**Report Title:** Peace River Site C Development – Fisheries Habitat and Tributary Surveys 1990 Studies
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**NOTE TO READER:**

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**During Stage 2 of the Site C Project, studies are underway to update many of the historical studies and information known about the project.**

**The potential Site C project, as originally conceived, will be updated to reflect current information and to incorporate new ideas brought forward by communities, First Nations, regulatory agencies and stakeholders. Today's approach to Site C will consider environmental concerns, impacts to land, and opportunities for community benefits, and will update design, financial and technical work.**

A 3698

*Second draft: subject to revision*



PEACE RIVER SITE C DEVELOPMENT:

# FISHERIES HABITAT AND TRIBUTARY SURVEYS

1990 Studies

Prepared for
BRITISH COLUMBIA HYDRO
Environmental Resources
Vancouver, B.C.

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# PART I

# INTRODUCTION

## 1.0 OBJECTIVES

In 1989, B.C. Hydro began a program of investigations designed to provide data which would be used in support of an Energy Certificate for construction of a dam at Site C on the Peace River. The studies included engineering design as well as an examination of fish populations in the mainstem Peace and Halfway rivers (Pattenden and Ash 1990), a sport fishing survey (DPA Group, Inc.) and fisheries assessment of Peace River and Halfway River tributaries plus a habitat mapping program of the Peace River, Halfway River and their tributaries (Slaney et al. 1991).

B.C. Hydro commissioned further fisheries studies in the Site C area during 1990. Aquatic Resources Ltd. was retained to collect additional information on sportfish utilization of Peace River and Halfway River tributary streams. The program entailed work to be conducted in each season through out the year. However, the fall and winter studies and some of the spring program were subsequently deferred due to budget constraints. The objectives of the revised program were:

1.) To quantify the extent of usage of the lower 10 km of Maurice Creek and Lynx Creek by spring spawning sportfish species.

2.) To quantify the extent of rearing by sportfish species in the lower 10 km of Maurice and Lynx Creeks.

3.) To assess the extent of movement of spawning sportfish from the Peace River into the Moberly River during the spring. Identify the main spawning areas for the major sportfish species. The Moberly River study area extended from the mouth to Moberly Lake 130 km upstream.

4.) To obtain information during the summer on fish species composition, distribution and habitat associations in the Graham, Blue Grave, Horseshoe, Chowade, and Cypress systems. These upper Halfway tributaries were identified during the 1989 studies as having suitable sportfish habitat (Slaney et al. 1991).

5.) To obtain water quality information for the five upper Halfway River tributaries. The information will be used to determine the presence of water quality problems which could limit fish production.

6.) To assess factors limiting fish production in the tributaries examined and to identify potential enhancement projects.

## 1.1 BACKGROUND

The Peace River was first dammed in 1968 after the completion of the W.A.C Bennett Dam near Hudson Hope. The dam created Williston Lake, the largest body of freshwater in B.C.. Following this, the construction of Peace Canyon dam, just above Hudson Hope, created Dinosaur Lake. Dinosaur Lake is a relatively small reservoir confined by the former Peace Canyon. A third dam at 'Site C' has been proposed to meet British Columbia's power requirements in the future. Site C is situated near Fort St. John, approximately 85 km downstream of the Peace Canyon Dam. The new dam will create a 2.3 billion $m^3$ reservoir between the dam site and Hudson Hope. As reservoir operation will be 'run of the river' like Dinosaur Lake there will not be large water level fluctuations.

B.C. Hydro applied for an Energy Project Certificate during the 70's to construct the Site C dam. A number of studies were conducted during the mid 70's, including a fisheries study (RRSC 1979) in preparation for hearings held during 1980. The B.C. Utilities Commission ruled that the dam was not required at that time due to revised energy projections. The commission also recommended that more extensive fisheries studies on potential impacts and on potential mitigation techniques should be conducted (BCUC 1983).

The status of the project again changed in 1989. Previous energy predictions indicated the power would be required by the mid-1990's, however revised energy projections again pushed the project back. In addition, the Federal Government deemed that it was necessary to hold full environmental hearings before the project could start. Prior to 1989, B.C. Hydro only had to demonstrate that need for the power as environmental hearings had already been conducted in the early 80's.

## 1.2 STUDY AREA

The Peace River flows east from the Peace Canyon dam for 145 km to the B.C.-Alberta border (Figure 1). Along this section the river is cut 150 to 220 m into the sedimentary deposits of the Alberta Plateau; a flat and gently rolling landscape east of the Rocky Mountain foothills. Site C is situated 85 km below the Peace Canyon dam near Fort St. John. The dam, if constructed, will create a reservoir almost up to the foot of the Peace Canyon dam. The reservoir will generally be less than 2 km across as it is contained by the steeply reposed valley walls of the Peace River. The full supply line will extend 15 km up some of the tributaries.

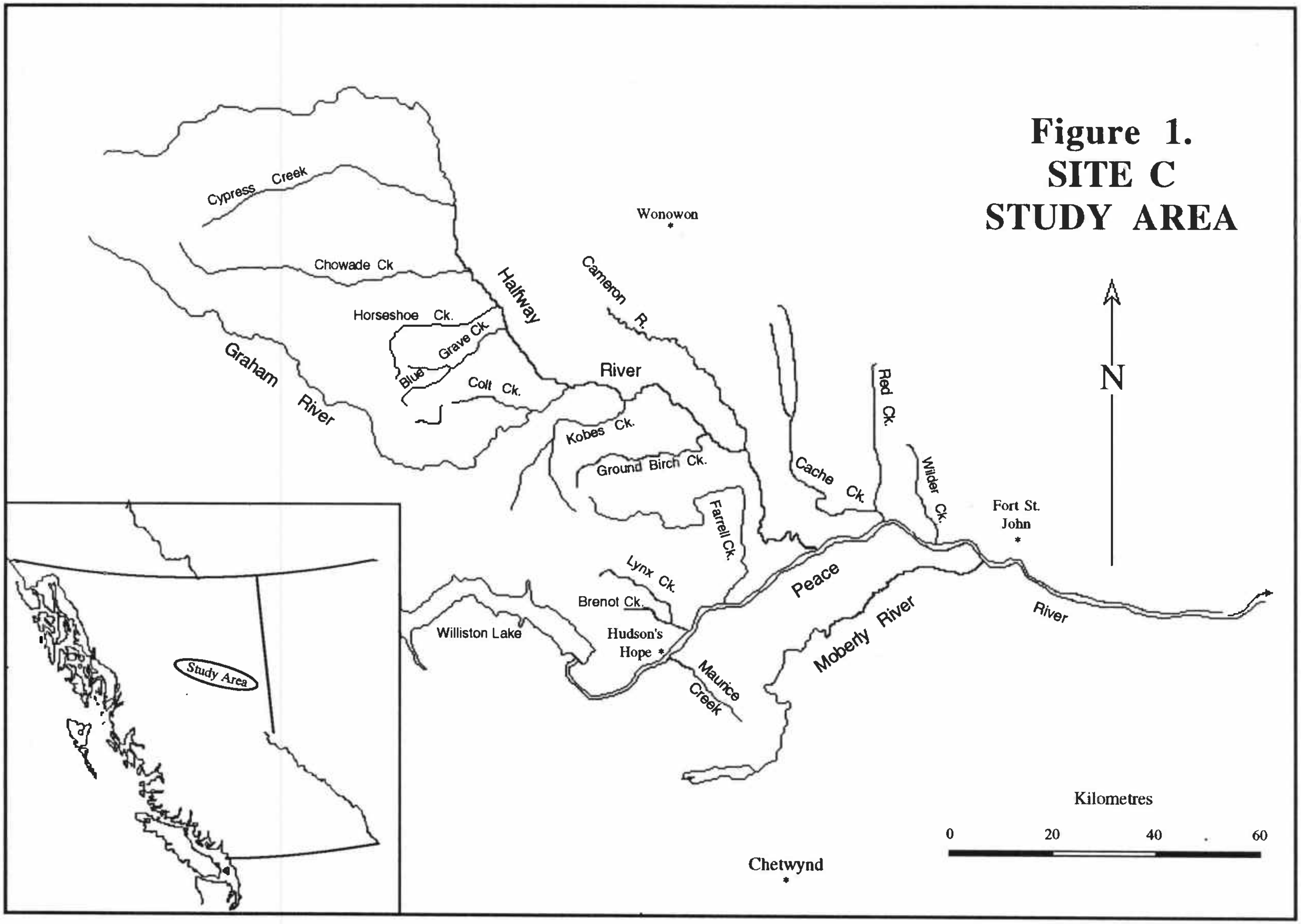



**Figure 1.**
**SITE C**
**STUDY AREA**

The Moberly and Halfway Rivers are the largest of the tributaries that flow into the Peace River between the Peace Canyon dam and the Site C dam site. The Moberly River flows northeast from the Rocky Mountain Foothills for approximately 230 km before flowing into the Peace River just above the dam site. As with most of the rivers in the area, the Moberly River in its lower reaches, is a silty, unstable system that is deeply incised into the surrounding plateau. The study area of the Moberly River encompassed the 130 km of habitat below Moberly Lake. This section has five reaches (Slaney et al. 1991). The lower reach is 25 km long, braided and unstable. This reach was subdivided into 1a, up to the lower 15 km below the full supply level, and 1b which is above the full supply level. Reach 2 is 50 km long, more stable and mainly confined to a single channel. Reach 3 is 40 km long, is a single channel, fairly stable and of low gradient. It is mainly slow flowing, meandering glide. Reach 4 is 15 km long and has a similar character to Reach 2. Finally, Reach 5 is 5 km and is a wide, slow moving glide just below Moberly Lake.

The Halfway River is the largest tributary in the study area. The system originates in the Rocky Mountain foothills north of the Peace River and flows for approximately 250 km before flowing into the Peace River 40 km above Site C. Most of the Halfway River is silty, unstable and deeply incised into the surrounding plateau. The Graham River, Blue Grave Creek, Horseshoe Creek, Chowade River and Cypress Creek are tributaries flowing east from the Rocky Mountain foothills into the upper Halfway River. These tributaries were found to have cooler water temperatures and were less silty than many of the other systems in the study area. Because of these attributes, these systems were thought to be particularly significant to sportfish and warranted further study (Slaney et al. 1991).

Lynx Creek and Maurice Creek flow into the upstream end of the study area near Hudson Hope. These two small creeks are the only systems flowing into the Peace River between the Peace Canyon dam and Site C that were found to contained significant numbers of rainbow trout (*Oncorhynchus mykiss*) (RRSC 1979; Slaney et al. 1991). Lynx Creek is the smaller of the two and flows from the north into the Peace River just below Hudson Hope. This system is accessible to fish for 10 km and has a very high silt load in the lower 6.5 km; even during the fall when many systems in the area have started to clear up. Maurice Creek enters the Peace River from the south opposite Hudson Hope. This system is accessible to fish for 3 km. The silt load of this system is low compared to the tributaries further east, and only becomes high during flood conditions.

## 1.2 PREVIOUS WORK IN THE STUDY AREA

Initial fisheries studies on the Site C project were conducted between 1974 and 1977 (RRCS 1979). The study assessed the impact of Site C on the fisheries, provided an inventory of fish in the area and provided information on the use of the system by anglers. The study found that mountain whitefish was the most prevalent species within the study area, although northern pike, rainbow trout and Arctic grayling were also found. Numbers of rainbow trout were low due to the lack of spawning habitat.

A new round of fishery studies were commissioned by B.C. Hydro in 1989. A habitat survey was conducted on the Peace River within the Site C area and many of the tributaries to the Peace River flowing into this area (Slaney et al. 1991). As part of the same study, information on fish species compositions, distributions, and morphology and age were collected from the Peace River Site C tributaries. R.L. and L. Environmental Services Ltd. collected information on population sizes and movement patterns on fish within the Peace and Halfway Rivers (Pattenden et al. 1990). The study was continued in 1990.

There has been few fisheries studies conducted in the study area other than the work commissioned by B.C. Hydro. The B.C. Ministry of Environment and Parks conducted a creel survey during 1985 (Hammond 1986).

# PART II

# METHODS

## 2.1 TIMING AND LOGISTICS

The 1990 fisheries survey of selected Peace River tributaries was conducted over two time periods. During the first period, from May 18 to June 27, a sportfish spawning survey was conducted on Maurice Creek, Lynx Creek and the Moberly River. During the period from July 30 to August 8 five upper Halfway River tributaries were examined for water quality as well as fish distributions and densities.

Sportfish spawning was investigated on Maurice and Lynx Creeks using fence traps (Figure 2) to capture upstream and downstream migrants. The fence traps were installed during the spring freshet when rainbow trout, Arctic grayling and walleye are thought to spawn. To collect data on fish distribution and densities, a short survey of the two creeks was conducted using beach seines and an electroshocker.

Sportfish spawning distributions in Reaches 1a, 1b, 2 and 5 of the Moberly River was assessed primarily by beach seine.

## 2.2 MAURICE AND LYNX CREEKS

### 2.2.1 Fence construction and maintenance.

Fence designs were similar to that of the juvenile downstream traps described by Conlin and Tutty (1979). The fences were basically a "V" configuration pointed downstream with a downstream trap at the apex of the "V". The Lynx Creek fence had upstream traps along the bank at the end of each wing of the "V" and the Maurice Creek fence had one upstream trap along one wing. The downstream trap of the Maurice Fence was closer to the east bank thus the west wing of the "V" was longer than the other. The upstream trap was located at the end of the longest wing. Fence panels were fabricated from 2.54 x 2.54 cm welded 16 gauge screen. The fences were 80 cm high.

The two fences were first installed during the latter part of May (Table 1). Both fences were washed out just after installation due to high discharges following heavy rainfall. The fences were reinstalled a second time during early June but were again washed out a short time later. The fences were installed a third time and then fished until June 27 when they were removed.

**Figure 2.**
**Sampling locations on**
**Lynx and Maurice Creeks, 1990.**

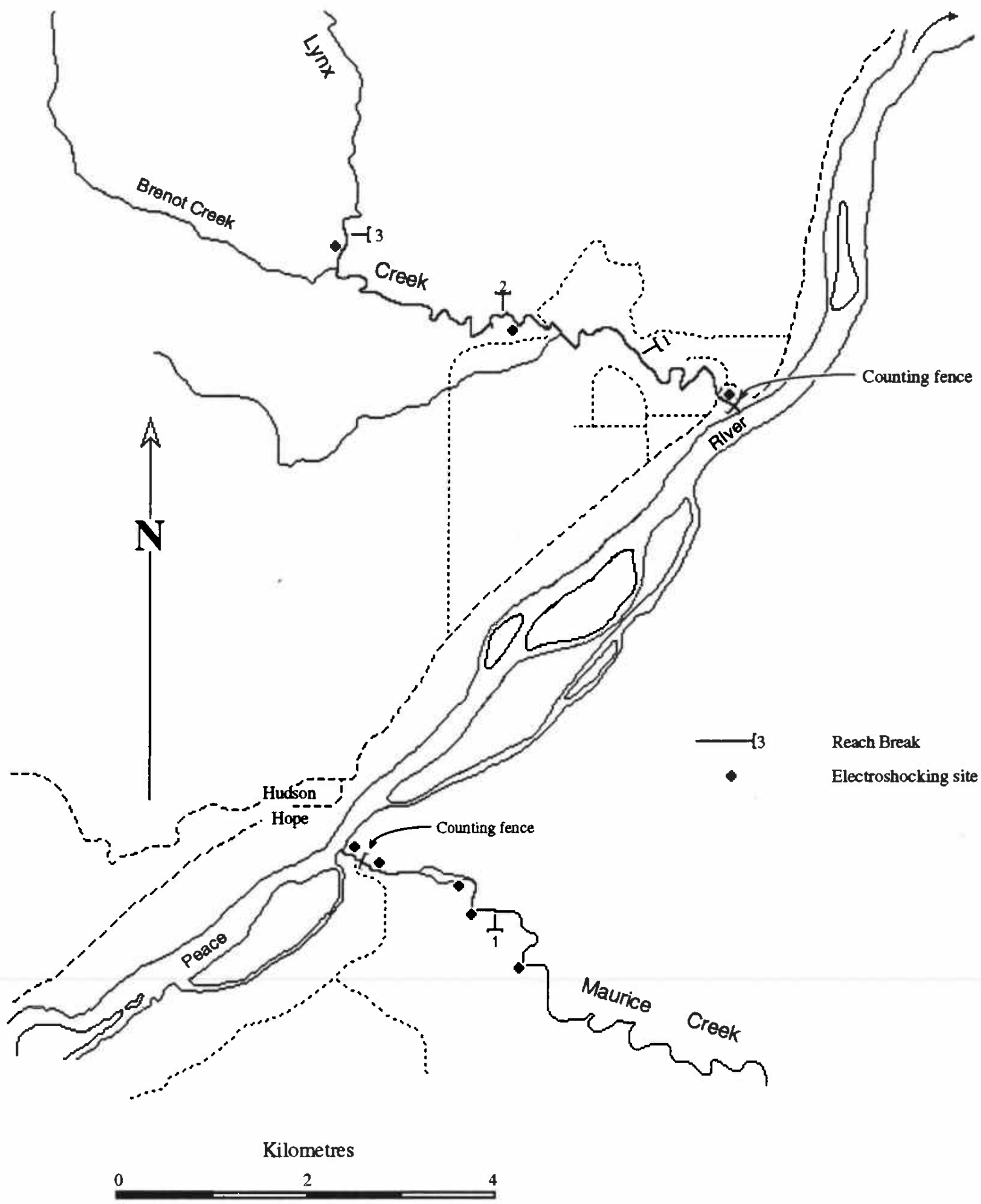


Table 1
Schedule of events for the Maurice and Lynx Creek fences.

| Event | Lynx fence | Maurice Fence |
|---|---|---|
| Installation | May 21-23 | May 23-25 |
| Fishing | May 23-26 | May 25 (1.5 h) |
| Washed out | May 26 | May 25 |
| Installation | June 2-3 | June 6-9 |
| Fishing | June 3-11 | June 9-11 |
| Washed out | June 11 | June 11 |
| Installation | June 18-19 | June 20-21 |
| Fishing | June 19-27 | June 21-27 |
| Removed | June 27 | June 27 |

### 2.2.2 Stream survey

An attempt was made to quantify the distribution of spawning and rearing sportfish in Maurice and Lynx Creeks on June 22 and 23, respectively. At intervals along the two creeks, sections were isolated with stop nets and were electoshocked using a backpack electroshocker. The fish were sampled and the densities estimated using the depletion-removal density estimation technique (Seber and LeCren 1967).

## 2.3 MOBERLY RIVER

The Moberly River was sampled for nine days between May 27 and June 17. The Peace River around the Moberly River mouth was sampled on May 27, 28 and June 14; Reach 1a was sampled May 29, 31, June 15, 16; Reach 1b was sampled May 31; Reach 2 on June 17; and Reach 5 on June 1 (Figure 3). Access to all the sites, except those in Reach 2 was by jet boat. Sample sites in Reach 2 were reached by road and on foot.

