	2	basal	37.56
405	SHS	CR	2	2	forskolin	77.15
270	SHS	E	1		basal	5.36
270	SHS	E	1		forskolin	6.14
271	SHS	E	1		basal	2.65
271	SHS	E	1		forskolin	3.97
273	SHS	E	1		basal	3.95
273	SHS	E	1		forskolin	7.03
274	SHS	E	1		basal	5.27
274	SHS	E	1		forskolin	8.78
276	SHS	E	1		basal	8.11
276	SHS	E	1		forskolin	3.06
277	SHS	E	1		basal	10.25
277	SHS	E	1		forskolin	4.92
279	SHS	E	1		basal	3.64
279	SHS	E	1		forskolin	10.80
280	SHS	E	1		basal	6.99
280	SHS	E	1		forskolin	9.29
281	SHS	E	1		basal	14.34
281	SHS	E	1		forskolin	5.26
282	SHS	E	1		basal	8.35
282	SHS	E	1		forskolin	5.44
418	SHS	E	1		basal	2.65

Fish #	Species	Site	Sex	Female Gonad Condition	Treatment	Testosterone (pg/ 20 mg testicular tissue or 10 ovarian follicles)
418	SHS	E	1		forskolin	12.66
419	SHS	E	1		basal	5.45
419	SHS	E	1		forskolin	13.23
420	SHS	E	1		basal	3.25
420	SHS	E	1		forskolin	7.48
421	SHS	E	1		basal	3.26
421	SHS	E	1		forskolin	10.60
422	SHS	E	1		basal	3.86
422	SHS	E	1		forskolin	13.95
272	SHS	E	2	1	basal	35.54
272	SHS	E	2	1	forskolin	216.05
275	SHS	E	2	1	basal	735.33
275	SHS	E	2	1	forskolin	1379.50
278	SHS	E	2	1	basal	19.07
278	SHS	E	2	1	forskolin	233.27
283	SHS	E	2	1	forskolin	314.63
416	SHS	E	2	1	basal	6.75
416	SHS	E	2	1	forskolin	24.81
417	SHS	E	2	1	basal	18.53
417	SHS	E	2	1	forskolin	275.58
431	SHS	NS	1		basal	3.43
431	SHS	NS	1		forskolin	21.48
434	SHS	NS	1		basal	1.54
434	SHS	NS	1		forskolin	15.11
437	SHS	NS	1		basal	2.93
437	SHS	NS	1		forskolin	24.35
456	SHS	NS	1		basal	5.61
456	SHS	NS	1		forskolin	17.56
457	SHS	NS	1		basal	3.90
457	SHS	NS	1		forskolin	15.21
459	SHS	NS	1		basal	5.77
459	SHS	NS	1		forskolin	12.32
464	SHS	NS	1		basal	3.43
464	SHS	NS	1		forskolin	6.62
429	SHS	NS	2	1	basal	50.85
429	SHS	NS	2	1	forskolin	63.22
430	SHS	NS	2	1	basal	386.93
430	SHS	NS	2	1	forskolin	1301.50

Fish #	Species	Site	Sex	Female Gonad Condition	Treatment	Testosterone (pg/ 20 mg testicular tissue or 10 ovarian follicles)
432	SHS	NS	2	1	basal	510.35
432	SHS	NS	2	1	forskolin	1102.83
433	SHS	NS	2	1	basal	250.65
433	SHS	NS	2	1	forskolin	1276.33
435	SHS	NS	2	1	basal	450.85
435	SHS	NS	2	1	forskolin	1411.67
436	SHS	NS	2	1	basal	6.75
436	SHS	NS	2	1	forskolin	17.77
453	SHS	NS	2	1	basal	15.50
453	SHS	NS	2	1	forskolin	180.40
454	SHS	NS	2	1	basal	609.97
454	SHS	NS	2	1	forskolin	1330.17
458	SHS	NS	2	1	basal	336.83
458	SHS	NS	2	1	forskolin	1549.50
460	SHS	NS	2	1	basal	376.68
460	SHS	NS	2	1	forskolin	341.15
462	SHS	NS	2	1	basal	449.95
462	SHS	NS	2	1	forskolin	1644.50
463	SHS	NS	2	1	basal	448.25
463	SHS	NS	2	1	forskolin	493.13
465	SHS	NS	2	1	basal	27.81
465	SHS	NS	2	1	forskolin	49.47

Spring 1995 *in vitro* 17β-Estradiol Data

Fish #	Species	Site	Sex	Gonad Condition	Treatment	Estradiol (pg/10 follicles)
33	SHS	HRL	2	1	basal	3.45
33	SHS	HRL	2	1	forskolin	3.58
38	SHS	HRL	2	1	basal	118.30
38	SHS	HRL	2	1	forskolin	199.80
46	SHS	HRL	2	1	basal	23.95
46	SHS	HRL	2	1	forskolin	17.35
49	SHS	HRL	2	1	basal	14.42
49	SHS	HRL	2	1	forskolin	12.50
51	SHS	HRL	2	1	basal	165.60
51	SHS	HRL	2	1	forskolin	353.27
53	SHS	HRL	2	1	basal	3.45
53	SHS	HRL	2	1	forskolin	19.03
54	SHS	HRL	2	1	basal	25.29
54	SHS	HRL	2	1	forskolin	33.28
119	SHS	HRL	2	1	basal	4.08
119	SHS	HRL	2	1	forskolin	5.68
123	SHS	HRL	2	1	basal	4.08
123	SHS	HRL	2	1	forskolin	5.68
125	SHS	HRL	2	1	basal	34.19
125	SHS	HRL	2	1	forskolin	40.47
305	SHS	HRR	2	1	basal	7.51
305	SHS	HRR	2	1	forskolin	24.58
306	SHS	HRR	2	1	forskolin	117.40
307	SHS	HRR	2	2	basal	11.40
307	SHS	HRR	2	2	forskolin	28.85
308	SHS	HRR	2	1	forskolin	47.88
309	SHS	HRR	2	2	basal	3.98
309	SHS	HRR	2	2	forskolin	21.27
310	SHS	HRR	2	2	basal	68.61
310	SHS	HRR	2	2	forskolin	73.23
313	SHS	HRR	2	1	basal	5.20
313	SHS	HRR	2	1	forskolin	4.28
314	SHS	HRR	2	1	basal	5.20
314	SHS	HRR	2	1	forskolin	4.28
317	SHS	HRR	2	1	basal	5.20
317	SHS	HRR	2	1	forskolin	4.28
319	SHS	HRR	2	2	basal	5.20
319	SHS	HRR	2	2	forskolin	62.90
321	SHS	HRR	2	1	basal	5.20

