Report Title: Peace River Site C Hydroelectric Development Pre-Construction Fisheries Studies – Fish Movements and Population Status 1990 Studies Interim Final Report
Issuer: RL&L Environmental Services Ltd. In association with LGL Ltd.
Date: July, 1991

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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.

PEACE RIVER SITE C HYDROELECTRIC DEVELOPMENT
Pre-construction Fisheries Studies

FISH MOVEMENTS AND POPULATION STATUS

1990 Studies

INTERIM FINAL REPORT

Submitted to

B.C. HYDRO
Environmental Resources Division

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July 1991

ACKNOWLEDGMENTS

The following people are gratefully acknowledged for providing information or assistance during this study:

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SUMMARY

This draft report entitled "Peace River Site C Hydroelectric Development - Fish Movements and Population Status - 1990 studies " has been submitted as partial fulfillment of contractual obligations to B.C. Hydro. This report presents the findings of the second year of a two year study program.

The objectives of this study were to provide a detailed inventory of fish populations and movement patterns within the Site C study area and to expand the existing database relating to water temperature and water quality.

The field sampling program on the Peace River which was initiated during 1989 was continued during 1990. This involved assessment of fish abundance, distribution and habitat use, collection of life history data, examination of fish for macroparasites, assessment of feeding habits for selected sportfish species, a mark-recapture program to develop fish population estimates and to identify general movement patterns, and finally, a radio telemetry program to identify pre- and post-spawning movement patterns of selected fish species. Temperature monitoring and seasonal water quality sampling programs also were continued.

During mid-May 1990, thermographs were re-installed at the tributary sites used in 1989; also, temperature data were downloaded from thermographs maintained overwinter at the Peace River sites. The thermographs recorded temperatures in tributaries until mid-October 1990. Thermographs located in the Peace River and in the Halfway River will continue to record data during winter 1990-1991. Seasonal water quality data were obtained during March, June, August, and October.

The water quality assessment revealed that the Peace River and tributaries in the Site C study area were generally well oxygenated and had an alkaline pH. High levels of suspended solids concentrations, turbidity, total nitrogen, total phosphorus, and total mercury occurred during some periods. The sources of the high values were probably natural and mainly associated with increased stream flow. Except for perhaps suspended solids and turbidity, these parameters possessed no limiting effects on aquatic organisms. Low levels of dissolved oxygen were observed in the Peace River and its tributaries during the summer period which may have had a limiting effect on sportfish populations.

In 1990, twelve sportfish species were encountered in the Peace River during investigations of the Site C study area. Major species, in order of numerical abundance, were lake whitefish, Arctic grayling, rainbow trout, and walleye. Low numbers of bull trout, kokanee, northern pike, goldeye, and burbot also were sampled. Catch rates and species occurrence were dependent on sampling location and sampling period. Lake whitefish and rainbow trout were most abundant upstream of the

Halfway River (Km 105) and Arctic grayling numbers were highest from the confluence with the Pine River (Km 48) to the confluence with the Halfway River (Km 105). Rainbow trout were most numerous in the region upstream of Hudson Hope (Km 143). Changes in abundance indices of juvenile mountain whitefish and Arctic grayling during late summer appear to indicate that they emigrate into the Peace River from its tributaries, particularly from the Halfway River. Bull trout were widespread throughout the river but kokanee were largely restricted to areas upstream of the Halfway River (Km 105). Species which prefer warmer regimes such as walleye, northern pike, goldeye and burbot, exhibited low catch rates and were encountered most often downstream from Taylor. Goldeye and burbot were restricted to areas downstream of Taylor. Walleye, which were most abundant downstream of Taylor, also were encountered in upstream areas as the season progressed. Concentrations of walleye were encountered at the mouth of the Beatton River (Km 26) during spring. Walleye were then encountered at the mouth of the Pine (Km 48) and Moberly (Km 66) rivers during summer and fall. These findings were similar to those obtained during the 1989 fisheries study.

Life history information was collected from several species in the Site C study area. These data were typical of life history information for the species sampled.

Feeding habits were assessed for selected fish species which reside in the Peace River. The most prevalent food group consumed by all species was insects, with most food items being benthic fauna such as dipterans and trichopterans. Zooplankton was not a major constituent of the food items consumed.

Few parasites were found during investigations of fish populations residing in the Peace River. The plerocercoid cysts of *Triaenophorus crassus* were recorded in three lake whitefish captured upstream of the Halfway River (Km 105). In total, 76 lake whitefish and 136 mountain whitefish were examined for the presence of this parasite during 1990.

Fish movements in the Site C study area were assessed using tag recoveries and from fish implanted with radio transmitters. Of the 11 125 tags applied during 1989 and 1990, 737 tags were recovered. Ninety-five individuals representing five fish species were implanted with radio transmitters during 1989 and 1990. None of the populations examined exhibited large scale unidirectional migrations past the proposed Site C dam site and Arctic grayling, rainbow trout, mountain whitefish, and northern pike populations appear to be sedentary. Although spawning movements were not identified for Arctic grayling, rainbow trout moved upstream during spring with some individuals entering Maurice and Lynx creeks, presumably to spawn. During fall, mountain whitefish dispersed from spring and summer feeding sites to spawning areas in the Peace and Halfway rivers. Radio transmittered bull trout exhibited extensive pre-spawning movements from the Peace River into the Halfway River during late summer. One individual travelled to an area near of Christina Falls on the

Graham River and then returned to the Peace River, a total distance of 457 km. Walleye was the only species whose individuals exhibited extensive unidirectional movements. A post-spawning upstream migration from Alberta appeared to occur during spring and summer, with some individuals moving past the Site C dam site.

Population estimates were developed for Arctic grayling, rainbow trout, lake whitefish, and walleye. Population estimates with relatively narrow confidence intervals were obtained for three of these species. There were approximately 4060 Arctic grayling, 5530 rainbow trout, and 2320 walleye utilizing the Site C study area during 1990.

Habitats utilized by adult fish in the Peace River were typical of the species examined. With the exception of mountain whitefish and northern pike, no spawning areas in the Peace River were identified for species residing in the Site C study area. Spawning mountain whitefish were widely distributed throughout the Peace River upstream of the Pine River (Km 48), while northern pike appeared to utilize snye habitats upstream of the Halfway River (Km 107). Potential rearing areas in the Peace River were severely limited for all species due to fluctuating water levels.

Mercury levels in fish tissues of the species examined did not exceed federal guidelines.

Several recommendations were made for future studies. The temperature monitoring program should be continued to provide a complete database for the Site C study area. Due to budget limitations imposed in 1990, planned fisheries investigations on the Halfway River and Pine River could not be conducted. Data gaps remain in the fisheries information for these systems. To supplement existing movement information, tag recovery data obtained from tags returned by anglers should be analyzed at a future date. To assess movements of fish which contain active transmitters (i.e., northern pike, Arctic grayling, bull trout, and walleye) the radio telemetry survey program should be continued during the spring and summer of 1991.

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SECTION 1
INTRODUCTION

1.1 BACKGROUND

Studies in the Site C development area conducted prior to 1989 obtained only cursory information relating to fish populations. This was primarily due to the limited amount of fish sampling and tagging that could be conducted within the time frame, scope and budgets available. Insufficient information was available on fish movements, life history, and habitat use to accurately assess sportfish populations that likely would develop in the proposed reservoir (i.e., migrations of certain species may be blocked during dam construction and the species may not be present in the reservoir at the time of filling). Without a detailed pre-construction database and accurate prediction of impacts, it would be difficult to determine compensation values and feasible options that could be initiated to mitigate any adverse effects of the development, or to enhance the sportfish populations in the reservoir or nearby areas.

In September of 1980, B.C. Hydro submitted an application to the B.C. Government for an Energy Project Certificate for the Site C development. The application was referred to the B.C. Utilities Commission (BCUC) which held public hearings on the development during 1981 and 1982. As part of their report and recommendations (BCUC 1983), the commission concluded that more information on the fisheries resource and utilization in the development area was needed to determine a compensation value for fisheries impacts, and therefore, they recommended additional fisheries studies be undertaken as a condition of an Energy Project Certificate for the development.

In 1989, B.C. Hydro commissioned additional pre-construction fisheries studies to update previous information, to increase the pre-development database relating to the fisheries resource and its use to which future studies can be compared, and to identify feasible mitigation and enhancement opportunities that exist in the development area. R.L. & L. Environmental Services Ltd. was contracted to complete the "Fish Movements and Population Status" component of the pre-construction fisheries investigations.

This draft report summarizes the findings of the second year of studies. To maintain continuity with the findings of the first year of studies, the format of this report closely follows that of the 1989 report.

1.2 OBJECTIVES

The 1990 study program was a continuation of the two year fisheries inventory program on the mainstem Peace River within the Site C development area. The main objectives of the 1990 study were as follows:

- to update previous programs;
- to provide a more detailed inventory of the fish populations and movement patterns within the development area; and,
- to expand the existing database relating to water temperature and seasonal water quality in the study area.

The study was divided into two tasks, each with specific objectives as follows:

- Task A - Temperature and Water Quality:
  - To obtain additional water temperature and seasonal water quality information for the Peace River and its major tributaries within the Site C area.
- Task B - Fish Population Status and Movements:
  - To obtain additional detailed information on seasonal fish distribution, abundance (estimate of population size, if possible), life history and habitat use in the Peace River within the Site C area.
  - To obtain additional samples from sportfish residing in the Peace River within the Site C area for determination of background mercury content.
  - To supplement existing information on fish migration and movement patterns within the Site C development area. These studies were to provide information on fish movements within the mainstem Peace River (including movements past the proposed dam site), and movements into and out of the major tributaries within the Site C study area.

1.3 STUDY AREA

The 1990 Site C study area included the mainstem Peace River from the B.C.-Alberta border to the Peace Canyon Dam (Figure 1.1). Emphasis was placed on the section of the Peace River situated upstream of the site of the proposed dam just downstream of the confluence of the Peace and Moberly rivers. The radio telemetry component of the study also included portions of the Peace River in Alberta to identify fish that may have moved downstream out of the Site C study area, as well as major tributaries entering the Peace River within the study area.

The Peace River section of the Site C study area (Figure 1.2) is 150 km in length and was divided into four reaches based on changes of physical habitat characteristics. These included gradient, water turbidity, and substrate type -- parameters which affect distribution and abundance of fish species (Hynes 1970). The reaches and their qualitative descriptions are given in Table 1.1.

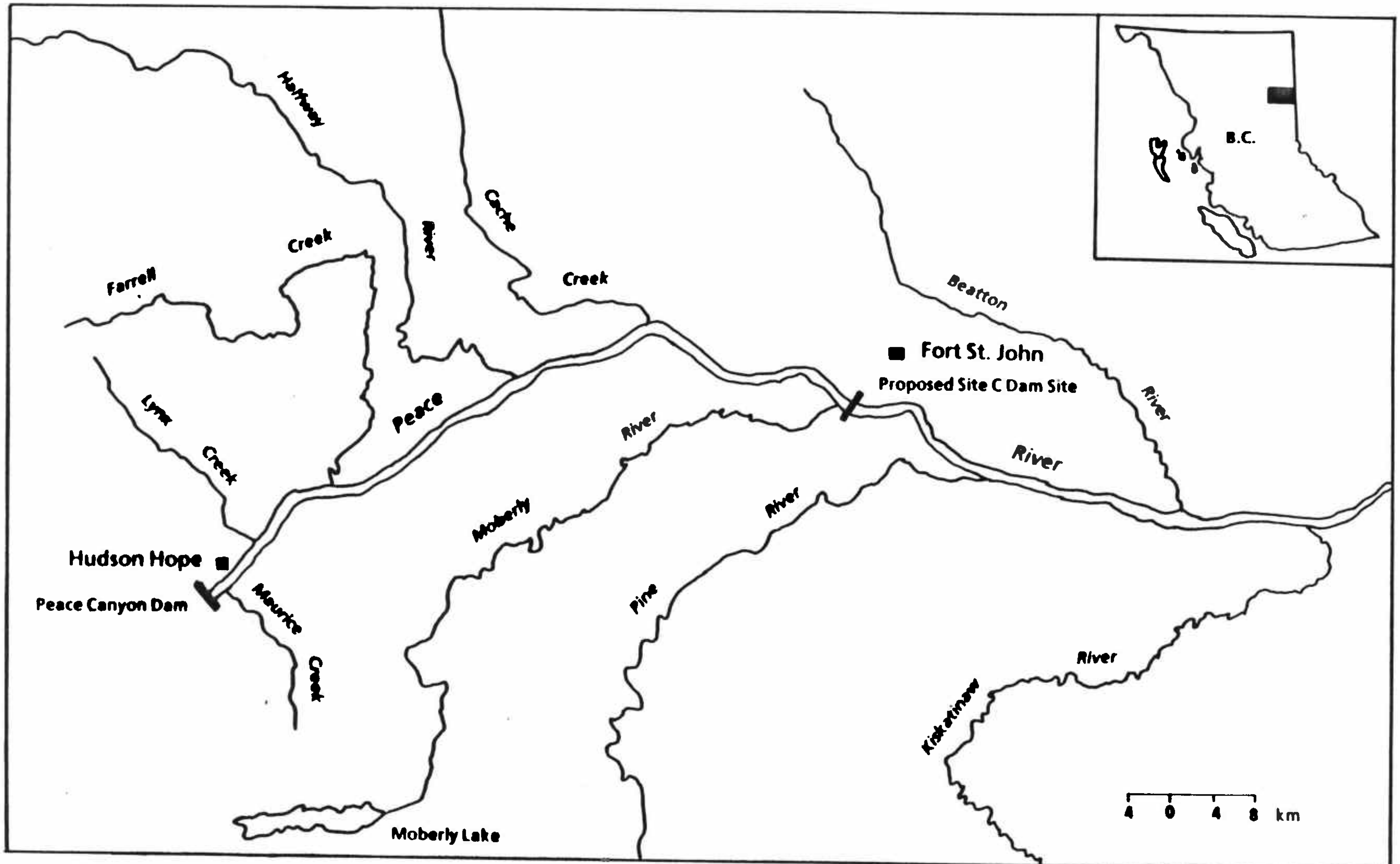

Figure 1.1 Site C study area location map, 1990

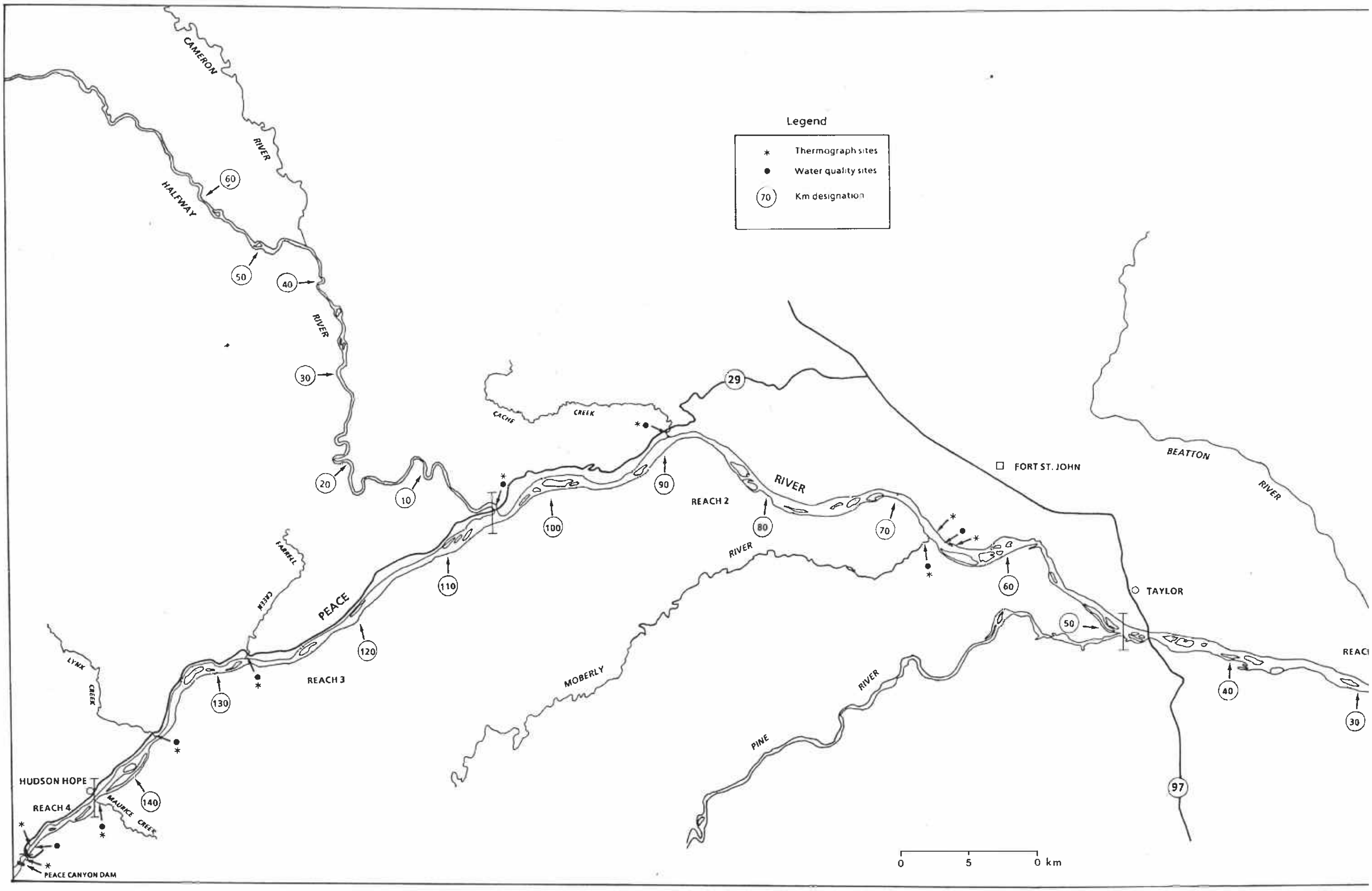
Legend
Thermograph sites
Water quality sites
Km designation
CAMERON
RIVER
HALFWAY
RIVER
CACHE
CREEK
29
FORT ST. JOHN
BEATTON
RIVER
REACH 2
RIVER
PEACE
REACH 3
REACH 4
HUDSON HOPE
PEACE CANYON DAM
LYNX
CREEK
FARRELL
CREEK
MAURICE
CREEK
MOBERLY
RIVER
PINE
RIVER
TAYLOR
97
0
5
0 km

Table 1.1 Peace River habitat reach description and location.

Reach	Kilometres	Location	Gradient	Turbidity	Predominant Substrate
1	Km 0-48[a]	B.C. - Alberta border to confluence of Peace and Pine rivers.	low	high	silt-gravel
2	Km 49-104	Just upstream of confluence of Peace and Pine rivers to confluence of Peace and Halfway rivers.	low-moderate	moderate	gravel
3	Km 105-143	Just upstream of confluence of Peace and Halfway rivers to just above confluence of Peace River and Maurice Creek.	low-moderate	low	gravel-cobble
4	Km 144-150	Just upstream of confluence of Peace River and Maurice Creek to just below Peace Canyon Dam.	high	low	bedrock-cobble

[a]For consistency with previous studies, the kilometre designations are from the B.C.-Alberta Border (Km 0).

The extreme upstream portion of Reach 4, the tailrace area of the Peace Canyon Dam, was surveyed during spring using boat electrofishing; therefore, unlike during 1989, that portion of the Peace River has been included in the study area.

The study area for the "temperature and water quality" component of the 1990 study was identical to that of 1989 and included the mainstem Peace River upstream of the site of the proposed dam and the lower sections of its major tributaries (i.e., Maurice, Lynx, Farrell, and Cache creeks, and the Moberly and Halfway rivers).

1.4 STUDY PERIOD

Field sampling was conducted during four periods. The first, from 19 to 24 May, was a limited survey of potential spawning areas in the mainstem Peace River. The remaining three were complete surveys and were conducted during the following periods: 3-23 June (spring), 1-21 August (summer), and 30 September - 18 October (fall). Radio tracking flights have been ongoing since November 1989.

The water quality and temperature monitoring components of the study, established during 1989, were reinitiated during mid-May of 1990.

Several components of this study utilized data obtained during the 1989 and 1990 field studies. These were fish movements (i.e., tag recovery and radio telemetry programs), population estimates, habitat use, and mercury analysis components of the study.

SECTION 2
METHODOLOGY

2.1 PHYSICAL AND CHEMICAL PARAMETERS

Temperature

Water temperature was monitored at hourly intervals in the mainstem Peace River and major tributaries using Ryan TempMentor thermographs. Thermographs were reinstalled (tributaries), or downloaded and redeployed (mainstem Peace River) at the following sites in May;

- Peace River near the Peace Canyon Dam (duplicate thermographs)
- Peace River near proposed Site C dam site (duplicate thermographs)
- Maurice Creek near confluence
- Lynx Creek near confluence
- Farrell Creek near confluence
- Halfway River near confluence
- Cache Creek near confluence
- Moberly River near confluence

Prior to winter, the thermographs in most tributaries were removed.

The temperature data collected were tabulated using the RTM software package supplied by Ryan Instruments, Inc. Data were then summarized to show daily average, maximum and minimum temperatures.

Water Quality

Water quality samples taken during 1990 were collected from the sites established during 1989 and included winter, spring, summer, and fall samples (Figure 1.2). The water samples were preserved in the field, kept cool and shipped as soon as possible to PowerTech Laboratories Ltd. in Surrey, B.C. These samples were analyzed for routine water quality parameters and macronutrients.

The following water quality field measurements were recorded at each site during each of the seasonal sampling programs, using the specified instruments:

- Temperature - Fisher Scientific pocket thermometer (accuracy ± 1°C)
- Dissolved Oxygen - IBC Dissolved Oxygen meter (±0.25 mg/L)
- pH - Fisher portable pH meter (±0.1 pH units)

- Conductivity - Chemtrix Type 700 portable temperature compensating conductivity meter (± 2% of full scale)
- Turbidity - HB Instruments Model DRT 15 Turbidity meter (± 1% of full scale).

The water quality of the Peace River and its major tributaries between the Peace Canyon Dam and the proposed Site C dam site was described according to physical and chemical parameters, and compared to Canadian Water Quality Guidelines (CWQG) established by The Canadian Council of Resource and Environmental Ministers in 1987. Comparisons also were made to historical data where relevant.

Stream discharge information for each site was obtained for the dates when water samples were collected. Where available, discharge information was obtained from sites with Water Survey of Canada (WSC) gauging stations (i.e., mainstem Peace River at Hudson Hope and at its confluence with the Pine River, the Halfway River, and the Moberly River -- Water Survey of Canada 1989, 1990). For tributaries without Water Survey of Canada gauging stations (i.e., Maurice, Lynx, Farrell, and Cache creeks), stream discharge was determined at the time of water sampling utilizing standard techniques (e.g., Bovee and Milhouse 1978) with a Marsh McBirney Model 201M electromagnetic current meter. A gauging transect was established in a section exhibiting relatively uniform bottom and flow characteristics.

2.2 FISH MOVEMENTS AND POPULATION STATUS

Fish Capture Program

Field Studies

Selected fish species, principally sportfish, were collected during spring, summer, and fall 1990 to acquire additional information on species composition and abundance, habitat use, life history parameters, movements and population sizes. Mountain whitefish and non-sportfish were not actively sampled during 1990, with two important exceptions. First, all fish exhibiting a tag were collected, regardless of species, and second, a random sample of mountain whitefish was obtained for life history analysis and for tissue samples to be used for mercury analysis. Mountain whitefish and non-sportfish were not actively sampled to allow more effort to be placed on the remaining sportfish species residing in the Site C study area.

A fisheries survey also was conducted during early spring to identify important spawning areas and concentrations of pre- or post-spawning fish in the Peace River and at the mouths of major tributaries. Effort was directed towards suspected mainstem spawning habitats for the following spring spawning species: rainbow trout, Arctic grayling, northern pike, and walleye.

Electrofishing was the primary fish capture method utilized, although gillnets, set lines, beach seines, and angling also were employed. Collections made by electrofishing entailed sampling sections of river not exceeding 2 km in length. For each section the location and sampling effort (no. of seconds) were recorded.

Electrofishing was conducted from a jet drive riverboat during daylight hours using a high output electrofisher (Smith Root Type VIA). The principal electrofishing system employed used two stationary anodes extending from the bow of the boat with two netters. The amperage used varied depending on water depth and conductivity; however, output ranged from 2.5-5.0 Amperes. Pulse rate and width of the DC voltage were set at 60 pps and 5-7 ms, respectively. Fish were held in a recovery tank until a sufficient number were available for processing. Also, an effort was made to consistently sample representative habitats during each sampling period. To increase the number of sampling intervals used in the population estimate procedures, two complete electrofishing runs were made of the entire Site C study area during each sampling period.

Gill nets and setlines were used to sample a number of snyes and side-channels where electrofishing was not an efficient collection method. Because these two methods caused a relatively high mortality rate of captured fish, their use was limited. Angling was employed at the tailrace area of the Peace Canyon Dam to establish the presence or absence of salmonids such as rainbow trout and bull trout during each sampling period. To assess habitat use of the mainstem Peace River by young-of-the-year fish, attempts also were made to sample representative habitats using beach seines and backpack shockers.

All fish over 250 mm in length (240 mm in length for kokanee and rainbow trout), and not needed for other study components, were marked with a numbered Floy FD68B anchor tag. In addition to the serial number, each tag carried the address of the B.C. Ministry of Environment office in Fort St. John to expedite tag returns from anglers. Only fish in good physical condition and exhibiting normal behaviour were tagged. The tag was first immersed in an antiseptic, then inserted, using a Dennison Mark II applicator gun, into the dorsal musculature immediately below the dorsal fin between the pterygiophores. The tag was then checked to ensure it was inserted securely. Information obtained from each tagged fish included: species, fork length, weight, tag number, date of tagging, release location, and sex and maturity when they could be determined through external examination.

All fish captured were examined for the presence of a mark (i.e., tag, clip, or evidence of a lost tag). When a tagged fish was recaptured, the species, fork length, weight, tag number, date of recovery and location of recovery were recorded.

Additional recapture information was obtained from anglers that returned tags to the B.C. Ministry of Environment or the creel survey consultant (The D.P.A. Group, Inc.). A public information program (e.g., posters, newspaper articles, etc.) was undertaken to inform the anglers about the purpose of the mark-recapture program, and an incentive program for the return of tags was promoted. A lottery for anglers who returned tags was developed, with fishing tackle as the prize.

Data Management

A data management system was implemented to assemble the data accurately and store it in an easily accessible format. Data were entered into IBM files using PC-FILE software. The contents of each IBM file were printed and compared with the field data forms. Programs were written to scan the data for incorrect numbers or letters in the data fields. Additional programs were written to link release and recovery data for the tags recovered during the fisheries surveys.

Data Analysis

Species composition and abundance were assessed during each sampling period by reach (see section 1.3 for description of reaches). Sampling intensity on the Peace River varied; however, adequate sampling effort was expended within each reach during all periods (Table 2.1).

Percent occurrence of fish in a particular section of river was calculated by dividing the number of electrofishing runs in which a species occurred by the total number of runs conducted in that section. Abundance was measured using catch-per-unit-effort (CUE) which provides an index of fish density. It was calculated as the number of fish captured during a particular electrofishing run divided by the number of seconds electrofished, and was presented as No. fish/h. A CUE value was calculated for each species during each sample run. These were then grouped according to sampling location and an average CUE value for a particular reach calculated.

The goal of tag return analysis was to produce summary tables and graphs which illustrated fish movements. Due to the length of sampling sections (2 km), data from fish which moved less than or equal to 2 km from point of capture were considered as exhibiting no net movement; to remove biases associated with short term trauma caused by the tagging procedure (i.e., downstream drift), individuals recaptured less than five days of tagging were omitted from the analysis. Recapture data were then grouped by species, recapture period and release location, and the distance then plotted.

The data were analyzed using Lotus 123 and SPSS-PC software programs. Statistical analyses followed methods outlined by Sokal and Rolhf (1981).

Population Estimates

The first step in any attempt to estimate the size of a population is to define the bounds for that population. For the Peace River studies the population bounds were, to a large extent, defined by the

Table 2.1 Electrofishing effort expended on the Peace River in the Site C study area during 1990.

Reach	Early Spring[a]		Spring			Summer			Fall			Total		
	No. Seconds	No. Runs	Session	No. Seconds	No. Runs	Session	No. Seconds	No. Runs	Session	No. Seconds	No. Runs	Session	No. Seconds	No. Runs
1	5 549	4	1	6 550	3	1	8 913	9	1	8 333	5	1	29 345	20
2	19 510	15	1	14 621	9	1	29 510	20	1	25 085	14	1	88 726	58
3	7 882	7	1	27 916	15	1	18 263	8	1	26 869	11	1	80 930	41
4	-	-	1	7 585	11	1	6 062	3	1	4 900	3	1	18 547	17
Total Session 1[b]				**56 672**	**38**		**62 748**	**40**		**65 187**	**33**		**217 548**	**136**
1	-	-	2	19 367	11	2	7 351	8	2	7 405	7	2	34 123	26
2	-	-	2	20 205	12	2	31 513	15	2	21 284	12	2	73 002	39
3	-	-	2	18 838	13	2	17 594	12	2	16 344	9	2	52 776	34
4	-	-	2	6 680	4	2	9 023	6	2	6 154	5	2	21 857	15
Total Session 2				**65 090**	**40**		**65 481**	**41**		**51 187**	**33**		**181 758**	**114**
Total	**32 941**	**26**		**121 762**	**78**		**128 229**	**81**		**116 374**	**66**		**399 306**	**250**

[a]Sampling effort directed towards suspected spawning habitats of selected fish species.

[b]Session number delineates one complete survey (reaches 1 through 4).

field procedures. The temporal bounds were defined by the survey periods (May - October 1989 and May - October 1990). The spatial bounds for each species could be defined at two levels: 1) the upstream and downstream limits of the field survey effort; and 2) sub-populations within the survey area. A simple movement analysis was used to examine the degree to which fish moved within the Peace River and its major tributaries and to assess the validity of stratifying the survey area. The size bound for each species was defined by the minimum size limits used in tag application (240 mm for rainbow trout and kokanee, and 250 mm for other species); however, a growth analysis had to be conducted and used to adjust the number of tagged fish released and recaptured to account for recruitment of small fish into the population. Finally, the number of tagged fish recaptured during electroshocking surveys determined the species for which population estimates could be produced. Population estimates were not attempted for any species with less than seven tag recoveries.

Movement analysis

Plots of distance travelled during time at large for tagged fish were used to provide a measure of dispersal after release. Correlation (Pearson correlation coefficient) between distance travelled and time at large by species was examined for statistical significance. The analysis included tag recoveries from all recovery methods (i.e., electrofishing, angling, gill netting).

Seasonal Growth

There was substantial growth of individuals of some species between sampling periods. Since application of tags is size dependent (240 mm for rainbow trout and kokanee, and 250 mm for all other species), there were more fish available to mark as the season progressed. In other words, fish were recruited into the markable population over the season. In order to quantify this recruitment, growth increments were calculated using two methods: 1) a weighted regression of the mean length at a given age by month, similar to the methodology used in 1989; and 2) the difference between the length of an individual at capture and recapture.

Mean Length at Age-Month

Length at age data were available from ageing samples taken during May, June, August, and October. Since there was a substantial overlap in length among age-classes, a method was developed to combine the length information from all the age-classes. First, the mean and standard deviation was calculated for each age-class and month combination where there were two or more observations. Second a "t" statistic, standardized to the length of interest, was calculated as follows:

$$t_i = \frac{m_i - m_o}{S_i}$$

where t_i is the standardized "t" statistic, m_i the mean of the i^{th} age-month combination, m_0 the standardization mean (240 mm for rainbow trout and kokanee, and 250 mm for all other species) and S_i the standard deviation. Third, the probability of each age-month mean length being less than the m_0 value was calculated as follows:

$$p_i = TCF\,(t_i n_i\text{-}1)$$

where p_i is the probability, TCF is the function that returns the proportion of the t distribution with n_i-1 degrees of freedom below the value t_i, and n_i is the number of observations for each age-month combination. Fourth, a weighted least squares linear regression (Draper and Smith 1981) of sampling interval (May, June, August, and October) on the mean lengths was conducted to obtain the increment in growth (i.e., the slope) for each age-class. Fifth and finally, the increments for each age-class were combined according to the overall weight of each age-class. The weights were defined as:

$$w_i = n_i p_i (1-p_i)$$

where w_i is the weighting given to each mean observed. Whether or not a fish belonged to the markable population was described as a binomial variate and each age-month mean length was weighted by the variance from that binomial distribution; therefore, the largest weights were given to the age-month mean lengths closest to the minimum tagging size (m_0) with the largest sample size. The assumptions required for this approach were that lengths are normally distributed for each age-month combination and that the increment in growth for each age-class over the season are similar and linear. The quantity of data available for this analysis was not sufficient to test either of these assumptions.

The fourth and fifth steps were calculated from the equivalent analysis of covariance model:

*weighted mean length = weight + weighted month + age + age*weight*

where *age* was treated as a categorical variable and the *weighted month* as the covariate. The estimated coefficient for the *weighted month* term was the estimated increment in growth.

Differences in Length at Capture and Recapture

Since the length of each fish was measured at both capture and recapture, these lengths could be regressed against time at large to obtain a growth increment. It was assumed that there were 30 days in a month to enable comparison with the age-month mean length method described above.

Population Estimates

Population estimates were developed from the mark-recapture data following Gazey and Staley (1986). Two population estimates were computed for each species using the 1990 tag recoveries. An estimate of the number of fish in the study area in May - June 1990 was completed using the tag release, recapture and sample size data from the seven survey intervals in 1990 (Table 2.2). An estimate of the number of fish in the study area in May - June 1989 was computed using the good in each of the three survey intervals in 1989 and the recoveries of these tags in 1990 along with the 1990 sample sizes.

Table 2.2 Definition of survey intervals used to compute population estimates from recoveries of 1989 and 1990 tag releases on the Peace River.

	Period	Dates
1989	A	26 May - 29 June
	B	9 - 30 August
	C	8 - 27 October
1990	1	20 May - 4 June
	2	5 - 11 June
	3	12 - 30 June
	4	1 - 11 August
	5	16 - 31 August
	6	30 September - 9 October
	7	10 - 15 October

Combinations of the three sampling intervals for 1989 with the seven sampling intervals in 1990 (Table 2.2) resulted in 21 sampling sequences for each of the 1989-1990 and 1990 population estimates. There were seven recovery intervals for each of the three 1989 release intervals and a decreasing number of recovery intervals for each of the 1990 release intervals (six recovery intervals for interval one releases, five recovery intervals for interval two releases, etc.). Tags released and recaptured during the same period were not used because the survey area was only covered once in each survey interval and these recaptures probably did not have sufficient time to mix with the unmarked fish.

Fish examined and tag recoveries were compiled only from the electrofishing data. The number of tags available for recapture in a sampling interval was the number of tags applied, less the known number of tags removed by samplers and anglers prior to the sampling interval. The number of fish examined (sample size), recoveries and number of marked fish in the population were adjusted for recruits into the markable population because of growth over the season; therefore, population estimates were for fish greater than the minimum tagging size m_0. The growth increment results from the "age-month mean length" method were used to facilitate comparison with results obtained in 1989. Standard errors were computed for each growth estimate and used in the definition of the following three recruitment scenarios:

1. No recruitment. The sample size was not adjusted.
2. Mean recruitment. The sample size was adjusted by using the growth increment obtained from the regressions.
3. Extreme recruitment. The growth increment was calculated as the regressed value (mean slope plus two standard errors.

The recommended population estimate is that generated by the mean recruitment scenario. The other scenarios are presented to display the sensitivity of using alternative recruitment levels. The posterior distributions were plotted for the mean recruitment scenario. For each species where there were sufficient data, the mean, median, mode (maximum likelihood estimate), 2.5 and 97.5% quantiles, and the 95% highest probability region (HPD) were calculated from the posterior distribution.

Radio Telemetry Program

Mature individuals of rainbow trout, bull trout, northern pike, and walleye were radio tagged during October 1989 to ensure a radio tagged cohort of spring spawners was available during the following spring. During the open water period of 1990 mature individuals of rainbow trout, bull trout, walleye, and Arctic grayling were radio tagged to assess pre- and post-spawning movements.

Materials

Transmitters utilized during this study were manufactured by Lotec Engineering Inc. (Aurora, Ontario), and were two sizes. Small transmitters (15 g) were rated for a minimum life span of nine months, while large transmitters (24 g) were rated at 20-32 months life (dependent upon the pulse rate). As a general rule, transmitters should not exceed $1\frac{1}{2}$% of body weight so as not to affect the buoyancy and swimming ability of the fish. Transmitters were low frequency (40.000-42.000 MHz) with a signal of 32 to 50 pulse per minute. Transmitter packages consisted of an encapsulated circuit/lithium battery, and a trailing fine diameter whip antennae. The encapsulating resin was tissue-compatible which allowed surgical implantation of the unit.

Transmitter Attachment

Apparatus consisted of a field operating shelter (window tent), a 500 L holding/recovery tank, and an anesthetic tank, located in close proximity to floating fish-holding pens in the river.

Fish selected for transmitter implantation were placed individually in the anesthetic tank. A commercial anesthetic "Finquel" (tricane methane sulfonate) was utilized at a concentration of 150 mg/L to induce rapid anesthesia. This concentration of anesthetic caused a pH drop of approximately 1.6 units in the water obtained from the study area; therefore, a small amount (1 g/10 L water) of sodium bicarbonate also was added as a buffer to control the pH change. Anesthesia inducement time was from 2.5 to 5 minutes; slower induction occurred when water temperatures fell below 5°C (i.e., late fall). Fish were then removed from the anesthetic tank, weighed, measured and placed on the operating table in a wetted, sponge-lined, trough.

A surgical implantation procedure was utilized following techniques described by Bidgood (1980) and Knecht et al. (1981). Prior to surgery, scales were removed from the mid-line of the ventral surface between the pelvic and pectoral girdles, and the area swabbed with surgical scrub solution (7.5% Povidone-iodine). A longitudinal incision approximately 3 cm in length was made in the body wall. A sterilized 10-cm No. 16 hypodermic needle was then inserted through the body wall 5-8 cm behind the incision and carefully guided forward in the body cavity until reaching the incision. The radio tag (sterilized in a 10% solution of surgical scrub and rinsed in distilled water) was placed in the body cavity of the fish, with the antennae being inserted into the hypodermic needle. The needle was removed, leaving the antennae wire exiting the ventral surface of the fish posterior to the incision. During 1989, a continuous suture of #00 silk was used to rejoin the incision. Although regarded as non-degradable, silk suture loses its strength after 3-4 months in water and was not anticipated to remain in place after healing. Biodegradable sutures were not utilized because of the uncertainty of incision healing time in cold water. During 1990 #00 biodegradable sutures were utilized. After suturing, the incision was washed with a 4% nitrofurazone solution (a wide spectrum antibiotic). Approximately 30 seconds prior to completion of suturing, water from an overhead reservoir was directed over the gills of the fish and continued until the fish was able to maintain voluntary respiration. The fish was then placed in the recovery tank and supported by hand until it could maintain its equilibrium independently. After the initial recovery period, the fish was relocated to a floating pen in the river and its condition monitored for a period of 2 to 4 hours prior to release. A small number of fish were retained for 24 h observations; however, fluctuating water levels caused by variable discharge from the Peace Canyon Dam made it difficult to maintain these pens without creating undue stress to the fish. As such, the 24 h holding procedure was discontinued.

Tracking

Tracking was accomplished primarily from a fixed-wing aircraft, although occasional surveys were also conducted from a ground vehicle or a riverboat. A schedule of completed surveys is outlined in Table 2.3. Survey coverage of a particular location was dependent on weather conditions, available flight time and the species targetted during that survey. A detailed summary of the radio tracking schedule, coverage, and species surveyed is provided in Table 2.4.

Whip antennae (one located on each wing strut) were utilized from the aircraft, with aircraft speeds of 90-140 km/h and altitudes of approximately 100-250 m above the water surface. Flight lines were generally positioned near the mid-point of the channel. The survey usually consisted of two complete passes, one upstream and one downstream, in addition to extra passes as required for coverage of braided areas. A single hand held whip antenna was utilized during the ground and boat surveys.

A scanning receiver (ATS Challenger 2000) was utilized during all surveys. This receiver was able to simultaneously search for and receive signals from several transmitters. The precise location of each radio tagged fish encountered during tracking surveys was marked on 1:50 000 scale maps and tabulated for future reference.

Habitat Use

Habitat use was assessed from information obtained during 1989 and 1990 field programs. During fisheries surveys, information was recorded on specific habitat type(s) sampled, and the fish species and size-classes present. Whenever distinct fish concentrations or indications of specific activities (i.e., spawning, rearing, etc.) were observed, these were recorded in association with the habitat type sampled.

Habitat classification closely followed FHIIP definitions (DFO/MOEP 1987) utilized by Slaney et al. (1991). These habitat categories were modified to better categorize the large system of the Peace River. Habitat types used are defined below:

Habitat Type	Definition
Shallow glide	Areas of flowing water; without surface waves; ≤ 1.0 m depth.
Deep glide	Areas of flowing water; without surface waves; > 1.0 m depth.
Shallow Pool	Areas of river with low or no water flow; ≤ 1.0 m depth.
Deep Pool	Areas of river with low or no water flow; > 1.0 m depth.
Shallow Riffle	Areas of river with swiftly flowing water; surface waves; 1.0 m depth.
Deep Riffle	Areas of river with swiftly flowing water; surface waves; > 1.0 m depth.
Shallow Snye	Areas of river with swiftly flowing water; surface waves; ≤ 1.0 m depth
Deep Snye	Side channel of mainstem river; exhibiting low or no water flow; > 1.0 m depth.
Shallow Backwater	Area associated with tributary confluence; water flow opposite to direction of river; ≤ 1.0 m depth.
Deep Backwater	Area associated with tributary confluence; water flow opposite to direction of river; > 1.0 m depth.