Most of the sampling was conducted with a 20 m x 3 m beach seine with 4 cm stretch mesh and an 8 m x 2.5 m beach seine with 1.0 cm stretch mesh. Sets were conducted to capture samples of sportfish, to determine distribution and to determine densities. Gill nets, 8 m long x 2.5 m deep with 7 cm stretch mesh, were also used in Reach 5 where there were very few sites to make beach seine sets from.

Sampling was first conducted at the mouth of the Moberly River to determine if sportfish were schooling around the mouth of the river in preparation to migrate upstream to spawn. Any sportfish collected at the mouth were tagged in order to collect data on possible movements to sites later sampled in the Moberly River.

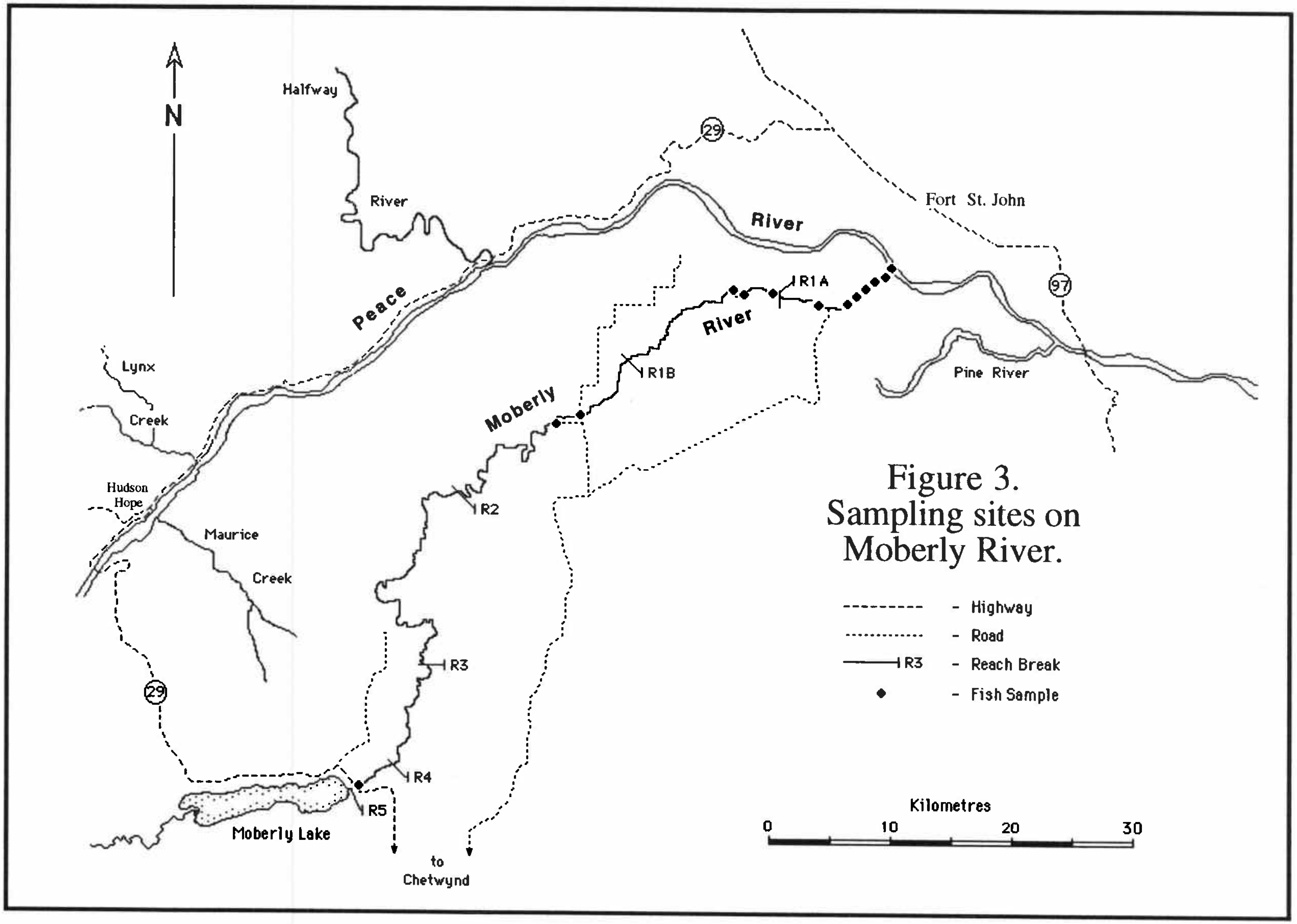



Figure 3.
Sampling sites on Moberly River.

## 2.4 UPPER HALFWAY RIVER TRIBUTARIES

The Graham, Blue Grave, Horseshoe, Chowade, and Cypress systems were sampled for water quality and fish distribution between August 2 and August 7, 1990. A truck was used to gain access to the Blue Grave, Horseshoe, Chowade and Cypress systems and a jet boat was used to gain access to most of the Graham River sample sites. Access to the upper most sample site on the Graham River was gained by truck and by foot.

### 2.4.2 Water quality

Water samples were collected from each of the five Halfway systems. The water samples were collected in glass and plastic containers, stored in coolers until the end of the sampling program, then shipped to Powertech Labs in Surrey for analysis. *In situ* measurements of temperature (±0.5°C) and pH (±0.1) were made with each collection. Water samples were collected near the mouth of each system and at a point approximately 15 km upstream (Figure 4).

### 2.4.3 Stream survey

The Graham River was sampled on August 2 and 4. Sampling was conducted at four sites in Reach 2 between 25 km and 33 km on August 2. Fish densities, species composition and species distribution were determined by beach seine sets and by divers floating sections of the river. A 2 m x 7 m juvenile seine and a 20 m x 3 m adult seine with a 4 cm stretch mesh were used. One site in Reach 3 was sampled at the 65 km mark near Crying Girl Prairie on August 4.

Horseshoe, Blue Grave and Cypress Creeks were sampled near the mouth and near the 15 km mark on August 3, 4, 5 and 7. Sampling was conducted by isolating sections of the creeks with nets and then making multiple passes through the sites with an electroshocker to determine species composition and densities.

The Chowade River was sampled on August 6 at the 5 and 15 km marks. Assessments of fish densities and species composition were made by floating sections of the river and by beach seine sets with the 2 m x 8 m juvenile seine.

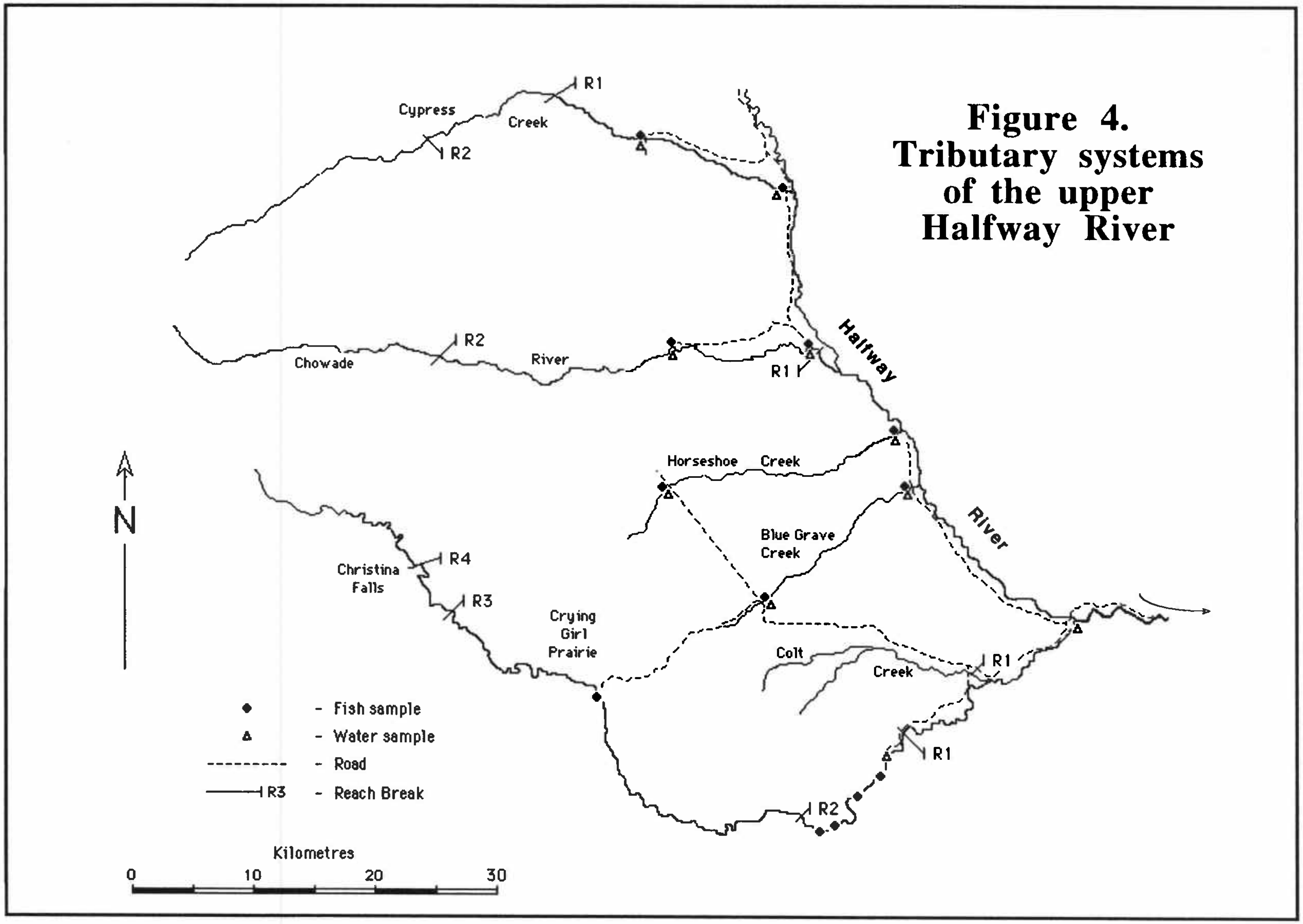



**Figure 4. Tributary systems of the upper Halfway River**

## 2.3 FISH SAMPLING

Sportfish captured at the fence sites and at the sample sites were weighed on a portable electronic scale to ±0.03 g if the fish were less than 150 g or, if they were larger, on spring scales ±0.05 kg. Nose-fork lengths were measured to ±0.5 mm if the fish were less than 200 mm or to ±2 mm if they were larger. Five to ten scales were taken from the preferred areas of rainbow trout, lake whitefish, mountain whitefish, Arctic grayling, and northern pike. Scales from the salmonids were taken just above the lateral line on a line between the posterior end of the base of the dorsal fin to the anterior edge of the anal fin. Scales from Arctic grayling were collected from the third row above the lateral line below the dorsal fin. Scales from northern pike were taken from between the dorsal fin and the lateral line. The scales were placed between microscope slides and read using a binocular microscope.

Prior to release, all sportfish larger than 250 mm were tagged with Floy tags. The tags were inserted in the back of the fish between the pterigiophores of the dorsal fin. Tag numbers were reported to R.L. & L Environmental Services Ltd. to assist in the determination of sportfish movements within the Peace River system.

The condition factor (K)(Ricker 1975) was calculated for sportfish species using the equation:

$$K = \frac{100W}{L^3}$$

Where W is weight in grams and L is fork length in centimetres.

# PART III

# RESULTS AND DISCUSSION

## 3.1 PHYSICAL CONDITIONS

### 3.1.1 Weather

Average mean daily air temperatures for the months May to August for 1990 at the Fort St. John weather station were similar to the 30 year averages (1951-1980, Table 2). The mean daily maximum, mean daily minimum and mean daily mean temperatures for all four months were all within 2°C of the 30 year average temperatures.

Precipitation exceeded the normal by 80% (31 mm) and 49% (33 mm) for May and June 1990, respectively (Table 2). Particularly heavy rainfalls were recorded on May 25-26 and June 10-12. Less rain fell than normal during July and August by 49% (38 mm) and 43% (26 mm), respectively.

Table 2
Adjusted average[1] total monthly precipitation and average mean daily temperatures by month for the period 1951 to 1980 and 1990 at the Fort St. John weather station.

| Month | Temperature (°C) Mean Maximum | | Mean Minimum | | Mean Mean | | Precipitation (mm) | |
|---|---|---|---|---|---|---|---|---|
| | 30 yr. | 1990 | 30 yr. | 1990 | 30 yr. | 1990 | 30 yr. | 1990 |
| May | 16 | 16 | 4 | 5 | 10 | 10 | 39 | 70 |
| June | 19 | 19 | 8 | 9 | 14 | 14 | 68 | 101 |
| July | 21 | 23 | 10 | 10 | 16 | 17 | 77 | 39 |
| August | 20 | 22 | 9 | 10 | 14 | 16 | 60 | 34 |

[1]30 year standard time period 1951 to 1980 (Atmospheric Environment Service)

### 3.1.2 Stream Conditions.

Discharges (Table 3, Figure 5) at the water survey stations located in Reach 2 of the Moberly River, above the Graham River on the Halfway River and in Reach 1 of the Graham River, were much higher than normal during spring 1990 due to larger than normal snow packs and rainfall (Table 2). Mean discharges for June were 102% higher than normal for the Halfway and 67% higher than normal for the Graham River. Moberly River discharge information for June 1990 was only available from June 1 to 21. Over this time period discharges were 156% higher than normal June discharges. Discharges fell below normal in all three rivers during July and August due to the lower than normal precipitation at that time.

Table 3
Mean discharges[1] ($m^3 \cdot s^{-1}$) for the Moberly River, Halfway River above Graham River, and the Graham River.

| Month | Moberly Average 1979-88 | Moberly 1990[2] | Halfway Average 1978-88 | Halfway 1990[2] | Graham Average 1981-88 | Graham 1990[2] |
|---|---|---|---|---|---|---|
| April | 5.3 | nd | 11.6 | 34.8 | 7.0 | nd |
| May | 29.5 | 37.9 | 57.8 | 101 | 40.9 | 57.2 |
| June | 44.1 | nd | 115 | 192 | 87.7 | 136 |
| July | 24.3 | nd | 80.9 | nd | 59.8 | 45.6 |
| August | 14.3 | nd | 45.4 | nd | 31.6 | 16.4 |

[1] - Water Survey of Canada
[2] - Water Survey of Canada preliminary data
nd - No data

The peak discharges of the Halfway (900 $m^3 \cdot s^{-1}$) and Graham rivers (450 $m^3 \cdot s^{-1}$) occurred on June 1 and June 2, respectively. There was little correlation between the periods of high rainfall at the Fort St. John weather station and peak discharges of the Halfway and Graham Rivers. The Halfway River discharge increased slightly on May 25 and June 11 during periods of heavy rain. Moberly River discharge did not increase during the first period of heavy rain and reached peak levels (146 $m^3 \cdot s^{-1}$) just after the heavy rainfall that hit the Fort St. John area on June 10-12.

Lynx Creek (Figure 6) and Maurice Creek water levels were directly related to rainfall. Few temperature and water level data were collected from Maurice Creek, however the trends are likely to be similar to those found in Lynx Creek. The peak discharges in both creeks occurred on May 26 and June 12, during the periods of heavy rainfall. Water levels dropped steadily during the dry periods.

Water temperatures were inversely related to water levels and generally increased throughout the project (Figure 6). Average water temperatures in Lynx Creek were near 10°C during early June and increased to approximately 14°C by June 22 - 24. Maximum water temperatures of 22°C were recorded on June 24.

Figure 5.
Discharge recorded at Water Survey of Canada stations, 1990.

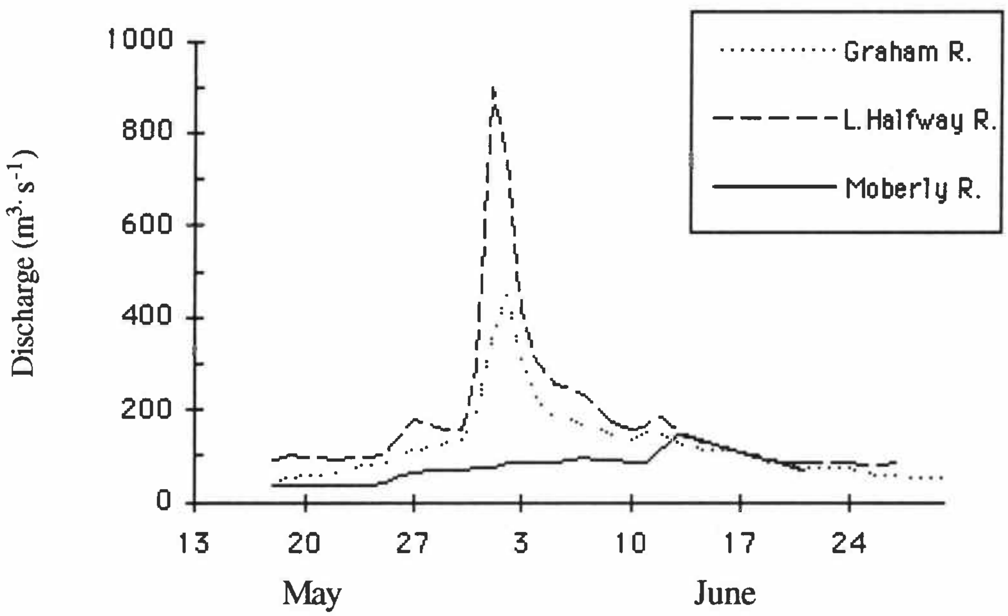
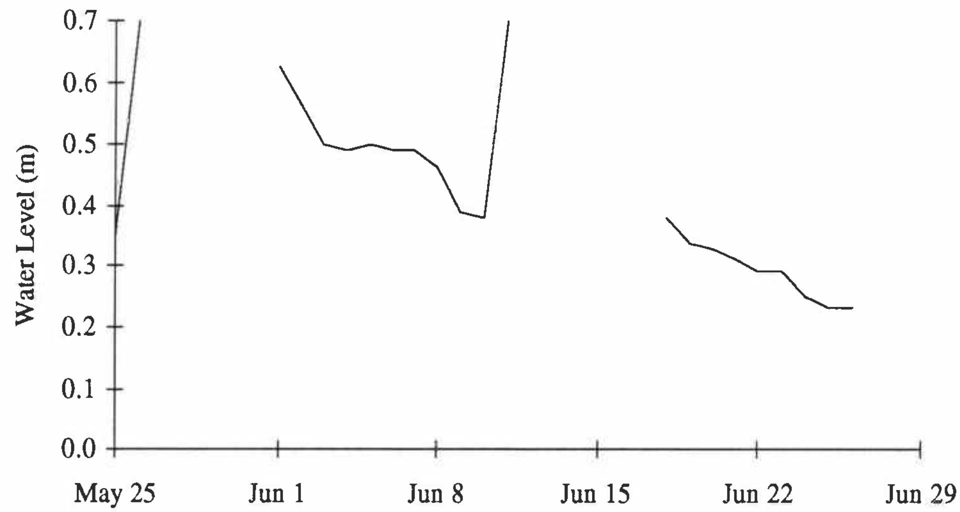
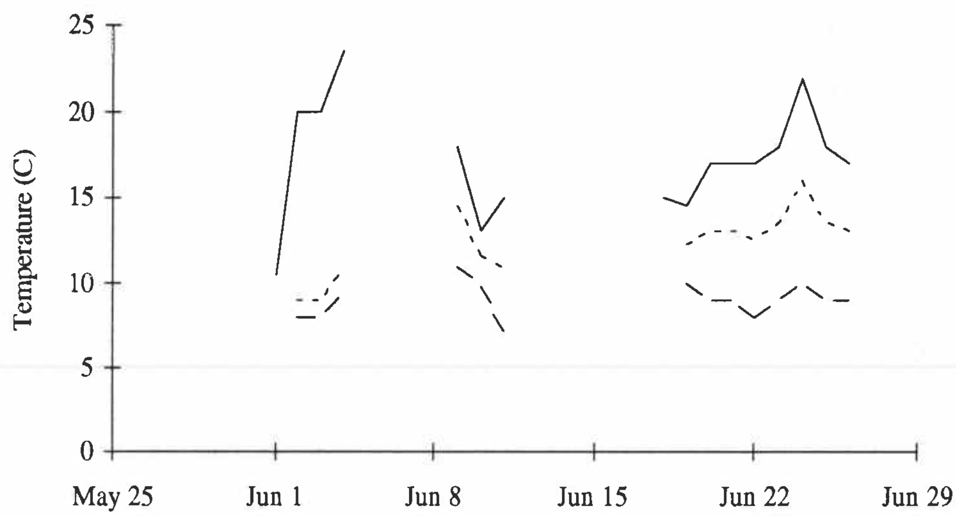


Figure 6
Lynx Creek water levels and temperatures, May - June, 1990



## 3.2 Fishery investigations

In total, 15 species of fish were captured during fisheries investigations conducted May to August, 1990 (Table 4). Of this number, eight were sportfish, four were minnows and three were suckers. In addition, members of the cottid family (sculpins) were captured but not identified to species.