Fish #	Species	Site	Sex	Gonad Condition	Treatment	Estradiol (pg/10 follicles)
321	SHS	HRR	2	1	forskolin	31.62
322	SHS	HRR	2	2	basal	12.71
322	SHS	HRR	2	2	forskolin	76.65
324	SHS	HRR	2	1	basal	5.20
324	SHS	HRR	2	1	forskolin	4.28
326	SHS	HRR	2	1	basal	5.20
326	SHS	HRR	2	1	forskolin	4.28
327	SHS	HRR	2	1	basal	5.20
327	SHS	HRR	2	1	forskolin	106.81
329	SHS	HRR	2	1	basal	5.20
329	SHS	HRR	2	1	forskolin	4.28
331	SHS	HRR	2	1	basal	5.20
331	SHS	HRR	2	1	forskolin	4.28
332	SHS	HRR	2	1	basal	5.20
332	SHS	HRR	2	1	forskolin	4.28
333	SHS	HRR	2	1	basal	5.20
333	SHS	HRR	2	1	forskolin	4.28
336	SHS	HRR	2	1	basal	5.20
336	SHS	HRR	2	1	forskolin	4.28
1	SHS	MAR	2	1	basal	14.10
1	SHS	MAR	2	1	forskolin	18.41
162	SHS	MAR	2	1	basal	4.08
162	SHS	MAR	2	1	forskolin	21.48
172	SHS	MAR	2	1	basal	4.08
172	SHS	MAR	2	1	forskolin	175.73
180	SHS	MAR	2	1	basal	150.17
180	SHS	MAR	2	1	forskolin	388.90
354	SHS	MAR	2	2	basal	7.71
354	SHS	MAR	2	2	forskolin	45.82
355	SHS	MAR	2	1	basal	5.20
355	SHS	MAR	2	1	forskolin	9.80
356	SHS	MAR	2	2	basal	5.18
356	SHS	MAR	2	2	forskolin	4.28
359	SHS	MAR	2	2	basal	18.29
359	SHS	MAR	2	2	forskolin	29.91
363	SHS	MAR	2	2	basal	25.77
363	SHS	MAR	2	2	forskolin	36.96
380	SHS	MAR	2	2	basal	13.31
380	SHS	MAR	2	2	forskolin	25.06

Fish #	Species	Site	Sex	Gonad Condition	Treatment	Estradiol (pg/10 follicles)
2	SHS	MAL	2	1	basal	3.45
2	SHS	MAL	2	1	forskolin	3.58
4	SHS	MAL	2	1	basal	3.45
4	SHS	MAL	2	1	forskolin	3.58
9	SHS	MAL	2	1	basal	3.45
9	SHS	MAL	2	1	forskolin	3.58
10	SHS	MAL	2	1	basal	13.68
10	SHS	MAL	2	1	forskolin	364.03
11	SHS	MAL	2	1	basal	9.49
11	SHS	MAL	2	1	forskolin	101.72
12	SHS	MAL	2	1	basal	13.30
12	SHS	MAL	2	1	forskolin	58.97
100	SHS	MAL	2	1	basal	3.45
100	SHS	MAL	2	1	forskolin	3.58
103	SHS	MAL	2	1	basal	10.53
103	SHS	MAL	2	1	forskolin	25.12
105	SHS	MAL	2	1	basal	4.08
105	SHS	MAL	2	1	forskolin	5.68
222	SHS	CL	2	1	basal	12.85
222	SHS	CL	2	1	forskolin	26.73
224	SHS	CL	2	1	basal	4.08
224	SHS	CL	2	1	forskolin	5.68
225	SHS	CL	2	2	basal	5.66
225	SHS	CL	2	2	forskolin	54.63
226	SHS	CL	2	2	basal	33.95
226	SHS	CL	2	2	forskolin	279.03
227	SHS	CL	2	1	basal	4.08
227	SHS	CL	2	1	forskolin	5.68
229	SHS	CL	2	2	basal	4.08
229	SHS	CL	2	2	forskolin	21.69
231	SHS	CL	2	2	basal	24.53
231	SHS	CL	2	2	forskolin	75.32
232	SHS	CL	2	2	basal	4.08
232	SHS	CL	2	2	forskolin	47.40
288	SHS	CL	2	2	basal	3.98
288	SHS	CL	2	2	forskolin	75.57
289	SHS	CL	2	2	basal	26.37
289	SHS	CL	2	2	forskolin	79.43
248	SHS	CR	2	2	basal	4.08

Fish #	Species	Site	Sex	Gonad Condition	Treatment	Estradiol (pg/10 follicles)
248	SHS	CR	2	2	forskolin	22.99
251	SHS	CR	2	1	basal	4.08
251	SHS	CR	2	1	forskolin	5.68
253	SHS	CR	2	2	basal	3.98
253	SHS	CR	2	2	forskolin	51.67
256	SHS	CR	2	1	basal	3.98
256	SHS	CR	2	1	forskolin	4.75
257	SHS	CR	2	1	basal	3.98
257	SHS	CR	2	1	forskolin	4.75
258	SHS	CR	2	1	basal	6.49
258	SHS	CR	2	1	forskolin	44.70
259	SHS	CR	2	1	basal	3.98
259	SHS	CR	2	1	forskolin	134.35
392	SHS	CR	2	2	basal	5.18
392	SHS	CR	2	2	forskolin	6.55
403	SHS	CR	2	2	basal	5.18
403	SHS	CR	2	2	forskolin	3.93
405	SHS	CR	2	2	basal	14.06
405	SHS	CR	2	2	forskolin	12.75
272	SHS	E	2	1	basal	10.10
272	SHS	E	2	1	forskolin	82.55
275	SHS	E	2	1	basal	275.77
275	SHS	E	2	1	forskolin	632.33
278	SHS	E	2	1	basal	3.98
278	SHS	E	2	1	forskolin	132.78
283	SHS	E	2	1	forskolin	233.87
416	SHS	E	2	1	basal	5.18
416	SHS	E	2	1	forskolin	3.93
417	SHS	E	2	1	basal	5.18
417	SHS	E	2	1	forskolin	145.72
429	SHS	NS	2	1	basal	12.33
429	SHS	NS	2	1	forskolin	15.29
430	SHS	NS	2	1	basal	364.95
430	SHS	NS	2	1	forskolin	786.33
432	SHS	NS	2	1	basal	203.17
432	SHS	NS	2	1	forskolin	554.75
433	SHS	NS	2	1	basal	422.00
433	SHS	NS	2	1	forskolin	975.83
435	SHS	NS	2	1	basal	412.15

Fish #	Species	Site	Sex	Gonad Condition	Treatment	Estradiol (pg/10 follicles)
435	SHS	NS	2	1	forskolin	792.83
436	SHS	NS	2	1	basal	5.18
436	SHS	NS	2	1	forskolin	3.93
453	SHS	NS	2	1	basal	5.18
453	SHS	NS	2	1	forskolin	85.18
454	SHS	NS	2	1	basal	252.38
454	SHS	NS	2	1	forskolin	564.28
458	SHS	NS	2	1	basal	379.95
458	SHS	NS	2	1	forskolin	1333.67
460	SHS	NS	2	1	basal	99.65
460	SHS	NS	2	1	forskolin	210.07
462	SHS	NS	2	1	basal	326.02
462	SHS	NS	2	1	forskolin	770.83
463	SHS	NS	2	1	basal	75.55
463	SHS	NS	2	1	forskolin	234.27
465	SHS	NS	2	1	basal	28.34
465	SHS	NS	2	1	forskolin	35.65

APPENDIX C:

SUMMARY OF HABITAT CLASSIFICATION

SITE HRL

River Name: Athabasca River	**Site:** HRL	**Latitude / Longitude:** N 53°24.25'/W 117°35.49'

Location: Mill A reference site located 0.25 km upstream of the mill A pumphouse, LUB of river, Hinton.