Life History

Data collected from most fish captured included fork length and weight. A representative sample of sportfish also were sacrificed to obtain information on sex, maturity, gonad weight, and food habits. In addition, an ageing structure was collected from a subsample of captured fish.

Table 2.3 Number and location of radio tracking surveys of the Site C study area, 1989 and 1990. Unless otherwise noted, all surveys were conducted from the air.

Year/Month	Peace River (B.C.)	Peace River (AB)	Maurice Creek	Lynx Creek	Farrell Creek	Halfway River	Cache Creek	Moberly River	Pine River	Beatton River	Kiskatinaw River
1989 Nov.	1										
1990 Jan.	1	1									
1990 Mar.	1										
1990 May	4	2	2	2	3	3	1	2	2	3	1
1990 June	3	2	2	2		1		1			
1990 July	1		1	1		1			1	1	
1990 Aug.	6[a]					3		1		1	
1990 Sep.	1					1					
1990 Oct.	2					1					
1990 Dec.	1	1									

[a]Three surveys from the air, two surveys by boat and one survey from the ground.

Table 2.4 Radio tracking schedule, survey coverage and species surveyed in the Site C study area, 1989 and 1990.

Date	Areas Surveyed		Species[a] Surveyed
20 Nov. 1989	Peace R.	- B.C./Alberta border to Peace Canyon Dam	RT NP DV YW
22 Jan. 1990	Peace R.	- B.C./Alberta border to Peace Canyon Dam	RT NP DV YW
		- B.C./Alberta border to Smoky R. (Alberta)	RT NP DV YW
2 March 1990	Peace R.	- B.C./Alberta border to Moberly R.	RT NP DV YW
7-8 May 1990	Peace R.	- B.C./Alberta border to Peace Canyon Dam	RT NP DV YW
		- B.C./Alberta border to Clear R. (Alberta)	YW
	Halfway R.	- confluence to Graham River	RT NP DV YW
	Farrell Cr.	- confluence to 15 km	RT NP DV YW
	Pine R.	- confluence to 30 km	RT NP DV YW
	Moberly R.	- confluence to 20 km	RT NP DV YW
	Beatton R.	- confluence to 60 km	YW
15 May 1990	Peace R.	- B.C./Alberta border to Peace Canyon Dam	RT NP DV YW
	Peace R.	- B.C./Alberta border to Montagneuse River (AB)	YW
	Beatton R.	- confluence to Doing R.	YW
	Kiskatinaw R.	- confluence to 20 km	YW
22 May 1990	Peace R.	- B.C./Alberta border to Peace Canyon Dam	RT NP DV YW
	Maurice Cr.	- confluence to falls	RT
	Lynx Cr.	- confluence to 5 km	RT
	Farrell Cr.	- confluence to 5 km	RT
	Cache Cr.	- confluence to 5 km	RT
	Moberly R.	- confluence to 10 km	YW
	Pine C.	- confluence to 20 km	YW
	Beatton R.	- confluence to 60 km	YW
	Halfway R.	- confluence to 50 km	RT NP DV YW
28 May 1990	Peace R.	- Km 26 to Peace Canyon Dam	RT NP DV YW
	Halfway R.	- confluence to 50 km	RT NP DV YW
	Maurice Cr.	- confluence to falls	RT
	Lynx Cr.	- confluence to 5 km	RT
	Farrell Cr.	- confluence to 5 km	RT
6 June 1990	Peace R.	- B.C./Alberta border to Peace Canyon Dam	RT NP DV YW
		- B.C./Alberta border to Smoky River (Alberta)	YW
	Halfway R.	- confluence to 50 km	RT DV
	Maurice Cr.	- confluence to falls	RT
	Lynx Cr.	- confluence to 5 km	RT
18 June 1990	Peace R.	- B.C./Alberta border to Peace Canyon Dam	RT NP DV YW
		- B.C./Alberta border to Clear R. (Alberta)	YW
	Moberly R.	- confluence to 30 km	YW
28 June 1990	Peace R.	- B.C./Alberta border to Peace Canyon Dam	RT NP DV YW
	Maurice Cr.	- confluence to falls	RT
	Lynx Cr.	- confluence to 5 km	RT
11 July 1990	Peace R.	- B.C./Alberta border to Peace Canyon Dam	RT DV YW
	Maurice Cr.	- confluence to falls	RT
	Lynx Cr.	- confluence to 5 km	RT
	Halfway R.	- confluence to Graham River	DV
	Pine R.	- confluence to 20 km	YW
	Beatton R.	- confluence to 4 km	YW

Table 2.4 Concluded.

Date	Areas Surveyed		Species[a] Surveyed
8 August 1990	Peace R.	- Km 26 to Peace Canyon Dam	RT NP DV YW
	Moberly R.	- confluence to 10 km	YW
	Halfway R.	- confluence to Graham River	DV
	Beatton R.	- confluence to 5 km	YW
11 August 1990 (boat)	Peace R.	- Km 45 to Km 26	YW
14 August 1990 (ground)	Peace R.	- Km 148 to Peace Canyon Dam	DV
17 August 1990	Peace R.	- Km 12 to Peace Canyon Dam	DV YW
	Halfway R.	- confluence to Graham River	DV
20 August 1990 (boat)	Peace R.	- Km 66 to Km 12	YW
21 August 1990	Peace R.	- Km 66 to Peace Canyon Dam	RT NP DV YW
	Halfway R.	- confluence to McKearney Ranch	DV
	Graham R.	- confluence to Km 50	DV
10-11 September 1990	Peace R.	- B.C./Alberta border to Peace Canyon Dam	NP DV YW
	Halfway R.	- confluence to Beatton Ranch	DV
	Graham R.	- confluence to Christina Falls	DV
2-3 October 1990	Peace R.	- B.C./Alberta border to Peace Canyon Dam	RT DV YW
	Halfway R.	- confluence to Robb Lake	DV
	Graham R.	- confluence to Christina Falls	DV
29-30 October 1990	Peace R.	- B.C./Alberta border to Peace Canyon Dam	YW
		- Km 45 to Peace Canyon Dam	AG RT DV
5 December 1990	Peace R.	- B.C./Alberta border to Peace Canyon Dam	AG RT YW DV
		- B.C./Alberta border to Dunvegan Bridge (AB)	YW

[a]For species designations see Table 4.1.

Ageing was conducted using the appropriate laboratory technique for each structure (Mackay et al. 1990). Scales were cleaned and mounted on a microscope slide. Finrays were set in epoxy resin and then sectioned into 0.5-1.0 mm cross-sections using a jeweller's saw. Sections were then placed in Diatex synthetic mounting medium on a microscope slide. To expose the annuli, small otoliths were carefully ground with fine emery cloth while large otoliths were split. Structures were aged using either a dissecting microscope or a microfiche reader-printer. A minimum of two independent estimates of age were made. Where a discrepancy existed, the structure was re-examined and a consensus was obtained as to its age allocation.

Life history data analyses were conducted using FISHPAK software developed by G. Ash. Data output included a printout of the individual life history information, as well as length-frequency, weight-frequency, length-weight regression, condition factor and age-growth data for each species.

To determine feeding habits, stomach contents were preserved in 70% isopropyl alcohol and were later examined in the lab. The procedure used for assessment of feeding habits followed the method described by Thompson (1959) which is a modification of the numerical method used by Hynes (1950). The stomach was examined and evaluated for fullness and allotted a certain number of points (i.e., 20 points for a full stomach and 0 points for an empty stomach). After points were allotted for the degree of fullness, the stomach was opened and its contents placed in a petri dish. The points were distributed among individual food categories observed based on volume using a 7x20 power dissecting scope to identify food categories. To account for the presence of empty stomachs, values of zero were incorporated into the analysis. This was accomplished by subtracting the total points of food items observed in a sample from the total potential points for that sample (i.e., number of fish in sample x 20, minus total points of food items observed). The resulting value was allotted to an "empty category". A point total was then calculated for each food group.

A sample of mountain whitefish and lake whitefish were dissected and examined for the plerocercoids of *Triaenophorus crassus* which occur as cysts in the flesh. Fish dissection entailed producing a "fillet" of meat from each side of the individual. The translucent fillet was then placed adjacent to a light source and examined for opaque yellowish areas in the flesh which represent cysts.

2.3 MERCURY ANALYSIS OF FISH TISSUES

During 1989 and 1990 an attempt was made to collect a full size range of fish for several species for analysis of mercury concentration in muscle tissue. Whenever possible, fish were collected upstream of the proposed Site C dam site (Km 65).

Prior to acquisition of a tissue sample, the appropriate life history information was taken from each individual. The dissection procedure for fish tissue sampling employed a number of safeguards to prevent contamination of samples. These included the use of aluminum foil to cover all surfaces of the measuring and dissecting boards, and the use of sterile stainless steel (rinsed in nitric acid) or disposable plastic dissecting instruments. Approximately 100-140 g of muscle tissue was dissected from each fish and placed into 220 mL sterile, acid-washed (5% nitric acid) specimen containers which were provided by PowerTech Laboratories Ltd. All tissue samples were frozen and forwarded to PowerTech Laboratories Ltd. for analysis.

Analysis results for the samples obtained during 1989 were expressed as micrograms of mercury/wet gram. Results for samples collected during 1990 were expressed as micrograms of mercury/dry gram; therefore, the 1990 data were converted to micrograms of mercury/wet gram before being analyzed with the 1989 data.

SECTION 3
PHYSICAL AND CHEMICAL PARAMETERS

An important component of the study was to obtain seasonal temperature and water quality data for the Peace River and major tributaries within the Site C study area associated with pertinent discharge information obtained at sampling locations.

3.1 TEMPERATURE

Commencing 13 August 1989, water temperatures were monitored in the Peace River and it's major tributaries. This information will be summarized in the final report.

3.2 WATER QUALITY

The water quality assessment of the Peace River and its tributaries was comprised of the following:

- a spatial and seasonal analyses of the data obtained during 1989 and 1990;
- a comparison of the survey data to historical information; and,
- a comparison of the survey data to surface water quality objectives for the protection of aquatic organisms.

Because the database included only two values for each month, no statistical evaluation was conducted.

Water samples and discharge measurements were collected from eight sampling locations during spring, summer, fall in 1989 and during winter, spring, summer, and fall in 1990. Discharge information has been presented in Table 3.1 and selected data have been illustrated in Figures 3.1 and 3.2. The results of the water quality analyses for 1989 and 1990 are presented in Tables 3.2a and 3.2b, respectively. Raw data used to generate discharges will be presented in Appendix 3.2A of the final report.

Discharge

Flow in the Peace River is regulated by the Peace Canyon Dam in association with the W.A.C. Bennett Dam. Historical data for the period 1979 to 1988, show that the highest mean monthly flows in the Peace River occurred during winter and the lowest mean monthly flows occurred in summer.

(Figure 3.1). In 1989 and 1990 the flow regimes were considerably different from the ten year mean. During both years, the flows were higher than average in winter. During 1989, notable increases in discharge occurred during July and August, but in 1990 flow rates were below average during the same months. In contrast, the flows in the Halfway River and other Site C tributaries were unregulated. For example, the highest flows in the Halfway River occurred during spring and early summer and the lowest flows occurred during winter (Figure 3.2). During 1990 a very high discharge occurred in June. Similar results were observed for other tributaries during 1989 and 1990 (Table 3.1).

Table 3.1 Discharge measurements of the Peace River and tributaries[a] in the Site C study area at the time of water quality sampling, 1989-1990.

Creek	1989 Date	1989 (m^3/s)	1990 Date	1990 (m^3/s)
Maurice Creek	27 June	4.67	4 June	6.46
	22 August	0.28	13 August	0.03
	10 October	0.36	14 October	0.11
Lynx Creek	29 June	1.08	4 June	2.04
	22 August	0.30	13 August	0.12
	10 October	0.16	14 October	0.10
Farrell Creek	29 June	6.02	23 June	2.58
	22 August	0.71	13 August	0.05
	10 October	0.62	14 October	0.03
Cache Creek	30 June	0.08	4 June	4.37
	22 August	0.25	13 August	0.003
	11 October	0.07	14 October	0.004
Moberly River	27 June	19.5	4 June	85.8
	20 August	13.6	13 August	3.55
	10 October	6.5	14 August	1.18
Halfway River	27 June	172.0	4 June	980
	20 August	130.0	13 August	39.9
	10 October	54.4	14 October	20.2
Peace River (Hudson Hope)	27 June	1160	4 June	587
	20 August	1300	13 August	813
	10 October	1090	14 October	1580
Peace River (upstream of Pine River)	27 June	1240	4 June	1450
	20 August	1330	13 August	961
	10 October	1090	14 October	1680

[a]Measurements taken close to confluence with Peace River.

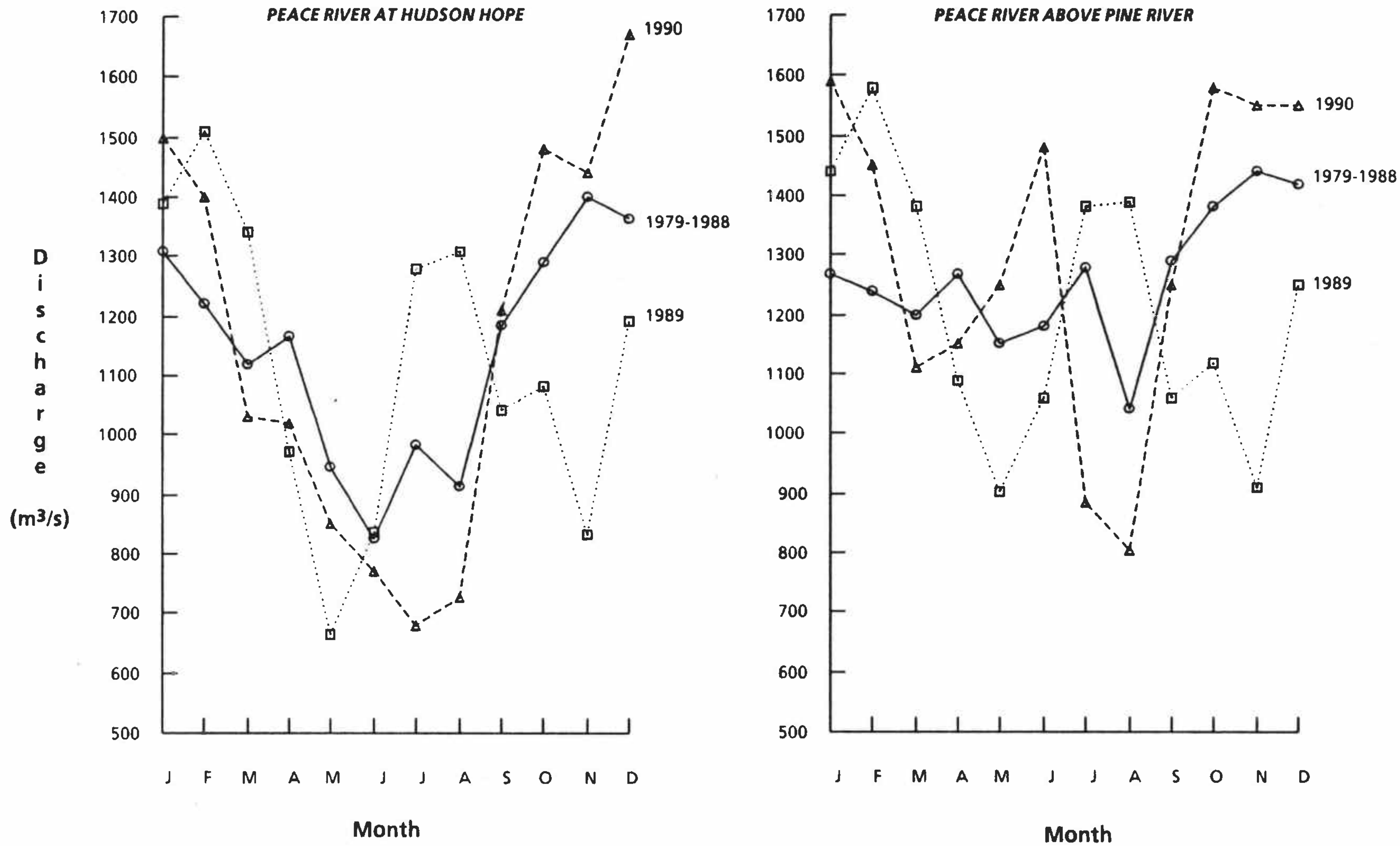

Figure 3.1 Mean monthly discharges for two stations on the Peace River in the Site C study area. Data obtained from Water Survey of Canada (1989, 1990).

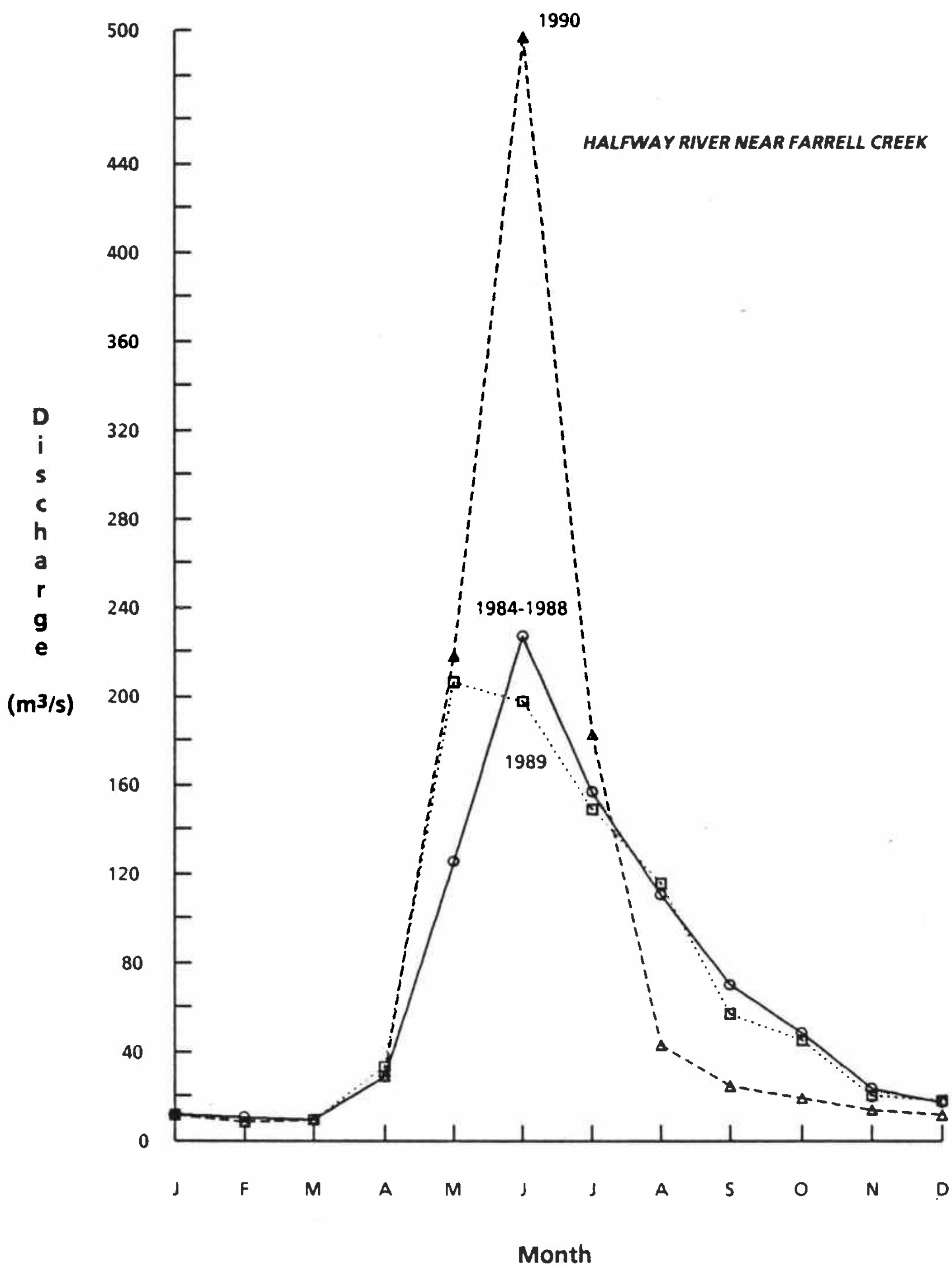

Figure 3.2 Mean monthly discharges for the Halfway River in the Site C study area. Data obtained from Water Survey of Canada (1989, 1990).

Table 3.2a **Water quality data from the Peace River and its major tributaries in the Site C study area obtained during spring, summer and fall 1989.**

Parameter[a]	Mainstem Peace River downstream of Peace Canyon Dam			Maurice Creek			Lynx Creek			Farrell Creek		
	27 June	20 Aug.	10 Oct.	27 June	20 Aug.	10 Oct.	27 June	20 Aug.	10 Oct.	27 June	20 Aug.	10 Oct.
Temperature (°C)*	9.0	8.5	9.0	12.0	17.3	6.0	15.0	16.6	6.5	18.0	19.3	6.5
Dissolved oxygen*		11.2	13.2		10.6	13.6		9.6	13.2		9.2	13.4
Dissolved oxygen saturation (%)		96	114		112	109		103	106		107	100
pH* (units)	8.13	8.24	8.29	8.32	8.53	8.55	8.65	8.45	8.84	8.6	8.61	8.47
Turbidity (NTU)*	5.6		6.3	164	15	42	384	820	570	65	24	180
pH (units)	8.32	8.23	7.98	8.70	8.56	8.37	8.49	8.41	8.33	8.52	8.58	8.45
Conductivity (µS/cm)	198	180	181	227	414	327	601	649	671	475	477	372
Suspended solids	4	<1	<1	284	<1	<1	5430	427	241	89	10	7
Total dissolved solids	52	85	79	107	245	227	363	426	478	267	216	268
Total alkalinity as $CaCO_3$	84	87	78	97	185	148	441	345	411	216	225	185
Carbonate alkalinity as $CaCO_3$	na	na	na	na[a]	10	4	2	8	5	7	16	10
Bicarbonate alkalinity as $CaCO_3$	84	87	78	97	175	144	439	337	406	209	209	175
Nitrate as N (µg/L)	<5	33	10	47	<5	<5	120	82	61	<5	<5	<5
Nitrite as N (µg/L)	<2	15	2	41	<2	<2	13	15	4	5	<2	4
Total Kjeldahl Nitrogen (µg/L)	0.5	650	170	3.2	1100	440	2.9	1080	590	0.3	700	440
Total Nitrogen as N (µg/L)	<7.5	698	182	91.2	<1107	<447	135.6	1177	655	<10.3	<707	<449
Total Phosphorous as P (µg/L)	22	7	7	569	9	29	1320	7	288	167	19	58
Total Organic Carbon	2.7	3.9	4.6	18.0	11.7	13.8	8.6	5.5	7.2	9.0	9.1	12.5
Reactive Silica as SiO_2	5	4	3.2	4	4	5.9	6	13	13.2	5	5	6.1
Chloride as Cl	1.9	0.6	0.6	2.2	0.5	0.9	1.5	2.8	1.1	1.8	1.5	1.9
Sulfate as SO_4	10	10	9	16	48	35	37	60	62	40	41	30
Calcium	29.2	26.1	31	35.1	66.3	109	404	111	53	68.9	67.4	47
Magnesium	6.5	5.9	9	8.1	19.5	49	91.9	51.0	17	21.4	22.0	14
Mercury, Total (µg/L)			<0.05			<0.05			0.08			<0.05
Potassium	<1	<1	<1	4.8	1.8	1	8.8	9.6	6	3.4	2.0	2
Sodium	2.1	1.6	1	4.05	10.6	5	3.6	9.0	16	10.1	10.6	8

[a]All values reported as mg/L unless otherwise stated.
*Measurements taken in the field.
P - Phosphorus; N - Nitrogen.

Table 3.2a Concluded.

Parameter[a]	Halfway River			Cache Creek			Moberly River			Mainstem Peace River near Site C damsite		
	27 June	20 Aug.	10 Oct.	27 June	20 Aug.	10 Oct.	27 June	20 Aug.	10 Oct.	27 June	20 Aug.	10 Oct.
Temperature (°C)*	13.5	16.1	6.5	21.0	19.4	4.5	15.5	19.0	6.0	11.0	11.0	9.0
Dissolved oxygen*		10.2	13.5		9.8	15.8		11.6	13.6		10.8	12.7
Dissolved oxygen saturation (%)		103	109		115	119		122	109		97	109
pH* (units)	8.4	8.4	8.37	8.44	8.05	8.48	8.33	8.49	8.16	8.26	8.25	8.26
Turbidity (NTU)*	120	320	105	15	26	70	58	18	120	26	5.4	17
pH (units)	8.25	8.42	8.41	8.38	8.36	8.40	8.30	8.36	8.37	8.30	8.30	8.23
Conductivity (µS/cm)	297	313	406	1110	1120	1150	206	202	214	208	202	192
Suspended solids	172	104	9	14	11	7	126	95	14	30	13	14
Total dissolved solids	248	222	226	652	589	925	121	93	140	106	95	106
Total alkalinity as $CaCO_3$	157	263	173	101	216	282	101	105	114	94	99	90
Carbonate alkalinity as $CaCO_3$		10	10	5	3	11	na	2	3	na	na	na
Bicarbonate alkalinity as $CaCO_3$	157	253	163	96	213	271	101	103	111	95	99	90
Nitrate as N (µg/L)	<5	<5	<5	<5	14	<5	<5	<5	<5	<5	27	<5
Nitrite as N (µg/L)	11	2	<2	3	<2	<2	4	<2	<2	3	2	<2
Total Kjeldahl Nitrogen (µg/L)	0.5	910	210	0.8	460	460	0.1	490	280	0.7	150	150
Total Nitrogen as N (µg/L)	<16.5	<917	<217	<8.8	<476	<467	<9.1	<497	<287	<8.7	179	<157
Total Phosphorous as P (µg/L)	306	180	34	38	19	26	63	93	38	159	24	10
Total Organic Carbon	3.6	7.1	5.6	13.0	10.8	11.8	2.7	6.4	6.9	5.4	3.8	4.2
Reactive Silica as SiO_2	3	5	4.4	5	6	4.5	4	3	3.7	4	4	3.3
Chloride as Cl	1.6	0.9	0.9	3.7	4.3	4.4	0.8	0.5	0.8	1.4	0.8	0.7
Sulfate as SO_4	20	27	36	304	449	367	10	8	8	11	15	12
Calcium	54.4	59.2	88	108	129	23	32.7	33.4	59	29.7	32.3	26
Magnesium	11.3	17.6	54	35.7	41.8	6	8.1	8.1	16	6.8	7.3	6
Mercury, Total (µg/L)			<0.05			<0.05			<0.05			<0.05
Potassium	1.7	1.5	<1	7.1	7.8	7	1.3	<1	<1	<1	<1	<1
Sodium	2.2	2.5	2	62.2	80.5	98	2.1	2.7	2	1.6	1.7	1

[a]All values reported as mg/L unless otherwise stated.
*Measurements taken in the field.
P - Phosphorus; N - Nitrogen.

Table 3.2b Water quality data from the Peace River and its major tributaries in the Site C study area obtained during spring, summer and fall 1990.

Parameter[a]	Mainstem Peace River downstream of Peace Canyon Dam				Maurice Creek				Lynx Creek				Farrell Creek			
	27 Feb.	4 Jun.	13 Aug.	14 Oct.	1 Mar.	4 Jun.	13 Aug.	14 Oct.	28 Feb.	4 Jun.	13 Aug.	14 Oct.	28 Feb.	4 Jun.	13 Aug.	14 Oct.
Temperature (°C)*	0.5	6.0	11.5	-	0	9.0	18.0	5.1	0.5	10.5	12.0	5.3	0	10.0	19.5	5.6
Dissolved oxygen*	12.8	13.0	6.0	12.5	13.6	10.6	4.4	14.6	12.2	10.2	2.2	15.0	11.4	9.8	3.2	15.0
Dissolved oxygen saturation (%)	88	103	54	-	93	92	45	114	85	90	19	118	75	85	34	118
pH* (units)	7.86	7.81	7.77	7.92	8.22	8.01	8.66	8.23	8.35	8.21	7.89	8.22	8.10	7.53	11.42	8.30
Turbidity (NTU)*	1.2	200	6	18.4	12.0	1080	5.4	9.0	360	2400	660	625	1.0	2880	7	19.0
pH (units)	8.1	8.1	8.1	8.3	8.3	8.1	8.6	8.3	8.1	8.3	8.4	8.3	7.9	8.0	8.6	8.5
Conductivity (µS/cm)	199	178	157	170	531	178	433	478	885	337	598	678	774	198	460	606
Suspended solids	<1	3	<1	<1	2	152	<1	<1	1450	543	89	86.3	<1	722	<1	<1
Total dissolved solids	123	116	97	97	359	208	321	295	581	280	439	399	499	292	341	381
Total alkalinity as $CaCO_3$	84	85	85	80	233	76	209	206	572	235	342	406	302	145	224	272
Carbonate alkalinity as $CaCO_3$	<1	<1	<1	<1	<1	<1	4	<1	<1	<1	5	<1	<1	<1	6	16
Bicarbonate alkalinity as $CaCO_3$	84	85	205	80	233	76	85	206	572	235	337	406	302	145	218	256
Nitrate as N (µg/L)	67	293	67	75	230	273	4	26	158	253	39	63	63	262	3	30
Nitrite as N (µg/L)	<1	21	<2	<2	<1	7	2	<2	2	21	3	<2	<1	27	2	<2
Total Kjeldahl Nitrogen (µg/L)	190	282	76	116	950	1540	391	269	1630	2490	317	479	580	3350	519	633
Total Nitrogen as N (µg/L)	257	596	143	191	1180	1820	397	295	1790	2764	359	542	643	3639	524	661
Total Phosphorous as P (µg/L)	8	28	<3	<3	22	227	<3	<3	1800	740	4	<3	6	795	4	<3
Total Organic Carbon	2.8	2.70	2.3	2.08	7.0	20.6	8.09	7.71	3.7	16.4	3.72	2.82	5.5	22.8	8.88	5.35
Reactive Silica as SiO_2	2	4	4	4	3	3	3	4	8	7	13	12	3	5	3	5
Chloride as Cl	0.6	0.6	<1	<1	0.8	1.0	<1	<1	1.1	0.9	<1	<1	2.7	1.5	<1	1.5
Sulfate as SO_4	9	13	8	8	51	36	68	55	60	33	63	61	102	45	67	84
Calcium	28.4	26.1	27.8	27.1	74.4	29.2	72.0	70.2	246	108	58.0	80.1	98.8	72.7	70.2	81.2
Magnesium	6.24	5.95	5.92	5.60	21.4	7.58	19.8	19.4	91.9	32.1	49.8	56.7	32.8	20.3	24.6	26.9
Mercury, Total (µg/L)	<0.05	0.05	0.14	<0.05	<0.05	0.06	0.07	<0.05	<0.05	0.07	<0.05	0.07	<0.05	0.12	0.12	<0.05
Potassium	<1	<1	0.4	0.4	2	3	2.2	1.6	12	5	4.0	4.4	0.07	8	2.3	1.9
Sodium	1.2	1.5	1.1	1.2	9	2.9	10.7	11.2	21	4.9	19.3	17.4	21	3.9	15.2	17.3

[a] All values reported as mg/L unless otherwise stated.
*Measurements taken in the field.
P - Phosphorus; N - Nitrogen.

Continued . . .

Table 3.2b Concluded.

Parameter[a]	Halfway River				Cache Creek				Moberly River				Mainstem Peace River near Site C damsite			
	28 Feb.	4 Jun.	13 Aug.	14 Oct.	1 Mar.	4 Jun.	13 Aug.	14 Oct.	1 Mar.	4 Jun.	13 Aug.	14 Oct.	1 Mar.	4 Jun.	13 Aug.	14 Oct.
Temperature (°C)*	0	8.0	19.5	-	0	15.0	20.0	4.6	0	13.0	22.0	-	1.5	7.0	14.0	-
Dissolved oxygen*	10.7	10.0	4.0	14.9	4.4	8.6	2.6	13.0	11.9	10.0	4.2	14.8	13.6	10.2	5.4	12.8
Dissolved oxygen saturation (%)	74	83	42	-	30	85	27	100	82	95	47	-	95	83	50	-
pH* (units)	8.24	7.42	10.15	8.33	7.36	7.49	10.83	8.03	8.0	7.13	11.97	8.29	8.14	8.16	10.3	8.02
Turbidity (NTU)*	4.0	4560	80	39.5	28.0	3080	37	50.2	28.0	2080	80	24.2	3.4	4880	21	21.0
pH (units)	8.0	8.1	8.6	8.4	7.6	8.1	8.0	8.2	8.1	8.0	8.5	8.4	8.2	8.0	8.2	8.4
Conductivity (µS/cm)	484	277	364	437	1643	296	1010	1409	298	199	240	336	199	228	166	175
Suspended solids	3	1713	7	1.7	4	451	4	1.4	2	528	5	<1	3	1936	1	2.2
Total dissolved solids	306	344	267	270	1282	400	923	1084	198	160	167	192	133	332	110	100
Total alkalinity as $CaCO_3$	206	254	196	209	321	145	310	272	135	110	135	165	88	250	91	84
Carbonate alkalinity as $CaCO_3$	<1	<1	5	8	<1	<1	<1	<1	<1	<1	2	5	<1	<1	<1	3
Bicarbonate alkalinity as $CaCO_3$	206	254	191	201	321	145	310	272	135	110	133	160	88	250	91	81
Nitrate as N (µg/L)	119	219	<2	28	10	135	<2	33	64	223	<2	30	46	240	43	63
Nitrite as N (µg/L)	<1	49	<2	<2	3	24	<2	<2	<1	27	<2	<2	7	57	<2	<2
Total Kjeldahl Nitrogen (µg/L)	290	4810	176	170	1050	2590	499	564	500	2160	237	92	220	5390	146	441
Total Nitrogen as N (µg/L)	409	5078	176	196	1063	2749	499	597	564	2410	237	122	273	5687	189	504
Total Phosphorous as P (µg/L)	15	2240	6	<3	20	610	4	<3	39	1150	<3	<3	8	2740	<3	5.8
Total Organic Carbon	2.2	14.2	2.35	1.57	7.2	27.0	3.57	11.0	4.4	7.19	4.7	2.63	2.5	14.2	2.4	1.92
Reactive Silica as SiO_2	2	4	4	4	3	5	7	6	2	3	3	4	2	3	3	4
Chloride as Cl	0.8	1.1	<1	<1	5.3	2.2	3.6	4.3	0.5	0.6	<1	<1	0.9	1.2	<1	<1
Sulfate as $SO_4^{=}$	40	38	36	42	570	62	369	533	16	18	12	19	10	35	10	9
Calcium	68.9	127	67.8	68.4	189	51.8	152	168	36.8	43.9	40.3	49.1	29.3	160	29.9	27.3
Magnesium	17.8	29.8	16.7	18.0	60.8	18.1	48.6	58.6	10.0	13.1	10.3	13.0	<0.01	36.6	6.6	5.78
Mercury, Total (µg/L)	<0.05	0.12	0.19	0.07	<0.05	0.12	0.16	<0.05	<0.05	0.07	0.16	<0.05	<0.05	0.21	0.14	<0.05
Potassium	<1	13	0.8	0.7	6	10	5.5	5.1	1	5	1.0	0.9	0.1	17	0.4	0.5
Sodium	3.6	2.9	2.5	3.3	89	13.9	62	81.9	3.9	2.1	3.3	5.3	1.2	2.9	1.2	1.3

[a] All values reported as mg/L unless otherwise stated.

*Measurements taken in the field.

P - Phosphorus; N - Nitrogen.

The hydrographs show an important difference in the flow regimes of the Peace River and its tributaries. This is particularly important when assessing water quality because the concentrations of some parameters are related to discharge (e.g., bicarbonate, magnesium, specific conductance, total organic carbon, total nitrogen, nitrate + nitrite, total phosphorus, suspended solids, and turbidity).

Dissolved Oxygen

In the Peace River, dissolved oxygen concentrations ranged from 5.4 to 13.6 mg/L during the 1989 and 1990 sampling periods (Tables 3.2a and 3.2b). Concentrations were highest during February and lowest during August, which reflects the greater solubility of oxygen at lower water temperatures. The concentrations in August 1990 at both sampling sites, Peace Canyon Dam (6.0 mg/L) and Site C dam site (5.4 mg/L) were unusually low. The concentrations were below the minimum acceptable level of 7.25 mg/L established for the Peace River (Kathman and Cross 1989). In addition, the oxygen saturation levels associated with these low concentrations were below 60%, a minimum level required for protection of most cold water biota (CCREM 1987). No recent historical data were available for comparison, but Alberta Environment (1990) reported maximum, average, and minimum concentrations of 13.7, 10.8 and 9.0 mg/L, respectively at a downstream location near the Alberta/British Columbia border during 1988-1989. It is possible that the unusually low levels of dissolved oxygen in August 1990 may have been the result of instrument malfunction.

The dissolved oxygen concentrations in the tributaries were generally similar to those in the Peace River. Despite ice cover, concentrations during the winter were similar to those recorded in other months, except for Cache Creek where the 1 March 1990 level decreased to 4.4 mg/L. During August 1990, high water temperatures may have reduced dissolved oxygen concentrations in all streams to levels below the water quality objective of 7.25 mg/L. It is unlikely; however, that oxygen levels could have fallen as low as was observed at that time. Because the 1989 data do not show this trend despite the occurrence of comparable high water temperatures, a more plausible explanation would be instrument malfunction.

Suspended Solids (Non-Filterable Residue) and Turbidity

In general, concentrations of suspended solids in rivers are highly variable and normally increase with discharge. Suspended solids concentrations in the Peace River were generally low, but ranged from <1 to 1936 mg/L (Tables 3.2a and 3.2b). The highest value occurred in June 1990 at the downstream sampling site. Sediment loadings from tributaries contributed to this unusually high level. The 1988-1989, levels at the Alberta-British Columbia border ranged from <1 to about 190 mg/L (Alberta Environment 1990). At another location on the Peace River, three kilometres upstream of the Moberly River, maximum, mean, and minimum values were 770, 155 and 10 mg/L, respectively (Kathman and Cross 1989). The surface water quality objectives for the Peace River state that induced suspended solids levels should not exceed 10 mg/L when background levels are <100 mg/L and should not be >10% of background when background is greater than 100 mg/L (Kathman and Cross 1989).

Suspended solid concentrations in the tributaries also showed seasonal differences, with the lowest levels generally occurring in February and the highest levels occurring in June, except for Lynx Creek. The concentrations in Lynx Creek were higher than those in other tributaries, particularly during June 1989 when a level of of 5430 mg/L was recorded. This high concentration was probably due to the highly erosional nature of the stream banks found within this system (Slaney et al. 1991).

Turbidity levels in the Peace River were generally low, ranging from 1.2 to 4880 NTU, and showed a seasonal pattern similar to that shown by suspended solids. The highest value was recorded in June 1990 at the downstream site near the proposed Site C damsite. Except for this value, turbidity levels were similar to the <1 to 200 NTU range for the Alberta/British Columbia border site in 1988-89 reported by Alberta Environment (1990).

Turbidity levels in the tributaries were notably higher than those in the Peace River with values generally highest during June. Lynx Creek exhibited the highest levels with values ranging from 360 to 2400 NTU; however, the highest value (4560 NTU) was recorded in the Halfway River.

High turbidity levels in the Peace River and the tributaries may have affected some aquatic biota. The surface water quality objectives for the Peace River state that induced turbidity levels should not exceed 5 NTU when the background is <50 NTU, and should not be >10% of background when it is >50 NTU (Kathman and Cross 1989).

Total Dissolved Solids, Specific Conductance and Major Ions

Total dissolved solids (TDS) is a measure of the concentration of dissolved matter in water and the concentration of TDS in water depends on geochemical weathering of rocks and soil, and the influence of anthropogenic sources. Also, TDS concentrations are generally positively correlated with specific conductance, which is a numerical expression of the water's ability to conduct an electrical current. In general, the major ions calcium, magnesium, sodium, potassium, bicarbonate, sulfate, and chloride account for most of the total dissolved solids in surface waters.

Total dissolved solids concentrations in the Peace River ranged from 52 to 332 mg/L and showed no discernible seasonal trend. They were generally higher at the downstream site which probably resulted from input from the tributaries. Similar concentrations (ranging from 80 to 120 mg/L) were found at the Alberta/British Columbia border in 1988-89 (Alberta Environment 1990). In general, rivers exhibit highest concentrations in winter during base flow conditions. The specific conductance levels ranged from 157 to 228 µS/cm, and showed a similar pattern to that of TDS. There are no water quality criteria established for TDS or specific conductance with respect to protecting aquatic organisms in the Peace River.

TDS concentrations and specific conductance levels in tributaries were notably higher than those in the Peace River, and showed a trend towards higher levels during low flow periods (i.e., winter). Levels of both parameters were generally highest in Cache Creek and Lynx Creek. Results from both creeks illustrate the strong influence of flow rates on dissolved solids concentrations.

The major ionic components in the Peace River and the tributaries, according to their dominance based on meq/L, were as follows: cations $Ca^{++} > Mg^{++} > Na^{+} > K^{+}$; anions $HCO_3^{-} > SO_4^{=} > Cl^{-}$. Alberta Environment (1990) reported the same ranking at the Alberta/British Columbia site in 1988-1989. The ionic concentrations in the tributaries showed a seasonal pattern. Concentrations of bicarbonate, calcium and magnesium decreased with increased discharge. No water quality criteria have been established for major ions with respect to protecting aquatic organisms in the Peace River.

