PEACE RIVER FISH COMMUNITY INDEXING PROGRAM

Phase 5 Studies 2005

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PEACE RIVER FISH COMMUNITY INDEXING PROGRAM - PHASE 5 STUDIES

Prepared for
B.C. Hydro
Power Supply Environmental Services
6911 Southpoint Drive
Burnaby, British Columbia
V3N 4X8

By

Mainstream Aquatics Ltd.
6956 Roper Road
Edmonton, Alberta
T6B 3H9

In association with
W. J. Gazey Research
1214 Cama Court
Victoria, British Columbia
V8X 4R1

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EXECUTIVE SUMMARY

B.C. Hydro initiated a Large River Program in the Peace River and Columbia River watersheds to help define the effects of dam and reservoir operations on fish communities. The ultimate goal was to develop monitoring tools that provide a reliable index of the fish community status. Phases 1 and 2 of the Peace River Fish Community Indexing Program focused on development of suitable monitoring tools. The primary objectives of Phases 3, 4, and 5 were to test whether the results were repeatable using the recommended approach and to extend time series data. Additions to the Phase 5 program included a pilot small fish program to evaluate the efficacy of monitoring pre-recruit life stages of target species in shallow water habitats, and an investigation of tagging and capture effects on mountain whitefish growth and condition.

The study area encompassed a 92 km portion of the Peace River from downstream of the Moberly River confluence to just downstream of the PCN Dam. Repeated sampling (six sessions) within three sections occurred from 17 August to 26 September 2005. Sampling methods included standard boat electrofishing of near-shore fish habitats and modified small fish boat electrofishing of shallow-water habitats.

Sampling Conditions

In 2005, Peace River discharge decreased during the first half of the study and then increased gradually until the end of the program. This discharge pattern had the potential to influence the fish indexing results. In contrast, water clarity was high and water temperatures remained above 8.0°C for the duration of the sampling program, which provided good conditions.

Fish Community Characteristics

There was no substantive change in general fish community characteristics compared to previous investigations. The results indicated a spatial transition in species assemblages within the study area. There was a shift in the relative importance of major fish groups from cold, clean-water species to cool, turbid-water species from upstream to downstream.

Biological Characteristics

The results of the present study were consistent with the findings of previous investigations. Specifically, there were spatial differences in biological characteristics of the three target fish populations. Younger Arctic grayling accounted for a large percentage of sample populations in Sections 3 and 5 and few fish

were older than Age 3. This suggests good recruitment into the population but high mortality of older fish, possibly due to angler harvest. Bull trout age structure differed between sections, but differences likely reflected presence/absence of post-spawning adult fish in each section rather than section differences in population age structure. Mountain whitefish sampled in Section 1 were dominated by fish Aged 4 and 5, while younger and older fish were scarce. In contrast, a wide range of age classes (Age 0 to Age 10) were present in Sections 3 and 5.

Annual differences included the presence of Age 1 and Age 2 bull trout in all sections during the present study compared to all previous investigations. This indicated there was either increased reproductive success of the study area population or atypical dispersal from rearing tributaries. In the present study, mountain whitefish exhibited reduced growth and body condition compared to fish sampled during the previous year. This was consistent in all sections and for the majority of age classes. The causal mechanism(s) for this are not known.

Relative Abundance

Catch rates of the three target species exhibited spatial differences between habitats and sections, which was similar to results of previous investigations. Arctic grayling were scarce in Section 1. In Sections 3 and 5 Arctic grayling were more numerous in SFC habitats compared to SFN habitats. Bull trout catch rates tended to be low and variable in all sections and this species was least abundant in Section 5. Mountain whitefish were abundant in all sections, but catch rates were higher in SFN habitats.

Catch rates for all three target species were negatively correlated with water level; correlations were strongest and were statistically significant for mountain whitefish. The negative correlations were similar to findings of 2004. During the present study discharge also declined during the field program. The causal mechanisms of the relationship between discharge and catch rate are not known. Lower discharge over an extended period, or diurnal fluctuations, may concentrate fish. For bull trout the observed changes in catch rate may have been related to an influx of post-spawning adults from tributaries rather than changes in discharge. The catch rate results will remain difficult to interpret without empirical data that describes fish movement in relation to discharge.

Arctic grayling and bull trout catch rates remained low during the present study, which is consistent to findings of previous investigations. Mountain whitefish catch rates in Section 1 declined in 2005 compared to 2004, which was the year of very high fish numbers. Mountain whitefish catch rates in

Section 3 have increased continuously since the first year of standardized sampling. Values are approaching those recorded in Section 1. No large annual change in catch rate was recorded in Section 5.

<u>Sampling Effects</u>

Mountain whitefish marked with Floy T-bar anchor tags had a lower growth rate and lower body condition compared to fish marked with PIT tags or unmarked control or study fish. These findings provided evidence that the Floy tags adversely affected the health of marked fish. Also, no-tag effects associated with fish capture and processing do not appear to adversely affect the health of marked fish. Evaluation of sampling and tagging effects on fish will continue during future investigations.

<u>Population Estimates</u>

Overall, the population estimate program was highly successful for mountain whitefish but less so for Arctic grayling and bull trout. Population estimates were made using a Bayesian sequential closed population model and with an open Jolly-Seber model for mountain whitefish. The population estimates were defensible for Section 1 but Sections 3 and 5 had a serious closure violation and the closed population model estimates were not valid. Unlike the previous studies significant heterogeneous capture probabilities were not observed during the present study. The consistency of the catchability coefficient across various population sizes and flow conditions in Section 1 suggests that any impact from heterogeneous capture should be small.

Population estimates were available for Arctic grayling, but the precision was poor. The precision for bull trout in Section 3 was acceptable (19.4%). However, data is insufficient to forecast effort levels needed for reliable population estimates for either species.

<u>Catch Rate as Index of Absolute Abundance</u>

The catchability estimate remained fairly robust despite a range of conditions encountered among sample years and sections. As such, catch rate can be used as an index of absolute abundance. Caveats related to this conclusion include the need for consistent sampling protocols, water clarity above 50 cm in order to eliminate effects on catchability, and target populations to remain closed during the period used to generate catch rates.

<u>Pilot Small Fish Program</u>

The pilot small fish program, which targeted fish < 200 mm length, accessed a different more diverse species assemblage than the standard program. In total 18 species were recorded during the pilot small fish program, which included 9 sportfish, 3 sucker, 5 cyprinid, and 2 sculpin species. Eight of these species were not previously encountered during the standard fish sampling program. Arctic grayling, bull trout, and mountain whitefish were well represented in the catch. Spatial differences in the small fish species assemblage were documented. Coldwater sportfish species were dominant only in Section 1, while cyprinids were absent. Nonsportfish species and sculpins increased in relative importance from upstream to downstream.

The pilot small fish program was effective at capturing the three target species and the data were sufficient to document species and section differences. Catch rates of the three target species differed between section. Small Arctic grayling were absent from Section 1, scarce in Section 3, and abundant in Section 5. Bull trout were not abundant, but a distinct trend of decreasing catch rate was recorded between Sections 1 and 5. Mountain whitefish were not abundant in Section 1, but were very abundant in Sections 3 and 5.

Samples of the three target species populations were dominated by younger age classes. These were Age 0 and Age 1 fish for Arctic grayling and mountain whitefish and Age 1 and Age 2 fish for bull trout. Information collected from these fish provided length-at-age data that was largely unavailable during the standard program. Sample sizes for mountain whitefish were sufficient to document section differences in population structure. In Section 1 Age 1 fish were largely absent, but this age class dominated in Sections 3 and 5.

The results of the pilot small fish program established the following regarding its use as a monitoring tool:

1. The modified boat electrofisher can effectively capture small fish (< 200 mm) in shallow water habitats in the Peace River.
2. The program accessed a different species assemblage and different age classes of the target species populations that were not previously available during the standard program.
3. The data provided useful information that described the abundance, distribution, and biological characteristics of younger age classes of target species populations.

Based on this information we can conclude that the small fish program has good potential to be an effective monitoring tool for the Peace River Fish Community Indexing Program. The pilot study was not designed to provide a detailed evaluation of sampling protocols. Several aspects need to be examined in more detail before it is incorporated as an integral part of the indexing program. As a corollary, the small fish program should be viewed the same way as the standard program during its initial stages of development.

Recommendations

The findings of the Phase 2 and 3 programs indicated that the monitoring protocols developed for the Peace River Fish Community Indexing Program were suitable to meet the overall objective of the program, particularly for mountain whitefish. Phase 4 and Phase 5 results have confirmed these findings.

We conclude that the program has become mature with diminishing returns with respect to the knowledge gained for the effort expended. A decision is now needed with respect to the future direction of the program. This is important for the following reasons:

1. The present scope of the program limits its ability to collect data that are needed to interpret the indexing results.
2. Adjustments to the program may be required in order to address monitoring needs of the Peace River Water Use Plan.

The Peace River Fish Community Program will continue to adhere to the overriding objective, which is to develop effective monitoring protocols. To this end we recommend the following for the Phase 6 program:

1. Repeat the standard program to extend the time series data and to assess whether flow conditions influence target fish populations.
2. Maintain the current study design and sampling protocols with the following adjustments:
   a. Restrict the marking system to use of PIT tags to address the issue of detrimental effects caused by the current marking system (Floy T-bar anchor tags).
   b. Quantify fish movements into and out of study sections by sampling in adjacent areas.
   c. Increase the number of marking sessions from four to five to examine use of open population estimate models and examine suspected violations of the closed population assumption.
   d. Expand and standardize the control fish program to provide a random sample of fish to evaluate non-tag effect sampling activities on target fish populations.
3. Build an age-structured model that will serve to synthesize catch rate, age, and abundance information.

These recommendations do not address a number of data gaps identified during the present and previous investigations. These data gaps relate to:

1. Improvement of some aspects of the indexing program (e.g., development of catchability coefficients for low water clarity conditions).
2. Collection of data to assist in the interpretation of the indexing information (e.g., fish movements, angler harvest, and river productivity).
3. Expansion of the indexing program to allow collection of additional types of information (e.g., small fish recruitment).

As recommended during previous investigations, consideration should be given to expanding the scope of the Peace River Fish Community Indexing Program in order to address these data gaps.

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The individuals associated with Mainstream Aquatics Ltd. who participated in the study were as follows:

Rick Pattenden	Senior Biologist and Coauthor
Chantal Pattenden	Senior Technician
Charlene Hinkel	Technician
Karl Zimmer	Technician
Darrien Genereux	Technician
Nick Barnes	Technician
Shaun Potvin	Technician
David Winarski	Freestone Fishing Systems
Don Albright	Wildlife and Vegetation Biology

The individuals of W.J. Gazey Research responsible for the population estimate and tagging effects components of the study were as follows:

Bill Gazey	Analyst and Coauthor

The individuals of Mike Miles and Associates Ltd. responsible for providing the water level recorders and for summarizing the water level data were as follows:

Mike Miles	Fluvial Geomorphologist
Elizabeth Goldsworthy	Technologist
Sandy Allegretto	Technologist

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1.0 INTRODUCTION

1.1 BACKGROUND

In 2001, B.C. Hydro initiated a Large River Program in the Peace River and Columbia River watersheds to help define the effects of dam and reservoir operations on fish communities. The ultimate goal of the program was to establish cost-effective monitoring protocols for the Columbia River and Peace River systems to provide reliable indices of fish population characteristics.

The program was designed to proceed in phases over five years. In Phase 1 (2001/02) sampling was undertaken to update basic information on fish populations and to test methodological assumptions. Efforts during Phase 2 (2002/03), 3 (2003/04), and 4 (2004/05) built on the previous findings to further refine sampling and analytical protocols. Phase 5 (2005/06) investigation was a continuation of this work.

Mainstream Aquatics Ltd. (Mainstream) and its study team completed Phases 1 to 4 of the Peace River component of the Large River Program. In 2005, Mainstream was contracted by BC Hydro to complete Phase 5 of the program. Similar to the previous investigations the study team consisted of three members. Mainstream Aquatics Ltd. was the overall managing consultant and was responsible for the field program, the biological characteristics component, and relative abundance component of the study. W.J. Gazey Research was responsible for the population estimate and tagging effects components. M. Miles and Associates Ltd. were responsible for the water level monitoring.

1.2 OBJECTIVES

The objectives of Phase 5 were similar to that of previous phases. The rationale for this was to ensure continuity with established sampling protocols, to ascertain whether the results were repeatable, and to assess inter-annual variation in catchability and other study parameters.

The objectives of Phase 5 were as follows:

1. To extend the time series data on the abundance, distribution, and biological characteristics of nearshore fish populations in the Peace River.
2. To build on previous investigations to further refine sampling strategy, sampling methods, and analytical procedures required to establish a long term monitoring program.
3. To update the existing electronic storage and retrieval database.

4. Prepare a concise technical report to document field-sampling protocol, the findings and recommendations of the Phase 5 investigations.
5. Participate in a Large River Program workshop with other Phase 5 investigators, regulatory agency representatives, selected scientists, and B.C. Hydro staff to disseminate results from the 2005 activities and to discuss recommendations for further actions.

Two additional tasks specific to Objective #2 were addressed by the 2005 program as follows:

1. Undertake a pilot small fish program to evaluate the efficacy of monitoring pre-recruit life stages of target species in shallow water habitats.

This task was undertaken to address a study requirement originally identify in the 2004 Terms of Reference, which was "To design and conduct a field sampling program to monitor annual changes in relative abundance and biological characteristics of pre-recruit life stages of key species in shallow water habitats".

2. Investigate the effects of tagging and capture on mountain whitefish growth and condition.

This task was a continuation of work initiated in 2004. The objective was to establish, what if any, adverse effects the fish indexing program may have on the target fish populations.

One task that was identified in the Phase 5 proposal was not completed. Approximately 300 randomly selected mountain whitefish were to be sacrificed to obtain data on sexual differences in growth rate and maturity. This study task was omitted due to the need to maximize the number of marked fish available for generation of more reliable population estimates.

1.3 TARGET SPECIES

Three target species were investigated during Phase 5:

- Mountain whitefish (*Prosopium williamsoni*)
- Arctic grayling (*Thymallus arcticus*)
- Bull trout (*Salvelinus confluentus*)

1.4 STUDY AREA

In general, the study area was similar to that of Phase 4 (Figure 1.1) and encompassed a 92 km section of the Peace River from downstream of the Moberly River confluence (Km 53) to just downstream of the PCN Dam (Km 145). In terms of river length this represents 62% of the total study area targeted by the program.

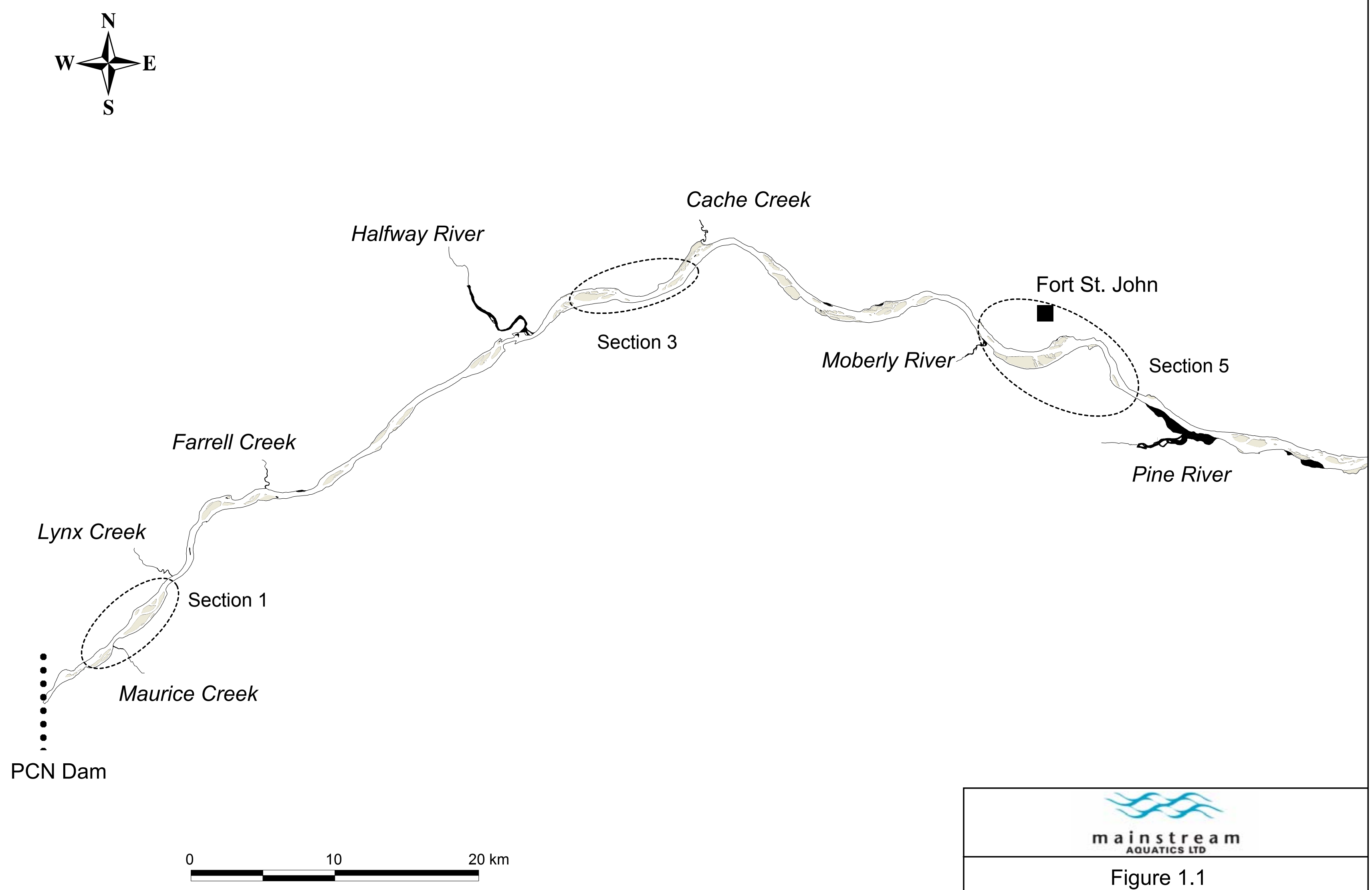

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Figure 1.1

Phase 5
Peace River Study Area, 2005.

Sample sections represented a continuum of habitat conditions (Vannote *et al.* 1980) and were positioned relative to inputs from two major tributaries: Halfway River and Moberly River. This approach allowed an assessment of spatial differences in target fish population characteristics.

Sample sections varied in total length from 7.3 km to 11.4 km (Table 1.1). Within each section between 52% and 66% of the available nearshore habitats were sampled.

Sample sections for the small fish pilot program were generally similar to the standard sample sections (Table 1.2).

Sampling also occurred immediately downstream of each standard section (Table 1.3). Samples of mountain whitefish were collected as control fish for comparison to mountain whitefish collected from the standard sample sections. These data were used to assist in the evaluation of effects of tagging and capture on fish growth and condition.

Table 1.1 Standard sample sections of the Phase 5 Peace River Fish Community Indexing Program, 2005.

Area	Section	Location	Section Length (km)	Sampled[a] Length (m)	Percent of Section Sampled[b]
Upstream of Halfway R.	1	Km 137.9 to 145.2	7.3	12 057	51.6
Downstream of Halfway R.	3	Km 89.8 to 99.2	9.4	19 467	65.5
Downstream of the Moberly R.	5	Km 53.4 to 64.8	11.4	14 196	51.8

[a] Length of nearshore bank habitat sampled in each section.
[b] Percent of total nearshore bank habitat sampled in each section.

Table 1.2 Small fish sample sections of the Phase 5 Peace River Fish Community Indexing Program, 2005.

Area	Section	Location	Section Length (km)	Sampled[a] Length (m)
Upstream of Halfway R.	1	Km 132.5 to 145.2	12.7	7 210
Downstream of Halfway R.	3	Km 90.0 to 99.0	9.0	6 070
Downstream of the Moberly R.	5	Km 57.0 to 64.8	7.8	5 110

[a] Length of shallow-water bank habitat sampled in each section.

Table 1.3 Control fish sample sections of the Phase 5 Peace River Fish Community Indexing Program, 2005.

Area	Section	Location	Section Length (km)	Sampled[a] Length (m)
Upstream of Halfway R.	1X	Km 127.0 to 131.5	4.5	4 500
Downstream of Halfway R.	3X	Km 83.0 to 87.0	4.0	4 000
Downstream of the Moberly R.	5X	Km 47.9 to 51.0	3.1	3 400

[a] Length of nearshore bank habitat sampled in each section.

1.5 SAMPLE PERIOD

Sampling occurred for 41 days between 17 August and 26 September 2005.

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2.0 METHODS

2.1 FIELD PROGRAM

2.1.1 Approach

The field program was designed to collect data needed to monitor fish numbers (relative abundance and population estimates) and biological characteristics of fish populations in the Peace River. Because the primary focus of Phase 5 was to generate reliable population estimates for target fish species, the approaches used for most study components were adjusted to accommodate this requirement.

2.1.1.1 Standard Sampling

As was used during previous studies, the study design involved repeated sampling (six sessions) of fifteen discrete sites located in each section using a boat electrofisher (Table 2.1; Appendix A). Each site represented one of two distinct habitat categories: nearshore habitat with physical cover (SFC) or nearshore habitat without physical cover (SFN). Sampling effort within each section was distributed as follows: eight SFC sites and seven SFN sites.

Table 2.1 Distribution of sampling effort (hours sampled) during Phase 5 of the Peace River Fish Community Indexing Program, 2005.

Zone	Section	Sampling Sequence						Total
		1	2	3	4	5	6	
Upstream of Halfway R.	1	1.7	2.0	1.8	1.9	2.0	2.0	11.5
Downstream Halfway R.	3	2.9	3.2	3.6	3.5	3.2	3.4	19.7
Downstream of Moberly R.	5	2.1	2.0	2.3	2.1	2.3	2.4	13.1
Total		**6.7**	**7.2**	**7.6**	**7.5**	**7.5**	**7.8**	**44.3**

The first four sessions were used to collect biological data from all fish species encountered and to mark and recapture target fish species. The last two sessions focused on obtaining recapture data for target species; therefore, only selected fish were marked and processed for biological data (Arctic grayling and bull trout). In general, two days were required to sample each section during each of the first four sessions. During each of the last two sessions, attempts were made to completely sample each section in one day. There was a nine day rest period between sample events during sessions one to four and a three day rest period between sessions five and six.

Sampling focused on two discrete habitat categories (SFC and SFN) to reduce variation in catch rates (P&E 2002). The SFC and SFN habitat categories were defined based on the physical characteristics established during Phase 2: bank slope/depth, water velocity, and the presence of physical instream cover (Table 2.2).

Table 2.2 Habitat categories sampled during Phase 5 of the Peace River Fish Community Indexing Program, 2005.

Habitat Category	**Bank Habitat**[a]	**Instream Habitat**	**Water Velocity**[b]	**Bank Configuration**[b]	**Physical Cover**	**Dominant Substrate**
SFN	A3	Run	Moderate to High	Gradual Slope/ Shallow Water	Absent	Rock
SFC	A1/A2	Run	Moderate to High	Gradual Slope/ Shallow Water	Present	Rock

[a] Habitat types defined in RL&L (2001).
[b] Based on subjective measure by experienced habitat biologist during Phase 2.

Low water levels in Section 1 early in the field program required use of four new sites during Phase 4. During Phase 5, water levels were sufficient to sample standard sites established during Phase 2. As such, the lengths and locations of sites were identical to those used during Phase 2 and Phase 3.

2.1.1.2 Small Fish Sampling

The purpose of the small fish program was to investigate the efficacy of small fish boat electrofishing to monitor relative abundance and biological characteristics of pre-recruit life stages of key species in shallow water habitats. Sampling occurred in Sections 1, 3, and 5 using a small fish boat electrofisher designed specifically for this purpose. Five to six sites were sampled in each section during each of the first three sessions (Table 2.3, Appendix A).

2.1.1.3 Control Fish Sampling

Control fish were collected in sites located immediately downstream of each standard section. Sampling occurred opportunistically in one to three sites in an effort to collect a sample of mountain whitefish (Table 2.4, Appendix A).

Table 2.3 Distribution of small fish sampling effort during Phase 5 of the Peace River Fish Community Indexing Program, 2005.

Zone	Section	Sampling Sequence						Total	
		1		2		3			
		Sites	Hours	Sites	Hours	Sites	Hours	Sites	Hours
Upstream of Halfway R.	1	5	2.3	6	2.2	6	2.5	16	7.0
Downstream Halfway R.	3	5	1.7	5	2.6	5	1.8	16	6.1
Downstream of Moberly R.	5	6	1.5	5	1.2	5	1.3	16	4.0
Total		**17**	**5.5**	**15**	**6.0**	**16**	**5.6**	**48**	**17.1**

Table 2.4 Distribution of control-fish sampling effort during Phase 5 of the Peace River Fish Community Indexing Program, 2005.

Zone	Section	Total	
		Sites	Hours
Upstream of Halfway R.	1X	3	1.2
Downstream Halfway R.	3X	2	0.5
Downstream of Moberly R.	5X	2	1.3
	Total	**7**	**3.0**

2.1.2 Fish Capture Methods

2.1.2.1 Standard Electrofishing

As was done during previous studies, a boat electrofisher was used to capture fish in nearshore habitats. Larger-sized fish were targeted (> 250 mm fork length) in water depths ranging from 0.5 to 2.0 m. Sampling was restricted to areas ≤ 2.0 m deep because previous studies have shown that boat electrofishing effectiveness on the Peace River is dramatically reduced beyond this depth.

A 5 m boat electrofisher propelled by a 175 Hp sport-jet inboard motor was used to sample fish. The craft was equipped with a fixed-boom anode system and Smith-Root Type VIA electrofisher system. Electrofisher settings were maintained at a constant amperage output of 3.0 to 3.5 A, pulsed DC current, and a frequency of 60 Hz. These settings were sufficient to immobilize all three target species and minimize injury rates of susceptible species such as mountain whitefish (see Section 3.5.3). The electrofisher settings used during Phase 5 were identical to those employed during previous studies.

The sampling procedure involved drifting downstream at motor idle along the channel margin, while outputting a continuous current of electricity. In general, boat position was maintained at a water depth of 1.25 m to 1.50 m by monitoring the depth with a sounder. The only instance when this sampling protocol changed occurred when backwater areas greater than two boat lengths were encountered. In these situations, the boat was turned into the backwater at its downstream end and the channel margin in the backwater area was sampled in an upstream direction.

Two netters positioned on a platform at the bow of the boat captured immobilized fish while the boat operator maintained the position of the craft along the channel margin. To provide a representative sample of the fish community netters were instructed not to bias their catch towards a particular species or fish size. Netters were equipped with nets having a diameter of 45 cm, a depth of 40 cm, and a mesh size of 5 cm. To facilitate capture of smaller fish, the bottom surface (40 cm^2) of each net had a mesh size of 1.5 cm. Netters were instructed to retrieve a random sample of immobilized fish that were accessible from their netting position on the platform. To minimize the potential for electrofisher induced injury, no more than one fish was netted at a time and immobilized fish were removed from the water as quickly as possible.

The only exception to the above sampling protocol occurred when a rare species or life stage was encountered. In this situation, the boat was turned towards the fish and netters made every effort to capture the individual.

Upon completion of an electrofishing section, captured fish were enumerated, processed, and released. To avoid recapture of previously collected fish, processed fish were released several hundred metres upstream in the same section.

2.1.2.2 Small Fish Electrofishing

The small fish boat electrofisher consisted of a double-bowed inflatable drift boat equipped with a Smith-Root Type VIA electrofisher system, two fixed boom anodes on the bow, and a cathode wire array on the stern. The system was specifically designed to allow sampling of shallow water areas (<0.5 m). Electrofisher settings were maintained at a constant amperage output of 4.0 to 4.5 A, pulsed DC current, and a frequency of 60 Hz. The unit was transported to and from each section by motorized river boat.

The sampling procedure involved drifting downstream adjacent to the channel margin, while outputting a continuous current of electricity. The front of the boat was positioned in water depths of 0.2 m to 0.5 m.

In order to minimize injury to non target fish (> 200 mm length) the power was turned off when larger-sized fish were encountered. This reduced capture efficiency; therefore, sampling was generally restricted to SFN habitats where shallow water depth precluded use by larger fish.

A single netter positioned at the bow of the boat captured immobilized fish while the boat operator maintained the position of the craft along the channel margin. To provide a representative sample of the fish community the netter was instructed not to bias their catch towards a particular species. They were instructed to restrict their catch to fish < 200 mm in length. The netter was equipped with a net having a mesh size of 0.5 cm. Immobilized fish were removed from the water as quickly as possible a placed into a 30 L live-well.

Upon completion of an electrofishing site, captured fish were processed and released.

2.1.2.3 Control Fish Electrofishing

Methods employed during standard sampling were used to capture control fish. Netters were instructed to collect a random sample of mountain whitefish. When approximately 200 fish were captured, sampling was terminated.

2.1.3 Observed Fish

A standardized approach to enumerate observed fish was used during the standard sampling program. Each netter was instructed to count un-netted fish ≥ 250 mm total length that were present in a defined observation zone at the bow of the boat electrofisher. Observations were restricted to four species: Arctic grayling, bull trout, mountain whitefish, and rainbow trout. At the end of a sample site, each netter recorded the number of observed fish on a data record sheet. To minimize observer bias, netters were not coached and they were instructed not to compare results.

2.1.4 Processing Fish

During the standard program all captured fish were held in a 230 L holding tank equipped with a water circulating system, which provided a water exchange rate of 19 L/min. Data recorded for each fish included species, fork length (to the nearest 1 mm), weight (to the nearest 2 g), and presence of a tag, tag scar, or fin clip. An appropriate nonlethal ageing structure (Mackay *et al.* 1990) was collected from all untagged individuals of the three target species. The first two rays of the right pectoral fin were collected from bull trout, while several scales situated immediately below the back third of the dorsal fin and above the lateral line were collected from Arctic grayling and mountain whitefish. Structures were placed in labeled envelopes and air-dried before storage.

As part of the population estimate component of the study, individuals of target fish species ≥ 250 mm fork length in good condition were marked using one of two tag types. The majority of fish were marked with Passive Integrated Transponder tags, or "PIT tags". Tags were of the FECAVA type (125 kHz), which have a 10 digit alpha-numeric code. Tags, tag applicators, and tag readers were supplied by AVID Canada. After tag insertion, a Power Tracker VIII tag reader was used to record the alpha-numeric code.

A small number of fish were marked with a uniquely numbered T-bar anchor Floy tag (FD-94). The tag, which was immersed in an antiseptic of 60% isopropyl alcohol, was 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. To estimate tag loss rate, the adipose fin of each tagged fish was clipped.

During small fish processing all fish were identified to species and enumerated. If a large number of fish was encountered at a site, a subsample of approximately 50 fish was measured for length. Small fish were not weighed. Ageing structures were collected from a sub-sample of target species to provide information on length-at-age of the younger age classes.

All control fish were measured for length, weighed, and an ageing structure collected.

2.1.5 Measured Parameters

In addition to fish capture and information on biological characteristics, other parameters measured for each site during the standard program included the following:

- Date and time
- Effort (seconds/meters)
- Sample method settings
- Water conductivity (microseimens)
- Water temperature (^{o}C)
- Light intensity (full sun [1]; partial cloud [2]; full cloud [3]; full shade [4])
- Water clarity (cm); using a secchi plate mounted on a pole (plate was 2.5 cm wide x 21 cm long partitioned into three equal sections of black, white, and black)
- Relative netter skill (high [1]; moderate [2]; low [3]; nil [4])
- Relative observer skill (high [1]; moderate [2]; low [3]; nil [4])
- Relative water velocity (fast [1]; moderate [2]; slow [3]; low or nil [4])

The information was either processed and analyzed, or stored for future reference (Appendix B).

2.1.6 Measurement of Water Levels and Water Temperatures

The 8007WDP water depth logger manufactured by Unidata, was used to monitor water levels (and temperature) in two sections. The instrument consists of a 4 cm diameter, 60 cm long submersible stainless steel tube containing a pressure sensitive transducer, thermistor, power supply, and data logger. The instrument cable contains a hollow polyethylene tube to provide an atmospheric pressure reference for the transducer and a communication line mounted within a urethane jacket protected with stainless wire mesh. The polyethylene tube is vented through a silica gel desiccant to minimize the potential for condensation. The data logger can store 52,000 entries. Each instrument was pre-programmed to measure water depths and water temperature every minute and record the average value every fifteen minutes. This sampling procedure increases the signal to noise ratio and the accuracy of the recorded data.

Both instruments were tested prior to being shipped to the field. The lower 15 m of polyethylene tube on each unit (i.e., section placed in the water) was protected using a metal flex conduit tube.

In Section 3 a Vemco® thermograph was installed to monitor water temperatures (±0.1°C) at one hour intervals. The thermograph was placed inside a 16 cm piece of galvanized steel pipe that was capped at both ends. Holes were drilled along the sides of the pipe to allow water to flow through. The pipe was set in the river and anchored with rocks and then fixed to shore with a steel cable.

2.2 OFFICE PROGRAM

2.2.1 Approach

Parameters used as monitoring tools included biological characteristics, relative abundance, and population estimates. The office program evaluated the efficacy of using these parameters as monitoring tools and it examined whether the Phase 5 findings were consistent with results of previous studies.

General methods used to evaluate the monitoring tools are described below. Unless otherwise stated, statistical analyses followed procedures described in Sokal and Rohlf (1981) and statistical significance was accepted at $P \leq 0.05$. To meet the assumptions required for parametric statistical analyses data were transformed where appropriate.

2.2.2 Biological Characteristics

Biological characteristics examined included length and age distribution, body condition, length-at-age, and mortality rate. Data from individual sections were analyzed separately due to potential for spatial differences in characteristics (P&E and Gazey 2003; Mainstream and Gazey 2004).

Size and Age Distribution

Fish of the three target species were measured for fork length. All collected Arctic grayling and bull trout were aged; however, the large numbers of processed mountain whitefish required use of a random subsample of ageing structures. A random number generator was used to select ageing structures from at least 10% of unmarked mountain whitefish in each section using SPSS© software.