Channel Type: U	**Survey Date**	**River Stage**	**Water Temp. (C°)**	**Sampling Depth (cm)**	**Mean Velocity (m/s)**
Special Habitat: see comments					
Bank Type: Depositional (D2)	15/05/94	medium	9.5	45	1.42
Substrate Type (%):	04/10/94	medium	11.0	40-50	NA
bedrock ø	14/04/95	low	4.5	45	0.81
boulder 30					
cobble 45					
gravel 20					
fines (sand/silt/clay) 5					
organic material ø					

Comments:

- spring 1995 exhibited below normal water levels
- banks during spring 1995 were extensively covered with shore ice (approx. 45-60 cm thick).
- a small shoal (and riffle zone) located upstream and across from the study site was prominent during the spring '95 trip.
- general area can be classified as shallow run habitat with small riffle areas and emergent boulders.

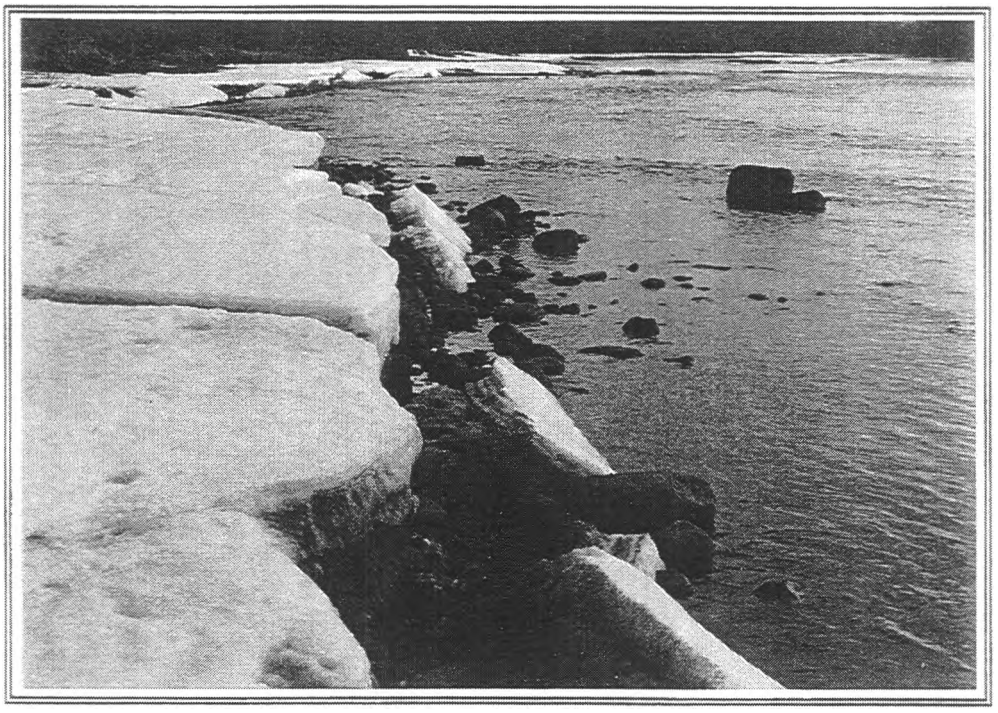


Figure C1. Photograph of sampling Site HRL, spring 1995 (view faces upstream).

SITE HRR

River Name: Athabasca River		**Site:** HRR	**Latitude / Longitude:** N 53°24.34'/W 117°35.56'			
Location: Mill A reference site located across river from Site HRL, RUB of river, Hinton.						
Channel Type:	U	**Survey Date**	**River Stage**	**Water Temp. (C°)**	**Sampling Depth (cm)**	**Mean Velocity (m/s)**
Special Habitat:	SH					
Bank Type: Depositional (D2)		18/04/95	low	6.0	40	0.76
Substrate Type (%):						
bedrock	ø					
boulder	30	**Comments:**				
cobble	25	• spring 1995 exhibited below normal water levels • shoal areas prominent due to low water level forming a small emergent cobble bar approximately 20 m from RUB. • general area can be classified as run habitat.				
gravel	30					
fines (sand/silt/clay)	15					
organic material	ø					

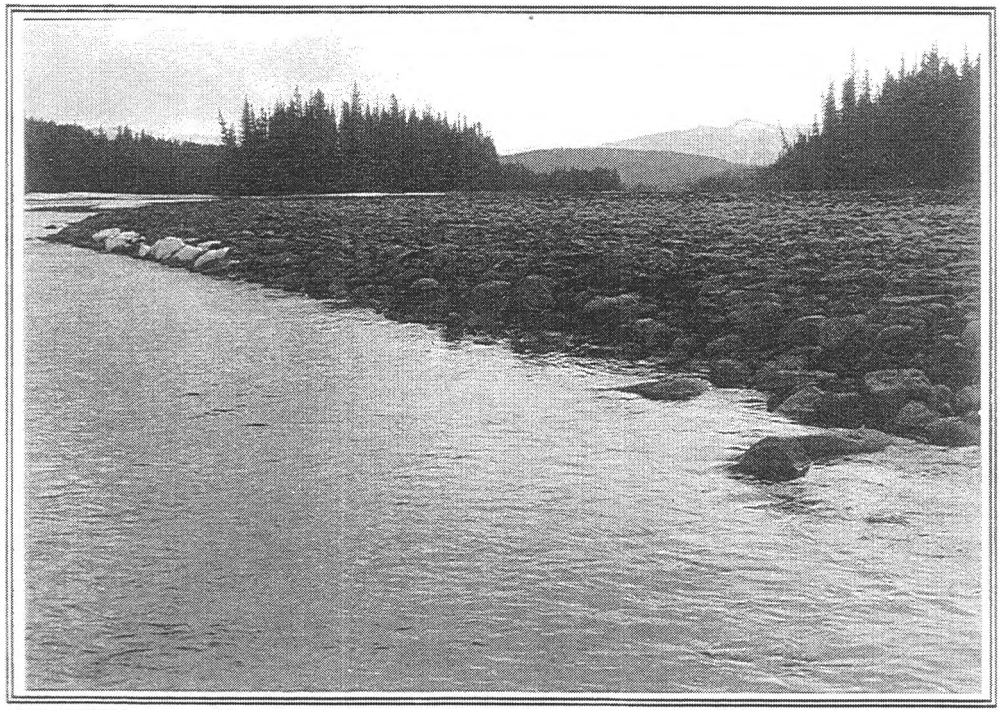


Figure C2. Photograph of sampling Site HRR, spring 1995 (view faces upstream).