Table 4
List of species sampled from Peace River tributaries, May to August, 1990.

| Group | Common name | Latin Name |
|---|---|---|
| Sportfish | Arctic grayling | *Thymallus arcticus* |
| | bull trout | *Salvelinus malma* |
| | burbot | *Lota lota* |
| | kokanee | *Oncorhynchus nerka* |
| | lake whitefish | *Coregonus clupeaformis* |
| | mountain whitefish | *Prosopium williamsoni* |
| | northern pike | *Esox lucius* |
| | rainbow trout | *Oncorhynchus mykiss* |
| Minnows | lake chub | *Couesius plumbeus* |
| | longnose dace | *Rhinichthys cataractoe* |
| | northern squawfish | *Ptychocheilus oregonensis* |
| | redside shiner | *Richardsonius balteatus* |
| | peamouth | *Mylocheilus caurinus* |
| Suckers | largescale sucker | *Catostomus macrocheilus* |
| | longnose sucker | *Catostomus catostomus* |
| | white sucker | *Catostomus commersoni* |
| Sculpins | sculpin | *Cottus* sp. |

### 3.2.1 LYNX CREEK

#### 3.2.1.1 Fence operations

Although the discharge of Lynx Creek is small, the large quantities of silt moving downstream made fence operations difficult, particularly during periods of high flows. Silt was carried downstream and then settled out in the slower moving water behind the fence, building up at a rate of a 50 - 60 cm in depth per day during high discharges. Much of the fence maintenance time was spent removing sand and silt (Figure 7).

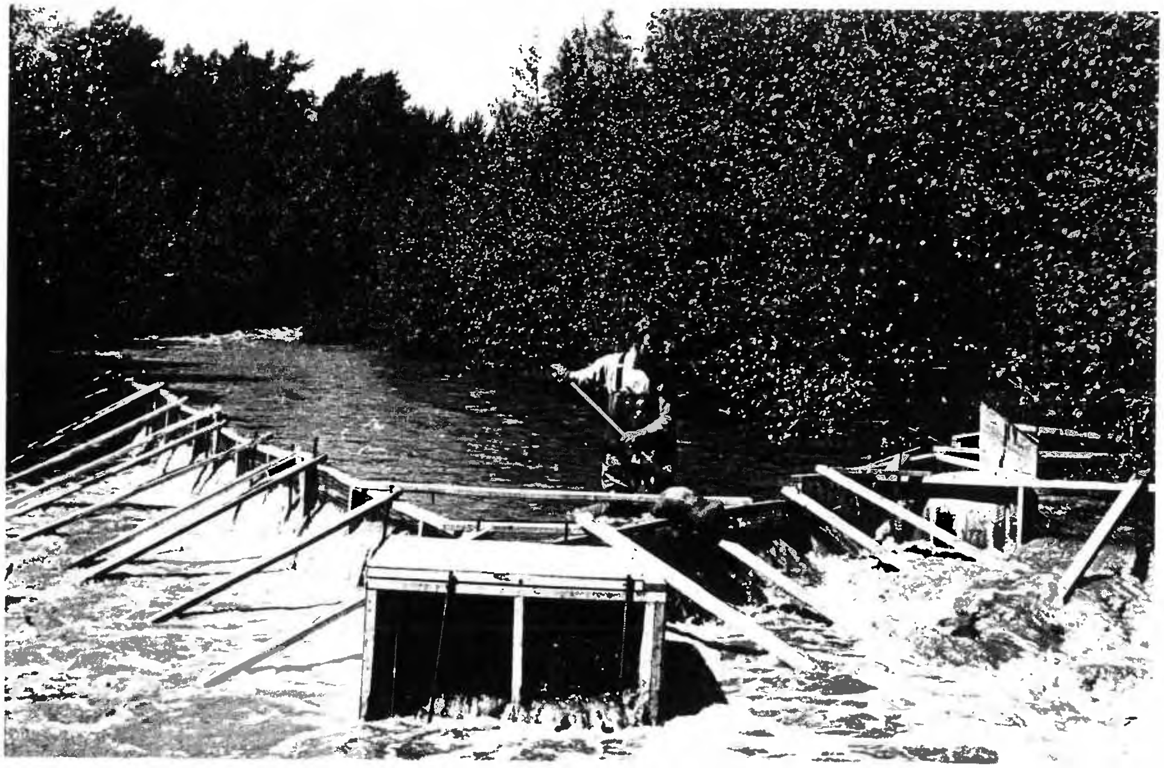


Figure 7.
Silt settling behind the Lynx Creek Fence made it difficult to manage (upper photo). The turbidity of Maurice creek was relatively low but the system had a much higher discharge which caused the fence to be washed out on two occasions (lower photo).

Seven species of fish were caught in the Lynx Creek fence trap during the 19 days it was in operation between May 24 and June 27 (Table 5). The fence was only in operation 54% of the time due to washouts on May 26 and June 11.

Longnose suckers were by far the most numerous species, contributing 86% (257 fish) of the total catch. They were followed by rainbow trout which contributed 10% (31 fish) of the catch. The other five species, (northern squawfish, largescale sucker, longnose dace, redside shiner and bull trout), comprised the remainder of the catch (3%).

The lack of continuity in the fence operation makes it difficult to determine the precise timing of migration (Table 6). It appeared that the fence had been installed after the start of spawning for rainbow trout as both upstream and downstream migrants were caught during the first few days of operation May 24 and 25. The majority of upstream rainbow trout migrants went through the fence during the first two weeks of June, the first period that the fence was in for any length of time. The peak catch (4) was made on June 3. The upstream migration of rainbow trout spawners started before May 24 and appeared to be finished by June 10. Downstream migration of rainbow trout spawners started on or before the end of May. Most of the downstream migration took place between June 20 and 27 when 12 rainbow trout were caught. A peak catch of six was made on June 24 near the end of the study. Some rainbow trout may still have been in the creek after the fence was removed on June 27. Although no adults were captured during a stream survey conducted on June 23, a survey of Maurice Creek on June 22 indicated there were still substantial numbers of adults in that system. The 1990 spring migration was possibly later than some years. A preliminary survey of Lynx Creek on June 9, 1989 found that the spring freshet was over and that there were few spawners of any species left in the system (Slaney et al. 1991).

Table 6
Timing of rainbow trout and longnose sucker migration
in Lynx Creek, 1990

| Species | Direction | Start | Peak | End |
|---|---|---|---|---|
| Rainbow | up | May? | June 3 | June 10 |
| | down | Late May? | June 24 | late June |
| Longnose sucker | up | May? | May? | mid-June |
| | down | late May | June 25 | early July |

Of the 29 rainbow trout sampled, 3% (1) were age one, 17% (5) were age two , 38% (11) were age three and 41% (12) were age four. The age 1 rainbow trout

Table 5
Summary of catch data collected from the Lynx Creek fence, May to June, 1990.

| | Longnose sucker | | Rainbow trout | | Northern squawfish | | Largescale sucker | | Longnose dace | | Redside shiner | | Bull trout | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | up | dn | up | dn | up | dn | up | dn | up | dn | up | dn | up | dn |
| May 24 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| May 25 | 1 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| June 3 | 2 | 1 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| June 4 | 3 | 7 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| June 5 | 2 | 5 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| June 6 | 1 | 6 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| June 7 | 8 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| June 8 | 3 | 6 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| June 9 | 3 | 29 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| June 10 | 10 | 15 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| June 11 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sub total | 37 | 74 | 11 | 8 | 2 | 0 | 0 | 1 | 0 | 2 | 0 | 2 | 0 | 0 |
| June 20 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| June 21 | 0 | 16 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| June 22 | 0 | 18 | 0 | 4 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| June 23 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| June 24 | 0 | 35 | 0 | 6 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| June 25 | 0 | 39 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| June 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| June 27 | 0 | 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sub total | 0 | 146 | 0 | 12 | 0 | 2 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 1 |
| Total | 37 | 220 | 11 | 20 | 2 | 2 | 0 | 3 | 0 | 2 | 0 | 2 | 0 | 1 |

was 90 mm long, age 2 rainbow trout averaged 206 mm long (s = 12.9), age 3 rainbow trout averaged 294 mm long (s = 37 mm) and age 4 rainbow trout averaged 370 mm long (s = 16 mm). It was not determined whether the two year old rainbow trout caught in both upstream and downstream traps, were immature or spawning fish. These fish were not differentiated into male or females; the lack of sexual characteristics indicates they were immature.

The average size of rainbow trout moving upstream was similar to those coming downstream. Although rainbow trout heading upstream were in slightly better condition than those heading downstream (1.15 vs 1.09) the difference was not statistically significant ($P \gg 0.50$). The average length of rainbow trout migrating through the fence was 311 mm (n = 31, s = 81, Table 7).

Table 7.
Fork length statistics and condition factor (K)
for fish caught in the Lynx Creek trap, May and June, 1990.

| Species | n | min (mm) | max (mm) | mean (mm) | Stdev. (mm) | K (mean) |
|---|---|---|---|---|---|---|
| Rainbow trout | 31 | 90 | 470 | 311 | 81 | 1.14 |
| Bull trout | 1 | - | - | 235 | - | 1.54 |
| Longnose sucker | 172 | 97 | 475 | 328 | 83 | 1.16 |
| White sucker | 3 | 190 | 410 | 310 | 111 | 1.52 |
| Northern squawfish | 4 | 90 | 235 | 189 | 68 | 0.93 |
| Longnose dace | 2 | 115 | 130 | 123 | 11 | 0.99 |
| Redside shiner | 2 | 40 | 110 | 75 | 49 | 1.37 |

The maturity and sex of only a portion of the rainbow trout caught were noted as these characteristics were not obvious in some of the migrants. Of the 11 rainbow trout caught moving upstream, two were identified as males and six as females, all of which were mature. Of the 20 downstream migrants caught, two were identified as males, ten as females of which eight were spent and two were still ripe.

Longnose suckers were the most abundant species caught in the fence trap. The catches indicate that these fish started to migrate into the system prior to installation fence on May 24. Upstream migration had finished by mid-June (Table 5). The downstream migration of spent spawners started in late May, peaked in mid- to late June and finished after the fence was removed on June 27. The peak upstream catch occurred on June 10 (n = 10) and the peak downstream catch occurred on June 25 (n = 39). A total of 37 longnose suckers was caught migrating upstream and 220 were caught migrating downstream.

Although the size range of longnose suckers moving through the traps was similar, those heading upstream were on average smaller (FL = 247 mm) than those heading downstream (FL = 350 mm). The largest suckers may have moved into the system to spawn first. The average condition of suckers heading upstream was significantly greater than that of suckers heading downstream (1.26 versus 1.14, $P \leq 0.001$). Lower condition of suckers heading downstream probably reflected their spawned out status.

No Arctic grayling were caught in the fence trap even though this species has been caught in Lynx Creek in the past (RRCS 1979). Arctic grayling generally reside in larger river systems, only occupying smaller tributaries to spawn. No Arctic grayling have been captured in the creek in recent years (Slaney et al. 1991). It appears that they no longer use Lynx Creek for spawning or rearing.

Only one bull trout, heading downstream during the latter part of June, was caught during the 19 days the fence was in operation. It would appear that this individual was a migrant from the Peace River that was inadvertently caught by the trap. As this species spawns in the fall it is unlikely that it represents the remnants of a spawning run. The creek does not appear to be important bull trout habitat as only the one individual was caught during 1990 and none have been observed in previous studies (Slaney et al. 1991, RRCS 1979).

#### 3.2.1.2 Stream survey

Seven sites were sampled on June 23, 1990 by electroshocker in Reaches 1, 2 and 3 of Lynx Creek. Fish densities at these sites were determined using the depletion-removal technique (Seber and LeCren 1967). Overall, the greatest densities of fish were caught in Reach 3 above the confluence of Brenot Creek, the primary source of silt in the lower sections of Lynx Creek (Figure 8). Brenot Creek has only become extremely silty in the past few years due to a spring that has developed along the bank several kilometres from the Lynx Creek confluence (L. Noble pers. comm.). The low densities of most species of fish encountered in Reaches 2 and 3 demonstrates the effect that the heavy silt load is having on the system (Table 8).

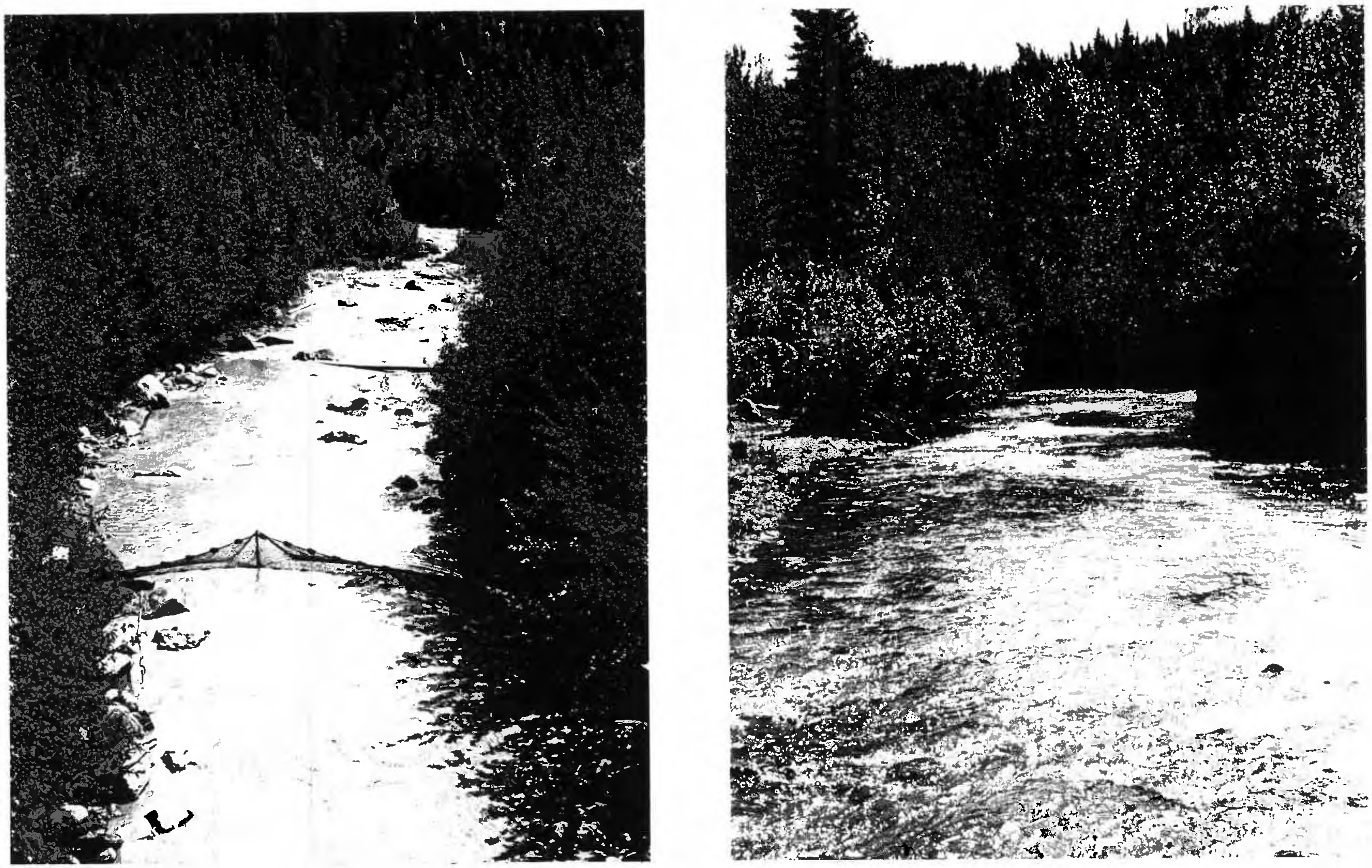


Figure 8.
The sampling site in Reach 1 (left) of Lynx Creek contained no rainbow trout possibly due to the high turbidity in this reach. They were captured at the site in Reach 3 (right) where turbidity levels were much less.

Table 8.
Densities (fish·100 $m^{-2}$) of fish caught by electroshocking in Lynx Creek, June 23, 1990.

| Species | Reach 1 | Reach 2 | Reach 3 |
|---|---|---|---|
| Rainbow trout | 0 | 0 | 2.33 |
| Northern squawfish | 0 | 1.15 | 9.88 |
| Longnose dace | 0 | 0 | 15.1 |
| Longnose sucker | 8.16 | 1.15 | 3.49 |
| Sculpins | 12.2 | - | 0.0 |
| Area sampled ($m^2$) | 24.5 | 174 | 172 |

A large number of stream resident rainbow trout were found in Brenot Creek during studies conducted between 1974 and 1977 (RRCS. 1979). With the high levels of silt that have occurred in the last few years, it seems unlikely that this population has escaped the impact.

Despite the high silt levels, the highest densities of longnose suckers (8.16 fish·100 $m^{-2}$) and sculpins (12.2 fish·100 $m^{-2}$) were encountered at the sample site in Reach 1. No rainbow trout, northern squawfish or longnose dace were caught. In Reach 2, only a few northern squawfish and longnose suckers were captured. The Reach 3 sites above Brenot Creek contained relatively high densities of all species except sculpins. Densities of longnose dace were particularly high (15.12 fish·100 $m^{-2}$).