Ageing procedures followed those described in Mackay *et al.* (1990). Bull trout fin rays were fixed in epoxy, sectioned with a jeweler's saw, and mounted on a slide for viewing under a dissecting microscope. Scales were immersed in water, cleaned and placed on a microscope slide for viewing. Two experienced individuals independently aged each structure.

Body Condition

The relationship between weight and length of fish was used as a measure of fish health. Fulton's Condition Index (K) was used for this purpose. To minimize potential problems associated with correlations between fish length and body condition (Cone 1989), samples were stratified by age or length class for analyses.

Growth Rate

Length-at-age was used to describe growth rates of sampled populations. For Arctic grayling and mountain whitefish the age-length relationship was described using the von Bertalanffy growth model based on the ageing of unmarked fish as described in Section 2.2.4. Convergence was not possible using the von Bertalanffy growth model for bull trout. For this species a best-fit curvilinear regression based on a two-parameter logarithmic equation was used as follows:

$$y = a * \ln(x - x_0)$$

Where y = fork length (mm), $a = y$ intercept and x = age (years). Mean length-at-age was the test variable used for analysis of growth rate. The age classes used for comparison were based on sample availability.

Mortality Rate

An estimate of instantaneous total mortality (Z) was calculated using the catch curve model presented in Ricker (1975). The estimate of Z was obtained using the least squares regression for the fully vulnerable age-classes.

2.2.3 Relative Abundance

Catch rate was used to provide an index of fish abundance. For boat electrofishing, catch rate was calculated by dividing the number of fish enumerated by the distance sampled and represented as number of fish per kilometre. For mountain whitefish, the number of fish enumerated equaled the number of fish captured. For Arctic grayling and bull trout, the number of fish enumerated equaled the number of fish captured plus the number of fish observed. The rationale for use of this approach is presented in Mainstream and Gazey (2004).

The approach used for statistical analyses of catch rate data was dependent on the questions asked and the characteristics of the data. For all analyses, it was assumed that catch rates differed between habitats; therefore, the data were stratified by habitat type. In general, data collected during individual sessions were grouped prior to analysis.

2.2.4 Sampling Effects

Phase 3 studies suggested that project activities adversely affected mountain whitefish (i.e., reduced growth and body condition). The use of Floy T-bar anchor tags rather than boat electrofisher capture was identified as the likely causal mechanism. Phase 4 studies examined growth differences between Floy marked and unmarked fish and concluded that Floy marked fish grew at a significantly lower rate and had lower body conditions than unmarked fish. Phase 5 growth comparisons of Floy, PIT, and unmarked mountain whitefish were made of samples obtained from the following sources:

1. Unmarked fish obtained from the study area sections (length-at-age, body condition).
2. Unmarked fish obtained from the control sections downstream of the associated study area sections (length-at-age, body condition).
3. Floy marked fish in 2004 obtained from the study area sections (length-at-age, body condition).
4. PIT marked fish in 2004 obtained from the study area sections (length-at-age, body condition).
5. Incremental growth over the time-at-large of Floy marked fish in 2001 to 2005 obtained from the study area sections.
6. Incremental growth over the time-at-large of PIT marked fish in 2004 and 2005 obtained from the study area sections.

Growth comparisons were made through the parameterization of von Bertalanffy growth models based on the ageing of unmarked fish and from the growth increment exhibited by marked and recaptured fish during the associated time-at-large. The models can be derived from the differential form of the von-Bertalanffy model described by Taylor (1963),

(1) $$\frac{dL}{dt} = KL_\infty - K \cdot t$$

where K is the growth coefficient, L_∞ is the asymptotic length coefficient and t is time. The integration of Equation (1) with initial conditions that length (L) equals 0 when age $t = t_0$ yields the usual formulation of the model suitable for length-at-age data:

(2) $$L = L_\infty \left[1 - \exp\{-K(t - t_0)\}\right]$$

Similarly, the integration of Equation (1) with initial conditions that length at release (L_0) equals length at recapture (L_r) when time-at-large is zero ($\Delta t = 0$) yields a formulation suitable to mark and recapture data:

(3) $$L_r = L_\infty - (L_\infty - L_0) \cdot \exp\{-K \cdot \Delta t\}$$

Estimates of the parameters of t_0, K and L_∞ were made through nonlinear least squares regression of Equations (2) and (3). Statistical comparisons of the length-at-age and mark-recapture sets were then made following Gallucci and Quinn (1979).

Body condition comparisons were completed using fish within the 25 to 75 percentile length distribution for the grouped sample. This was done to minimize effects of outlier lengths on body condition and to standardize the range of lengths used for analyses.

Statistical comparisons of treatment groups was attempted using Analysis of Covariance using section as a covariate to account for section differences in body condition. Slopes were not homogeneous; therefore, data for each section were analyzed separately using Oneway Analysis of Variance.

2.2.5 Population Estimates and Catchability

A mark-recapture program was conducted on mountain whitefish, Arctic grayling and bull trout over the period August 17, 2005 to September 26, 2005 (duration of 41 days). Three sections were sampled (Figure 1.1) by six sequential sessions (Table 2.5). During the first four sessions marks were applied, but during the final two sessions emphasis was placed on searching for the presence of a mark encountered on fish. Overall, the program was highly successful (in terms of the number marks applied and recaptured) for mountain whitefish but much less so for Arctic grayling and bull trout. Therefore, the methodologies described (diagnostics, population estimation, catchability and sampling power analyses) were comprehensively applied to mountain whitefish. For Arctic grayling and bull trout, only the closed population estimation methodology could be applied because of sparse data.

Table 2.5 Sampling dates by zone and session and the study days used for the Jolly Seber model during Phase 5 Peace River Fish Community Indexing Program, 2005.

Session	Section		
	One	**Three**	**Five**
Actual Sampling Dates			
1	17, 18, 19 Aug	20, 22 Aug	25, 26 Aug
2	28, 29 Aug	31 Aug, 1 Sep	3, 4 Sep
3	6, 7 Sep	9, 11, 12 Sep	12, 13 Sep
4	15, 16 Sep	17, 18 Sep	19, 20 Sep
5	21 Sep	22 Sep	23 Sep
6	24 Sep	25 Sep	26 Sep
Mid or Study Day			
1	1	4	9
2	12	15	18
3	21	25	27
4	30	32	34
5	36	37	38
6	39	40	41

There were limitations to the implemented tagging program with reference to the population estimation methodology and subsequent limitations of the estimates. First, the capture of fish may be heterogeneous (i.e., some fish are more likely to be caught than others) because of spatial distribution or the reaction of the fish to electrofishing. Second, marks were applied only to fish greater than 250 mm; thus, any estimates are only applicable to that portion of the population. Third, fish can grow over the life of the study such that fish recruit into the portion of the population greater than 250 mm when the study commenced. However, given the short duration of the study, appreciable growth was not expected. Fourth, marked fish can move to sections where capture vulnerability may be different because of possible differences in catchability, number of available marks for recapture or the population size.

In order to address these characteristics, we first examined the capture behavior of the marked fish. We identified the following mark types: (1) Floy and PIT tags applied in 2005 and (2) Floy tags applied in 2001 to 2004 and PIT tags applied in 2004 that were available for recapture in 2005 (the fish had to be caught and the tag recorded to qualify for a 2005 mark release). The recapture rate of tag types were compared (G-test, Sokal and Rohlf, 1969) as well as the time-at-large for the release types. We also compared the frequency of multiple recaptures following Seber (1982). Length histograms of the fish marked and recaptured were examined to reveal any selectivity patterns generated by the presence of a mark. These patterns were further evaluated by lumping the lengths into 25 mm intervals and conducting tests of independence (G-test) for each section. Growth over the period of the Phase 5 study was examined by regressing the time at large (days) of a recaptured fish on the increment in growth (difference in length measured at release and recapture). Possible tag effects on growth and condition were also investigated as described above. The movement of fish between sections within 2005 and over a year (marked in 2002 to 2004 and recaptured in 2005) was assessed through weighting the recaptures by sampling intensity.

The large number of mountain whitefish recaptures allowed for quantitative model selection using POPAN-5 (UFIT module) software for mark-recapture data (Arnason *et al.* 1998). For the purpose of total survival estimates, the time of sampling was assumed to be the mid-point of the actual sampling dates (see Table 2.5). Each section was modeled independently with recaptured fish in other sections treated as removals. For Sections 1 and 5, the model selection was for a closed population (no change in population size over the period of the study); however, the model selection was for an open population in Section 3. A Jolly-Seber open population model (allows for recruitment into the population and survival less than 1.0) using the POPAN-5 software was applied to each section as well as a Bayesian mark-recapture model for closed populations (Gazey and Staley 1986, and Gazey 1994) adapted to accommodate adjustments for movement to the data, allow for stratified capture probabilities and cope with sparse recaptures characteristic of Arctic grayling and bull trout. The major assumptions required for the Bayesian model are as follows:

1. The population size in the study area does not change over the period of the experiment. If mortality occurs then it can be specified independent of the mark-recapture information. Fish can move within the study area (to different sections); however, the movement is fully determined by the history of recaptured marks.
2. All fish in a stratum (day and section), whether marked or unmarked, have the same probability of being caught.
3. Fish do not lose their marks over the period of the study.

4. All marks are reported when the fish are recaptured. If marks are not detected then the rate can be specified independent of mark-recapture information.

The following data needs to be extracted from the mark-recapture database in order to generate population estimates:

m_{ti} – the number of marks applied or first observed in 2005 from a previous study during day t in section i,
c_{ti} – the number of fish examined for marks during day t in section i,
r_{ti} – the number of recaptures in the sample c_{ti}, and
d_{ti} – the number of fish removed or killed of the recaptures r_{ti}.

A fish had to be greater than or equal to 250 mm to be a member of m_{ti}. A fish was counted as examined (a member of c_{ti}) only if the fish was landed and examined for the presence of a mark and was greater than or equal to 250 mm in length. A fish was counted as a recapture (r_{ti}) only if it was a member of the sample (c_{ti}), was a member marks applied (m_{ti}) and was recaptured in a session later than the release session. A fish was counted as removed (d_{ti}) if it was not returned to the river or the fish was deemed to be unlikely to survive.

The number of marks available for recapture, adjusted for movement, was determined by first estimating the proportion on marks released in section i moving to section j (p_{ij}). Note by definition:

$$\sum_j p_{ij} = 1$$

Assuming that the movement of marked fish is determined by the recapture history corrected for the sampling intensity then:

(4) $$\hat{p}_{ij} = \frac{\dfrac{w_{ij}}{\sum_t c_{tj}}}{\sum_j \dfrac{w_{ij}}{\sum_t c_{tj}}}$$

where w_{ij} is the total number of recaptures that were released in section *i* and captured in section *j* over the entire study. The maximum number of releases available for recapture during day *t* in section *j* (m^*_{tj}) is then:

(5) $$m^*_{tj} = \sum_i \hat{p}_{ij} m_{ti}$$

The usual closed population model assumptions (e.g., Gazey and Staley 1986) may be invalidated by natural mortality, unaccounted fishing mortality, the emigration of fish from the study area and non-detection of a mark when the fish was sampled. Thus, the number of marks available for recapture at the start of day *t* in section *i* (M_{ti}) consists of the releases in each of the sections corrected for removals (mortality and emigration) summed over time, i.e.,

(6) $$M_{ti} = \sum_{v=1}^{t-h} \exp\left\{\frac{v+h-t}{365} Q\right\} (m^*_{vi} - d_{vi})$$

where *Q* is the instantaneous annual rate of removal and *h* is the number of lag or mixing days (nominally set to three days). The number of fish examined during day *t* in the i'th region (C_{ti}) does not require correction, i.e.,

(7) $$C_{ti} = c_{ti}$$

The recaptures in the sample, C_{ti}, however, need to be corrected for the proportion of undetected marks (*u*), i.e.,

(8) $$R_{ti} = (1+u) r_{ti}$$

The corrected marks available, sample and recaptures (Equations 6, 7, and 8) are the input information required by the Gazey and Staley (1986) to form the population estimates.

The estimation of population size was accomplished with a Microsoft Excel© spreadsheet model that consisted of macros coded in Visual Basic. The procedure required the execution of two passes (macros update and estimate). First (execute macro update), the mark-recapture data were assembled by sections under the selection criteria of minimum time-at-large (days) and minimum length (mm) specified by the user. For the second pass (execute macro estimate), the sections to be included in the estimate were specified along with the annual instantaneous removal rate, the proportion of undetected marks and the confidence interval percentage desired for the output. The model assembled the adjusted mark-recapture data (Equations 6, 7, and 8) and followed Gazey and Staley (1986) using the replacement model to compute the population estimates. Output included the posterior distributions, the Bayesian mean, standard deviation, median, mode, symmetric confidence interval and the highest probability density (HPD) interval.

Population estimates were generated for the three sections using marks applied at a start-date of 17 August 2005, a minimum length of 250 mm, an annual instantaneous removal rate (represents natural mortality, unobserved removals and emigration) of 0.0 and a undetected mark rate of 0%. Other parameter values were applied in order to reveal the sensitivity of the population estimates to failures in the closed model assumptions. The total population estimate for the study area was obtained by summing the section estimates. The confidence interval for the total study area estimate was calculated invoking a normal distribution under the central limit theorem with a variance equal to the sum of the variances for the sections.

The very sparse recoveries (n=1) for bull trout in Section 1 made any point estimates of population size highly unreliable. However, the Bayesian approach enables the calculation of the posterior distribution of population size N_i from which the probability that the population size is greater than some reference population level, V_j, can be constructed as the compliment of the cumulative density, i.e.,

(9) $$P(N > V_j) = 1 - \sum_{i=1}^{j} P(N_i)$$

The calculation of these minimum population estimates and associated precision has been shown to be very robust even under very sparse recoveries (Gazey 1994).

One of the key quantities of interest is the catchability coefficient. If it is constant across years (2002 to 2005) and river sections then indices of abundance (such as catch-per-unit-of-effort) are comparable. An estimate for catchability for the i'th section was calculated as:

(10) $$\hat{q}_i = \frac{\sum_t C_{ti}}{E_i \cdot N_i}$$

where E_i is effort and N_i is the population estimate for section *i.* Given the mark recapture and effort data, the variance of catchability is:

(11) $$Var(\hat{q}_i) = \left(\frac{\sum_t C_{ti}}{E_i} \right)^2 Var\left(\frac{1}{N_i} \right)$$

where the reciprocal of estimated abundance is distributed normally and can be estimated using the following expression (Ricker 1975):

(12) $$Var\left(\frac{1}{N_i} \right) = \frac{\sum_t R_{ti}}{\left(\sum_t M_{ti} C_{ti} \right)^2}$$

In order to explore the precision that may be obtained under alternative sampling intensities, a simple power analysis was conducted on mountain whitefish from 2002, 2003, 2004 and the present study. We assumed that the estimate of the Bayesian mean ($\overline{N}$) was the actual population size and adjusted the data for an altered sampling factor for any sequence as follows:

(13) $$M'_t = \left[1 - \left(1 - \frac{M_t}{\overline{N}} \right)^f \right] \cdot \overline{N}$$

(14) $$C'_t = \left[1 - \left(1 - \frac{C_t}{\overline{N}} \right)^f \right] \cdot \overline{N}$$

(15) $$R'_t = R_t \cdot \frac{M'_t}{M_t} \cdot \frac{C'_t}{C_t}$$

where f is the sampling factor (e.g., $f = 2$ represents a doubling of the sampling effort), M_t is the number of marks applied at the start of the t^{th} sampling sequence, C_t is the total number of fish examined for marks, and R_t is the number of recaptured marks. The prime notation represents the data generated for a specified sampling factor. Since the number of marks applied for fish examined is small in relation to the population size, a sampling factor of two nearly doubles the marks applied and examined and quadruples the recoveries.

For the purposes of this analysis we defined precision to be half of the 80% highest probability density (HPD) expressed as a percentage of the mean. If the posterior distribution were perfectly symmetrical, then our precision definition would equate to the plus/minus 80% confidence interval.

A survival estimate was obtained from the population size structure by obtaining the age associated with each observed length from the inverse of Equation (2):

(16) $$t_i = t_0 + \frac{1}{K}\left[\ln(L_\infty) - \ln(L_\infty - L)\right]$$

Each fish was then summed into Q_i (number of fish of age t_i) and a simple "catch curve" decay regression (Ricker 1975) was constructed as:

(17) $$\ln(Q_i) = \ln(Q_0) - Z \cdot t_i$$

where Q_0 is a reference abundance (of no interest) and Z is the apparent instantaneous mortality that includes all mortalities and emigration. An estimate of Z was obtained through simple least squares regression for the fully vulnerable age classes and converted to survival ($S = \exp\{-Z\}$). Since the "catch curve" model assumes the size composition is stable over long periods of time (i.e., recruitment into the population and mortality for all size classes is constant), the survival rate estimate should be regarded as crude.

2.2.6 Data Management System and Update Database

Microsoft® Access 2000 was used to enter, check and store the raw fish and habitat data collected during Phase 5. This information was used to update the Peace River Fish Community Indexing Program database.

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3.0 RESULTS AND DISCUSSION

Two primary objectives of Phase 5 were to extend the time series data describing nearshore fish populations in the Peace River and to ascertain whether the results were repeatable. This section provides a summary of the general characteristics of the fish community, an evaluation of the monitoring protocols, and a comparison to previous results. For simplicity the information has been grouped into seven component sections: sampling conditions, fish community characteristics, biological characteristics, relative abundance, tagging effects, and population estimates, and catchability. Raw data are provided in Appendices B, C, D, and E.

3.1 SAMPLING CONDITIONS

Sampling conditions examined included discharge, water temperature, and water clarity.

3.1.1 Discharge

Mean daily discharge from the PCN Dam at the start of the field program was approximately 1500 cms, but dropped continuously to approximately 900 cms during the first half of the field program (17 August to 10 September) (Figure 3.1). Discharge then gradually increased to approximately 1000 cms by the end of the program (26 September). Hourly discharge fluctuated during each 24 h period, which is the typical flow regime that occurs during the field program (Figure 3.2).

This discharge pattern differed from that of previous studies. In 2004 discharge during the first 18 days of sampling was low (approximately 405 cms). In addition, hourly water flows remained relatively stable. During the latter portion of the field program discharge increased to approximately 725 cms. Discharge in 2003 started higher (approximately 1700 cms) and gradually increased throughout the entire program. A similar pattern was recorded in 2002 (P&E and Gazey 2003).

Unlike the 2004 program, in the 2005 program, there were no spatial differences in discharge pattern in study sections due to inputs from the Halfway and Moberly Rivers. Flows of these tributaries decreased for the duration of the 2005 program (Water Survey Canada unpublished data).

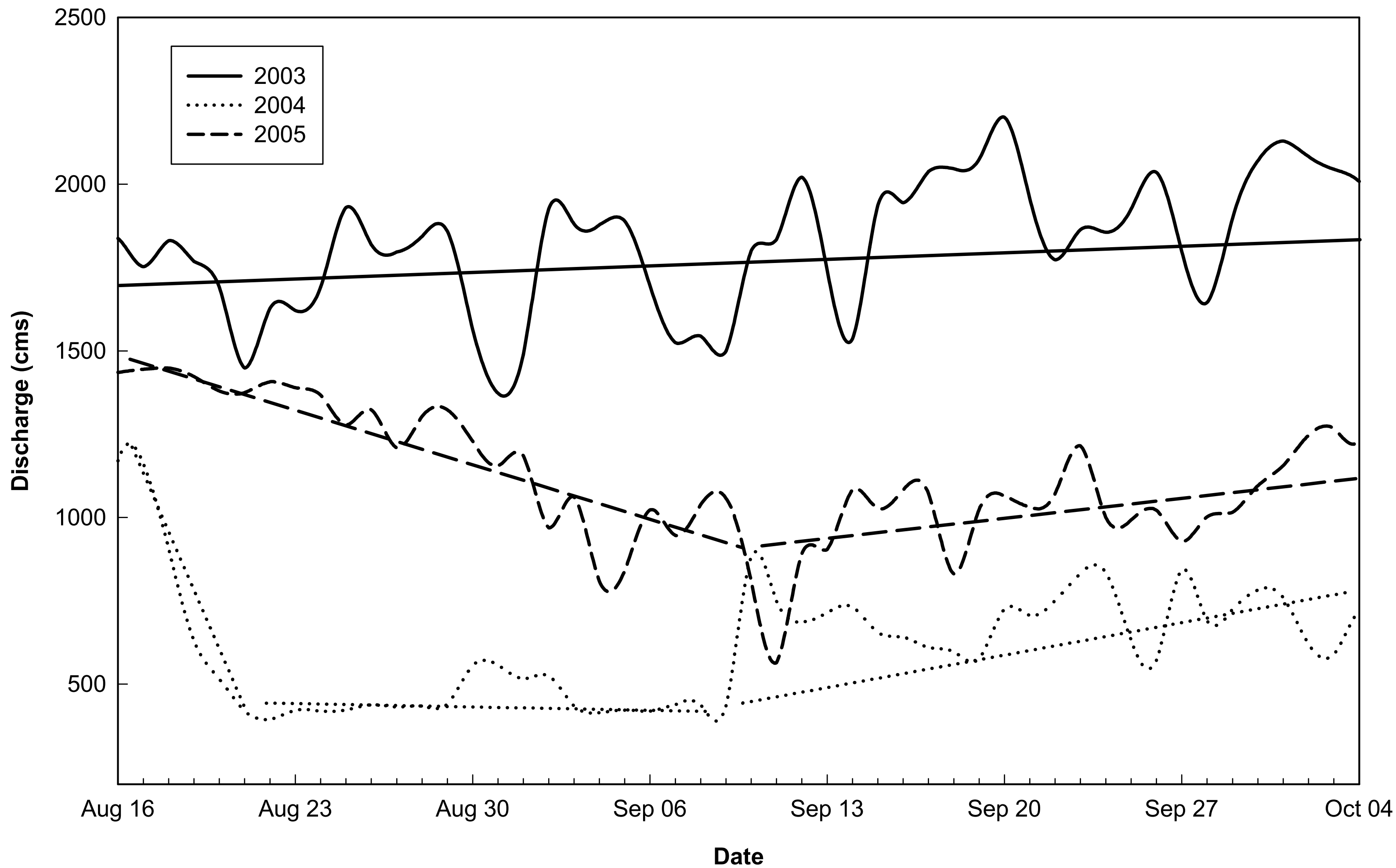


Figure 3.1 Comparisons of Peace River discharge during field sessions of the Peace River Fish Community Indexing Program, 2003 to 2005 (Patterns represent daily means and general trends). (Data from Water Survey of Canada Hudson's Hope Station[2003] or BC Hydro PCN Dam Station [2004 and 2005]).

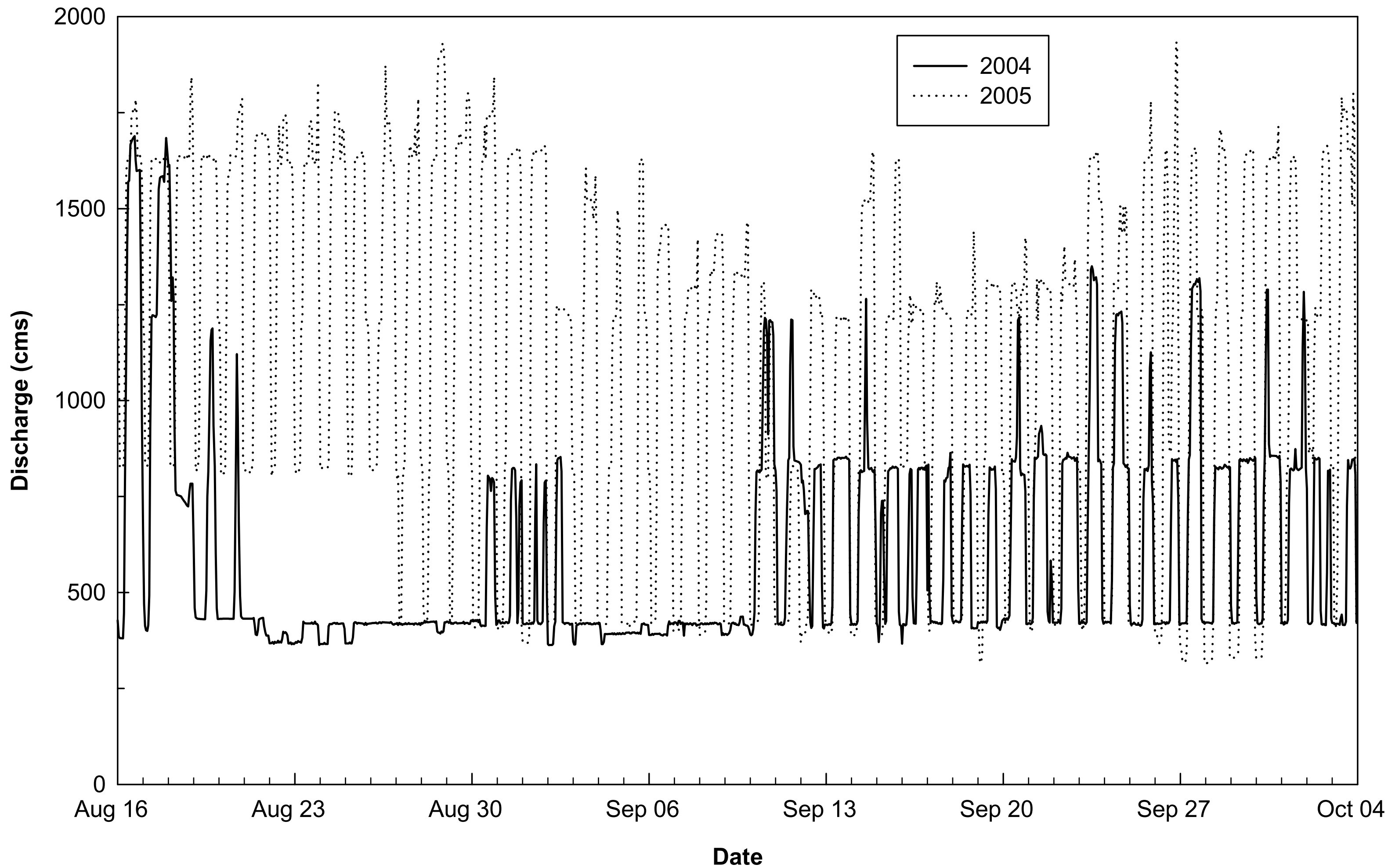


Figure 3.2 Comparisons of Peace River hourly discharge during field sessions of the Peace River Fish Community Indexing Program, 2004 and 2005 (Data from BC Hydro PCN Dam Station).

3.1.2 Water Clarity

Spatial differences in water clarity occur in the Peace River depending on location. In general, water clarity upstream of the Halfway River is high compared to locations downstream of the Halfway River and other tributaries, depending on inputs from these systems. Work by P&E (2002) indicated that water clarity of 50 cm was the threshold at which there was a negative effect on capture efficiency.

In 2005, water clarity was high in all three sections (Table 3.1; Figure 3.3). Mean values exceeded 150 cm and daily values remained above 100 cm. Lowest water clarity (60 cm) occurred at sites located immediately downstream of tributary confluences in Sections 3 and 5. As such, water clarity had no measurable influence on capture efficiency in 2005; these results were similar to 2002 and 2003.

Table 3.1 Water clarity (cm) during field programs in 2002, 2003, 2004, and 2005 during the Peace River Fish Community Indexing Program.

Year	Section					
	1		3		5	
	Mean (±SE)	**Range**	**Mean (±SE)**	**Range**	**Mean (±SE)**	**Range**
2005	204 ± 1	180 - 210	141 ± 6	60 - 210	179 ± 3	65 - 210
2004	160 ± 7	28 - 210	30 ± 2	4 - 80	22 ± 2	3 - 52
2003	220	-	195 ± 4	88 - 220		
2002	201 ± 2	153 - 220	190 ± 4	85 - 220		

In 2004, water clarity was lower and was not consistent between sections (Table 3.1; Figure 3.3). Values were much higher in Section 1 (160 cm) compared to Sections 3 and 5 (30 cm and 22 cm, respectively). Water clarity also was more variable in Section 1 as evidenced by the higher standard error and the wide range of recorded values. Water clarity levels in Sections 3 and 5 influenced capture efficiency.

3.1.3 Water Temperature

Mean daily water temperatures ranged from 8.5°C to 13.2°C during the 2005 program (Figure 3.4). Temperatures were slightly higher in Section 5 and 3 compared to Section 1. This was in contrast to the temperature regime in 2004, when water temperatures were lower and approached the threshold for initiation of mountain whitefish spawning (Mainstream and Gazey 2005).

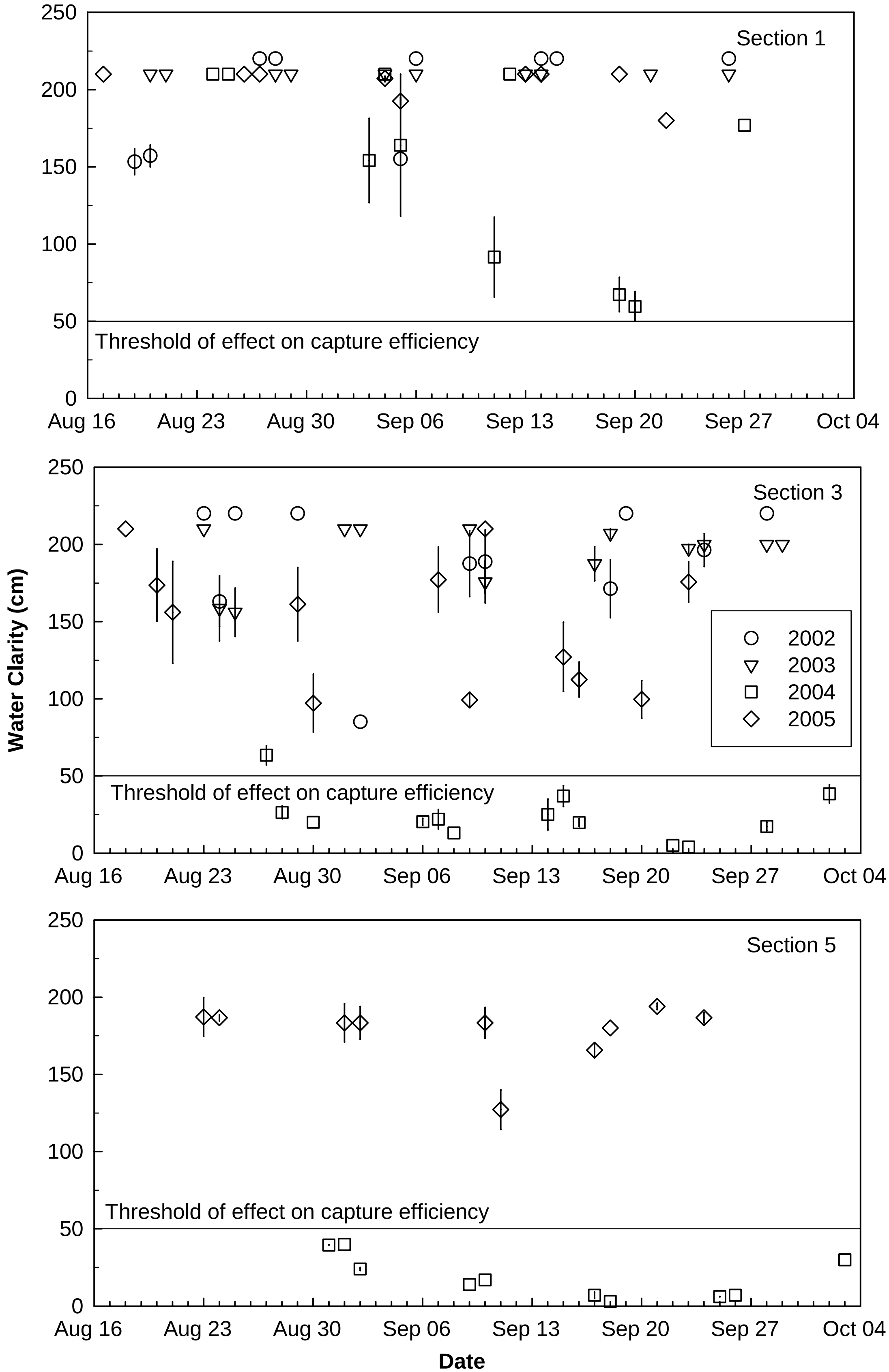


Figure 3.3 Mean water clarity (±SE) during field programs of the Peace River Fish Community Indexing Program, 2002 to 2005.