Alkalinity and pH

Alkalinity refers to the acid-neutralizing capacity of water. In most surface waters, it is controlled primarily by the carbonate, bicarbonate, and hydroxide content in the water.

In the Peace River, total alkalinity levels ranged from 78 to 250 mg/L and the pH (lab) ranged from 7.98 to 8.4. The alkalinity level (250 mg/L) recorded during June at the downstream site was unusually high as was the pH field measurement (10.3) taken in August. The reasons for these levels are unknown but the sources are probably natural. Neither total alkalinity nor pH showed a relationship with discharge rates or season. Alberta Environment (1990) reported total alkalinity levels ranging from 82 to 92 mg/L and pH values ranging from 7.2 to 8.3 during 1988-1989. They also found that neither parameter was correlated with discharge, nor did they observe significant seasonal trends. At another location on the Peace River, three kilometres upstream of the Moberly River, Kathman and Cross (1989) reported pH maximum, mean and minimum values of 8.1, 8.0 and 7.9, respectively for the period 1970 to 1985.

Total alkalinity levels in the tributaries, particularly Lynx and Cache creeks were generally higher than those in the Peace River and there were no seasonal trends. The values indicate that the tributaries had a strong buffering capacity against acids. The pH of the tributaries were similar to that of the Peace River. Field measurements in August 1990, recorded unusually high values in Farrell Creek, Halfway River, Cache Creek, and Moberly River. Reasons for these differences are unknown but may have resulted from instrument malfunction.

The pH and alkalinity levels recorded in the Peace River and its tributaries during this study had no limiting effects on aquatic organisms. Except for some high field measurements, the pH of the Peace River and its tributaries were in compliance with the water quality criteria (6.5-9.0) established for the Peace River (Kathman and Cross 1989).

Nutrients

Nitrogen and phosphorus are major nutrients required by plants, and the primary productivity in streams is usually determined by the dissolved forms of these nutrients. As well, total organic carbon is used by bacteria and other heterotrophic organisms. The sources of nutrients can be natural and/or anthropogenic.

Nitrogen

Total nitrogen concentrations in the Peace River ranged from <7.5 to 5687 µg/L and showed a positive relationship with discharge. The highest concentration occurred in June 1990 at the downstream site, which was similar to that found for suspended solids levels. The total nitrogen concentrations consisted mainly of Kjeldahl nitrogen (organic nitrogen plus ammonia nitrogen). The low levels of nitrate and nitrite concentrations suggest that most of the nitrogen consisted of particulate organic matter. These findings also were reported by Alberta Environment (1990). They found that in 1988-1989, total nitrogen ranged from about 350 to 650 µg/L and the total Kjeldahl minus ammonia averaged 87% of total nitrogen at the Alberta/ British Columbia border site.

In the Site C tributaries, total nitrogen concentrations were generally higher than those in the Peace River, but the composition of total nitrogen and its relationship to discharge was the same.

No water quality objectives have been established for total nitrogen in the Peace River. In many cases, the survey data indicate that total nitrogen values, particularly in the tributaries, did not comply with the CCREM guideline of 1000 µg/L (CCREM 1987).

Phosphorus

Total phosphorus concentrations in the Peace River ranged from <3 to 2740 µg/L and showed a positive relationship to discharge and suspended solids levels. The highest value was recorded in June 1990 at the downstream site and was probably the result of the increased suspended solids originating from the tributaries. Except for one high value, the total phosphorus concentrations were similar to those recorded in 1988-1989 at the Alberta/British Columbia border site by Alberta Environment (1990). They reported maximum, mean and minimum values of 300, 100 and <10 µg/L, respectively.

Concentrations of total phosphorus in the tributaries were generally higher than those in the Peace River, but the positive relationship with discharge and suspended solids remained the same. The sample obtained from the Halfway River in June 1990 had the highest value (2240 µg/L).

No criteria has been established for acceptable levels of total phosphorus in the Peace River. The survey data from the tributaries; however, indicate that total phosphorus concentrations often exceeded the acceptable concentration of 100 µg/L in flowing water (McNeely et al. 1979).

Carbon

Total organic carbon concentrations in the Peace River ranged from 2.3 to 14.3 mg/L and showed a positive relationship with stream flow. These concentrations were similar to the maximum, mean and minimum values of 7.5, 3.5 and 2.0 mg/L, respectively, reported by Alberta Environment (1990). They found that in 1988-89 the total organic carbon values comprised 94% of dissolved organic carbon. Total organic carbon concentrations in the tributaries were generally higher than those in the Peace River. They also showed a positive relationship with discharge.

Concentrations in the Peace River and its tributaries are relatively low. No water quality objectives have been established for total organic carbon in the Peace River but, the total organic carbon content in natural waters may vary between 1 to 30 mg/L (McNeely et al. 1979) with higher levels usually resulting from anthropogenic inputs.

Silica

Silica concentrations in the Peace River ranged from 2 to 5 mg/L and were generally higher during June and August. This pattern was opposite to that reported by Alberta Environment for 1988-1989 (Alberta Environment 1990). The reason for the difference is uncertain. The concentrations in the tributaries were generally higher than those in the Peace River but they showed the same seasonal pattern. Most natural waters contain less than 5 mg/L of silica, although a range from 1 to 30 mg/L is not uncommon (McNeely et al. 1979).

Mercury

Mercury concentrations in the Peace River and tributaries were usually less than the detection limit (<0.05 µg/L); however, some concentrations, such as 0.21 µg/L at the downstream Peace River site, exceeded the British Columbia water quality criteria for acceptable mercury levels. The 30 day average from at least five weekly samples should not exceed 0.02 µg/L and the maximum level measured should not exceed 0.1 µg/L (Kathman and Cross 1989).

SECTION 4
FISH MOVEMENTS AND POPULATION STATUS

4.1 SPECIES COMPOSITION, ABUNDANCE AND DISTRIBUTION

During the present study 12 sportfish species were captured from the Peace River (Table 4.1). Two species sampled, lake trout and yellow perch, were encountered infrequently. It is likely that the single lake trout captured at the base of the Peace Canyon Dam during June originated from Williston Lake, as this species has been reported from that waterbody (Ted Down, B.C. Ministry of the Environment, pers. comm.). A small number of yellow perch (seven) were captured from a snye of the Peace River located 11 km downstream from the confluence with the Moberly River. A population of yellow perch is thought to exist in Moberly Lake ; therefore, it is probable that these fish were flushed from the lake via the Moberly River and re-established themselves in the snye. Yellow perch were not encountered during 1989 investigations of the Site C study area (Pattenden et al. 1990), nor was this species found during an extensive survey of the Peace River in Alberta (Hildebrand 1990).

Table 4.1 Species list of sportfish captured from the Peace River in the Site C study area, 1990.

Common Name	Abbreviation	Latin Name
Arctic grayling	AG	*Thymallus arcticus* (Pallas)
Rainbow trout	RT	*Oncorhynchus mykiss* Richardson[a]
Bull trout[b]	DV	*Salvelinus confluentus* (Walbaum)
Kokanee	K	*Oncorhynchus nerka* (Walbaum)
Lake trout	LT	*Salvelinus namaycush* (Walbaum)
Lake whitefish	LW	*Coregonus clupeaformis* (Mitchill)
Mountain whitefish	MW	*Prosopium williamsoni* (Girard)
Goldeye	GE	*Hiodon alosoides* (Rafinesque)
Walleye	YW	*Stizostedion vitreum* (Mitchill)
Yellow perch	YP	*Perca flavescens* (Mitchill)
Northern pike	NP	*Esox lucius* (Linnaeus)
Burbot	LING	*Lota lota* (Linnaeus)

[a]Formerly *Salmo gairdneri*.
[b]Also commonly referred to as Dolly Varden, formerly *Salvelinus malma*.

The relative contribution to the catch by the sampling methods employed during each sampling period, are summarized in Table 4.2. In total, 5216 fish were captured from the mainstem Peace River and the majority of these were captured by electrofishing (i.e., 97.9% of the total catch). Although

Table 4.2 Number of fish captured by sampling method, during spring, summer, and fall, Peace River, 1990.

Species	Spring					Summer				
	Angling	Gill net	Beach seine	Set line	Electro-fishing	Angling	Gill net	Beach seine	Set line	Electro-fishing
SPORTFISH										
Arctic grayling	-	-	-	-	455	-	-	4	-	510
Bull trout	1	-	-	-	37	-	-	-	-	30
Goldeye	-	-	-	-	7	-	-	-	-	8
Kokanee	-	-	-	-	101	-	-	-	-	26
Burbot	-	1	-	4	16	-	-	-	-	4
Lake trout	-	-	-	-	1	-	-	-	-	-
Lake whitefish	-	8	-	-	1120	-	-	-	-	218
Mountain whitefish	-	1	-	-	109	-	-	18	-	130
Northern pike	-	5	-	-	33	-	-	-	-	97
Rainbow trout	45	-	-	-	515	7	-	-	-	172
Walleye	-	-	-	-	76	-	-	-	-	161
NON-SPORTFISH										
Longnose sucker	-	-	-	-	2	-	-	-	-	1
Largescale sucker	-	-	-	-	-	-	-	-	-	2
Northern squawfish	-	-	-	-	-	-	-	-	-	-
Total	**46**	**15**	-	**4**	**2472**	**7**	-	**22**	-	**1359**
Percent	**1.9**	**0.6**	-	**0.2**	**97.3**	**0.5**	-	**1.6**	-	**97.9**

Note: Sampling was selective for certain fish species (mountain whitefish and non-sportfish were not collected in proportion to their abundance); consequently the numbers do not accurately represent actual species composition and abundance.

Table 4.2 Concluded.

Species	Fall					Total					Total Methods Combined
	Angling	Gill net	Beach seine	Set line	Electro-fishing	Angling	Gill net	Beach seine	Set line	Electro-fishing	
SPORTFISH											
Arctic grayling	-	-	-	-	440	-	-	4	-	1435	1439
Bull trout	1	-	-	1	41	2	-	-	1	115	118
Goldeye	-	-	-	-	-	-	-	-	-	16	16
Kokanee	-	-	-	-	59	-	-	-	-	186	186
Burbot	-	-	-	-	-	-	1	-	4	20	25
Lake trout-	-	-	-	-	-	-	-	-	-	1	1
Lake whitefish	-	-	-	-	117	-	8	-	-	1556	1564
Mountain whitefish	-	-	-	-	92	-	1	18	-	334	353
Northern pike	-	-	-	-	80	-	5	-	-	225	230
Rainbow trout	1	-	-	-	202	66	-	-	-	917	983
Walleye	-	-	-	-	51	-	-	-	-	288	288
NON-SPORTFISH											
Longnose sucker	-	-	-	-	6	-	-	-	-	10	10
Largescale sucker	-	-	-	-	-	-	-	-	-	2	2
Northern squawfish	-	-	-	-	-	-	-	-	-	1	1
Total	**2**	**-**	**-**	**1**	**1088**	**68**	**15**	**22**	**5**	**5106**	**5216**
Percent	**0.2**	**-**	**-**	**0.1**	**99.7**	**1.3**	**0.3**	**0.4**	**0.1**	**97.9**	

Note: Sampling was selective for certain fish species (mountain whitefish and non-sportfish were not collected in proportion to their abundance); consequently the numbers do not accurately represent actual species composition and abundance.

being a highly efficient method of capture which permits release of fish back to their environment unharmed, some species such as walleye, bull trout, lake whitefish, and large size-classes of rainbow trout, which characteristically inhabit the lower strata of a deep river, were not efficiently sampled. Also, smaller size-classes (i.e., <100 mm) of all species were difficult to capture, and therefore, were under represented in the sample. These factors should be considered when interpreting the results.

Composition, abundance and distribution of the sportfish species that were actively pursued have been assessed by sampling period and reach. Mountain whitefish and non-sportfish were not actively sampled, and therefore, have not been included in the analyses. Percent composition of sportfish species in the catch is presented in Table 4.3 and abundance and distribution information are illustrated in Figures 4.1 and 4.2, respectively. Maximum catch rates at specific locations in the Peace River have been tabulated in Table 4.4. Catch rates for juveniles (i.e., fish ≤200 mm) of selected sportfish species have been summarized in Table 4.5. Detailed information of the above will be presented in Appendix 4.1A of the final report.

Table 4.3 Number and percent composition of major sportfish captured by all sampling methods[a] during spring, summer and fall, Peace River, 1990.

Species	Spring		Summer		Fall		Total	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Arctic grayling	455	18.8	514	41.3	440	44.3	1409	30.3
Bull trout	38	1.6	30	2.4	43	4.3	111	2.4
Goldeye	7	0.3	8	0.6	-	-	15	0.3
Kokanee	101	4.2	26	2.1	59	5.9	186	4.0
Burbot	21	0.9	4	0.3	-	-	25	0.5
Lake whitefish	1128	46.5	218	17.5	117	11.8	1463	31.4
Northern pike	38	1.6	97	7.8	80	8.1	215	4.6
Rainbow trout	560	23.1	179	15.0	203	20.4	942	20.2
Walleye	76	3.1	161	12.9	51	5.1	288	6.3
Total	2424	100	1237	100	993	100	4654	100

[a] Capture methodology principally electrofishing.
Note: Sampling was selective for certain fish species (mountain whitefish and non-sportfish were not collected in proportion to their abundance); consequently the numbers do not accurately represent actual species composition and abundance.

Major Sportfish Species

Lake whitefish

In terms of the total catch, lake whitefish was the most abundant species encountered in the Peace River during 1990; 1463 individuals represented 31.4% of the selected sportfish sample (Table 4.3). A very high proportion of these fish was obtained during spring which, can be attributed to seasonal differences in sampling conditions. Because this species typically inhabits deep water

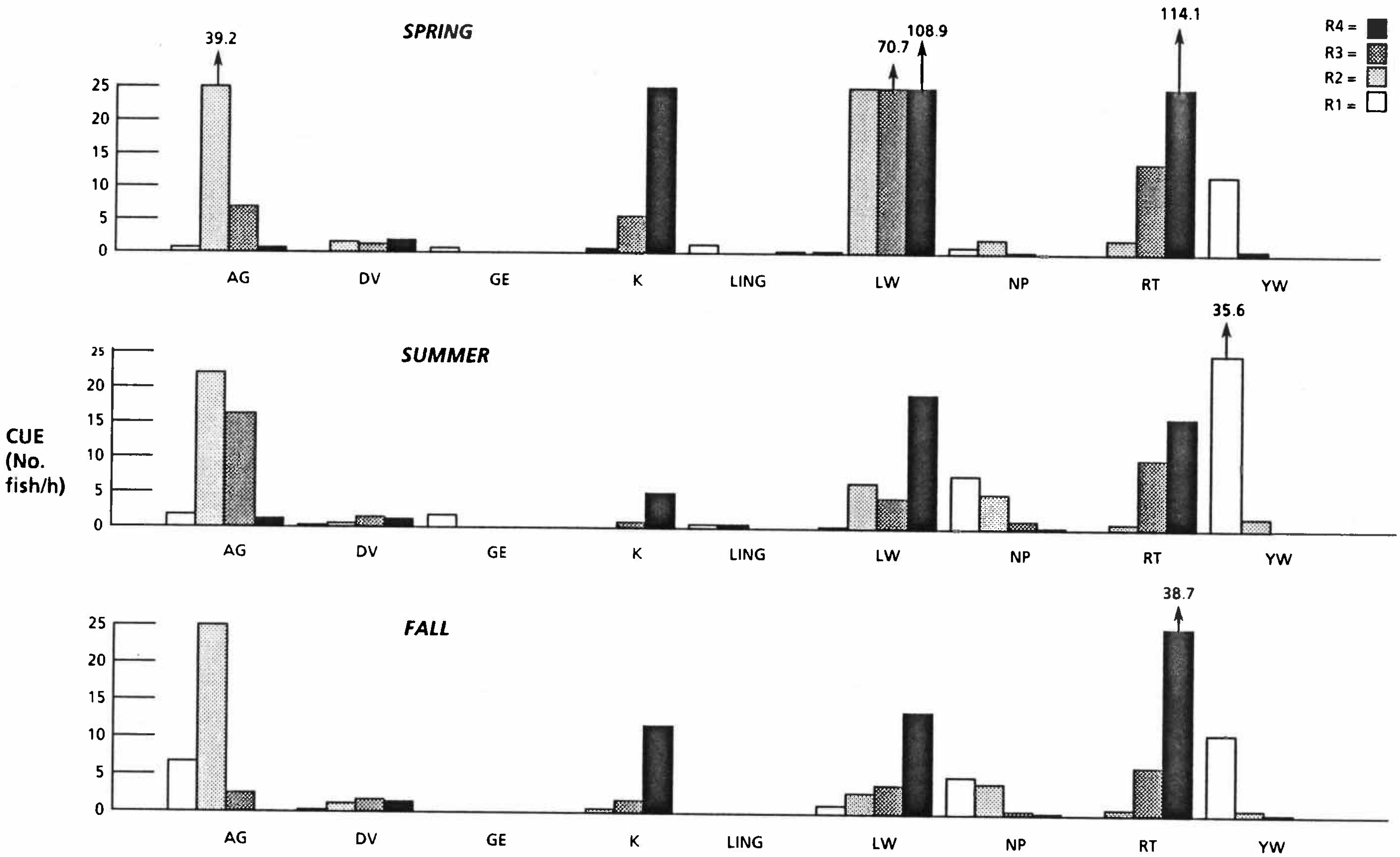

Figure 4.1 **Catch-per-unit-effort of sportfish captured by electrofishing during spring, summer and fall sampling periods, Peace River, 1990.**
Note: Sampling was selective for certain fish species (mountain whitefish and non-sportfish were not collected in proportion to their abundance).

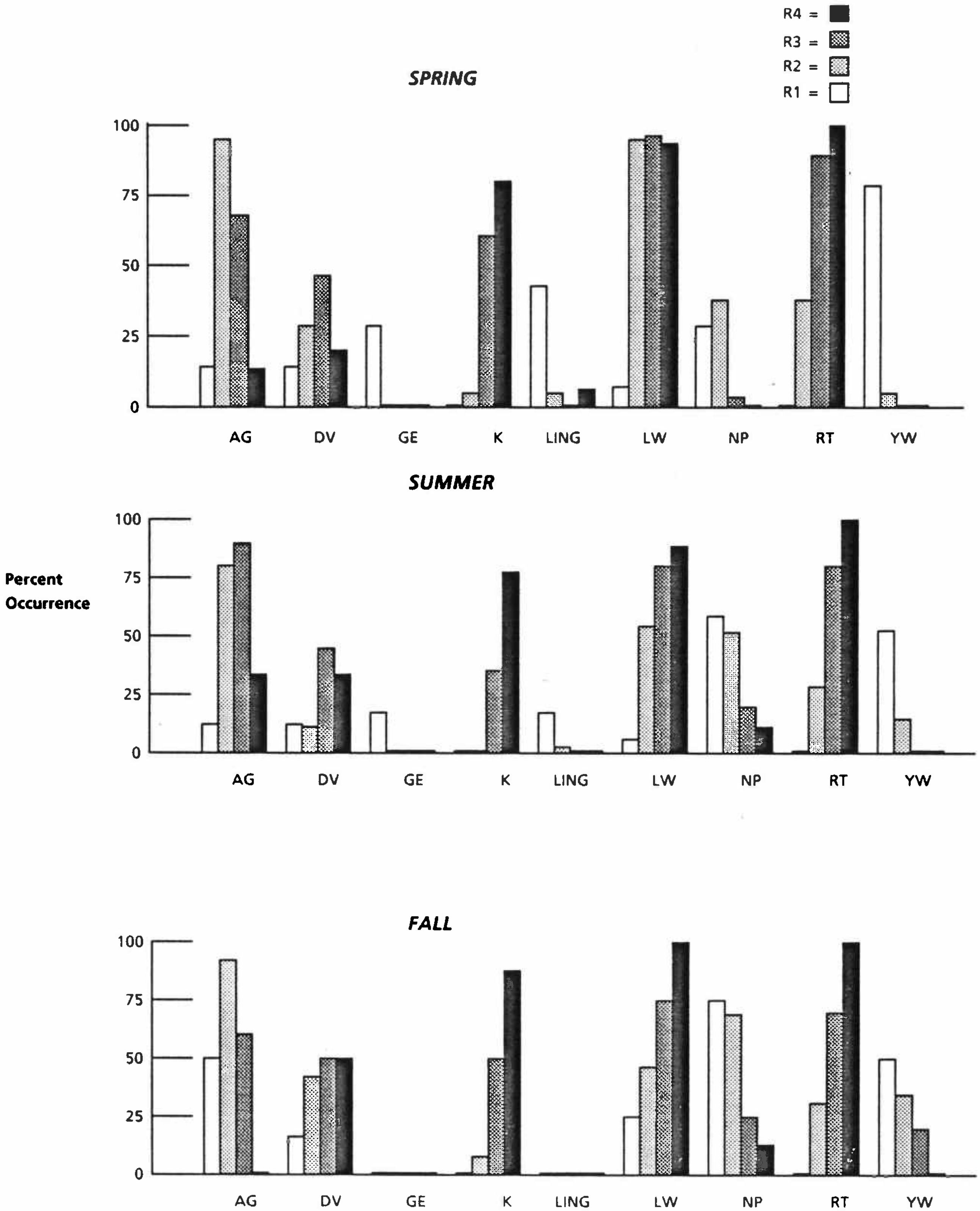

Figure 4.2 **Percent occurrence of sportfish captured in electrofishing runs during spring, summer and fall sampling periods, Peace River, 1990.** Note: Sampling was selective for certain fish species (mountain whitefish and non-sportfish were not collected in proportion to their abundance).

during daylight hours, sampling efficiency was low under normal conditions; however, high turbidity and low water levels during most of the spring sampling period created ideal conditions to capture this species via electrofishing. Numbers of lake whitefish captured during summer and fall, periods of low water turbidity, were not as high.

Table 4.4 Highest catch-per-unit-effort (no. fish/h) and kilometre location for sportfish species captured by electrofishing during spring, summer, and fall, Peace River, 1990.

Session	Reach	SPECIES #fish/h (km location)								
		AG	DV	GE	K	LING	LW	NP	RT	YW
Spring	1	3.2(38)	1.1(40)	4.2(40)	-	8.9(10)	1.1(40)	5.1(26)	-	39.1(26)
	2	98.6(91)	20.7(105)	-	3.0(93)	2.4(82)	128.8(102)	23.4(78)	17.0(91)	2.5(57)
	3	30.6(107)	7.4(106)	-	21.6(143)	-	328.3(143)	7.2(143)	51.9(133)	-
	4	7.8(144)	16.2(150)	-	194.6(150)	2.3(150)	372.9(150)	-	437.8(150)	-
Summer	1	18.9(38)	3.4(27)	17.4(26)	-	3.6(48)	3.8(38)	52.5(48)	-	172.5(48)
	2	98.4(83)	7.5(80)	-	-	2.9(59)	92.3(102)	44.5(54)	7.6(91)	31.0(66)
	3	89.6(107)	7.1(120)	-	4.9(138)	-	12.8(107)	11.8(143)	40.6(130)	-
	4	6.9(144)	6.7(144)	-	16.3(149)	-	50.9(149)	2.3(144)	28.3(145)	-
Fall	1	26.5(46)	1.9(31)	-	-	-	6.0(46)	12.8(27)	-	60.9(27)
	2	102.5(72)	5.5(90)	-	8.3(100)	-	13.7(78)	20.6(78)	9.5(92)	5.0(66)
	3	11.9(128)	7.9(128)	-	6.9(140)	-	20.1(110)	4.5(113)	29.8(128)	2.1(130)
	4	-	3.3(148)	-	32.9(149)	-	29.8(149)	2.5(146)	68.4(148)	-

Lake whitefish were captured in all reaches during all seasons but were most abundant in Reaches 2, 3, and 4 (Figure 4.1). In general, density indices were lower in downstream reaches. Average CUE values were variable and ranged from 108.9 fish/h in Reach 4 during spring to 2.8 fish/h in Reach 2 during fall. Maximum CUE values for this species (Table 4.4) occurred during spring at Km 150 (372.9 fish/h) and Km 143 (328.3 fish/h). The percent occurrence data illustrate a clear pattern (Figure 4.2); lake whitefish were encountered most often in Reach 4 (100% occurrence) followed by Reach 3 (>75% occurrence) and Reach 2 (>45% occurrence). This species was encountered infrequently in Reach 1.

Arctic grayling

Arctic grayling were the second most abundant species encountered; 1409 fish captured represented 30.3% of the total catch. The relative abundance of this species did not remain constant between seasons. Arctic grayling contributed much less to the catch during spring than during the summer and fall. This was principally due to the high proportion of lake whitefish in the catch during spring.

Arctic grayling were most abundant in Reach 2 (Figure 4.1); however, density estimates for a given reach differed between seasons. For example, CUE values in Reach 2 ranged from a high of 39.2 fish/h during spring to a low of 22.0 fish/h during summer. This probably was due to variable sampling conditions. Results do show consistent differences in abundance between reaches. Reach 2 contained the highest densities of Arctic grayling in the study area. Maximum catch rates, 102.5 fish/h and 98.6 fish/h, were obtained at Km 72 and Km 91, respectively. Arctic grayling were not as abundant in other reaches, averaging 8.5 fish/h (Reach 3), and <3.0 fish/h in reaches 1 and 4. Distribution patterns (percent occurrence) of Arctic grayling showed trends similar to the density indices. This species occurred in over 80% of all electrofishing runs in Reach 2, approximately 70% of all runs in Reach 3, and on average, <30% of runs in reaches 1 and 4.

Abundance indices for Arctic grayling ≤200 mm (i.e., juveniles) were low, but exhibited the same distribution pattern as the overall data (Table 4.5). These fish were most abundant in Reach 2 followed by Reach 3. The number of juveniles also increased as the season progressed. This was evident in reaches 1 to 3 but was most pronounced in Reach 2. Because sampling effort was constant between periods, this trend suggests that an influx of juveniles occurred (presumably from the tributaries) during summer and fall.

Table 4.5 Catch-per-unit-effort (No. fish/h) of smaller size-classes[a] of selected sportfish captured by electrofishing during all sampling periods, Peace River, 1990.

Species	Spring				Summer				Fall			
	Reach 1	Reach 2	Reach 3	Reach 4	Reach 1	Reach 2	Reach 3	Reach 4	Reach 1	Reach 2	Reach 3	Reach 4
Arctic grayling	0.08	1.54	0.22	-	0.49	5.27	1.02	-	3.74	5.26	0.35	-
Mountain whitefish[b]	0.13	11.8	8.6	-	-	14.0	22.5	0.68	0.46	12.1	20.0	-
Rainbow trout	-	0.18	2.27	3.03	-	0.14	1.01	1.92	-	0.12	0.80	4.11

[a]Smaller size-class defined as fish ≤200 mm.

[b]Includes fish observed (but not captured) during electrofishing surveys.

Rainbow trout

Rainbow trout were the third most abundant species encountered in the Site C study area. In total, 942 rainbow trout contributed 20.2% to the total sportfish catch. This species was most abundant in Reach 4, with average CUE values ranging from a high of 114.1 fish/h during spring to 16.0 fish/h during summer. The seasonal differences between these indices represent both variable sampling conditions and sampling intensity. During spring, high water turbidity and low water levels made rainbow trout more accessible to electrofishing. Also, sampling effort was extended upstream to the base of the Peace Canyon Dam during spring, an area of high rainbow trout density. A maximum density of 437.8 fish/h was obtained from this area at that time. Dangerous sampling conditions prevented this area from being sampled by electrofishing during subsequent periods.

Catch rates for rainbow trout progressively decreased in a downstream direction through the study area (i.e., >16.0 fish/h in Reach 4, >6.3 fish/h in Reach 3, >0.9 fish/h in Reach 2, and 0.0 fish/h in Reach 1). Percent occurrence information exhibited a similar pattern. Rainbow trout were captured most often in Reach 4 (100% occurrence), in approximately 80% of runs in Reach 3 and <40% of runs in Reach 2.

Rainbow trout ≤200 mm in length were not abundant in the catch but their distribution was similar to the distribution of overall catch data for rainbow trout. Juveniles were most abundant during spring and were predominantly found in Reach 4. The highest average CUE value for this group was obtained during fall in Reach 4.

Walleye

Walleye contributed 6.3% to the total catch during the study. CUE values were comparatively high in Reach 1, ranging from 10.7 fish/h to 35.6 fish/h, but were low in all other reaches. Although average CUE values were low in Reach 2, a concentration of walleye (31.0 fish/h) was encountered at the mouth of the Moberly River (Km 66) during summer. The highest density index (172.9 fish/h) occurred in Reach 1 at the mouth of the Pine River (Km 48) during summer. Water levels were extremely low at the time of sampling making individuals of this species, which prefer deep water, accessible to electrofishing.

Percent occurrence data show that, although walleye are relatively abundant in Reach 1, their presence was not widespread, occurring in about 50% of the runs during most of the sampling periods. This was due to most walleye being captured at major creek mouths. During spring they were encountered at the Kiskatinaw (Km 12) and Beatton (Km 26) rivers. During summer, they also were found at the Pine (Km 48) and Moberly (Km 66) rivers, and during fall, walleye were encountered as far upstream as Lynx Creek (Km 137). The data indicate that an upstream movement occurred as the season progressed. Walleye were not encountered in Reach 1 in early spring during surveys for spawning individuals of this species. Numbers of walleye were then encountered in Reach 1 during late spring sampling, in Reach 2 during summer, and as far upstream as Reach 3 during fall.

Mountain whitefish

Although sampling effort was not directed towards this species during 1990, abundance indices generated from observations made during electrofishing surveys indicate a pattern in the distribution and abundance of juvenile mountain whitefish. Juveniles were abundant in reaches 2 and 3 during all seasons; however, indices increased during the summer period, particularly in Reach 3. This increase probably represents an influx of small fish into the Peace River during the summer sampling period.

Minor Sportfish Species

Low numbers of bull trout were encountered during all sampling periods; its relative abundance did not exceed 5.0%. Catch rates were low in all reaches and never exceeded 2.0 fish/h. The species; however, exhibited a widespread distribution, and occurred in many of the electrofishing runs.

Kokanee contributed 4.0% to the total catch. Catch rates were generally low in all but Reach 4, where average CUE values usually exceeded 10.0 fish/h. Kokanee appeared to be most abundant during spring although this may be an artifact of sampling conditions rather than changes in seasonal abundance.

Northern pike were not abundant in the Site C study area during 1990. This species contributed <5.0% to the total catch and was most often captured in Reaches 1 and 2. Although most numerous in the lower reaches, northern pike were encountered throughout the study area as far upstream as Km 147. Burbot and goldeye occurred infrequently in the catch, and were restricted mainly to Reach 1. Goldeye were captured only in the lowest reach; however, burbot were encountered as far upstream as Km 150 in Reach 4.

Summary and Comparisons to the 1989 Study

Twelve sportfish species were encountered in the Peace River during investigations of the Site C study area during 1990. Major species, in order of numerical importance, included lake whitefish, Arctic grayling, rainbow trout, and walleye. Low numbers of bull trout, kokanee, northern pike, goldeye, and burbot also were sampled. Two species, lake trout and yellow perch, were encountered rarely. Although abundant in the Site C study area, mountain whitefish and sucker species were not actively sampled during 1990; therefore, their relative abundance was not established.

These results are very similar to that of 1989 (Pattenden et al. 1990). The dominant species in the catch remained the same and their relative abundance was similar with one exception; lake whitefish was the most abundant species captured during 1990, but was the third most abundant species (excluding mountain whitefish) in the 1989 surveys. This is explained by the large number of lake whitefish captured during spring 1990, which skewed the importance of this species in the total catch upward. As discussed earlier, sampling, conditions during spring, (i.e., high water turbidity and low water levels) allowed more efficient capture of this species. This suggests that abundance indices obtained during summer and fall (i.e., periods of low water turbidity) may be underestimates of the abundance of this species. Population estimates developed for lake whitefish (see Section 4.5) indicate that this species was more abundant than the CUE values would suggest.

Another difference between 1989 and 1990 are higher density indices obtained for most species during the present study. This can be explained by the increased effort expended for target species during 1990. Mountain whitefish, the most abundant species during 1989, was excluded from systematic sampling during 1990. Consequently, the remaining species were sampled more intensively.

Similar to the 1989 results, the abundance of a particular species during 1990 was dependent on location in the Peace River and sampling period. Arctic grayling, rainbow trout, and lake whitefish appeared to have sedentary populations which exhibited well defined areas of abundance. Arctic grayling were most numerous in Reach 2, while rainbow trout and lake whitefish numbers were highest in Reach 4. Bull trout were low in number but were widespread throughout the river. Kokanee also were limited in number, but appeared to prefer reaches 3 and 4. Cool water species such as walleye, northern pike, goldeye and burbot exhibited low densities but were most abundant in Reach 1. Walleye and northern pike were the dominant species in this group and occurred in other reaches of the study area. Walleye numbers appeared to increase in an upstream direction as the season progressed from spring to fall. Although northern pike exhibited this pattern in 1989, this trend was not evident in 1990.

Changes in abundance indices of juvenile Arctic grayling and mountain whitefish suggest that there is an influx of these fish into the Peace River. Juveniles of both species probably originated primarily from the Halfway River and represent movement out of rearing areas during summer and fall prior to winter. The increased abundance of mountain whitefish in Reach 3, which is located upstream of the Halfway River (Km 105), may represent movement of juveniles upstream once they enter the Peace River. Juvenile Arctic grayling increased in abundance in reaches 1, 2, and 3. These fish may have been individuals which redistributed themselves in the Peace River after entering from the Halfway River system, or they may have emigrated from tributary streams associated with each reach (i.e., Farrell Creek in Reach 3; Moberly River in Reach 2; Pine River in Reach 1). The abundance of small rainbow trout increased in Reach 4 during fall. This increase was likely due to immigration of hatchery fish into the Site C study area from upstream release sites (T. Down, Ministry of the Environment, pers. comm.). Movements of juvenile fish will be discussed in more detail in Section 4.4.

As shown by the present study and the 1989 study, cold water sportfish species such as mountain whitefish, lake whitefish, Arctic grayling, and rainbow trout dominate the fish assemblages encountered in upper reaches of the Site C study area of the Peace River. Reach 1 appears to be a transition zone between cold water species and cool water fish such as walleye, northern pike, and goldeye. This is due to changes in habitat characteristics of the river, such as higher water temperatures, higher water turbidity, lower gradient, and finer substrate composition, which occur in a downstream direction. Studies conducted on the Peace River in Alberta (Hildebrand 1990) show quite clearly the near absence of cold water species such as rainbow trout and Arctic grayling downstream of the B.C.-Alberta border. These findings suggest that these species are restricted primarily to the B.C. portion of the Peace River.

4.2 LIFE HISTORY

During the 1990 study, life history data were collected from a sample of captured individuals from several species. To complete other components of the study (i.e., mark-recapture study), most fish upon capture, were tagged and released. Due to these factors only a limited number of fish were sacrificed; therefore, small sample sizes were available for some components of the analyses (i.e., age at maturity and the degree of gonad development). To reduce variation of estimates which are correlated with growth (see Section 4.5 for examples), life history analyses were conducted using databases acquired during a single sampling period (i.e., spring, summer, or fall). Life history parameters examined included length distributions (Figure 4.3), condition factors, length-weight relationships and age-length relationships, age at maturity, and the gonadosomatic index (GSI). Complete life history information for all species will be tabulated in a limited distribution data volume. Summaries for major fish species captured from the Peace River are presented in the following section.

Life History Summaries

Lake Whitefish

Lake whitefish from the Peace River were sampled for life history information during spring. The median length of 1174 fish sampled was 335 mm. A narrow length distribution was encountered (Figure 4.5) with most fish belonging to the 320 to 339 mm size-class (34.9%). The mean condition factor for this species was 1.09 and the length-weight relationship was as follows:

$$W = (0.626 \times 10^{-5}) \times L^{3.09} \qquad (n=1171;\ r^2 = 0.882)$$

where W = weight in g
L = fork length in mm
n = sample size; and
r^2 = coefficient of determination.

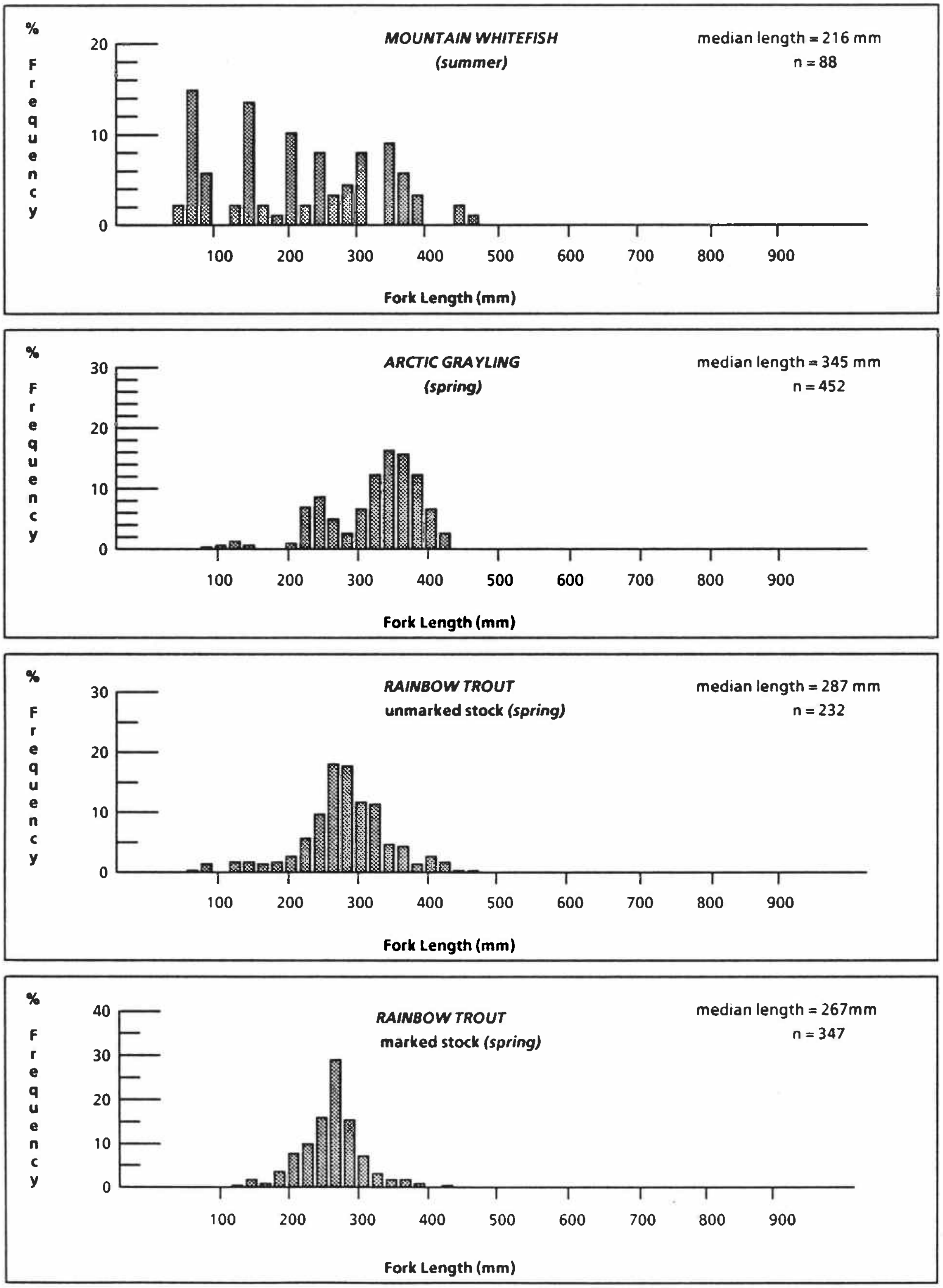

Figure 4.3 Length frequencies of selected sportfish captured from the Peace River, 1990.

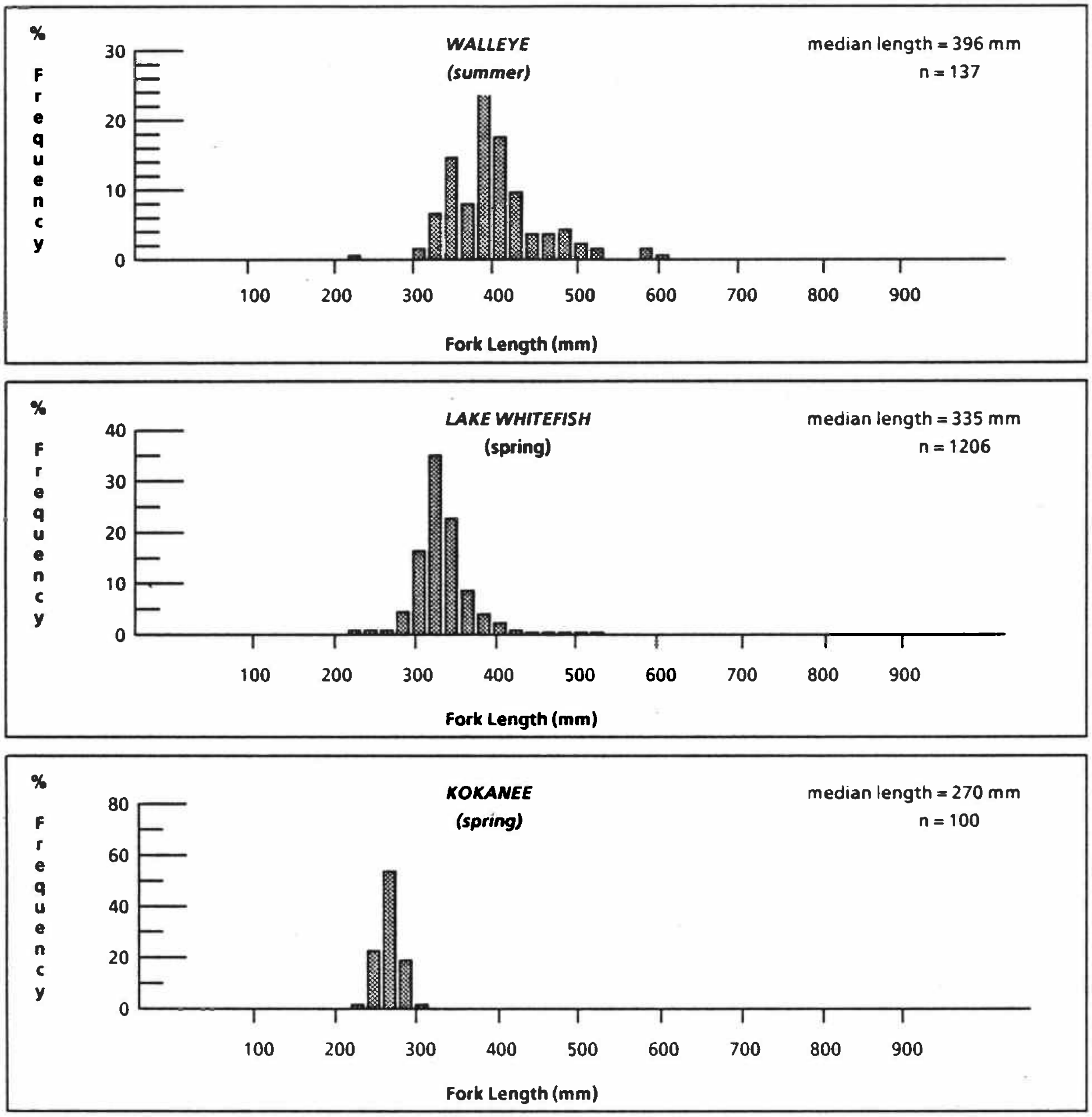

Figure 4.3 Continued.