No adult rainbow trout were found in any of the sites sampled. However, a few juvenile rainbow trout (2.33 fish·100 $m^{-2}$) ranging in size from 73 to 90 mm were caught in Reach 3 above the confluence of Brenot Creek, again illustrating the impact of this tributary on resident fish in the lower reaches. The juvenile rainbow trout population of Reach 3 would be 280 fish with densities of 2.33 fish·100 $m^{-2}$, an average wetted width of 6.1 m at this time of year and a length of 2 km. Rainbow trout catches of 8 fish·100 $m^{-2}$ were made at sites in Reach 3 during the fall of 1989 (Slaney et al. 1991). The estimated population of rainbow trout in Reach 3 above Brenot Creek was estimated at 700 rainbow trout at that time. Catches of 2.30 fish·100 $m^{-2}$ and 2.55 fish·100 $m^{-2}$ were made in Lynx Creek at sites below Brenot Creek during the spring and fall of 1989, respectively. It appears that the large amount of silt in this area has decreased the suitability of this habitat for rearing by rainbow trout juveniles.

In general, the fish caught were small (Table 9). The only exception were the longnose suckers which ranged in size up to 295 mm. This may be a function of water level which is quite low following the spring freshet. It may also reflect a limitation in the creek's productivity. In general longnose suckers caught in the traps (Table 7) were larger (length = 328 mm, n = 172, s = 83) than those which were caught by electroshocker on June 23, 1990 (length = 152 mm, n = 9, s = 80, Table 9). In addition, the larger fish in the Lynx system appear to occupy this stream for only spawning purposes. Many of the larger fish expressed milt or eggs when handled. They apparently do not reside in the stream year round. Sampling conducted in October and September 1989 (Slaney et al. 1991) showed that only small suckers averaging 105 mm reside in the creek at this time of the year. It would appear Lynx Creek is important longnose sucker habitat for spawning and rearing, but larger individuals reside in the Peace River.

Table 9.
Fork length statistics of fish
caught in Lynx Creek by electroshocker, June 23, 1990.

| Species | n | Min (mm) | Max (mm) | Mean (mm) | Stdev (mm) |
|---|---|---|---|---|---|
| Rainbow | 4 | 73 | 90 | 82 | 7 |
| Northern squawfish | 16 | 60 | 97 | 86 | 9 |
| Longnose dace | 49 | 54 | 97 | 77 | 11 |
| Longnose sucker | 9 | 67 | 295 | 152 | 80 |
| Sculpins | 3 | 49 | 63 | 58 | 8 |

No mountain whitefish were caught during the spring of 1990 or in the fall of 1989 although they were caught in relatively high numbers during the fall of 1974 and some age 1 mountain whitefish were captured in the spring of 1989 (RRCS 1979, Slaney et al. 1991). These data suggest that mountain whitefish may rear in Lynx Creek in some years, possibly moving in after freshet subsides in the spring. However, numbers appear to be much reduced in recent years, which is likely due to the high siltation of the creek.

### 3.2.2 MAURICE CREEK

#### 3.2.2.1 Fence Operations

Operation of the fence trap on Maurice Creek was limited due to the high discharges that were encountered. Construction of the first fence was completed on May 25 but rapidly rising water levels washed the fence out later that day. The fence was reconstructed on June 9, and washed out on June 11. Finally the fence was reinstalled on June 21 (Figure 7) and was dismantled on June 27. Once the fence was installed on June 21 the upstream trap became inoperative after a few days due falling water levels. However it is unlikely that many fish were migrating upstream during this period as few were caught during the first few days that the upstream trap was in operation (Table 10).

Table 10
Summary of catch data collected from the Maurice Creek fence, May to June, 1990.

| | Bull trout | | Longnose sucker | | Rainbow trout | | Northern pike | | Lake whitefish | | Arctic grayling | | Mountain whitefish | | Largescale sucker | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | up | dn | up | dn | up | dn | up | dn | up | dn | up | dn | up | dn | up | dn |
| May 25 | 0 | 0 | 0 | 11 | 0 | 3 | 0 | 0 | 0 | 12 | 0 | 1 | 0 | 3 | 0 | 0 |
| June 10 | 0 | 1 | 1 | 7 | 0 | 1 | 0 | 3 | 2 | 3 | 0 | 0 | 0 | 1 | 0 | 0 |
| Sub total | 0 | 1 | 1 | 18 | 0 | 4 | 0 | 3 | 2 | 15 | 0 | 1 | 0 | 4 | 0 | 0 |
| June 21 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| June 22 | 0 | 0 | 1 | 11 | 1 | 2 | 0 | 1 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 |
| June 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| June 24 | 0 | 0 | 0 | 22 | 0 | 5 | 0 | 5 | 0 | 6 | 0 | 1 | 0 | 0 | 0 | 3 |
| June 25 | 0 | 0 | 0 | 4 | 0 | 1 | 0 | 1 | 0 | 3 | 0 | 0 | 0 | 1 | 0 | 1 |
| June 26 | 0 | 0 | 0 | 12 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| June 27 | 0 | 0 | 0 | 6 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Sub total | 0 | 0 | 1 | 55 | 1 | 11 | 0 | 8 | 0 | 20 | 0 | 1 | 0 | 3 | 0 | 4 |
| Total | 0 | 1 | 2 | 73 | 1 | 15 | 0 | 11 | 2 | 35 | 0 | 2 | 0 | 7 | 0 | 4 |

*Second draft: subject to revision*

As in Lynx Creek, longnose suckers were predominate in the catch. In total, 73 longnose suckers were caught in the downstream trap and two in the upstream trap during the nine days that the traps were in operation. The trap catches suggest that the suckers had migrated upstream from the Peace River before the trap was in place, had spawned and then many were on their way back downstream during June. The longnose suckers were generally large in size with fork lengths averaging 357 mm (n = 58, s = 86 mm, Table 11). Their mean size was slightly larger than those captured in the Lynx Creek trap (length = 328 mm, n = 172, s = 83). Because only juveniles were found in the system when it was surveyed in September and October 1989 (Slaney et al. 1991), it would appear that the larger fish only move into the system to spawn in the spring and then return to the Peace River as water levels fall. The large numbers of migrants caught in the short time the trap was in operation suggests that Maurice Creek is an important spawning area for longnose suckers.

Table 11.
Fork length statistics and condition factor (K)
of fish caught in the Maurice Creek trap, May and June, 1990.

| Species | n | min (mm) | max (mm) | mean (mm) | Stdev. (mm) | K (mean) |
|---|---|---|---|---|---|---|
| Rainbow trout | 16 | 205 | 385 | 299 | 61 | 1.33 |
| Arctic grayling | 2 | 215 | 350 | 283 | 95 | 1.21 |
| Bull trout | 1 | - | - | 740 | - | 1.23 |
| Lake whitefish | 37 | 185 | 390 | 309 | 57 | 1.15 |
| Mountain whitefish | 7 | 220 | 365 | 282 | 68 | 1.39 |
| Northern pike | 11 | 220 | 750 | 387 | 154 | 0.97 |
| Longnose sucker | 58 | 122 | 500 | 357 | 86 | 1.55 |
| White sucker | 4 | 450 | 560 | 508 | 61 | 1.15 |

Six species of sportfish were caught at the Maurice Creek fence trap (Table 10). These included rainbow trout, Arctic grayling, bull trout, lake whitefish, mountain whitefish and northern pike. With the exception of a few rainbow trout and lake whitefish, all were caught in the downstream trap suggesting that they had migrated upstream prior to trap installation.

The presence of adult rainbow trout, Arctic grayling and bull trout have all been documented before (Slaney et al. 1991; RRCS 1979). It has long been suspected that rainbow trout and Arctic grayling spawn in Maurice Creek. Although not conclusive, the current survey lends credence to this notion, particularly for rainbow trout, which have been found in spawning condition both at the fence and during a stream survey on June 22, 1990.

The age distribution of rainbow trout (Table 12), ranging from two to four years, is similar to that found in Lynx Creek. Seventeen percent (n = 2) of the rainbow trout sampled were two years old, the same proportion that were captured in the Lynx Creek trap. Most of the rainbow trout (50%) were age 3 and the rest were age 4 (33%). The presence of two year old rainbow trout suggests that a portion of the population may move down to the Peace River to rear after rearing in the creek for two years, or may move back and forth between the two systems. Alternately, but less likely, these fish may reach maturity at two years old. Their maturity was not determined during sampling as their sex and maturity were not evident from external characteristics.

Table 12
Age structure and average lengths[1] (mm) of sportfish caught in the fence trap on Maurice Creek, May and June, 1990.

| | Age | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Species | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 10 |
| Rainbow | 210(2) | 263(6) | 373(4) | - | - | - | - | - |
| Lake whitefish | - | 200(2) | 276(6) | 318(8) | 350(11) | 390(1) | - | - |
| Mountain whitefish | - | 232(3) | 220(1) | - | - | - | - | - |
| Northern pike | 220(1) | 243(2) | 305(4) | 383(2) | - | - | 600(1) | 750(1) |
| Arctic grayling | - | 215(1) | - | - | - | - | - | - |
| Bull trout | - | - | - | - | - | - | 740(1) | - |

[1]Values enclosed in brackets indicate the sample size used to compute the average size.

The mean length of the rainbow trout was 299 mm (n = 16, s = 61), which was smaller than the Lynx Creek migrants (length = 311, n = 31, s = 81 (Table 7)). The mean lengths of age 2 and age 4 rainbow trout were similar for both creeks, but age 3 Lynx Creek rainbow trout (length = 294 mm) were larger than age 3 Maurice Creek rainbow trout (length = 263 mm).

Information on the timing of the run is limited due to the short time that the fence trap was operational. The upstream migration of rainbow trout had finished by June 22 as no rainbow trout were caught in the upstream trap after that date. The downstream migration likely had started before the first day the trap was fishing on May 25. The end of the downstream migration occurred after the fence was removed on June 27 as substantial numbers of migrants were still being caught up to that time. The peak catch of downstream migrants (five) occurred on June 24. It appears that the migration occurred later in 1990 than in 1989. The lower reaches of the creek were sampled on June 11, 1989 after the spring freshet and no rainbow trout adults and few adults of other species were caught at that time.

Only two Arctic grayling were caught, of which only one was aged (3 years), precluding any age structure analysis. The sole bull trout captured in the fence was 8 years old. Both Arctic grayling and bull trout have historically been caught at relatively low frequencies in this system. Thus the low numbers observed during the current survey are not indicative of a significant change in distribution. Arctic grayling generally spawn soon after ice break up. As the fence trap was only operational during the last week of June, it is likely that the spawning run of this species in Maurice Creek, if it occurs at all, was missed. If that is the case, then the two individuals caught at the fence probably represent the tail end of the run.

By far the most abundant of the sportfish caught were lake whitefish. They ranged in size from 185 to 390 mm and averaged 309 mm (n = 37, s = 57 mm)(Table 11). Most of the fish were between 4 and 6 years of age, although overall, ages ranged between 2 to 7 years (Table 12). At present it is unclear as to why this species migrated into Maurice Creek during spring. They are not spring spawners and have not been previously observed in the system despite the extensive sampling done in the past (Slaney et al. 1991; RRCS 1979). These fish appeared to be foraging. However, as was hypothesized for mountain whitefish, they may spawn during late fall and early winter and only migrate out of the system after overwintering. But given the size of the system, this is unlikely.

Northern pike, another species not previously observed in this system (Slaney et al. 1991; RRCS 1979) wee also collected at the counting fence. The 11 pike sampled ranged in size from 220 to 750 mm and were aged 2 to 10 years. Most were between 3 and 5 years of age.

Four white suckers were collected. This low number is similar to that observed by the previous surveys although those caught at the fence ranged in size between 450 and 560 mm, which is considerably larger than any of those caught previously in the creek.

The presence of mountain whitefish in Maurice Creek has been documented previously, but none have been older than 1 year, regardless of season. Those caught in the fence trap during 1990, ranged in length from 220 to 365 mm and the subsample aged were 3 and 4 years old.

Large mountain whitefish were also captured by electroshocker at sites further up the creek on June 22, 1990. These adult fish may have moved into the creek from the Peace River with the spring freshet while foraging, since they do not spawn in the spring. Mountain whitefish juveniles have been found in the creek during previous studies (Slaney et al. 1991, RRCS 1979) which suggests that mountain whitefish may spawn in Maurice Creek although the juveniles may migrate from the Peace River.

3.2.2.2 Stream survey

Seven sites, totaling 489 $m^2$, were electroshocked in the lower 3 km of Maurice Creek accessible to Peace River fish (Table 13). In Reach 1, 314 $m^2$ were sampled and in Reach 2, 175 $m^2$ were sampled (Figure 9). Apparent in the data is the greater diversity of fish species in Reach 1 than in Reach 2. The larger number of species in Reach 1 may be a function of its proximity to the Peace River mainstem.

Table 13.
Densities (fish·100 $m^{-2}$) of fish caught in Maurice Creek by electroshocker, June 22, 1990.

| Species | Reach 1 | Reach 2 |
|---|---|---|
| Rainbow trout - adults | 0.63 | 1.14 |
| Rainbow trout - juveniles | 1.27 | 8.57 |
| Arctic grayling | 0.32 | 0 |
| Mountain whitefish (A) | 0.32 | 0 |
| Mountain whitefish (J) | 1.59 | 0 |
| Lake whitefish | 0.32 | 0 |
| Longnose sucker | 8.92 | 12.0 |
| White sucker | 0.32 | 1.14 |
| Longnose dace | 2.23 | 0 |
| Northern Squawfish | 0.96 | 0 |
| Sculpins | 8.92* | 27.4* |
| Area sampled ($m^2$) | 314 | 175 |

* Catch densities only. Actual densities are higher.

Four sportfish species were caught in Reach 1. The Arctic grayling and lake whitefish were of adult size (>200 mm) while juveniles predominated the catch of mountain whitefish. Only one adult mountain whitefish was caught.

The catch of rainbow trout ranged in size from 72 to 351 mm long (Table 14). It included both adults and juveniles, the latter predominating by a factor of over 4 to 1. In Reach 2, the only sportfish caught were rainbow trout. The ratio of juveniles to adults there was 6.5 to 1. As the adult trout caught in both reaches were in spawning condition it would appear that these fish only ascend Maurice Creek to spawn. In a previous survey of Maurice Creek done in the fall, only juvenile rainbow trout (aged 0+ and 1+) were caught (Slaney et al. 1991). The

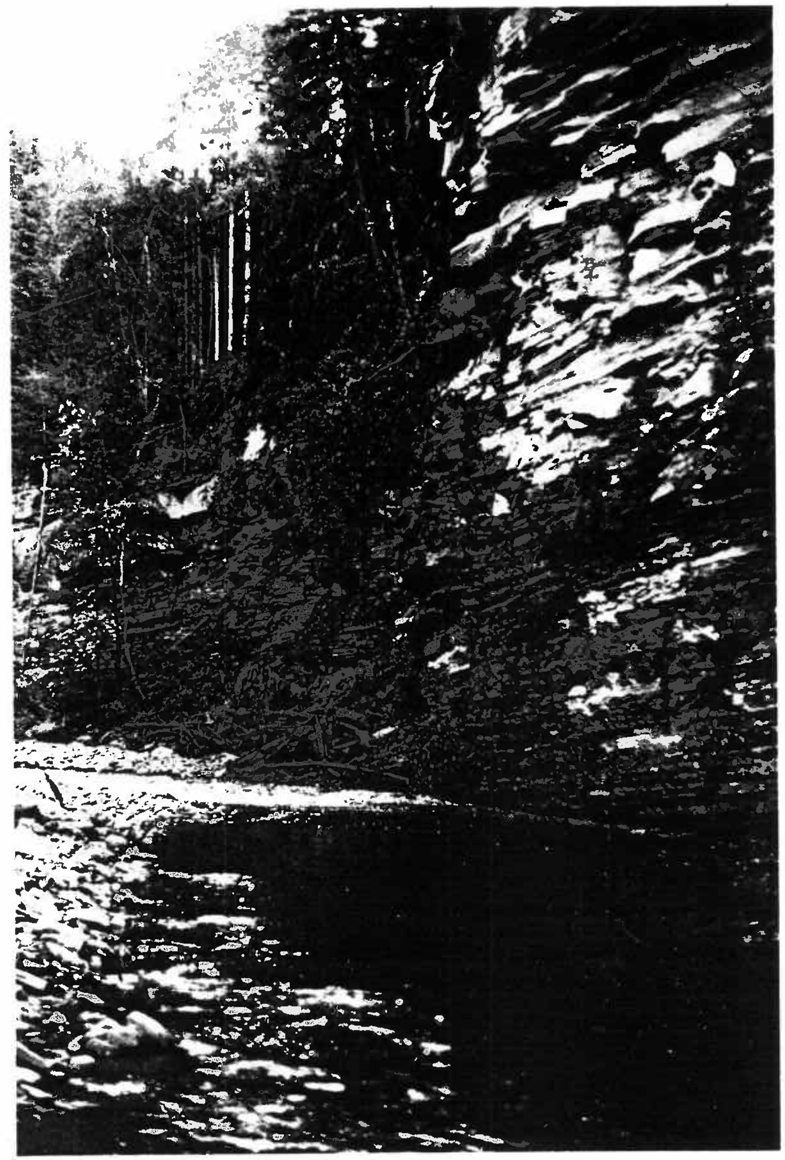


Figure 9.
Rainbow trout juveniles and spawning adults were both captured in Reach 1 (above) and 2 (right) of Maurice Creek.

juveniles apparently reside in the creek for about two years and then migrate into the Peace River.

Table 14.
Fork length statistics of fish caught in Maurice Creek by electroshocker, June 23, 1990.

| Species | n | Min (mm) | Max (mm) | Mean (mm) | Stdev. (mm) |
|---|---|---|---|---|---|
| Rainbow trout | 19 | 72 | 351 | 154 | 78 |
| Arctic grayling | 1 | - | - | 374 | - |
| Mountain whitefish | 6 | 111 | 277 | 143 | 66 |
| Lake whitefish | 1 | - | - | 374 | - |
| Longnose sucker | 42 | 70 | 440 | 212 | 117 |
| White sucker | 3 | 174 | 370 | 259 | 100 |
| Longnose dace | 3 | 60 | 96 | 73 | 20 |
| Northern squawfish | 4 | 87 | 250 | 191 | 72 |
| Sculpins | 59 | 41 | 97 | 63 | 16 |

Maurice Creek appears to be an important contributor to the Peace River rainbow trout population. Using the densities determined during the study (Table 13), an average wetted width of 11 m during the spring survey, and lengths of 1.7 km and 1.3 km for Reaches 1 and 2, respectively, the total population of rainbow trout adults was estimated at 280 adults, with 120 adults in Reach 1 and 160 adults in Reach 2. The juvenile population was estimated at 240 in Reach 1, and 1,200 in Reach 2 for a total of about 1,400. These figures indicate that Maurice Creek is an important spawning area for rainbow trout especially considering some had already migrated out of the system, prior to June 22.