SITE MAL

River Name: Athabasca River		**Site:** MAL	**Latitude / Longitude:** N 53°25.73'/W 117°33.17'			
Location: Mill A near-field site ≈ 0.25 km downstream of Helge-Nelson Bridge, LUB of river, Hinton.						
Channel Type:	U	**Survey Date**	**River Stage**	**Water Temp. (C°)**	**Sampling Depth (cm)**	**Mean Velocity (m/s)**
Special Habitat:	none					
Bank Type: Depositional (D2)		04/10/94	medium	11.0	30-100	0.85
Substrate Type (%):		09/04/95	low	7.0	35-65	1.10
bedrock	ø					
boulder	40	**Comments:**				
cobble	45	• spring 1995 exhibited below normal water levels				
gravel	5	• much of the fall sampling site was de-watered at the time of the spring '95 survey.				
fines (sand/silt/clay)	10	• general area can be classified as run habitat.				
organic material	ø					

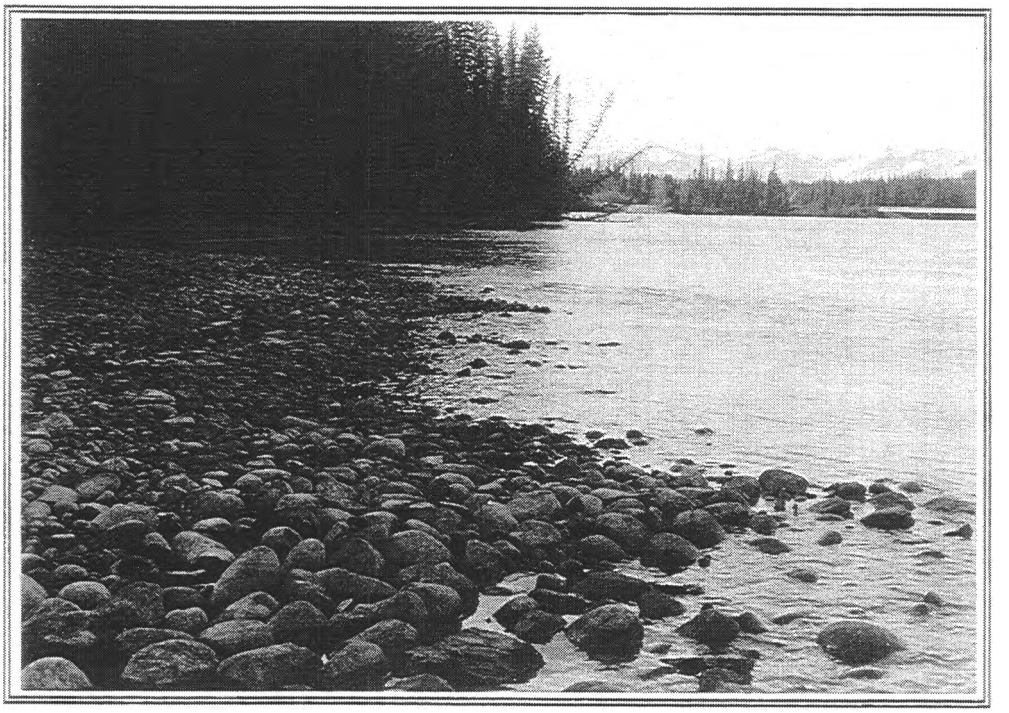


Figure C3. Photograph of sampling Site MAL, fall 1994 (view faces upstream).

SITE MAR

River Name: Athabasca River	**Site:** MAR	**Latitude / Longitude:** N 53°24.63'/W 117°33.46'			
Location: Mill A near-field site located at Helge-Nelson Bridge, RUB of river across from plume tracking.					
Channel Type: U **Special Habitat:** see comments	**Survey Date**	**River Stage**	**Water Temp. (C°)**	**Sampling Depth (cm)**	**Mean Velocity (m/s)**
Bank Type: Depositional (D2)	15/05/94	medium	9.5	NA	NA
Substrate Type (%):	04/10/94	medium	11.0	25-70	1.27
bedrock ø	10/04/95	low	6.0	25-40	1.22
boulder 30	**Comments:**				
cobble 40	• spring 1995 exhibited below normal water levels • a mid-channel shoal was present during the spring '95 survey (not part of the immediate sampling site area). • immediately upstream of the sampling area is a small backwater. • general area can be classified as riffle/run habitat.				
gravel 20					
fines (sand/silt/clay) 10					
organic material ø					

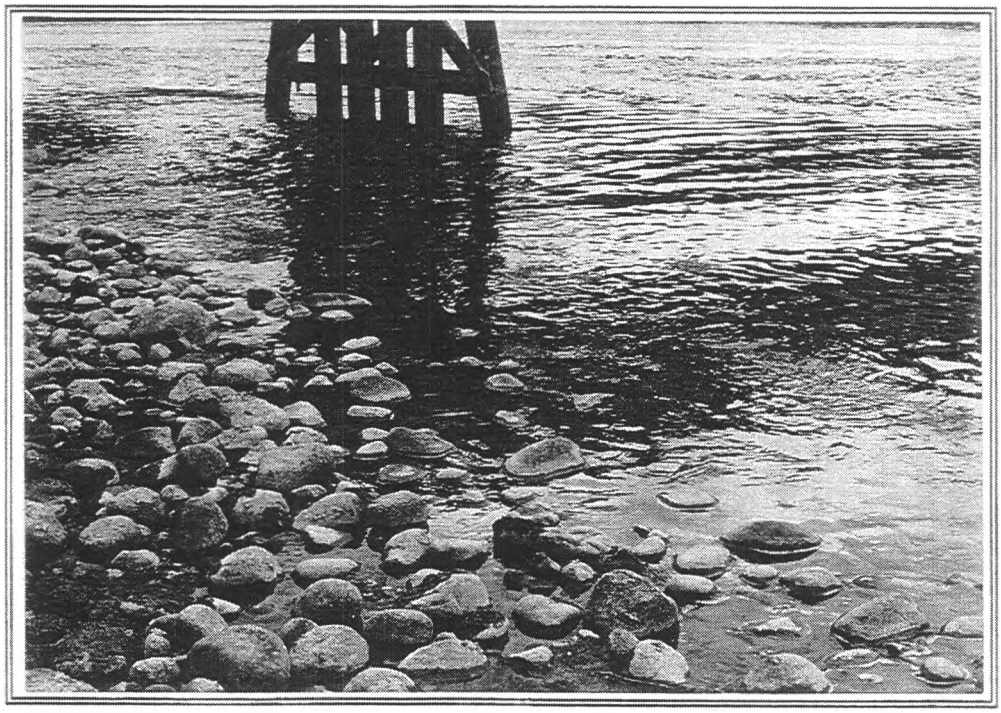


Figure C4. Photograph of sampling Site MAR, spring 1995 (view faces downstream).

SITE CL

River Name: Athabasca River		**Site:** CL	**Latitude / Longitude:** N 53°32.03'/W 117°20.74'			
Location: Mill A far-field site ≈ 0.75 km downstream of Obed Mtn. Coal Ltd. Bridge, LUB of river, Hinton.						
Channel Type:	U	**Survey Date**	**River Stage**	**Water Temp. (C°)**	**Sampling Depth (cm)**	**Mean Velocity (m/s)**
Special Habitat:	none					
Bank Type: Erosional	(E5)	11/04/95	low	6.5	30-60	1.27
Substrate Type (%):						
bedrock	5					
boulder	40	**Comments:**				
cobble	35	• spring 1995 exhibited below normal water levels • bed material very angular • general area can be classified as shallow run habitat with small riffle areas and emergent boulders				
gravel	15					
fines (sand/silt/clay)	5					
organic material	ø					