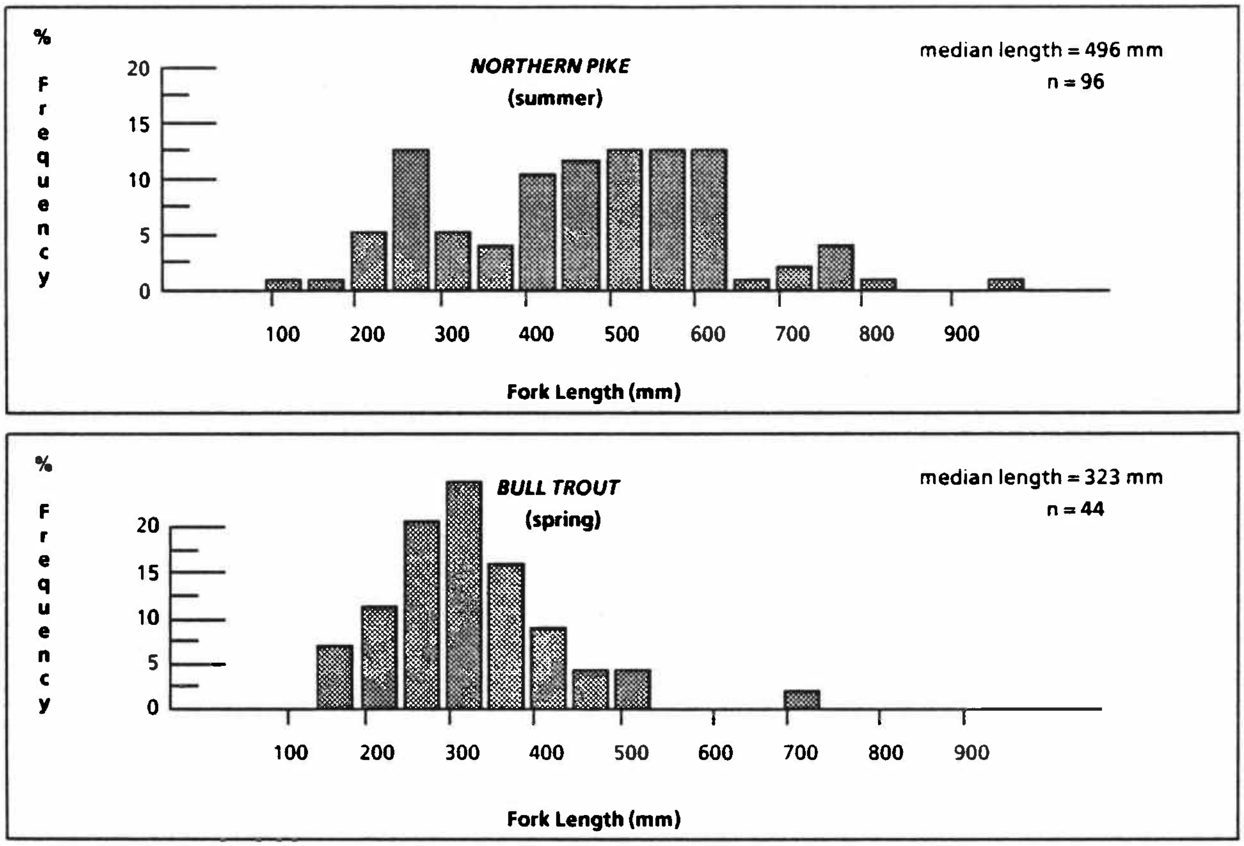

Figure 4.3 Concluded.

Table 4.6 Age-length data for lake whitefish sampled from the Peace River (Site C study area) collected during 1990 ($\bar{x}$ = mean fork length (mm) and n = sample size).

Location		Age														
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Peace River (1990)	$\bar{x}$	-	109	-	250	324	336	365	400	415	451	450	472	536	523	531
	n	-	1	-	14	44	31	21	18	20	6	3	5	6	2	1

Arctic Grayling

In total, 425 Arctic grayling from the Peace River were sampled for life history information during spring. The median length of these fish was 345 mm. The predominant size-class was the 340 to 359 mm class which contained 16.4% of the individuals. The largest individual encountered was 434 mm in length and weighed 987 g. The mean condition factor for this species was 1.19.

The length-weight relationship for Arctic grayling was as follows:

$$W = (0.793 \times 10^{-5}) \times L^{3.070} \qquad (n = 425;\ r^2 = 0.986)$$

where W = weight in g
L = fork length in mm
n = sample size; and
r^2 = coefficient of determination

Table 4.7 Age-length data for Arctic grayling sampled from the Peace River (Site C study area) collected during 1989 and 1990 ($\bar{x}$ = mean fork length in mm and n = sample size).

Location		Age									
		0	1	2	3	4	5	6	7	8	9
Peace River(1989)	$\bar{x}$		184	280	332	353	427	436			
	n		17	12	2	7	2	2			
Peace River(1990)	$\bar{x}$		127	248	320	366	391	413	429		
	n		11	76	41	42	14	14	5		

Rainbow Trout

The rainbow trout population in the Peace River was composed of two separate stocks: hatchery fish (marked stock) which were recruited directly into the river by transplanting or by entrainment from Dinosaur Lake, and wild fish (unmarked stock) which were produced in the Peace River (Hammond 1986). The relative importance of these stocks to the total catch is outlined in Table 4.8. Overall, the marked stock contributed 55.1% of the 983 fish checked for marks. A creel survey of the

Peace River fishery conducted by B.C. Ministry of Environment during 1985 (Hammond 1986) found that marked fish accounted for 38.3% of the total catch.

Table 4.8 Number and percentage of catch of unmarked and marked rainbow trout captured from the Site C study area, Peace River 1990.

Stock (Year Class)	Reach 4 No. (%)	Reach 3 No. (%)	Reach 2 No. (%)	Reach 1 No. (%)	Total No. (%)
Unmarked	206(37.4)	186(51.1)	49(72.1)	-	441(44.9)
Marked					
L. Max. (1988)	79	125	12	-	216
R. Max. (1988)	27	7	2	-	36
Ad. (1987)	234	43	4	-	281
L. Max. (1986)	3	-	-	-	3
R. Max. (1985)	1	-	-	-	1
Ad. (1984)	1	3	1	-	5
Hatchery Total (%)	345(62.6)	178(48.9)	19(27.9)	-	542(55.1)
Overall Total	551	364	68	-	983

Because life history parameters such as age-length relationships may differ between hatchery and wild fish these groups will be discussed separately in the following section.

Marked stock

Three hundred and forty seven marked rainbow trout were sampled for life history information during spring. The predominant size-class was the 260 to 279 mm class which contained 29.1% of the individuals. The median size was 267 mm; 1.03 was the mean condition factor. The largest marked rainbow trout sampled was 391 mm in length.

The length-weight relationship for hatchery rainbow trout was as follows:

$$W=(0.466 \times 10^{-5}) \times L^{3.141} \qquad (n=333;\ r^2=0.958)$$

where W = weight in g
L = fork length in mm
n = sample size; and
r^2 = coefficient of determination

Unmarked stock

In total, 232 unmarked rainbow trout from the Peace River were sampled for life history information during spring. The median length for these fish was 287 mm. The predominant size-class was the 260 to 279 mm class which contained 18.1% of the individuals. The largest fish encountered was 356 mm in length and the mean condition factor for unmarked rainbow trout was 1.09.

The length-weight relationship for these fish was as follows:

$$W=(0.118 \times 10^{-5}) \times L^{2.984} \qquad (n=216;\ r^2=0.973)$$

where W = weight in g
L = fork length in mm
n = sample size; and
r^2 = coefficient of determination

Table 4.9 Age-length data for rainbow trout from the Peace River (Site C study area) collected during 1989 and 1990 ($\bar{x}$ = mean fork length in mm and n = sample size).

Location		Age 0	1	2	3	4	5	6	7	8	9
Peace River(unmarked)											
1989	$\bar{x}$		116	226	285	350	399				
	n		*5*	*23*	*11*	*6*	*1*				
1990	$\bar{x}$			193	288	333	394	356			
	n			*17*	*63*	*38*	*7*	*1*			
Peace River(marked)											
1989	$\bar{x}$		127	208	302		372				
	n		*7*	*27*	*5*		*2*				
1990	$\bar{x}$			215	273	289	324	385			
	n			*82*	*198*	*44*	*13*	*2*			

Walleye

One hundred thirty seven walleye were examined for life history information during summer. The median size of fish in this sample was 396 mm. The predominant size-class included the 380 to 399 mm group which each contributed 24.1% of the individuals. The largest fish encountered weighed 2510 g and was 601 mm in length. The mean condition factor for this species was 1.08.

The length-weight relationship for walleye in the Peace River was as follows:

$$W = (0.902 \times 10^{-5}) \times L^{3.030} \qquad (n = 136; r^2 = 0.976)$$

where W = weight in g
L = fork length in mm
n = sample size; and
r^2 = coefficient of determination

Table 4.10 Age-length data for walleye from the Peace River (Site C study area) collected during 1989 and 1990 ($\bar{x}$ = mean fork length (mm) and n = sample size).

Location		Age 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	15+
Peace River (1989)	$\bar{x}$						314	384	412	418	445	466	435	546			586	
	n						4	2	3	5	6	4	3	1			1	
Peace River (1990)	$\bar{x}$					351	375	379	396	429	443	442	499	554				
	n					7	26	24	18	20	8	8	4	3				

Bull trout

A limited number of bull trout were sampled for life history information from the Peace River. In total, 44 were collected during the spring sampling period. The median length of these fish was 323 mm. The predominant size-classes included the 300 to 349 mm group, which represented 25.0% of the total. The largest individual encountered was 500 mm in length and weighed 1918 g. The mean condition factor was 1.18 for this species.

The length-weight relationship for bull trout was as follows:

$$W = (0.818 \times 10^{-5}) \times L^{3.062} \qquad (n=43;\ r^2 = 0.983)$$

where W = weight in g
L = fork length in mm
n = sample size; and
r^2 = coefficient of determination

Since very few of these individuals were killed, insufficient data were obtained for presentation of age-length data.

Mountain whitefish

The median length of mountain whitefish captured during the summer was 216 mm. The predominant size-class was 60 to 90 mm which represented 14.8% of the individuals sampled (Figure 4.3). The largest individual captured was 453 mm in length and weighed 1112 g. The mean condition factor for this species was 1.08 and the length-weight relationship was as follows:

$$W = (0.426 \times 10^{-5}) \times L^{3.171} \qquad (n=77;\ r^2 = 0.992)$$

where W = weight in g
L = fork length in mm
n = sample size; and
r^2 = coefficient of determination

Table 4.11 Age-length data for mountain whitefish sampled from the Peace River (Site C study area) collected during 1989 and 1990 ($\bar{x}$ = mean fork length in mm and n = sample size).

Location		Age														
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Peace River(1989)	$\bar{x}$	93	172	220	249	273	295	323	342	365	369		429	448	453	476
	n	5	4	3	3	5	11	3	1	4	4		3	2	1	1
Peace River(1990)	$\bar{x}$		181	212	234	284	306	339	357	359	387	468	453			
	n		2	6	8	6	6	3	6	4	4	2	1			

Northern pike

The median size of individuals captured during summer was 496 mm. Two size groups dominated the sample. Size-class 250 to 299 mm represented 12.5% of the individuals (Figure 4.3) while size-classes 500 to 549, 550 to 599 and 600 to 649 mm each accounted for 12.5% of the fish captured. The largest individual encountered was 860 mm in length and weighed 4908 g. The mean condition factor for this species was 0.72 and the length weight relationship was as follows:

$$W = (0.570 \times 10^{-4}) \times L^{3.040} \qquad (n=91;\ r^2 = 0.993)$$

where W = weight in g
L = fork length in mm
n = sample size; and
r^2 = coefficient of determination.

Table 4.12 Age-length data for northern pike sampled from the Peace River (Site C study area) collected during 1990 ($\bar{x}$ = mean fork length (mm) and n = sample size).

Location	Age									
	0	1	2	3	4	5	6	7	8	9
Peace River (1990) $\bar{x}$		162	345	428	535	651	641	780	808	876
n		1	17	21	21	9	7	2	1	1

Kokanee

A limited number of kokanee were sampled for life history information during spring. The median length of these fish was 270 mm. The predominant size-class was 260-279 mm which represented 54.0% of the sample. The largest individual encountered was 300 mm and weighed 342 g. The mean condition factor for this species was 1.27.

The length-weight relationship for kokanee was as follows:

$$W = (0.333 \times 10^{-3}) \times L^{2.416} \qquad (n=99;\ r^2 = 0.808)$$

where W = weight in g
L = fork length in mm
n = sample size; and
r^2 = coefficient of determination.

Twenty five of the 26 fish aged were from age-class 3.

4.3 FEEDING HABITS

The results in the following section are based on analyses of a relatively small number of stomachs of selected sportfish species. Data were obtained from fish that succumbed during sampling or from fish which were sacrificed for other components of the study. They represent a range of size-classes taken during the three sampling periods in a wide variety of habitats. The data are insufficient to properly assess the relationship between feeding habitats and fish rearing or invertebrate production areas, and therefore; the discussion provides a general overview. Summary information is presented in Table 4.13 and is illustrated by percent occurrence of food items in stomachs (Figure 4.4) and percentage of food points allotted to food items (Figure 4.5), a volumetric measure of fullness. Data used for these analyses will be presented in Appendix 4.3A. of the final report.

Arctic grayling

Stomach contents from 37 Arctic grayling, ranging in size from 181 to 421 mm, were examined. One stomach was empty and the average fullness index exceeded 68.2% (Table 4.13). A diverse assemblage of insects were consumed; trichopterans were the predominant food item occurring in 37.8% of all stomachs examined (Figure 4.4) but hymenopterans accounted for the highest volume (15.5%) (Figure 4.5). Hemipterans ("true bugs") and coleopterans (beetles) also were prevalent food items consumed.

Rainbow trout

Of the 23 fish analyzed, four contained empty stomachs and the average fullness was 44.5%. Insects were the major food group utilized (60.9% occurrence and 29.3% fullness). Within this group, hemipterans and ephemeropterans accounted for most of the food items consumed. Fish remains were found in two stomachs, accounting for 8.7% occurrence and 3.3% fullness. Crossman and Larkin (1959) noted a wide variety of organisms in the diet of rainbow trout including plankton, fish, and insects; small forage fish appeared to be a major food item of fish greater than 200 to 250 mm. In the absence of small forage fish, the authors indicated that benthic invertebrates became the major component of the diet. The results of the present analysis, which examined fish ranging in size from 252 mm to 403 mm, are very similar; rainbow trout predominantly fed on aquatic insects.

Kokanee

The stomach contents of 18 kokanee were examined; eight stomachs were empty and the average fullness was 20.8%. The diet of kokanee in the Peace River consisted of a variety of food organisms of which insects, principally trichopterans (16.7% occurrence and 4.4% fullness), were the dominant food item. Zooplankton are a major constituent of the kokanee diet in lentic environments

Table 4.13 Results of stomach content analyses of selected sportfish captured from the Peace River during spring,summer, and fall, 1990.

Food item	Species																			
	Arctic grayling (n = 37)				Rainbow trout (n = 23)				Kokanee (n = 18)				Mountain whitefish (n = 115)				Lake whitefish (67)			
	No. in which item occurred		Food 'point' total		No. in which item occurred		Food 'point' total		No. in which item occurred		Food 'point' total		No. in which item occurred		Food 'point' total		No. in which item occurred		Food 'point' total	
	Occurrence	%	Points	%	Occurrence	%	Points	%	Occurrence	%	Points	%	Occurrence	%	Points	%	Occurrence	%	Points	%
Insecta	31	83.8	301	40.7	14	60.9	135	29.3	6	33.3	36	10.0	65	56.5	523	22.7	16	23.9	154	11.5
Coleoptera (Col.	9	24.3	36	4.9	5	21.7	18	3.9	-	-	-	-	1	0.9	1	<0.1	-	-	-	-
Hymenoptera (Hym.)	13	35.1	115	15.5	2	8.7	17	3.7	1	5.6	2	0.6	1	0.9	1	<0.1	-	-	-	-
Ephemeroptera (Eph.)	4	10.8	11	1.5	3	13.0	24	5.2	2	11.1	11	3.1	30	26.1	99	4.3	9	13.4	83	6.2
Trichoptera (Tri.)	14	37.8	56	7.6	1	4.3	2	0.4	3	16.7	16	4.4	46	40.0	330	14.3	3	4.5	35	2.6
Hemiptera (Hem.)	8	21.6	48	6.5	5	21.7	55	12.0	-	-	-	-	3	2.6	11	0.5	4	6.0	23	1.7
Diptera[a] (Dip.)	4	10.8	11	1.5	6	26.1	19	4.1	1	5.6	4	1.1	21	18.3	61	2.7	4	6.0	11	0.8
Plecoptera (Ple.)	4	10.8	24	3.2	-	-	-	-	-	-	-	-	12	10.4	20	0.9	-	-	-	-
Terrestrial (Terr.)	-	-	-	-	-	-	-	-	1	5.6	3	0.8	-	-	-	-	1	1.5	2	0.1
Mollusca	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	5	4.3	22	1.0	8	11.9	63	4.7
Gastropoda (Gas.)	-	-	-	-	-	-	-	-	-	-	-	-	5	4.3	22	1.0	7	10.4	44	3.3
Pelecypoda (Pele.)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	7.5	19	1.4
Copepoda	1	2.7	1	0.1	1	4.3	5	1.1	2	11.1	6	1.7	1	0.9	1	<0.1	1	1.5	1	<0.1
Fish	0	0.0	0	0.0	2	8.7	15	3.3	0	0.0	0	0.0	2	1.7	11	0.5	1	1.5	5	0.4
Unidentified (Uni.)	23	62.2	203	27.4	11	47.8	50	10.9	7	38.9	33	9.2	38	33.0	148	6.4	6	9.0	12	0.9
Empty	1	2.7	-	31.8	4	17.4	-	55.4	8	44.4	-	79.1	44	40.9	-	69.3	47	4.5	-	82.5
Average Fullness			13.6	68.2			8.9	44.6			4.2	20.9			6.1	30.4			3.5	17.5

[a] Principally chironomid larvae.

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movements. This information should be incorporated into the present database and movement patterns reassessed at a future date.

Radio Telemetry

The radio telemetry program initiated in 1989 has been ongoing. Many transmitters implanted during 1990 will remain active through to fall 1991 (i.e., 22 walleye, 7 bull trout, 5 northern pike, and 7 Arctic grayling). The radio tracking program should be continued during spring and summer 1991 to take advantage of information available from radio tagged fish in the system. The data obtained will provide valuable information on pre- and post-spawning movements of these species.

SECTION 6 CONSIDERATIONS FOR FUTURE STUDIES

Although a significant amount of information has been obtained from the study program, gaps in the database still remain.

6.1 WATER TEMPERATURE

To develop a complete and comprehensive database of water temperatures in the study area, thermographs should be reinstalled in tributaries during early spring of 1991 and left in place until just prior to freeze-up (October 1991). Thermographs in the mainstem Peace River should be downloaded and redeployed in early spring of 1991.

6.2 FISH POPULATION STATUS AND MOVEMENTS

Halfway River - Species Abundance, Distribution and Habitat Use

Due to budget restrictions imposed in 1990, limited information on species abundance and distribution in the mainstem Halfway River was obtained during the Site C fisheries study. This river system is apparently an important spawning area for mountain whitefish, and possibly for bull trout, but the extent of this activity is unknown. Due to the size of this river (i.e., largest tributary of Peace River within the Site C study area), a more complete database is required.

Pine River Studies

Due to budget restrictions imposed in 1990, the fisheries studies planned for the Pine River system had to be deferred. Prior to re-initiation of the Site C project, the studies of the Pine River should be completed.

Fish Movements

Tag Recoveries

A concerted effort was made to tag a large number of fish during the study. As a result of this effort, tags recovered by recreational anglers will continue to be submitted to the Ministry of the Environment for several years to come. These tags represent valuable information pertaining to fish

Table 5.3 Results of studies which assessed mercury concentration in muscle tissue of fish captured from the Peace River during 1987 and 1988.

Species	Sample Size	Mean Length (mm)	Mean Mercury Conc.[a]	Standard Deviation	Maximum	Minimum	Corr. Mercury Content-Length
Reuben (1989)							
Bull trout	2	531.0	0.24	0.057	0.28	0.20	-
Rainbow trout	3	310.3	0.05	0.029	0.08	0.03	0.396[n.s.]
Kokanee	1	317	0.06	-	-	-	-
Lake whitefish	20	338.2	0.09	0.033	0.17	0.05	0.129[n.s.]
Northern pike	1	613	0.10	-	-	-	-
Zenon Environmental Inc. (1987)							
Bull trout	1	545	0.07	-	-	-	-
Whitefish[b]	1	500	<0.05	-	-	-	-
Walleye	4	455.8	0.17	0.108	0.32	0.07	-

[a]Value expressed as milligrams of mercury/wet kilogram of muscle tissue.
[b]Species unknown.
[n.s.]Not significant.

the 0.5 mg/kg maximum allowable limit. Five additional bull trout samples exceeded 0.1 mg/kg. Other species which exhibited high maximum values were walleye (seven of eight samples exceeded 0.1 mg/kg), northern pike (seven of 31 samples exceeded 0.1 mg/kg) and burbot (six of nine samples exceeded 0.1 mg/kg). Lake whitefish exhibited a mean value of 0.073 which was similar to that of northern pike. This high mean value can probably be attributed to a value of 0.130 found in one sample. All other species exhibited mean values ≤0.07 mg/kg. The lowest mean values of mercury concentration in muscle tissue were observed for rainbow trout and Arctic grayling (0.034 mg/kg), and kokanee (0.020 mg/kg), species which generally were not piscivorous (see section 4.3).

Table 5.2 Mercury analysis of muscle tissue from fish captured from the Peace River, 1989 and 1990.

Species	Sample Size	Mean Mercury Concentration[a]	Standard Deviation	Max.	Min.	Corr. Mercury Content-Length
Arctic grayling	2	0.034	0.0106	0.041	0.026	-
Bull trout	13	0.153	0.2139	0.835	0.013	0.819*
Kokanee	23	0.020	0.0105	0.038	0.001	0.303[n.s.]
Burbot	9	0.126	0.0482	0.201	0.062	0.298[n.s.]
Lake whitefish	11	0.073	0.0260	0.130	0.046	0.476*
Mountain whitefish	34	0.043	0.0313	0.120	0.001	0.543*
Northern pike	31	0.073	0.0510	0.250	0.003	0.450*
Rainbow trout	33	0.034	0.0171	0.092	0.012	0.011[n.s.]
Walleye	8	0.147	0.0763	0.240	0.010	0.107[n.s.]

[a]Value expressed as milligrams of mercury/wet kilogram of muscle tissue.
*Significant at $P<0.05$.
[n.s.]Not significant.

Mercury concentration in muscle samples showed a positive correlation with body length in all species for which a sufficient sample size was available for comparison. This relationship was statistically significant in four cases, the highest correlation being expressed for bull trout ($r=0.819$). The higher mercury level in larger (older) fish probably reflects the bioaccumulation and long retention time of mercury in aquatic biota.

A limited amount of information was available from the Peace River for comparative purposes. Fish tissue samples collected from the Taylor area (Km 45) during 1987 (Zenon Environmental Inc. 1987) and from the Hudson Hope area (Km 143) of the Peace River during 1988 (Rueben 1989) are summarized in Table 5.3. The results of these studies appear to be similar to those of the Site C study. Statistical comparisons of sample means between studies could be performed for two species -- lake whitefish and walleye. These tests showed no statistical differences (T-test; $P>0.40$).

SECTION 5
MERCURY ANALYSIS OF FISH TISSUES

During 1989 and 1990 background data were collected for mercury concentrations in muscle tissue samples of fish captured from the Peace River. In total, 164 tissue samples were obtained from nine fish species.

The majority of fish were collected from within the Site C development area (upstream of Km 66); however, to augment the database, 8 walleye, 10 northern pike, and 2 burbot were collected downstream of Taylor (Km 45). For each species a wide range of size-classes was obtained (Table 5.1). The results of the analysis are presented in Table 5.2. Detailed data will be presented in Appendix 5.0A of the final report.

Table 5.1 Number and size range of fish sampled for mercury analysis captured from the Peace River, 1989 and 1990.

Species	Number Sampled	Age		Length (mm)		Weight (g)	
		Mean	Range	Mean	Range	Mean	Range
Arctic grayling	2(2)[a]	4.0	3-5	368.0	361-375	772.0	682-862
Bull trout	13(10)	6.9	4-9	473.3	330-814	1550.5	408-5700
Kokanee	23(21)	2.9	2-3	291.2	254-334	307.3	203-449
Burbot	9(9)	5.9	3-9	527.0	370-729	1000.8	342-2068
Lake whitefish	11(11)	5.8	4-11	373.1	320-513	720.6	380-2300
Mountain whitefish	34(33)	7.8	4-14	369.9	272-487	672.2	222-1294
Northern pike	31(9)	4.7	3-9	534.8	310-790	1297.9	210-3650
Rainbow trout	33(29)	3.3	1-5	323.1	247-425	435.9	178-878
Walleye	8(8)	7.1	5-9	388.8	343-415	722.6	484-936
Total	**164**						

[a]Sample size of aged fish given in brackets.

The maximum allowable level of mercury in muscle tissue of fish sold in Canada for human consumption is 0.5 mg/kg wet weight (Bruce and Spencer 1979). Mercury concentration in muscle samples collected during the present study varied depending on the species and fish size. Highest mean values were observed for bull trout (0.153 mg/kg), walleye (0.147 mg/kg), burbot (0.126 mg/kg), and northern pike (0.073 mg/kg), species which are typically piscivorous (i.e., fish eaters) and most likely to bioaccumulate significant levels of methyl mercury (Bruce and Spencer 1979). The highest value recorded was 0.835 mg/kg obtained from a bull trout and was the only sample which exceeded population estimates for rainbow trout should be used with caution. In contrast, the consistency in Arctic grayling population estimates, catch rates, and substantial number of tags recovered in 1990 (53 - 69), are good indications that the 1990 estimates for Arctic grayling are reliable. The population estimate for walleye could be an overestimation if any immigrants from outside the study area were included in the fish sampled for marks. Again, the consistency between the three population estimates suggests that immigrants were either a consistent or small portion of the total walleye population in the study area. Finally, the bounds for the lake whitefish population estimates computed from 1990 tag recoveries suggest that this population was at least 24 000 individuals and could be as large as 140 000. These population estimates are a clear reflection of the substantial number of fish examined in 1990 and the low number of tags recovered.

The 1990 field season included two minor adjustments to the 1989 study design. First, length measurements were obtained for all marked fish recaptured. These measurements provided a direct estimate of the growth rates for each species that verified the results of the 1990 growth analysis based on age-length data. Second, the number of sampling intervals was expanded from three to seven. The additional four sampling intervals were achieved with a limited amount of field effort but increased the number of sampling sequences from 3 to 21, and provided clear indications of within season population trends or estimation biases. These modest reallocations of survey effort contributed to the substantial improvements in both the accuracy and precision of the Arctic grayling, rainbow trout, and walleye population estimates.

The second assumption requires that the marks be applied throughout the study area, that the marked individuals mix with the unmarked population and that recovery efforts are made on the same population as was marked. The sampling periods and data used in the analyses were selected so as not to violate these requirements (i.e., growth analysis). Within each sampling period tagging and tag recovery was conducted throughout the study area using the same fishing gear. The probability that tagged fish mixed with the untagged population is high if there are several days between the tag release and recapture periods. While release and recapture data were obtained from each sampling period, only those fish recaptured more than two weeks after release were included in the population analysis.

The population estimates represent the estimated number of fish of each species in the study area of taggable size (i.e., >240 mm for rainbow trout and kokanee, and >250 mm for other species). Each data component used to produce the population estimates (tags applied, tags recovered and fish examined) was adjusted to account for the recruitment of small fish into the population represented by the tags applied in the spring (May - June) survey periods. While these adjustments substantially increase the complexity of the population analysis, they appear to be very important to the production of reliable estimates for Arctic grayling. Population estimates derived from unadjusted data (Figure 4.19) showed clear evidence of recruitment in to the Arctic grayling population throughout the field season and resulted in a population estimate almost twice as large as the estimate adjusted for mean recruitment (Table 4.21).

No adjustments were made to the 1990 tag recovery data to account for tag loss because data from 1989 indicated that neither direct tag loss or differential mortality of tagged verses untagged fish was sufficient to affect the population estimates (Pattenden et al. 1990).

The last assumption requires that all marked individuals in the sample were detected and recorded. It is unlikely that tagged fish captured escaped detection. Only fish brought on board were included in the sample of fish examined and virtually all of these fish were marked prior to being released. The action of marking a fish would in itself ensure that the presence of a tag or tag scar would be detected.

In summary, there was a fair degree of consistency in the three population estimates computed for each of Arctic grayling, walleye and lake whitefish. The statistically significant difference between the 1989-1989 population estimate and the other two estimates for rainbow trout suggest that the 1989 surveys probably did not represent the total rainbow trout population in the survey area. While the latter two population estimates are similar, both data sets suggest a decreasing trend in the rainbow trout population from June to October. This coupled with the variability in rainbow trout catch rates between survey periods and the low number of tag recoveries (19 - 26) suggest that the

A key component of any mark-recapture study is the assessment of the assumptions associated with the field and analytical procedures. The assumptions associated with the methods used to produce the population estimates were:

- the population is closed, so the population size does not change over the period of the experiment;
- the probability of capturing a marked individual at any given time is equal to the proportion of marked members in the population at that time;
- animals do not lose their marks over the period of the study, or the mark loss rate can be estimated; and
- all marked individual in a sample are reported on recovery.

The two primary sources of violations to the first assumption are the migration of unmarked fish into the surveyed area, and changes in the vulnerability of fish to sampling gear between release and recapture periods.

Migrations of fish into the Site C study area from downstream populations probably did not occur for Arctic grayling, rainbow trout, or lake whitefish because most of the fish in each of these populations reside in the upper reaches of the Peace River between the confluence of the Halfway River and the Peace Canyon Dam. In addition, most of the recoveries of these species were within a few kilometres of the release locations (Figure 4.16). It is not known if significant numbers of rainbow trout or lake whitefish entered the study area from upstream reservoirs by entrainment at the Peace Canyon Dam. Migrations of unmarked walleye into the survey area from downstream areas may have occurred because this species was most common in the lower 30 km of the study area and a significant portion of the 1989 and 1990 recoveries of walleye had travelled 5 - 40 km upstream from the tagging location. The net result of walleye immigration into the study area would be an overestimate of the walleye population.

Changes in the vulnerability of fish to sampling gear could have had a substantial effect on the population estimates for rainbow trout. Electrofishing conditions in the spring of 1990 were ideal for fish capture in the upper Peace River (i.e., moderate water turbidity and low water levels). Under these conditions field crews were able to catch substantial numbers of rainbow trout from areas where previous efforts resulted in much lower catch rates and few tags applied (see Section 4.2). The sampling limitations associated with using electrofishing techniques to capture rainbow trout in clear deep water could have removed the deep water portion of the trout population from the population estimates presented in the 1989 report. Similar fishing conditions encountered in the summer and fall surveys of 1990 (i.e., clear water) could explain the decreasing trend in the sequential population estimates (posterior distributions) produced by the Bayesian estimation procedure (Figure 4.19).

Table 4.21 Population estimates for four sportfish species residing in the Peace River within the Site C study area. The lower and upper bounds for each estimate represent the 2.5 and 97.5% quantiles, respectively.

	Maximum Likelihood	Bounds		Total Tag Recoveries
		Lower	Upper	
Arctic grayling				
No Recruitment				
90-90	7 800	6 200	10 000	69
89-90	11 000	8 480	14 720	53
89-89	3 980	2 760	7 120	18
Mean Recruitment				
90-90	4 060	3 210	5 180	68
89-90	5 980	4 600	7 960	53
89-89	3 880	2 700	6 980	18
Extreme Recruitment				
90-90	3 830	3 050	4 920	68
89-90	5 380	4 140	7 160	53
89-89	3 760	2 600	6 760	18
Rainbow trout				
No Recruitment				
90-90	7 620	5 280	11 550	27
89-90	9 360	6 280	14 880	23
89-89	1 440*	1 010	2 520	19
Mean Recruitment				
90-90	5 530	3 820	8 500	26
89-90	3 880	2 560	6 300	21
89-89	1 270*	890	2 230	19
Extreme Recruitment				
90-90	5 110	3 490	7 900	25
89-90	2 740	1 760	4 580	18
89-89	1 170	820	2 050	19
Walleye				
Mean Recruitment				
90-90	2 320	1 260	4 990	10
89-90	2 380	1 580	3 840	21
89-89	1 780	1 040	6 160	6
Lake whitefish				
Mean Recruitment				
90-90	65 500	35 500	143 000	10
89-90	41 500	24 100	80 200	13
89-89	13 700	6 900	125 300	3

*Population estimate significantly different from other estimates for that recruitment group.

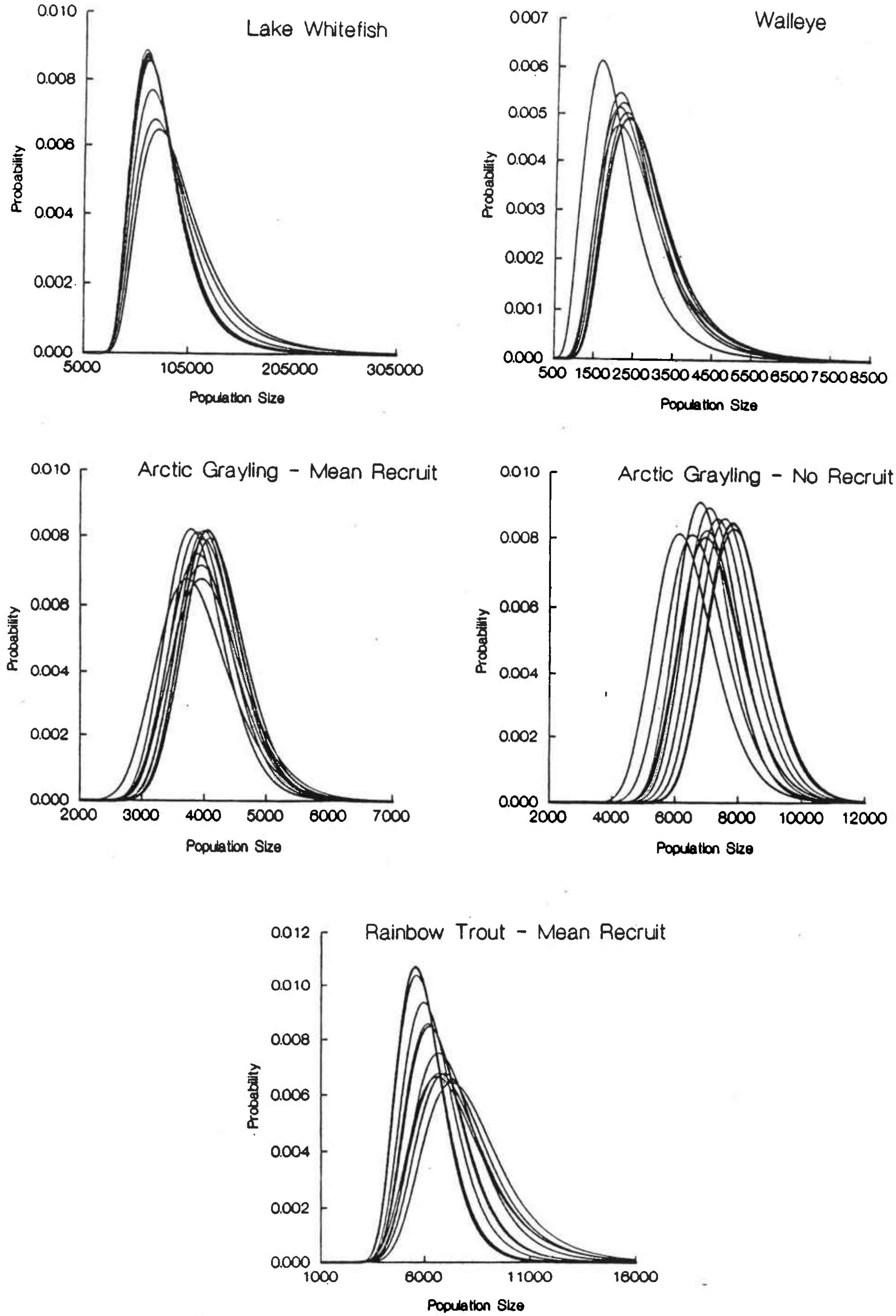


Figure 4.19 **Sequential posterior distribution for the Bayesian population estimates for lake whitefish, walleye, Arctic grayling, and rainbow trout, Site C study area. Data adjustment for no recruitment presented for Arctic grayling.**

population estimates will be provided in Appendix 4.6C. The bold line in each figure is the final distribution from which all the Bayesian population statistics were calculated. Table 4.21 gives the maximum likelihood estimate, and the 2.5% and 97.5% quantiles (95% confidence interval with 2.5% in each tail) for the three population estimates computed for each species. The 1989-1989 and 1989-1990 estimates are for the population of fish greater than the minimum tagging size in May - June 1989 and the 1990-90 estimate is for the population of similar size fish in May - June 1990.

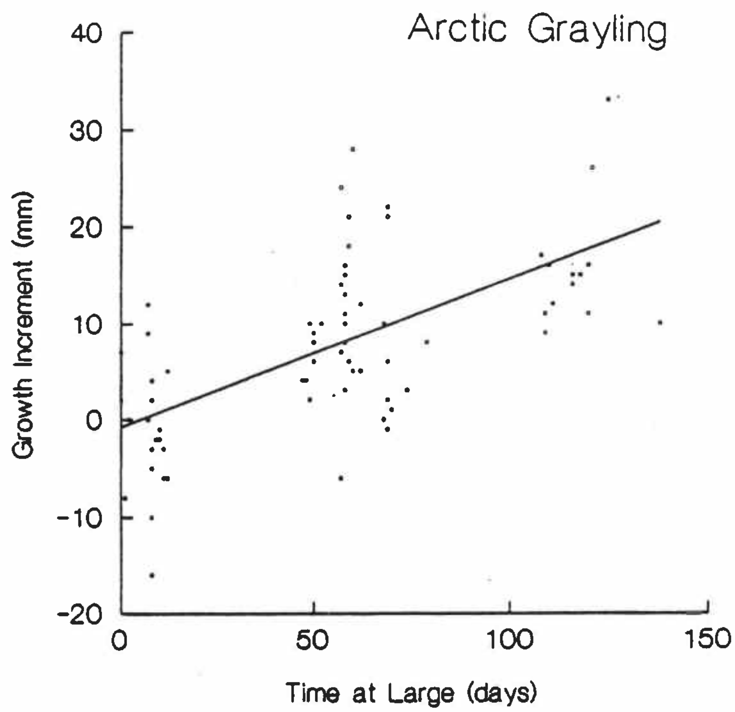
Important observations on the estimates are as follows:

Arctic Grayling. There was a substantial change in the estimates when recruitment to the population was taken into consideration (Table 4.21). This was due to the large change in the number of fish sampled in each recruitment scenario (i.e., many of the fish captured were just slightly greater than the 250 mm). The final six posterior sequences for the mean and maximum recruitment options appear stable, indicating the closed population assumption was not violated.

Rainbow Trout. There also was a large change in the population estimate when the recruitment was considered. The posterior sequences clearly indicate a decreasing population size. Either the capture probabilities were heterogeneous (fish with tags were more likely to be recaptured than fish without tags) or there was unaccounted removals from the population (mortality or unreported recapture of tags). In either case, there was insufficient recaptures to allow a correction or to apply open population models. Rainbow trout was the only species where the population estimate for the 1989 field season (1989-1989) was statistically significantly different from those estimated using the 1990 recovery data.