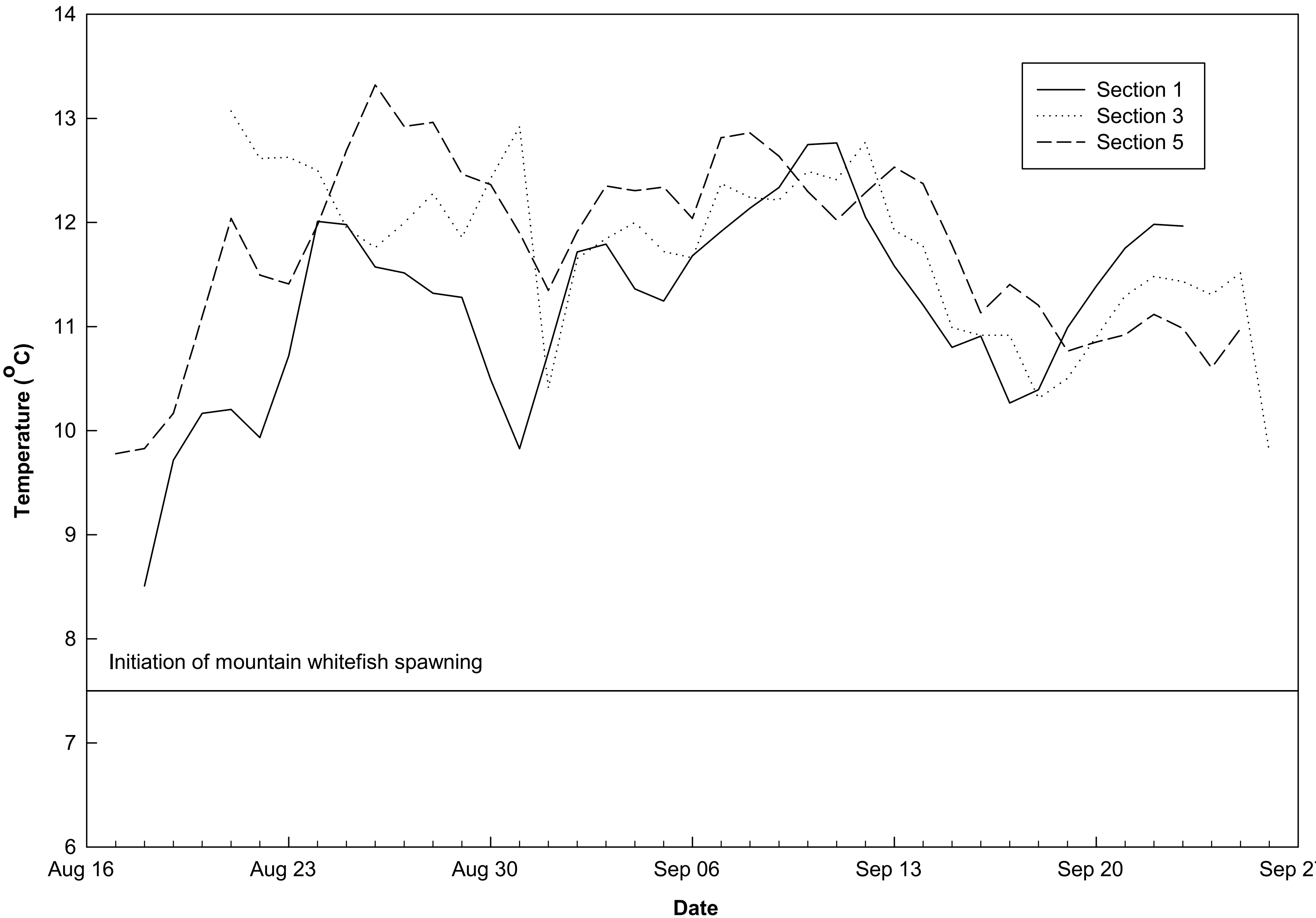


Figure 3.4 Mean daily water temperature in Sections 1, 3, and 5 during the Phase 5 Peace River Fish Community Indexing Program, 2005.

3.2 GENERAL CHARACTERISTICS OF THE FISH COMMUNITY

In total, 13 421 large fish representing 13 species were recorded during standard sampling in 2005 (Table 3.2). The species included 9 sportfish, 3 suckers, and 1 cyprinid. Mountain whitefish were very numerous and dominated the sample (11 651 fish or 86.8%). The two other target species were not abundant; in total 282 Arctic grayling were recorded (2.1%), while 200 bull trout were recorded (1.5%). After mountain whitefish, longnose sucker was the most prominent species (909 fish, 6.8%). The results were similar to findings of previous studies (2002 to 2004). Mountain whitefish was the dominant species followed by much lower numbers of all other species including sportfish and longnose sucker was the second most numerous species recorded.

Table 3.2 Number and percent composition of fish species recorded during the Phase 5 Peace River Fish Community Indexing Program, 2005.

Family	Common Name	Scientific Name	Number	Percent
Salmonidae	Arctic grayling	*Thymallus arcticus* (Pallas)	282	2.1
	Bull trout	*Salvelinus confluentus* (Suckley)	200	1.5
	Kokanee	*Oncorhynchus nerka* (Walbaum)	42	0.3
	Lake trout	*Salvelinus namaycush* (Walbaum)	1	<0.1
	Mountain whitefish	*Prosopium williamsoni* (Girard)	11 651	86.8
	Rainbow trout	*Oncorhynchus mykiss* (Walbaum)	91	0.7
Gadidae	Burbot	*Lota lota* (Linnaeus)	2	<0.1
Esocidae	Northern pike	*Esox lucius* Linnaeus	5	<0.1
Percidae	Walleye	*Sander vitreus* (Mitchell)	6	<0.1
Catostomidae	Largescale sucker	*Catostomus macrocheilus* Girard	183	1.4
	Longnose sucker	*Catostomus catostomus* (Forster)	909	6.8
	White sucker	*Catostomus commersoni* (Lacépède)	1	<0.1
Cyprinidae	Northern pikeminnow	*Ptychocheilus oregonensis* (Richardson)	48	0.4
Total			**13 421**	**100.0**

The majority of species were widely distributed (Table 3.3). Lake trout, burbot, and white sucker were the exceptions, each of which was recorded in only one section. These findings were generally similar to those recorded during previous studies with some exceptions. In 2004, Arctic grayling were absent in Section 1 and lake whitefish widely distributed. During the present study Arctic grayling were recorded in Section 1 and lake whitefish were not encountered.

Table 3.3 Spatial distribution of fish species recorded during Phase 5 of the Peace River Fish Community Indexing Program, 2005.

Name	Section		
	1	3	5
Arctic grayling	*	*	*
Bull trout	*	*	*
Kokanee	*	*	*
Lake trout			*
Mountain whitefish	*	*	*
Rainbow trout	*	*	*
Burbot			*
Northern pike	*		*
Walleye		*	*
Largescale sucker	*	*	*
Longnose sucker	*	*	*
White sucker			*
Northern pikeminnow	*	*	*

3.3 BIOLOGICAL CHARACTERISTICS

Biological characteristics examined for target populations included length and age distributions, growth rate, length-at-age, body condition, and mortality rate. Data were presented for each section because there are spatial differences in the sampled populations (P&E and Gazey 2003; Mainstream and Gazey 2004). Temporal changes in population characteristics also were examined. Age data collected during the pilot small fish program were used to increase sample sizes of younger age-classes for the analyses of length-at-age and growth rate.

3.3.1 Arctic grayling

In total, 275 unmarked Arctic grayling were sampled for biological characteristics: 5 in Section 1, 101 in Section 3 and 169 in Section 5. The fish fork length of sample populations ranged from 126 mm to 394 mm, which represented fish aged 0 to 5 (Figure 3.5).

Age 0 fish and fish older than Age 3 were largely absent from the samples. There also were spatial differences in length and age distributions of Arctic grayling. In Section 3, the sample consisted primarily of age-classes 1 to 3, with Age 2 fish being dominant (48% of the sample). In Section 5, Ages 1 and 2 fish dominated the sample (88%).

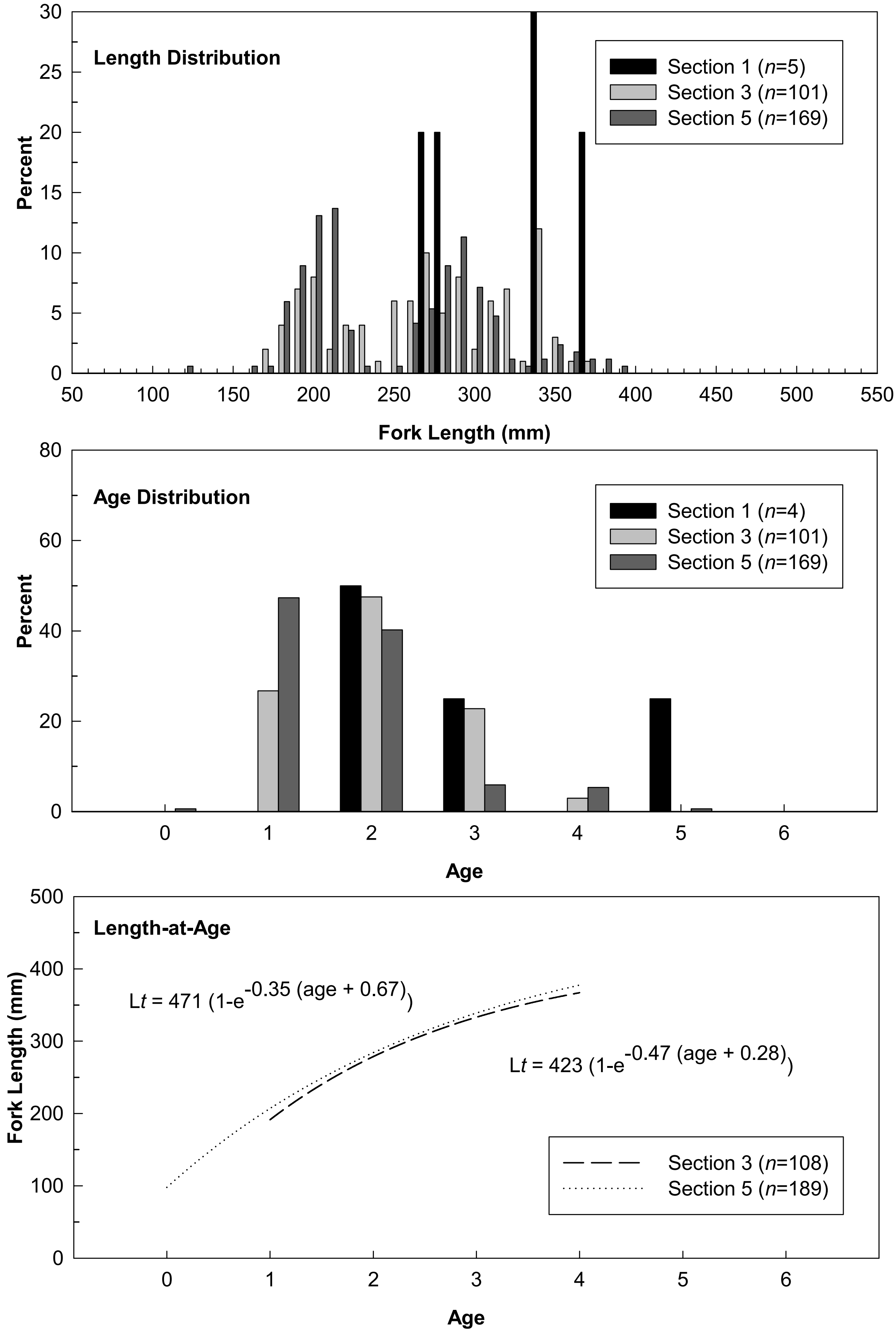


Figure 3.5 Length and age distributions and length-at-age relationships of Arctic grayling sampled during Phase 5 of the Peace River Fish Community Indexing Program, 2005 (Length-at-age relationship described using the von Bertalanffy growth model).

Predicted length-at-age relationships of fish sampled from each section were similar, but Section 5 Arctic grayling were larger at a given age than those sampled in Section 3 (Table 3.4, Figure 3.5). Comparisons of individual age-classes indicated significant differences for Ages 1 and 2. Spatial differences in length-at-age also were recorded during Phases 2 and 3. Mean lengths of some age-classes were higher in downstream sections compared to upstream sections.

Table 3.4 Mean length-at-age of Arctic grayling sampled during Phase 5 of the Peace River Fish Community Indexing Program, 2005.

Age	Section 1		Section 3		Section 5		P-value[a]
	n	**Mean Fork Length (± SE)**	***n***	**Mean Fork Length (± SE)**	***n***	**Mean Fork Length (± SE)**	
0	-	-	-	-	13	106.8 ± 3.2	-
1	-	-	34	192.0 ± 4.3	88	202.4 ± 1.4	0.003
2	2	279.0 ± 1.0	48	277.2 ± 3.4	68	290.0 ± 1.8	0.002
3	1	340.0	23	337.6 ± 3.3	10	337.5 ± 8.1	0.431
4	-	-	3	352.0 ± 9.2	9	367.6 ± 4.9	0.148
5	1	345.0	-	-	1	319.0	

[a] Based on Independent samples t-test comparison of Sections 3 and 5.

Body condition-at-age of Arctic grayling in study sections generally were similar (Table 3.5).

Table 3.5 Mean body condition (*k*) of Arctic grayling sampled during Phase 5 of the Peace River Fish Community Indexing Program, 2005.

Age	Section 1		Section 3		Section 5		P-value[a]
	n	**Mean Body Condition (± SE)**	***n***	**Mean Body Condition (± SE)**	***n***	**Mean Body Condition (± SE)**	
0	-	-	-	-	3	0.84 ± 0.08	-
1	-	-	34	1.25 ± 0.02	83	1.24 ± 0.01	0.410
2	2	1.29 ± 0.01	47	1.36 ± 0.02	68	1.34 ± 0.01	0.368
3	1	1.33	23	1.40 ± 0.03	10	1.28 ± 0.04	0.046
4	-	-	3	1.27 ± 0.09	9	1.32 ± 0.06	0.336
5	1	1.39	-	-	1	1.23	

[a] Based on Independent samples t-test comparison of Sections 3 and 5.

Yearly comparisons of length and age distributions, and apparent mortality rates are presented in Figure 3.6. In Section 3, length and age distributions did not differ between 2004 and 2005. In Section 5, the strong Age 1 class in 2004 resulted in a strong Age 2 class in 2005. Of note during both years was the scarcity of older (> 3 years of age), larger (> 300 mm fork length) fish.

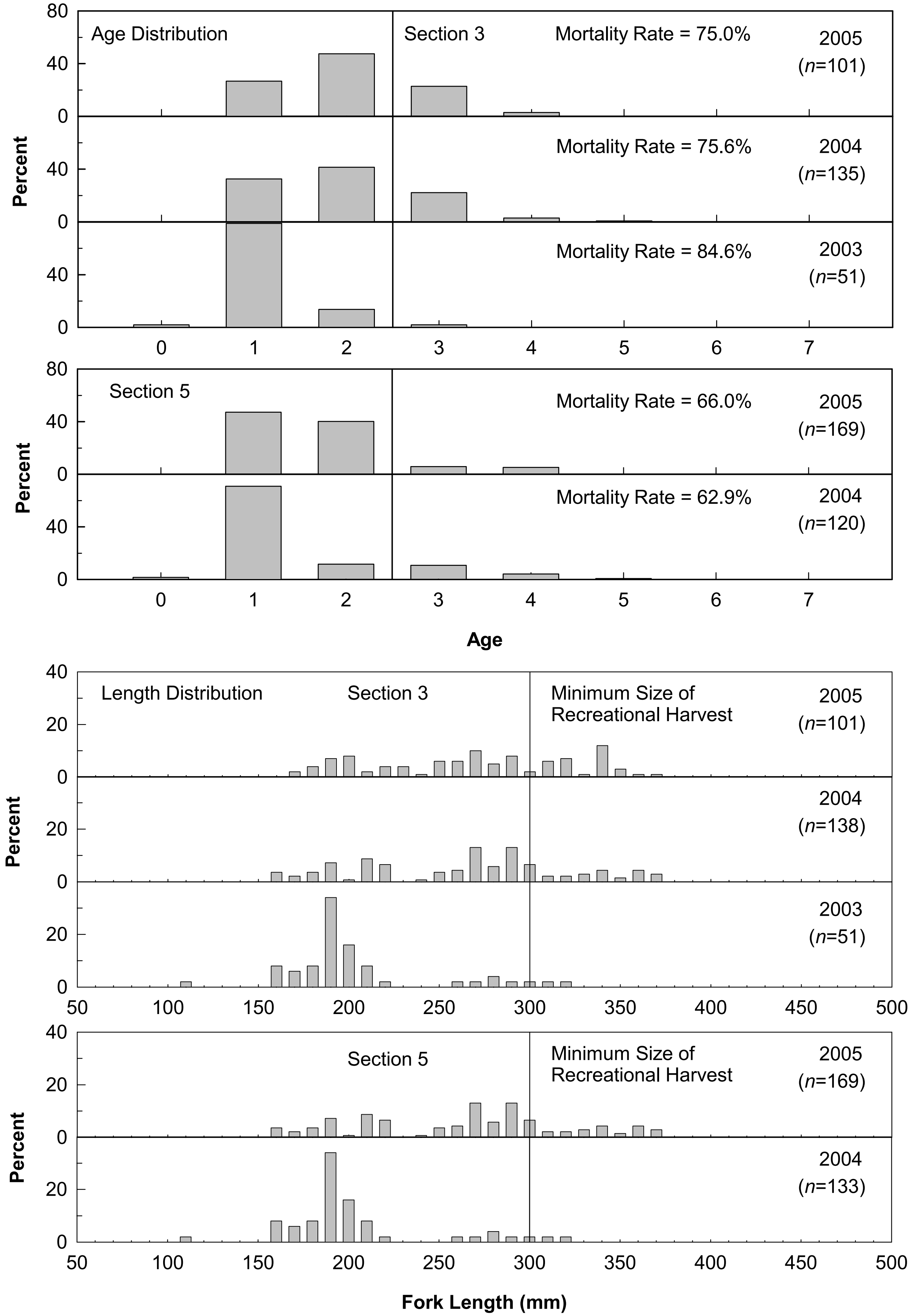


Figure 3.6 Yearly comparisons of age and length distributions and mortality rates of Arctic grayling sampled in Sections 3 and 5 during the Peace River Fish Community Indexing Program, 2002 to 2005.

Recreational angling harvest may explain the scarcity of larger fish in the sample populations. Current regulations specify a minimum harvest size of 300 mm.

Age-specific increment growth of Arctic grayling decreased between 2004 and 2005 (Figure 3.7). The decrease was recorded for all age classes in both sections. These decreases were significant only for Age 1 and Age 3 fish.

The opposite results were recorded for body condition. Fish tended to be in better body condition during the present study compared to 2004.

3.3.2 Bull trout

In total, 145 unmarked bull trout were sampled for biological characteristics. Fork lengths ranged from 177 mm to 844 mm with ages ranging from Age 1 to Age 10.

Length and age distributions of bull trout suggested that there were spatial differences in population structure (Figure 3.8). The median size of fish differed between sections: 248 mm in Section 1, 388 mm in Section 3, and 289 mm in Section 5. Age 2 fish was the most prominent group in Section 1 (49% of the sample). In Sections 3 and 5 Age 2 fish were prominent (26% and 31% of samples, respectively), but there was better representation by older fish.

A visual assessment of growth curves indicated that bull trout in Sections 3 and 5 had similar growth rates, but fish in Section 5 tended to be larger at a given age compared to fish in Section 5. Comparisons of mean length-at-age found no statistical differences between the samples (Table 3.6). The apparent growth rate of bull trout in Section 1 was lower compared to downstream sections. This may have been an artifact of differences in age distribution between sections, but this is unlikely due to higher numbers of younger, faster growing fish in Section 1. Despite the apparent difference in growth rate, a statistical difference was identified only for Age 4 fish.

Age-specific mean body condition is presented in Table 3.7.

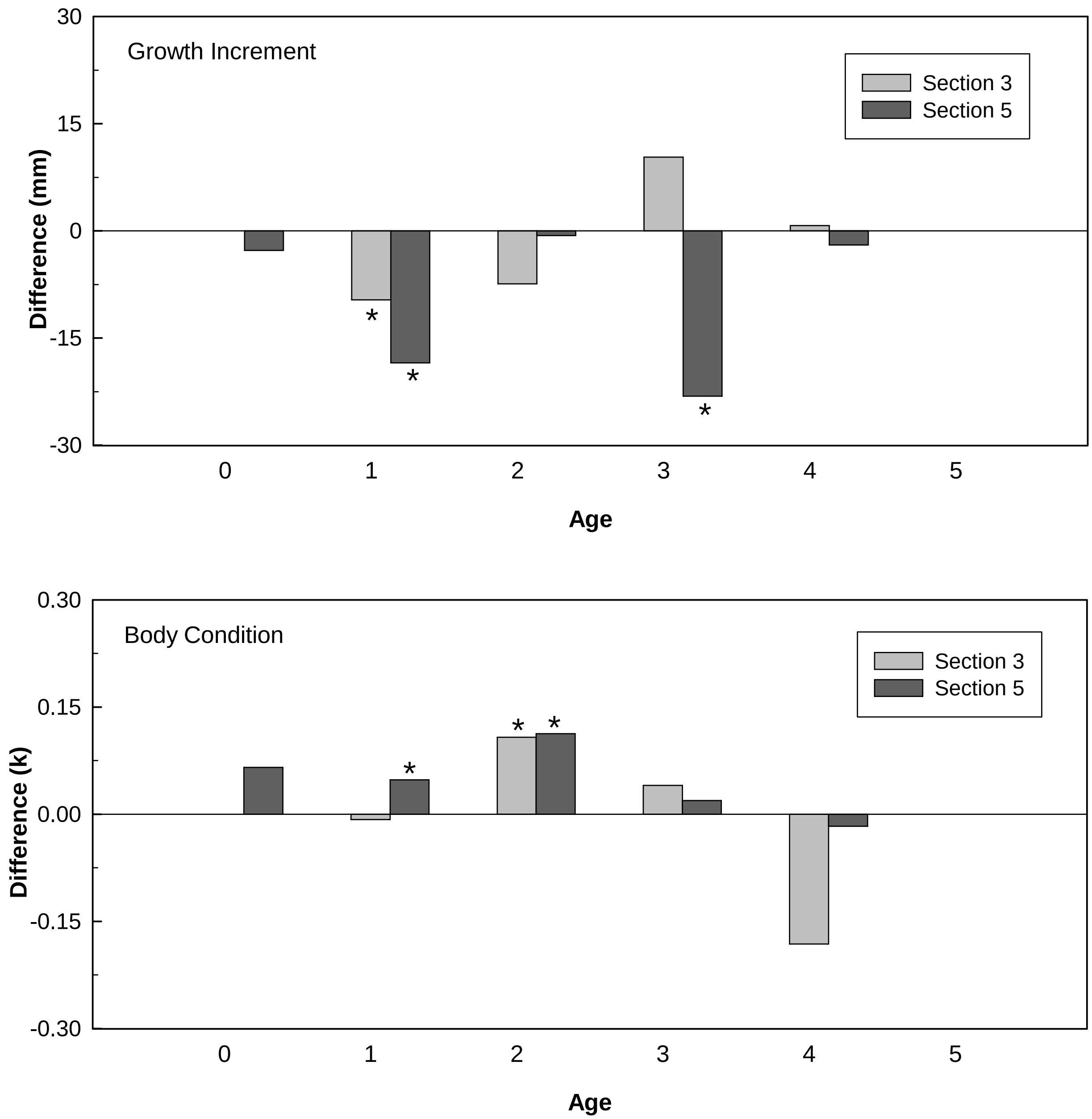


Figure 3.7 Comparisons of yearly changes in growth increment and body condition (k) between 2004 and 2005 of Arctic grayling sampled in Sections 3 and 5 during the Peace River Fish Community Indexing Program. (Values represent differences from previous year; Asterix represents statistical difference at $P \leq 0.05$, Independent samples t-test).

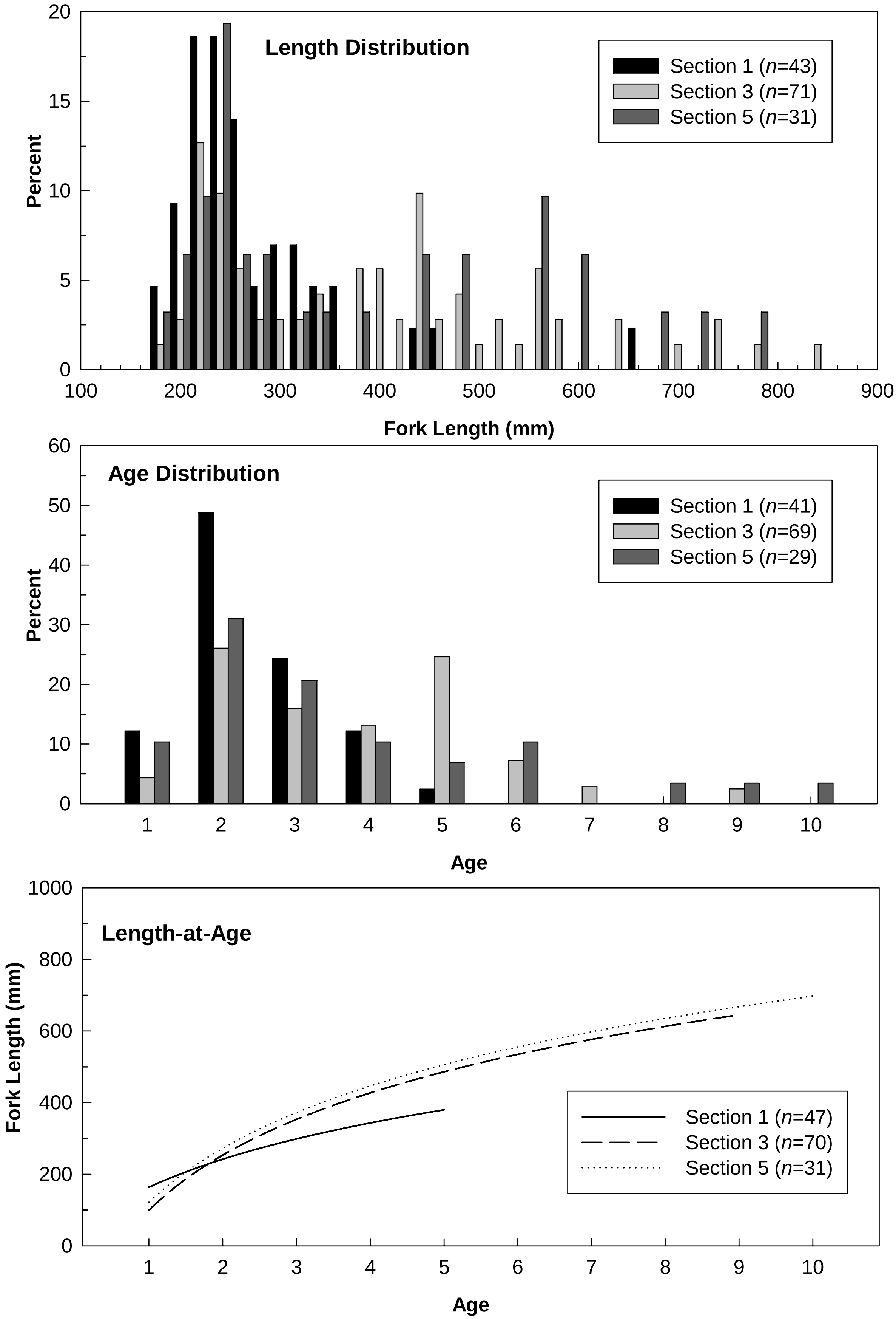


Figure 3.8 Length and age distributions and length-at-age relationships of bull trout sampled during Phase 5 of the Peace River Fish Community Indexing Program, 2005. Best fit regression curve for age-length relationship generated using a two-parameter logrithmic equation [$y=a*\ln(x-x_o)$].

Table 3.6 Mean length-at-age of bull trout sampled during the Phase 5 Peace River Fish Community Indexing Program, 2005.

Age	Section 1		Section 3		Section 5	
	n	Mean Fork Length (± SE)	*n*	Mean Fork Length (± SE)	*n*	Mean Fork Length (± SE)
1	8	186.5 ± 6.0	4	195.8 ± 4.7	5	181.8 ± 5.7
2	23	228.5 ± 4.4	18	233.9 ± 3.7	9	233.4 ± 4.7
3	10	288.7 ± 8.3	11	316.2 ± 14.9	6	310.7 ± 17.3
4	5	374.4 ± 22.7 (A)[a]	9	411.9 ± 17.1 (AB)	3	472.3 ± 14.2 (B)
5	1	440.0	17	470.7 ± 13.4	2	499.0 ± 55.0
6	-	-	5	547.6 ± 10.3	3	582.7 ± 15.4
7	-	-	-	-	-	-
8	-	-	-	-	-	-
9	-	-	4	751.5 ± 32.7	1	711.0

[a] Based on post-hoc comparisons means test; different letter denotes statistical difference at $P \leq 0.05$.

Table 3.7 Mean body condition (*k*) of bull trout sampled during the Phase 5 Peace River Fish Community Indexing Program, 2005.

Age	Section 1		Section 3		Section 5	
	n	Mean Body Condition (± SE)	*n*	Mean Body Condition (± SE)	*n*	Mean Body Condition (± SE)
1	8	0.98 ± 0.05	4	1.00 ± 0.04	4	0.92 ± 0.03
2	22	1.11 ± 0.03	18	1.09 ± 0.03	9	1.03 ± 0.04
3	10	1.11 ± 0.02	11	1.04 ± 0.02	6	1.04 ± 0.04
4	5	1.08 ± 0.04	9	1.01 ± 0.03	3	1.01 ± 0.04
5	1	1.16	17	0.97 ± 0.02	2	0.93 ± 0.05
6	-	-	5	0.97 ± 0.01	3	1.28 ± 0.23
7	-	-	-	-	-	-
8	-	-	-	-	-	-
9	-	-	4	1.28 ± 0.05	1	1.11

Yearly age distributions and mortality rates are presented in Figure 3.9. During the present study, there was a strong contribution of Age 1 and Age 2 fish in each section. During previous years these age-classes were largely absent. The results suggest good recruitment of bull trout into the Peace River population. The presence of these young fish is unclear for two reasons. First, major spawning and rearing streams for this population are located in the Halfway River system. This makes it difficult to explain large numbers of young bull trout in Section 1, which is 45 km upstream of the Halfway River confluence. Second, young bull trout typically do not leave their rearing streams until Age 3, and therefore, should not be present in the Peace River. As such, displacement of fish by flood events in tributaries could explain the presence of these fish in study sections rather than good recruitment.

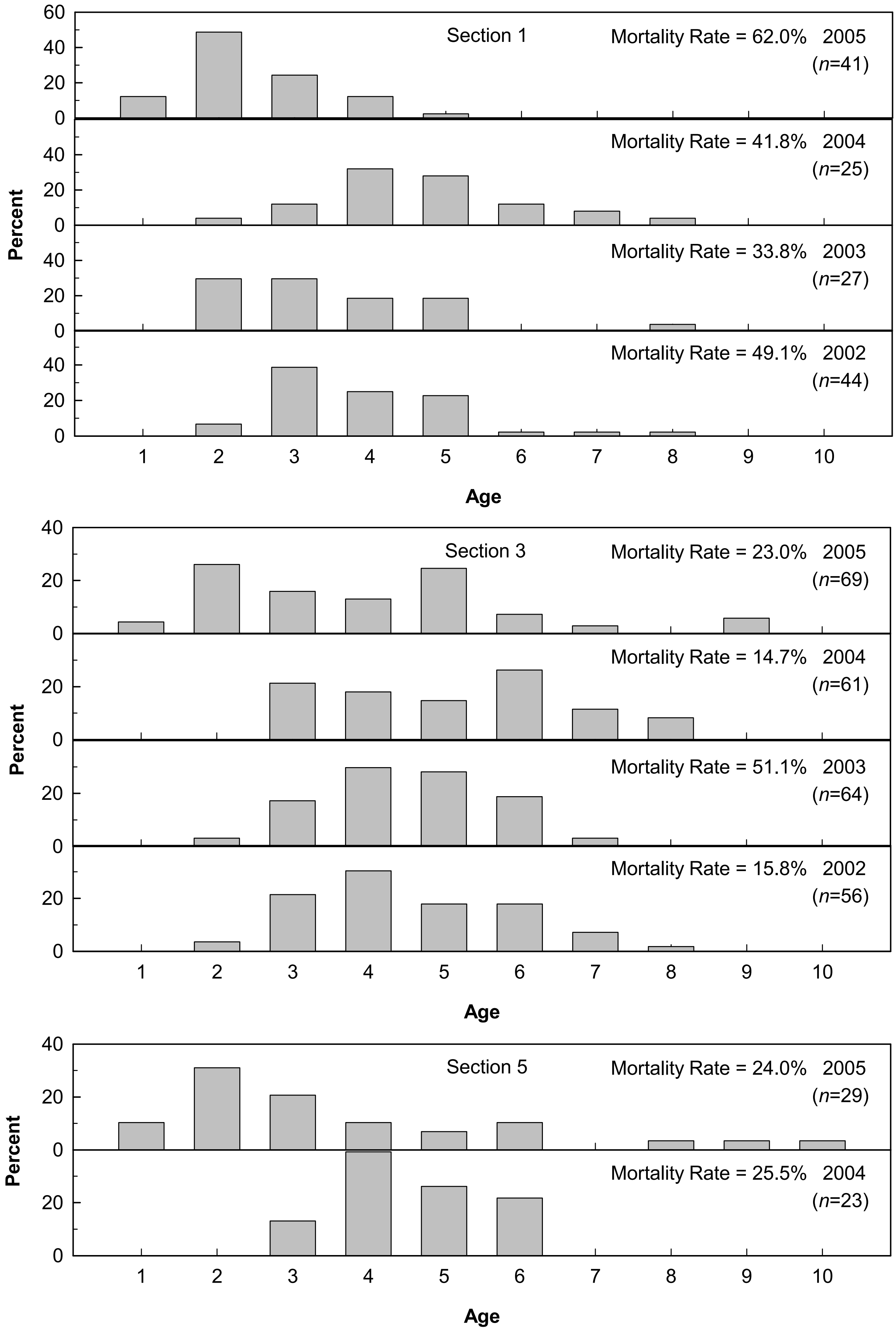


Figure 3.9 Yearly comparisons of age distributions and mortality rates of bull trout sampled in Sections 1, 3, and 5 during the Peace River Fish Community Indexing Program, 2002 to 2005.

There were yearly differences for the adult cohort (Age 6 and older), but it is unlikely that these differences represent actual changes in population age structure. It more likely is an artifact of small sample sizes, or as suggested in Mainstream and Gazey (2004), the absence of the adult cohort during some years may be a reflection of the timing of spawning activity in tributaries.

Similarly, apparent mortality rates varied among years. Given that bull trout should experience high survival (i.e., relatively long-lived, few natural predators, and zero recreational harvest), the mortality rate should be relatively low and stable. A mortality rate approximating 20% may be most representative of the actual mortality rate of the Peace River bull trout population.

Yearly differences in growth and body condition were ambiguous (Figure 3.10). Age 3 bull trout were smaller in 2005 compared to 2002, while other age-classes were larger. There was no trend for condition.