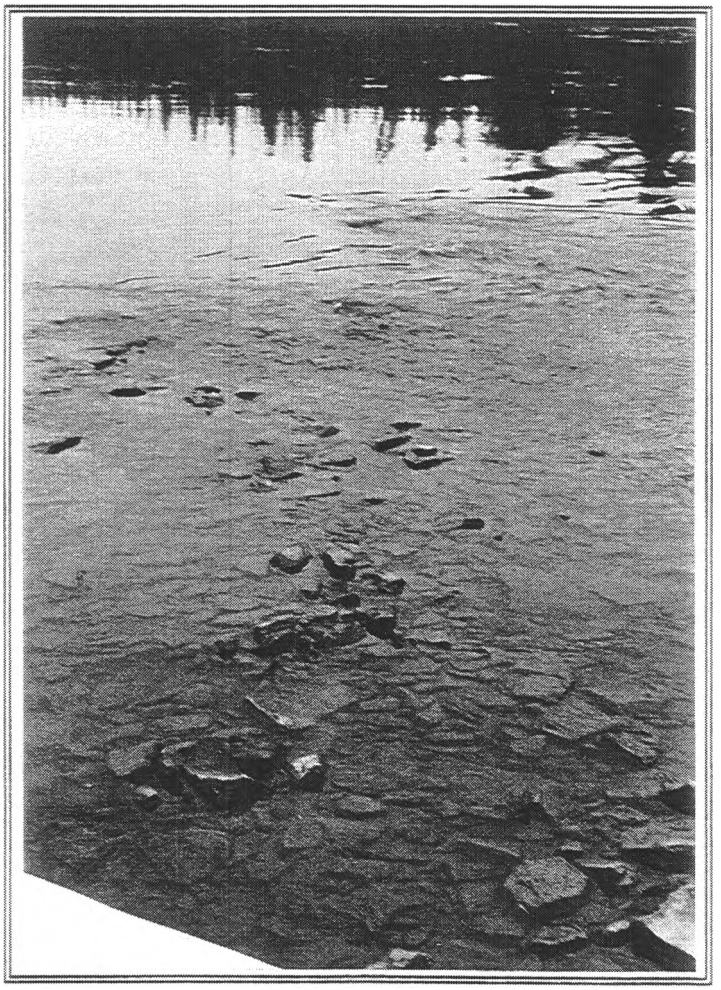


Figure C5. Photograph of sampling Site CL, spring 1995 (view faces across stream).

SITE CR

River Name: Athabasca River		**Site:** CR	**Latitude / Longitude:** N 53°31.95'/W 117°20.76'			
Location: Mill A far-field site ≈ 0.75 km downstream of Obed Mtn. Coal Ltd. Bridge, RUB of river, Hinton.						
Channel Type:	U	**Survey Date**	**River Stage**	**Water Temp. (C°)**	**Sampling Depth (cm)**	**Mean Velocity (m/s)**
Special Habitat:	none					
Bank Type: Depositional (D2)		14/04/95	low	6.5	35-75	0.57
Substrate Type (%):						
bedrock	ø					
boulder	20	**Comments:**				
cobble	70	• spring 1995 exhibited below normal water levels				
gravel	5	• banks during spring 1995 were extensively covered with shore ice (approx. 30-45 cm thick).				
fines (sand/silt/clay)	5	• general area can be classified as slow moving run habitat.				
organic material	ø					

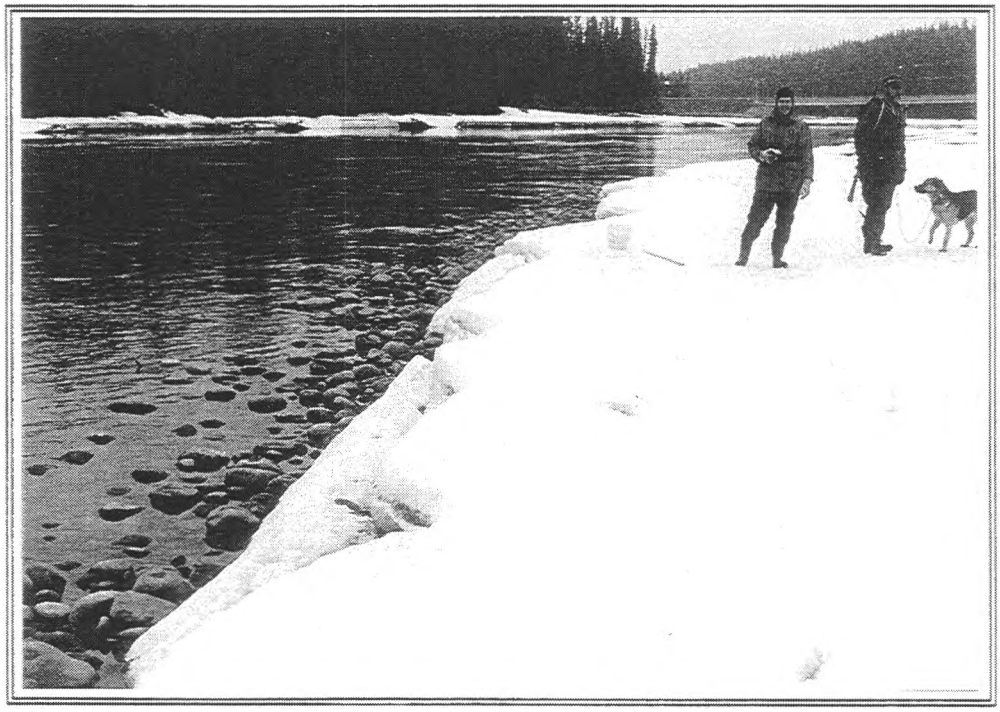


Figure C6. Photograph of sampling Site CR, spring 1995 (view faces upstream).

SITE E

River Name: Athabasca River	Site: E	Latitude / Longitude: N 53°42.46'/W 117°10.13'
Location: Mill A far-field site located ≈ 0.75 km downstream of Emerson Bridge, LUB of river, Hinton.		

Channel Type: U	Survey Date	River Stage	Water Temp. (C°)	Sampling Depth (cm)	Mean Velocity (m/s)
Special Habitat: see comments					
Bank Type: Depositional (D2)	12/04/95	low	4.5	30-55	0.59
Substrate Type (%):					
bedrock ø					
boulder 35	**Comments:**				
cobble 50	• spring 1995 exhibited below normal water levels				
gravel 10	• banks during spring 1995 were extensively covered with shore ice				
fines (sand/silt/clay) 5	• singular island located approx. 200 m downstream of site with riffle zones on either side of the island.				
organic material ø	• small riffle habitat associated with shore cobble bar (see photo).				
	• general area can be classified as a slow run with small riffle habitat.				