Walleye. Since marks were not applied during the first sampling interval in 1990, only 15 sampling sequences were available. An assumption of no recruitment of fish into the markable population made the population estimates the same under the three scenarios. The substantial improvements in precision for the 1989-1990 and 1990-1990 estimates correspond with the increased number of walleye tag recoveries in 1990.

Lake Whitefish. While the 1990 estimates were more reliable than the 1989 estimate, the confidence intervals were still very large, thus making the point estimates meaningless. The data, however, do provide good evidence that the population was substantially larger than that estimated in 1989. There is a 97.5% chance that there are more than 24 000 lake whitefish in the study area.



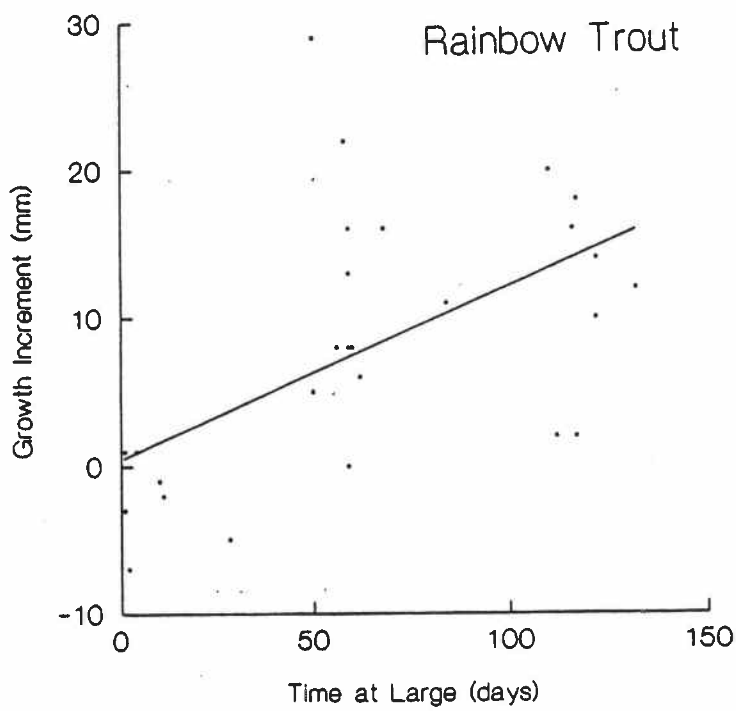


Figure 4.18 **Growth regression line for individually tagged Arctic grayling and rainbow trout measured at release and recapture. Each data point represents one fish.**

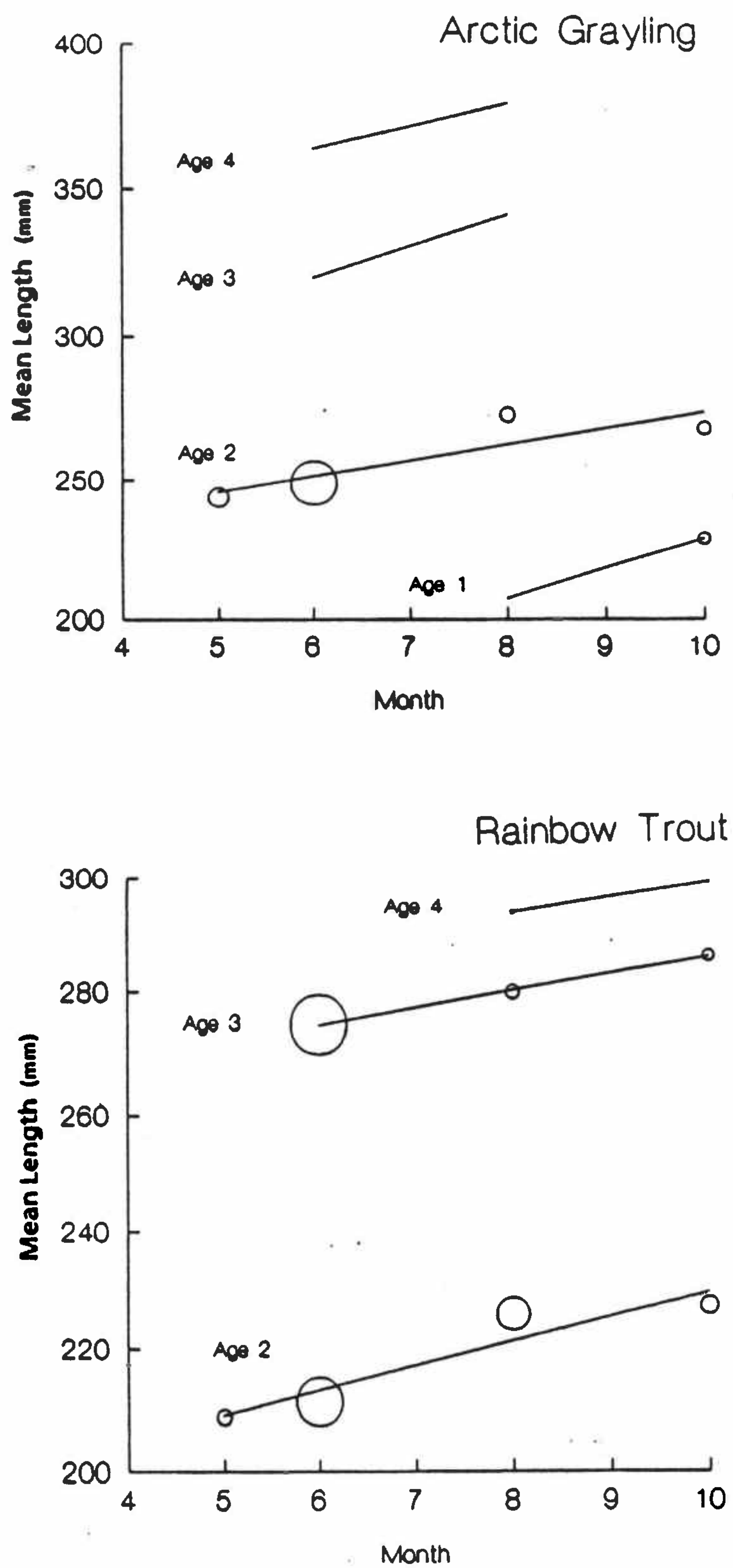


Figure 4.17 **Weighted growth regression line for Arctic grayling and rainbow trout, Site C study are The area of the plotted circles is proportional to the amount of weight given to the me length for each age-class.**

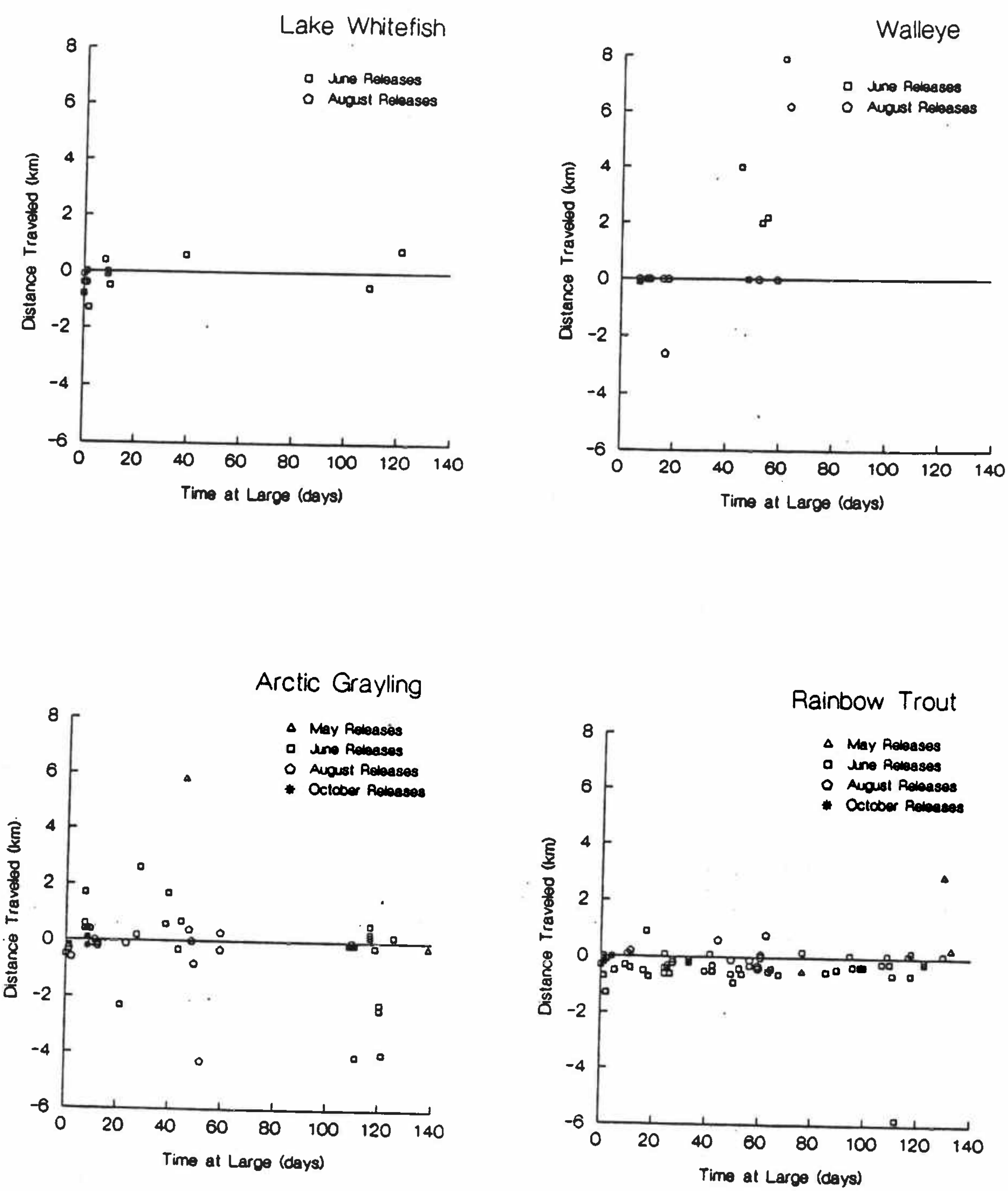


Figure 4.16 **Plot of kilometres travelled versus days at large for lake whitefish, walleye, Arctic grayling, and rainbow trout tagged along the Peace River during 1990.**

and time at large for any species during the sampling period (May through October 1990); however, walleye had a propensity to move upstream (Sign test $P<0.05$) and rainbow trout were recaptured slightly downstream from the point of release.

In Season Growth

The results of the growth analysis for Arctic grayling and rainbow trout are given in Table 4.20. The two methods employed did not yield significantly different estimates in the growth increment (T-test, $P>0.05$). Growth analyses for lake whitefish and walleye were not conducted because most fish captured were greater than 250 mm. Figure 4.17 provides the plots of the mean lengths by age where the amount of weight given to each mean is proportional to the area of plotted circle. Figure 4.18 displays the increment in growth of individual fish for Arctic grayling and rainbow trout, respectively. Fish which were at large for only a short time (i.e., <10 days) should exhibit only a very small increment in growth and should not shrink; thus, they provide some information on the measurement error in taking length measurements. Inspection of Figure 4.18 indicates a measurement error with approximately 3 - 5 mm deviation and no bias (regression intercept not significantly different from 0, $P = 0.26$ for both species).

Table 4.20 Results of the growth analyses for Arctic grayling and rainbow trout captured from the Peace River between May and October 1990.

Species	Increment (mm)	Std. Error	T Value	Prob.
Age-Month Means:				
Arctic grayling	4.1	1.37	2.97	0.002
Rainbow trout	5.2	2.02	2.59	0.005
Length Differences:				
Arctic grayling	4.6	0.69	6.64	<0.001
Rainbow trout	3.5	1.00	3.53	0.002

Population Estimates

Appendix tables 4.6A-1 through 4.6A-4 will provide the data used for 1990 population estimates for Arctic grayling, rainbow trout, walleye, and lake whitefish, respectively. Appendix tables 4.6B-1 through 4.6B-4 will provide the data used for the 1989 population estimates derived from 1990 tag recoveries of tags applied in 1989. The number of tags applied, tags recovered and fish examined decreased with the level of recruitment because individuals close to the minimum tagging size were eliminated from the analysis. All other species had fewer than seven recoveries; therefore, population estimates were not attempted. Sample plots of the posterior distribution for the last 10 sampling sequences are presented for the 1990 population estimates (Figure 4.19). Similar plots for the 1989-90 were not conducted. Although data from the Site C study show that bull trout will move great distances during the spawning period it appears that no fish moved below the proposed Site C dam site to utilize downstream tributaries such as the Pine River.

Northern pike

Tag recovery data and information from radio transmittered fish suggest that the northern pike population in the Site C study area is resident. Most individuals did not undertake extensive spawning or feeding related movements. Limited data are available for comparative purposes. RRCS (1978) encountered low numbers of northern pike during their study of the Site C area. Northern pike sometimes migrate into tributary streams for spawning purposes (Tripp and McCart 1979) but radio transmittered fish in the Peace River did not show this pattern. Northern pike moved into Maurice Creek during spring 1990 (T. Slaney, Aquatic Resources Ltd., pers. comm.), but this was related to foraging rather than spawning activity.

Lake whitefish

No movement patterns were established for this species in the Site C study area. Lake whitefish observed during the present study were likely individuals recruited from populations located in Williston and Dinosaur lakes, and possibly from Moberly Lake. Migration into the Site C study area from locations downstream of the B.C. - Alberta border was unlikely as very low numbers of lake whitefish occur in this area (Hildebrand 1990). Although extensive spawning related movements have been documented for this species in other river systems (O'Neil et al. 1982; Berry 1986) no evidence of such movements was observed in the Site C study area.

Suckers spp.

Suckers are abundant in the Site C study area. Most tagged individuals exhibited little movement and were found at tributary mouths. RRCS (1978) documented spawning movements of these species into Farrell Creek and the same phenomenon was observed at Lynx and Maurice creeks during 1990 (T. Slaney, Aquatic Resources Ltd., pers. comm.). These fish were probably individuals which reside at the tributary mouths during the remainder of the year.

4.7 POPULATION ESTIMATES

Assumption of Closed Populations

Figure 4.16 displays distance travelled versus time at large during 1990 for Arctic grayling, rainbow trout, walleye, and lake whitefish, respectively. In general the fish did not move large distances. There was not a statistically significant ($P>0.05$) correlation between distance travelled

Studies have documented the occurrence of extensive feeding and spawning migrations by mountain whitefish. Davies and Thompson (1976) observed that in the Sheep River, Alberta, upstream feeding migrations from overwintering areas occurred in late spring and early summer. Fish subsequently moved downstream during fall and formed large aggregations on the spawning grounds. Petit and Wallace (1975) found that mountain whitefish in the North Fork Clearwater River, Idaho, also migrated to feeding and spawning areas from overwintering sites. The Peace River data show no large scale movements related to feeding during spring and summer, but dispersal to spawning areas does take place during fall. The apparent lack of movement to overwintering sites by the mountain whitefish population is probably related to moderate water temperatures and the presence of overwintering habitat in the Peace River. Downstream dispersal by juvenile mountain whitefish during late summer and fall also was documented by Davies and Thompson (1976) and Petit and Wallace (1975). It is likely that this phenomenon occurred for juvenile mountain whitefish in the Halfway River system. This would explain the increase in abundance of juvenile mountain whitefish in the Peace River during summer. Despite large-scale movements by adult fish during fall, the data show that no major upstream or downstream migration past the proposed Site C dam site occurs for this species.

Bull trout

A resident population of bull trout exists in the Peace River portion of Site C study area. No large scale movements past the proposed dam site were detected during the study, although one radio transmittered individual did migrate past the dam site to reach the Halfway River System. Abundance indices, tag recovery results and information from the radio telemetry program indicate that bull trout from the Peace River utilized the Halfway River system for spawning. Catch rates for bull trout in the Peace River decreased during August 1989 (Pattenden et al. 1990) suggesting movement of fish into tributaries (likely the Halfway River). A tag was recovered in the Peace River from a fish originating in the Halfway River, and radio transmittered fish entered the Halfway River during summer. Spawning related movements made by radio transmittered fish were extensive and accomplished over short periods of time. One individual migrated to the Christina Falls area on the Graham River, in 34 days, a distance of 200 km from the Peace River.

RRCS (1978) noted that a bull trout tagged in Farrell Creek in the spring of 1975 was subsequently captured in May 1977 at Km 19.3 of the Halfway River. McPhail and Murray (1979) found that bull trout undergo pre-spawning migrations into MacKenzie Creek, B.C. during mid-summer. Bull trout residing in Clearwater River, Alberta, undertake extensive migrations in excess of 60 km into small tributaries to spawn (Allan 1980) and Bjorn and Mallet (1964) documented movements of over 300 km for bull trout in an Idaho population. Slaney et al. (1991) found little evidence of spawning activity for bull trout in the Halfway River system; however, detailed surveys was some indication that individuals undertake an upstream migration in the Peace River from overwintering sites during summer. During fall, downstream movement may occur back to the overwintering sites. Movements related to spawning activity were not identified for Arctic grayling in the Site C study area, but indirect evidence suggest that the Arctic grayling spawn in tributaries such as the Halfway River, Moberly River, and Farrell Creek. Changes in abundance indices suggested that there was an influx of juveniles into the Peace River during late summer and fall.

Arctic grayling have been known to undertake extensive migrations between spawning, wintering and feeding areas. Arctic grayling of the Wapiti River system in Alberta migrate distances up to 100 km into tributary streams to spawn (D. Schroeder, Alberta Fish and Wildlife Division, pers. comm.). Stein et al. (1973) reported a tagged Arctic grayling which moved into the Great Bear River after spawning in Stewart Creek (a tributary to the Mackenzie River), covering a total distance of 159 km. McCart et al. (1972), in a study of Arctic grayling movements in Alaska, noted that summer feeding areas for adults were often in locations considerably removed from spawning and overwintering areas. The tagging study of Arctic grayling conducted by RRCS (1978) in the Site C study area was inconclusive. Most recoveries occurred at tagging locations; however, Arctic grayling were known to migrate from the Peace River into Farrell Creek to spawn during early spring. Spent fish subsequently returned to the Peace River during early summer. On the other hand, Arctic grayling in the Skunka River drainage, part of the Pine River watershed, do not exhibit extensive movement patterns (Stuart and Chislett 1979).

Craig and Poulin (1975), in a study of Arctic grayling in Alaska, documented movement of juveniles and fry out of small tributaries during summer and fall. The influx of juvenile Arctic grayling into the Peace River during summer suggests that this phenomenon also occurs in the Site C study area. Slaney et al. (1991) documented the presence of juvenile Arctic grayling in Halfway River tributaries and in the Moberly River.

Mountain whitefish

A large resident population of mountain whitefish exists in the Site C study area. Tagged fish moved little during spring and summer; however, both upstream and downstream dispersal occurred during the fall spawning period. Tagged fish appeared to move towards the Halfway River which was an important spawning area for this species. Fish originally tagged in the Peace River were recaptured in the Halfway River during fall. Also, fish tagged in the Halfway River during fall were recaptured in the Peace River during the following year. Extensive spawning also occurred in the mainstem Peace River. The abundance of juvenile mountain whitefish in the Peace River increased during summer, and was probably related to an influx of fish from the Halfway River system.

that walleye do not spawn upstream of the proposed Site C dam site. During the late spring and summer, a portion of the walleye population appears to migrate up to the Moberly River (Km 66) which is immediately upstream of the proposed Site C dam site, and a few individuals move as far upstream as the Halfway River (Km 105).

Little historical data are available from the Peace River population. Walleye were encountered by Renewable Resources Consultant Services (RRCS 1978) in downstream reaches of the Site C study area. Hildebrand (1990) found walleye distributed throughout the Peace River from the B.C.- Alberta border to the Peace-Athabasca Delta. Walleye are known to undertake extensive post-spawning movements (Machniak 1975). This has been documented for populations in the Athabasca and Clearwater rivers of Alberta (Tripp and McCart 1979), in the Churchill River system (Bodaly 1980) and in the Columbia River (R.L. & L. Environmental Services Ltd., unpubl. data). Similarly, the walleye residing in the Peace River undertook extensive movements during the post spawning period. The section of the river above the proposed Site C dam is probably utilized by a portion of the walleye population as a foraging area during late spring, summer, and early fall, after which time walleye migrate back downstream.

Rainbow trout

The rainbow trout population in the Site C study area is resident. Tag recovery and radio telemetry data indicate that individuals undertake movements during the spring spawning period. Fish, presumably spawners, moved upstream to locate potential spawning tributaries, and some individuals entered these tributaries (i.e., Lynx and Maurice creeks). Subsequently, fish moved back downstream to feeding areas during the post spawning period. Many fish remained stationary after the initial movements during spring.

Investigations conducted from 1974 to 1977 (RRCS 1978) suggested that prior to construction of the Peace Canyon Dam, rainbow trout exhibited an upstream movement from the Site C study area to spawn in tributary streams such as Johnson Creek. Subsequent to spawning, fish moved back downstream into the Site C study area. Movement by adult spawners from large rivers into small tributary streams has been documented for other rainbow trout populations in the Bow River, Alberta (Sosiak 1986) and in the Columbia River system, B.C. (R.L. & L. Environmental Services Ltd., unpubl. data). The use of Lynx and Maurice creeks as spawning areas by rainbow trout residing in the Peace River also has been documented by Site C tributary studies conducted in 1990 (T. Slaney, Aquatic Resources Ltd., pers. comm.).

Arctic grayling

The Arctic grayling population in the Site C study area primarily resides upstream of the proposed Site C dam site. Distinct movement patterns were not apparent for this species, but there

(Hildebrand 1985). Although the exact date of entry into the Halfway River was unknown, the first individual (fish *084*) was located in the system on 22 May. Four other individuals (fish *024*, *044*, *054*, and *074*) entered the Halfway River by 17 August. The last fish (fish *235*) entered the Halfway River on 3 October. Rapid upstream migration was exhibited during the spawning period. Fish *054* travelled 30 km in nine days during August. Fish *074* migrated 178 km upstream between 17 August and 11 September, a period of 25 days. Fish *074* was the only individual for which post-spawning downstream movements could be assessed. It returned to the Peace River (Km 93) travelling a distance of 212 km in 49 days.

Northern pike

Of the nine northern pike receiving radio transmitters, all provided useful information on movements within the Site C study area (Figure 4.15). All transmittered fish remained in the Peace River during the survey period and most fish did not undertake extensive movements. For example, fish *014*, *064*, *034*, and *674* travelled no more than 10 km from their release sites. Fish were usually located in snyes (i.e., side channels of mainstem Peace River) which are a typical habitat utilized by this species.

During spring, transmittered fish were located in the snyes which suggests that these areas were used for spawning. Six transmittered fish congregated in one large side channel located upstream of the Halfway River (Km 106-109); presumably to spawn. Two of these individuals (fish *834* and *794*) underwent pre-spawning movements downstream to this location.

Post-spawning migrations occurred in only two instances. Fish *794* moved downstream from Km 132 to a large snye and spent 20 days at this location. It then migrated back upstream to Km 132, a distance of approximately 20 km. Fish *624* travelled from the Beatton River area (Km 24) to above the Moberly River (Km 67) during the summer period.

Summary and Comparisons to Other Studies

Walleye

The walleye population residing in the Site C study area appear good to be migratory. Results from the electrofishing survey (CUE values), the tag recovery data and the radio telemetry study indicate that post-spawning individuals moved upstream from Alberta into the Site C study area during late spring. As the season progressed, fish continued to move upstream to as far as Reach 3. Commencing in fall, walleye reversed the migration direction and returned downstream. Walleye appear to vacate the Site C area during the winter period. The absence of walleye in the study area during early spring and the subsequent appearance of spent individuals during late spring suggests which was downstream of the Halfway River, to Lynx Creek (Km 137). Several other fish also migrated upstream from the Halfway River area to the upper reach of the Site C study area; fish *864* and *784* moved to the base of the Peace Canyon Dam (Km 150) and fish *844* moved to Maurice Creek (Km 143). Tributary streams appeared to be the primary destination of some of these fish; likely for spawning purposes. Fish *954* entered Lynx Creek and remained in this tributary for several days. Fish *844* entered Maurice Creek at approximately the same time. Fish *784* spent approximately 15 days at the mouth of Farrell Creek (Km 126) before moving upstream to the mouth of Maurice Creek (Km 143) and then to the base of the Peace Canyon Dam (Km 150); it then moved back downstream and entered Maurice Creek. Fish *864* may have been seeking suitable spawning habitat as well, but being unable to find a suitable area, it moved upstream as far as possible before being halted by the Peace Canyon Dam.

After the spawning period, some individuals (fish *844* and *784*) moved downstream. Fish implanted during June 1990 showed a similar pattern. Fish *425*, *395*, *495* and *475* all moved downstream from their release locations. This movement may have been stress induced (i.e., implantation of the transmitter); however, the fish ended this movement in the same general area as the 1989 fish. This may indicate the use of this region (Km 100-Km 80) for feeding and overwintering.

Bull trout

In total, eight bull trout were surgically implanted with radio transmitters. Seven of these fish provided usable information (Tables 4.18 and 4.19). Six fish moved from the Peace River into the Halfway River system (Figure 4.14), exhibiting typical spawning-related movement for this species. Fish *264*, which remained in the Peace River, was one of the smaller individuals implanted, which suggests that it may not have been mature.

Bull trout moved into the Halfway River system from release sites located both upstream and downstream of its confluence with the Peace River (Km 105). Fish *235* migrated 45 km downstream from the base of the Peace Canyon Dam (Km 150) to the Halfway River while two fish (*054* and *074*) moved upstream 38 km from the Moberly River area (Km 67). The distances travelled by some fish were substantial. One individual (fish *024*) was located at the mouth of the Graham River, approximately 98 km from the Peace River, another fish (fish *084*) was located at Km 84 of the Halfway River before being captured by an angler. Fish *074* travelled the farthest, migrating to the Christina Falls area on the Graham River, 200 km from the confluence with the Peace River. It was subsequently monitored moving down the Graham River (3 October) and by 5 December had relocated near its original release site in the Peace River during 1989. The total round-trip movement by this individual during the survey period was over 450 km. Some of the bull trout exhibited typical spawning-related movements; spawning generally occurs between August and October for this species

4.12). Twelve fish were located outside the study area, in the Alberta portion of the river. Five individuals which remained in the study area had moved downstream immediately upon release, but then exhibited no net movement after that time. Although it was anticipated that during late spring and summer some of these fish would move upstream into the Site C study area, none of the 1989 fish undertook an upstream movement before the radio signals terminated in summer 1990.

Thirty-three walleye were implanted with radio transmitters during 1990 -- 14 during spring, 14 fish during summer, and 5 during fall. Twenty-four of these fish provided usable movement information (Figure 4.12). Many of the fish implanted during spring and summer undertook distinct upstream migrations. Sixteen of the walleye moved upstream from their release sites, and of these, 10 individuals moved in excess of 25 km. Transmittered fish were usually found near or in tributary mouths, principally those of the Beatton, Pine, and Moberly rivers. One individual (fish *245*[1]) migrated to the Lynx Creek area (Km 136) from the Beatton River (Km 26), an upstream distance of 110 km. Ten radio tagged walleye moved upstream past the proposed Site C dam site with six of these fish being located as far upstream as the Halfway River area (Km 105). Two individuals (fish *245* and *315*) were located in the Pine River. Fish *245* was found a short distance upstream (Km 2) before it moved back to the Peace River. Fish *315* was located in the Pine River on two occasions during summer 1990, moving as far upstream as Km 20 before its signal was lost. No radio-tagged fish were found in the other major tributaries surveyed (i.e., Kiskatinaw, Beatton, and Moberly rivers). Some walleye exhibited rapid movements over short time periods. Fish *245*, which was released on 19 June at the Beatton River migrated upstream 22 km to the Pine River in 22 days. Fish *165*, which was also released at the Beatton River migrated 58 km upstream in only 21 days.

By mid- to late-October 1990, a number of fish had begun to move downstream, although the occasional individual remained upriver (i.e., fish *115*, Km 107). The final survey (5 December), near freeze-up revealed that most fish were in the lower part of the study area, below Taylor, or had dropped below the Alberta/B.C. border. Three fish were located below the border; one (fish *415*) was 103 km downstream of the border.

Two individuals did not move from their release sites during the survey period. Both remained near the mouth of the Beatton River (Km 26).

Rainbow trout

Of 18 radio transmittered rainbow trout, 12 individuals were located on more than two occasions during radio tracking surveys. The movement patterns of these fish are illustrated in Figure 4.13. Most rainbow trout implanted during October 1989 moved little during the winter season. Prior to and during spring, a number of fish migrated upstream. Fish *954* moved from Km 97,

[1] The fish number designation is derived from the decimal component of the frequency as given in Table 4.18 and Table 4.19.

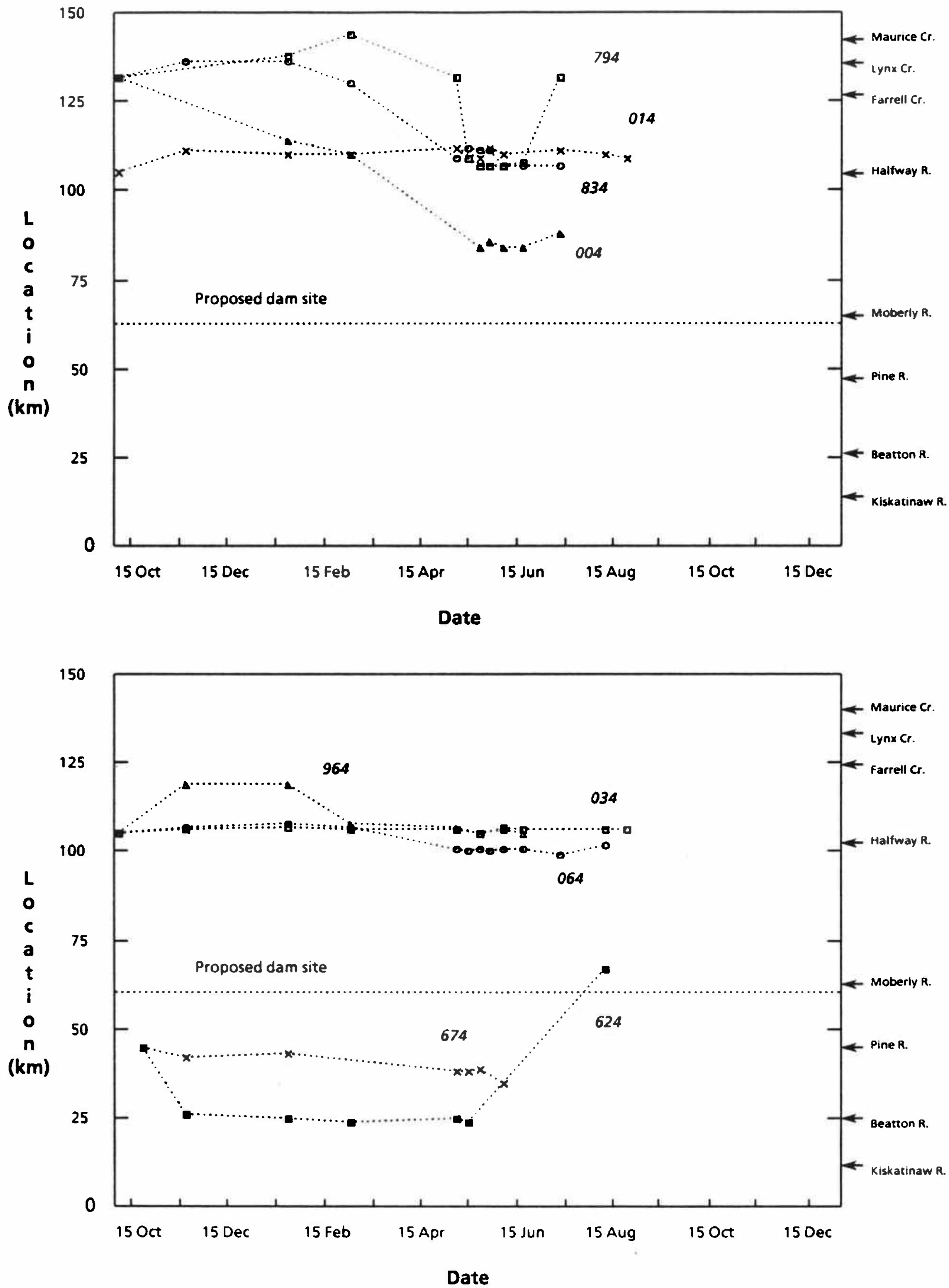


Figure 4.15 Location of radio transmittered northern pike in the Site C study area during 1989 and 1990.

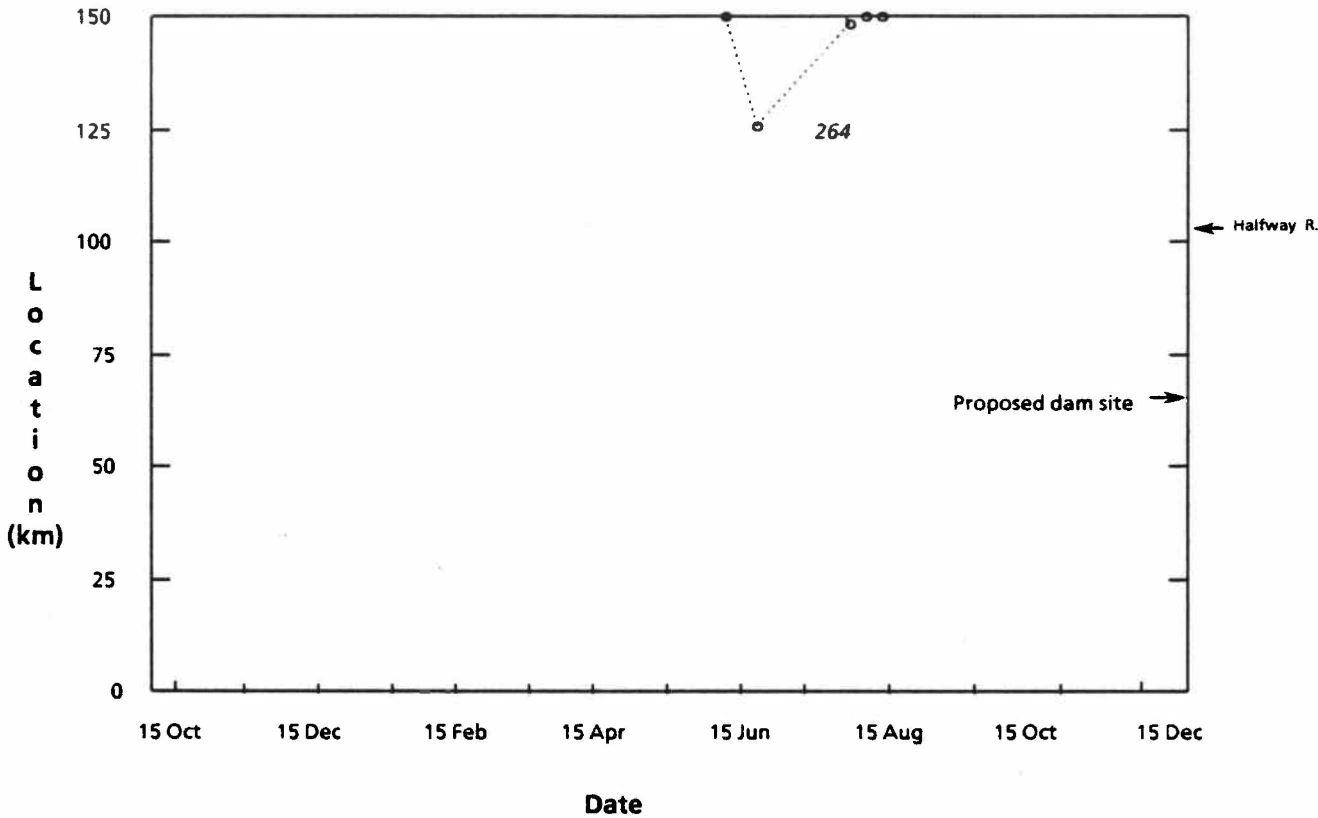
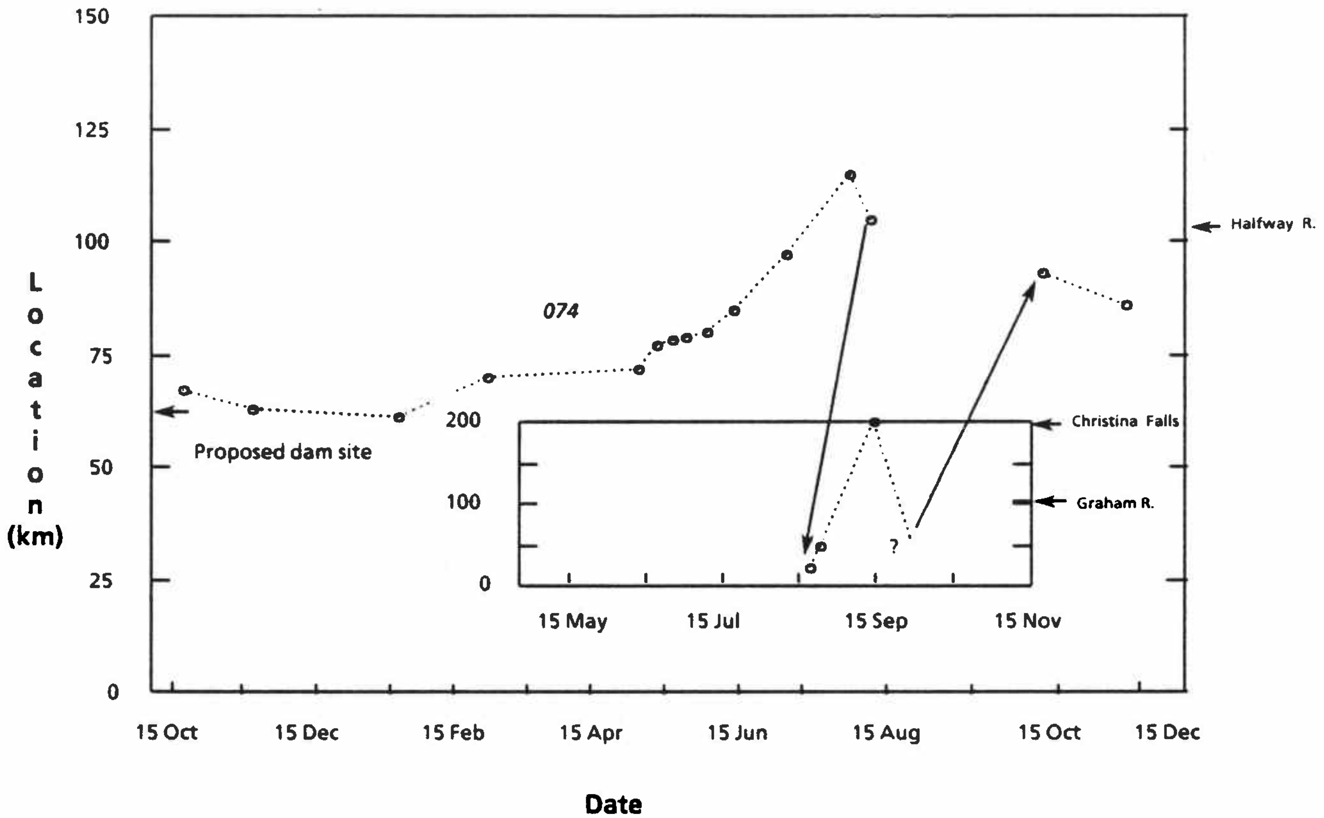


Figure 4.14 Concluded.