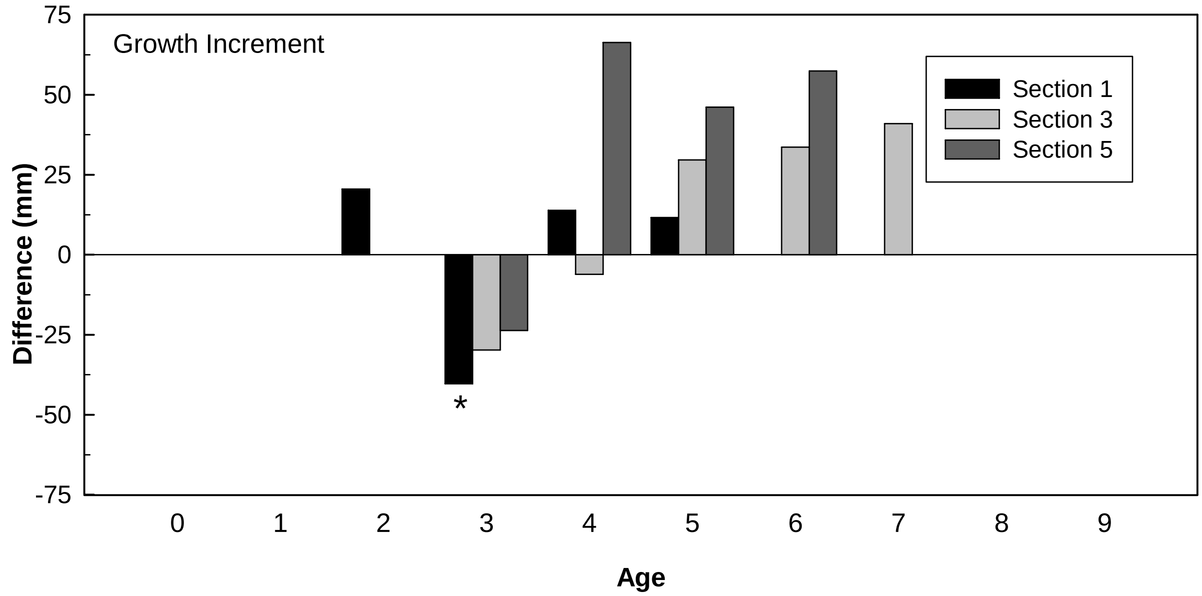
3.3.3 Mountain whitefish

In total, 5316 unmarked mountain whitefish fish were measured for length and weight. In all, 632 fish or 12% of the sample were aged.

A comparison of length and age distributions of mountain whitefish indicated that there were spatial differences in sampled populations (Figure 3.11). Fish in Section 1 exhibited a truncated length distribution (modal peak at 300 mm fork length). This pattern was explained by the preponderance of Ages 4 and 5, which accounted for 52% of the sample. A smaller modal peak occurred at 210 mm, which represented Age 2 fish. Fish younger than Age 2 and older than Age 7 were absent or scarce in Section 1.

In contrast, mountain whitefish in Sections 3 and 5 exhibited broad multi-modal length distributions. Modal peaks occurred at 150 mm, 210 mm, 240, and 320 mm frequency intervals, which corresponded to Ages 1, 2, 3, and 5, respectively. Ages 1 to 9 were well represented and Age 0 fish where present.

The length-at-age results suggested spatial differences in growth (Table 3.8, Figure 3.11). Mountain whitefish Aged 2 and 3 tended to grow at a faster rate in Section 1. However, older fish in Section 1 had lower growth rates compared to fish in Sections 3 and 5. Age-specific comparisons indicated that many of these differences were statistically significant. It should be noted that mountain whitefish in Section 1 are fully recruited into the spawning cohort by Age 4, while full recruitment in other sections does not occur until Age 6 or 7 (Mainstream and Gazey 2005).



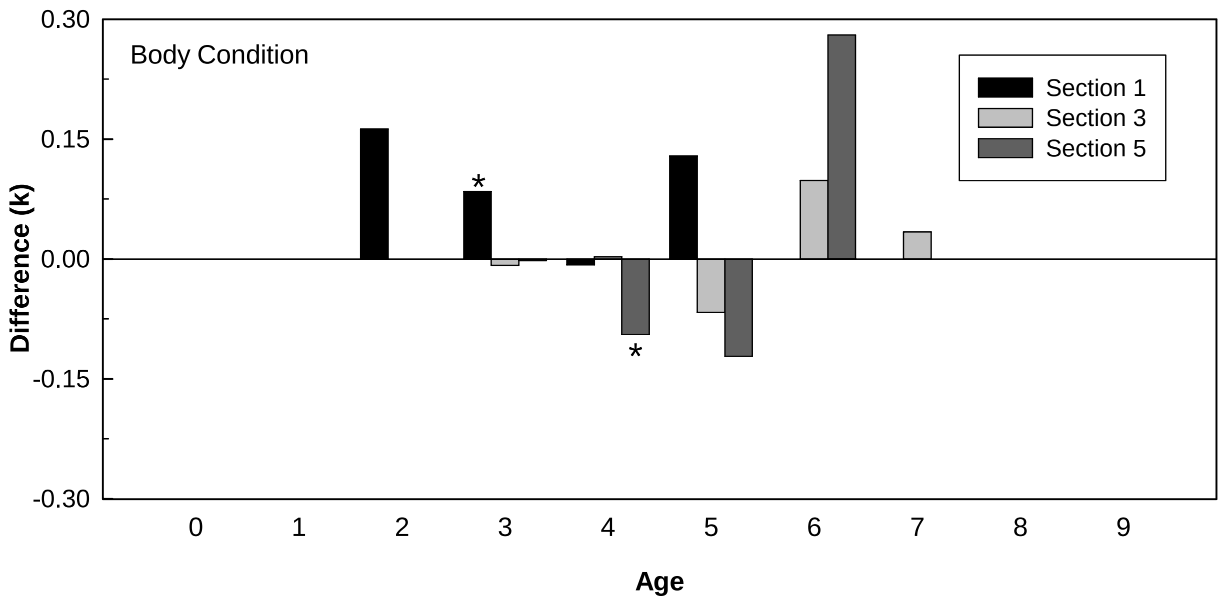


Figure 3.10 Comparisons of yearly changes in growth increment and body condition (k) between 2004 and 2005 of bull trout sampled in Sections 1, 3, and 5 during the Peace River Fish Community Indexing Program. (Values represent differences from previous year; Asterix represents statistical difference at $P \leq 0.05$, Independent samples t-test).

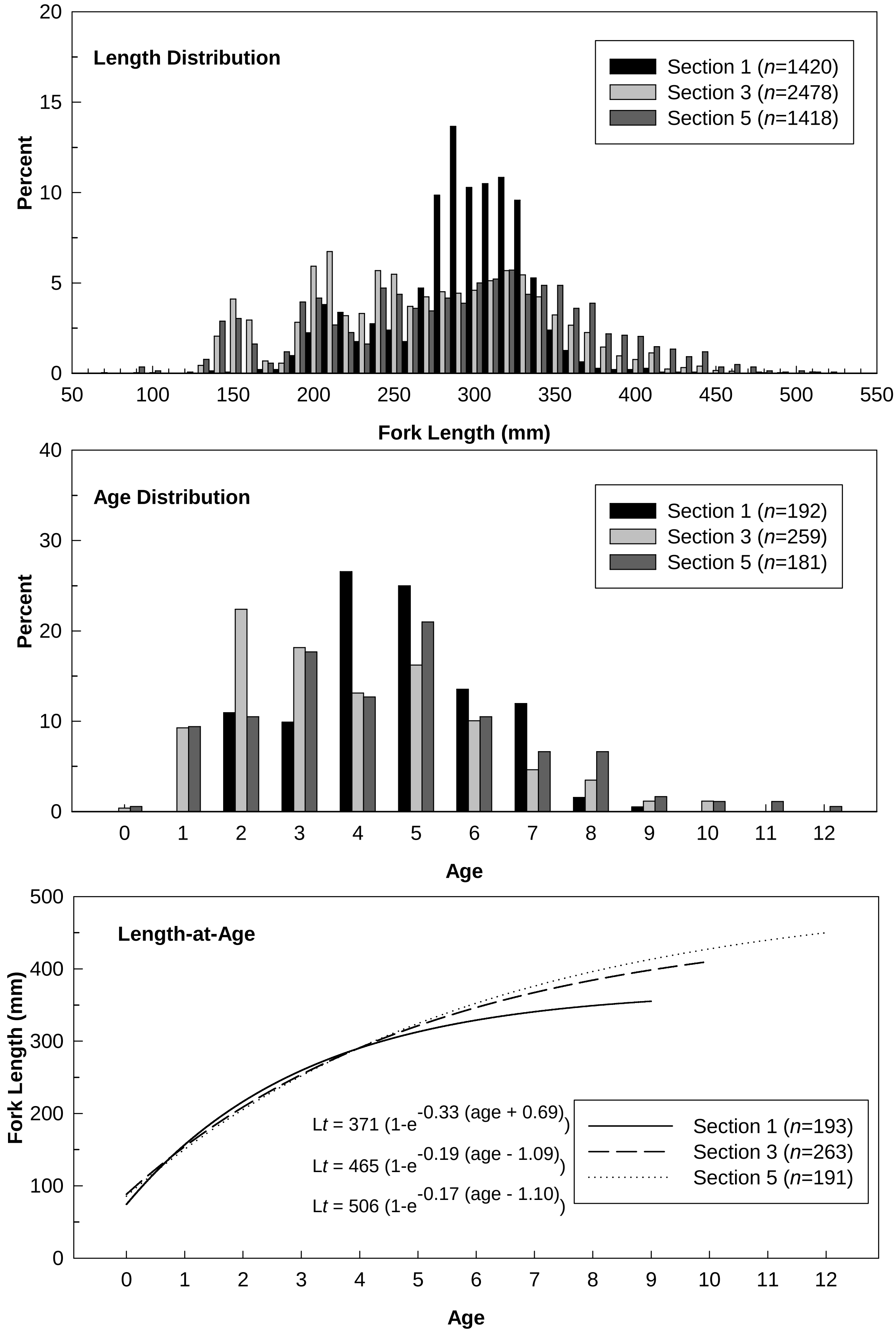


Figure 3.11 Length and age distributions and length-at-age relationships of mountain whitefish sampled during the Phase 5Peace River Fish Community Indexing Program, 2005. (Length-at-age relationship described using the von Bertalanffy growth model).

Table 3.8 Mean length-at-age of mountain whitefish sampled during Phase 5 of the Peace River Fish Community Indexing Program, 2005.

Age	Section 1		Section 3		Section 5	
	n	**Mean Fork Length (± SE)**	***n***	**Mean Fork Length (± SE)**	***n***	**Mean Fork Length (± SE)**
0	1	80.0	5	79.2 ± 9.7	11	81.6 ± 3.5
1	-	-	24	156.9 ± 1.7	17	154.2 ± 2.0
2	21	215.1 ± 2.3 (B) [a]	58	209.9 ± 1.4 (AB)	19	203.7 ± 2.6 (A)
3	19	258.4 ± 4.1	47	252.2 ± 1.8	32	252.8 ± 2.6
4	51	291.9 ± 2.1	34	290.1 ± 2.9	23	292.3 ± 3.3
5	48	313.7 ± 2.2 (A)	42	322.8 ± 2.8 (B)	38	325.8 ± 4.2 (B)
6	26	327.7 ± 1.9 (A)	26	347.6 ± 3.8 (B)	19	353.1 ± 4.9 (B)
7	23	337.9 ± 3.1 (A)	12	363.3 ± 6.6 (B)	12	364.0 ± 6.6 (B)
8	3	341.3 ± 8.0 (A)	9	376.9 ± 8.9 (AB)	12	397.0 ± 8.9 (B)
9	1	412.0	3	409.0 ± 4.4	3	414.7 ± 13.8
10	-	-	3	422.0 ± 10.5	2	435.5 ± 4.5

[a] Based on post-hoc comparisons means test; different letter denotes statistical difference at $P \leq 0.05$.

The opposite trend was recorded for body condition (Table 3.9). Up until Age 3, the body condition of mountain whitefish was slightly higher in Section 1. After Age 5, age-specific body condition of fish in Section 1 was lower compared to fish in Sections 3 and 5.

Table 3.9 Mean body condition (*k*) of mountain whitefish sampled during Phase 5 of the Peace River Fish Community Indexing Program, 2005.

Age	Section 1		Section 3		Section 5	
	n	**Mean Body Condition (± SE)**	***n***	**Mean Body Condition (± SE)**	***n***	**Mean Body Condition (± SE)**
0	1	1.17	5	0.92 ± 0.17	11	0.77 ± 0.06
1	-	-	24	1.11 ± 0.02	17	1.07 ± 0.03
2	21	1.15± 0.02	58	1.14 ± 0.01	19	1.12 ± 0.03
3	19	1.16 ± 0.02	47	1.14 ± 0.01	32	1.12 ± 0.02
4	51	1.15 ± 0.02	34	1.15 ± 0.02	23	1.18 ± 0.02
5	48	1.09 ± 0.02 (A) [a]	41	1.14 ± 0.02 (B)	37	1.19 ± 0.02 (C)
6	26	1.04 ± 0.02 (A)	24	1.12 ± 0.02 (B)	19	1.11 ± 0.02 (B)
7	23	1.02 ± 0.02 (A)	12	1.03 ± 0.03 (B)	12	1.16 ± 0.04 (B)
8	3	1.12 ± 0.08	9	1.04 ± 0.02	12	1.11 ± 0.03
9	1	1.02	3	1.17 ± 0.04	3	1.19 ± 0.07
10	-	-	3	1.05 ± 0.04	2	1.17 ± 0.09

[a] Based on post-hoc comparisons means test; different letter denotes statistical difference at $P \leq 0.05$.

These spatial differences in growth and body condition may reflect differences in section productivity Alternatively the spatial differences may reflect differences in the proportion of each population that spawns in a given year and the stage of gonad development of this fall spawning species. Age-dependent allocation of energy reserves to reproductive organs may explain the section differences in growth rate.

Strong yearly differences in the length and age distributions of sampled mountain whitefish were not apparent in each of the sections (Figures 3.12 and 3.13). In Section 1 Age 2 fish were more prominent during the present study compared to previous investigations. Apparent mortality also increased from 40% to 55%, which likely reflected the shift in population structure from Age 4 to Age 5 fish.

Length and age distributions of mountain whitefish in Sections 3 and 5 remained stable between years. Apparent mortality was approximately 34% in Sections 3 and 5. Of interest; however, was a shift in length distribution modal peaks of younger fish between 2004 and 2005. Younger fish appeared to be smaller during the present study.

There were yearly differences in growth of mountain whitefish in all three sections (Figure 3.14). Fish were smaller at a given age in 2005 compared to 2004 (16 of 21 comparisons). These differences were statistically significant for Ages 1, 2, and 3. Between-year differences in body condition were similar to findings for growth. All comparisons indicated lower body condition in 2005 compared to 2004 and most were statistically significant. The results suggested that conditions in 2005 were less optimal for mountain whitefish growth compared to 2004.

The reduction in growth and body condition could be related to perturbations associated with weather or river discharge that resulted in reduced productivity. Alternatively, it could be due to overcrowding related to fish movements (Mainstream and Gazey 2005; see Section 3.6 of present study), or it may simply reflect normal changes in general population health. Empirical data that describes these ecological factors are needed in order to interpret the biological characteristic results.

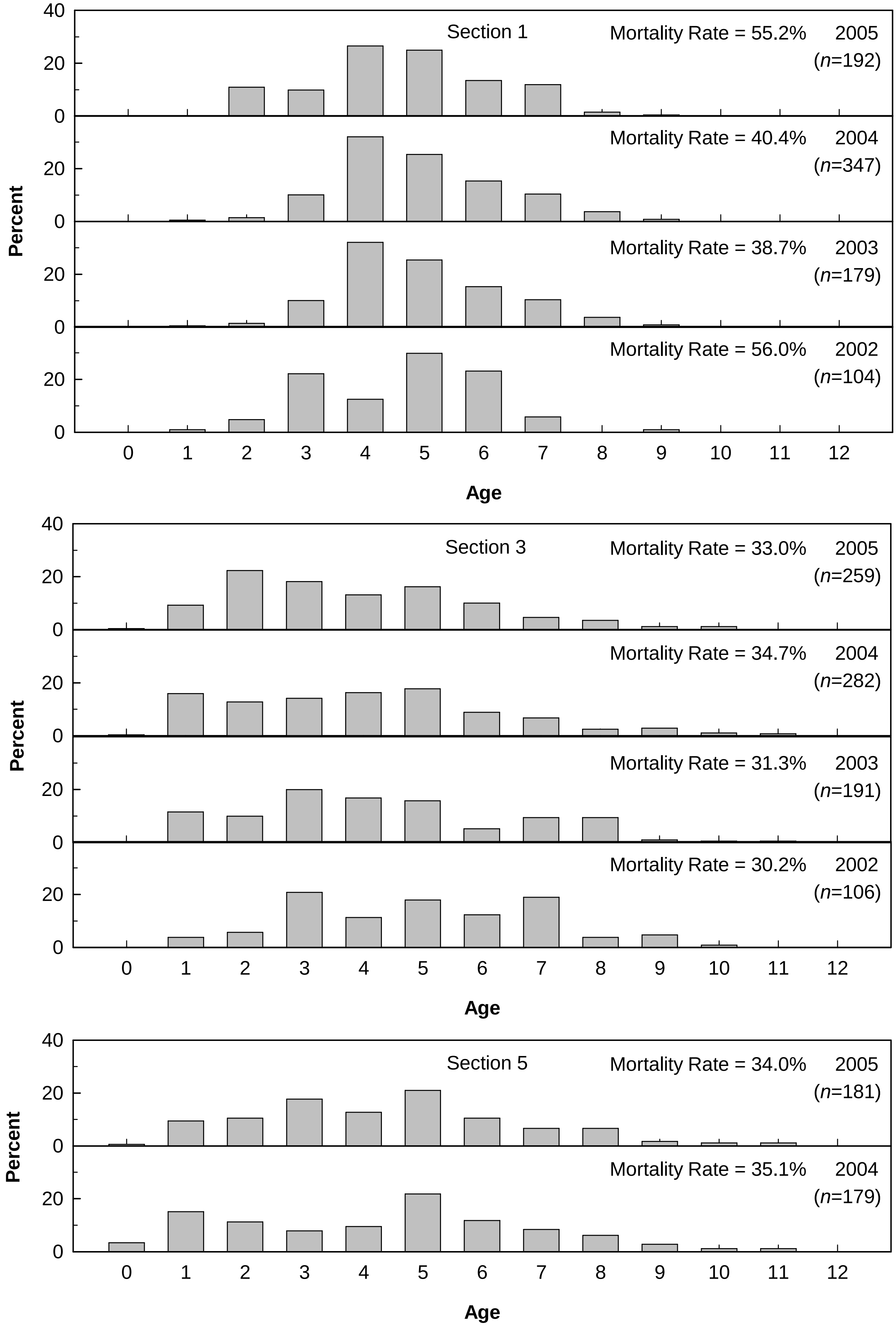


Figure 3.12 Yearly comparisons of age distributions and mortality rates of mountain whitefish sampled in Sections 1, 3, and 5 during the Peace River Fish Community Indexing Program, 2002 to 2005.

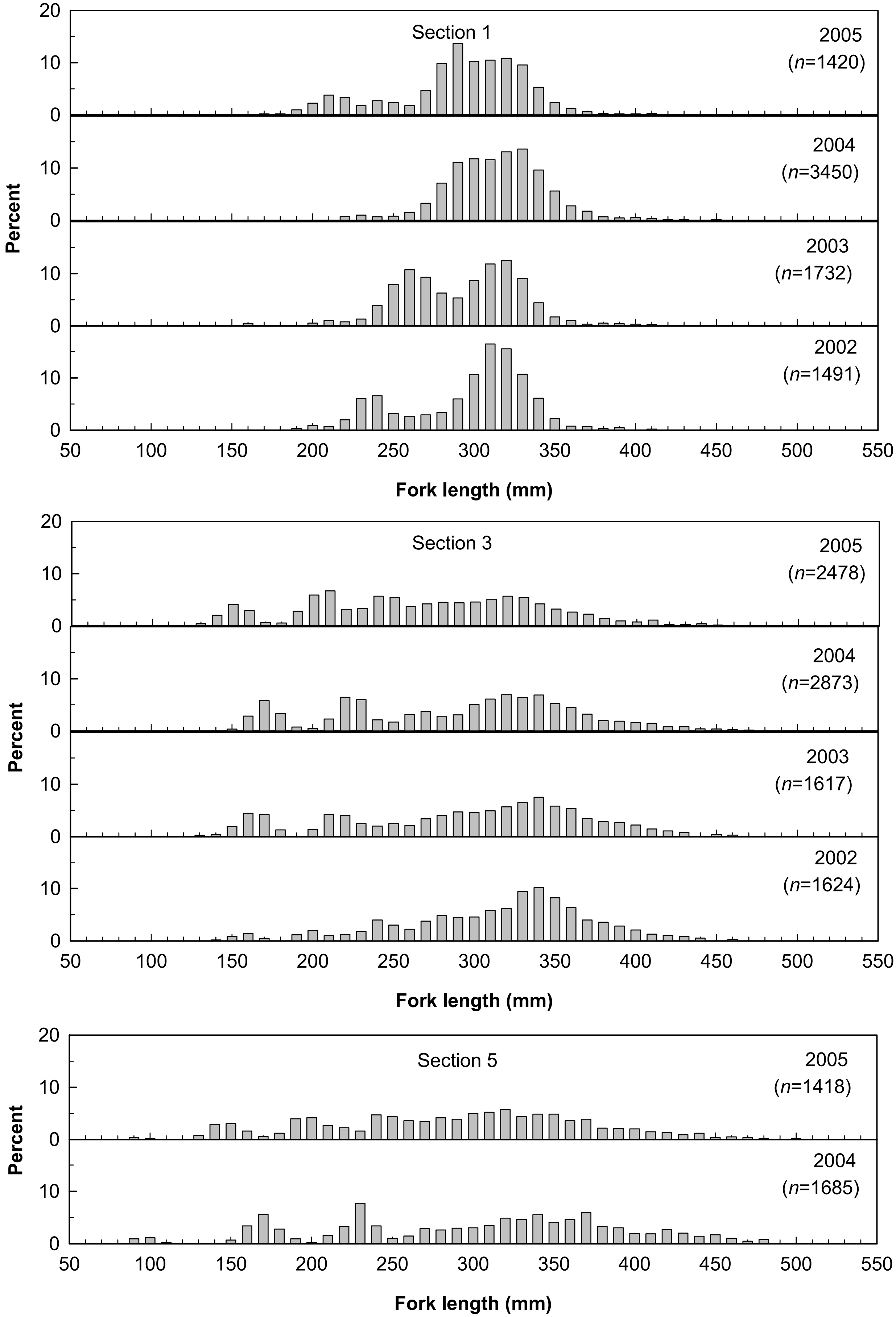


Figure 3.13 Yearly comparisons of length distributions of mountain whitefish sampled in Sections 1, 3, and 5 during the Peace River Fish Community Indexing Program, 2002 to 2005.

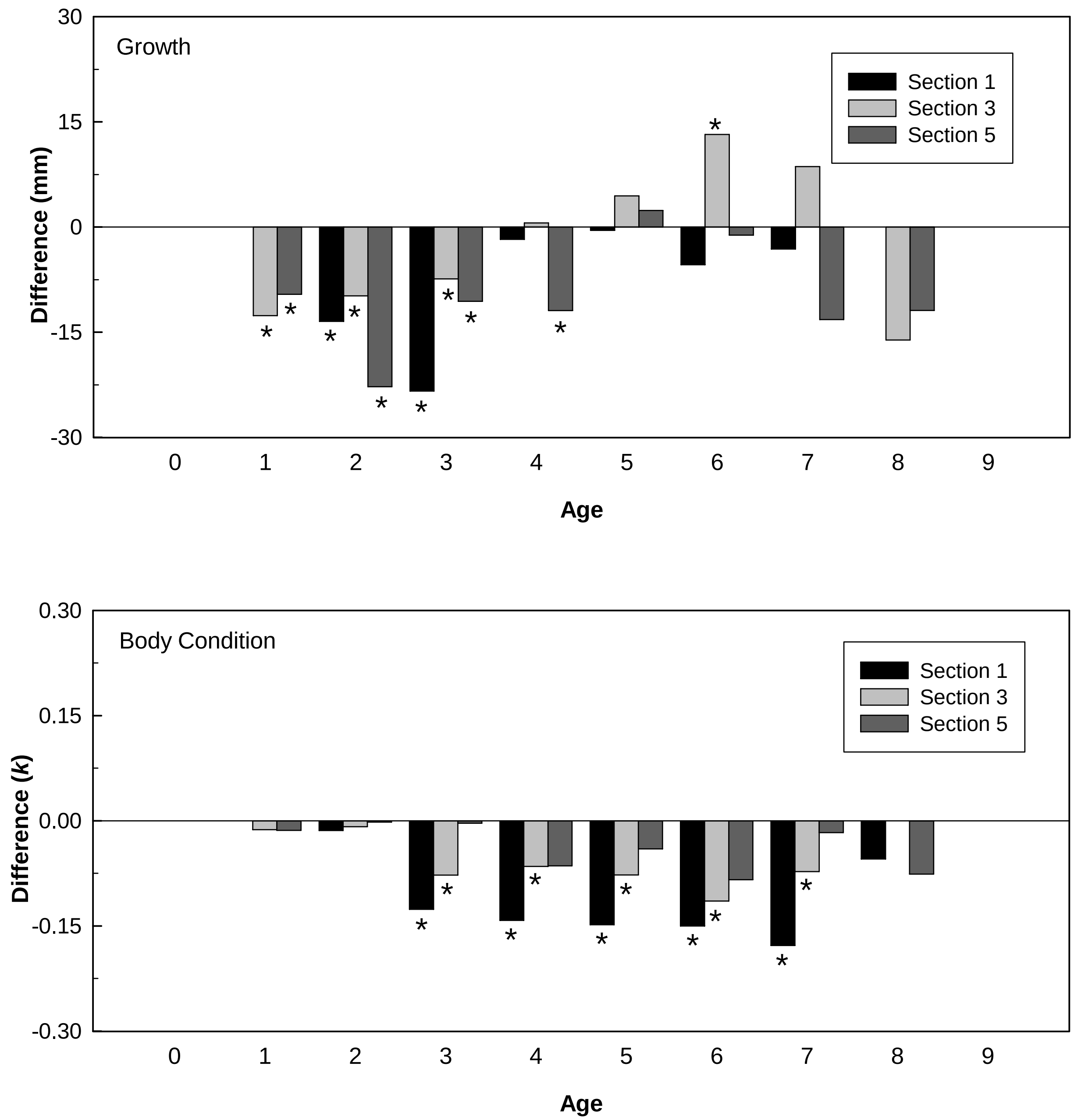


Figure 3.14 Comparisons of yearly changes in growth increment and body condition (k) between 2004 and 2005 of mountain whitefish sampled in Sections 1, 3, and 5 during the Peace River Fish Community Indexing Program. (Values represent differences from previous year; Asterix represents statistical difference at $P \leq 0.05$, Independent samples t-test).

3.4 RELATIVE ABUNDANCE

Previous investigations examined several aspects of relative abundance, or catch rate, to ascertain whether this parameter was a suitable monitoring tool for the Peace River Fish Community Indexing Program. The primary focus was an examination of catchability and sample variability. Those studies established that factors under the control of the sampler (i.e., boat electrofisher operation, use of observed fish, stratification, and analytical protocols) could be adjusted to reduce sample variation and to stabilize catchability. Factors outside the control of the sampler (i.e., water clarity and discharge) also were examined. Low water clarity reduced capture efficiency, but changes in discharge likely did not.

Based on this work it was concluded that for Arctic grayling and bull trout, catch rate data were not sufficient to detect changes in relative abundance due to insufficient statistical power caused by low fish numbers (i.e., within sample variation exceeded between sample differences); however, trend data could be used to track gross changes in fish abundance. The work established that catch rate was an appropriate tool for mountain whitefish as long as sampling protocols addressed factors that could potentially influence reliability of the data.

The present study examined the effectiveness of sampling protocols, evaluated the effects of changes in discharge on catch rate, and documented annual trends in fish abundance.

3.4.1 General

Previous studies established that catch rates of target fish species were influenced by habitat and river section. The 2005 results supported these findings. Mean catch rates differed between species, section, and habitat (Table 3.10 and Figure 3.15). Catch rates for Arctic grayling and bull trout were low in all sections. Values ranged from 0.21 to 3.21 fish/km and 0.43 to 1.79 fish/km respectively. Catch rates for mountain whitefish were much greater than for the other two target species. Mean values exceeded 34 fish/km.

Mean catch rates differed between sections. Arctic grayling were scarce in Section 1, moderately abundant in Section 3, and most abundant in Section 5. These differences were caused by the relative contribution of young fish to the samples. Bull trout tended to be least abundant in Section 5. Catch rates of mountain whitefish were consistently higher in SFN compared to SFC habitats in three sections, and differences were significant in Sections 1 and 3.

Table 3.10 Mean catch rates of the three target species stratified by section and habitat during the Phase 5 Peace River Fish Community Indexing Program, 2005.

Species	Section	SFC Habitat		SFN Habitat		P-value[a]
		n	Mean (± SE)	*n*	Mean (± SE)	
Arctic grayling	1	48	0.21± 0.07 (A)	42	0.35± 0.11 (A)	0.367
	3	48	2.02 ± 0.27 (B)	42	0.52 ± 0.15 (A)	0.000
	5	48	3.21 ± 0.44 (B)	42	2.67 ± 0.44 (B)	0.274
P-value[b]		0.000		0.000		
Bull trout	1	48	1.27 ± 0.22 (A)	42	0.48 ± 0.13 (A)	0.004
	3	48	1.27 ± 0.24 (B)	42	1.79 ± 0.21 (B)	0.031
	5	48	0.82 ± 0.13 (A)	42	0.43 ± 0.12 (A)	0.017
P-value		0.369		0.000		
Mountain whitefish	1	48	41.50 ± 4.19	42	63.37 ± 6.75 (B)	0.040
	3	48	40.62 ± 3.01	42	50.23 ± 3.50 (B)	0.039
	5	48	34.42 ± 2.51	42	34.91 ± 3.08 (A)	0.919
P-value		0.343		0.003		

[a] Based on Independent samples t-test using log-transformed data.
[b] Based on One-way Analysis of variance using log-transformed data. Different letters designate significantly different ($P \leq 0.05$) values using post hoc comparison means test.

Mean catch rates differed between sections. Arctic grayling were scarce in Section 1. These differences were caused by the relative contribution of young fish to the samples. Bull trout catch rates tended to be highest in Sections 1 and 3 compared to Section 5. Mountain whitefish exhibited spatial differences in abundance from upstream to downstream. Mean catch rates were higher in Section 1 (upstream) compared to Sections 3 and 5 (downstream). Statistical analysis confirmed these trends in SFN habitat.

3.4.2 Confounding Variables

The field program was structured to collect information for calculation of population estimates. As such, sampling was repeated six times in each section. During previous studies catch rates tended to decrease over time, which indicated that this level of sampling intensity may have negatively affected target fish species. In 2004, catch rates changed during the program but factors other than repeated sampling appeared to influence catch rate. One of these factors was discharge.

In 2005, discharge declined during the first half of the field program and then remained relatively constant for the latter half of the program. Plotting mean catch rate versus mean water level by session was used to ascertain whether there was a relationship between catch rate and discharge. No clear pattern was recorded for Arctic grayling, but bull trout and mountain whitefish catch rates increased. Catch rates and water level at the time of sampling were compared to examine this relationship (Figures 3.16 to 3.18).

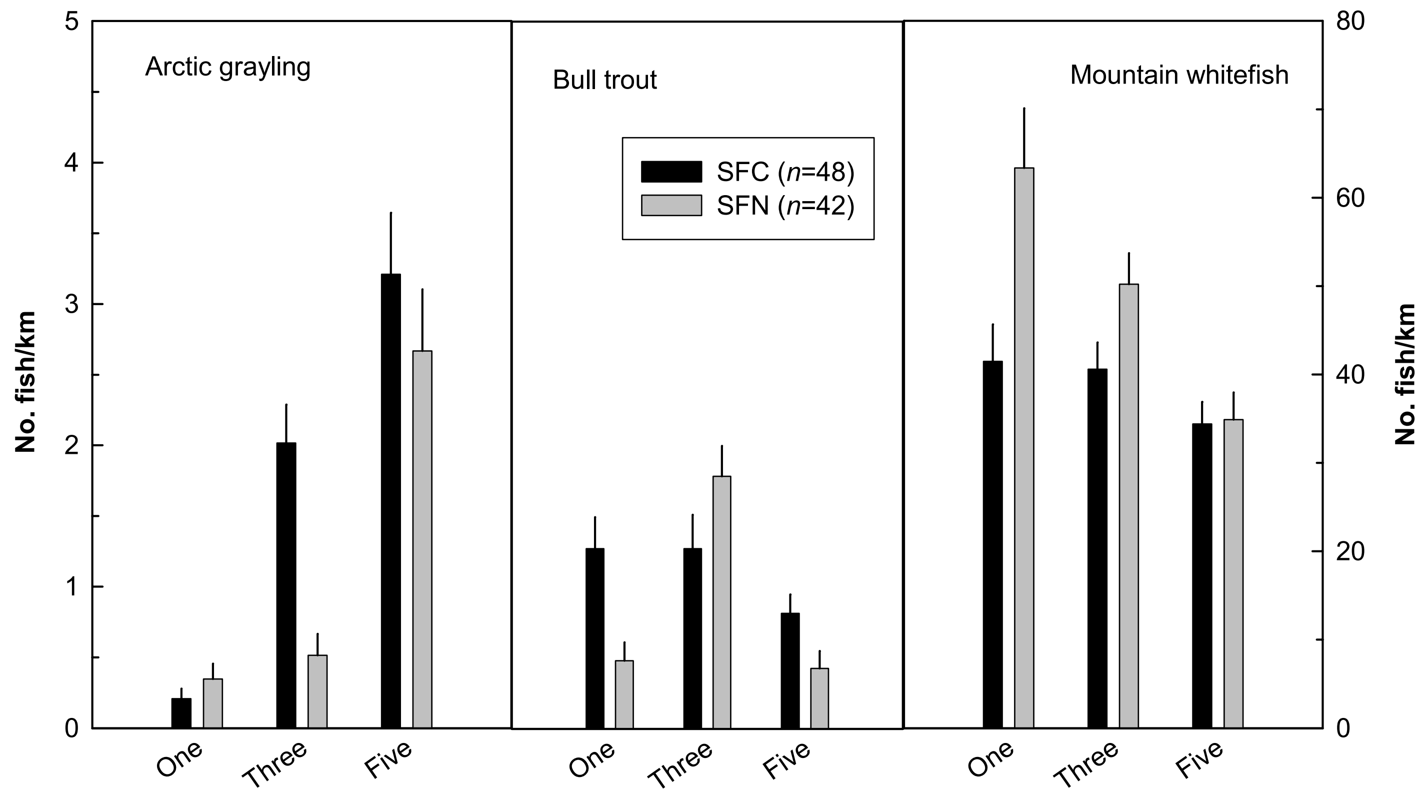


Figure 3.15 Mean catch rate (+ SE) of three target species stratified by section and habitat during the Phase 5 Peace River Fish Community Indexing Program, 2005.