The densities of adults in glide, pool and riffle ranged from 0.62 to 0.93 fish·100 $m^{-2}$ with densities greatest in pool habitat (Table 15). The densities of the juveniles ranged from 3.54 to 4.35 fish·100 $m^{-2}$, with densities slightly greater in glide habitat.

Table 15.
Densities (fish·100 $m^{-2}$) of rainbow trout within different habitat types in Maurice Creek by electroshocker, June 22, 1990.

| Habitat | Area sampled ($m^2$) | Adults | Juveniles |
|---|---|---|---|
| Glide | 161 | 0.62 | 4.35 |
| Riffle | 113 | 0.88 | 3.54 |
| Pool | 215 | 0.93 | 3.72 |

Longnose suckers and sculpins predominated in the catch from both reaches surveyed. The former ranged in size from 70 to 440 mm in size, indicating the presence of both juveniles and adults. Whereas all of the longnose suckers caught in Reach 2 were 250 mm or less, larger fish were found only in Reach 1. In addition, several of the larger fish expressed milt or eggs when handled, indicating that many were in spawning condition. This indicates that longnose suckers mainly spawn in Reach 1.

Although in much smaller numbers, three other non-sportfish species were caught in Reach 1 of Maurice Creek. These included longnose dace, northern squawfish and white sucker. Of the three species, only the white sucker was caught in Reach 2.

### 3.2.3 MOBERLY RIVER

The Moberly River was sampled primarily by beach seine in Reaches 1a, 1b, 2 and 5 between May 29 and June 17, 1990. In addition, the Peace River around the mouth of the Moberly River was sampled extensively by beach seine on May 27, 28 and June 13 and 14.

Near the Moberly River mouth, five sportfish species were captured: mountain whitefish, Arctic grayling, northern pike, kokanee and burbot. All of these species, except kokanee, were also captured in the Moberly River. Lake whitefish were captured in the Moberly River just below Moberly Lake and one bull trout was caught in Reach 1a.

Mountain whitefish were the most prevalent sportfish species caught near the Moberly River mouth and in Reaches 1 and 2 of the Moberly River. Catches averaged 0.33 fish·100 $m^{-2}$ near the mouth, 0.25 fish·100 $m^{-2}$ in Reach 1a and 5.41 fish·100 $m^{-2}$ in Reach 2 (Table 16). No mountain whitefish were captured in Reaches 1b or 5. Mountain whitefish captured near the mouth were larger and older than those caught in the Moberly River (Table 17 and 18). In addition, within each age group, the Peace River mountain whitefish were larger in size than those of the same age group in the Moberly River. For example, mountain whitefish age two collected at the mouth had a mean length of 234 mm ($n = 7$, $s = 28$) and were significantly larger ($P \leq 0.02$) than age two mountain whitefish captured from the Moberly River with a mean length of 199 mm ($n = 8$, $s = 22$ mm).

Table 16
Beach seine catches (fish·100 $m^{-2}$) in the Moberly River, May 27 to June 17, 1990.

| Species | Reach | | | | |
|---|---|---|---|---|---|
| | Mouth | 1a | 1b | 2 | 5 |
| Mt. whitefish | 0.33 | 0.24 | 0 | 5.41 | 0 |
| Arctic grayling | 0.08 | 0 | 0 | 0.56 | 0 |
| Northern pike | 0.02 | 0 | 0 | 0 | 0.19 |
| Kokanee | 0.02 | 0 | 0 | 0 | 0 |
| Lake whitefish | 0 | 0 | 0 | 0 | 8.68 |
| Bull trout | 0 | 0.02 | 0 | 0 | 0 |
| Burbot | 0.08 | 0.02 | 0 | 0.11 | 0 |
| Redside shiner | 0.27 | 0.12 | 0 | 0.79 | 0 |
| Peamouth | 0.02 | 0 | 0 | 0 | 0 |
| N. squawfish | 0.06 | 0.27 | 0 | 0 | 0 |
| Lake chub | 0 | 0.07 | 0 | 0 | 0 |
| Longnose dace | 0 | 2.01 | 3.49 | 8.90 | 0 |
| Longnose sucker | 0.44 | 0.61 | 0 | 1.24 | 0.19 |
| Largescale sucker | 0.13 | 0.15 | 0 | 0 | 0 |
| White sucker | 0 | 0 | 0 | 0 | 11.32 |
| Sculpins | 0.31 | 0.05 | 0.32 | 6.64 | 0 |
| Area sampled ($m^2$) | 6,385 | 4,121 | 630 | 888 | 530 |

Table 17
Comparison of age-fork length (mm) data for mountain whitefish ages 0+ to 6 from the Peace and Moberly Rivers collected during various studies.

| System | | Age | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Peace[a] | mean | 93 | 172 | 220 | 249 | 273 | 295 | 323 |
| (1989) | n | 5 | 4 | 3 | 3 | 5 | 11 | 3 |
| Peace[b] | mean | - | 78 | 178 | 225 | 292 | 341 | 365 |
| (1975) | n | 0 | 15 | 12 | 13 | 9 | 8 | 5 |
| Peace[c] | mean | - | 153 | 234 | 291 | 352 | 404 | 485 |
| (1990) | n | 0 | 3 | 7 | 7 | 15 | 15 | 1 |
| Moberly[c] | mean | 38 | 114 | 199 | 237 | 280 | - | - |
| (1990) | n | 29 | 1 | 8 | 1 | 1 | 0 | 0 |
| Moberly[d] | mean | 69 | 153 | 222 | 243 | 270 | 307 | 355 |
| (1989) | n | 9 | 6 | 3 | 5 | 4 | 6 | 1 |

[a]Pattenden and Ash 1990
[b]RRCS 1979
[c]present study
[d]Slaney et al. 1991

Table 18.
Summary of size data from sportfish
sampled from the Moberly River, May 27 to June 17, 1990.

| | | | Length (mm) | | | | Weight (g) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Species | Age | Reach | Mean. | (range) | n | Stdev | Mean | (range) | n | Stdev |
| Mountain Whitefish | All | Mouth | 263 | (93 - 492) | 54 | 115 | 383 | (35 - 1,280) | 40 | 263 |
| Mountain Whitefish | 1 | Mouth | 152 | (113 - 195) | 3 | 41 | 57.5 | (35 - 80) | 2 | 32 |
| Mountain Whitefish | 2 | Mouth | 234 | (197 - 280) | 7 | 28 | 176 | (80 - 275) | 7 | 75 |
| Mountain Whitefish | 3 | Mouth | 290 | (255 - 324) | 7 | 28 | 251 | (200 - 300) | 7 | 42 |
| Mountain Whitefish | 4 | Mouth | 352 | (290 - 424) | 15 | 34 | 441 | (275 - 765) | 15 | 135 |
| Mountain Whitefish | 5 | Mouth | 404 | (348 - 492) | 15 | 54 | 704 | (425 - 1,280) | 6 | 345 |
| Mountain Whitefish | 6 | Mouth | 485 | | 1 | - | 1,000 | | 1 | - |
| Mountain Whitefish | All | All | 84 | (26 - 280) | 42 | 76 | 108 | (20 - 260) | 9 | 74 |
| Mountain Whitefish | 0+ | All | 38 | (26 - 88) | 29 | 11 | - | | 0 | - |
| Mountain Whitefish | 1+ | All | 114 | | 1 | - | - | | 0 | - |
| Mountain Whitefish | 2 | All | 199 | (175 - 241) | 8 | 22 | 90.8 | (60 - 170) | 6 | 43 |
| Mountain Whitefish | 3 | All | 237 | | 1 | - | 150 | | 1 | - |
| Mountain Whitefish | 4 | All | 280 | | 1 | - | 260 | | 1 | - |
| Arctic Grayling | - | Mouth | 187 | (96 - 403) | 4 | 145 | - | | - | - |
| Arctic Grayling | 1 | Mouth | 115 | (96 - 132) | 3 | 18 | - | | - | - |
| Arctic Grayling | 3 | Mouth | 403 | | 1 | - | 675 | | 1 | - |
| Arctic Grayling | All | All | 242 | (127 - 419) | 4 | 125 | 352 | (26 - 900) | 3 | 478 |
| Arctic Grayling | 1 | All | 127 | | 1 | - | - | | 0 | - |
| Arctic Grayling | 2 | All | 210 | (195 - 225) | 2 | 21 | 78 | (26 - 130) | 2 | 74 |
| Arctic Grayling | 4 | All | 419 | | 1 | - | 900 | | 1 | - |
| Burbot | - | Mouth | 337 | (282 - 445) | 5 | 67 | 375 | (175 - 675) | 4 | 227 |
| Burbot | - | All | 198 | (120 - 275) | 2 | 110 | 125 | | 1 | - |
| Lake Whitefish | All | Reach 5 | 297 | (235 - 350) | 20 | 32 | 353 | (150 - 600) | 20 | 120 |
| Lake Whitefish | 2 | Reach 5 | 235 | | 1 | - | 150 | | 1 | - |
| Lake Whitefish | 3 | Reach 5 | 271 | (250 - 295) | 4 | 20 | 275 | (250 - 300) | 4 | 20 |
| Lake Whitefish | 4 | Reach 5 | 293 | (275 - 315) | 9 | 15 | 326 | (250 - 400) | 9 | 55 |
| Lake Whitefish | 5 | Reach 5 | 295 | (285 - 305 | 2 | 14 | 325 | (300 - 350) | 2 | 35 |
| Lake Whitefish | 6 | Reach 5 | 345 | (335 - 350) | 3 | 8.7 | 542 | (500 - 575) | 3 | 38 |
| Lake Whitefish | 7 | Reach 5 | 350 | | 1 | - | 600 | | 1 | - |
| Northern Pike | All | Mouth | 427 | (61 - 640) | 7 | 228 | 945 | (95 - 1750) | 6 | 678 |
| Northern Pike | 0+ | Mouth | 61 | | 1 | - | - - | | - | - |
| Northern Pike | 1 | Mouth | 220 | | 1 | - | 95 | | 1 | - |
| Northern Pike | 2 | Mouth | 322 | | 1 | - | 225 | | 1 | - |
| Northern Pike | 4 | Mouth | 520 | | 1 | - | 850 | | 1 | - |
| Northern Pike | 5 | Mouth | 622 | (595 - 640) | 3 | 24 | 1,500 | (1250 - 1750) | 3 | 250 |
| Northern Pike | All | Reach 5 | 482 | (410 - 535) | 3 | 65 | 700 | (325 - 1,200) | 3 | 451 |
| Northern Pike | 3 | Reach 5 | 410 | | 1 | - | 325 | | 1 | - |
| Northern Pike | 4 | Reach 5 | 518 | (500 - 535) | 2 | 25 | 888 | (575 - 1200) | 2 | 442 |
| Bull trout | - | Reach 1a | 249 | | 1 | - | 150 | | 1 | - |
| Kokanee | 2 | Mouth | 272 | | 1 | - | 200 | | 1 | - |

Most of the mountain whitefish sampled from the Peace River were adults at least three years old, while the majority of those from the Moberly were less than three years old. The Moberly River mountain whitefish were mainly age 0+ collected from Reach 2. These data along with those collected in 1989 suggest that the Moberly River is used for spawning by mountain whitefish from the Peace River. Mountain whitefish sampled from the Peace River during 1989 were similar in size to those sampled from the Moberly River during 1989 (Table 17). Large numbers of adult mountain whitefish were captured in the Moberly River during October 1989 where few had been caught a month earlier. The similarity in size of these fish indicates that adult mountain whitefish from the Peace River may have moved upstream to spawn and then returned to the Peace River after spawning was finished. During May and June 1990, concentrations of 0+ mountain whitefish fry were captured in low velocity habitat in Reach 2 (Figure 10). No 0+ fry and only three 1+ mountain whitefish were captured in the Peace River near the Moberly River mouth. The lack of juveniles in the Peace suggests that little spawning takes place in this portion of the mainstem. Spawning in Reach 1 also appears to be very light as only three 0+ juveniles were captured in this area.

There was no indication that Arctic grayling were congregating at the mouth of the Moberly River in preparation for moving upstream to spawn. However, sampling may have been conducted too late for this species. Spawning typically takes place soon after break up (McPhail and Lindsey 1970) although it occasionally extends into early June in the Sukunka system (Stuart and Chislett 1979). Arctic grayling collected by electrofishing in the mainstem Peace River May 19 - 25, 1990 were all spent suggesting that spawning had occurred some time earlier (Pattenden et al. 1991). Only four Arctic grayling were caught along the Peace River shores near the mouth of the Moberly River, including three 1+ juveniles and a 3 year old adult (Table 18).

No spawners were observed within the river as all of the Arctic grayling were captured in Reach 2 (beach seine catches = 0.56 fish·100 $m^{-2}$) and of the four sampled, three were 1+ juveniles and the other a 4 year old adult. During the fall of 1989, Arctic grayling were found in low numbers in Reaches 1 - 3 with seine catches ranging from 0.2 - 2.1 fish·100 $m^{-2}$ (Slaney et al. 1991).

Small catches of northern pike were made near the mouth of the river and in Reach 5 (Table 16). The northern pike sampled near the mouth ranged in size from 61 to 640 mm and from 0+ to 4 years of age. The northern pike captured in Reach 5 ranged in size from 410 to 535 mm and from 3 to 4 years of age. The

Figure 10
No spawning sportfish were captured in Reach 1 of the Moberly River (upper photo). This reach was very unstable. Reach 2 was much more stable and appeared to be more suitable spawning habitat (lower photo).

majority of the northern pike occupy low velocity habitats in Reaches 3 and 5. There is little of this type of habitat in the lower reaches.

One kokanee was captured in the Peace near the Moberly River mouth and none were caught in the Moberly River. The kokanee was 272 mm long and two years old.

### 3.2.4 UPPER HALFWAY TRIBUTARIES

The composition of fish species collected from the five Halfway River tributaries (Table 19) was similar to that sampled in 1989 (Slaney et al. 1991). Mountain whitefish, rainbow trout, Arctic grayling and bull trout were caught in all the systems except Cypress Creek. No rainbow trout or bull trout were caught in that system during 1989 or 1990.

Table 19.
Species composition of the Halfway River tributaries
surveyed August 2 - 7, 1990.

| Species | Graham | Blue Grave | Horseshoe | Chowade | Cypress |
|---|---|---|---|---|---|
| Mountain whitefish | + | + | + | + | + |
| Rainbow trout | + | + | + | + | - |
| Arctic grayling | + | + | + | + | + |
| Bull trout | + | + | + | + | - |
| Longnose sucker | + | + | + | + | + |
| Longnose dace | - | + | + | - | - |
| Northern squawfish | - | + | - | - | - |
| Sculpins | + | + | + | + | + |

Beach seine catches, snorkel counts and depletion-removal density estimates for all sampling sites within each system are detailed in Appendix XI. The results are combined and summarized in Table 20. In general, mountain whitefish were the most numerous sportfish in the larger systems ie., Graham River, Chowade River and Cypress Creek. Rainbow trout were most numerous in the two smallest systems (Blue Grave and Horseshoe Creeks), however they were mainly juveniles less than 3 years old. During both 1989 and 1990, all of the rainbow trout sampled and observed from the two large systems, the Graham and Chowade Rivers, were adults (Slaney et al. 1991). Arctic grayling were present in all the systems, but no significant concentrations were found at any site. Concentrations were the greatest in the Graham River (0.18 fish$\cdot$100 m$^{-2}$).

Table 20.
Nominal densities[1] (fish·100 $m^{-2}$) of sportfish
from the Halfway River tributaries surveyed on August 2 - 7, 1990.

| Species | Graham | Blue Grave | Horseshoe | Chowade | Cypress |
|---|---|---|---|---|---|
| Mountain whitefish | 0.65 | 0.79 | 0.92 | 4.08 | 5.47 |
| Rainbow trout | 0.09 | 2.78 | 3.37 | 0.05 | 0.18 |
| Arctic grayling | 0.18 | * | * | 0.08 | 0 |
| Bull trout | 0.04 | 1.19 | 0.31 | 0.03 | 0 |
| Area sampled($m^2$) | 5,420 | 252 | 226 | 4,000 | 1,134 |

[1] Combined beach seine catch densities, float counts and depletion-removal density estimates (See Appendix XI).

* - present.

Bull trout were the most numerous in the two smallest creeks (Horseshoe and Blue Grave Creeks) (Table 20). Both systems contained substantial numbers of juveniles and adults. Bull trout were most prevalent in Blue Grave Creek with densities of 1.19 fish·100 $m^{-2}$ and, despite the small size of this system, several adults were also collected from the upper sample site. It appears that both these small creeks are important habitat for rearing and possibly spawning of this species. Only adults were captured in the Graham and Chowade rivers.

Whitefish samples from the five upper Halfway systems ranged in length from 38 mm to 423 mm. Ages ranged from 0+ to 5 years (Table 21). Few 0+ mountain whitefish, and no mountain whitefish older than 3+ years, were sampled from Blue Grave or Horseshoe creeks. The lack of 0+ mountain whitefish in the two smallest creeks suggests the smaller systems may not be used for spawning. However, the lowest reach of these creeks appears to be utilized for rearing by age 1+ and 2+ mountain whitefish as juveniles were found at the sites near the mouth. They may have moved in from the Halfway River.

Although the smaller systems do not appear to be important mountain whitefish spawning habitat, they may to be important spawning areas for rainbow trout. Juveniles, 0+ to 2+ years of age, were found in Blue Grave and Horseshoe creeks (Table 22). Conversely, no juveniles were found at sites in the Graham River and Chowade River, the two largest systems. The rainbow trout sampled ranged in size from 73 mm to 342 mm and ranged in age from 0+ to 3+ years of age (Table 22).

Small numbers of Arctic grayling were sampled from all five systems (Tables 23 and 24). Ages ranged from 1+ to 3+ years old and lengths ranged from 146 to 274 mm. No 0+ Arctic grayling were captured.