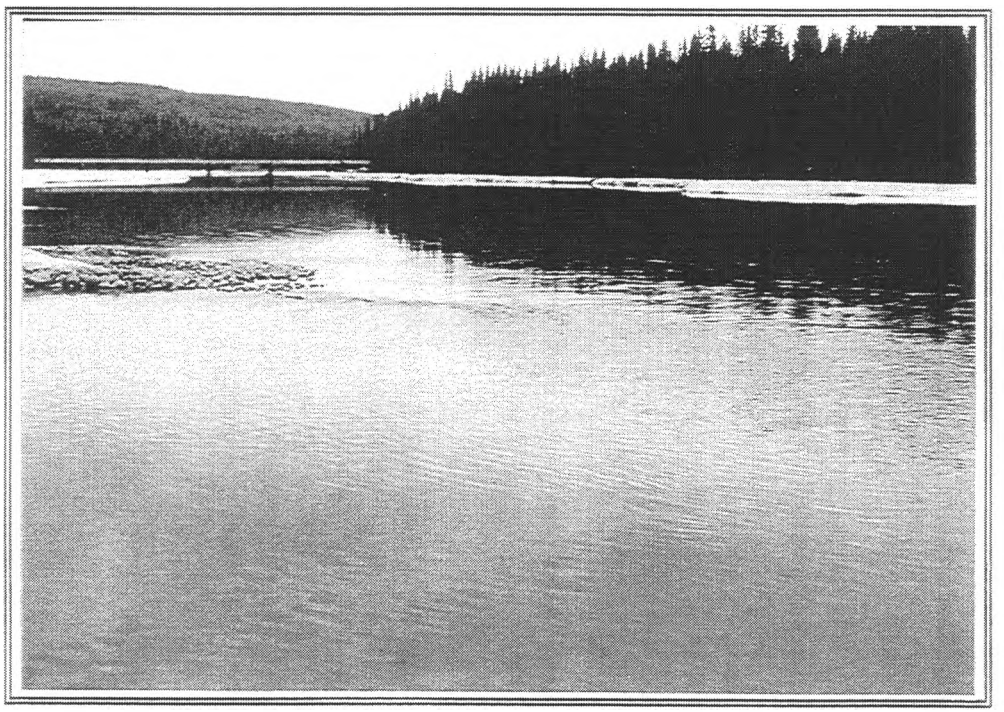


Figure C7. Photograph of sampling Site E, spring 1995 (view faces upstream).

SITE WF

River Name: Athabasca River		**Site:** WF	**Latitude / Longitude:** N 54°12.16'/W 116°04.15'			
Location: Mill B & C reference site immediately downstream of Windfall Bridge, LUB of river, Whitecourt.						
Channel Type:	U	**Survey Date**	**River Stage**	**Water Temp. (C°)**	**Sampling Depth (cm)**	**Mean Velocity (m/s)**
Special Habitat:	none					
Bank Type:	A1 or E3	12/05/94	medium	13.0	30-55	0.59
Substrate Type (%):		04/10/94	medium	7.0	20-45	0.53
bedrock	ø					
boulder	50	**Comments:**				
cobble	35	• bank type during low flow conditions could be considered armoured and stable(A1) dominated by boulder and cobble substrates.				
gravel	10	• high flow conditions would submerge the boulder/cobble and the river would interact with the actual bank and riparian vegetation. At this time the banks may be considered susceptible to erosion (E3).				
fines (sand/silt/clay)	5	• general area can be classified as run habitat.				
organic material	ø					

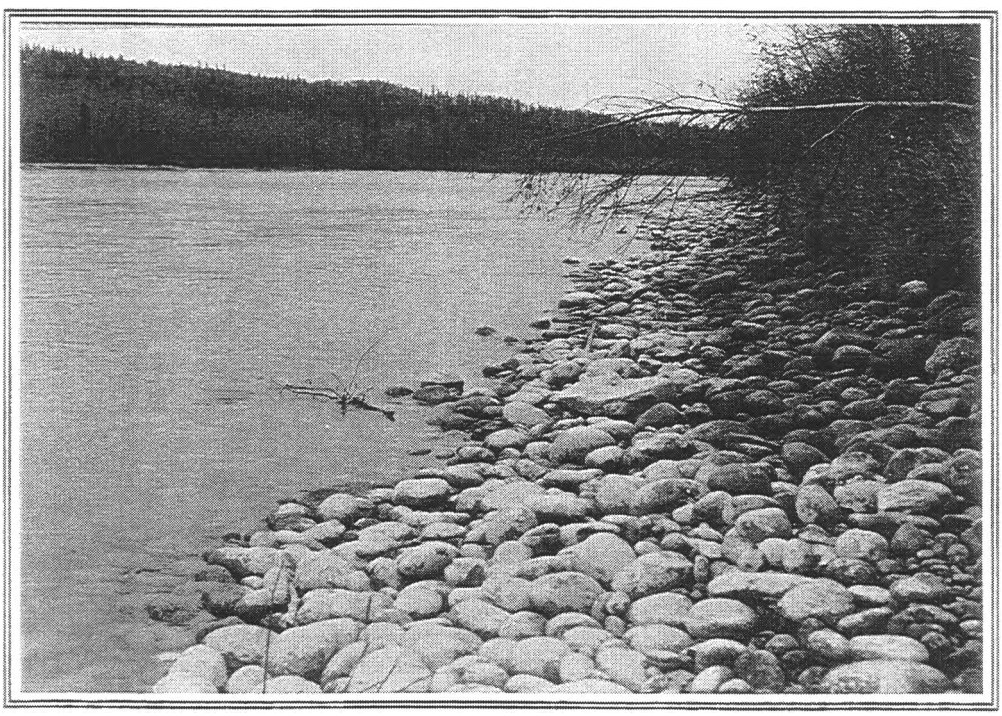


Figure C8. Photograph of sampling Site WP, fall 1994 (view faces downstream).

SITE R2

River Name: Athabasca River		Site: R2	Latitude / Longitude: N 52°11.28'/W 115°50.31'			
Location: Mill B & C 2nd reference site ≈ 2 km upstream from the mill B outfall, RUB of river, Whitecourt.						
Channel Type:	U	**Survey Date**	**River Stage**	**Water Temp. (C°)**	**Sampling Depth (cm)**	**Mean Velocity (m/s)**
Special Habitat:	BW					
Bank Type:	A2 - E4	04/10/94	medium	7.0	30-50	0.93
Substrate Type (%):						
bedrock	ø					
boulder	40	**Comments:**				
cobble	40	• bank habitat is generally armoured and stable (A2) with isolated areas of instability (E4).				
gravel	15	• small backwater area in middle of sampling site				
fines (sand/silt/clay)	5	• most fish caught along slow margin of the river.				
organic material	ø	• general area can be classified as a slow moving run with small backwater habitat				

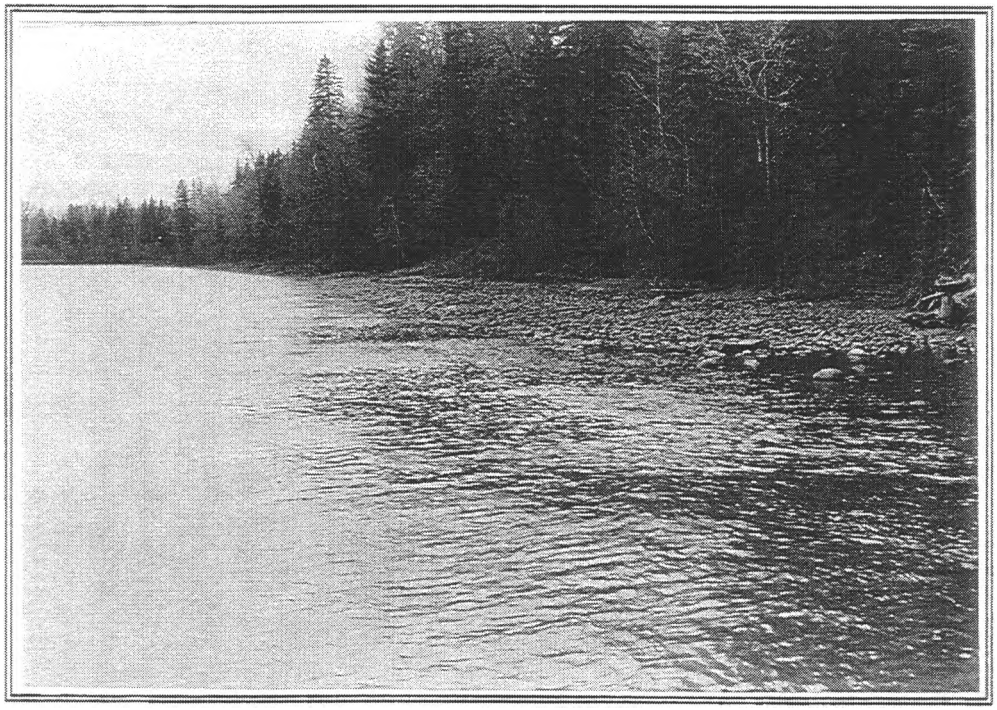


Figure C9. Photograph of sampling Site R2, fall 1994 (view faces upstream).