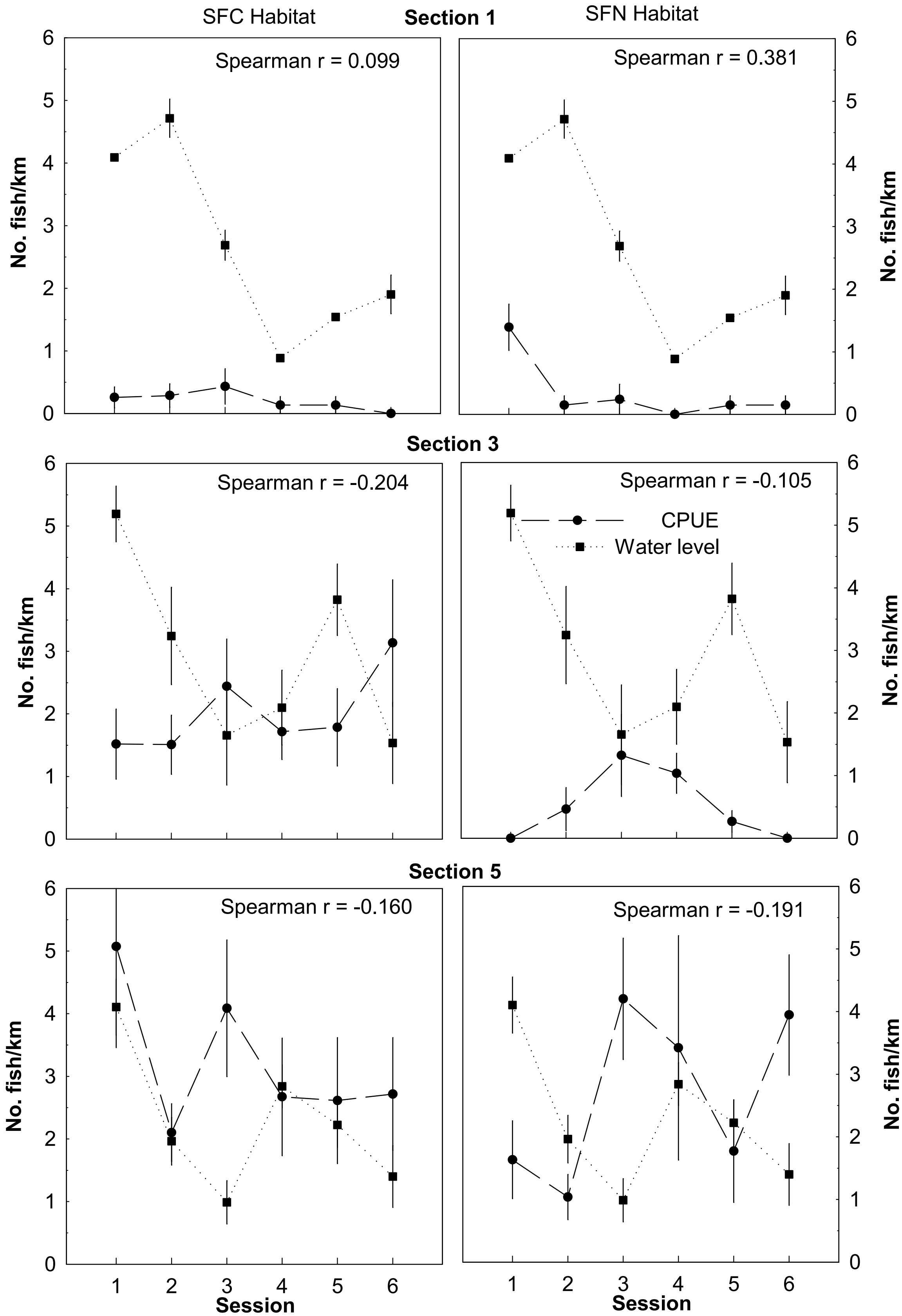


Figure 3.16 Relationship between Arctic grayling catch rate and water level (mean ± SE) by session during the Phase 5 Peace River Fish Community Indexing Program, 2005 (Spearman's rank correlation coefficient (one-tailed) based on combined sample; * denotes $P \leq 0.1$, ** denotes $P \leq 0.05$).

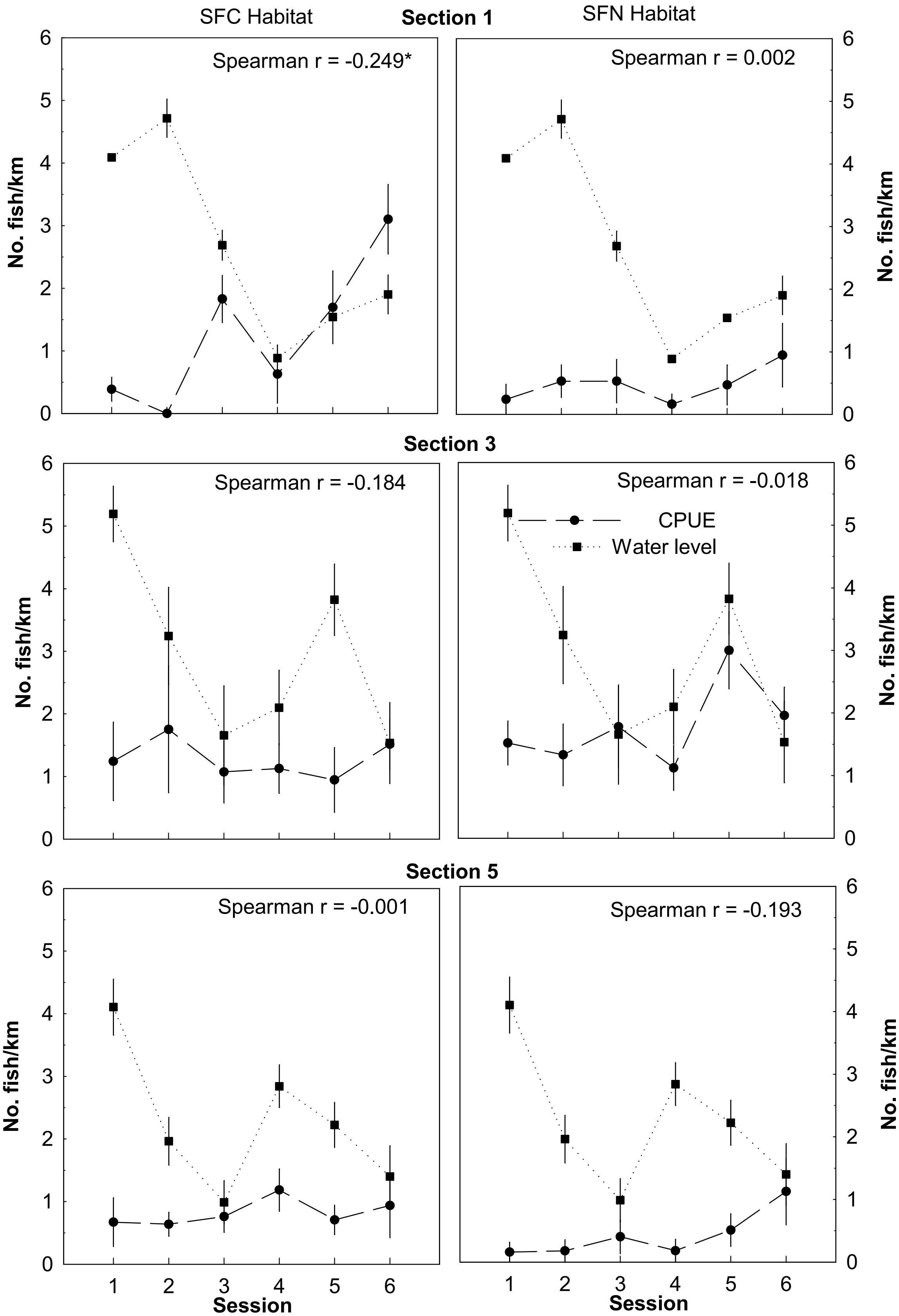


Figure 3.17 Relationship between bull trout catch rate and water level (mean ± SE) by session during the Phase 5 Peace River Fish Community Indexing Program, 2005 (Spearman's rank correlation coefficient (one-tailed) based on combined sample; * denotes $P \leq 0.1$, ** denotes $P \leq 0.05$).

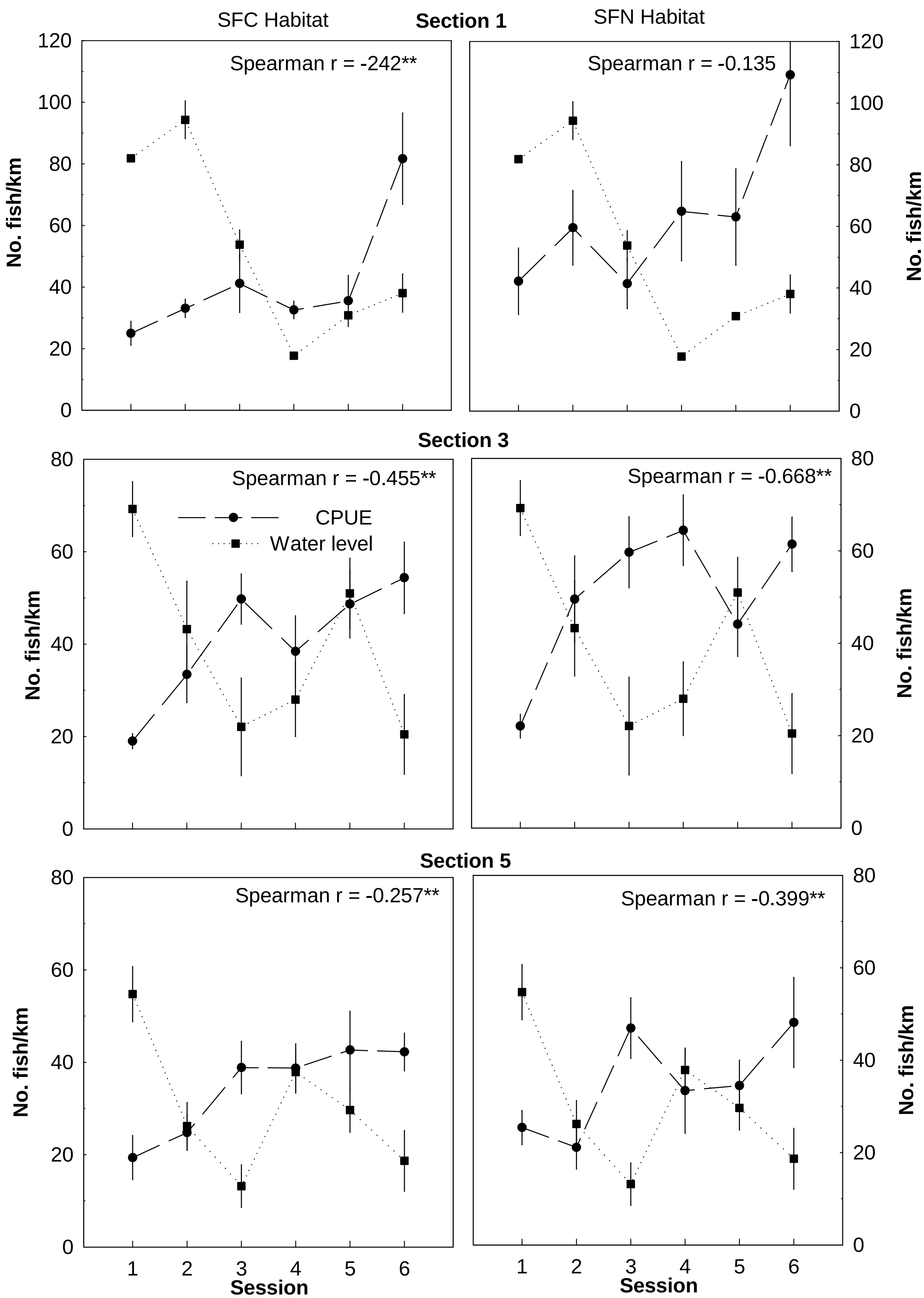


Figure 3.18 Relationship between mountain whitefish catch rate and water level (mean ± SE) by session during the Phase 5 Peace River Fish Community Indexing Program, 2005 (Spearman's rank correlation coefficient (one-tailed) based on combined sample; * denotes $P \leq 0.1$, ** denotes $P \leq 0.05$).

Most comparisons indicated that catch rate was negatively correlated with water level (Table 3.11). These correlations were strongest and were significant for mountain whitefish. For this species, discharge may have influenced catch rate, which is similar to the 2004 findings.

Table 3.11 Correlation between species catch rate and water level during the Phase 5 Peace River Fish Community Indexing Program, 2005.

Species	Section	Water Level (mm)	
		SFC (n = 48)	**SFN (n = 42)**
Arctic grayling	1	0.099	0.381
	3	-0.204	-0.105
	5	-0.160	-0.191
Bull trout	1	-0.249*[a]	0.002
	3	-0.184	-0.018
	5	-0.001	-0.193
Mountain whitefish	1	-0.242**	-0.135
	3	-0.455**	-0.668**
	5	-0.257**	-0.399**

[a] Based on Spearman's coefficient of rank correlation (one-tailed); * denotes significance at $P \leq 0.1$, ** denotes significance at $P \leq 0.05$.

The potential causal mechanisms of this relationship are complex. Lower discharge over an extended period, or diurnal fluctuations, may have concentrated fish within the study section into smaller areas and improved catchability, thereby causing an artificial increase in fish density. Alternatively, lower discharge may have forced fish to move into the study section from unsampled areas (side channels) resulting in a real increase in fish density. For bull trout an increase in catch rate may have been related to an influx of post-spawning adults from tributaries. The 2004 results and those of the present study (see Section 3.6.1.2) suggested that the latter was the more likely explanation. The catch rate results will remain difficult to interpret without empirical data that describes fish movement in relation to discharge.

3.4.3 Comparison to Previous Studies

An objective of Phase 5 was to extend time series data of the abundance of nearshore fish populations in the Peace River. Catch rates of target species populations changed between years (Figure 3.19). Arctic grayling were present in Section 1 during the present study and catch rates were similar to those recorded in 2002. Mean catch rates of Arctic grayling in Section 3 decreased slightly in 2005 after the increase that was recorded between 2003 and 2004. There was a strong upward trend in catch rate in Section 5. Although values were low (< 4 fish/km) mean catch rates in this section approximately doubled.

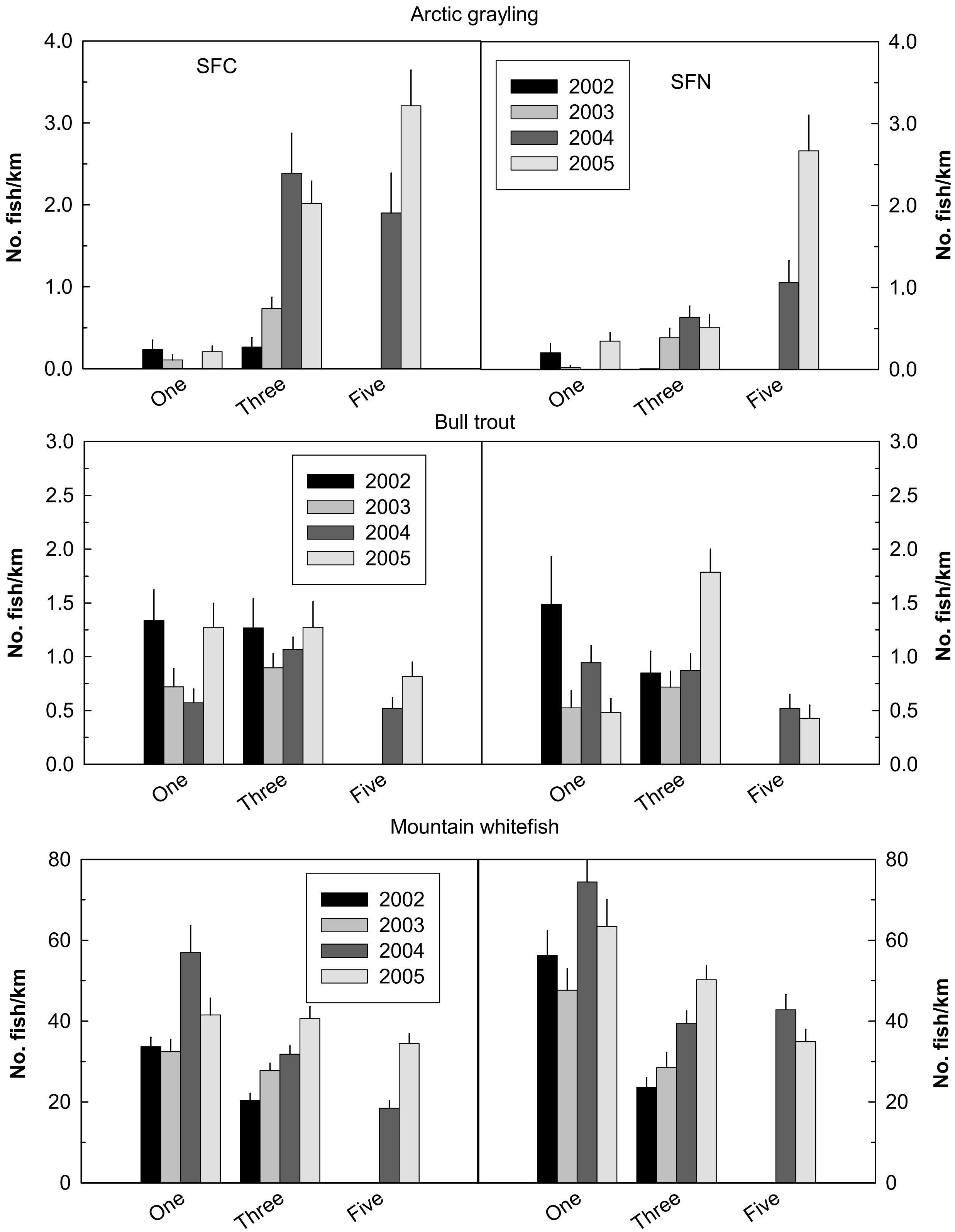


Figure 3.19 Comparisons of mean catch rates (±SE) of target fish species in Sections 1, 3, and 5 during the Peace River Fish Community Indexing Program, 2002 to 2005.

Bull trout catch rates in SFC habitat increased slightly from 2004 to 2005. In SFN habitats the results were ambiguous.

Mountain whitefish catch rates in Section 1 declined in 2005 compared to 2004. In contrast, the upward trend in catch rates has continued in Section 3 since the first year of standardized sampling. Values are approaching those recorded in Section 1, which historically has been the section with the highest number of mountain whitefish. Results for Section 5 were contradictory; catch rates increased in the SFC habitat, but decreased in the SFN habitat between 2004 and 2005.

3.5 SAMPLING EFFECTS

Work completed in 2004 established that the growth and body condition of Floy marked mountain whitefish was less than unmarked mountain whitefish. The mechanism of this effect could not be differentiated between tag effects, capture effects, or processing effects. A subsample of mountain whitefish were marked with PIT tags in 2004 to further evaluate tag effects. Floy and PIT marked fish recaptured during the present study were used for this purpose. In addition, control fish were sampled from areas outside the standard sections to examine whether repeated annual sampling adversely affected mountain whitefish growth and body condition.

3.5.1 Growth

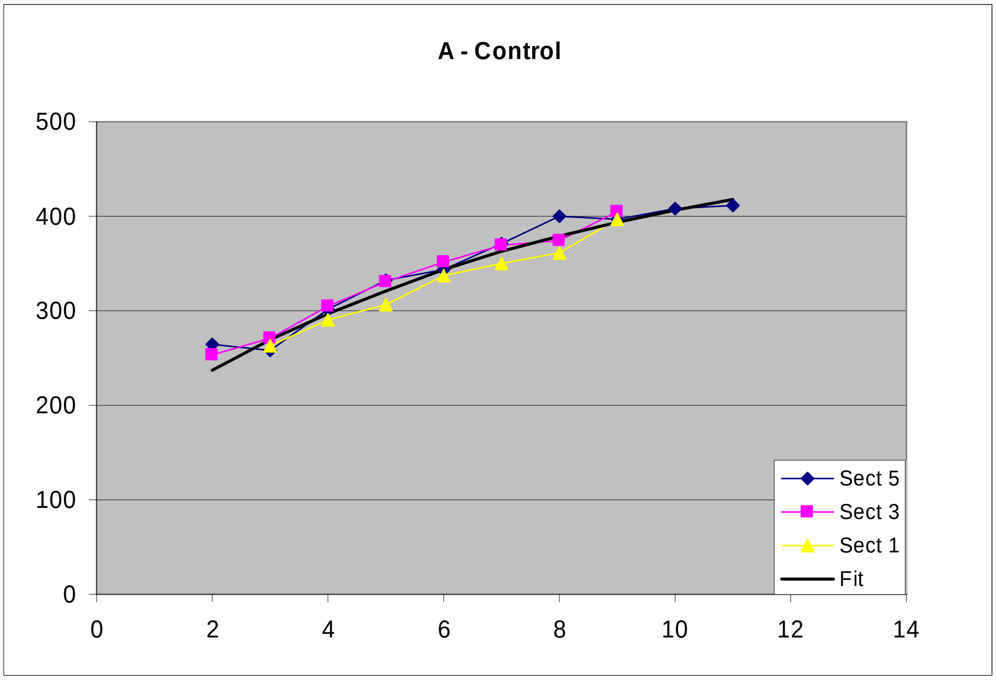
Mean length-at-age data taken in 2005 from unmarked mountain whitefish (control and study sites) are listed in Table 3.12 and plotted by section in Figure 3.20. Individual fish length-at-age measures, pooled over sections, were fit to the von Bertalanffy growth model (Equation 1 and Figure 3.20). Similarly, the mean length-at-age data from marked fish are listed in Table 3.13 and plotted in Figure 3.21 with the von Bertalanffy fitted growth model. For the incremental growth of marked fish, all available data were used over the period 2001 to 2005 to increase contrast and the sample size to deal with large variation.

Since a three-dimensional plot of the scatter (Equation 3) would be difficult to interpret we plotted the predicted versus observed relative growth (as a fraction of the maximum possible given length-at-release and time-at-large) based on mark-recapture incremental growth (Figure 3.22). Note that all measurement error is included in the observed relative growth. Figure 3.23 plots growth curves derived from the incremental growth of Floy and PIT marked fish starting from a common length (250 mm) over a year to illustrate the divergence in predicted lengths (about 4 mm after a year). Estimates of the non-linear von Bertalanffy parameters for the length-at-age data (Equation 2) and the mark-recapture length increment data (Equation 3) are listed in Table 3.14. Comparison between growth curves are complicated by the large negative correlation between the asymptotic length (L_∞) and the growth coefficient (K). Following Gallucci and Quinn (1979) the products $\omega = L_\infty K$, termed the anabolic constant, were calculated and listed in Table 3.14 and plotted in Figure 3.24. With respect to the figure and table the following should be noted:

1) The anabolic constants derived from incremental growth of Floy and PIT marked mountain whitefish were significantly different (the 95% confidence intervals do not overlap).
2) The interval derived from incremental growth of PIT marked fish are not significantly different (overlap) from the age-length derived intervals for unmarked (study and control) fish.
3) The age-length derived intervals for marked fish are large but consistent with the previous observations.

Table 3.12 Length-at-age data taken from unmarked mountain whitefish in Sections 1, 3, and 5 during the Phase 5 Peace River Fish Community Indexing Program, 2005.

Age	Section								
	One			Three			Five		
	Length	SD	*n*	Length	SD	*n*	Length	SD	*n*
Control Fish									
0									
1									
2				254.0	2.83	2	265.0		1
3	263.0	8.86	8	271.8	11.39	8	258.3	6.73	10
4	290.3	12.81	13	305.2	15.94	5	302.4	16.56	13
5	306.8	22.96	21	330.4	15.79	18	333.0	30.47	21
6	336.8	13.89	10	351.4	26.13	9	343.0	34.68	12
7	349.3	24.56	10	369.0	12.33	5	370.9	15.51	9
8	361.0	20.48	5	373.5	32.19	6	400.7	17.39	3
9	397.2	19.46	5	405.0		1	397.3	16.26	3
10							408.0		1
11							412.0		1
12									
Standard Fish									
0				109.0		1	104.0		1
1				156.9	8.53	24	154.2	8.23	17
2	215.1	10.53	21	209.9	10.29	58	203.7	11.52	19
3	258.4	17.82	19	253.3	14.89	48	251.7	15.76	33
4	291.9	15.02	51	289.4	16.88	33	294.6	19.37	24
5	313.7	15.19	48	322.8	18.43	42	325.8	25.96	38
6	327.7	9.85	26	347.6	19.47	26	356.7	26.36	20
7	337.9	14.74	23	363.3	23.02	12	370.7	32.59	13
8	341.3	13.80	3	376.9	26.79	9	392.1	26.81	11
9	367.7	39.80	3	409.0	7.55	3	414.7	23.86	3
10				422.0	18.25	3	435.5	6.36	2
11							419.0	12.73	2
12							518.0		1



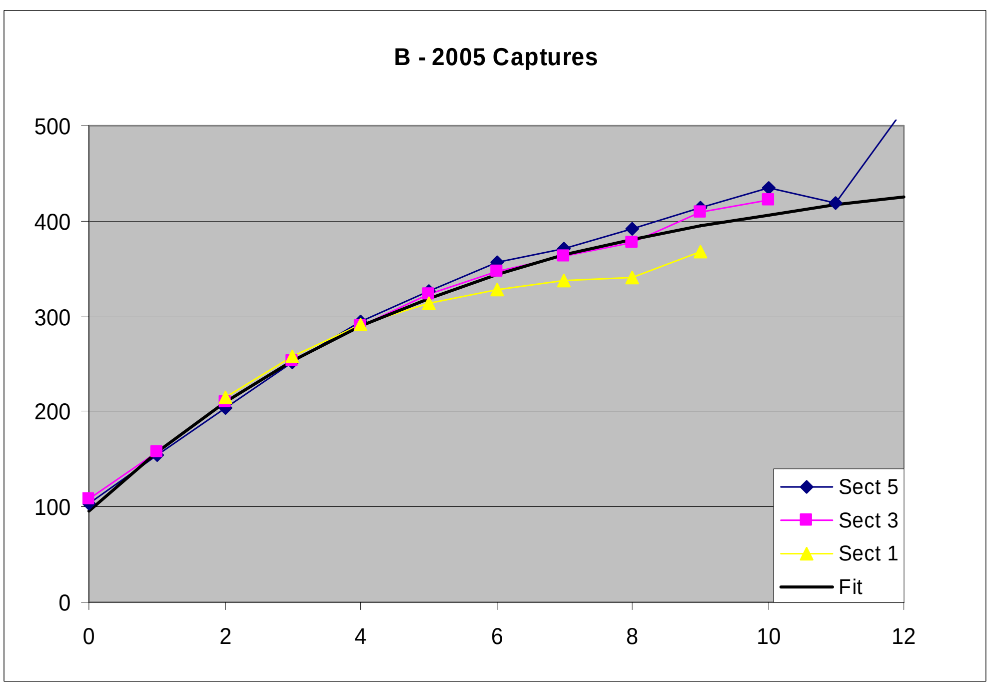
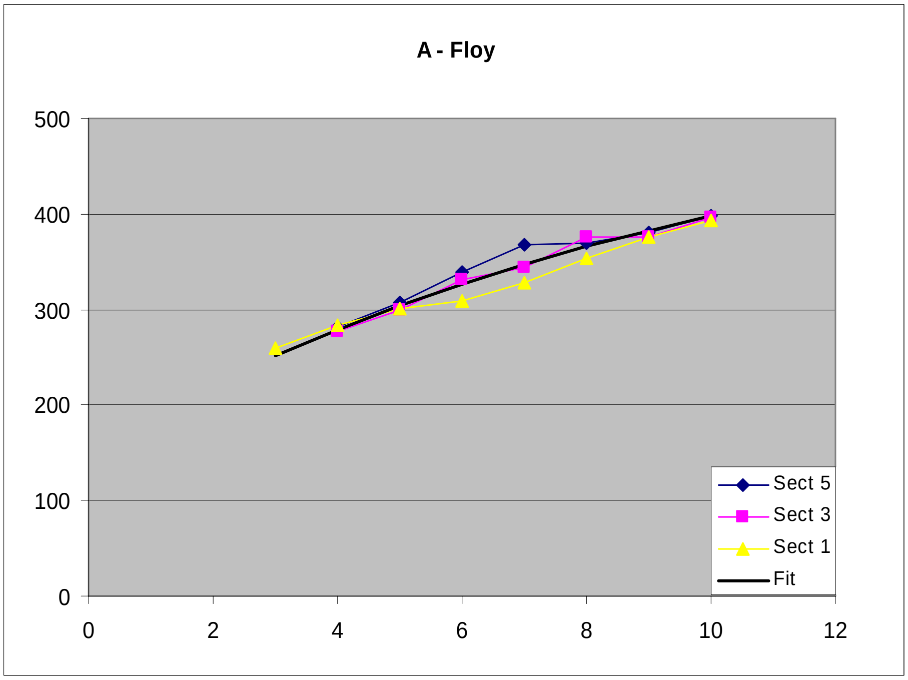


Figure 3.20 Length-at-age by section for unmarked mountain whitefish and the predicted (fitted) von Bertalanffy growth model during the Phase 5 Peace River Fish Community Indexing Program, 2005 (Plot A is the control fish and Plot B is for fish captured standard sections).

Table 3.13 Length-at-age data from mountain whitefish marked in 2004 and aged in 2005 in Sections 1, 3, and 5 during the Phase 5 Peace River Fish Community Indexing Program, 2005.

Age	Section								
	One			Three			Five		
	Length	SD	*n*	Length	SD	*n*	Length	SD	*n*
Floy Tags									
0									
1									
2									
3	259.0		1						
4	283.0	8.49	2	277.5	9.35	11	281.7	12.10	3
5	300.5	13.49	26	299.9	8.18	10	307.7	15.79	7
6	308.6	16.05	27	332.0	31.61	39	338.9	22.38	28
7	328.1	22.14	19	343.4	20.21	16	367.9	32.43	19
8	354.0	7.01	6	375.1	25.44	11	369.8	25.41	18
9	375.3	26.58	3	375.3	18.37	12	380.5	32.44	14
10	394.0		1	396.0	33.34	4	397.3	23.82	6
11									
12									
PIT Tags									
0									
1									
2									
3									
4	304.0	8.49	2	285.1	10.47	13	288.3	16.40	7
5	286.4	18.37	20	292.9	14.39	8	295.8	21.75	4
6	302.7	16.99	9	314.5	14.79	26	326.5	15.39	20
7	330.3	16.89	9	328.5	18.16	11	326.3	9.34	7
8				343.5	6.60	6	355.0	14.93	3
9				340.0		1			
10									
11									
12									

The results indicated that growth of mountain whitefish was adversely affected by Floy tag marks, which was similar to the 2004 results. PIT marked fish demonstrated similar growth as unmarked study and control fish suggesting that PIT tags did not adversely affect mountain whitefish growth. An additional finding was that the growth of unmarked study fish and control fish did not differ statistically. This provided evidence that sampling activities not associated with marking effects that have occurred repeatedly since 2002 (i.e., fish capture by boat electrofishing) likely have not affected mountain whitefish growth.



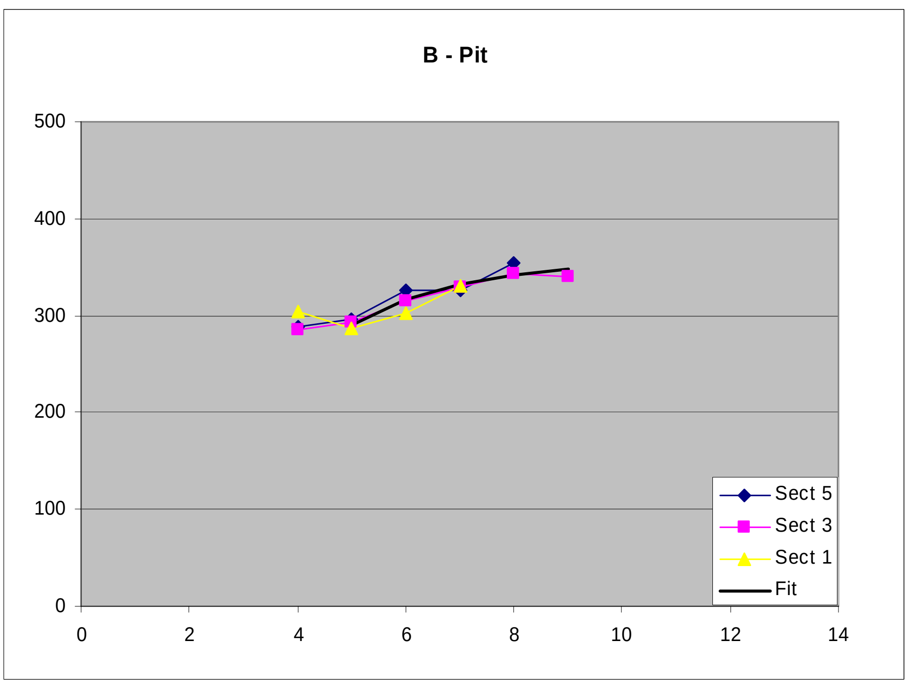
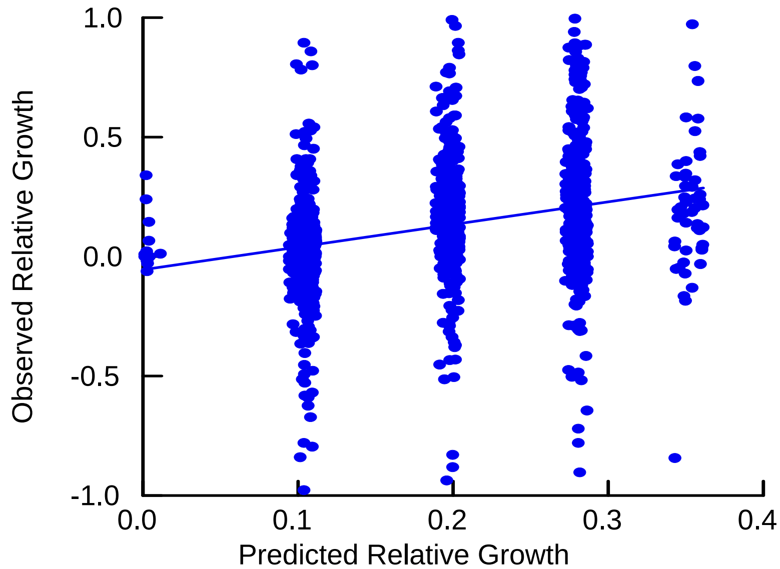


Figure 3.21 Length-at-age by section for marked mountain whitefish and the predicted (fitted) von Bertalanffy growth model during the Phase 5 Peace River Fish Community Indexing Program, 2005 (Plot A is the Floy marked fish and Plot B is for the PIT marked fish).