Table 21.
Fork length-age relationship and condition factor for mountain whitefish in the Halfway River tributaries sampled on August 2 - 7, 1990

| System | Age | n | Min (mm) | Max (mm) | Mean (mm) | Stdev. (mm) | Condition (mean K) |
|---|---|---|---|---|---|---|---|
| Graham River | 0+ | 3 | 41 | 42 | 41 | 0.6 | 0.8 |
| | 1 | 1 | - | - | 129 | - | 1.03 |
| | 2 | 5 | 136 | 160 | 149 | 11.0 | 1.68 |
| | 3 | 7 | 215 | 332 | 261 | 43.2 | 1.22 |
| | 4 | 2 | 305 | 322 | 313 | 12.0 | 1.09 |
| Blue Grave Creek | 1 | 3 | 120 | 140 | 129 | 10.1 | 1.00 |
| | 2 | 1 | - | - | 184 | - | 1.37 |
| Horseshoe Creek | 0+ | 1 | - | - | 99 | - | 0.96 |
| | 1 | 5 | 90 | 187 | 139 | 34.4 | 0.98 |
| | 2 | 12 | 144 | 244 | 184 | 30.0 | 1.05 |
| Chowade River | 0+ | 15 | 33 | 51 | 44 | 3.7 | 0.91 |
| | 1 | 12 | 86 | 154 | 109 | 25.9 | 0.96 |
| | 2 | 14 | 122 | 197 | 158 | 27.8 | 1.06 |
| | 3 | 4 | 257 | 293 | 275 | 19.9 | 1.24 |
| Cypress Creek | 0+ | 20 | 40 | 54 | 47 | 3.9 | 0.90 |
| | 1 | 17 | 98 | 133 | 110 | 11.6 | 0.95 |
| | 2 | 8 | 121 | 223 | 162 | 36.0 | 1.17 |
| | 3 | 2 | 202 | 259 | 231 | 40.3 | 1.25 |
| | 4 | 3 | 268 | 327 | 304 | 31.6 | 1.14 |
| | 5 | 1 | - | - | 423 | - | 1.07 |

Table 22.
Fork length-age relationship and condition factor for rainbow
in the Halfway River tributaries sampled on August 2 to 7, 1990.

| System | Age | n | Min (mm) | Max (mm) | Mean (mm) | Stdev. (mm) | Condition (mean K) |
|---|---|---|---|---|---|---|---|
| Graham River | 3 | 1 | - | - | 342 | - | 1.46 |
| Blue Grave Creek | 0 | 2 | 73 | 81 | 77 | 5.7 | 1.19 |
| | 1 | 10 | 136 | 166 | 153 | 10.8 | 1.27 |
| | 2 | 1 | - | - | 212 | - | 1.27 |
| Horseshoe Creek | 0 | 9 | 76 | 92 | 82 | 5.9 | 1.12 |
| | 1 | 8 | 119 | 168 | 143 | 17.2 | 1.36 |
| | 2 | 2 | 182 | 223 | 203 | 29.0 | 1.27 |
| Chowade River | - | 1 | - | - | 282 | - | - |

Table 23.
Fork length-age relationship and condition factor for Arctic grayling in the Halfway River tributaries sampled on August 2 - 7, 1990.

| System | Age | n | Min (mm) | Max (mm) | Mean (mm) | Stdev. (mm) | Condition (mean K) |
|---|---|---|---|---|---|---|---|
| Graham River | 2 | 2 | 190 | 202 | 196 | 8.5 | 1.29 |
| | 3 | 3 | 244 | 274 | 261 | 15.4 | 1.34 |
| Blue Grave Creek | 1 | 1 | - | - | 179 | - | 1.05 |
| | 2 | 1 | - | - | 262 | - | 1.17 |
| Horseshoe Creek | 1 | 1 | - | - | 131 | - | 0.98 |
| | 2 | 1 | - | - | 238 | - | 1.11 |
| Chowade River | 1 | 1 | - | - | 146 | - | 1.02 |
| Cypress Creek | 2 | 1 | - | - | 192 | - | 1.14 |
| | 3 | 1 | - | - | 270 | - | 1.27 |

Table 24.
Summary of length-weight relationship of fish
caught in Peace and Halfway River tributaries, August, 1990.

| Species | System | b ± 2 SE* | a ± 2 SE* | Adjusted R | Condition (mean K) |
|---|---|---|---|---|---|
| Bull trout | | | | | |
| | Blue Grave | 3.02 ± 0.14 | -5.04 ± 0.30 | 1.00 | 1.00 |
| Arctic grayling | | | | | |
| | Colt | 3.03 ± 0.06 | -5.66 ± 0.10 | 1.00 | 1.00 |
| | Graham | 3.02 ± 0.24 | -5.19 ± 0.56 | 0.99 | 0.85 |
| | Moberly | 3.09 ± 0.16 | -5.14 ± 0.30 | 0.99 | 1.10 |
| Lake whitefish | | | | | |
| | Moberly | 2.99 ± 1.00 | -4.88 ± 2.52 | 0.90 | 1.22 |
| Mountain whitefish | | | | | |
| | Chowade | 3.05 ± 1.10 | -5.14 ± 2.46 | 0.67 | 1.22 |
| | Colt | 3.07 ± 0.12 | -5.81 ± 0.24 | 0.99 | 0.91 |
| | Graham | 3.06 ± 0.10 | -5.20 ± 0.22 | 0.98 | 0.86 |
| | Kobes | 3.04 ± 0.18 | -5.12 ± 0.36 | 0.99 | 0.90 |
| | Moberly | 3.17 ± 0.10 | -5.36 ± 0.22 | 0.99 | 1.08 |
| Northern pike | | | | | |
| | Moberly | 3.13 ± 0.12 | -5.51 ± 0.30 | 0.99 | 0.66 |
| Rainbow | | | | | |
| | Colt | 3.04 ± 0.12 | -5.03 ± 0.24 | 1.00 | 1.11 |
| | Lynx | 2.98 ± 0.18 | -4.90 ± 0.38 | 0.99 | 1.18 |
| | Maurice | 3.02 ± 0.08 | -4.99 ± 0.16 | 0.99 | 1.14 |

* Regression equation: log(W) = log(a) + b•log(L) where W = weight (g) and L = length (mm)

3.2.4.1 Graham River

Reaches 2 and 3 of the Graham River (Figures 4 & 11)were sampled on August 2 and 4, 1990 using methods similar to those used in Reach 1 during October, 1989 (Slaney et al. 1991) although a larger seine was used during 1990. Sportfishing pressure appeared to be low in all of the sites examined in 1990 as access was poor.

Species composition and observed densities in Reach 2 (Table 25) were similar to those found in Reach 1 with one exception. The catches of mountain whitefish were much greater during October 1989 (13 fish·100 $m^{-2}$) compared to beach seine catches and diver observations of 0.65 fish·100 $m^{-2}$ in Reaches 2 and 3 during 1990. Although mountain whitefish were still the most numerous species caught in the Graham River during August 1990, the larger catches during October 1989 suggests that they may have moved from other areas to spawn in the fall, or possibly to overwinter. Similar densities of mountain whitefish were observed in both Reaches 2 and 3, although no juveniles were observed in the site that was sampled in Reach 3, and 40% of the mountain whitefish observed in Reach 2 were juveniles. The mountain whitefish sampled averaged 199 mm in length (n = 20, stdev = 93.2 mm, Table 26) and ranged in age from 0 to 4 years (Table 21). The median age was 3 years. Mountain whitefish sampled in 1989 averaged 112 mm (n = 87, stdev. = 63.0, Slaney et al. 1991)

Table 25.
Nominal fish densities (fish·100 $m^{-2}$) for the Graham River,
August 2 and 4, 1990.

| Species | Reach 2 | Reach 3 | overall |
|---|---|---|---|
| Mountain whitefish | 0.66 | 0.63 | 0.65 |
| Rainbow trout | 0.05 | 0.23 | 0.09 |
| Arctic grayling | 0.21 | 0.08 | 0.18 |
| Bull trout | 0.05 | 0.00 | 0.04 |
| Longnose sucker | 0.05 | 0.39 | 0.13 |
| Sculpins | present | - | present |
| Area sampled ($m^2$) | 4,140 | 1,280 | 5,420 |

[1] Combined beach seine catch densities and float counts (See Appendix XI).

Overall beach seine catches and diver observations of rainbow trout in Reaches 2 and 3 were 0.09 fish·100 $m^{-2}$). These densities were similar to that found in Reach 1 during 1989 (0.1 fish·100 $m^{-2}$, Slaney et al. 1991). The highest concentrations (0.23 fish·100 $m^{-2}$ were found in Reach 3. All of the rainbow trout observed in Reaches 2 and 3 were adults. The only rainbow trout sampled was three years old and 342 mm long.

Figure 11.
Rainbow trout, Arctic grayling and mountain whitefish were observed at the sample site in Reach 3 of the Graham river (upper photo). On Blue Grave Creek (lower photo) the upper sample site which is 16 km upstream from the mouth, contained juvenile rainbow trout and bull trout as well as adult bull trout.

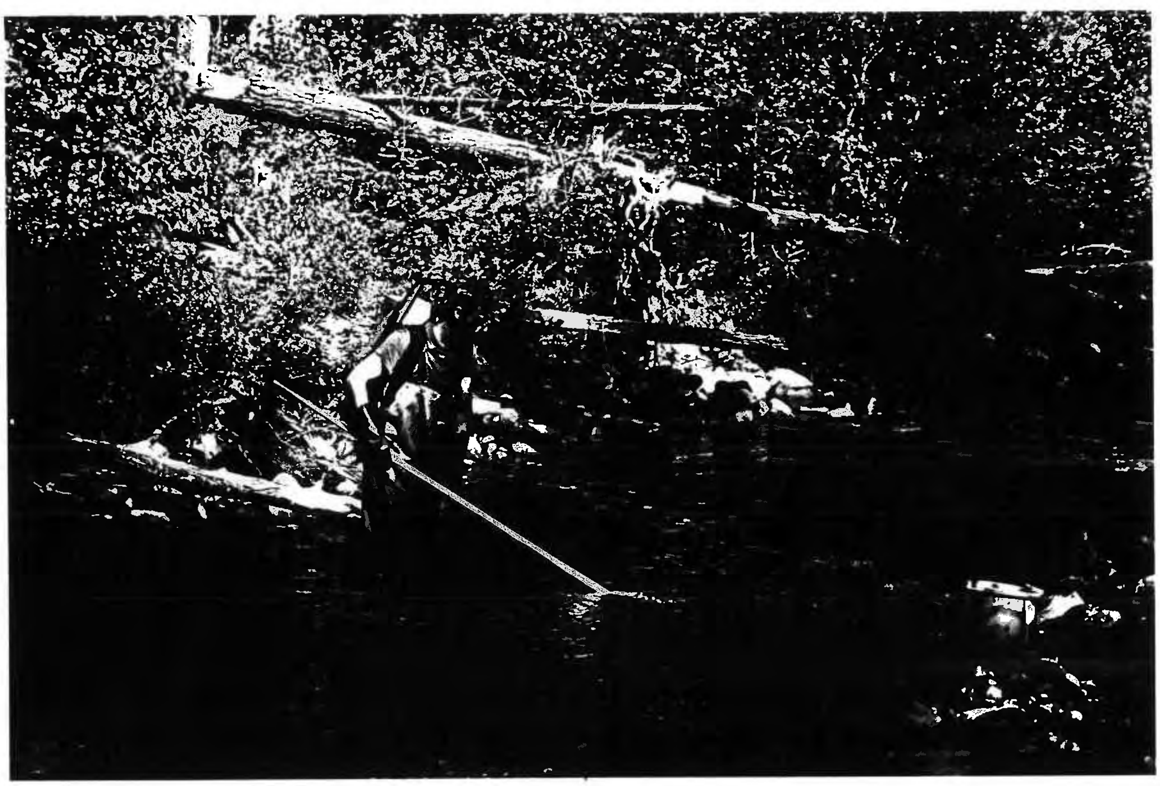


Table 26.
Summary of size data collected from sportfish from the Graham River, August 2 and 4, 1990.

| | Length (mm) | | | | Weight (g) | | | |
|---|---|---|---|---|---|---|---|---|
| Species | Mean | (range) | n | Stdev. | Mean | (range) | n | Stdev. |
| Mountain whitefish | 199 | (41 - 332) | 20 | 93.2 | 146 | (0.45 - 450.00) | 20 | 129 |
| Rainbow | 342 | - | 1 | - | 585 | - | 1 | - |
| Arctic grayling | 235 | (190 - 274) | 5 | 37.5 | 182 | (85.00 - 260.00) | 5 | 81.1 |
| Bull trout | 253 | - | 1 | - | 240 | - | 1 | - |

Overall beach seine catches and diver observations of Arctic grayling were 0.18 fish·100 $m^{-2}$, most of which were observed in the Reach 2 sites. Higher catches (0.60 fish·100 $m^{-2}$) of Arctic grayling were made in Reach 1 during 1989. The five Arctic grayling sampled varied in age from 2 to 3 years and had average lengths of 235 mm (n = 5, stdev = 37.5; Tables 23 and 26). The samples collected in Reach 2 were similar in size to those collected in Reach 1 during 1989 (mean length = 247 mm n = 4, stdev = 109 mm; Slaney et al. 1991).

Few bull trout were caught or observed in Reaches 2 and 3. This species was the least numerous of the four sportfish species caught. Nominal density was 0.04 fish·100 $m^{-2}$. Catches were greater in Reach 1 during 1989 (0.20 fish·100 $m^{-2}$). The one bull trout sampled in August 1990 was 253 mm long.

#### 3.2.4.2 Blue Grave Creek

Blue Grave Creek was sampled by electroshocker near the mouth and near the bridge crossing at 16 km on August 3 and 5, 1990. Sites were isolated with stop nets and the sites were shocked using the multiple removal technique (Seber and LeCren 1967) in order that population estimates could be made (Table 27). Near the creek mouth, four sportfish species were present, (mountain whitefish, rainbow trout, Arctic grayling and bull trout) along with four non sportfish species. Only two sportfish species, bull trout and rainbow trout, and one non sportfish species were encountered further up the creek at 16 km (Figure 11). Densities of fish were also higher near the mouth.

No Arctic grayling were captured in the electroshocking sites but two Arctic grayling, along with two mountain whitefish and a rainbow trout, drifted into the upper stop net while one site was being shocked. Similar movement was also noted on Horseshoe Creek where fish also drifted into the shocking site. The movement of fish into the shocking site appears to indicate that fish were migrating downstream at the time in both systems and may have been a function of dropping water levels. The fish moving downstream were generally larger in size than those caught in the shocking sites. Lower numbers of fish were encountered in both Horseshoe and Blue Grave Creeks during October 1989 which may be a result of larger fish moving out of these systems as water levels drop during summer.

Table 27.
Fish densities determined by electroshocking in Blue Grave Creek, August 3 and 5, 1990.

| Species | Fish Densities (fish·100 m$^{-2}$) 0.5 km | 16 km | Overall |
|---|---|---|---|
| Mountain whitefish | 1.39 | 0 | 0.79 |
| Rainbow trout | 3.47 | 1.85 | 2.78 |
| Arctic grayling | present[1] | 0 | present[1] |
| Bull trout | 1.39 | 0.92 | 1.19 |
| Longnose sucker | 0.69 | 0 | 0.40 |
| Longnose dace | 1.39 | 0 | 0.79 |
| Northern squawfish | 0.69 | 0 | 0.40 |
| Sculpins | 6.94 | 8.32 | 7.53 |
| Area sampled (m$^2$) | 144 | 108 | 252 |

[1]Arctic grayling were not caught in shocking sites but were present in the area.

Blue Grave Creek had the highest densities of bull trout of all the tributaries to the upper Halfway River system that were sampled (Table 20). Densities at sampling sites at 0.5 and 16 km averaged 1.19 fish·100 m$^{-2}$ and were similar at both sites. High densities of bull trout were also found in this system during October, 1989 (Slaney et al. 1991). Bull trout samples ranged in length from 86 to 377 mm (Table 28). Three adults over 320 mm long, one of which was angler caught, were sampled from the 16 km site. These fish were unusually large considering the size of the creek in this area.

Table 28.
Summary of size data collected from sportfish
from Blue Grave Creek, August 3 and 5, 1990.

| | Length (mm) | | | | Weight (g) | | | |
|---|---|---|---|---|---|---|---|---|
| Species | Mean | (range) | n | Stdev. | Mean | (range) | n | Stdev. |
| Mountain whitefish | 143 | (120 - 184) | 4 | 28.5 | 37.6 | (17.1 - 85.1) | 4 | 31.9 |
| Rainbow trout | 146 | (73 - 212) | 13 | 35.9 | 45.0 | (4.25 - 125) | 13 | 27.9 |
| Arctic grayling | 221 | (179 -262) | 2 | 58.7 | 135 | (60.3 - 210) | 2 | 106 |
| Bull trout | 173 | (86 - 377) | 15 | 96.1 | 114 | (7.10 - 575) | 15 | 183 |

Rainbow trout were the most numerous of the sportfish species, averaging 2.78 fish·100 $m^{-2}$ at the 0.5 and 16 km sites. Densities were greatest at the lower site (3.47 fish·100 m-2). All of the rainbow trout sampled were juveniles ranging in age from 0+ to 2 years old, most of which were 1 year old (Table 22).

Mountain whitefish were only found at the 0.5 km site. Densities there were 1.39 fish·100 $m^{-2}$, and all the samples were juveniles 1 to 2 years old.

### 3.2.4.3 Horseshoe Creek

The species composition in Horseshoe Creek was very similar to that of Blue Grave Creek with the four sportfish; mountain whitefish, rainbow trout, Arctic grayling and bull trout found in both systems. As in Blue Grave Creek, bull trout and rainbow trout were the only sportfish found at the 16 km sample site. Mountain whitefish, rainbow trout and Arctic grayling were found at the 0.5 km sample site (Figure 12). However, as in Blue Grave Creek, no bull trout were captured at the lower site.

Two sites were electroshocked at 0.5 km. As in Blue Grave Creek, it appeared that fish were migrating downstream while the area was being sampled. Relatively large mountain whitefish, Arctic grayling and bull trout appeared to move up against the two shocking sites after an initial pass with the electroshocker.

Figure 12
Although the lower reaches of Horseshoe Creek were unstable, relatively high concentrations of rainbow trout, mountain whitefish, and Arctic grayling were captured (upper photo). Rainbow trout and bull trout juveniles were found at the upper site (lower photo).

Table 29.
Fish densities determined by electroshocking
in Horseshoe Creek, August 3 and 5, 1990.

| | Fish Densities (fish·100 m$^{-2}$) | | | |
|---|---|---|---|---|
| Species | 0.5 km[1] | | 16 km | Overall |
| Mountain whitefish | 1.35 | (8.07) | 0 | 0.92 |
| Rainbow trout | 4.48 | | 0.97 | 3.37 |
| Arctic grayling | 0 | (0.89 ) | 0 | 0 |
| Bull trout | 0 | (0.89 ) | 0.97 | 0.31 |
| Longnose sucker | 2.24 | | 0 | 1.53 |
| Longnose dace | 2.69 | | 0 | 1.84 |
| Sculpins | 21.5 | | 65.3 | 35.3 |
| Area sampled (m$^2$) | 223 | | 103 | 326 |

[1] - Densities in brackets represent catch densities including fish that moved onto site after the first pass was completed.

Most of the sportfish sampled from Horseshoe Creek were juveniles. The rainbow trout ranged in length from 76 to 223 mm and ranged in age from 0+ to 2 years old (Tables 22 and 30). Many (47%) of the rainbow trout sampled were 0+ years of age.

Mountain whitefish were only caught at the lower site in Horseshoe Creek. Only one very large 0+ mountain whitefish juvenile was captured in this creek. The scarcity of 0+ juveniles suggests that this creek is probably not utilized by spawning mountain whitefish. The 1 and 2 year old mountain whitefish may have moved into the system from the Halfway River. Age 0+ mountain whitefish were mainly captured in the larger systems.

Two Arctic grayling, 131 and 238 mm in length, 1 and 2 years old, were caught at the lower sample site. The Arctic grayling were caught in the stop net after a pass had been made so they may have been moving downstream at the time. No Arctic grayling were caught at the 16 km site.