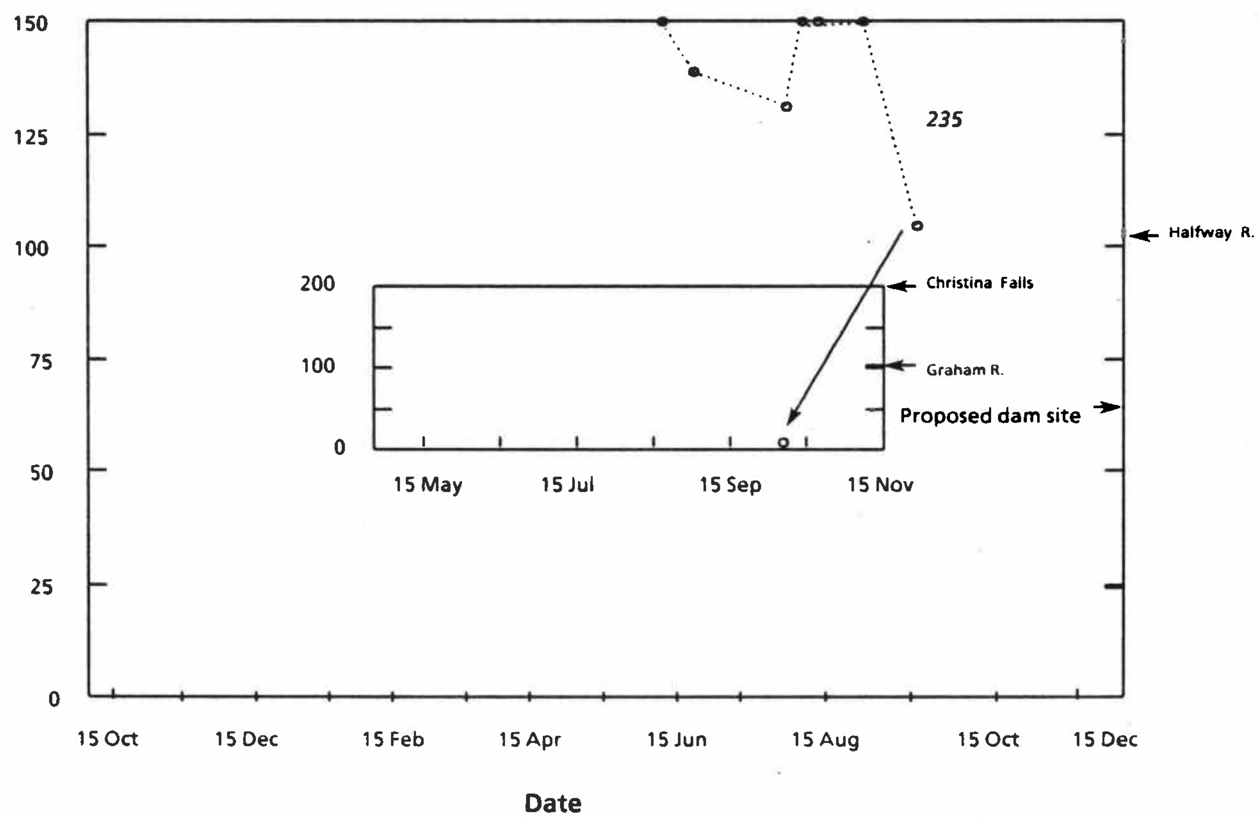
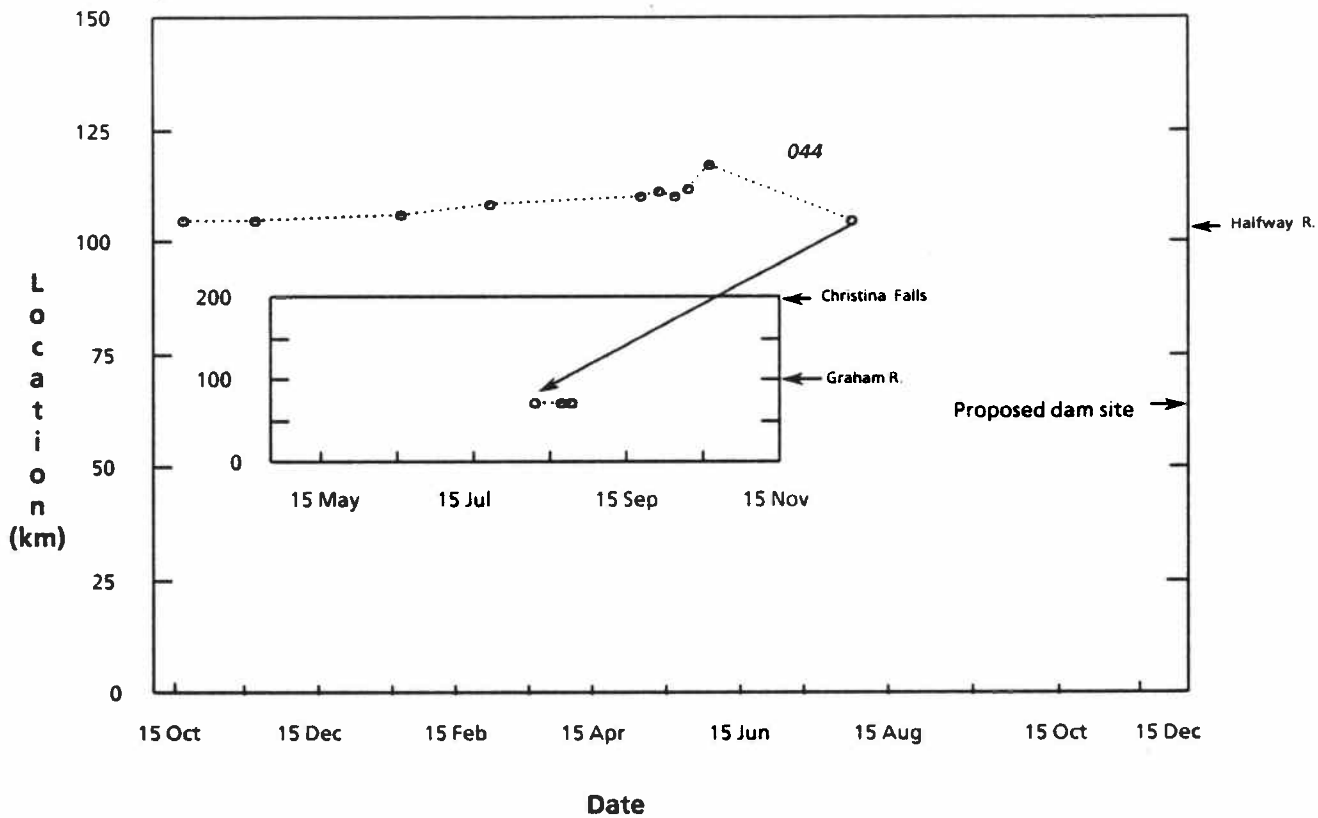


Figure 4.14 **Continued.**



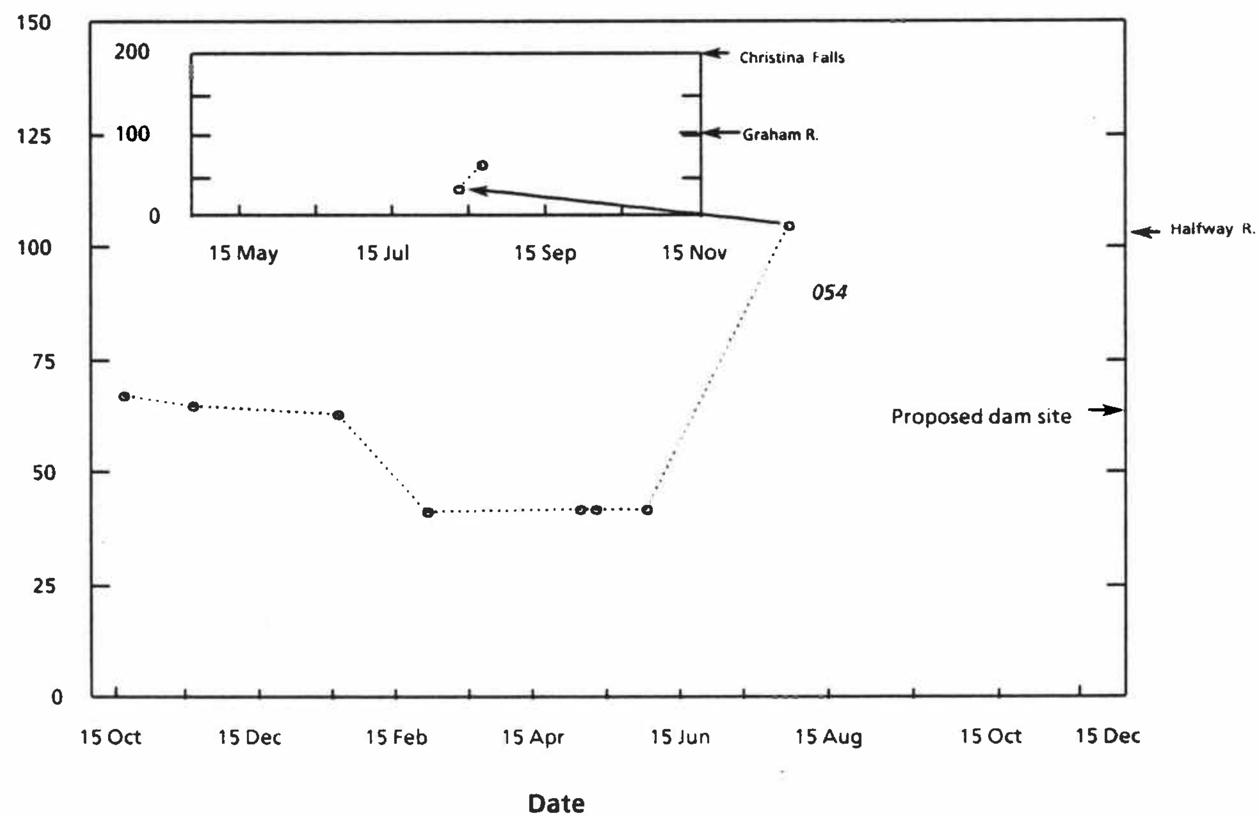
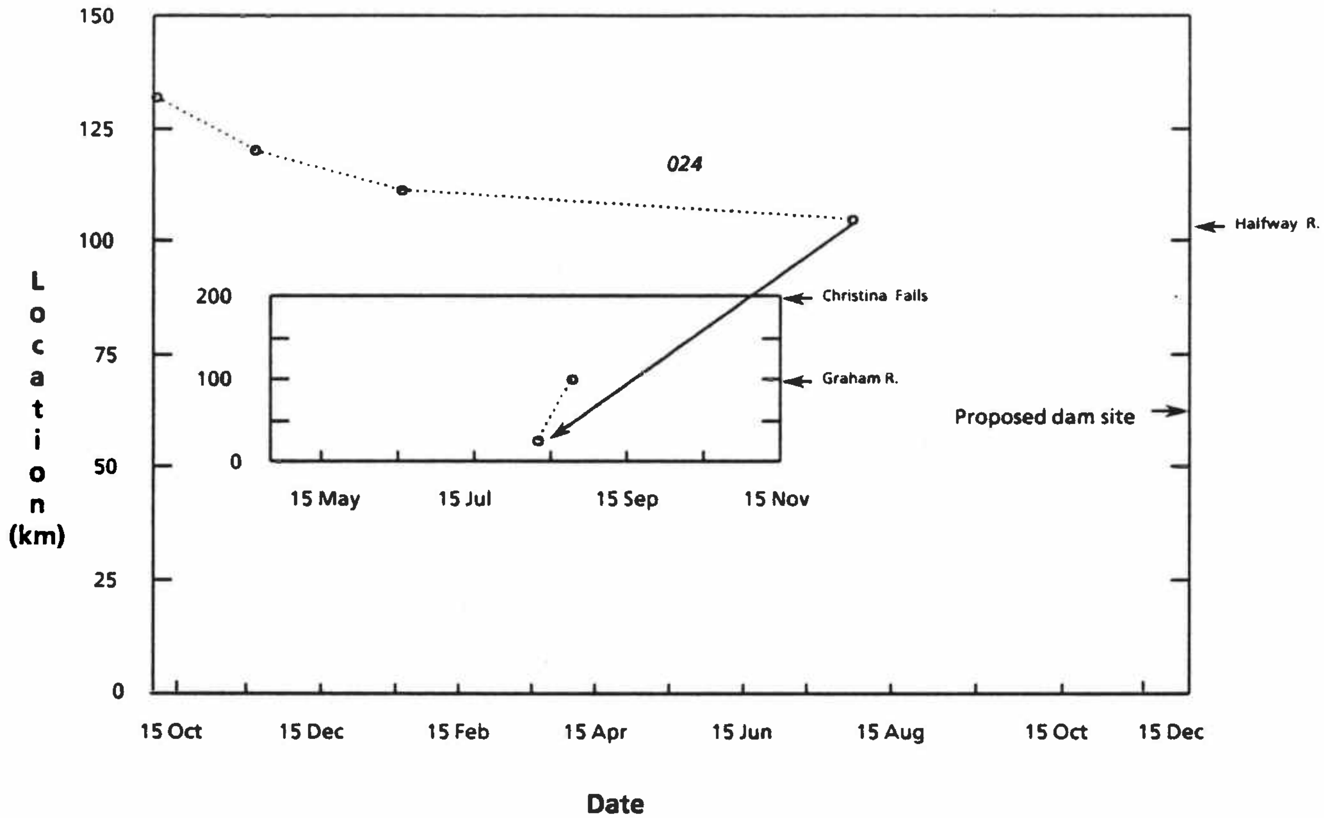


Figure 4.14 Continued.



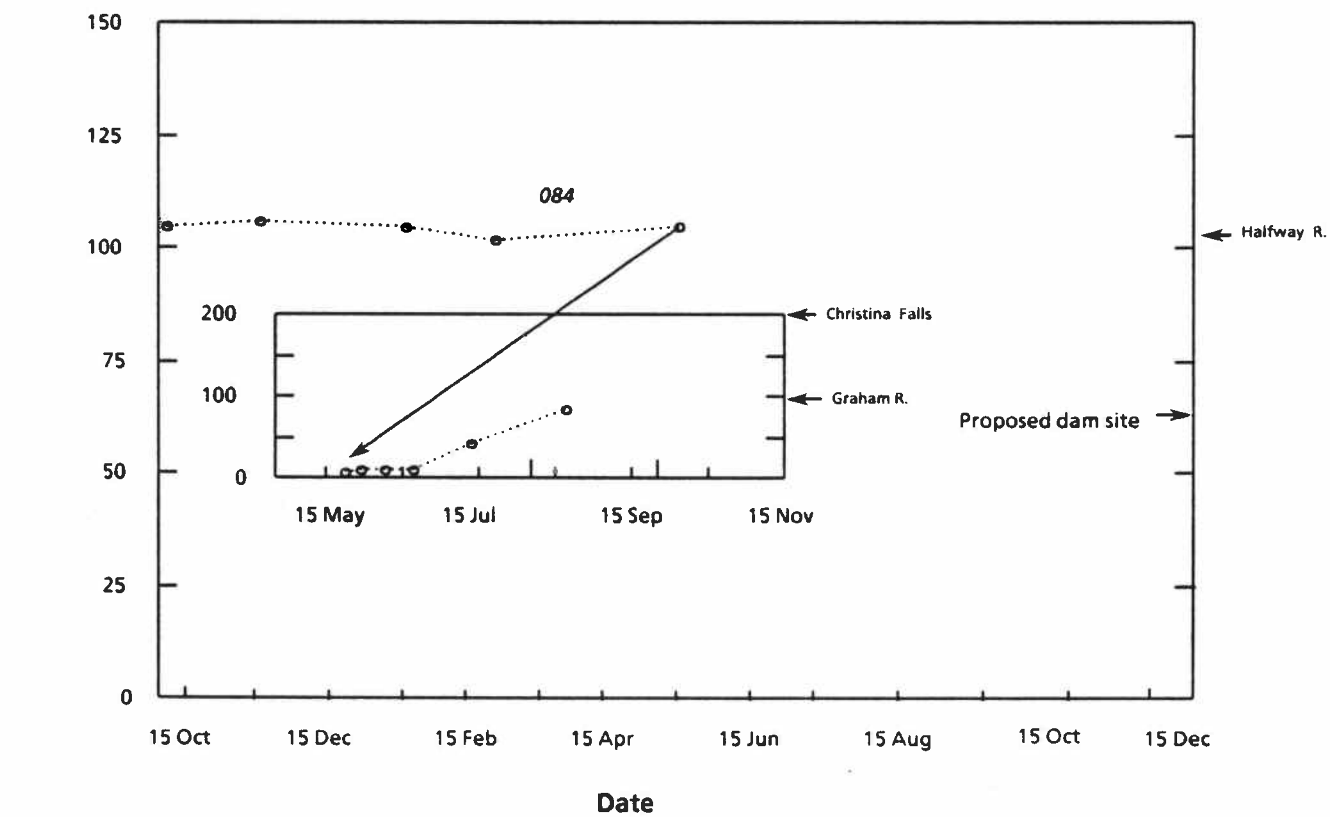
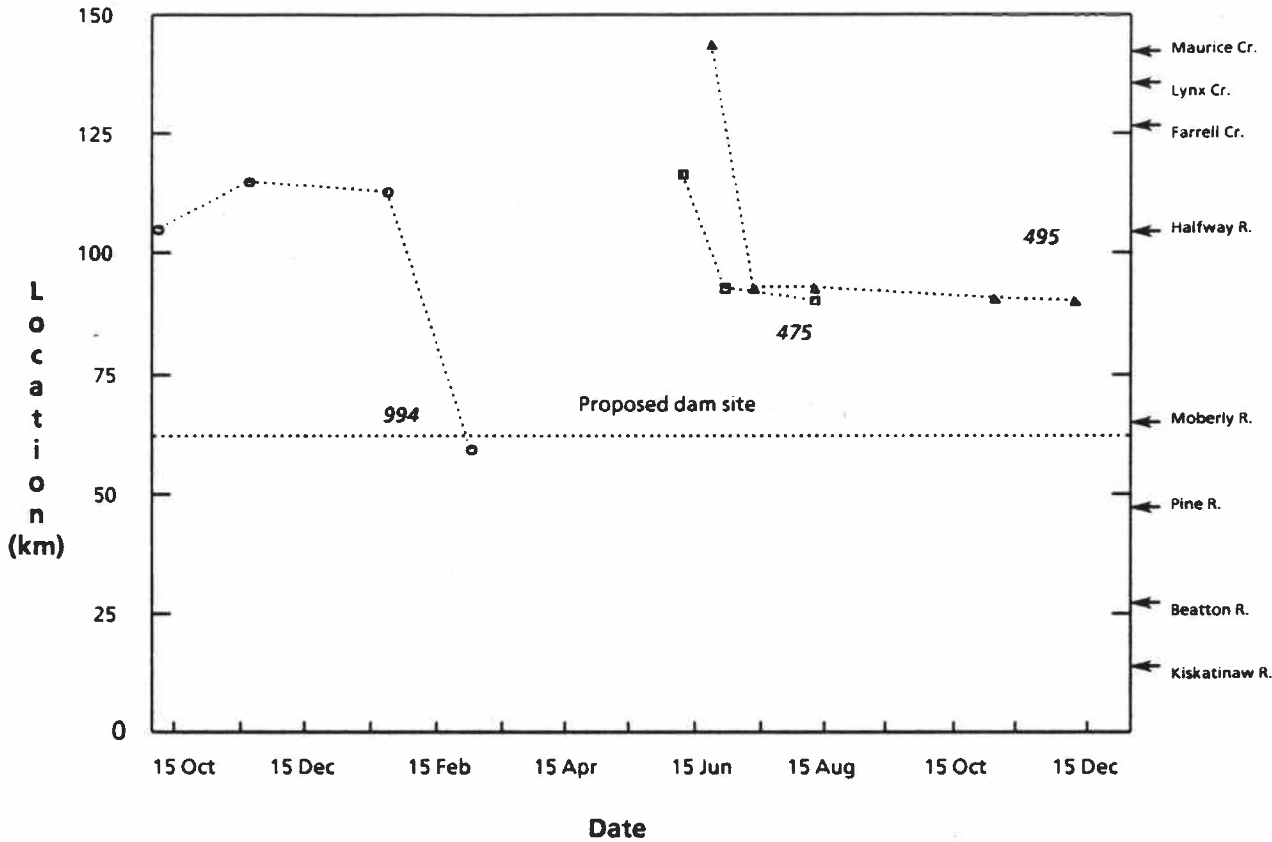


Figure 4.14 **Location of radio transmittered bull trout in the Site C study area during 1989 and 1990.**



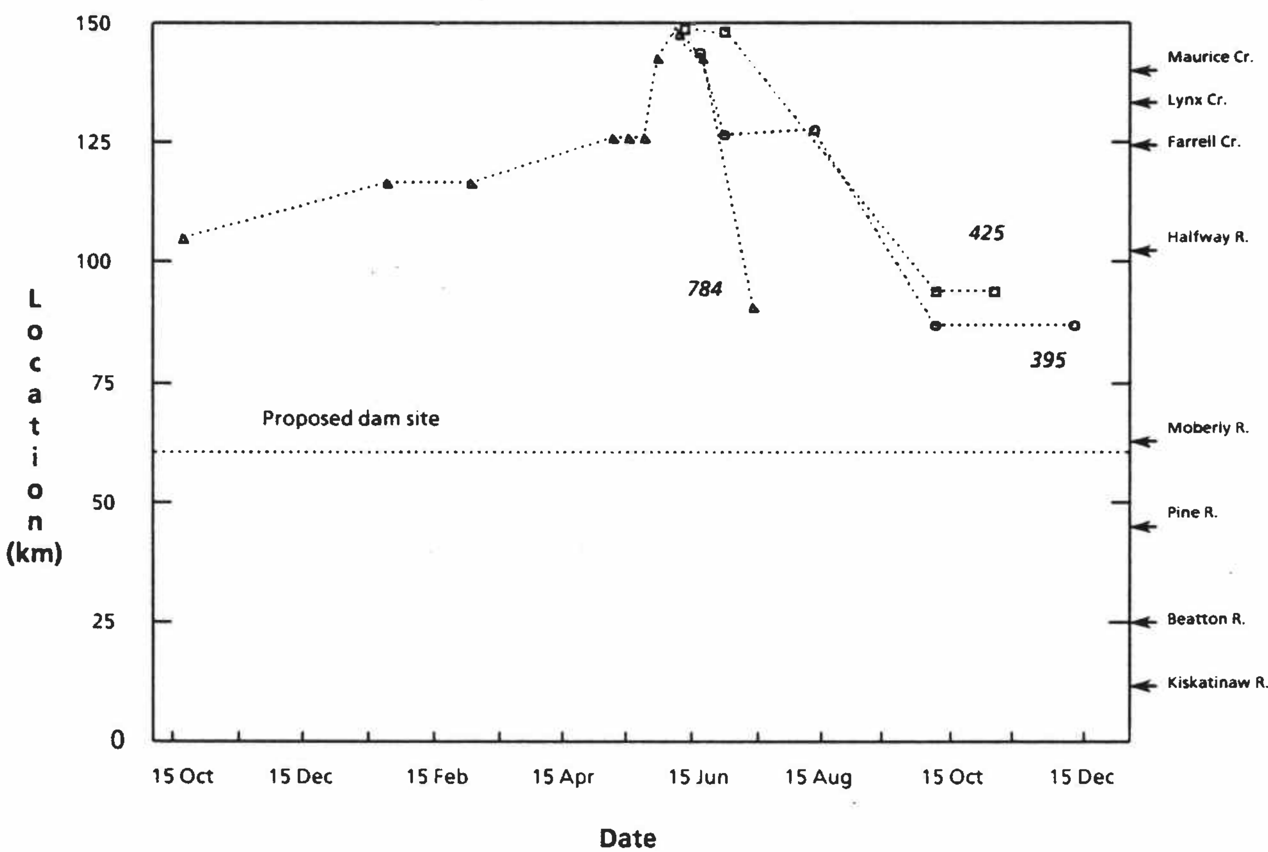
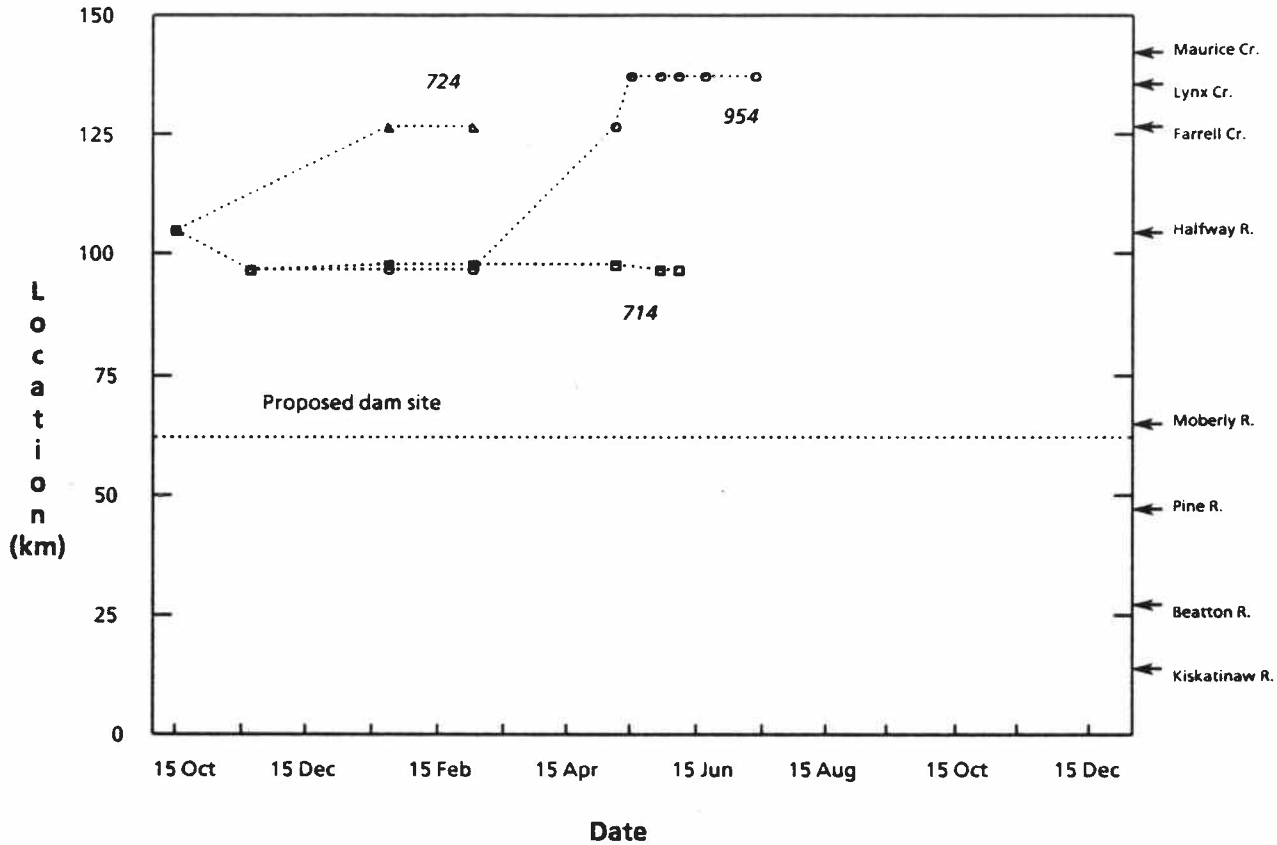


Figure 4.13 Continued.



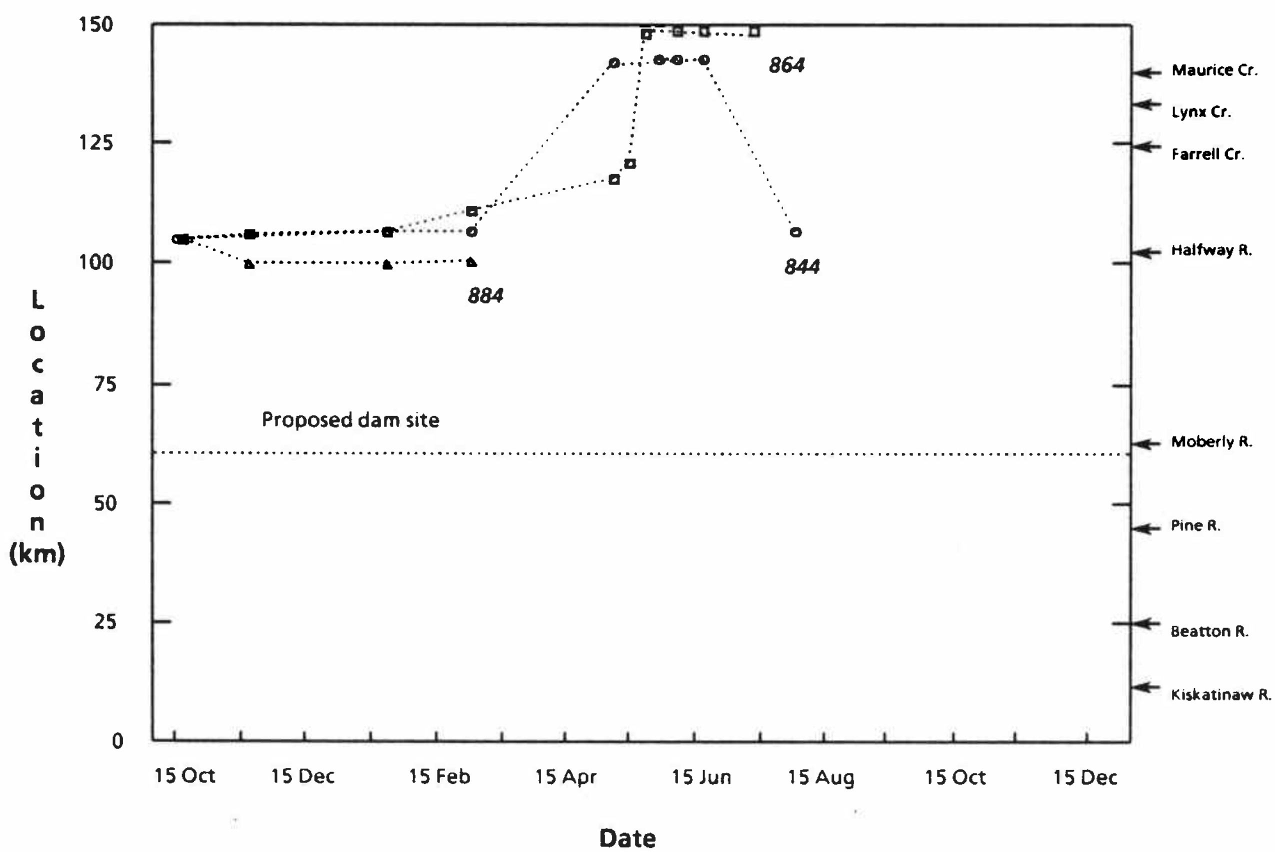
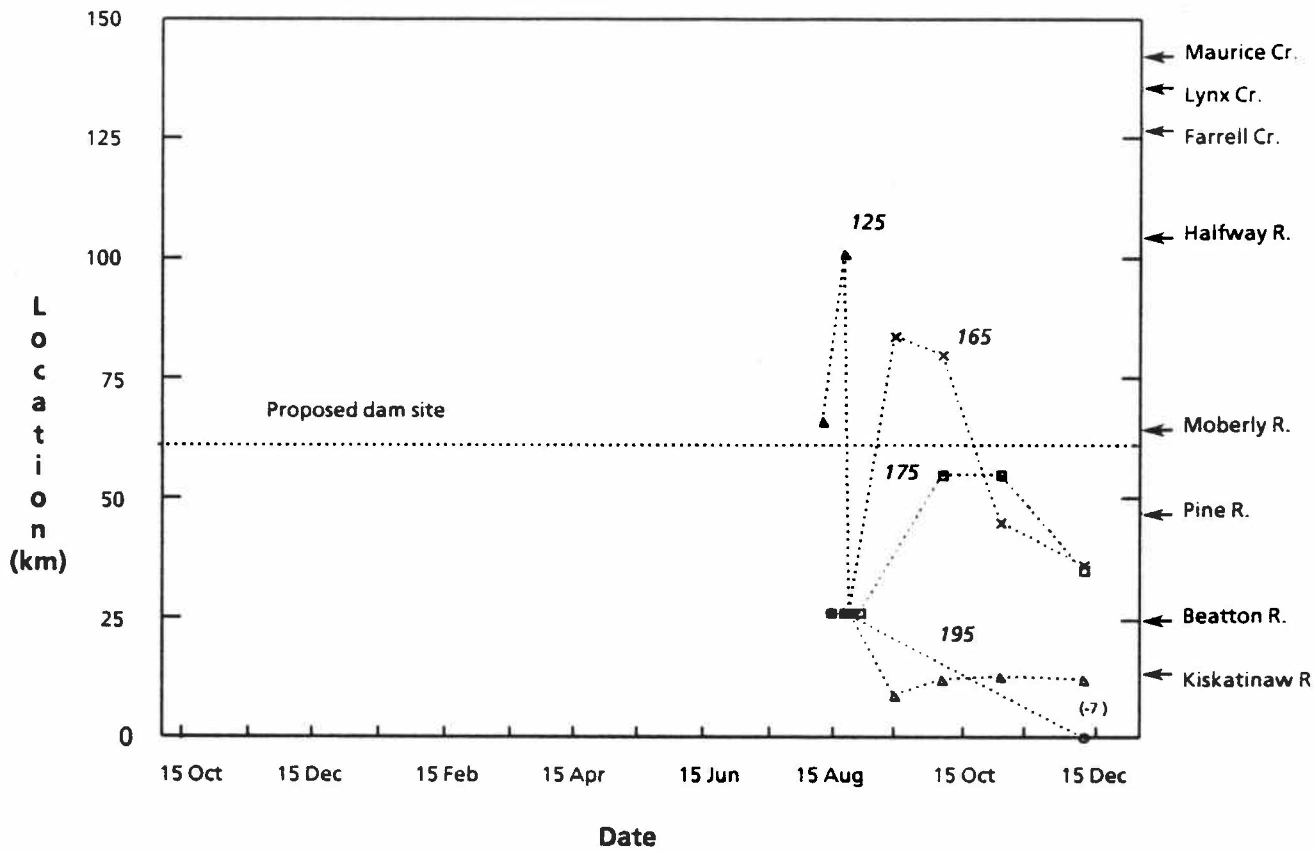


Figure 4.13 Location of radio transmittered rainbow trout in the Site C study area during 1989 and 1990.



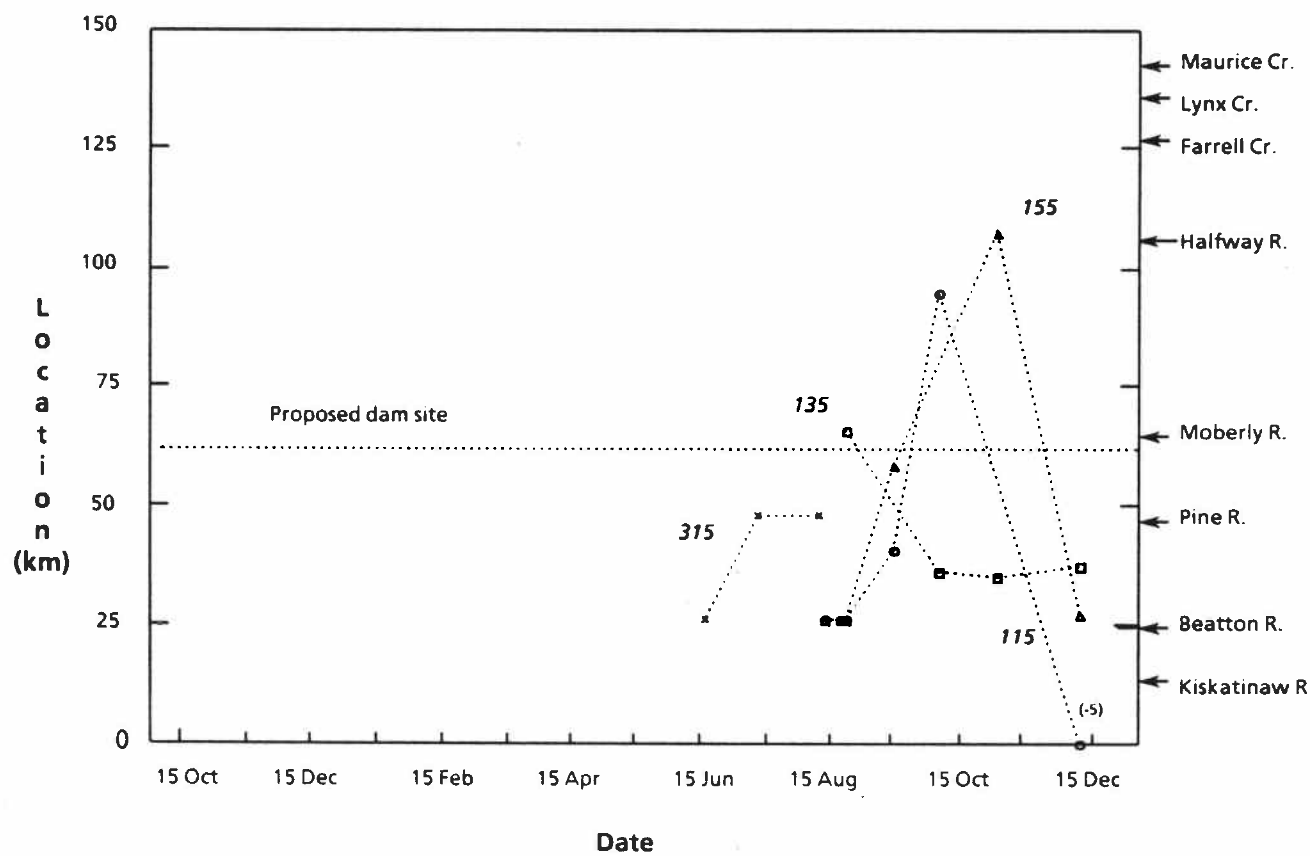
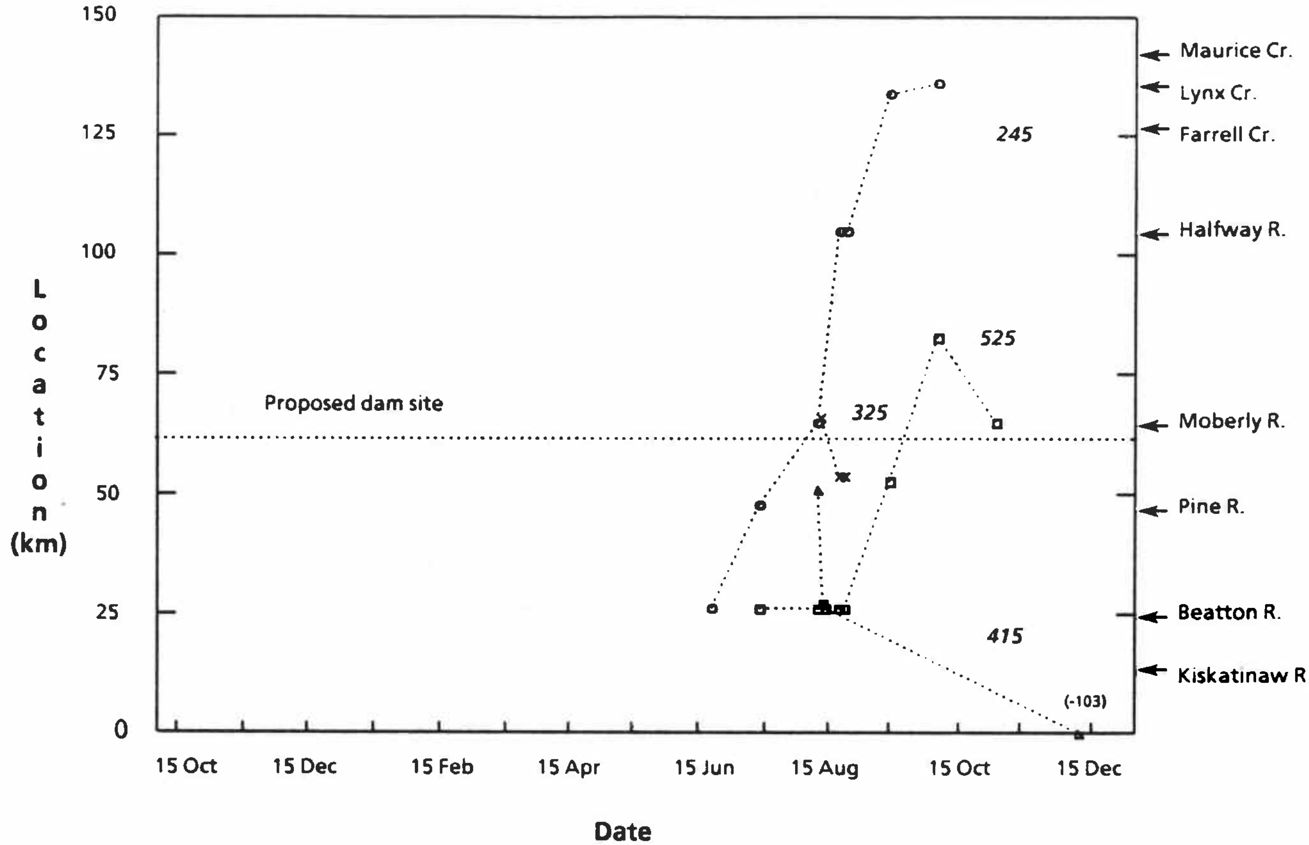


Figure 4.12 Concluded.



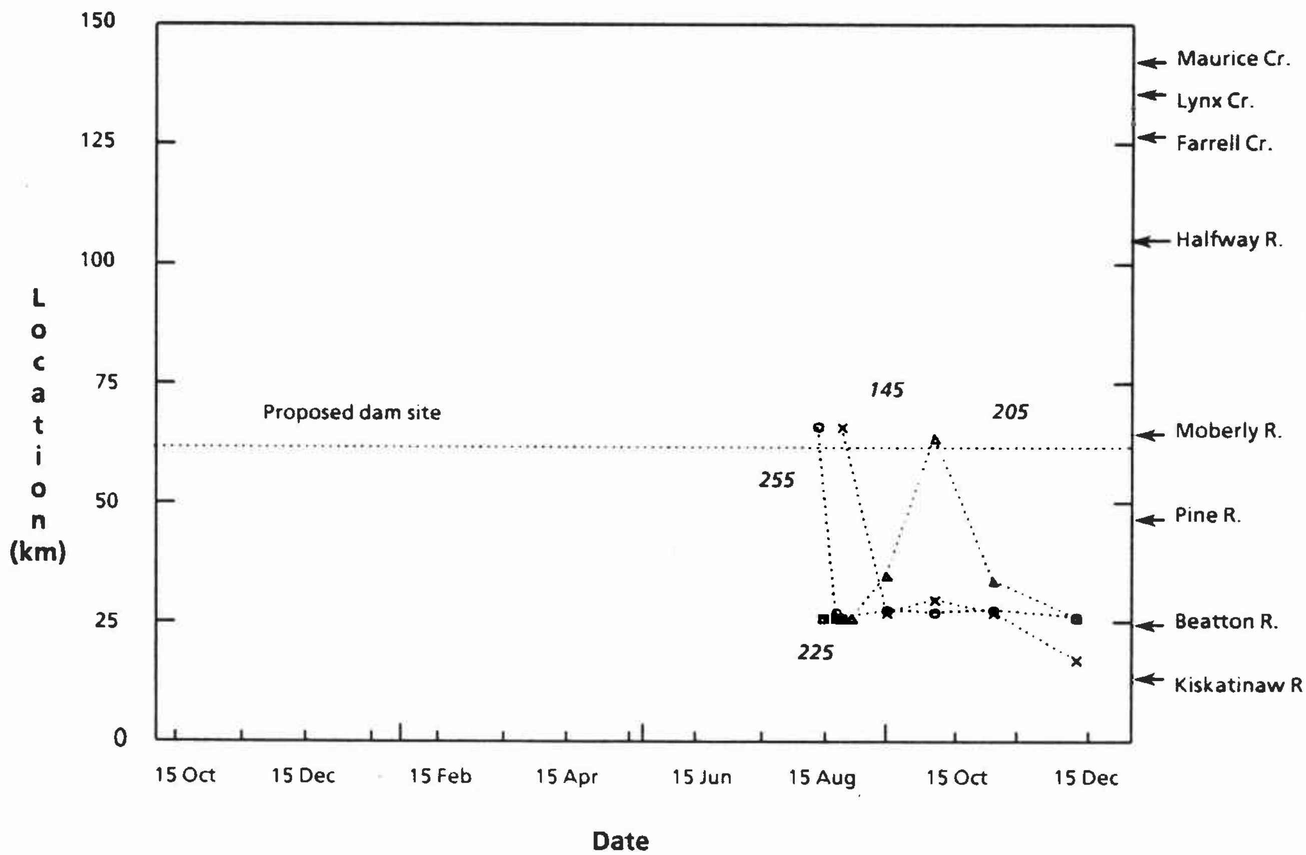


Figure 4.12 Continued.