A) Floy



A) PIT

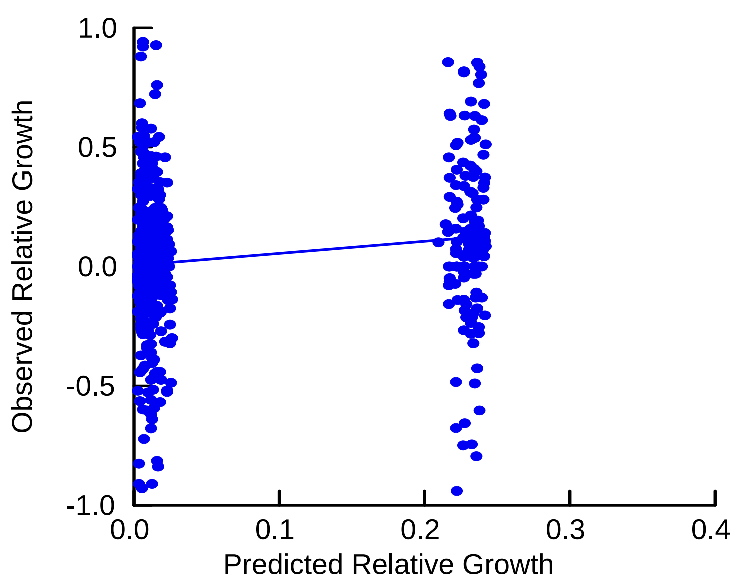


Figure 3.22 Predicted versus observed relative growth as a fraction of the maximum possible given length-at-release and time-at-large) for Floy tags (A) and PIT tags (B) based on mark-recapture incremental growth of mountain whitefish during the Phase 5 Peace River Fish Community Indexing Program, 2005. Predicted = 1-exp(-KΔt) and observed = (Lr-L0)/(L∞-L0). All measurement error is included in the observed relative growth.

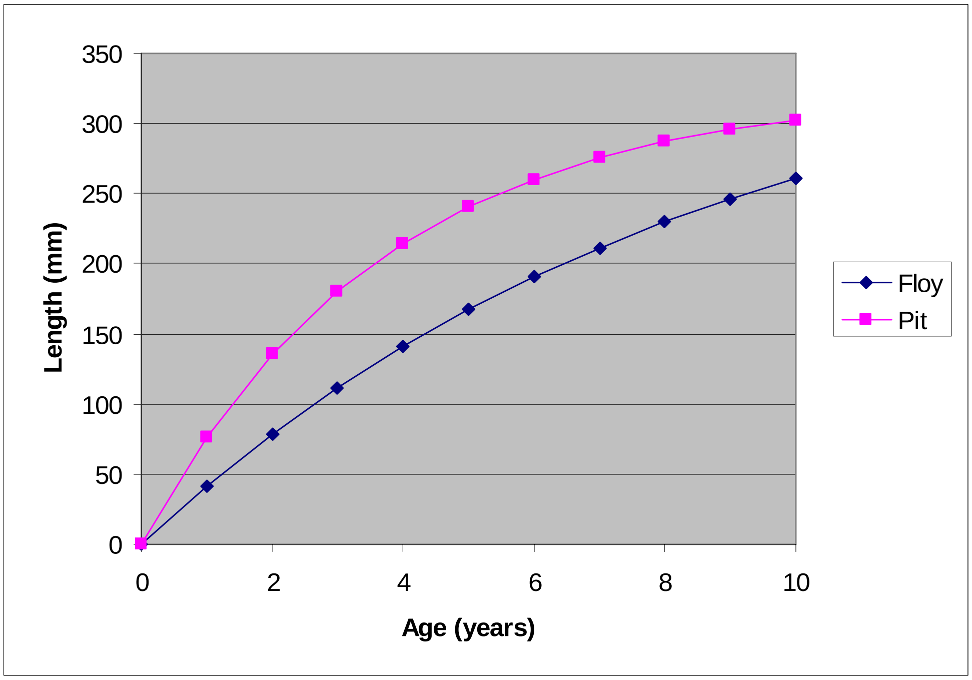


Figure 3.23 Predicted growth of mountain whitefish using a von Bertalanffy growth model with parameters based on length-at-age of Floy and PIT marked fish and the incremental growth obtained from length at release and recapture of tagged fish during the Phase 5 Peace River Fish Community Indexing Program, 2005.

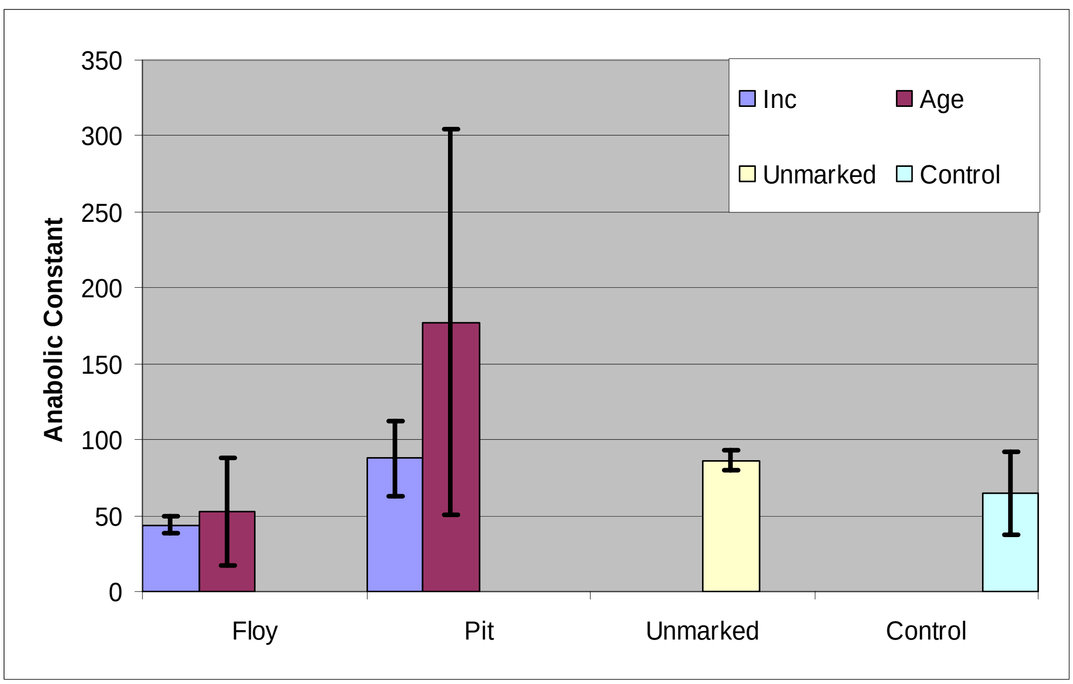


Figure 3.24 Comparison of the anabolic constant ($\omega = L_{\infty}k$) with the associated 95% confidence intervals (bars) determined from incremental growth and age for mountain whitefish marked in 2004 and unmarked fish collected in 2005 in standard and control sections during the Phase 5 Peace River Fish Community Indexing Program, 2005.

Table 3.14 Parameter estimates using nonlinear regression on von-Bertalanffy growth models for mountain whitefish during the Phase 5 Peace River Fish Community Indexing Program, 2005.

Parameter	**Estimate**	**Asymptotic SE**	**Correlation L_∞**
Length Increment of Floy Marked Fish (n = 1699)			
K	0.1150	0.0078	-0.827
L_∞	382.2	4.2	
Product(K,L_∞)	43.96	2.58	
Length Increment of PIT Marked Fish (n = 699)			
K	0.2696	0.0401	-0.519
L_∞	324.7	4.3	
Product(K,L_∞)	87.53	12.45	
Age-at-Length of Floy Marked Fish (n = 285)			
K	0.0948	0.0509	-0.996
L_∞	554.4	113.7	
t_0	-3.37	1.93	
Product(K,L_∞)	52.57	17.53	
Age-at-Length of PIT Marked Fish (n = 124)			
K	0.4975	0.1987	-0.968
L_∞	356.7	15.8	
t_0	1.64	1.02	
Product(K,L_∞)	177.43	63.30	
Age-at-Length of Unmarked Fish in 2005 (n = 637)			
K	0.1861	0.0109	-0.974
L_∞	464.1	10.2	
t_0	-1.24	0.11	
Product(K,L_∞)	86.37	3.23	
Age-at-Length of Unmarked Control (n = 200)			
K	0.1288	0.0410	-0.990
L_∞	500.4	53.8	
t_0	-2.99	1.03	
Product(K,L_∞)	64.47	13.69	

3.5.2 Body Condition

Body condition was used to examine tag effects and sampling effects on mountain whitefish. The mean body condition of Floy versus PIT unmarked fish and unmarked control versus study fish were compared. The results indicated that FLOY marked fish had a lower body condition than PIT marked fish in each of the three sections and these differences were significant (Sections 1 and 3) or near significant (Section 5) (Table 3.15, Figure 3.25). A visual assessment also suggested that body condition of PIT marked fish was higher than body condition of unmarked control and unmarked study fish in Section 1. This apparent difference was not significant (oneway analysis of variance, P = 0.300).

Table 3.15 Mean body condition (*k*) of PIT and Floy marked, and unmarked control and unmarked study mountain whitefish during the Phase 5 Peace River Fish Community Indexing Program, 2005.

Group[a]	Section 1		Section 3		Section 5	
	n	**Mean Body Condition (± SE)**	***n***	**Mean Body Condition (± SE)**	***n***	**Mean Body Condition (± SE)**
PIT Marked	21	1.13 ± 0.029	36	1.14 ± 0.018	30	1.15 ± 0.015
Floy Marked	113	1.07 ± 0.011	127	1.09 ± 0.008	98	1.12 ± 0.010
P-value[b]	0.046		0.020		0.088	
Unmarked Control	30	1.08± 0.006 (A)	52	1.13 ± 0.011 (A)	110	1.13 ± 0.009 (A)
Unmarked Study	1096	1.09 ± 0.003 (A)	1150	1.13 ± 0.003 (A)	733	1.14 ± 0.004 (A)
P-value[a]	0.122		0.561		0.302	

[a] To minimize effects of length on body condition analyses was restricted to the 25 to 75 percentile length distribution of the combined sample (275 to 400 mm fork length).
[b] Based on independent samples t test.

Comparisons of unmarked control fish to unmarked study fish indicated that body condition was not different. This finding was consistent in all three section areas.

The tag results confirm the initial findings in 2004 which suggested adverse effects of Floy marks on mountain whitefish body condition. Results of the present study also indicated that PIT tags do not adversely affect body condition when compared to values from unmarked control and unmarked study fish. In addition, there was no statistical difference in body condition between unmarked control and unmarked study fish. This provided evidence that sampling activities not associated with marking effects that have occurred repeatedly since 2002 (i.e., fish capture by boat electrofishing) likely have not adversely affected mountain whitefish.

3.5.3 Short-term Effects

The tag effects on growth and body condition were distinct and statistically significant. Because the absolute biological impacts likely are large in terms of growth and body condition significant impacts on survival and vulnerability to recapture are likely to occur over the long term. Since the study was conducted over a short period (41 days) the immediate impact on fish is believed to be small. Also, effects associated with fish capture by boat electrofishing and fish processing procedures were not detected. However, measures of immediate mortality can provide an indication of short term effects. Direct mortality of mountain whitefish associated with capture by boat electrofishing was negligible during Phase 5. In total, 30 mountain whitefish suffered immediate mortality during the program, which represented 0.26% of the catch.

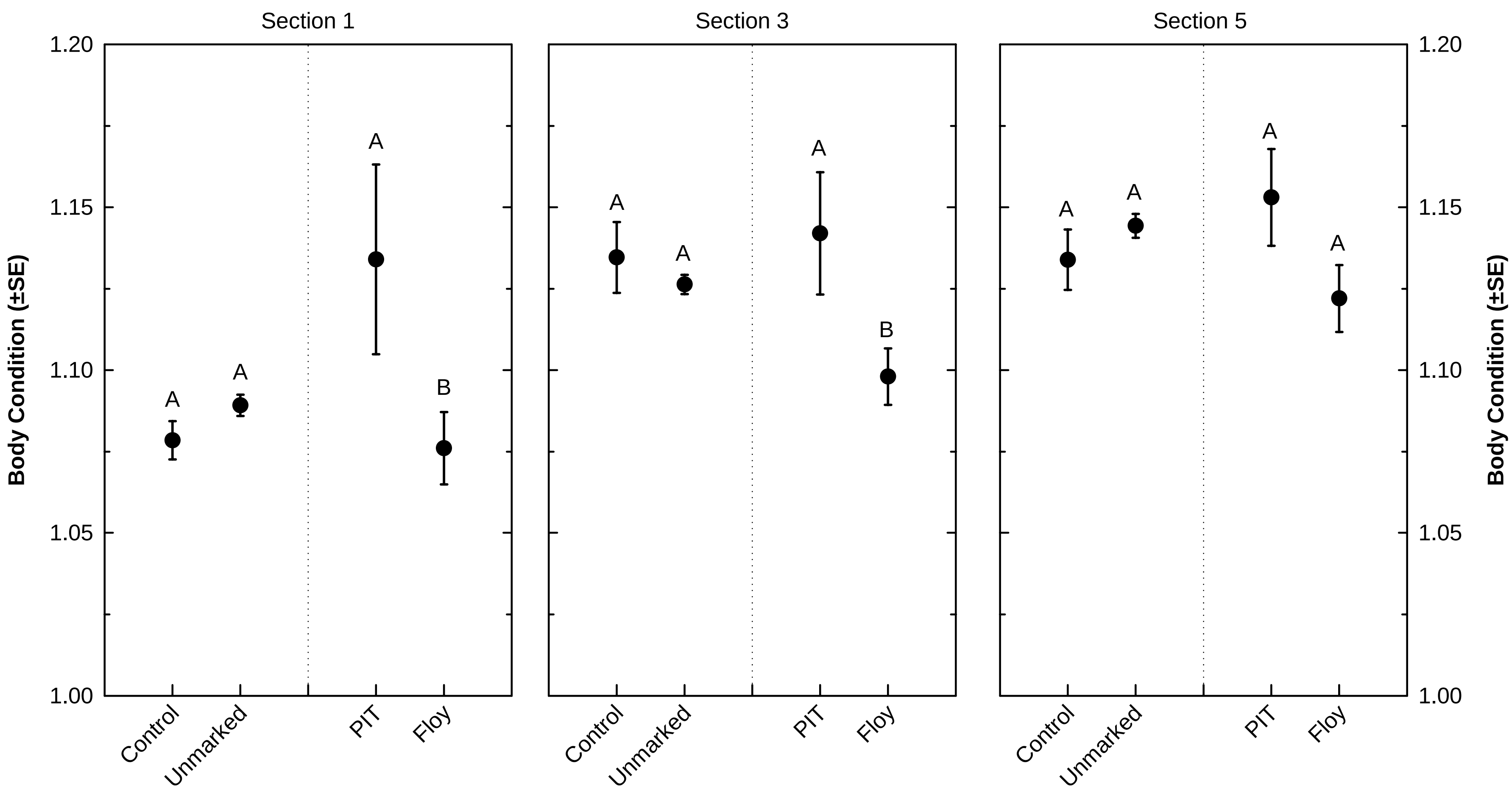


Figure 3.25 Mean body condition mountain whitefish groups during the Phase 5 Peace River Fish Community Indexing Program. Groups include a) Floy and PIT marked fish tagged and released in 2004, and b) Control fish captured in the control sections and unmarked fish captured in standard sections in 2005 (Different letters denote significant difference based on independent samples t test within each group).

3.6 POPULATION ESTIMATES, CATCHABILITY, AND SURVIVAL

3.6.1 Mountain whitefish

A comparison of mountain whitefish recapture rate by tag type is plotted in Figure 3.26. The most dissimilar rate was for Floy tags applied in 2005 (20 recaptures); however, it was not significantly different than the others (P = 0.399, Chi-squared test). A comparison of the recovery rates by the year of tag application and section is recorded in Table 3.16. Again, rates of recapture by year of release were not significantly different for any of the sections or overall.

Figure 3.27 plots the proportion of available marked fish recaptured two and three times by sampling session. If fish were not influenced by electrofishing (more or less prone to subsequent recapture) then the lines in Figure 3.27 should coincide and be horizontal. With the exception of session 3, the confidence bounds on the recapture proportions, assuming a binomial distribution, overlap all other points.

Histograms of the mountain whitefish lengths at release and recapture are plotted in Figures 3.28 and 3.29, respectively. Inspection of the figures reveals that smaller fish (250-275 mm) were not recaptured with the same frequency. A comparison of the lengths (accumulated into 25 mm intervals) by section is tabulated in Table 3.17. While significant differences ($P > 0.05$) were not observed in any of the sections, a slight under representation of smaller fish in the recapture record has been seen consistently in all of the previous studies. Time at large of recaptured mountain whitefish regressed on the growth increment (length at release minus length at recapture) is plotted in Figure 3.30. There was no significant growth of marked fish over the 41 days of the study. Therefore, the broader histogram of the growth increment provides an indication of measurement error (a standard deviation of 7.2 mm for each measurement).

The movement of recaptured mountain whitefish between sections during 2005 is listed in Table 3.18 along with the estimates of the migration proportions adjusted for the number of fish examined (Equation 4). These proportions are plotted in Figure 3.31. Within each section are 15 sampling sites each with a unique river kilometre (kilometres from the BC-AB boundary). Figure 3.32 provides a bar plot of the distance traveled. Positive values indicate fish were recaptured upstream of the release site and vice-versa. Note that most fish were recaptured in the same site-of-release. The movement of recaptured whitefish with the marks applied in 2002 to 2004 is tabulated in Table 3.19 and plotted in Figures 3.33, 3.34 and 3.35.

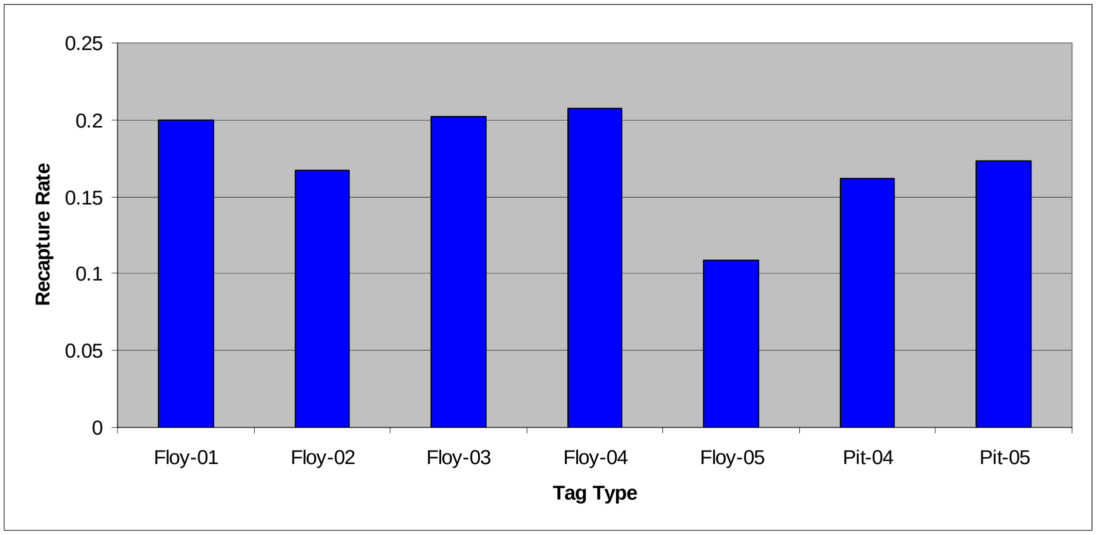


Figure 3.26 Recapture rate by tag type for mountain whitefish during the Phase 5 Peace River Fish Community Indexing Program, 2005.

Table 3.16 A comparison of mountain whitefish recaptured in 2005 that were marked during the Peace River Fish Community Indexing Program, 2001 to 2005.

	Section			**Total**
	One	**Three**	**Five**	
2001 Releases				
Recaptures	3	1	5	9
Marks	23	9	13	45
Percent	13.0	11.1	38.5	20.0
Time-at-large (days)	25.3	10.0	12.6	16.6
2002 Releases				
Recaptures	23	49	1	73
Marks	155	270	10	435
Percent	14.8	18.1	10.0	16.8
Time-at-large (days)	14.1	14.1	3.0	14.0
2003 Releases				
Recaptures	39	44	4	87
Marks	209	211	11	431
Percent	18.7	20.9	36.4	20.2
Time-at-large (days)	17.6	14.9	14.0	16.0
2004 Releases				
Recaptures	31	51	42	124
Marks	222	232	172	626
Percent	18.2	16.5	16.0	19.8
Time-at-large (days)				
2005 Releases				
Recaptures	165	225	188	578
Marks	1022	1416	963	3401
Percent	17.5	14.9	13.4	15.0
Time-at-large (days)				
Independence Test				
Probability	0.823	0.252	0.359	0.453

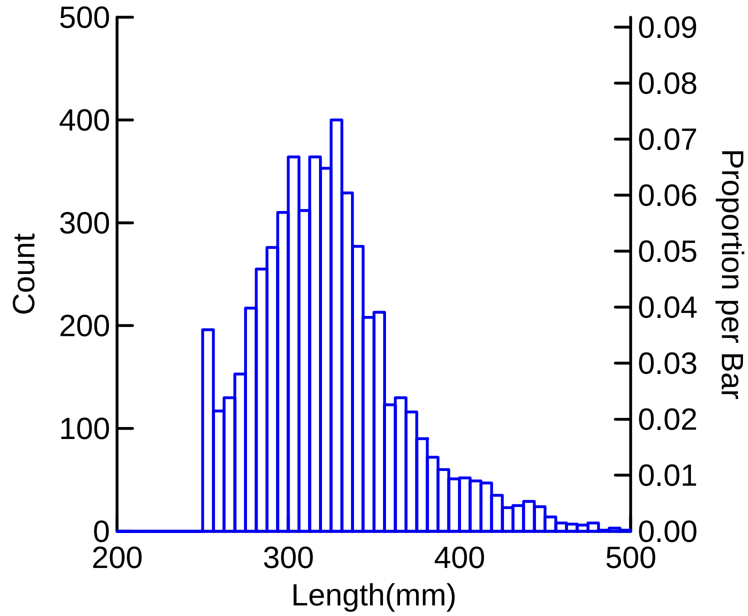


Figure 3.27 Proportion of mountain whitefish recaptured two and three times by sampling session during the Phase 5 Peace River Fish Community Indexing Program, 2005. Error bars represent the 95% confidence interval assuming a binomial distribution (the confidence bounds are underestimated).

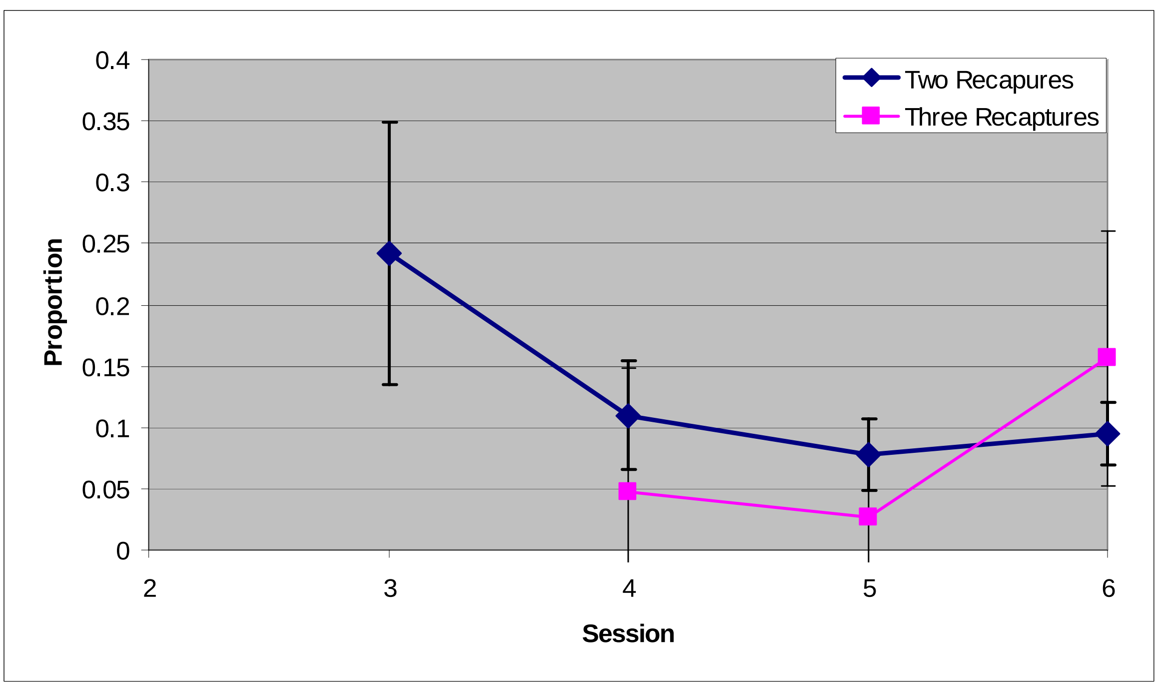


Figure 3.28 Histogram of mountain whitefish lengths at release during the Phase 5 Peace River Fish Community Indexing Program, 2005.

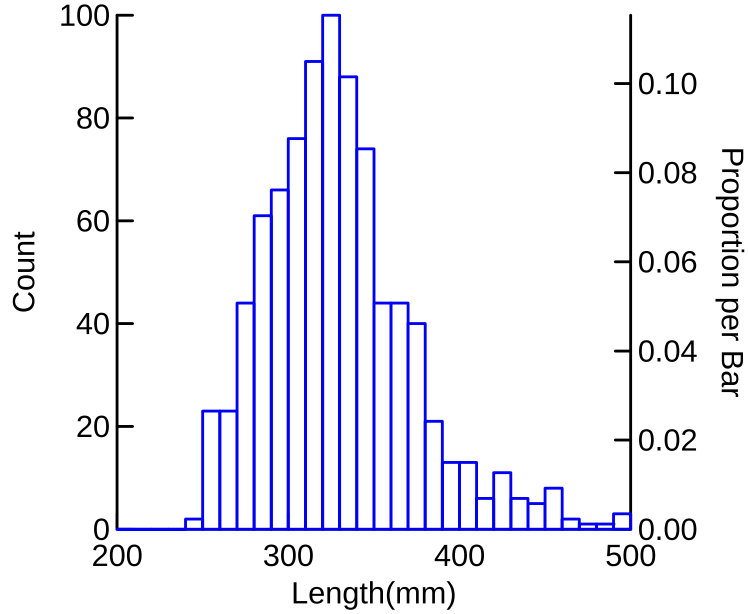


Figure 3.29 Histogram of mountain whitefish lengths at recapture during the Phase 5 Peace River Fish Community Indexing Program, 2005.

Table 3.17 Comparison of mountain whitefish lengths and recapture by section during the Phase 5 Peace River Fish Community Indexing Program, 2005.

Length Interval (mm)	Section							
	One		Three		Five		Total	
	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Recaptures								
250-275	12	4.6	31	8.5	19	8.4	62	7.3
275-300	66	25.4	72	19.8	17	7.5	155	18.2
300-325	101	38.8	79	21.7	39	17.3	219	25.8
325-350	67	25.8	91	25.0	53	23.5	211	24.8
350-375	6	2.3	54	14.8	51	22.6	111	13.1
375-400	6	2.3	23	6.3	22	9.7	51	6.0
400-425	2	0.8	12	3.3	12	5.3	26	3.1
425-450			2	0.5	13	5.8	15	1.8
Total	**260**	**100.0**	**364**	**100.0**	**226**	**100.0**	**850**	**100.0**
Releases								
250-275	98	6.0	275	13.0	133	11.7	506	10.3
275-300	464	28.4	328	15.5	152	13.4	944	19.3
300-325	547	33.5	456	21.5	208	18.3	1211	24.8
325-350	399	24.4	490	23.1	212	18.6	1101	22.5
350-375	93	5.7	291	13.7	193	17.0	577	11.8
375-400	20	1.2	149	7.0	100	8.8	269	5.5
400-425	7	0.4	90	4.2	85	7.5	182	3.7
425-450	4	0.2	43	2.0	54	4.7	101	2.1
Total	**1632**	**100.0**	**2122**	**100.0**	**1137**	**100.0**	**4891**	**100.0**
Like Ratio Chi-Square	5.83		7.77		7.54		6.14	
Probability	0.442		0.354		0.375		0.523	

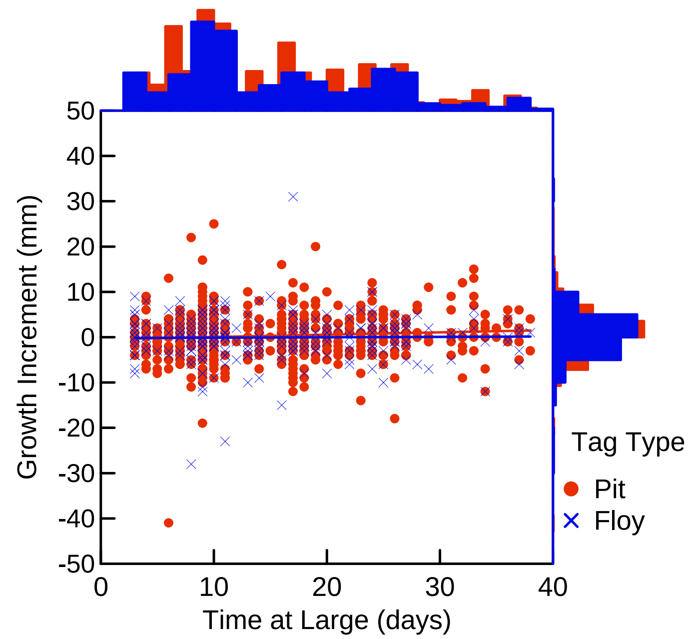


Figure 3.30 Growth over the study period of mountain whitefish with border histograms of time at large and growth increment by tag type during the Phase 5 Peace River Fish Community Indexing Program, 2005.

Table 3.18 Mountain whitefish recaptures and migration proportions adjusted (inverse weight) for fish examined by section released and recaptured during the Phase 5 Peace River Fish Community Indexing Program, 2005.

Release Section	**Recapture Section**			
	One	**Three**	**Five**	**Total**
Recaptures				
One	165	6	0	171
Three	0	218	7	225
Five	0	1	172	173
Sample	3119	3624	2132	8875
Percent Recaptured	5.29	6.21	8.40	
Proportions				
One	0.970	0.030	0.000	1.000
Three	0.000	0.948	0.052	1.000
Five	0.000	0.003	0.997	1.000

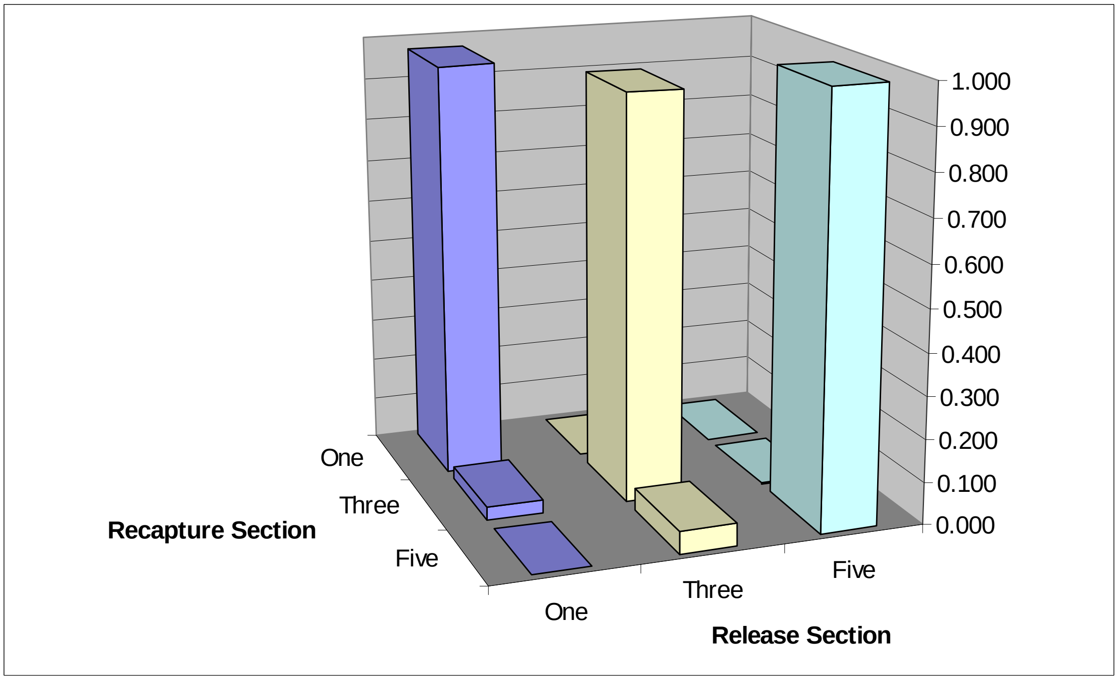


Figure 3.31 Distribution of recaptured marks released in 2005 standardized for sampling effort by section of release for mountain whitefish during the Phase 5 Peace River Fish Community Indexing Program, 2005.