SITE MB

River Name: Athabasca River		**Site:** MB	**Latitude / Longitude:** N 54°09.79'/W 115°45.54'			
Location: Mill B near-field site = 3.5 km downstream of the mill B outfall, RUB of river, Whitecourt.						
Channel Type:	U	**Survey Date**	**River Stage**	**Water Temp. (C°)**	**Sampling Depth (cm)**	**Mean Velocity (m/s)**
Special Habitat:	BW					
Bank Type: Erosional	(E4)	12/05/94	medium	14.5	25-30	2.69
Substrate Type (%):		10/04/94	medium	11.0	40-50	1.36
bedrock	ø					
boulder	35	**Comments:**				
cobble	50	• most fish were caught along the margin of the river where the water velocity was substantially lower.				
gravel	5	• small backwater habitat was present due to a small cobble bar protruding downstream from the bank				
fines (sand/silt/clay)	5	• general area can be classified as run habitat with a small backwater zone.				
organic material	5					

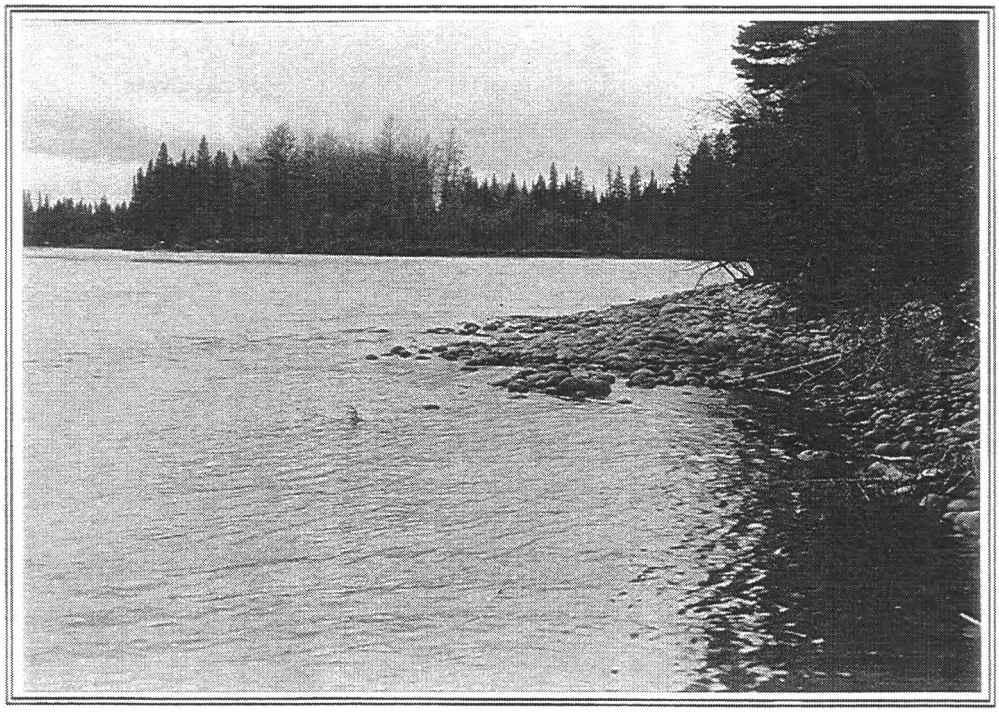


Figure C10. Photograph of sampling Site MB, fall 1994 (view faces upstream).

SITE MC

River Name: Athabasca River	**Site:** MC	**Latitude / Longitude:** N 54°09.95'/W 115°40.10'				
Location: Mill C near-field site ≈ 2.25 km downstream of the mill C outfall, LUB of river, Whitecourt.						
Channel Type: U	**Survey Date**	**River Stage**	**Water Temp. (C°)**	**Sampling Depth (cm)**	**Mean Velocity (m/s)**	
Special Habitat: none						
Bank Type: Depositional (D2)	15/05/94	medium	9.5	45	1.42	
Substrate Type (%):	10/04/94	medium	11.0	40-50	NA	
bedrock ø						
boulder 40	**Comments:**					
cobble 40	• channel immediately upstream of site consists of multiple islands • riffle habitat ≈ 2 m out from shore consisting of boulders and cobble. • most fish were caught along the quieter margin of the river. • general area can be classified as run/riffle habitat.					
gravel 15						
fines (sand/silt/clay) 5						
organic material ø						

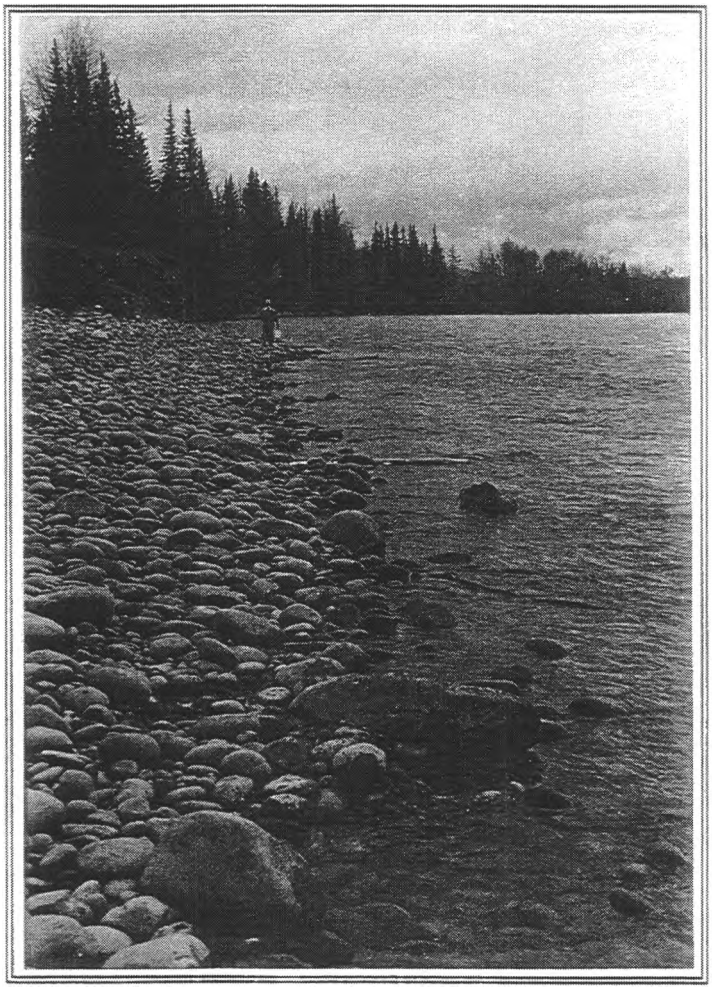


Figure C11. Photograph of fish sampling Site MC, fall 1994 (view faces upstream).