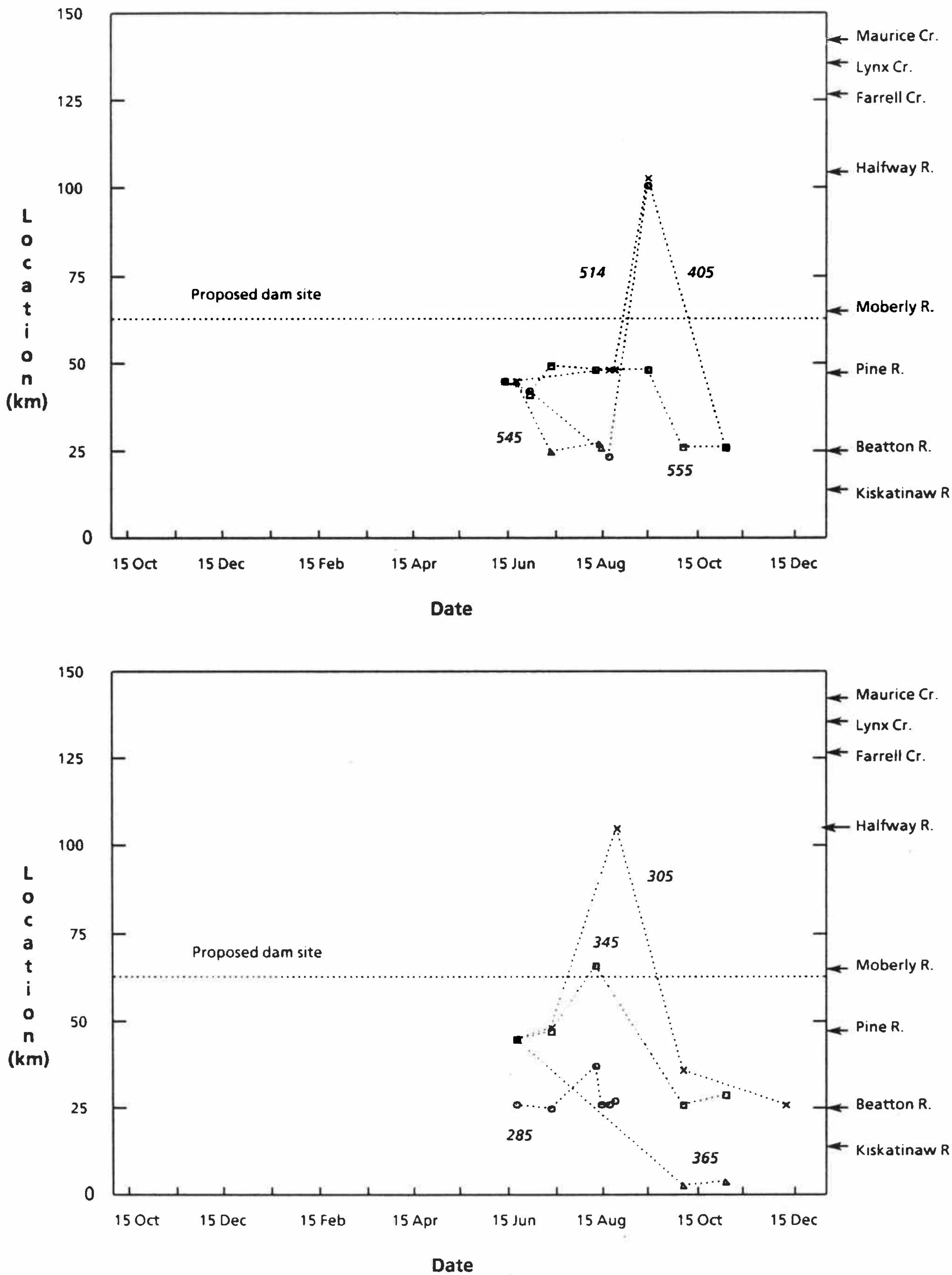


Figure 4.12 Location of radio transmittered walleye in the Site C study area during 1990. Brackets ( ) denote distance travelled downstream of the B.C./Alberta border.

Table 4.19 Concluded.

Species	Freq.	Release Date (1990)	Release Loc. (km)	Air[a] 28 Jun.	30 Jun.	Air 11 Jul.	Air 8 Aug.	Boat[d] 10 Aug.	Boat 11 Aug.	Boat 14 Aug.	Air 17 Aug.	Boat 20 Aug.	Air 21 Aug.	25 Aug.	Air 10 Sep.	Air 2 Oct.	Air 3 Oct.	Air 29 Oct.	Air 30 Oct.	Air 5 Dec.
Walleye (cont'd)	40.165	11 Aug.	26								26	26			84	80		45		36
	40.175	11 Aug.	26								26	26		26[b]		54.5		55		35
	40.185*	20 Aug.	66																	
	40.195	11 Aug.	26								26									-7(AB)
	40.205	11 Aug.	26								26	26		26[b]	35	64		34		26
	40.215*	20 Aug.	66												27					
	40.225	11 Aug.	26								26	26								
	40.245	19 Jun.	26			P2[g]	65				105		105		134	136				
	40.255	9 Aug.	66								27	26			38	27		28		26
	40.285	19 Jun.	26			25	37		26		26	27								
	40.305	19 Jun	45			48							105			36				26
	40.315	19 Jun.	26			P10	P20													
	40.325	9 Aug.	66								54	54								
	40.345	19 Jun.	45			47	66									26		29		
	40.355	19 Jun.	45								24									
	40.365	19 Jun.	45													3		4		
	40.405	19 Jun.	45								48	48			103			26		
	40.415	23 Jun.	45				51	27[c]	26											-103(AB)
	40.445*	23 Jun.	45																	
	40.514	12 Jun.	45	42							23				101					
	40.525	23 Jun.	45			26	26	27[c]	26		26	26			53	83		68		
	40.545	19 Jun.	45			25		27[c]												
	40.555	12 Jun.	45	41		49	48								48	26		26		
	40.614*	16 Oct.	26															26		
	40.654*	3 Oct.	131															35		
	40.665*	16 Oct.	26															26		
	40.684*	9 Oct.	26															26		
	40.694*	6 Oct.	81															26		

Table 4.19 Radio tracking survey results for transmitters implanted and monitored during 1990, Site C study area.

Species	Freq.	Release Date (1990)	Release Loc. (km)	Survey Method, Date, and Kilometre Location																
				Air[a]		Air	Air	Boat[d]	Boat	Boat	Air	Boat	Air		Air	Air	Air	Air	Air	Air
				28 Jun.	30 Jun.	11 Jul.	8 Aug.	10 Aug.	11 Aug.	14 Aug.	17 Aug.	20 Aug.	21 Aug.	25 Aug.	10 Sep.	2 Oct.	3 Oct.	29 Oct.	30 Oct.	5 Dec.
Bull trout	40.235	14 Jun.	151	139			131			150			150		150		H11[f]			
	40.264	14 Jun.	151	126			148			150			150							
Arctic grayling	40.295*	6 Oct.	81																	
	40.335*	6 Oct	81																	
	40.385*	6 Oct.	81																	
	40.455*	12 Oct.	90																	
	40.485*	8 Oct.	65																	
	40.505*	8 Oct.	65																	
	40.535*	6 Oct.	81																	
Rainbow trout	40.275*	14 Jun.	151										142							
	40.375*	14 Jun.	151	151	148[b]	-[e]														
	40.395	16 Jun.	144	127			128										87			87
	40.425	14 Jun.	151	151													94		94	
	40.435*	14 Jun.	151				112													
	40.455*	21 Jun.	144		148[b]															
	40.465*	8 Jun.	117				125													
	40.475	8 Jun.	117	93			90													
	40.495	21 Jun.	144			93	93										91		91	90
Walleye	40.115	11 Aug.	26								26	26			41	94				-5(AB)[h]
	40.125	8 Aug.	66								101	26			9	12.0		13		12
	40.135	20 Aug.	66													36		35		37
	40.145	20 Aug.	66												27	30		27		17
	40.155	11 Aug.	26								26	26			58			107		26

[a] Survey from air.
[b] Captured by angling
[c] Captured by electroshocking.
[d] Survey from boat or ground.
[e] Termination of signal transmission.
[f] Halfway River location (H).
[g] Pine River location (P).
[h] Designates kilometre location downstream of Alberta-B.C. border.
*Designates individual which exhibited non-typical movement pattern or not located on more than two surveys.

Continued . . .

Table 4.18 Concluded.

Species	Freq.	Release Date (1989)	Release Loc. (km)	Survey Method, Date, and Kilometre Location																		
				Air[a]	Air	Air	Air	Air	Air	Air	Air	Air	Air	Air	Air	Air	Air	Air	Air	Air	Air	Air
				20 Nov.	22 Jan.	2 Mar.	7 May	8 May	15 May	22 May	28 May	6 Jun.	18 Jun.	11 Jul.	8 Aug.	17 Aug.	21 Aug.	11 Sep.	2 Oct.	3 Oct.	30 Oct.	5 Dec.
Walleye	40.984*	8 Oct.	132	38	35	35			-16(AB)[h]			-16(AB)										
	40.104*	20 Oct.	105																			
	40.765*	20 Oct.	105	35	4	4	4		4	4		4	4									
	40.704*	20 Oct.	105	43	41	35	35					-91(AB)										
	40.854*	20 Oct.	105	55		55						-167(AB)										
	40.774*	24 Oct.	45	18	-5(AB)				-39(AB)			-34(AB)										
	40.804*	24 Oct.	45		-9(AB)																	
	40.824*	24 Oct.	45	35	36		26		-19(AB)			-46(AB)										
	40.924*	24 Oct.	45	22	-142(AB)							-142(AB)										
	40.934*	24 Oct.	45		-107(AB)							-111(AB)										
	40.904*	24 Oct.	45		-32(AB)																	
	40.944*	25 Oct.	44		-20(AB)																	
	41.914*	25 Oct.	44																			
	40.754*	25 Oct.	44	36	3	3						4	3									
	40.894*	25 Oct.	44	23	4	4	4		4	4		4	4									
	40.734*	25 Oct.	44	35	34	8	36		36	35		36	35									
	40.874*	25 Oct.	44	15	12	12	10					12										
	40.974*	25 Oct.	44		20																	
	40.094*	25 Oct.	44	3	-8(AB)				-61(AB)			-62(AB)										-62(AB)
	40.634*	25 Oct.	44		-3(AB)				-68(AB)			-78(AB)										-72(AB)

Table 4.18 Radio tracking survey results for transmitters implanted during 1989 and monitored through 1990, Site C study area.

Species	Freq.	Release Date (1989)	Release Loc. (km)	Survey Method, Date, and Kilometre Location																				
				Air[a]	Air	Air	Air	Air	Air	Air	Air	Air	Air	Air		Air	Air		Air	Air	Air	Air	Air	Air
				20 Nov.	22 Jan.	2 Mar.	7 May	8 May	15 May	22 May	28 May	6 Jun.	18 Jun.	11 Jul.	30 Jul.	8 Aug.	17 Aug.	20 Aug.	21 Aug.	11 Sep.	2 Oct.	3 Oct.	30 Oct.	5 Dec.
Bull trout	40.024	8 Oct.	132	120	111											H26[c]			G2[d]					
	40.084	10 Oct.	105	106	105	102				H7	H10	H10	H10	H41			H84	H84[b]	-[g]					
	40.044	20 Oct.	105	105	106	108	110		111	110	112	117				H67	H70		H70					
	40.054	21 Oct.	67	65	63	41		42	42			42				H35	H65							
	40.074	21 Oct.	67	63	61	70	72		77	78	79	80	85	97		115	H22		H47	G100		G58	93	86
	40.605*	24 Oct.	44	38	38	39		36		31		38	36	37							37			
Rainbow trout	40.994	10 Oct.	105	115	113	59																		
	40.954	17 Oct.	105	97	97	97	127			L[e]	L	L	L	L										
	40.714	17 Oct.	105	97	98	98	98				97	97												
	40.724	18 Oct.	105		127	127																		
	40.844	18 Oct.	105		107	107	142			M2[f]	M3	M	M		107[b]									
	40.744*	20 Oct.	105	107																				
	40.784	20 Oct.	105		117	117	126		126	126	143	150	M	91										
	40.864	20 Oct.	105	106	107	111	118		121	150	150	150	150	150										
	40.884	20 Oct.	105	100	100	101																		
Northern pike	40.834	8 Oct.	132	136	136	130	109		112	111	111	107	107	107										
	40.794	10 Oct.	132		138	144	132		109	107	107	107	108	132										
	41.004	10 Oct.	132		114	110				84	86	84	84	88										
	40.014	10 Oct.	105	111	110	110	112			109	112	110		111		110			109					
	40.064	10 Oct.	105	107	108	107	101		100	101	100	101	101	99		102								
	40.034	10 Oct.	105	106	107	106	106			105		107	106			106			106					
	40.964	10 Oct.	105	119	119	108	107			105	108	106	108											
	40.674	24 Oct.	45	42	43		38		38	39		35												
	40.624	24 Oct.	45	26	25	24	25		24							67								

[a] Survey from air.
[b] Captured by angling
[c] Halfway River location (H).
[d] Graham River location (G).
[e] Lynx Creek location (L).
[f] Maurice Creek location (M).
[g] Termination of signal transmission.
[h] Designates kilometre location downstream of Alberta-B.C. border.
*Designates individual which exhibited non-typical movement pattern or not located on more than two surveys.

Continued . . .

Table 4.17 Release locations on the Peace River of radio tagged fish during 1989 and 1990.

Release Location	Number of Each Species Released					
	Arctic grayling	Bull trout	Northern pike	Rainbow trout	Walleye	Total
Km 26	-	-	-	-	22	22
Km 45	-	1	-	-	9	2
Km 45	-	-	2	-	8	10
Km 65	2	-	-	-	-	2
Km 66	-	-	-	-	7	7
Km 67	-	2	-	-	-	2
Km 81	4	-	-	-	1	5
Km 90	1	-	-	-	-	1
Km 105	-	2	4	9	4	19
Km 117	-	-	-	2	-	2
Km 131	-	-	-	-	1	1
Km 132	-	1	3	-	1	5
Km 133	-	-	-	3	-	3
Km 149	-	2	-	4	-	6
Total	**7**	**8**	**9**	**18**	**53**	**95**

Eight radio transmittered fish were recaptured by anglers (one bull trout, three rainbow trout, and four walleye); all were in good physical condition and had no external infections around the incision. Five additional radio transmittered walleye were recaptured during electrofishing surveys. These fish also were in good condition. One individual contained an inoperative transmitter. One walleye, captured during fall, was apparently trying to expel the transmitter from its body cavity. The transmitter, which had been implanted 52 days previously, was encapsulated in scar tissue and was extruding from the ventral surface of the fish. Because the individual appeared vigorous and in good condition, the transmitter was placed back into the body cavity, the incision re-sutured, and the fish released.

Survey results for all transmittered fish have been presented in Tables 4.18 and 4.19. Individual movement patterns have also been illustrated in Figures 4.12 to 4.15. Data for fish which were located on less than three occasions have not been graphed nor have fish which showed abnormal movement patterns (i.e. large-scale unidirectional movement out of study area). Survey results are not available for seven Arctic grayling and five walleye since they were radio tagged in fall 1990.

Walleye

In total, 53 walleye were implanted with radio transmitters during 1989 and 1990. Most of the 20 individuals implanted during fall 1989 exhibited unidirectional movements downstream (Table

Northern Pike

Few tag returns were obtained for northern pike. Five of the eight returns were from stationary fish (Figure 4.11). During summer one individual moved downstream 24 km and during fall two recaptured fish had moved upstream from their original tagging locations.

Longnose sucker

Longnose sucker was the only non-sportfish species for which more than five tag recoveries were obtained. No clear movement pattern was illustrated by the data (Figure 4.11). Seven of the eleven tagged fish were recovered at creek mouths. Four fish were recovered in Lynx Creek during the spring spawning period, 1990. All of these fish had been originally tagged at the creek mouth during the previous summer.

Some fish exhibited more extensive movements. One individual moved downstream 71 km from the Halfway River area (Km 97) to the Beatton River (Km 26), while four individuals moved upstream from their tagging location.

Radio Telemetry Program

During 1989 and 1990, 95 individuals of five fish species were implanted with radio transmitters. The size (i.e., weight) of fish selected for implants varied (Table 4.16), but all fish utilized were mature individuals. Fish were released at several locations throughout the Site C study area (Table 4.17). In 1990, transmittered fish were released as close as possible to their point of capture.

Table 4.16 Number and weight range of fish utilized for radio transmitter implants, Peace River, 1989 and 1990.

Species	Large Transmitters (24 g)			Small Transmitters (15 g)			Total No. Radio-Tagged
	No. Radio-Tagged	Fish Weight (g)		No. Radio-Tagged	Fish Weight (g)		
		Median	Range		Median	Range	
Arctic grayling	-	-	-	7	957	837-1114	7
Bull trout	7	2950	1225-6500	1	1862	-	8
Northern pike	5	2500	1525-4650	4	1820	1009-3000	9
Rainbow trout	-	-	-	18	830	634-1780	18
Walleye	22	1603	1192-3090	31	1027	706-2048	53
Total	34			61			95

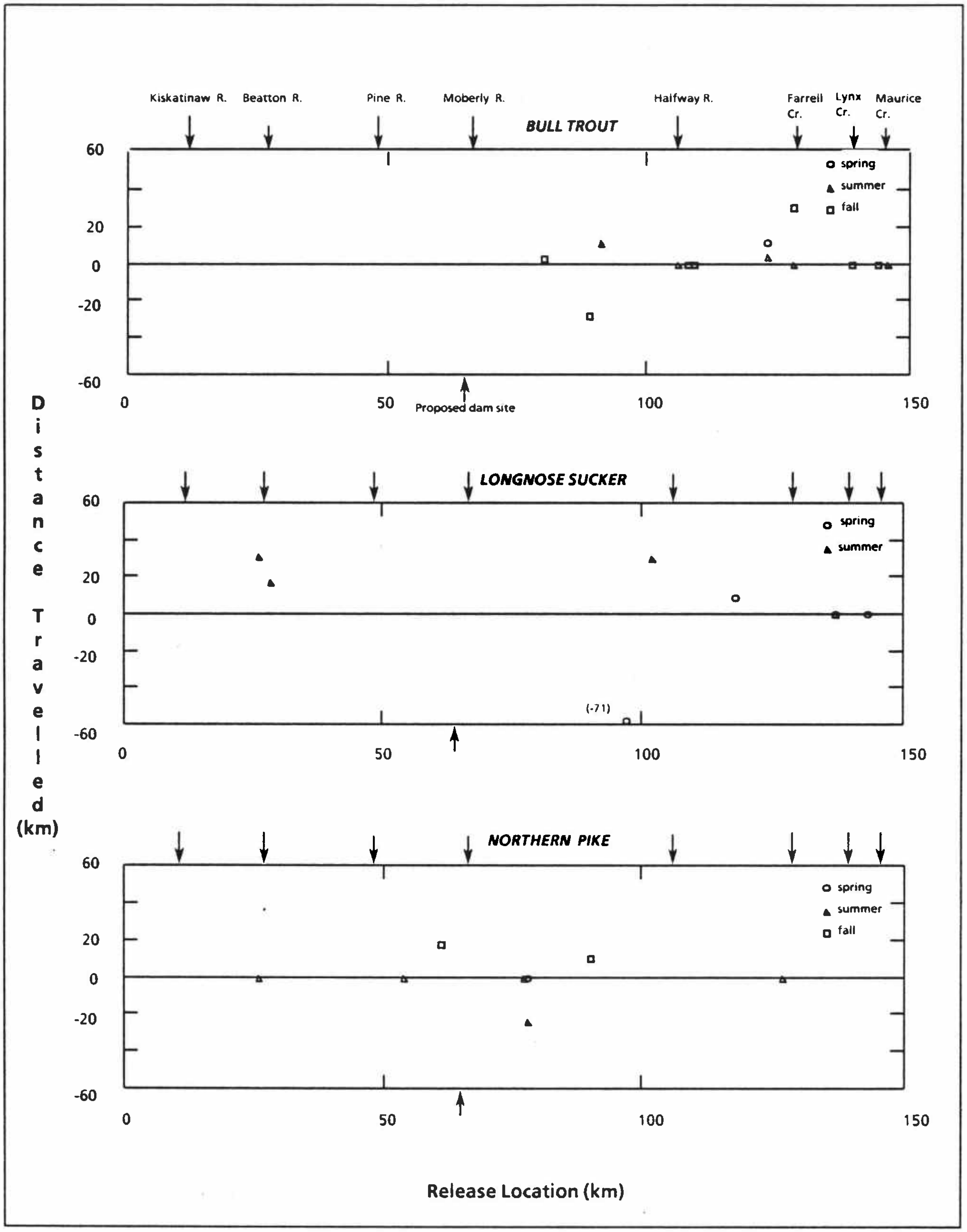


Figure 4.11 Distance travelled by tagged bull trout, longnose sucker, and northern pike recaptured during spring, summer, and fall on the Peace River, Site C study area. Tag returns for 1989 and 1990 are combined. Brackets ( ) designate actual distance travelled for movements greater than the graphed range.

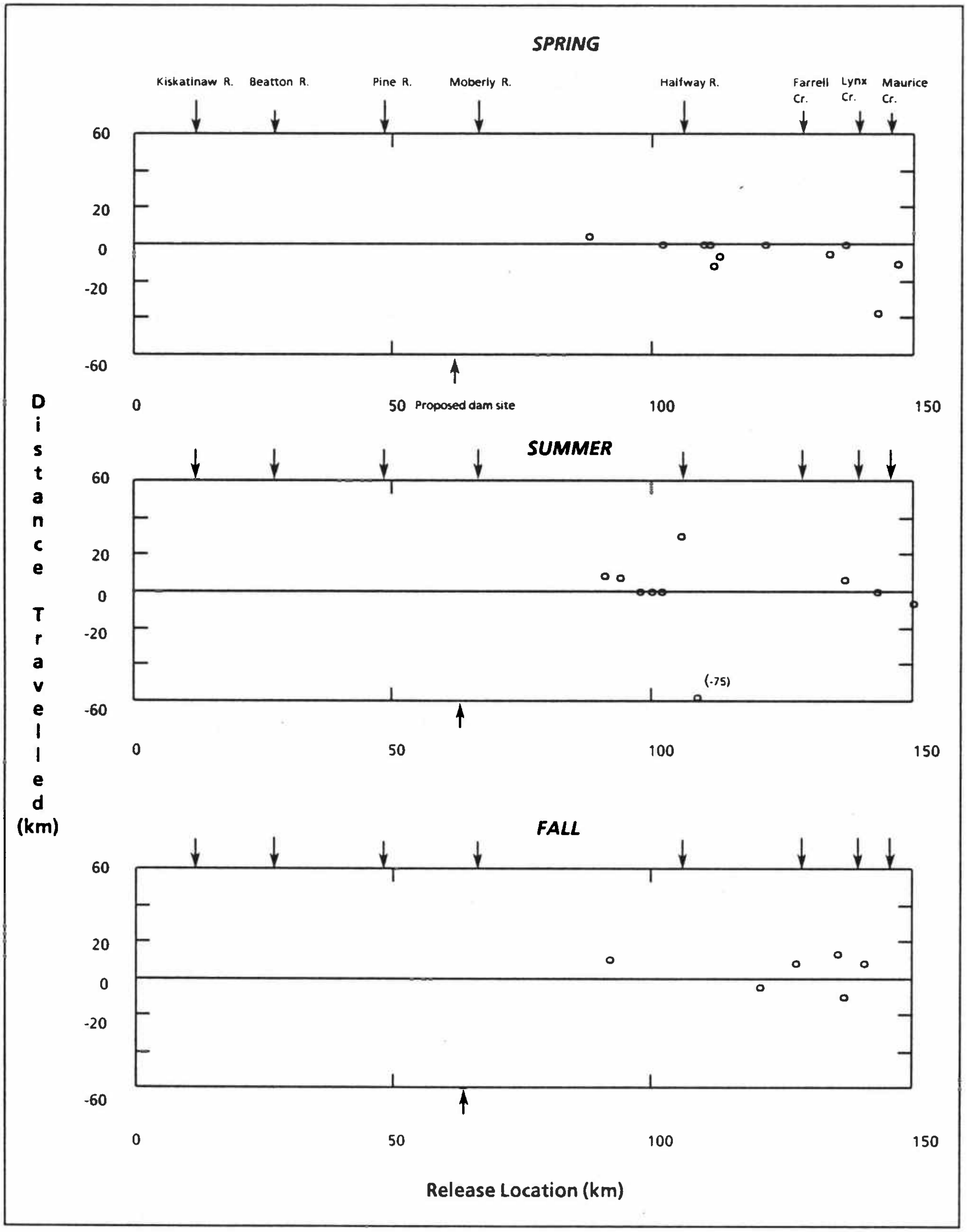


Figure 4.10 **Distance travelled by lake whitefish recaptured during spring, summer, and fall on the Peace River, Site C study area. Tag returns for 1989 and 1990 are combined. Brackets ( ) designate actual distance travelled for movements greater than the graphed range.**

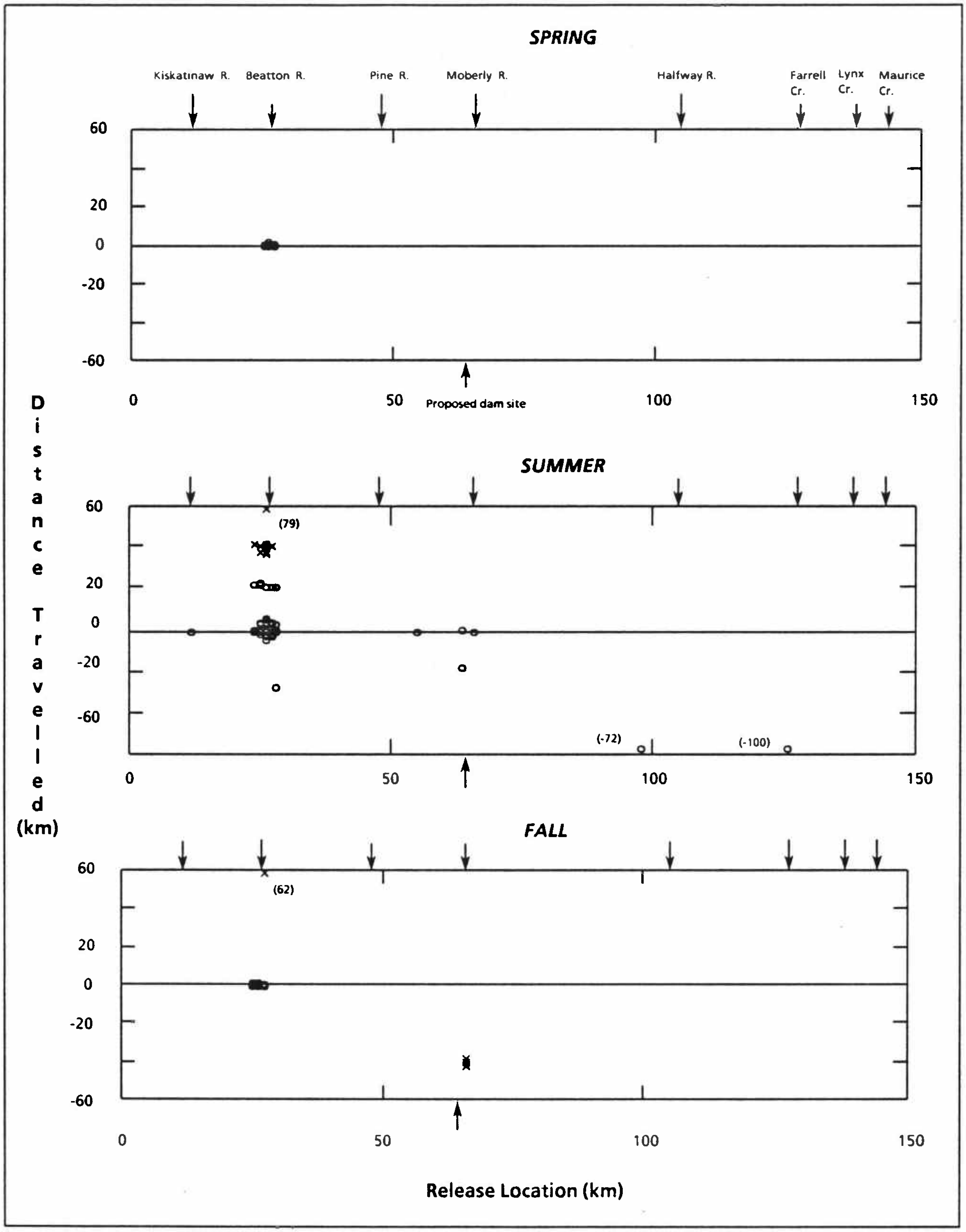


Figure 4.9 Distance travelled by tagged walleye recaptured during spring, summer, and fall on the Peace River, Site C study area. Tag returns for 1989 and 1990 are combined. Brackets ( ) designate actual distance travelled for movements greater than the graphed range.

were stationary. These fish either had not moved from the tagging location or were recaptured after completing a migratory circuit. Eight of the fish had originally been released during the same sampling period of the previous year. It is unlikely that these fish had remained stationary. Intense sampling at this location during early spring yielded no walleye, either captured or observed. During summer the majority of tag recoveries also were from stationary fish (62.7%), but there was a statistically significant tendency for tag recoveries of fish which exhibited some movement to be made upstream of their tagging locations (Sign test, $P<0.05$). The average distance travelled by these fish exceeded 30 km. Also, all fish which exhibited upstream movement were originally tagged at the mouth of the Beatton River (Km 26). Conversely, downstream recoveries (five tags) were made from fish released at sites upstream of this location. A limited number of tags were recovered during fall. Of these, eight were from stationary fish, and three were from those which travelled downstream and one fish was recaptured upstream of its tagging location. These data suggest that an upstream movement of walleye occurred during summer.

Lake Whitefish

Twenty nine usable recoveries were obtained from tagged lake whitefish but no clear movement pattern could be discerned (Figure 4.10). Tag recoveries were usually made upstream from the Halfway River (Km 105) and maximum distances travelled rarely exceeded 20 km. One exception was a fish which travelled downstream from the Halfway River area (Km 109) to below Taylor (Km 34), a distance of 75 km. There appears to be a tendency for tagged lake whitefish to be recovered upstream of their release sites during spring and summer, and downstream of their release sites during fall, but these trends were not statistically significant (Sign test, $P>0.05$).

Bull trout

Seventeen bull trout were recaptured -- 13 from the Peace River (Figure 4.11), and four from the Halfway River system. The low number of tag returns precluded detailed analyses but some trends were apparent. Most recoveries (seven tags) were from stationary fish ;however, two fish tagged in the Halfway River during spring 1989 moved downstream into the Peace River by the following summer. One of these continued downstream to an area above the Moberly River (Km 75), a distance of 55 km. Two fish tagged in the lower Halfway River during fall 1989 were subsequently recaptured approximately 60 km upstream, one near the mouth of the Graham River and one from the Graham River itself. Both recaptures were obtained by anglers during mid-summer. The recapture data suggest that there was some movement of bull trout between the Peace and Halfway river systems. This movement is probably related, in part, to spawning activity.

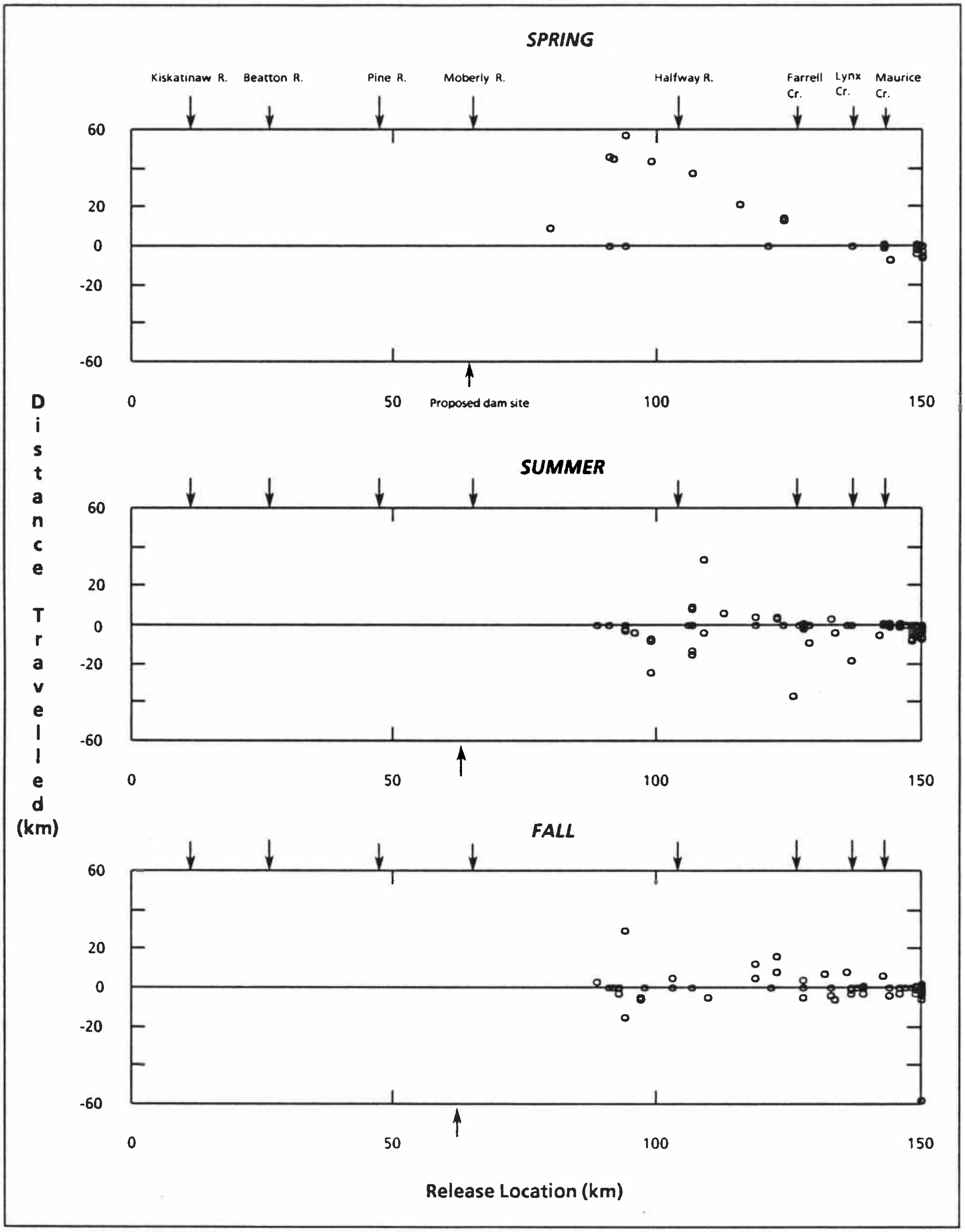


Figure 4.8 Distance travelled by tagged rainbow trout recaptured during spring, summer, and fall on the Peace River, Site C study area. Tag returns for 1989 and 1990 are combined.

above the Halfway River. This trend was not statistically significant (Sign Test P,>0.05). These patterns may represent dispersal to feeding areas during summer and the subsequent return of fish to overwintering areas later in the season. The limited number of tag returns obtained during spring did not allow meaningful assessment of movements related to spawning activity. During surveys for spawning fish conducted in early spring 1990 only spent individuals were encountered which suggested that the fish present in the Peace River had already returned from spawning areas in tributary streams.

Rainbow trout

During 1989 and 1990, 155 usable tag recoveries were obtained for this species. The majority of these were from stationary fish or those exhibiting movement less than 10 km. Maximum distances travelled during summer and fall sampling periods were low compared to other species and were restricted, to a large extent, to areas upstream of the Halfway River (Figure 4.8).

Recovery data during spring showed a distinct upstream movement of tagged fish. The greatest distances travelled by rainbow trout occurred at this time. One individual travelled 57 km from the Halfway River area (Km 94) to the base of the Peace Canyon Dam (Km 150). Five other individuals travelled upstream in excess of 20 km. The five individuals which moved downstream from their release site during spring had all originally been tagged above Maurice Creek (Km 143). The spring recovery pattern was probably related to pre-spawning movements by fish trying to locate spawning areas. In fact, five recoveries were from fish which had entered Lynx Creek and one was made from an individual which had moved into Maurice Creek.

During summer, tagged fish tended to be captured downstream of their tagging locations (Sign Test $P<0.05$). The reason for this is unclear but may be due to dispersal of post-spawning fish from the upper sections of the Peace River.

Walleye

Of the 443 walleye tagged during 1989 and 1990, 81 usable tags were recovered. This species exhibited the greatest amount of movement of any sportfish surveyed in the Site C study area. Migrations exceeding 50 km were not uncommon. The greatest distance travelled was 100 km and was made by a fish which moved downstream from Farrell Creek (Km 127) to the Beatton River (Km 27). Most of the tagged fish were recovered from the mouth of the Beatton River (70.3% of tag returns) which reflects the importance of this habitat to walleye, and also the high degree of sampling intensity in this area.

Figure 4.9 illustrates the long distances travelled by this species and the limited number of areas, principally creek mouths, where it was recaptured. Of ten fish recaptured during spring, all

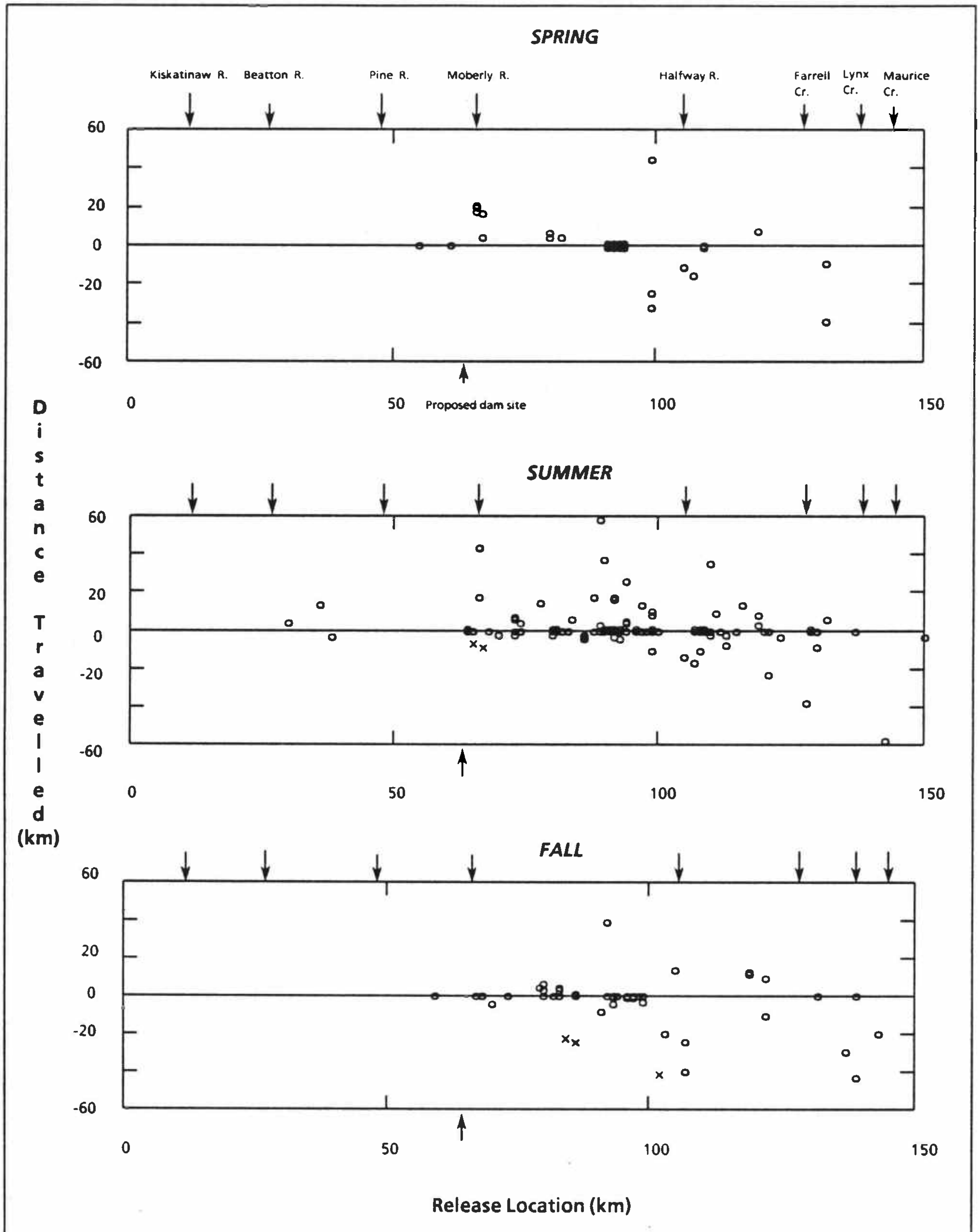


Figure 4.7 Distance travelled by tagged Arctic grayling recaptured during spring, summer, and fall on the Peace River, Site C study area. Tag returns for 1989 and 1990 are combined.