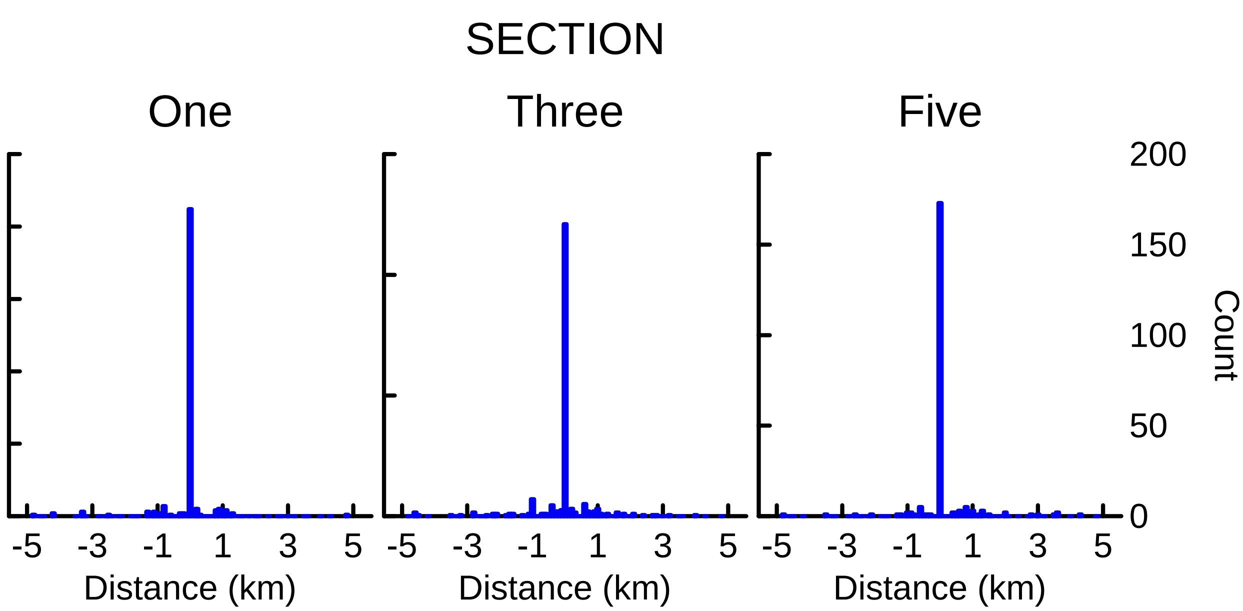


Figure 3.32 Bar plot of the travel distance of recaptured mountain whitefish released in 2005 within each of the sections sampled (positive values indicate upstream movement and vice-versa) during the Phase 5 Peace River Fish Community Indexing Program, 2005.

Table 3.19 Mountain whitefish recaptures and migration proportions adjusted (inverse weight) for fish examined by section released during 2002, 2003, 2004, and recaptured in 2005 during the Peace River Fish Community Indexing Program, 2002 to 2005.

Release Section	Recapture Section			
	One	Three	Five	Total
2002 Releases				
Recaptures				
One	175	6	2	183
Two	4	3	2	9
Three	2	309	5	316
Four	1	6	4	11
Sample	3119	3624	2132	8875
Percent Recaptured	5.84	8.94	0.61	
Proportions				
One	0.956	0.028	0.016	1.000
Two	0.421	0.272	0.308	1.000
Three	0.007	0.966	0.027	1.000
Four	0.083	0.430	0.487	1.000
2003 Releases				
Recaptures				
One	247	2	1	250
Two		2	2	4
Three	1	246	6	253
Four	1	5	7	13
Sample	3119	3624	2132	8875
Percent Recaptured	7.98	7.04	0.75	
Proportions				
One	0.987	0.007	0.006	1.000
Two	0.000	0.370	0.630	1.000
Three	0.005	0.956	0.040	1.000
Four	0.064	0.277	0.659	1.000
2004 Releases				
Recaptures				
One	247	65	1	313
Three	1	215	52	268
Five	10	8	163	181
Sample	3119	3624	2132	8875
Percent Recaptured	8.27	7.95	10.13	
Proportions				
One	0.811	0.184	0.005	1.000
Three	0.004	0.706	0.290	1.000
Five	0.039	0.027	0.934	1.000

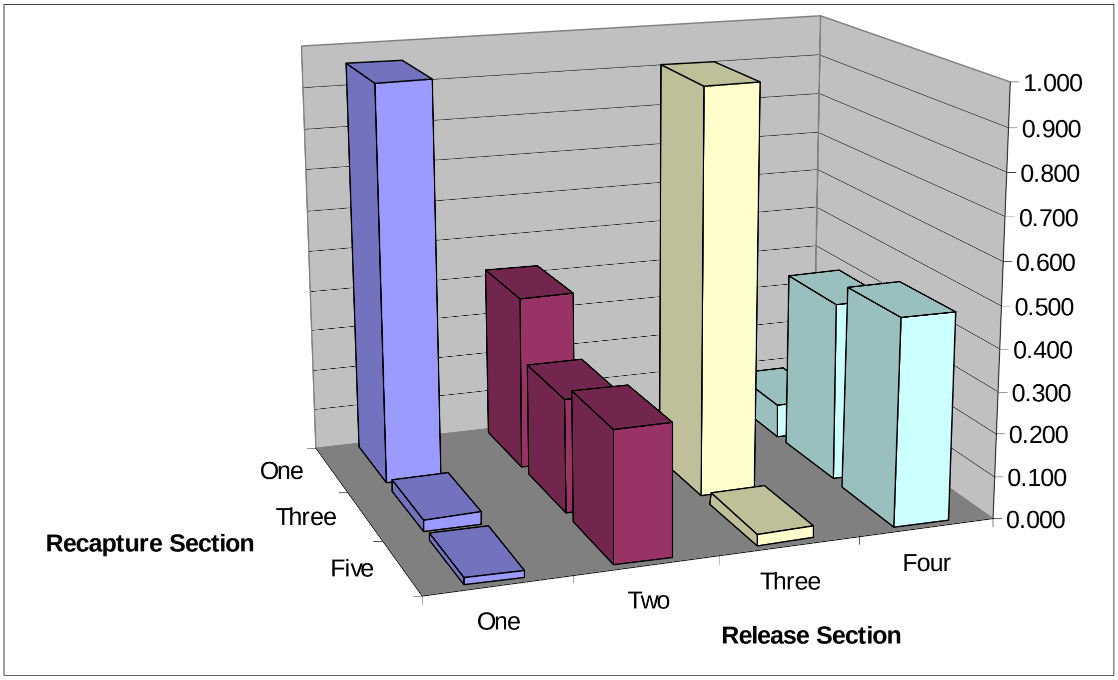


Figure 3.33 Distribution of recaptured marks in 2005 standardized for sampling effort by section of release for mountain whitefish released in 2002 during the Peace River Fish Community Indexing Program, 2002 to 2005.

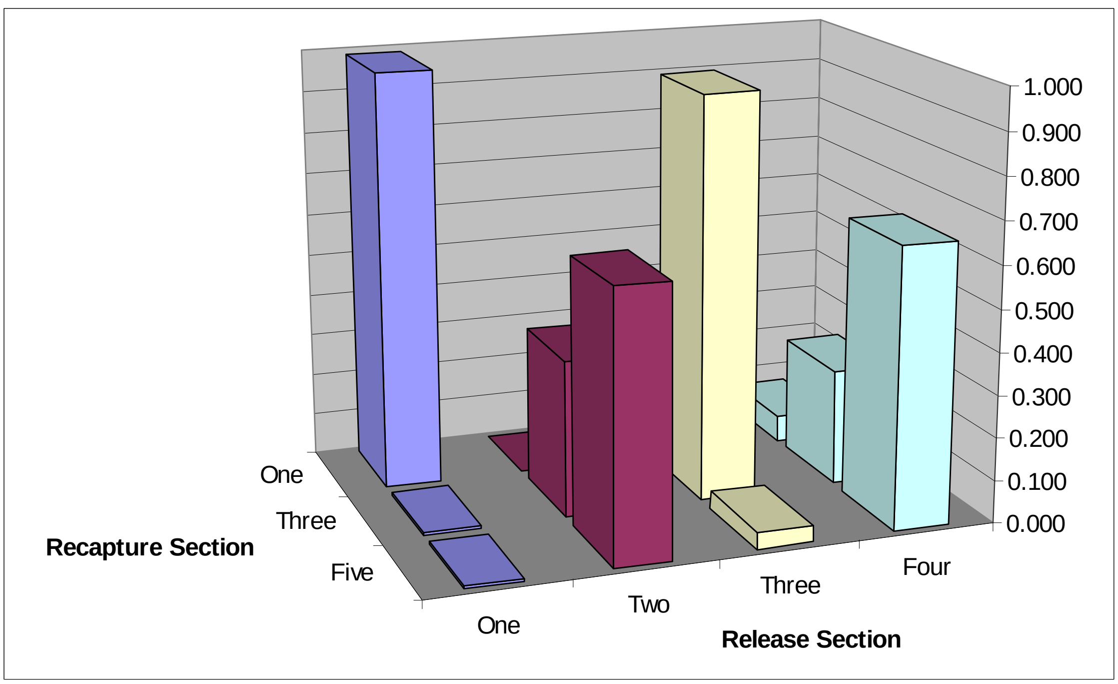


Figure 3.34 Distribution of recaptured marks in 2005 standardized for sampling effort by section of release for mountain whitefish released in 2003 during the Peace River Fish Community Indexing Program, 2002 to 2005.

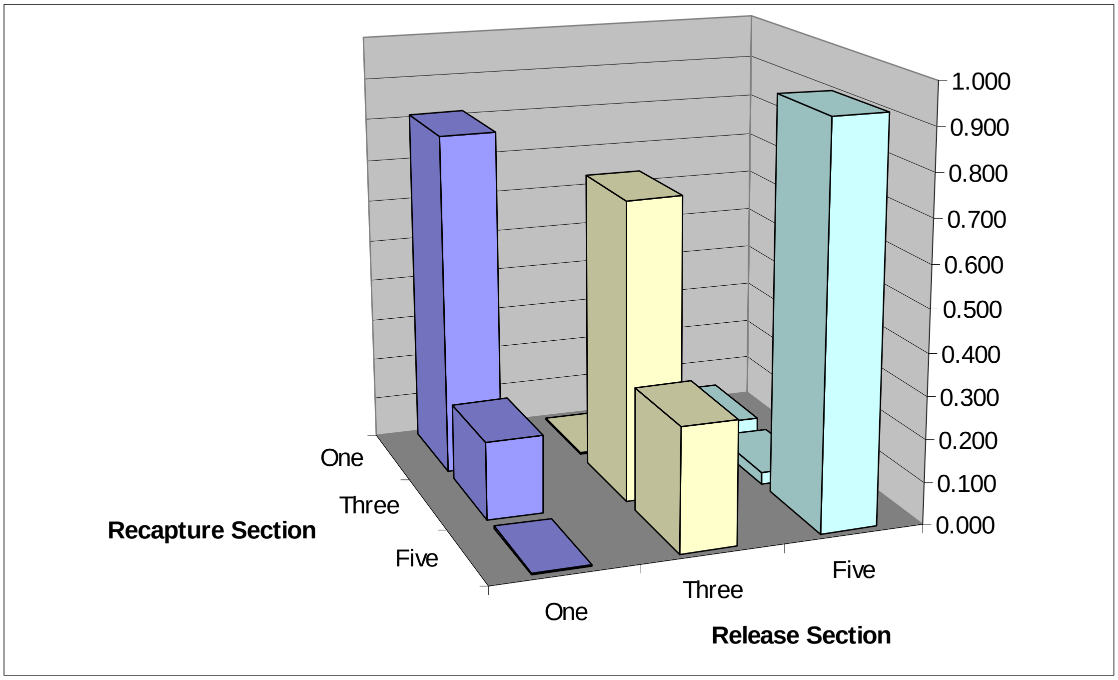


Figure 3.35 Distribution of recaptured marks in 2005 standardized for sampling effort by section of release for mountain whitefish released in 2004 during the Peace River Fish Community Indexing Program, 2002 to 2005.

For the 2004 releases, a bar plot of the distance traveled is displayed in Figure 3.36. Consistent with movement patterns observed in Phase 3 and 4 of the study, the mountain whitefish released in 2002 and 2003 were remarkably senescent. However the fish released in 2004, particularly those released in Sections 1 and 3, demonstrated substantially more movement between sections (Figure 3.35). Similarly, the movement within a section, particularly those released in Sections 3 and 5, demonstrated substantive movement with a downstream trend (i.e., negative values, Figure 3.36). Since there is little movement between river sections (i.e., little mixing) within 2005, population estimates should be stratified by section.

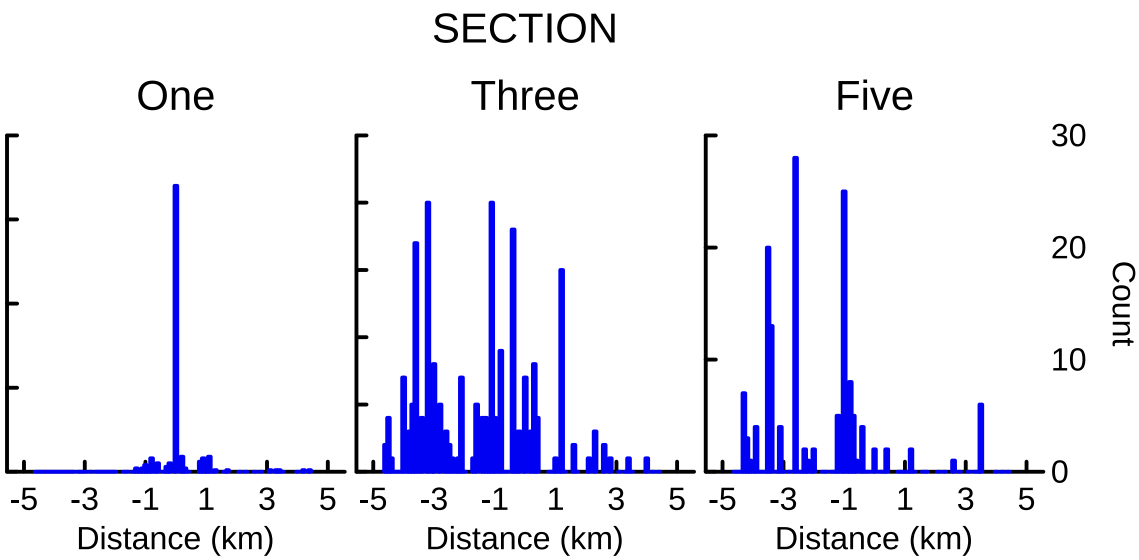


Figure 3.36 Bar plot of the travel distance of recaptured mountain whitefish released in 2004 within each of the sections sampled (positive values indicate upstream movement and vice-versa) during the Peace River Fish Community Indexing Program, 2002 to 2005.

The data summary for the Jolly-Seber open population model (Seber 1982) and the associated estimates of abundance, survival (from any source of mortality or movement from the section) and births (immigration into the section) by river section are provided in Table 3.20. The total row for each section provides the mean estimated abundance over the sampled sessions, total survival is under the constant survival option and total births is the simple sum of estimated births by session. In all cases, the 95% confidence interval for survival included 1.0. In Sections 1 and 5 the 95% interval for births included 0; however, Section 3 births were significant.

The mark-recapture data were extracted by section from the database using marks applied during 2005 (Floy and PIT) and marks that were observed during 2005 that were applied in 2001 to 2004 and a minimum length of 250 mm. Table 3.21 lists mountain whitefish examined for marks and recaptures by date and section. The releases, adjusted for movement between sections (Equation 4) by section and date, are given in Table 3.22. The compilations of marks available (Equation 6), fish examined (Equation 7), and recaptures (Equation 8) assuming 0.0 removal and 0% undetected mark rate are listed in Table 3.23. The subsequent population estimates using the Bayesian closed model are given in Table 3.24. The sequential posterior probability plots by section are provided in Appendix E (Figures E1 to E3) and the final posterior distributions for the three sections are drawn in Figure 3.37.

Table 3.20 Jolly-Seber population estimates by river section for mountain whitefish during Phase 5 of the Peace River Fish Community Indexing Program, 2005.

Session	Marks	Sample	Recapture of Fish Marked at Session					Total	Abundance	Survival	Births
			1	2	3	4	5				
Section 1											
1	316										
2	416	471	16					16	8,650	1.040	11
3	344	406	10	17				27	8,953	0.967	63
4	308	490	10	20	21			51	8,663		
5	87	463	8	22	11	14		55			
6		947	16	40	18	29	9	112			
Total			60	99	50	43	9		8,756	0.994	73
Section 3											
1	266										
2	481	554	32					32	4,588	1.016	2,831
3	626	733	26	42				68	7,417	1.001	1,135
4	546	676	9	18	27			54	8,454		
5	115	640	13	23	25	29		90			
6		734	13	33	34	27	10	117			
Total			93	116	86	56	10		6,820	1.004	3,966
Section 5											
1	219										
2	239	264	16					16	3,480	1.077	831
3	347	422	21	28				49	4,551	0.786	2,198
4	310	387	18	14	23			55	5,715		
5	29	380	5	8	18	18		49			
6		451	10	13	14	20	3	60			
Total			70	63	55	38	3		4,582	0.836	3,029

Table 3.21 Sample size and recaptures of mountain whitefish by section and date during Phase 5 of the Peace River Fish Community Indexing Program, 2005.

Date (2005)	Section						Total	
	One		Three		Five			
	Sample	Recapture	Sample	Recapture	Sample	Recapture	Sample	Recapture
17-Aug	52	0	0	0	0	0	52	0
18-Aug	168	0	0	0	0	0	168	0
19-Aug	122	0	0	0	0	0	122	0
20-Aug	0	0	69	0	0	0	69	0
21-Aug	0	0	0	0	0	0	0	0
22-Aug	0	0	160	0	0	0	160	0
23-Aug	0	0	58	0	0	0	58	0
24-Aug	0	0	0	0	0	0	0	0
25-Aug	0	0	0	0	122	0	122	0
26-Aug	0	0	0	0	106	0	106	0
27-Aug	0	0	0	0	0	0	0	0
28-Aug	224	7	0	0	0	0	224	7
29-Aug	247	9	0	0	0	0	247	9
30-Aug	0	0	0	0	0	0	0	0
31-Aug	0	0	228	16	0	0	228	16
1-Sep	0	0	326	16	0	0	326	16
2-Sep	0	0	0	0	0	0	0	0
3-Sep	0	0	0	0	182	14	182	14
4-Sep	0	0	0	0	82	2	82	2
5-Sep	0	0	0	0	0	0	0	0
6-Sep	251	21	0	0	0	0	251	21
7-Sep	155	6	0	0	0	0	155	6
8-Sep	0	0	0	0	0	0	0	0
9-Sep	0	0	327	30	0	0	327	30
10-Sep	0	0	0	0	0	0	0	0
11-Sep	0	0	371	35	0	0	371	35
12-Sep	0	0	35	3	125	21	160	24
13-Sep	0	0	0	0	297	28	297	28
14-Sep	0	0	0	0	0	0	0	0
15-Sep	292	34	0	0	0	0	292	34
16-Sep	198	17	0	0	0	0	198	17
17-Sep	0	0	285	16	0	0	285	16
18-Sep	0	0	391	40	0	0	391	40
19-Sep	0	0	0	0	147	19	147	19
20-Sep	0	0	0	0	240	40	240	40
21-Sep	463	55	0	0	0	0	463	55
22-Sep	0	0	640	93	0	0	640	93
23-Sep	0	0	0	0	380	51	380	51
24-Sep	947	112	0	0	0	0	947	112
25-Sep	0	0	734	121	0	0	734	121
26-Sep	0	0	0	0	451	65	451	65
Total	**3119**	**261**	**3624**	**370**	**2132**	**240**	**8875**	**871**

Table 3.22 Mountain whitefish marks applied by section adjusted for migration during Phase 5 of the Peace River Fish Community Indexing Program, 2005.

Date (2005)	Section			Total
	One	Three	Five	
17-Aug	46	1	0	47
18-Aug	152	3	0	155
19-Aug	111	3	0	114
20-Aug	0	62	3	65
21-Aug	0	0	0	0
22-Aug	0	143	7	150
23-Aug	0	48	3	51
24-Aug	0	0	0	0
25-Aug	0	1	118	119
26-Aug	0	1	99	100
27-Aug	0	0	0	0
28-Aug	185	4	0	189
29-Aug	222	5	0	227
30-Aug	0	0	0	0
31-Aug	0	179	9	188
1-Sep	0	279	14	293
2-Sep	0	0	0	0
3-Sep	0	1	160	161
4-Sep	0	0	78	78
5-Sep	0	0	0	0
6-Sep	207	5	0	212
7-Sep	129	3	0	132
8-Sep	0	0	0	0
9-Sep	0	266	14	280
10-Sep	0	0	0	0
11-Sep	0	298	15	313
12-Sep	0	29	97	126
13-Sep	0	1	250	251
14-Sep	0	0	0	0
15-Sep	150	3	0	153
16-Sep	152	3	0	155
17-Sep	0	207	11	218
18-Sep	0	312	16	328
19-Sep	0	1	122	123
20-Sep	0	1	186	187
21-Sep	85	2	0	87
22-Sep	0	109	6	115
23-Sep	0	0	29	29
24-Sep	156	4	0	160
25-Sep	0	102	5	107
26-Sep	0	0	25	25
27-Sep	0	0	0	0
28-Sep	0	0	0	0
Total	**1,594**	**2,075**	**1,268**	**4,938**

Table 3.23 Mountain whitefish sample cumulative marks available for recapture and recaptures by section during Phase 5 of the Peace River Fish Community Indexing Program, 2005.

Date	Sample	Marks	Recaptures
Section 1			
28-Aug	224	309	7
29-Aug	247	309	9
6-Sep	251	715	21
7-Sep	155	715	6
15-Sep	292	1052	34
16-Sep	198	1052	17
21-Sep	463	1353	55
24-Sep	947	1438	112
Section 3			
20-Aug	69	1	
22-Aug	160	7	
23-Aug	58	69	
31-Aug	228	265	16
1-Sep	326	271	16
9-Sep	327	734	30
11-Sep	371	737	35
12-Sep	35	1003	3
17-Sep	285	1331	16
18-Sep	391	1334	40
22-Sep	640	1858	93
25-Sep	734	1970	121
Section 5			
25-Aug	122	11	
26-Aug	106	13	
3-Sep	182	240	14
4-Sep	82	255	2
12-Sep	125	506	21
13-Sep	297	506	28
19-Sep	147	868	19
20-Sep	240	879	40
23-Sep	380	1204	51
26-Sep	451	1238	65

Table 3.24 Population estimates by section for mountain whitefish during Phase 5 of the Peace River Fish Community Indexing Program, 2005.

Section	Bayesian Mean	MLE	95% HPD		Standard Deviation	CV (%)
			Low	High		
One	11,370	11290	10,080	12,700	668	5.9
Three	11,628	11,570	10,540	12,760	563	4.8
Five	6,969	6,910	6,160	7,800	417	6.0
Total	**29,967**		**28,069**	**31,865**	**969**	**3.2**

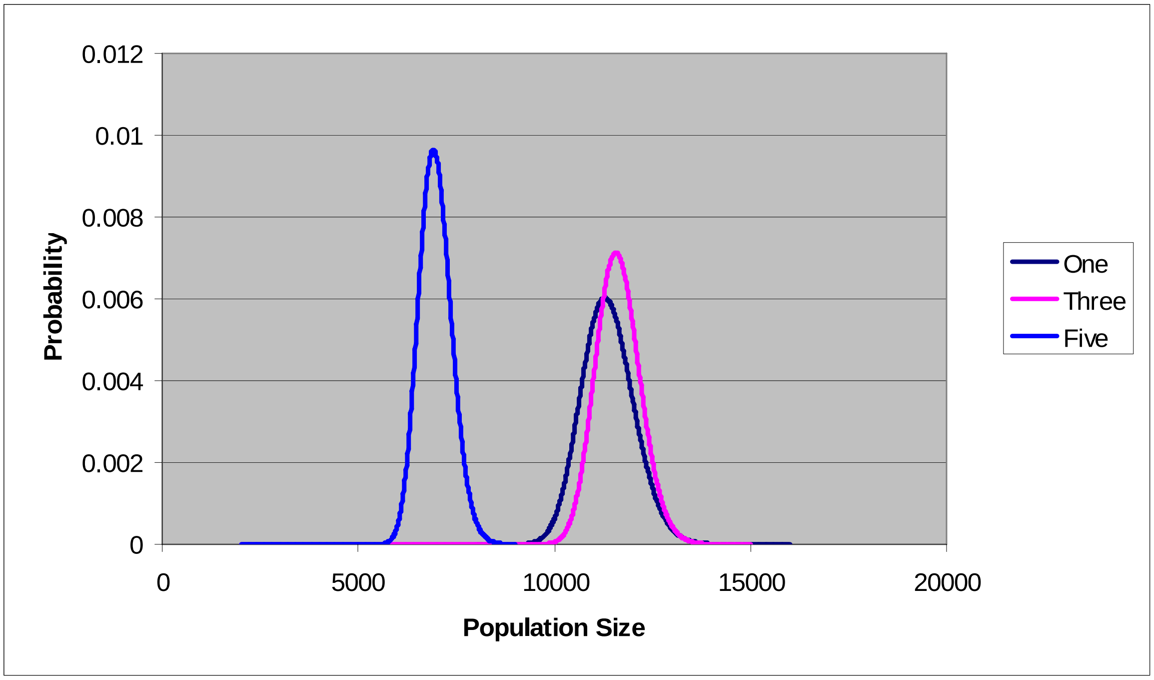


Figure 3.37 Final posterior distributions by section for mountain whitefish during the Phase 5 Peace River Fish Community Indexing Program, 2005.

The sequence of posterior probability plots can be used as an indicator of closure or change in the population size over the study period (Gazey and Staley 1986). Inspection of the plots in Appendix E reveals that Section 1 shows evidence of in-migration during session 6 consistent with the sampling-per-unit-effort (Figure 3.18). The mean population estimate for the section will be an under-estimate but bias is likely small because the shift in the posterior distributions was relatively small. The sequences of posterior probability plots for Sections 3 and 5 indicate a strong in-migration of fish over the study period. The closure assumption violation appears to be substantial and we view the population estimates as deficient for these sections. However, Gazey and Staley (1986) showed that if immigration were the only assumption violation (e.g., no substantial mortality or emigration) then the subsequent population estimates of the monotonically increasing population provide a mean estimate weighted by mark application and sampling intensity over the period of the study.

The catchability coefficients and associated population estimates, standard deviation estimates and effort (Equations 10 -12) by section are listed in Tables 3.25 and 3.26 using effort measured in kilometers traveled or the hours of electrofishing to collect the samples. Each table presents the catchability coefficients from the 2002 to 2005 studies. Figure 3.38 plots the catchability coefficients using two effort measures (time and distance) and the associated 95% confidence intervals.

Table 3.25 Catchability of mountain whitefish by section (effort by kilometers) during the Peace River Fish Community Indexing Program, 2002 to 2005.

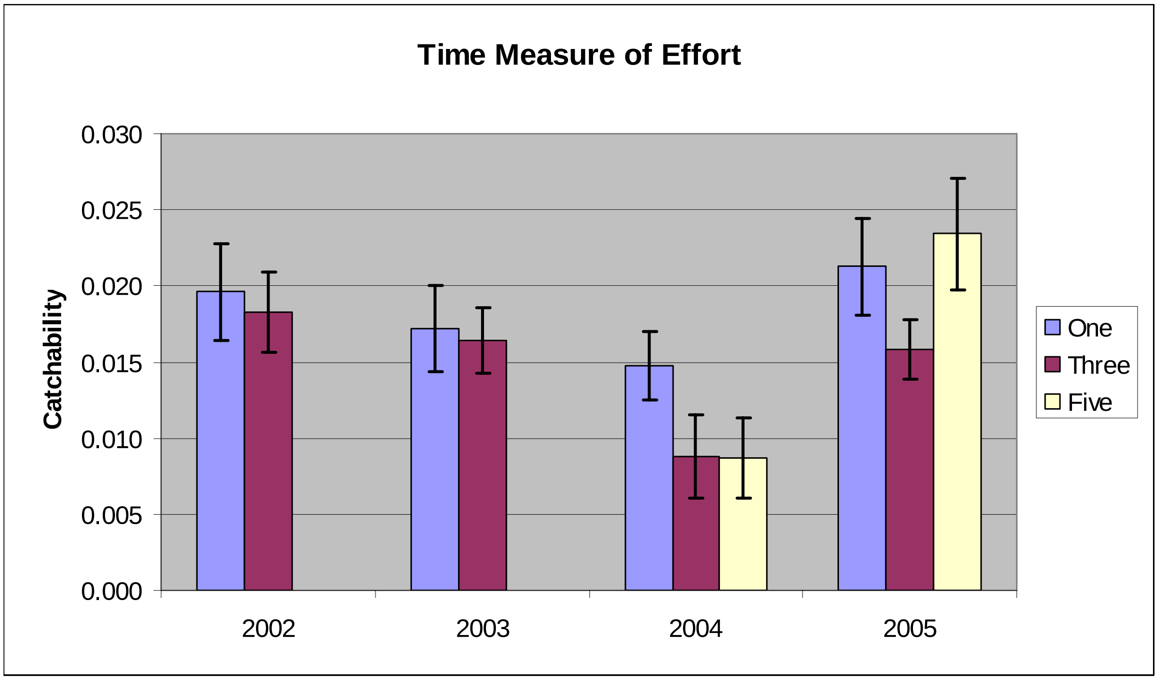
Statistic	Section					Total
	One	Two	Three	Four	Five	
2002 Study						
Sample	2,845	2,611	2,363	2,105		9,924
Effort	78.13	90.90	124.85	119.34		413.22
Abundance (N)	12,534	10,587	7,066	6,045		36,232
SD(1/N)	5.614E-06	6.493E-06	8.794E-06	1.024E-05		3.998E-06
Catchability (q)	2.905E-03	2.713E-03	2.679E-03	2.918E-03		2.804E-03
SD(q)	2.044E-04	1.865E-04	1.665E-04	1.805E-04		9.602E-05
CV(q)	7.0%	6.9%	6.2%	6.2%		3.4%
2003 Study						
Sample	2,145	1,896	2,546	1,883		8,470
Effort	74.51	86.98	116.80	112.24		390.53
Abundance (N)	12,165	8,911	7,955	7,252		36,283
SD(1/N)	5.876E-06	7.591E-06	7.388E-06	1.039E-05		3.989E-06
Catchability (q)	2.367E-03	2.446E-03	2.740E-03	2.313E-03		2.467E-03
SD(q)	1.692E-04	1.655E-04	1.610E-04	1.743E-04		8.652E-05
CV(q)	7.1%	6.8%	5.9%	7.5%		3.5%
2004 Study						
Sample	3,514		2,972		1,549	8,035
Effort	69.16		116.80		85.18	271.13
Abundance (N)	21,121		17,912		14,409	53,442
SD(1/N)	2.959E-06		7.388E-06		8.969E-06	3.997E-06
Catchability (q)	2.406E-03		1.421E-03		1.262E-03	1.696E-03
SD(q)	1.504E-04		1.880E-04		1.631E-04	1.184E-04
CV(q)	6.2%		13.2%		12.9%	7.0%
2005 Study						
Sample	2,777		3,624		2,132	8,533
Effort	72.34		116.80		85.18	274.32
Abundance (N)	11,370		11,628		6,969	29,967
SD(1/N)	5.496E-06		4.538E-06		9.47E-06	3.952E-06
Catchability (q)	3.376E-03		2.668E-03		3.592E-03	3.212E-03
SD(q)	2.110E-04		1.408E-04		2.371E-04	1.229E-04
CV(q)	6.2%		5.3%		6.6%	3.8%

Note that Section 1 catchabilities in the present study are consistent with all previous studies both for Section 1, but also in all other sections. In 2004 (Phase 4) Sections 3 and 5 experienced water clarity below the threshold judged to impact capture efficiency. While the catchability coefficients taken in Sections 3 and 5 in 2005 are consistent with measures taken in other sections and years, the underlying population estimates are suspect.

Table 3.26 Catchability of mountain whitefish by section (effort in hours) during the Peace River Fish Community Indexing Program, 2002 to 2005.

Statistic	Section					Total
	One	Two	Three	Four	Five	
2002 Study						
Sample	2,845	2,611	2,363	2,105		9,924
Effort	11.58	14.39	18.31	17.59		61.86
Abundance (N)	12,534	10,587	7,066	6,045		36,232
SD(1/N)	5.614E-06	6.493E-06	8.794E-06	1.024E-05		3.998E-06
Catchability (q)	1.960E-02	1.714E-02	1.827E-02	1.980E-02		1.870E-02
SD(q)	1.379E-03	1.178E-03	1.135E-03	1.225E-03		6.414E-04
CV(q)	7.0%	6.9%	6.2%	6.2%		3.4%
2003 Study						
Sample	2,145	1,896	2,546	1,883		8,470
Effort	12.29	15.31	19.49	18.67		65.76
Abundance (N)	12,165	8,911	7,955	7,252		36,283
SD(1/N)	5.876E-06	7.591E-06	7.388E-06	1.039E-05		3.989E-06
Catchability (q)	1.722E-02	1.652E-02	1.642E-02	1.659E-02		1.669E-02
SD(q)	1.231E-03	1.118E-03	9.651E-04	1.249E-03		5.800E-04
CV(q)	7.1%	6.8%	5.9%	7.5%		3.5%
2004 Study						
Sample	3,514		2,972		1,549	8,035
Effort	11.29		18.87		12.35	42.51
Abundance (N)	21,121		17,912		14,409	53,442
SD(1/N)	2.959E-06		7.388E-06		8.969E-06	6.923E-06
Catchability (q)	1.473E-02		8.791E-03		8.708E-03	1.074E-02
SD(q)	9.208E-04		1.163E-03		1.125E-03	1.308E-03
CV(q)	6.2%		13.2%		12.9%	12.2%
2005 Study						
Sample	2,777		3,624		2,132	8,533
Effort	11.49		19.70		13.06	44.26
Abundance (N)	11,370		11,628		6,969	29,967
SD(1/N)	5.496E-06		4.538E-06		9.47E-06	3.952E-06
Catchability (q)	2.126E-02		1.582E-02		2.342E-02	2.016E-02
SD(q)	1.328E-03		8.347E-04		1.546E-03	7.620E-04
CV(q)	6.2%		5.3%		6.6%	3.8%

A crude survival estimate was obtained from the population structure by constructing a catch curve for mountain whitefish (Equations 16 and 17) and is plotted in Figure 3.39. Inspection of the plot indicates that the fish do not become fully vulnerable to the sample gear until Age 5. Using Age 5 and older results in an apparent total instantaneous mortality of 0.53 (+/- .093, 95% confidence interval) or survival is between 0.54 and 0.65 with 95% confidence. Again, this estimate assumes a stable size composition over many years.