SITE MCS

River Name: Athabasca River	**Site:** MCS	**Latitude / Longitude:** N 54°09.76'/W 115°38.64'

Location: Mill C near-field seining site approx. 3.5 km downstream of outfall, LUB of island, Whitecourt.

		Survey Date	**River Stage**	**Water Temp. (C°)**	**Sampling Depth (cm)**	**Mean Velocity (m/s)**
Channel Type:	S					
Special Habitat:	SH					
Bank Type: Depositional (D2)		12/05/94	medium	16.0	40-70	0.60
Substrate Type (%):						
bedrock	ø					
boulder	20					
cobble	40					
gravel	20					
fines (sand/silt/clay)	20					
organic material	ø					

Comments:

- seining site below mill C outfall.
- site is located across from unknown outfall.
- a small riffle zone is present approx. 100 m upstream from the site (upstream tip of island).
- general area can be classified as a slow moving depositional zone

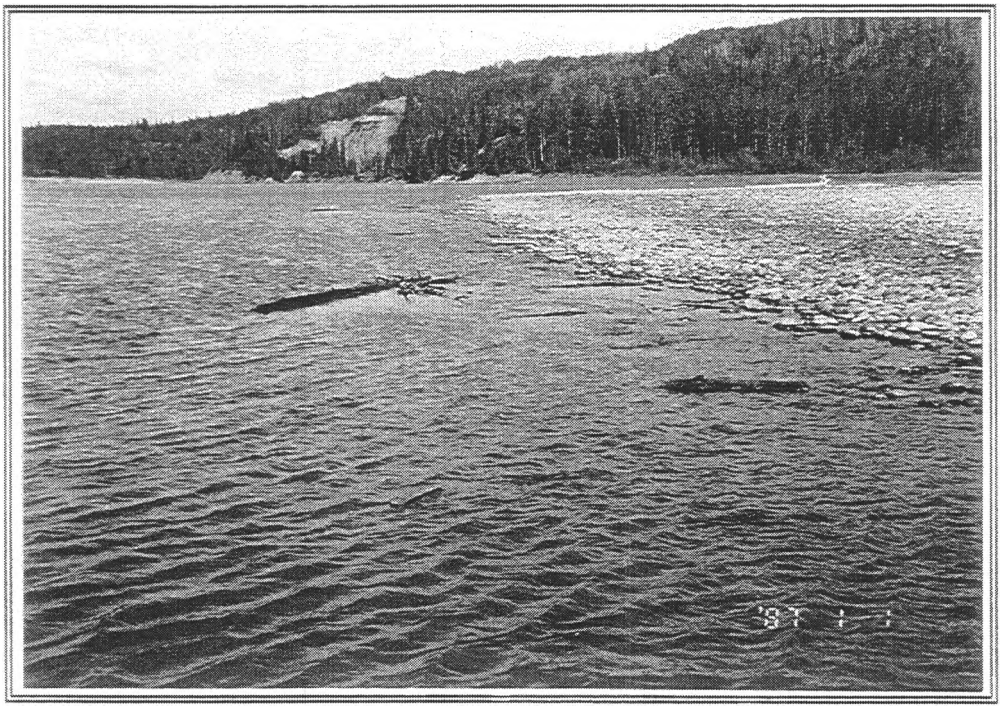


Figure C12. Photograph of sampling Site MCS, spring 1994 (view faces upstream).

SITE NS

River Name: N. Saskatchewan		Site: NS	Latitude / Longitude: N 52°23.60'/W 115°18.64'			
Location: Reference site on N. Sask. River along LUB of island across from Horburg recreation area (AFS).						
Channel Type:	S	**Survey Date**	**River Stage**	**Water Temp. (C°)**	**Sampling Depth (cm)**	**Mean Velocity (m/s)**
Special Habitat:	none					
Bank Type:	D2/E4	22/04/95	variable	5.0	25-75	1.97
Substrate Type (%):						
bedrock	ø					
boulder	30	**Comments:**				
cobble	40	• depositional (D2) habitat along mid-channel island, steep eroding banks (E4) along left upstream bank of channel.				
gravel	25	• water level varied daily by approximately 0.75-1.0 m due to upstream regulation of flow (Big Horn dam).				
fines (sand/silt/clay)	5	• general area can be classified as run habitat (small riffles along margin).				
organic material	ø					

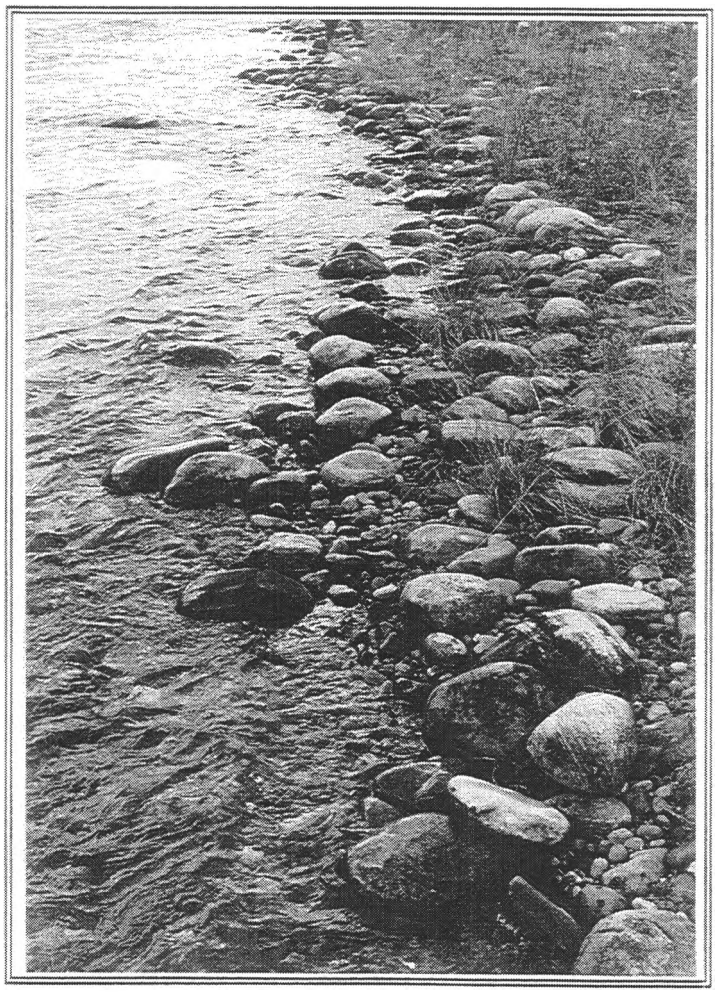


Figure C13. Photograph of fish sampling Site NS, spring 1995 (view faces upstream).