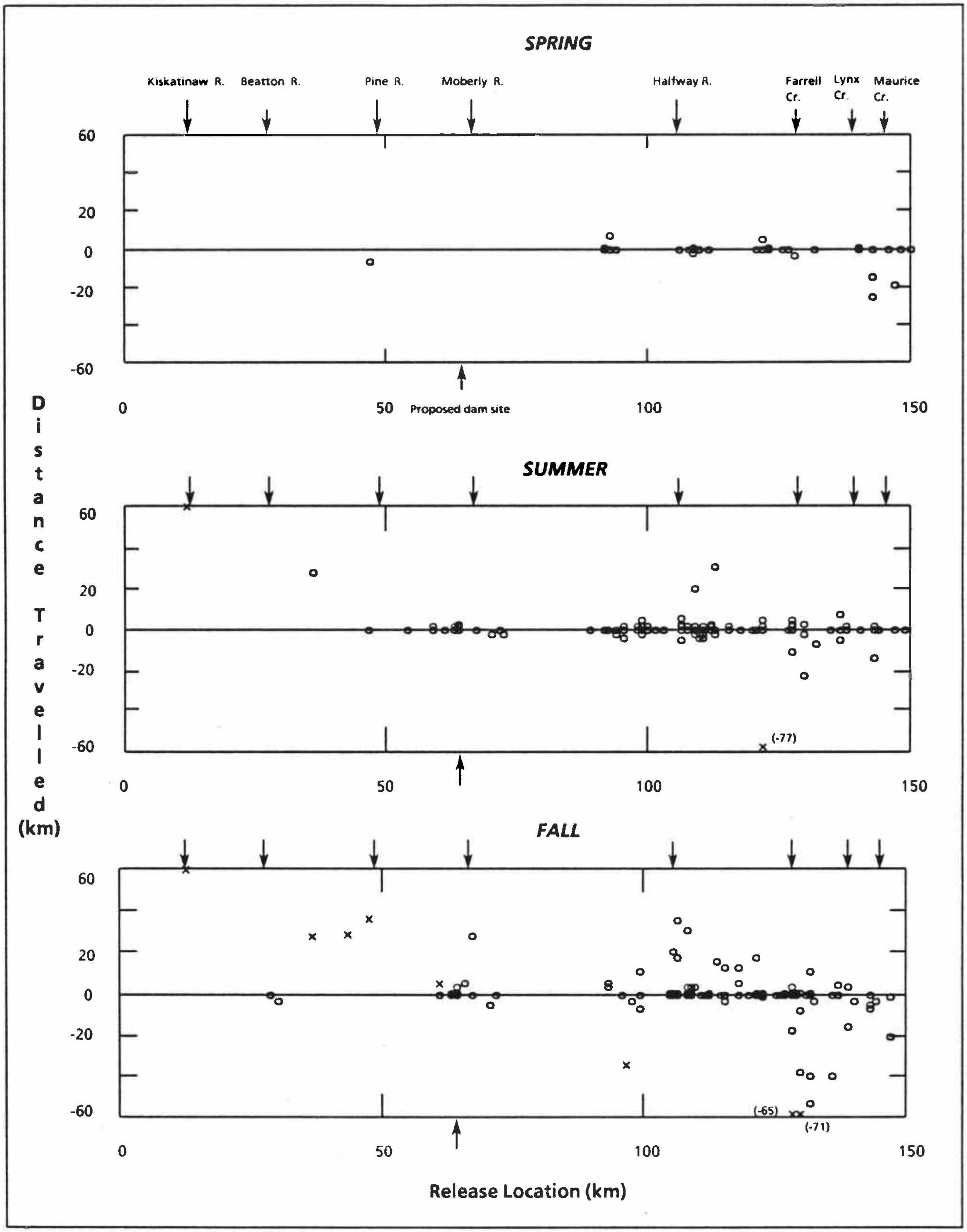


Figure 4.6 Distance travelled by tagged mountain whitefish recaptured during spring, summer, and fall on the Peace River, Site C study area. Tag returns for 1989 and 1990 are combined. X designates movement past dam site. Brackets ( ) designate actual distance travelled for movements greater than the graphed range.

during spring and summer illustrated a sedentary pattern with most fish moving very little. This pattern changed during fall, in that many recoveries were made either upstream (25 tags) or downstream (22 tags) of the release site. The degree of dispersion (sample variance) of the recoveries increased significantly between spring, summer and fall (6.5, 9.0 and 15.9, respectively) (Bartletts' test of variance homogeneity, $P<0.001$). Also, movement direction was related to release location. Fish tagged downstream of Km 120 tended to move upstream (Sign test, $P< 0.05$) while those released upstream were usually recaptured downstream of their tagging site (Sign test, $P<0.05$). A number of recoveries (14 tags) were made near the mouth of the Moberly River (Km 66) during fall. Three of these fish had moved in excess of 30 km upstream to reach this area.

Mountain whitefish are fall spawners which would account for the dispersed pattern of the recoveries made during this period. During the falls of 1989 and 1990 spawning concentrations of mountain whitefish were encountered from Hudson Hope (Km 143) to the Moberly River (Km 66) but large numbers of spawning fish also were captured from the mainstem Halfway River during the 1989 survey (Pattenden et al. 1990). Three recoveries in the Halfway River were obtained from fish originally tagged in the Peace River. Conversely, six fish originally tagged in the Halfway River during fall 1989, were subsequently recaptured in the Peace River. These data suggest that movement of fish from the Peace River into the Halfway River occurs during the fall spawning period. Concentrations of pre-spawning fish were also encountered at the mouth of the Moberly River and spawning fish were sampled from the mainstem Moberly River during 1989 (Slaney et al. 1991) and during previous fisheries studies (RRCS 1978). This suggests that the Moberly River likely also is used as a spawning area by the Peace River mountain whitefish population.

Arctic grayling

One hundred and ninety usable tag recoveries were made for Arctic grayling during 1989 and 1990. During each sampling period individuals moved great distances both upstream and downstream, with average distances travelled exceeding 10 km. The maximum recorded movement for Arctic grayling, 59 km, was made by an individual which travelled downstream from Maurice Creek (Km 143) to upstream of the Moberly River (Km 90). This distance was almost achieved by another fish which travelled upstream 58 km between the same two locations. Although many fish exhibited some movement, the greatest number (98 recoveries) were captured at the original release sites. Tag recoveries illustrated by Figure 4.7 show no clear movement pattern. Movement up and downstream occurred during each season and was generally restricted to areas of the Peace River between the Moberly River (Km 66) and Maurice Creek (Km 143); however, recovery data obtained during summer showed a statistically significant upstream movement by fish tagged below the Halfway River (Km 105) (Sign test $P,< 0.05$ for fish moving in excess of 10 km). Conversely, during fall, most fish exhibiting movements in excess of 10 km had travelled downstream from release sites

Table 4.15 **Concluded.**

Species	Fall								Total Recaptured (All Sessions Combined)						
	Stationary	Downstream (km)			Upstream (km)			Total	Stationary		Downstream (km)		Upstream (km)		Total
	No.	No.	Avg.	Max.	No.	Avg.	Max.	No.	No.	%	No.	%	No.	%	No.
SPORTFISH															
Arctic grayling	21	14	-20.9	-43	10	10.5	39	45	98	51.6	45	23.7	47	24.7	190
Bull trout	4	2	-29.0	-30	1	3	3	7	7	53.8	2	15.4	4	30.8	13
Goldeye	-	-	-	-	-	-	-	-	1	100.0	-	-	-	-	1
Kokanee	-	-	-	-	1	3	3	1	1	33.3	-	-	2	66.6	3
Lake whitefish	-	2	-7.5	-10	4	9.8	13	6	11	37.9	9	31.0	9	31.0	29
Mountain whitefish	63	22	-21.0	-71	25	13.9	37	110	166	64.6	51	19.8	40	15.6	257
Northern pike	-	-	-	-	2	13.5	17	2	5	62.5	1	12.5	2	25.0	8
Rainbow trout	27	18	-7.7	-58	11	9.4	29	56	68	43.9	59	38.1	28	18.1	155
Walleye	8	3	-40.0	-40	1	62	62	12	55	67.9	8	9.9	18	22.2	81
NON-SPORTFISH															
Longnose sucker	-	-	-	-	-	-	-	-	6	54.5	1	9.1	4	36.4	11
Largescale sucker	-	-	-	-	1	4	4	1	1	33.3	1	33.3	1	33.3	3
Northern squawfish	-	-	-	-	-	-	-	-	3	75.0	1	25.0	-	-	4
White sucker	1	-	-	-	-	-	-	1	1	100.0	-	-	-	-	1

Table 4.15 **Summary of fish movements[a] assessed from tag returns during spring, summer, and fall, Peace River, 1989 and 1990.**

Species	Spring								Summer							
	Stationary	Downstream (km)			Upstream (km)			Total	Stationary	Downstream (km)			Upstream (km)			Total
	No.	No.	Avg.	Max.	No.	Avg.	Max.	No.	No.	No.	Avg.	Max.	No.	Avg.	Max.	No.
SPORTFISH																
Arctic grayling	17	6	-22.0	-39	10	14.5	45	33	60	25	-10.3	-59	27	15.0	58	112
Bull trout	-	-	-	-	1	11	11	1	3	-	-	-	2	7.5	11	5
Goldeye	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Kokanee	1	-	-	-	1	52	52	2	-	-	-	-	-	-	-	-
Lake whitefish	6	5	-14.2	-37	1	4	4	12	5	2	-40.5	-75	4	13.3	30	11
Mountain whitefish	23	6	-12.3	-26	2	6.0	7	31	80	23	-8.4	-77	13	9.2	31	116
Northern pike	1	-	-	-	-	-	-	1	4	1	-24	-24	-	-	-	5
Rainbow trout	13	5	-5.0	-7	9	31.8	57	27	28	36	-7.2	-37	8	9.0	34	72
Walleye	10	-	-	-	-	-	-	10	37	5	-49.0	-100	17	34.5	79	59
NON-SPORTFISH																
Longnose sucker	5	1	-71	-71	1	9	9	7	1	-	-	-	3	26.0	31	4
Largescale sucker	-	-	-	-	-	-	-	-	1	1	-63	-63	-	-	-	2
Northern squawfish	1	-	-	-	-	-	-	1	2	1	-61	-61	-	-	-	3
White sucker	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	

[a]Those individuals recaptured <5 days from release date excluded from analysis and those individuals recaptured ≤ 2 kilometres from release point given distance travelled value of zero kilometres (see Methodology).

Continued . . .

during 1989 and 1990 are summarized in Table 4.14 and movement information for all species have been presented in Table 4.15 while detailed information will be presented in Appendix 4.6A of the final report. Movement patterns will be discussed and illustrated (Figures 4.6 to 4.11) for species for which more than five tags where recovered.

Mountain whitefish

A large number of tags were recovered for mountain whitefish (Table 4.14). Of the 257 usable returns, 64.6% were from fish exhibiting no net movement; however, some individuals travelled considerable distances (Table 4.15). Eleven fish moved in excess of 20 km downstream from their tagging locations, the greatest maximum distance being 77 km travelled by an individual tagged near Farrell Creek (Km 122) and recaptured near Taylor (Km 45). Upstream movement in excess of 20 km was noted for ten individuals. One fish travelled from the Pine River (Km 47) to upstream of the Moberly River (Km 90), a distance of 37 km.

Table 4.14 Number of fish tagged and number recaptured from the Site C Study Area during 1989 and 1990.

Species	1989		1990		Total		No. Recaptured by method			
	No. Tagged	No. Recap.	No. Tagged	No. Recap.	No. Tagged	No. Recap.	Angling[a]	Electro-shocking	Gill netting[b]	Fish trap[c]
SPORTFISH										
Arctic grayling	452	45	796	160	1248	205	47	158	-	-
Bull trout	94	6	86	11	180	17	7	10	-	-
Goldeye	17	1	4	1	21	2	1	1	-	-
Kokanee	62	3	126	3	188	6	2	4	-	-
Lake whitefish	360	7	1111	32	1471	39	2	37	-	-
Burbot	8	-	4	-	12	-	-	-	-	-
Mountain whitefish	5316	203	-	119	5435	322	17	304	-	-
Northern pike	53	2	192	6	245	8	3	5	-	-
Rainbow trout	267	43	668	127	935	170	79	84	1	7
Walleye	200	25	243	67	443	92	36	54	2	-
NON-SPORTFISH										
Longnose sucker	686	3	-	8	686	11	-	7	-	4
Largescale sucker	250	2	-	2	250	4	-	4	-	-
Northern squawfish	61	2	-	2	61	4	3	1	-	-
White sucker	68	1	-	-	68	1	-	1	-	-
Total	**7895**	**343**	**3230**	**538**	**11 125**	**881**	**197**	**670**	**3**	**11**

[a] Includes recoveries during field sampling and from recreational anglers.
[b] Recoveries submitted by Environment Canada.
[c] Recoveries obtained from field program conducted by Aquatic Resources Ltd. during 1990.

Although recovery data suggest that most fish do not move great distances, distinct differences exist in movement patterns relative to season and release location (Figure 4.6). Recoveries made were fish prevented from continuing their migration upstream. Successful spawning in the tailrace area was very unlikely due to fluctuating water levels, high water velocities, and a bedrock substrate.

Sucker species

The three sucker species encountered during the study, longnose, largescale, and white sucker, exhibited similar habitat preference and will be discussed as a group. Habitat use was similar between seasons but varied between age-classes.

Adult suckers were most abundant in areas with low water velocity and with a fine sediment substrate. Habitat types best suited for this group were deep pool, glide, and backwater areas. Concentrations of suckers were encountered at tributary mouths (i.e., Farrell, Lynx, and Maurice creeks) during all seasons. Highest densities occurred during the spring period when individuals of these species apparently were attempting to migrate into the tributary streams to spawn (Slaney et al. 1991). Longnose suckers will spawn in large river systems (Walton 1980) but no spawning fish were encountered away from tributary mouths during the spring surveys. The cold temperature and fluctuating water levels in the mainstem likely makes it unsuitable spawning habitat for suckers.

Large numbers of Y-O-Y and juvenile suckers were encountered throughout the Peace River as far upstream as Km 143. Habitats used most often were shallow pool, glide, and backwater areas over a fine sediment substrate.

4.6 FISH MOVEMENTS

Tag Recoveries

During the 1989 and 1990 field programs, 11 125 individuals of 14 fish species were tagged in the Site C study area (Table 4.14). Of this total, 881 tags were recovered -- 343 during the first year and 538 during the second. The number of tags recovered for a particular species depended on the number of tags applied, sampling intensity and methodology utilized. For example, few tags were recovered for bull trout due to the low number of fish tagged. Also, mountain whitefish were not actively sampled during 1990; therefore, the number of recoveries made during that year were much lower. than those obtained during 1989. And finally, a large number of tag recoveries for sportfish such as Arctic grayling, rainbow trout and walleye were made by anglers.

Recovery data for 1989 and 1990 were combined for the analyses. Recoveries made less than five days from the release date were excluded since they may have represented individuals suffering from tagging stress (i.e., downstream drift immediately after application of tag). Those recoveries made less than or equal to two kilometres from the point of release were given a distance travelled value of zero kilometres (see Section 2.2: Methodology). The results of the tagging programs conducted mouths and enter shallow areas of the mainstem river in search of forage fish. Forage fish such as juvenile suckers and cyprinids also were abundant in the tributary mouths; therefore, it is difficult to predict whether or not walleye left these areas to feed.

Deep water habitat in the mainstem Peace River also would provide cover for adult walleye. Because of the survey method utilized (i.e., electrofishing) the presence of walleye in this habitat could not be assessed. Evidence from the radio telemetry program does indicate that walleye utilized deep pools, glides, and snyes in the Peace River, but were most often located at tributary mouths.

Walleye do not spawn in the Site C study area. Extensive sampling during early spring produced no walleye in the study area and individuals captured later in the spring were spent.

No juvenile or Y-O-Y walleye were encountered during the study.

Northern pike

This species typically inhabits lake environments but also occurs in river systems (Crossman 1978). In the Peace River, northern pike were restricted to calm water areas. All age-classes were most abundant in snye habitat off the mainstem river, presumably locations where forage fish were most abundant. Northern pike were closely associated with cover within this habitat. The most important cover type encountered were beaver lodges and food caches.

Post-spawning northern pike were encountered during surveys conducted in early spring. Large numbers of spent fish were sampled from snyes located at Km 61 and Km 78 which appeared suitable as spawning habitat. Successful reproduction did occur as evidenced by the presence of juvenile fish in these particular areas and in other snyes.

Snyes were utilized as rearing sites by younger age-classes. Fish were closely associated with limited amounts of submergent vegetation in shallow water. These locations supplied both protection from predators and an abundant food supply (i.e., Y-O-Y cyprinids and suckers).

Kokanee

Kokanee were most abundant in large deep backwater habitats adjacent to strong currents. This species also utilized similar habitats as rainbow trout and were often captured in association with this species.

No evidence of spawning activity by kokanee was observed in the Site C study area. It is likely that individuals present in the study area immigrated from Williston Lake. Dense aggregations of pre-spawning kokanee, as indicated by their red body colour, were observed in the tailrace area of the Peace Canyon Dam during 1989. Because spawning kokanee traditionally home to the small tributaries where they originated (Lorz and Northcote 1965), it is assumed that these aggregations

Lake whitefish

Lake whitefish are typically a species of deep water habitats (Scott and Crossman 1973) and as such were not efficiently sampled by boat electrofishing. As a result, it was difficult to access the habitat preferences of this species, but inferences could be made from the survey results.

Adults were the only age group of this species captured from the Peace River. Lake whitefish exhibited schooling behaviour and were most often sampled from deep pool and backwater habitats. Fish were most abundant at tributary confluences which created areas of high water turbidity. Deep snyes were also important habitats during early spring. This habitat was probably utilized due to the warmer water temperatures in the snyes relative to the mainstem Peace River. Lake whitefish were abundant and widely distributed in all habitat types during spring 1990; a period when water turbidity levels were high. Individuals were close to the surface and accessible to electrofishing. These results suggest that habitat use by lake whitefish is more extensive than the survey data indicate.

This species typically spawns during fall (Scott and Crossman 1973). Although suitable spawning substrate exists in the Site C study area (i.e., cobble and rubble), no evidence of spawning activity in the Peace River was documented, nor were Y-O-Y or juvenile age-classes encountered.

Bull trout

Bull trout were widely distributed in the Peace River but were not abundant. Habitats utilized by individuals of this species were typically deep (i.e., <1.5m) glide, pool, and riffle habitats. No distinct preferences were observed; however, individuals were usually associated with some form of cover such as boulders or debris. Limited numbers of smaller fish were captured during the study. These fish utilized shallow riffle habitat adjacent to shoreline cover. Habitat preference did not change between seasons.

Spawning bull trout were not observed in the Peace River. Results from the radio telemetry program (see Section 4.4) suggest that individuals migrate to tributary streams to spawn.

Walleye

Adult walleye were encountered almost exclusively at the confluences of major tributaries, these being the Kiskatinaw, Beatton, Pine, and Moberly rivers. The habitat types present in these areas included deep riffle (Kiskatinaw), deep glide (Pine River), shallow glide (Beatton River), and deep backwater habitat (Moberly River). The one characteristic common to all these areas was high water turbidity. Because this species is sensitive to high light intensities (Ali and Anctil 1977), turbid water found at the major tributary confluences provided the necessary shelter during daylight. Sampling was not conducted during night periods. Presumably, individuals would leave the tributary

No young-of-the-year rainbow trout were encountered in the Peace River during the study. It is assumed that this species utilized rearing areas in tributary streams (Slaney et al. 1991).

Arctic Grayling

Arctic grayling were encountered singly or in loose aggregations. Although habitat preference varied depending on age and season, the habitat types utilized were discreet and predictable.

Adult Arctic grayling were most often captured in two habitat types. These were deep glide habitat associated with a cobble substrate interspersed with boulders and exhibiting a steeply receding bottom contour, and shallow glide habitat with a cobble substrate exhibiting a gentle slope immediately downstream from a deep riffle or glide. The deep glide habitat was utilized during all seasons and contained high densities of fish encountered as single individuals. The shallow glide habitat contained dense aggregations of adult fish only during the spring period. The seasonal change in habitat preference may be related to post-spawning activity, but is more likely related to areas of highest food abundance. Dense concentrations of emerging chironomid larvae were observed in shallow glide habitats during the springs of 1989 and 1990. Adult fish also were located in backwater habitats of tributary confluences, but the numbers of fish sampled were small relative to the numbers found in the preferred habitats.

Spawning Arctic grayling were not encountered during extensive sampling in early spring. All fish assessed for spawning condition were spent which suggests that spawning activity had been completed by this time. This species characteristically travels great distances to spawn in small tributary streams (Craig and Poulin 1975) and it is suspected of utilizing Moberly River (Slaney et al. 1991), Farrell Creek (RRCS 1978), and possibly the Halfway River system, for this purpose.

Rearing habitat utilized by Arctic grayling was typically shallow glide. Juveniles were encountered singly interspersed with the larger adults. Juveniles were also encountered in shallow riffle habitats in close association with shoreline structures such as boulders and debris. Attempts were made to identify habitats utilized by young-of-the-year (Y-O-Y) Arctic grayling. A variety of sampling methods (i.e., boat electrofishing, backpack shocking and beach seines) produced only four Y-O-Y fish. These individuals were encountered in a shallow pool immediately downstream from a riffle. Because spawning likely takes place in tributary streams, Y-O-Y of this species probably rear in these areas and would not normally be found in large rivers before late summer and fall, when they emigrate to wintering areas (Kratt and Smith 1977).

Rearing areas for younger age-classes of mountain whitefish were characterized as shallow glide habitat associated with shoreline areas. Dense aggregations of juvenile fish were sampled in this habitat during all seasons but were rarely encountered in other habitat types. Attempts were made to identify habitats utilized by young-of-the-year (Y-O-Y) fish. Beach seining and backpack electrofishing conducted during summer 1990 yielded limited results (i.e., 18 captured fish). Y-O-Y fish were captured in habitats similar to those frequented by juveniles and also in shallow pool habitats at the base of riffles. Y-O-Y mountain whitefish were probably most abundant in shallow pool habitat where they avoided higher water velocities and predators.

Rainbow trout

Individuals of this species were usually encountered singly and were restricted to shoreline areas. No Y-O-Y rainbow trout were encountered in the Peace River; therefore, the discussion is restricted to juvenile and adult fish.

Adult and juvenile rainbow trout preferred similar habitat types during all seasons. Fish were encountered in pool, glide and riffle habitats which contained a variety of substrate types varying from fine sediments to boulders; however, fish were invariably associated with structures which provided cover. Boulders, submerged trees, undercut banks and depressions in the bottom substrate were all utilized, when available. Because the majority of these structures were associated with the shoreline, rainbow trout tended to be most abundant in this region. One additional cover type, high water turbidity, also was utilized. The Peace River was typically characterized as having low water turbidity (see Section 3.2), and as such, areas of high water turbidity were restricted to backwater habitats associated with tributaries. Rainbow trout were often encountered in these locations.

Adult rainbow trout were most abundant in deep water areas. The largest fish were usually encountered in backwater habitats. Juvenile rainbow trout were most abundant in shallow riffle habitats and when present in association with larger fish, were usually restricted to shallow water close to the shoreline.

A very limited amount of spawning habitat is available to rainbow trout in the Peace River within the Site C study area. This is due to the paucity of suitable substrate (i.e., gravel) and daily fluctuations in water levels associated with water releases from the Peace Canyon Dam. Extensive sampling during early spring identified no actively spawning fish in the mainstem Peace River. This evidence suggests that little spawning activity takes place in the mainstem Peace River. Rainbow trout usually spawn in streams (Raleigh et al. 1984). It is likely that the rainbow trout of the Peace River utilized small tributaries as spawning habitat (Slaney et al. 1991).

use. The environment (i.e., water temperature, velocity, depth, turbidity, etc.) will affect the habitat preference of an individual. The survey technique also will affect the assessment of habitat use by a species. Boat electrofishing is a highly efficient method of capture which permits release of fish back into their environment unharmed; however, this sampling method is restricted to areas with water depths between 0.25 m and 2.0 m. Individuals which inhabit areas outside this range will be under represented in the sample. Adult fish of species such as walleye, bull trout, lake whitefish and large size-classes of rainbow trout generally will be found in deeper water, while smaller size-classes of all species generally will reside in very shallow water. These factors should be considered when interpreting the data.

This section is based on the qualitative assessment of habitat use by major fish species encountered in the Site C study area during fisheries surveys of the Peace River in 1989 and 1990. Discussions of habitat use are based on three major life history requisites -- feeding, spawning and rearing.

Mountain whitefish

Mountain whitefish were widely distributed throughout the Peace River. Fish were encountered in loose aggregations numbering from a dozen to hundreds of fish, and were found from the river thalweg to the shoreline.

During all seasons adult mountain whitefish were most numerous in deep glide habitats which contained cobble to cobble-gravel substrate. Dense concentrations were encountered in this habitat type when it was situated immediately upstream of deep riffle areas. Presumably, this habitat provided optimum feeding areas for this species which characteristically prefers benthic organisms (see Section 4.3). Mountain whitefish also were numerous in deep riffle habitats but tended to be restricted to shoreline areas. Adult fish were not abundant in pool habitats during spring and summer, nor were they present in areas where the substrate was dominated by fine sediments. This was probably again related to food abundance.

Adult fish utilized different habitats during fall, which is the spawning period for this species. Although widely distributed, dense concentrations of pre-spawning and spawning fish were encountered in pools and backwaters adjacent to deep riffles or in the riffle habitat proper. Pool and backwater areas were usually deep, but were invariably associated with riffles. This habitat was presumably a holding area for spawning fish. Mountain whitefish utilize gravel to cobble sized substrate for spawning (Scott and Crossman 1973), which was abundant in riffle habitats of the Peace River. Limited sampling in the Halfway River also showed that spawning fish utilized similar habitat types for spawning.

copepods were the most abundant food organisms present, and food analyses for other species in the Site C area indicated that copepods were an important constituent of their diet.

Based on the results of the present study, it appears that either zooplankton were no longer available in the Site C study area or alternate food sources (i.e., dipterans) were preferred. Of the 260 stomachs examined only six contained zooplankton. It is possible that the reduced importance of zooplankton as a food resource may be related to reduced zooplankton production in Williston Lake, or the removal of zooplankton from the system by predation in Dinosaur Lake.

4.4 PARASITES

Most fish sampled for life history information were given a cursory examination for the presence of macro-parasites. Very few parasites were found during the investigations. Nematodes residing in the swim bladder were observed on several occasions in rainbow trout and Arctic grayling. These most likely belonged to the genus *Eustrongylides* which has been found in salmonids sampled from the Peace River drainage of British Columbia (Bangham and Adams 1954). Seventy six lake whitefish and 136 mountain whitefish were examined for the plerocercoid cysts of *Triaenophorus crassus*. Cysts were identified in three lake whitefish captured from Reach 3 during spring. None of these fish were heavily infected, with less than three cysts observed in each fish. This parasite was not recorded from the Peace River during 1989 studies (Pattenden et al. 1990). Seven lake whitefish and 37 mountain whitefish were examined for the presence of *Triaenophorus crassus* at that time. This parasite is apparently present in lake whitefish in Moberly Lake (T. Down, Ministry of Environment, pers. comm.). This lake is connected to the Peace River drainage by the Moberly River, and therefore, the potential exists for the presence of this parasite in the Peace River. Based on the sampling conducted to date, *Triaenophorus crassus* does not appear to be prevalent in whitefish species residing in the Peace River.

A wide variety of parasites are normally associated with freshwater fish populations. The absence of observed parasites in this sample, with the exception of *Triaenophorus crassus*, probably reflects the sampling technique employed rather than a paucity of parasitic organisms. The data do show that the sportfish populations residing in the Site C study area do not suffer from intense parasite infections.

4.5 HABITAT USE

Habitat use by individuals of a particular species is influenced by numerous factors. Age, the point in the annual life cycle (e.g., spawning period) and critical habitat requirements, affect habitat

(Reiman and Bowler 1980) but samples obtained from kokanee in the Peace River did not contain large amounts of zooplankton. Past studies of the Peace River (RRCS 1976) have shown that significant numbers of zooplankton, which originated from Williston Lake, were utilized by several species located downstream in the Site C study area. During 1990 this resource was either not utilized by kokanee, or more likely, was no longer as abundant as in previous years.

Mountain Whitefish

Examination of stomach contents of mountain whitefish ranging in size from 155 to 464 mm indicated that their diet was based on a wide variety of food organisms including benthic invertebrates and, to a lesser extent, gastropods and fish. Of the 115 stomachs examined, 44 were empty and the average fullness was 30.6%. Ephemeropterans and trichopterans were the prevalent food items, occurring in more than 26.0% of all stomachs containing food and contributing a minimum of 4.3% to the food 'point' total.

Lake whitefish

Of the 67 stomachs examined, 47 were empty, and the average fullness was 17.5%. Items most frequently encountered were ephemeropterans (13.4% occurrence and 6.2% of food volume index). The high percentage of empty stomachs may reflect evacuation of stomach contents. This behaviour was observed on several occasions which likely resulted from capture and handling stress, and has been documented by other studies (O'Neil et al. 1982).

Summary and Comparisons to Other Studies

Feeding habits of five fish species were assessed. The most prevalent food group consumed by all species were insects, of which most were benthic fauna such as dipterans and trichopterans. Rainbow trout and Arctic grayling utilized similar food items. In addition to benthic fauna, these species also consumed invertebrates such as coleopterans and hemipterans, which normally are located in midwater areas. In general, mountain whitefish preferred benthic invertebrates. Zooplankton was not a prevalent food item consumed by any fish species examined.

The feeding habits described are typical for the species examined (Scott and Crossman 1973) and are similar to results documented during the 1989 study (Pattenden et al. 1990). Studies conducted on the Peace River in or adjacent to the Site C study area during the 1970's (RRCS 1978) stated that zooplankton, particularly the large calanoid copepod, *Heterocope septentrionelis*, which originated from Williston Lake, were an important food source for species such as mountain whitefish, lake whitefish, and rainbow trout which reside downstream of that reservoir. Results of stomach content analysis of mountain whitefish from the Peace River at that time showed that calanoid

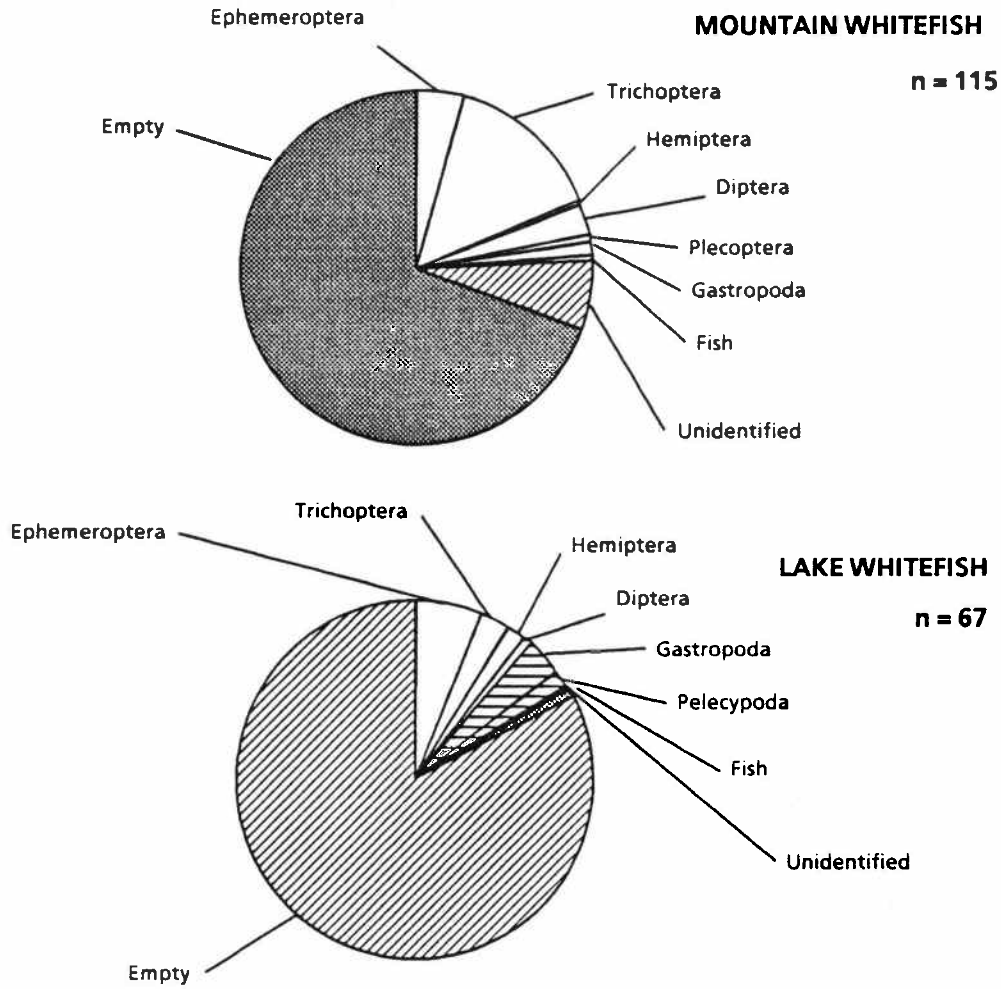


Figure 4.5 Continued.

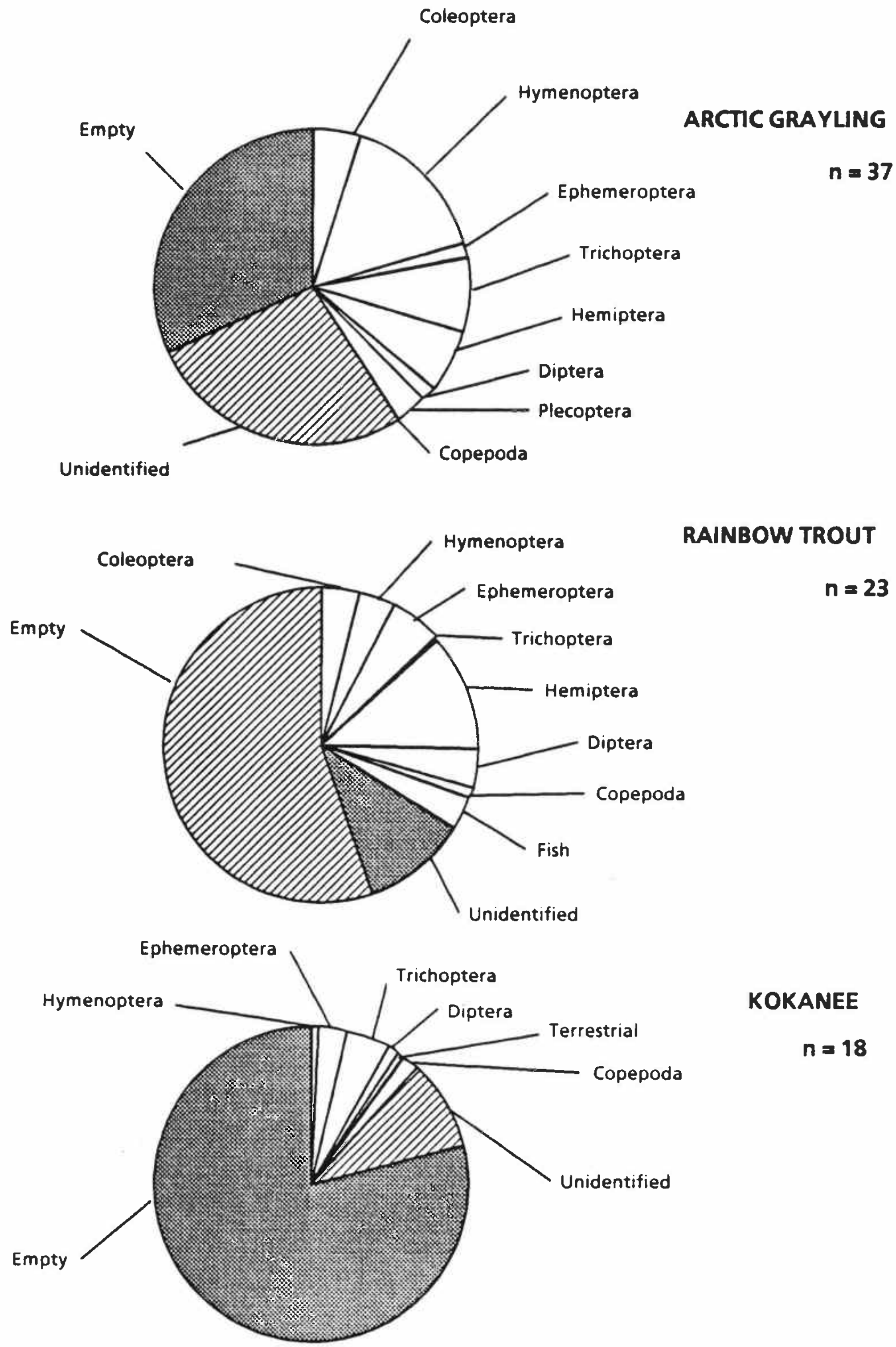


Figure 4.5 Percentage of food points allotted to food items in stomachs of Arctic grayling, rainbow trout, kokanee, mountain whitefish, and lake whitefish captured from the Peace River, 1990.

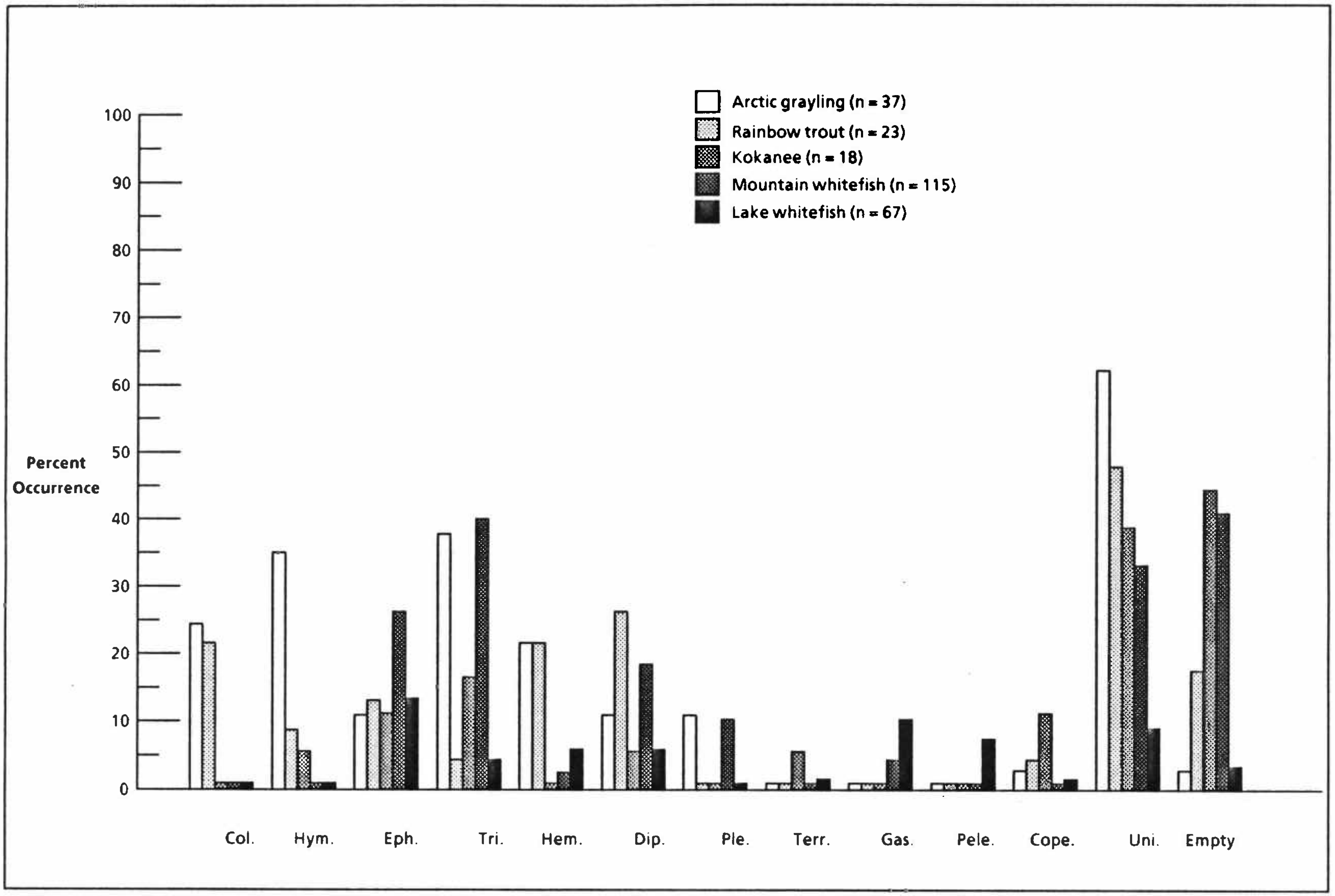


Figure 4.4 Percent occurrence of food items in stomachs of selected sportfish captured from the Peace River, 1990.

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