Two adult bull trout, 305 and 317 mm in length, were also caught in one of the lower shocking sites after a pass had been made. These fish also appeared to be moving downstream. Moderate densities (0.92 fish·100 m$^{-2}$) of bull trout juveniles ranging in length from 151 to 162 mm were captured at 16 km. The presence and density of the bull trout juveniles indicates that the upper area of Horseshoe Creek may be important for both rearing and spawning by this species.

Table 30.
Summary of size data collected from sportfish sampled from Horseshoe Creek, August 3 and 4, 1990.

| | Length (mm) | | | | Weight (g) | | | |
|---|---|---|---|---|---|---|---|---|
| Species | Mean | (range) | n | Stdev. | Mean | (range) | n | Stdev. |
| Mountain whitefish | 167 | (90 - 244) | 18 | 39.5 | 54.6 | (7.20 - 120) | 18 | 33.3 |
| Rainbow trout | 120 | (76 - 223) | 19 | 43.4 | 31.8 | (4.65 - 133) | 19 | 34.5 |
| Arctic grayling | 185 | (131 - 238) | 2 | 75.6 | 86.0 | (22.0 - 150) | 2 | 90.5 |
| Bull trout | 218 | (151 - 317) | 5 | 85.5 | 147 | (38.4 - 325) | 5 | 143 |

### 3.2.4.4 Chowade River

The Chowade River was sampled on August 6, 1990 at 5 and 15 km using an 8 m x 2.5 m seine with 1 cm stretch mesh. In addition, float counts were made. Mountain whitefish, rainbow trout, Arctic grayling and bull trout were the four sportfish species observed (Table 31). Fish densities appeared to be similar at both 5 km and 15 km sample sites (Figure 13). The small mesh seine captured mainly juvenile fish along the shoreline and a few adults, while adult fish were mainly observed during the float counts by diver.

Table 31
Nominal fish densities[1] (fish·100 $m^{-2}$) from the Chowade River, August 6, 1990.

| Species | Small mesh Seine | Float Count | Nominal densities |
|---|---|---|---|
| Mountain whitefish (total) | 12.2 | 1.68 | 4.08 |
| Mountain whitefish (juveniles) | 11.8 | 0.32 | 2.93 |
| Mountain whitefish (adults) | 0.44 | 1.35 | 1.15 |
| Rainbow trout | 0.11 | 0.03 | 0.05 |
| Arctic grayling | 0.11 | 0.06 | 0.08 |
| Bull trout | 0.11 | - | 0.03 |
| Longnose sucker | - | 0.19 | 0.15 |
| Sculpins | 0.11 | - | - |
| Area Sampled ($m^2$) | 910 | 3,090 | 4,000 |

[1] Combined beach seine catch densities and float counts (See Appendix XI).

Mountain whitefish were the most numerous species observed. Average beach seine catches of 12.2 mountain whitefish·100 $m^{-2}$ were made at the two sites, most of which were juveniles 0+ to 2+ years old (Table 21). The catch and observed densities of adults (mountain whitefish over 3 years old) was 0.44 fish·100 $m^{-2}$ by beach seine and 1.35 fish·100 $m^{-2}$ in snorkel counts. The mountain whitefish sampled ranged in length from 38 to 293 mm (Table 32)

Figure 13.
Sample sites at 5 km (upper photo) and 15 km (lower photo) on the Chowade River contained bull trout, Arctic grayling, rainbow trout and mountain whitefish

and in age from 0+ to 3+ years (Table 21). The 0+ mountain whitefish were the most abundant age group captured.

Low densities of rainbow trout, Arctic grayling and bull trout were also noted at the two sample sites (Table 31). Only one of each of these species was sampled (Table 32). The Chowade River is locally renowned for bull trout angling, although sizes and catch rates are reported to have declined in recent years (H. Trask, local resident, pers. comm.). Fishing pressure on the system appears to be relatively high as the area is popular among local all-terrain vehicle users and fishermen.

Table 32.
Summary of size data collected from sportfish from the Chowade River, August 6, 1990.

| | Length (mm) | | | | Weight (g) | | | |
|---|---|---|---|---|---|---|---|---|
| Species | Mean | (range) | n | Stdev. | Mean | (range) | n | Stdev. |
| Mountain whitefish | 118 | (38 - 293) | 45 | 71.0 | 42.2 | (0.50 - 315) | 45 | 73.3 |
| Rainbow trout | 282 | | 1 | - | 265 | | 1 | - |
| Arctic grayling | 146 | | 1 | - | 31.7 | | 1 | - |
| Bull trout | 425 | | 1 | - | 625 | | 1 | - |

### 3.2.4.5 Cypress Creek

Cypress Creek was sampled by 8 m x 2.5 m seine and electroshocker on August 6, 1990 at 1 km and 15 km (Figures 4 and 14). Densities were estimated using the depletion-removal technique by electroshocker (Seber and LeCren 1967) at the 15 km site and catch densities were also calculated from the beach seine data (Table 33). Arctic grayling and mountain whitefish were the only sportfish captured. Longnose suckers and sculpins were captured at the lower site but not at the upper site.

Figure 14.
Arctic grayling and mountain whitefish were the only sportfish species sampled from sites located at 15 km (upper photo) and 1 km (lower photo) on Cypress Creek.

Table 33
Nominal fish densities (fish·100 $m^{-2}$) from Cypress Creek, August 7, 1990.

| Species | 1.25 km seine | 15 km shocker | 15 km seine | 15 km all | Both sites |
|---|---|---|---|---|---|
| Mountain whitefish | 5.69 | 9.90 | 2.89 | 5.26 | 5.47 |
| Arctic grayling | 0.18 | 0.52 | 0 | 0.18 | 0.18 |
| Longnose sucker | 0.53 | 0 | 0 | 0 | 0.26 |
| Sculpins | 0.18 | 0 | 0 | 0 | 0.09 |
| Area Sampled ($m^2$) | 562 | 192 | 380 | 572 | 1,134 |

Mountain whitefish were the most prevalent species at both sites. Catches and density estimates averaged 5.47 mountain whitefish·100 $m^{-2}$. Of the mountain whitefish caught, 86% were classified as juveniles (<200 mm) and the remainder adults (>200 mm). Those sampled ranged in size from 40 to 423 mm and in age from 0+ to 5+ years (Tables 34 and 21).

Only two Arctic grayling, 2 and 3 years old (192 and 270 mm, Table 34), were captured at the sample sites. Catch densities and density estimates averaged 0.18 Arctic grayling·100 $m^{-2}$ (Table 33).

Table 34.
Summary of size data collected from sportfish
from Cypress Creek, August 7, 1990.

| Species | Length (mm) Mean | (range) | n | Stdev. | Weight (g) Mean | (range) | n | Stdev. |
|---|---|---|---|---|---|---|---|---|
| Mountain whitefish | 118 | (40 - 423) | 52 | 85.0 | 71 | (0.65 - 810) | 52 | 140 |
| Arctic grayling | 231 | (192 -270) | 2 | 55.2 | 165 | (80.9 - 250) | 2 | 120 |

## 3.3 WATER QUALITY

Water quality samples were taken at two stations on the Graham, Blue Grave, Horseshoe, Chowade and Cypress systems (Figure 4). The results of the laboratory analysis are summarized in Table 35. In general, all of the samples were within recommended limits for aquatic life (CCREM 1987, Sigma 1983).

All five systems are typical mountain streams with ad nutrient levels. Total phosphorous ranged from undetectable to 0.010 mg·$L^{-1}$ while nitrates ranged from undetectable to 0.004 mg·$L^{-1}$. The only exception was the 15 km sample from Blue Grave Creek which contained 0.224 mg·$L^{-1}$ nitrates. However

Table 35
Summary of water quality analysis, Upper Halfway River Tributaries, August 1990.

| | Graham | | Blue Grave | | Horseshoe | | Chowade | | Cypress | |
|---|---|---|---|---|---|---|---|---|---|---|
| Parameters* | Mouth | 15 km | 1 km | 15 km | 1 km | 15 km | 5 km | 15 km | 1 km | 15 km |
| Alkalinity (Total 4.5) | 191 | 187 | 192 | 189 | 155 | 152 | 196 | 196 | 187 | 178 |
| Ammonia | 0.005 | 0.005 | 0.017 | 0.018 | 0.011 | 0.007 | 0.005 | 0.018 | 0.028 | 0.008 |
| Carbon (Organic) | 2.0 | 1.4 | 6.2 | 2.6 | 4.3 | 2.0 | 1.9 | 1.8 | 2.6 | - |
| Cond (umhos/cm) | 322 | 333 | 322 | 321 | 267 | 277 | 349 | 358 | 231 | 318 |
| Hardness (calc.) | 219 | 219 | 216 | 220 | 174 | 179 | 234 | 233 | 221 | 217 |
| Nitrate | 0.003 | <0.002 | 0.002 | 0.224 | <0.002 | <0.002 | <0.002 | <0.002 | 0.002 | 0.004 |
| Nitrite | 0.002 | 0.002 | <0.002 | 0.002 | 0.002 | <0.002 | 0.002 | 0.002 | 0.002 | 0.002 |
| pH (rel. u) - Lab | 8.5 | 8.6 | 8.5 | 8.3 | 8.4 | 8.2 | 8.3 | 8.3 | 8.5 | 8.4 |
| Phosphorous | <0.003 | <0.003 | 0.005 | 0.005 | <0.003 | 0.010 | <0.003 | 0.005 | 0.004 | 0.008 |
| Solids, Dissolved | 225 | 230 | 176 | 257 | 184 | 178 | 242 | 199 | 215 | 147 |
| Solids, Suspended | 2 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Aluminium | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 |
| Arsenic | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Barium | <0.110 | 0.095 | 0.17 | 0.12 | 0.16 | 0.12 | 0.098 | 0.1 | 0.13 | 0.12 |
| Berylium | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 | <0.005 |
| Bismuth | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 |
| Boron | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 |
| Cadmium | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 | <0.010 |
| Calcium | 60.1 | 60.4 | 62.0 | 61.9 | 47.4 | 46.9 | 67.9 | 67.4 | 63.8 | 61.2 |
| Chromium | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 |
| Cobalt | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 |
| Copper | <0.001 | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.001 | <0.001 | <0.001 | <0.001 |
| Iron | 0.11 | 0.044 | 0.16 | 0.033 | 0.15 | <0.015 | 0.048 | 0.025 | 0.081 | 0.069 |
| Lead | <0.003 | <0.003 | <0.003 | <0.003 | <0.003 | <0.003 | <0.003 | <0.003 | <0.003 | <0.003 |
| Magnesium | 16.7 | 16.5 | 14.8 | 16.0 | 13.6 | 15.0 | 15.7 | 15.7 | 15.0 | 15.6 |
| Manganese | 0.006 | <0.005 | 0.007 | <0.005 | 0.014 | <0.005 | 0.006 | <0.005 | <0.005 | <0.005 |
| Molybdenum | <0.030 | <0.030 | <0.030 | <0.030 | <0.030 | <0.030 | <0.030 | <0.030 | <0.030 | <0.030 |
| Nickel | <0.020 | <0.020 | <0.020 | <0.020 | <0.020 | <0.020 | <0.020 | <0.020 | <0.020 | <0.020 |
| Potassium | 0.5 | 0.4 | 1.0 | 0.5 | 0.8 | 0.5 | 0.5 | 0.5 | 0.6 | 0.5 |
| Silver | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 | <0.015 |
| Silicon | 1.75 | 1.68 | 2.38 | 2.25 | 2.31 | 2.5 | 1.97 | 1.91 | 2.15 | 2.14 |
| Sodium | 1.4 | 1.3 | 2.1 | 1.2 | 1.6 | 1.2 | 1.7 | 1.7 | 1.7 | 1.4 |
| Zinc | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 | <5 |

* Total mg/L unless specified.

this appears to be a result of sample contamination as there is no sign of even slightly elevated levels in the lower sample from this system. Organic carbon ranged from 1.4 to 2.6 $mg \cdot L^{-1}$ except in the lower samples from Blue Grave and Horseshoe Creeks. Concentrations in these samples were 6.2 and 4.3 $mg \cdot L^{-1}$ respectively. This probably reflects organic inputs from bank erosion plus a small amount of organic decay in swampy tributaries as the systems cross the Halfway valley.

## 3.4 LIMITS TO FISH PRODUCTION

Fish and habitat investigations completed during 1990 were designed to answer some of the questions which were outstanding at the end of the 1989 program (Slaney et al. 1991). The following sections outline our evaluation of the population constraints in the Site C area as of the end of the second field season. Although the Peace and Halfway mainstems, and the plateau tributaries were not examined during 1990, sections from the earlier report are included so that the overall assessment could be summarized in one report.

### 3.4.1 Reservoir

Fish productivity within the reservoir appears likely to be limited by three factors: low summer temperatures, rapid flushing, and an absence of suitable spawning habitats (RRCS 1979, Hammond 1987). The problems of temperature and flushing are probably unavoidable in a reservoir of this type although warmer temperatures may occur in the inlet arms created by the Halfway River, Moberly River, and Cache Creek.

Spawning habitats for sportfish appear to be extremely limited within the reservoir. Existing cobble and gravel areas, other than the west end of Reach 4, will become too deep and in many areas will be covered by silt. Higher up, near the full service level, there appears to be little of the rock or gravel these species typically require.

### 3.4.2 Major tributaries

The Moberly and Halfway rivers differ substantially in size and many physical aspects but both have highly variable discharges, low winter flows and poor water quality during spring. Fish densities are however, much higher in the Moberly River which suggests that its more varied character presents fewer limiting factors to fish production.

Halfway River

Overall limits to fish productivity in the Halfway River are difficult to assess at this time as the fish populations are still poorly understood; particularly in regard to the life stages using the mainstem. Information collected by RRCS (1979) and Pattenden and Ash (1990) confirms that adult sportfish are found in the river and that some species, particularly bull trout, appear to migrate over most of its length. There is however little data available on its importance in rearing, spawning and over wintering.

Habitat surveys conducted in 1989 suggest that spring spawning is probably limited by discharge variability and by extreme silt loads. By fall, the silt and turbidity have decreased substantially but are still quite high. In addition, although there are numerous areas of gravel and cobble substrates, the interstices generally contain large quantities of sand and silt. These factors, together with the rapidly declining temperatures and water levels suggest that fall spawning by species such as bull trout is unlikely. Overwintering opportunities also appear to be limiting fish populations in the Halfway River. There are some deeper holes and groundwater seepages apparent along the sandstone outcrops near the Graham River and a few more near the lower powerline crossing but these are exceptions. The remainder of the system is of nearly constant grade with few pool areas likely to provide refuge during the low water levels of late winter. The significance of the lack of over wintering habitat is difficult to assess at this stage. Although mountain whitefish have been observed to spawn in the lower Halfway River (RRCS 1979), tagging studies (Pattenden and Ash 1990) suggest that other species, including bull trout, may overwinter or rear in downstream areas, using the Halfway River only as a corridor to spawning and rearing habitats in the mountain tributaries. Similarly, the importance and limitations of the Halfway River as rearing habitat are difficult to assess. Certainly there are fish in the river, and there appear to be few juveniles, but there are little data to indicate whether the fish are all transient or what the overall densities are. However, looking at the physical habitat again suggests that low water temperatures, high silt loads and system instability are likely to limit rearing success.

Moberly River

The Moberly River has a highly variable flow regime like the Halfway River but still supports a diverse assemblage of both adult and juvenile fishes. However, the instability and turbidity which accompany freshet flows may limit utilization by spring spawners.

Very few spring spawning sportfish have been captured in the system. No rainbow trout adults or juveniles have been captured and no walleye have been captured. Arctic grayling were sampled from Reach 2 during June 1990 but it was not determined if individuals from the Peace River utilize the Moberly River for spawning and it was not determined if significant numbers of Arctic grayling spawn in the Moberly River. Arctic grayling prefer small clear water streams for spawning (McPhail and Lindsey 1970) so a large system such as the Moberly may not provide ideal spawning habitat. The small numbers of adult and juvenile Arctic grayling captured in the system during fall 1989 (Slaney et al. 1991) indicate that it is not important Arctic grayling habitat. The Site C project is likely to have little effect on spring spawning sportfish in the Moberly River due to the apparent lack of spawning activity and the instability of the lower reaches.

Two factors appear to make the Moberly River suitable for fall spawners. First, the high turbidity and silt loads of spring freshet usually declines later in the year so that there are extensive areas of clean gravel. Second, the system is much more stable once the freshet flows of spring subside. Mountain whitefish were observed spawning in this system in the fall of 1989 with highest concentrations observed in Reach 2 (Slaney et al. 1991).

Rainbow trout and Arctic grayling appear to be limited by the lack of spawning habitat. During the spring, flows are extremely high, suspended sediment levels are also high and the system is very unstable. In other parts of the study area, these two species appear to spawn in small tributary habitat which is absent in the lower Moberly River.

Reaches 3 and 5 provide excellent northern pike habitat with an abundance of low velocity areas and aquatic vegetation. That type of habitat is scarce in Reaches 1 and 2. As a consequence, northern pike were concentrated in Reaches 3 and 5, and virtually absent in Reaches 1 and 2.

### 3.4.3 Plateau Tributaries

Many of the plateau tributaries that were examined appeared to be poor sportfish habitat. Wilder Creek, Cache Creek, Kobes Creek, Ground Birch Creek and the Cameron River all had very low densities of sportfish during 1989 (Slaney et al. 1991). Farrell Creek supports a resident population of small rainbow trout in its upper reaches, and supports spawning Arctic grayling (RRCS 1979), but like the other systems it has high silt loads and high summer water temperatures, as well as reduced flows in late summer and fall. Given the low water levels and apparent absence of groundwater inputs, opportunities for overwintering appear to be severely limited. Maurice and Lynx Creeks do support sportfish, but they share many of the same characteristics and there appear to be severe limits to their productivity.

Substrates in the plateau tributaries appeared to be highly unstable with large amounts of erosion and bed movement occurring every year. The high proportion of fine material (silt and sand) coupled with this instability severely limits sportfish which are typically substrate spawners.

The plateau tributaries, being relatively small, are ungauged. However the discharges appear to be even more variable than those of the Halfway and Moberly systems. Sudden discharge peaks follow snow melt as well as severe rain squalls which can occur at any time from April through October. The problem is accentuated by the lack of storage in the system. Freshet events start and finish soon after rainfalls.

In Lynx Creek, rainbow trout were found rearing throughout Reaches 1-4. However, most of the fish were 0+ - 1+ in age and average size was only 124 mm. The spawning gravel is not particularly good as it has a large silt fraction, and by late summer few of the pools could accommodate larger fish. Cover, generally considered essential to rearing trout, is almost completely lacking. There are a few areas of groundwater upwelling, particularly in the major tributary Brenot Creek, but these filter through the overburden and carry large amounts of silt into the system.

In the past several years Lynx Creek has been subject to very high silt loads from Brenot Creek (L. Noble pers. comm.), which has reduced the suitability of the creek below the Brenot - Lynx confluence for fish. Suspended solid levels were as high as 5,430 $mg \cdot L^{-1}$ during June 1989 compared to 284 $mg \cdot L^{-1}$ for Maurice Creek (Pattenden and Ash 1990). Levels in Lynx Creek decreased to 427 and 241 $mg \cdot L^{-1}$ during August and October, respectively, although these levels are still high. The recommended maximum concentrations for rearing and holding for fish culture purposes is 25 $mg \cdot L^{-1}$ (Sigma 1983). Turbidity levels at km 1.6 were 15 FTU on October 28, 1974, 170 FTU in Brenot Creek on May 29, 1975, 11 FTU on May 9 1977 at km 1.6 and 10 FTU near the mouth on June 7, 1977. All except one of these measurements were within the recommended levels of 1-60 FTU for fish culture (MacKinlay 1984.). It therefore appears that the creek has only become less suitable for fish in recent years.

The total 1990 migration of rainbow trout to Lynx Creek appears to have been close to 50 fish. Spawning locations were not determined, but the high levels of silt below Brenot Creek seem to make Reaches 1 and 2 unsuitable for spawning. The highest concentrations of juvenile rainbow trout were found above the Brenot Creek confluence indicating that Reach 3 was more suitable for rearing and possibly spawning. An estimated 280 juveniles were residing in the accessible portion of Lynx Creek. Local residents report that the creek used to support substantial numbers of rainbow trout in the years before the creek became so silty (L. Noble pers.comm.). The increase in the silt load has likely caused a decline in the rainbow trout population.

The sparse data that were collected from the Maurice Creek fence suggest that the creek is important habitat for rainbow trout, northern pike, lake whitefish and longnose suckers. The creek may be particularly important to rainbow trout due to the apparent lack of other spawning habitats in the study area. Only 15 rainbow trout migrating downstream and one migrating upstream were captured by the fence traps, however the traps were only operating for a total of 8.5 days. A survey of the system conducted on June 22, 1990 suggests that approximately 280 adult rainbow trout and 1,400 juveniles were in the creek at that time. The 15 adult rainbow trout moving downstream through the fence trap, the fact that the fence was inoperative from May 25 - June 9, plus the fact that downstream migrants were collected as early as May 24 when the fence was first installed, all suggest that the total run was much larger, making Maurice Creek a significant rainbow trout spawning stream.

Maurice Creek, although generally similar to the other plateau tributaries, lies at the western limit of the plateau. From three to five kilometers above the mouth, a series of water falls mark the system's passage over the sandstone and siltstone edge of the foothills. As a result, large areas of otherwise serviceable rearing habitat are isolated above the falls.

The production of rainbow trout in Maurice Creek is limited by the small amount of spawning and rearing area available. Only 3 km of the stream is accessible and in that area only 10% of the substrate is gravel. Rainbow production is also likely limited by low late summer and winter flows which reduce rearing habitat. None the less, Maurice Creek appears to be fairly productive in the available area.

In addition to spawning, the system is used by foraging sportfish in the spring such as lake whitefish, mountain whitefish, and bull trout. But these species appear to leave the system as soon as water levels fall in late spring. The use of this system is limited by water levels through the remainder of the year.

A small number of Arctic grayling may spawn in Maurice Creek. Only 2 downstream migrants were collected at then fence and 1 individual was collected by electroshocking. The two downstream migrants may represent the tail end of a run, but the cause of the low numbers rearing in the watershed is not clear. Arctic grayling do not appear to be limited by habitat. Possibly the population may have been reduced by angling pressure in the Peace mainstem.

### 3.4.4 Mountain Tributaries

Of the tributaries examined during the study, the mountain tributaries in the upper Halfway area appeared to be the most suitable as sportfish habitat; particularly bull trout, rainbow trout and Arctic grayling.

The bull trout which reside in the Peace River and spawn in the upper Halfway River tributaries, are probably the only fish utilizing the upper Halfway River tributaries whose habitat would be directly affected by the Site C project. Radio tag data suggests that some Peace River bull trout migrate into the Graham River to spawn (Pattenden and Ash 1990).

Despite low nutrient levels, the low densities of bull trout observed during 1990 suggest that they are not constrained by habitat capacity. They do however, seem to have incurred heavy angling pressure over the last few years, particularly as access to the area has improved dramatically. According to long time local resident, H. Trask, the population and size of bull trout in the Chowade River has declined in recent years due to heavy fishing pressure on this system. Bull trout are popular sportfish in the area due to their large size. If, as it appears, Halfway and Peace River bull trout migrate into the Graham River and other upper Halfway River tributaries to spawn, the stock may be fished more heavily than had previously been anticipated. Fishing pressure on the Chowade and Graham Rivers is likely to increase as logging improves access into these systems.

Rainbow trout were found in all the systems except Cypress Creek. The Site C project is not likely to affect this species in the upper Halfway River area as there is probably little movement of fish from the Site C area to the upper Halfway area. The limiting factor in terms of rainbow trout production may be the small numbers of tributaries for spawning and rearing, like Blue Grave, Horseshoe and Colt Creeks. The larger systems contained adults but there was no evidence to indicate that spawning took place. The smaller tributaries appear to be important habitat for rearing (and possibly spawning) bull trout and could also be utilized by Arctic grayling for spawning. As these small tributaries appear to be important fish habitat, industrial activity in their vicinity should be minimized. Logging activity has only recently started in the upper Halfway river watersheds and probably has as yet had little impact on these systems. However, impacts on these small systems may increase as activity increases. The systems may be particularly be vulnerable during the spring thaw when erosion and siltation are most likely to occur. This is also the time that most of the rainbow trout and Arctic grayling spawning takes place.

Other potential limits to fish production in the mountain tributaries could include altitude and overwintering conditions. Altitude results in low water temperatures during spring and fall, a short growing season, and limited benthic productivity. All of the systems appeared to have deep pools and cover sufficient to provide overwintering. However the fish may either leave the system completely or may key on warmer groundwater seepages in the lower reaches of these streams. Certainly late season aggregations were noted in the Graham, Chowade and Blue Grave systems (Slaney et al. 1990).

## 3.5 MITIGATION AND ENHANCEMENT OPPORTUNITIES

The development of the Site C dam will result in major impacts on the aquatic habitats of the Peace River. The following sections provide a preliminary outline of techniques which could be used either to mitigate the impacts or to compensate for them. In general, the discussion focuses on the limits to production identified in 3.4 above and some of the means which can be used to remove them. The first section examines techniques which could be used to boost productivity within the reservoir itself. This is followed by a discussion of some of the off-site mitigation opportunities which exist in the tributaries. As in section 3.4, the discussion summarizes the results of both 1989 and 1990 investigations.

### 3.5.1 Reservoir

The productivity of a Site C reservoir is likely to be limited by low temperatures and high flushing rates (RRCS 1979). In addition, many sportfish species are likely to be limited by a scarcity of suitable spawning substrates. None the less, although the physical characteristics of the reservoir are difficult to alter, there are techniques which can be used to mitigate or compensate for changes in fish production.

Spawning and Incubation

Spawning and incubation habitats can be augmented by hatchery operations or by habitat creation. The biggest problem from a planning perspective appears to lie in identifying the species to be assisted. RRCS (1979) suggested that the reservoir would support walleye and Arctic grayling. However, since that time it has become apparent that Arctic grayling, such as those in Williston Lake, can not support the intensive fisheries likely to follow impoundment. Unassisted, walleye success also appears doubtful due to the low water temperatures and lack of substrates (Hammond 1987). Rainbow trout may be a better prospect (Hammond 1987) but spawning and rearing habitats in Maurice and Lynx Creeks appear limited and hatchery operations in Dinosaur Lake have proved a mixed success (Stone 1987).

Some of the approaches which may be taken to increase the supply of spawning habitat for reef and littoral spawners are outlined below:

a). Where gravel substrates are known to exist in littoral or shallow depths, clearing and scarification should be used to create spawning reefs. This is, however, likely to be successful only in areas which are well flushed and unlikely to slump or be silted over.

b). Rock used to provide bank stabilization, such as along highway alignments, bridges, etc., should be placed in a manner which will keep the outside face well flushed. This type of rip-rap placement forms a good spawning substrate for species such as walleye (Michaletz 1986).

c). Where littoral spawning habitats, such as the rip rap mentioned above are used, reservoir operations should be planned to ensure that incubating eggs are not de-watered during critical stages.

d). In the absence of suitable spawning or incubation conditions and habitat, hatchery incubation could be considered.

Stream spawners

The development of resident populations of stream spawning fish within the reservoir is likely to require some form of incubation or artificial habitat. Opportunities for improving natural spawning habitats for these fish within the reservoir appear limited. At most locations substrates, water quality and quantities are unsatisfactory for most forms of fish culture.

At the Peace Canyon dam many kokanee die unspawned every year (Pattenden and Ash 1990). It appears that these fish are almost all strays from upstream areas which are trying to get back over the dam. Given some form of artificial incubation, these fish could make a substantial contribution to reservoir productivity either as sportfish or as forage for larger piscivours. Options for kokanee enhancement are discussed further in following sections.

Hatchery

Maintenance of sportfish populations large enough to supply interesting angling opportunities on the Site C reservoir may require hatchery assistance. Hatcheries could be used to:

a). Supplement natural rainbow trout spawning which appears to be limited by marginal habitat quality in Lynx and Maurice Creeks.

b). Incubate kokanee and assist in the development of a resident population. Kokanee from upstream are now rearing in the Peace River below the Peace Canyon dam (Pattenden and Ash 1990). Although conditions for kokanee in the study area may improve following impoundment, the population is limited to individuals immigrating from upstream areas. No natural spawning has been observed downstream of the Peace Canyon 1 dam.

c). Provide hatchery support for Arctic grayling populations. Some experimentation would be required to determine whether fry or fingerlings would have better success in the reservoir. Both have shown promise in other areas (Kindschi and Barrows 1990).

d). Incubate and rear walleye. Raising walleye to at least the fingerling stage would also increase stocking success by decreasing losses due to low temperatures during early rearing (Smith and Koenst 1975, Loadman et al. 1989). However, a supply of 15 - 20°C water would be required.

Productivity

The productivity of the Site C reservoir is expected to be restricted by low temperatures and high flushing rates (RRCS 1979). High flushing rates tend to limit primary and secondary productivity while cool temperatures limit feeding and growth in fish.

Water temperatures within the Site C reservoir are likely to be only slightly warmer than those in Dinosaur Lake where a summer maximum of 12-13°C was observed (Hammond 1987). This is likely to minimize walleye success within the reservoir (Hammond 1987) as walleye growth requires temperatures >12°C (Kelso 1972). However, walleye should not be totally discounted as they currently rear in the Peace system which is probably 1-2°C cooler than the proposed reservoir (although spawning appears to take place in other tributaries such as the Beatton River (Pattenden et al. 1991). This suggests that the Peace River walleye stocks: may be better adapted to low temperatures than those examined by Kelso; are occupying warmer microhabitats rather than the thalweg; or that temperature effects are most detrimental to walleye at juvenile and incubation stages. Difficulties might also be overcome by focusing mitigation in the inlet arms which are likely to be somewhat warmer in summer, by aligning rip-rap bank protection for highways and bridge abutments to create downstream backwaters, or through hatchery incubation and rearing.

During the summer months, reservoir tributaries are likely to be much warmer and more productive than the reservoir itself. To maximize the utilization of this warmer water, the tributary side of rip-rapped highway alignments in inlet areas could be used as current deflectors to reduce the incursion of cool Peace River flows and create higher productivity backwaters.

Fertilization has been shown to increase the productivity of some lakes including a number of regulated systems (Hyatt and Stockner 1985). The technique may be useful in increasing productivity of the proposed reservoir's Moberly Arm. Summer nutrient samples in Moberly Lake suggest the Moberly River is ad (Slaney and Lewynsky in prep.). In addition, the Moberly arm is likely to have the longest residence time of any part of the reservoir, particularly during July and August. In contrast, applying nutrients to the Peace River or the Halfway Inlet arm would be difficult due to the high flushing rates and the volumes of water involved. Even if residence time were increased by fertilizing further upstream, mixing at Peace Canyon dam would limit its effectiveness.

Regulation

It may also be necessary to monitor the fishery closely and alter angling regulations. For example, following impoundment, Arctic grayling may become particularly susceptible to angling. Although the Arctic grayling collapse in Williston Lake may have been an inevitable result of reservoir aging, limiting daily takes may either prolong or reverse the process.

### 3.5.2 Major Tributaries

The factors limiting fish production in the major Peace River tributaries have, for the most part, not been determined. Some of the more obvious problems include instability, poor water quality, lack of spawning and incubation habitat, low productivity, and lack of overwintering habitat. However, with the limited information available it is difficult to establish the importance of these factors. For example, it appears that there is little deep water suitable for winter refuge in the Halfway system. However, as fish are known to migrate from the Peace mainstem (Pattenden and Ash 1990) which has relatively large amounts of overwintering habitat, there is no indication that the shortage of overwintering habitat in the Halfway River actually limits the fish population. Given this uncertainty, more life history information will be required before the relative merits of enhancement techniques can be discussed in any detail.

The Halfway and Moberly rivers are instable, both in terms of their hydrologic regimes (peak daily flows >70 times minimum daily flows), and in terms of substrate movement. These factors are detrimental to fish production, particularly for substrate spawners. As the mainstem rivers are too large to facilitate many physical habitat improvement techniques, abandoned side channels could be improved and protected to provide spawning and early rearing habitats. This technique has had little application to rainbow trout or Arctic grayling but has been effective in enhancing chum and coho (Sheng et al. 1990). On the Moberly River, side channel enhancement could prove an effective adjunct to kokanee introductions. Kokanee from Williston Lake appear to use this type of groundwater fed side channel on the Finlay River (Fielden 1991).

Overwintering habitats are, as noted previously, quite scarce in the Halfway River and in the lower Moberly River. Although the importance of these habitats has not been confirmed, it appears that this type of habitat may limit fish production. A few groundwater seepages were observed during 1989 which could be channelized to provide additional winter habitat if required. A search for additional groundwater sources is recommended.

The Moberly River appeared to have substantial populations of both northern pike and mountain whitefish. However both of these species are probably not fished to their full potential due to the remoteness and inaccessibility of much of the system. Northern pike were abundant in the slow glide and slough habitat of Reaches 3 and 5. This species likely receives little fishing pressure in this area, particularly in Reach 3, due to the difficult access. However an attempt to enhance pike in this area would probably be of little value as the stocks do not seem to be fished to their potential at the present time. A road into the Reach 3 along with a boat launch and possibly a campsite would be one method of increasing the fishing potential and use of this system. Increasing access into this area may be controversial, however, as there would be increased pressure on other wildlife as well.

### 3.5.3 Plateau Tributaries

There appears little opportunity for enhancement or mitigation in most of these systems due to the high silt loads, bed movement, and high summer water temperatures, and low discharges during late summer and winter. The major limitation is that there is little water storage; spring freshet and storm run-off are discharged almost immediately. This is compounded by the fine, unstable substrates. Structures such as storage dams or excavated pools are likely to be rapidly filled by bed material. Finally, techniques such as side channel enhancement, which provide stable refugia in unstable systems, would be difficult to apply due to the canyonous, single thread nature of these channels. The only exceptions are Lynx and Maurice creeks which are on the edge of the plateau region, have existing sportfish populations, and appear to have some potential for increased rearing by juvenile rainbow trout.

The main factor limiting production in Lynx Creek appears to be the high turbidity in the lower reaches in this creek. The extremely high levels of sediment moving out of Brenot Creek has only occurred in the last few years with the development of a spring in a highly unstable area along the creek. Previous studies (RRSC 1979) indicate that the creek had higher densities of rainbow trout juveniles and probably adult spawners in the past. It is possible the area may stabilize in the future and the lower reaches may once again become productive rainbow trout spawning and rearing habitat. However it may be possible stop the erosion by driving a well or drains into the spring and piping the water to Brenot Creek. If the erosion can be stopped, the lower portion of Brenot Creek and the lower 6.5 km of Lynx Creek may once again become productive rainbow trout habitat. Even with the stabilization of the main source of sediment, Lynx Creek may never be high quality rainbow trout habitat as the lower 13 km of the creek cuts through unstable sediments which increase turbidity during spring freshet and during periods of heavy rain. None the less, despite the instability of the area, Lynx Creek appears to have been a significant producer of rainbow trout in previous years.

Maurice Creek appears to be the most significant rearing and spawning area for Peace River rainbow trout in the Site C area although only 3 km of the stream is accessible to Peace River fish. High discharges during the spring freshet and the small proportion of gravel in the reach (10%) are factors that may limit the production of rainbow trout from the accessible area. Spawning and rearing for rainbow trout may be enhanced in this system through the construction of a spawning channel or enhanced side channel in the upper part of Reach 1 where the valley width increases to >150 m.

Another possibility for enhancement would be a headwaters stocking program to utilize the habitat above the falls for rainbow trout which would eventually migrate into the proposed reservoir. The total amount of suitable habitat above the falls is unknown but even at low densities the 15 km of stream could rear a significant number of juvenile trout.

Other enhancement possibilities in Maurice Creek include removing the falls or establishing a resident rainbow trout population above the falls. Neither appears feasible. Clearing the obstructions would be expensive as the five sets of falls vary in height between 2.5 and 30 m and would have to be removed or bypassed. The potential production of trout in the upper reaches of this small system is unlikely to warrant the expense that would be required for such an undertaking. Certainly, the productivity of the area should be tested by a stocking program before obstruction removal is considered. As a further possibility, the upper reaches of Maurice Creek could be colonized with a resident rainbow trout population. However it is unlikely that this introduced population would provide many angling opportunities due to the difficulty of access to the area. In addition, any fish remaining in the system are unlikely to grow very large.

### 3.5.4 Mountain Tributaries

Fish populations in the upper Halfway tributaries have been receiving increasing amounts of angling pressure in recent years and, although the low nutrient levels and short season ultimately limit system productivity, it appears that present populations may be below capacity.

Bull trout appear to be a popular sportfish in the mountain tributaries and hatchery support may be warranted to help maintain the stocks. Releases could be made in the Graham, Chowade and Cypress systems. This would distribute the fish through the area but would minimize the risk of harmful interactions with wild stocks rearing in the Horseshoe and Blue Grave systems. Growth is however, likely to be slow in this area. Prior to a stocking program, further life history information on the existing wild stocks will be needed to ensure that stocked fish do not result in counter productive interactions.

The Site C development may divert fishing pressure from the reservoir area to the Halfway River and upper tributaries which would increase the pressure on bull trout. Stricter fishing regulations may therefore be required to prevent further declines in bull trout populations before introduced fish attain harvestable size. Currently, fishermen are restricted to three bull trout per day over 30 cm of which one may be over 50 cm except during September and October when no fish can be taken.

To maximize rainbow trout populations in the upper Halfway River tributaries, logging and clearing activity in the vicinity of the smaller upper Halfway River tributaries should be minimized and efforts made to limit livestock access. Enhancement activities could include outplanting rainbow trout in the Chowade and Graham Rivers where only adults have been observed. Outplanting into the smaller tributaries should be avoided as it may adversely affect the wild juveniles already present. Other techniques such as substrate improvements and channel modifications are unlikely to be useful in this setting due to high spring flows and substrate instability. The feasibility of rehabilitating abandoned side channels should be investigated further.