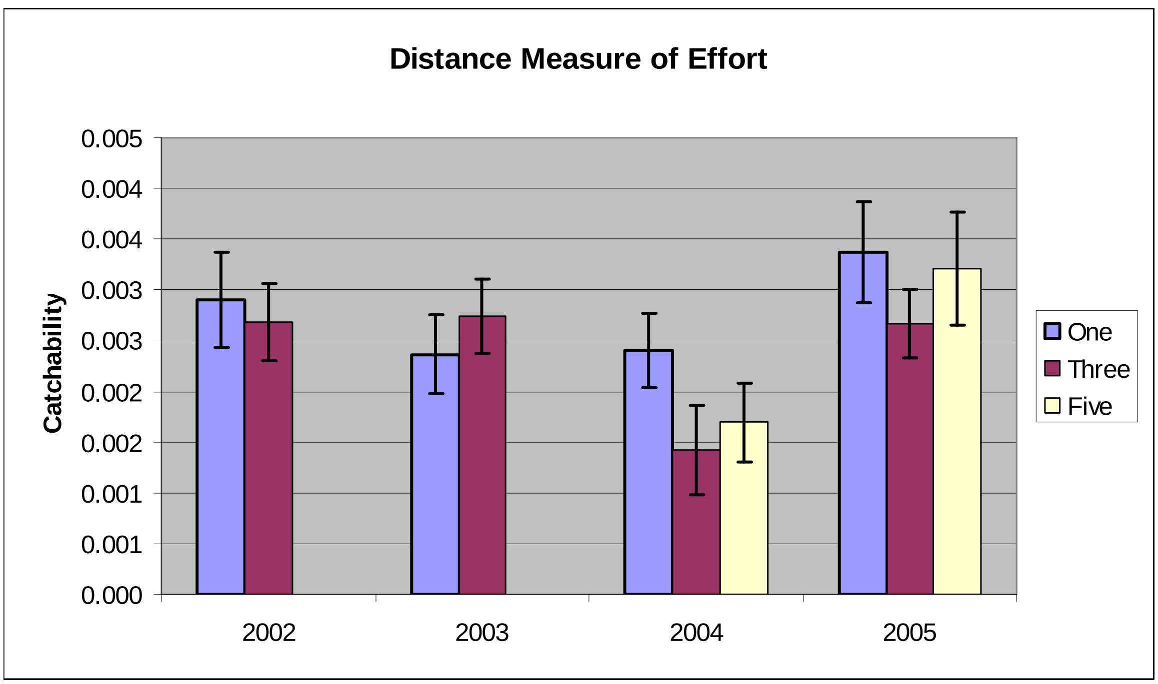


Figure 3.38 Catchability using time (hours - panel A) and distance (km – panel B) by section for mountain whitefish during the Phase 5 Peace River Fish Community Indexing Program, 2005. The error bars represent the 95% confidence interval.

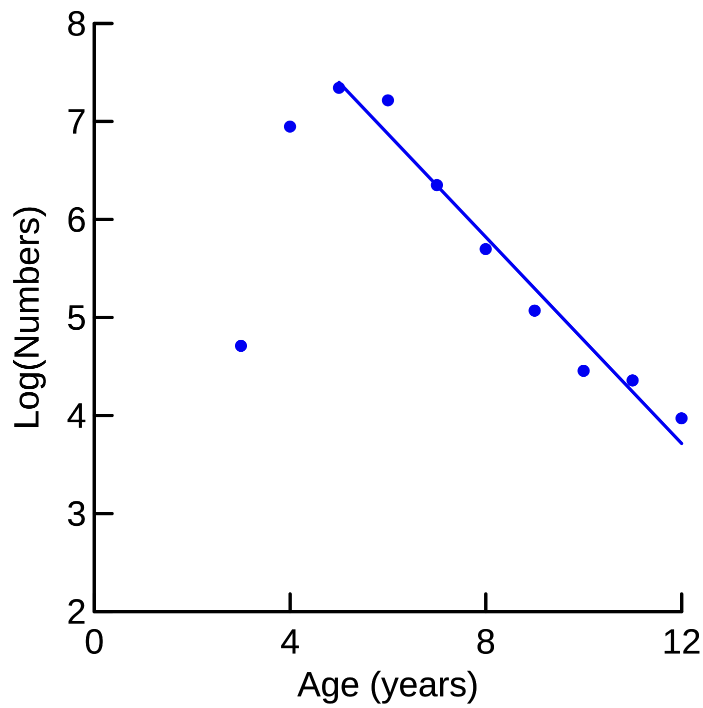


Figure 3.39 Catch curve for mountain whitefish based on an assumed stable size composition during the Phase 5 Peace River Fish Community Indexing Program, 2005.

3.6.2 Arctic grayling

The mark-recapture data were extracted by section from the database using all available marks with a minimum length of 250 mm. Table 3.27 lists Arctic grayling examined for marks and recaptures by date and section. Only 5 Arctic grayling were sampled in Section 1 with no recaptured marks. Three recaptures occurred in each of Sections 3 and 5. There was no movement between sections. Given the sparse recoveries, length histograms and a growth regression were not conducted. The releases by section and date are given in Table 3.28. Sections 3 and 5 were combined for the purpose of population estimation. The compilations of marks available (Equation 6), fish examined (Equation 7), and recaptures (Equation 8) assuming 0.0 removal and 0% undetected mark rate are listed in Table 3.29. The population estimate using the Bayesian closed model is given in Table 3.30, the associated sequential posterior probability plots are provided in Appendix E (Figure E4) and the final posterior distribution is drawn in Figure 3.40.

Table 3.27 Sample size and recaptures of Arctic grayling by section and date during Phase 5 of the Peace River Fish Community Indexing Program, 2005.

Date (2005)	Section						Total	
	One		Three		Five			
	Sample	Recapture	Sample	Recapture	Sample	Recapture	Sample	Recapture
17-Aug	2	0	0	0	0	0	2	0
18-Aug	0	0	0	0	0	0	0	0
19-Aug	1	0	0	0	0	0	1	0
20-Aug	0	0	7	0	0	0	7	0
21-Aug	0	0	0	0	0	0	0	0
22-Aug	0	0	6	0	0	0	6	0
23-Aug	0	0	1	0	0	0	1	0
24-Aug	0	0	0	0	0	0	0	0
25-Aug	0	0	0	0	26	0	26	0
26-Aug	0	0	0	0	13	0	13	0
27-Aug	0	0	0	0	0	0	0	0
28-Aug	0	0	0	0	0	0	0	0
29-Aug	0	0	0	0	0	0	0	0
30-Aug	0	0	0	0	0	0	0	0
31-Aug	0	0	14	1	0	0	14	1
1-Sep	0	0	0	0	0	0	0	0
2-Sep	0	0	0	0	0	0	0	0
3-Sep	0	0	0	0	8	0	8	0
4-Sep	0	0	0	0	9	0	9	0
5-Sep	0	0	0	0	0	0	0	0
6-Sep	1	0	0	0	0	0	1	0
7-Sep	1	0	0	0	0	0	1	0
8-Sep	0	0	0	0	0	0	0	0
9-Sep	0	0	19	1	0	0	19	1
10-Sep	0	0	0	0	0	0	0	0
11-Sep	0	0	8	1	0	0	8	1
12-Sep	0	0	3	0	13	1	16	1
13-Sep	0	0	0	0	27	1	27	1
14-Sep	0	0	0	0	0	0	0	0
15-Sep	0	0	0	0	0	0	0	0
16-Sep	0	0	0	0	0	0	0	0
17-Sep	0	0	4	0	0	0	4	0
18-Sep	0	0	12	0	0	0	12	0
19-Sep	0	0	0	0	13	0	13	0
20-Sep	0	0	0	0	16	0	16	0
21-Sep	0	0	0	0	0	0	0	0
22-Sep	0	0	13	0	0	0	13	0
23-Sep	0	0	0	0	22	0	22	0
24-Sep	0	0	0	0	0	0	0	0
25-Sep	0	0	20	0	0	0	20	0
26-Sep	0	0	0	0	30	1	30	1
Total	**5**	**0**	**107**	**3**	**177**	**3**	**289**	**6**

Table 3.28 Arctic grayling marks applied by section and date during Phase 5 of the Peace River Fish Community Indexing Program, 2005.

Date (2005)	Section			Total
	One	Three	Four	
17-Aug	1.0	0.0	0.0	1
18-Aug	0.0	0.0	0.0	0
19-Aug	1.0	0.0	0.0	1
20-Aug	0.0	7.0	0.0	7
21-Aug	0.0	0.0	0.0	0
22-Aug	0.0	4.0	0.0	4
23-Aug	0.0	1.0	0.0	1
24-Aug	0.0	0.0	0.0	0
25-Aug	0.0	0.0	16.0	16
26-Aug	0.0	0.0	8.0	8
27-Aug	0.0	0.0	0.0	0
28-Aug	0.0	0.0	0.0	0
29-Aug	0.0	0.0	0.0	0
30-Aug	0.0	0.0	0.0	0
31-Aug	0.0	10.0	0.0	10
1-Sep	0.0	0.0	0.0	0
2-Sep	0.0	0.0	0.0	0
3-Sep	0.0	0.0	3.0	3
4-Sep	0.0	0.0	4.0	4
5-Sep	0.0	0.0	0.0	0
6-Sep	1.0	0.0	0.0	1
7-Sep	1.0	0.0	0.0	1
8-Sep	0.0	0.0	0.0	0
9-Sep	0.0	9.0	0.0	9
10-Sep	0.0	0.0	0.0	0
11-Sep	0.0	0.0	0.0	0
12-Sep	0.0	1.0	8.0	9
13-Sep	0.0	0.0	10.0	10
14-Sep	0.0	0.0	0.0	0
15-Sep	0.0	0.0	0.0	0
16-Sep	0.0	0.0	0.0	0
17-Sep	0.0	2.0	0.0	2
18-Sep	0.0	9.0	0.0	9
19-Sep	0.0	0.0	9.0	9
20-Sep	0.0	0.0	9.0	9
21-Sep	0.0	0.0	0.0	0
22-Sep	0.0	9.0	0.0	9
23-Sep	0.0	0.0	4.0	4
24-Sep	0.0	0.0	0.0	0
25-Sep	0.0	16.0	0.0	16
26-Sep	0.0	0.0	13.0	13
Total	**4.0**	**68.0**	**84.0**	**156**

Table 3.29 Arctic grayling sample, cumulative marks available for recapture and recaptures (Section 3 and 5 combined) during Phase 5 of the Peace River Fish Community Indexing Program, 2005.

Date (2005)	Sample	Marks	Recapture
23-Aug	1	7	
25-Aug	26	11	
26-Aug	13	12	
31-Aug	14	36	1
3-Sep	8	46	
4-Sep	9	46	
9-Sep	19	53	1
11-Sep	8	53	1
12-Sep	16	62	1
13-Sep	27	62	1
17-Sep	4	81	
18-Sep	12	81	
19-Sep	13	81	
20-Sep	16	83	
22-Sep	13	101	
23-Sep	22	110	
25-Sep	20	119	
26-Sep	30	123	1

Table 3.30 Population estimates for Arctic grayling (Sections 3 and 5 combined) during Phase 5 of the Peace River Fish Community Indexing Program, 2005.

Section	Bayesian Mean	MLE	95% HPD		Standard Deviation	CV (%)
			Low	High		
Total	4,582	3,248	1,532	8,984	2,049	44.7

3.6.3 Bull trout

The mark-recapture data were extracted by section from the database using all marks applied with a minimum length of 250 mm. Table 3.31 lists bull trout examined for marks and recaptures by date and section. Twenty-three out of 27 total recaptures were observed in Section 3 and no movement between sections was noted. The releases by section and date are given in Table 3.32. The compilations of marks available (Equation 6), fish examined (Equation 7), and recaptures (Equation 8) assuming 0.0 removal and 0% undetected mark rate are listed in Table 3.33. The subsequent population estimates for Sections 3 and 5 using the Bayesian closed model are given in Table 3.34, the associated sequential posterior probability plots are provided in Appendix E (Figures E6 and E7) and the final posterior distributions are drawn in Figure 3.41. The posterior sequence in Section 3 (Figure E6) suggests that fish may have been immigrating into the section. The sparse recoveries (1) in Section 1 made point estimates highly unreliable. The minimum population size probability plot (Equation 9) is supplied in Figure 3.42 from which it can be determined that there is a 95% probability that the population size is at least 350 in Section 1.

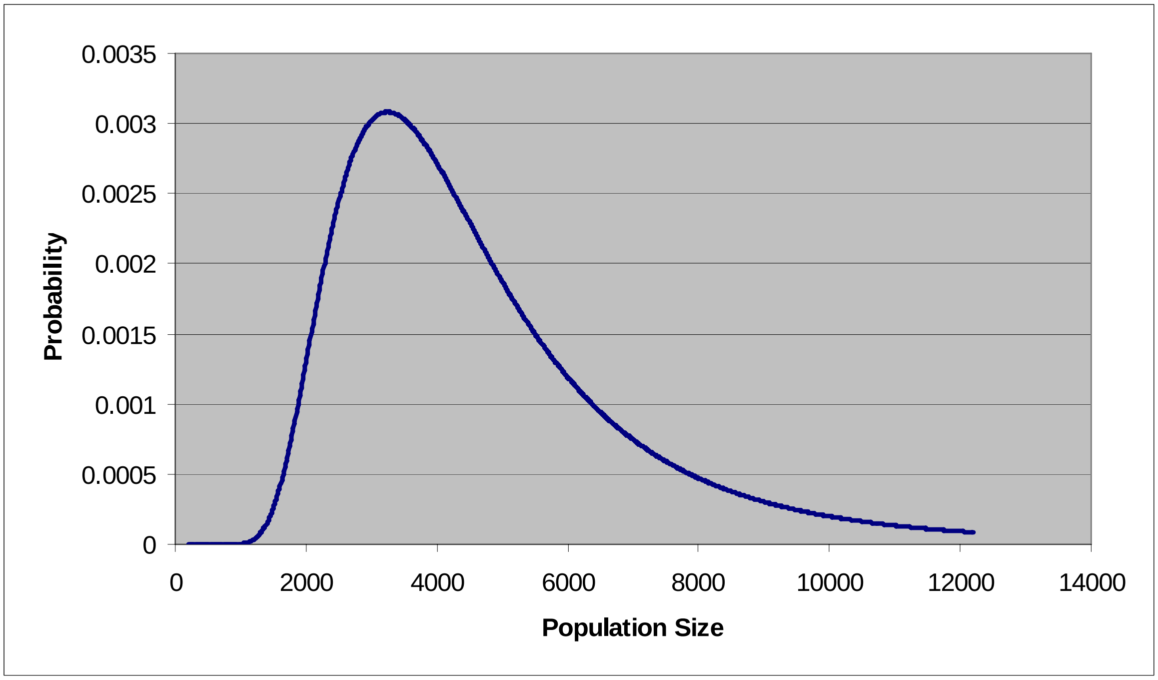


Figure 3.40 Final posterior distribution (Sections 3 and 5 combined) for Arctic grayling during the Phase 5 Peace River Fish Community Indexing Program, 2005.

3.6.4 Evaluation as a Monitoring Tool

A key objective of this study was to establish an index to use as a monitoring tool for the fourth year. Ideally, the index (e.g., catch-per-unit-effort) should remain proportional to abundance across locations (river sections) and under various abundance levels. In order to compare the catchability coefficient across years the 2005 results using all marked fish should be used. We argue that a tag would have been applied to a fish but for the presence of the old tag. For mountain whitefish, this proportionality constant (the catchability coefficient) was demonstrated to be constant in Section 1 over all years sampled (see Tables 3.25 and 3.26 and Figure 3.39) even though there was a two-fold difference in the population size and different flow regimes between the years, there was a substantial ability (high power) to differentiate small changes in catchability (a CV of less than 7.1% in any year). Similarly, Section 3 in 2002 and 2003 confirmed a consistent catchability coefficient.

In Sections 3 and 5 the catchability was significantly smaller in 2004 because water clarity was below the threshold identified (50 cm) as having an effect on capture efficiency (Mainstream and Gazey 2005). While the catchability coefficients calculated in 2005 are somewhat consistent with measures taken in other sections and years, the underlying population estimates are suspect.

Table 3.31 Sample size and recaptures of bull trout by section and date during the Phase 5 Peace River Fish Community Indexing Program, 2005.

Date (2005)	Section						Total	
	One		Three		Five			
	Sample	Recapture	Sample	Recapture	Sample	Recapture	Sample	Recapture
18-Aug	1	0	0	0	0	0	1	0
19-Aug	1	0	0	0	0	0	1	0
20-Aug	0	0	6	0	0	0	6	0
21-Aug	0	0	0	0	0	0	0	0
22-Aug	0	0	4	0	0	0	4	0
23-Aug	0	0	8	0	0	0	8	0
24-Aug	0	0	0	0	0	0	0	0
25-Aug	0	0	0	0	5	0	5	0
26-Aug	0	0	0	0	0	0	0	0
27-Aug	0	0	0	0	0	0	0	0
28-Aug	0	0	0	0	0	0	0	0
29-Aug	0	0	0	0	0	0	0	0
30-Aug	0	0	0	0	0	0	0	0
31-Aug	0	0	7	1	0	0	7	1
1-Sep	0	0	14	2	0	0	14	2
2-Sep	0	0	0	0	0	0	0	0
3-Sep	0	0	0	0	4	1	4	1
4-Sep	0	0	0	0	2	0	2	0
5-Sep	0	0	0	0	0	0	0	0
6-Sep	5	0	0	0	0	0	5	0
7-Sep	4	0	0	0	0	0	4	0
8-Sep	0	0	0	0	0	0	0	0
9-Sep	0	0	4	0	0	0	4	0
10-Sep	0	0	0	0	0	0	0	0
11-Sep	0	0	11	3	0	0	11	3
12-Sep	0	0	2	0	4	1	6	1
13-Sep	0	0	0	0	2	0	2	0
14-Sep	0	0	0	0	0	0	0	0
15-Sep	2	0	0	0	0	0	2	0
16-Sep	1	0	0	0	0	0	1	0
17-Sep	0	0	5	0	0	0	5	0
18-Sep	0	0	11	2	0	0	11	2
19-Sep	0	0	0	0	5	1	5	1
20-Sep	0	0	0	0	2	0	2	0
21-Sep	11	0	0	0	0	0	11	0
22-Sep	0	0	25	8	0	0	25	8
23-Sep	0	0	0	0	4	0	4	0
24-Sep	19	1	0	0	0	0	19	1
25-Sep	0	0	24	7	0	0	24	7
26-Sep	0	0	0	0	10	0	10	0
Total	**44**	**1**	**121**	**23**	**38**	**3**	**203**	**27**

Table 3.32 Bull trout marks applied by section and date during Phase 5 of the Peace River Fish Community Indexing Program, 2005.

Date	Section			Total
	One	Three	Five	
18-Aug	1.0	0.0	0.0	1
19-Aug	1.0	0.0	0.0	1
20-Aug	0.0	4.0	0.0	4
21-Aug	0.0	0.0	0.0	0
22-Aug	0.0	4.0	0.0	4
23-Aug	0.0	7.0	0.0	7
24-Aug	0.0	0.0	0.0	0
25-Aug	0.0	0.0	5.0	5
26-Aug	0.0	0.0	0.0	0
27-Aug	0.0	0.0	0.0	0
28-Aug	0.0	0.0	0.0	0
29-Aug	0.0	0.0	0.0	0
30-Aug	0.0	0.0	0.0	0
31-Aug	0.0	3.0	0.0	3
1-Sep	0.0	10.0	0.0	10
2-Sep	0.0	0.0	0.0	0
3-Sep	0.0	0.0	1.0	1
4-Sep	0.0	0.0	1.0	1
5-Sep	0.0	0.0	0.0	0
6-Sep	3.0	0.0	0.0	3
7-Sep	0.0	0.0	0.0	0
8-Sep	0.0	0.0	0.0	0
9-Sep	0.0	3.0	0.0	3
10-Sep	0.0	0.0	0.0	0
11-Sep	0.0	8.0	0.0	8
12-Sep	0.0	2.0	2.0	4
13-Sep	0.0	0.0	2.0	2
14-Sep	0.0	0.0	0.0	0
15-Sep	2.0	0.0	0.0	2
16-Sep	1.0	0.0	0.0	1
17-Sep	0.0	4.0	0.0	4
18-Sep	0.0	6.0	0.0	6
19-Sep	0.0	0.0	3.0	3
20-Sep	0.0	0.0	1.0	1
21-Sep	5.0	0.0	0.0	5
22-Sep	0.0	12.0	0.0	12
23-Sep	0.0	0.0	4.0	4
24-Sep	9.0	0.0	0.0	9
25-Sep	0.0	13.0	0.0	13
26-Sep	0.0	0.0	4.0	4
Total	**22.0**	**76.0**	**23.0**	**121**

Table 3.33 Bull trout sample, cumulative marks available for recapture and recaptures by section during Phase 5 of the Peace River Fish Community Indexing Program, 2005.

Date (2005)	Sample	Marks	Recapture	Date (2005)	Sample	Marks	Recapture
Section 1				**Section 3**			
6-Sep	5	2		23-Aug	8	4	
7-Sep	4	2		31-Aug	7	15	1
15-Sep	2	5		1-Sep	14	15	2
16-Sep	1	5		9-Sep	4	28	
21-Sep	11	8		11-Sep	11	28	3
24-Sep	19	13	1	12-Sep	2	31	
6-Sep	5	2		17-Sep	5	41	
Section 5				18-Sep	11	41	2
3-Sep	4	5	1	22-Sep	25	51	8
4-Sep	2	5		25-Sep	24	63	7
12-Sep	4	7	1				
13-Sep	2	7					
19-Sep	5	11	1				
20-Sep	2	11					
23-Sep	4	15					
26-Sep	10	19					
3-Sep	4	5	1				

Table 3.34 Population estimates by section for bull trout during Phase 5 of the Peace River Fish Community Indexing Program, 2005.

Section	Bayesian Mean	MLE	95% HPD		Standard Deviation	CV (%)
			Low	High		
Three	204	188	135	284	40	19.4
Five	308	140	51	807	223	72.3
Total	**512**		**69**	**955**	**226**	**44.2**

3.6.4.1 Sample Design and Assumptions

The factors that affect the population estimates can be evaluated through an assessment of assumptions required for the closed sequential stratified population model.

1. The population is closed, so the population size does not change over the period of the experiment. Very few mountain whitefish were recaptured in river sections other than the section of release (2%, approximately). Therefore the number of whitefish leaving the study area over the study period must have been very small (if any). Fish can move within the study area (to different sections); however, the movement is fully determined by the history of recaptured marks. While few Arctic grayling and bull trout were recaptured, none were observed to move to a different river section. Because mountain whitefish and Arctic grayling reside in the study area, fish are not expected to immigrate or emigrate to/from the study area. Mortality and growth recruitment were not expected to be issues because the study period was short. On the other hand, the sequence of daily posterior distributions provided clear empirical evidence that this assumption was violated in Sections 3 and 5 for mountain whitefish.

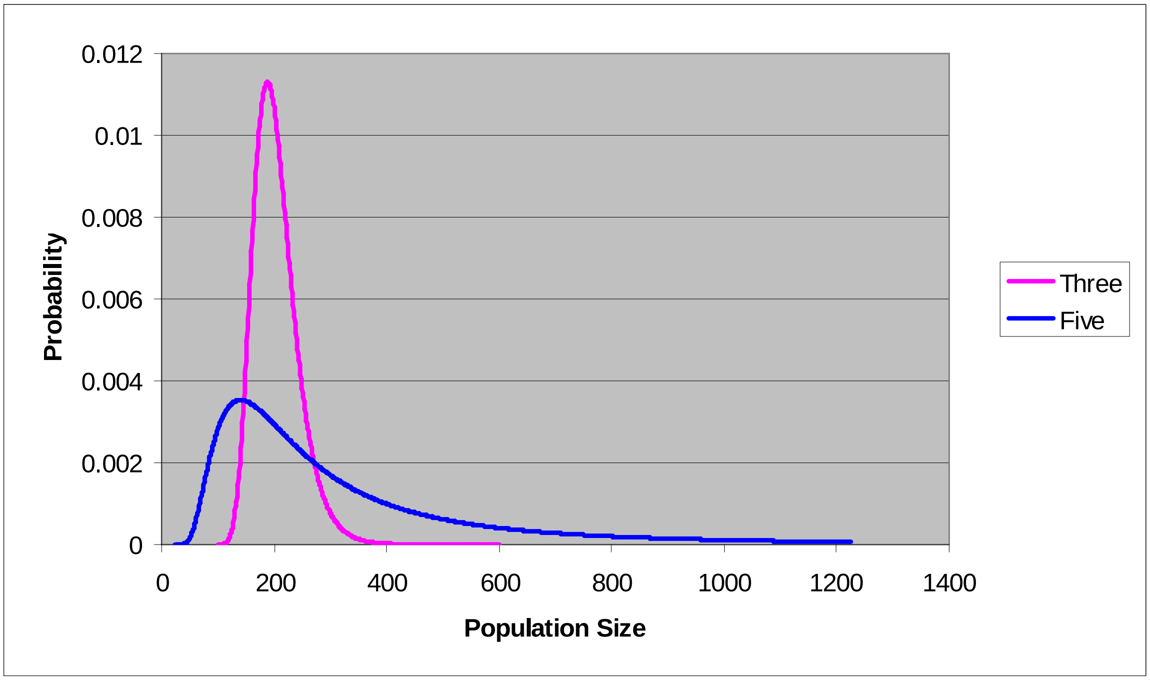


Figure 3.41 Final posterior distribution by Sections 3 and 5 for bull trout during the Phase 5 Peace River Fish Community Indexing Program, 2005.

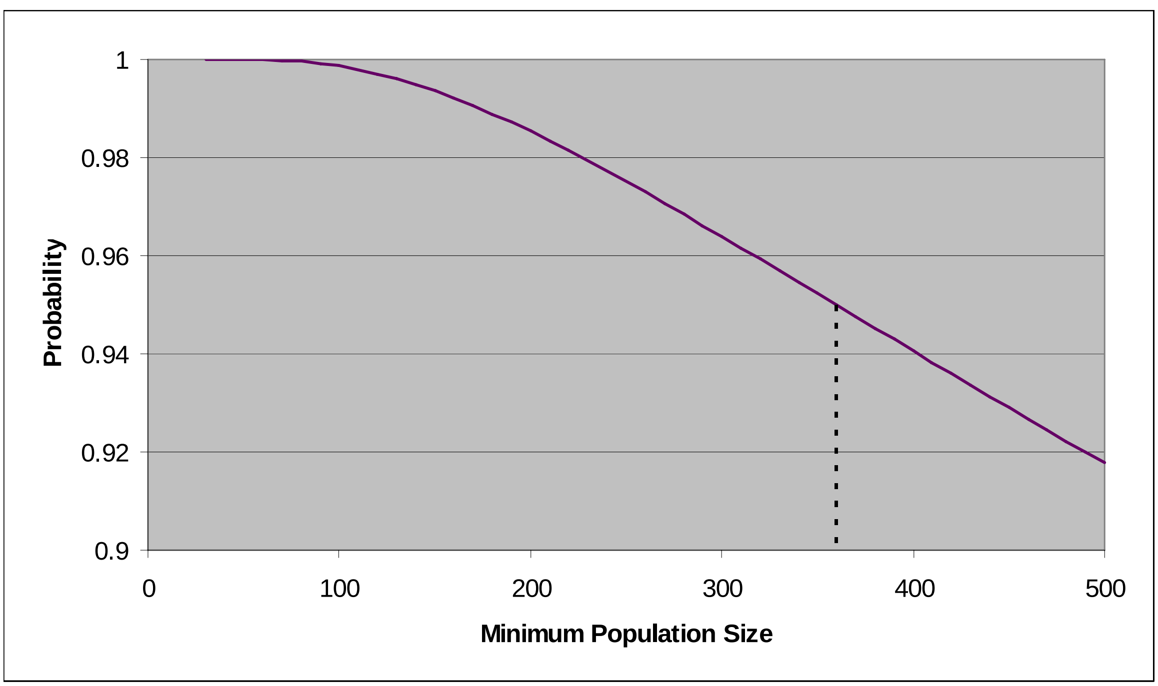


Figure 3.42 Minimum population estimates for bull trout in Section 1 during the Phase 5 Peace River Fish Community Indexing Program, 2005. Dashed line indicates the 95% percentile.

2. All fish in a stratum (day and section), whether marked or unmarked, have the same probability of being caught. The study area was stratified into three river sections to account for any differences in catchability, lack of mixing, marks applied or population size. Unlike the previous studies (Maintstream and Gazey 2004 and 2005) significant heterogeneous capture probabilities were not observed (see Table 3.16 and Figure 3.26). The consistency of the catchability coefficient across various population sizes and flow conditions in Section 1 argues that any impact was small.
3. Fish do not lose their marks over the period of the study. Each captured fish was examined for the presence of a scar. Only two mountain whitefish with recent scarring (assumed to be marked in 2005) out of 578 captures (0.4%) were observed. The impact on the closed population model should be small. However, 36 old scars (assumed to be marked 2001 to 2004) out of 293 captures (12.3%) were observed indicating that multi-year year mark-recapture experiments using Floy tags may be confounded by tag loss.
4. All marked fish are reported on recovery. Only fish brought on board were included in the number of fish examined for a mark; thus, it is unlikely that a tagged fish would escape detection.

3.6.4.2 Effort Needed to Detect Change

Because there is little movement of fish between the river sections, sampling intensity can be isolated to a section. Figure 3.43 plots the precision as a function of electrofishing effort (hours) using Equations 13, 14 and 15 for mountain whitefish in Section 1. For reference, the 2005 effort expended is also plotted. The other sections are not presented because the population estimates in Sections 3 and 5 may not be reliable. The sampling efficiency is very similar to that computed in 2004. The plots indicate that an effort reduction in Section 1 may risk substantive loss of power. Future project planning should focus on the addition or removal of sections rather than amend the sampling intensity of a section.

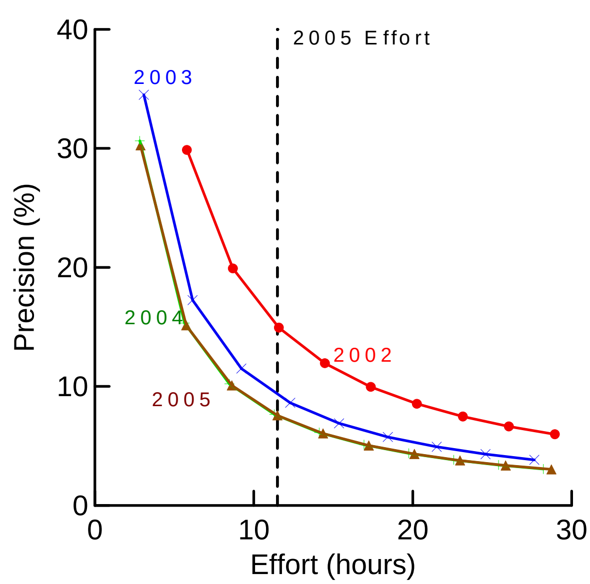


Figure 3.43 Precision (percentage of the mean) of the population estimate of Section 1 at various effort levels for mountain whitefish by project year during the Peace River Fish Community Indexing Program, 2002 to 2005.

There was insufficient data to generate a power curve for Arctic grayling and bull trout.

3.6.5 Comparison to Previous Studies

Table 3.35 provides the historical estimates of population size by species. The effort column refers to the total number of hours of electrofishing expended in the study. Precision is defined as half the 95% HPD expressed as a percentage of the Bayesian mean. Note that very large precision values (e.g., greater than 100%) imply that any point estimates are highly unreliable. Also, direct comparison of population estimates between some years, other than 2002 to 2005, is difficult because different sections were sampled. Bar plots of the population estimates for the 2002 to 2005 studies with sections common to 2005 are provided in Figures 3.44 and 3.45 for mountain whitefish and bull trout, respectively.

Table 3.35 Historical population estimates generated during the Peace River Fish Community Indexing Program.

	Effort (hrs)	Arctic grayling	Mountain whitefish	Lake whitefish	Rainbow trout	Walleye	Bull trout
1989	95.9						
Recoveries		18	126	3	19	6	
Mean		4,359	117,593	33,814	1,418	2,591	
Precision (%)		47.1	17.4	136.6	41.3	86.1	
1990	110.9						
Recoveries		37		7	19	7	
Mean		4,160		82,012	5,995	2,881	
Precision (%)		32.9		65.5	39	64.7	
2001	26.2						
Recoveries		2	3				
Mean		7,700	560,000				
Precision (%)		175.0	140.0				
2002	61.9						
Recoveries		3	954				12
Mean		1,283	36,232				2,049
Precision (%)		137.6	6.5				105.4
2003	65.8						
Recoveries		2	901				9
Mean		2,136	36,283				1,447
Precision (%)		196.0	6.4				67.7
2004	61.9						
Recoveries		15	492				17
Mean		1,165	53,442				774
Precision (%)		54.3	4.6				42.3
2005	44.3						
Recoveries		6	871				27
Mean		4,582	29,967				512
Precision (%)		44.7	3.2				44.2

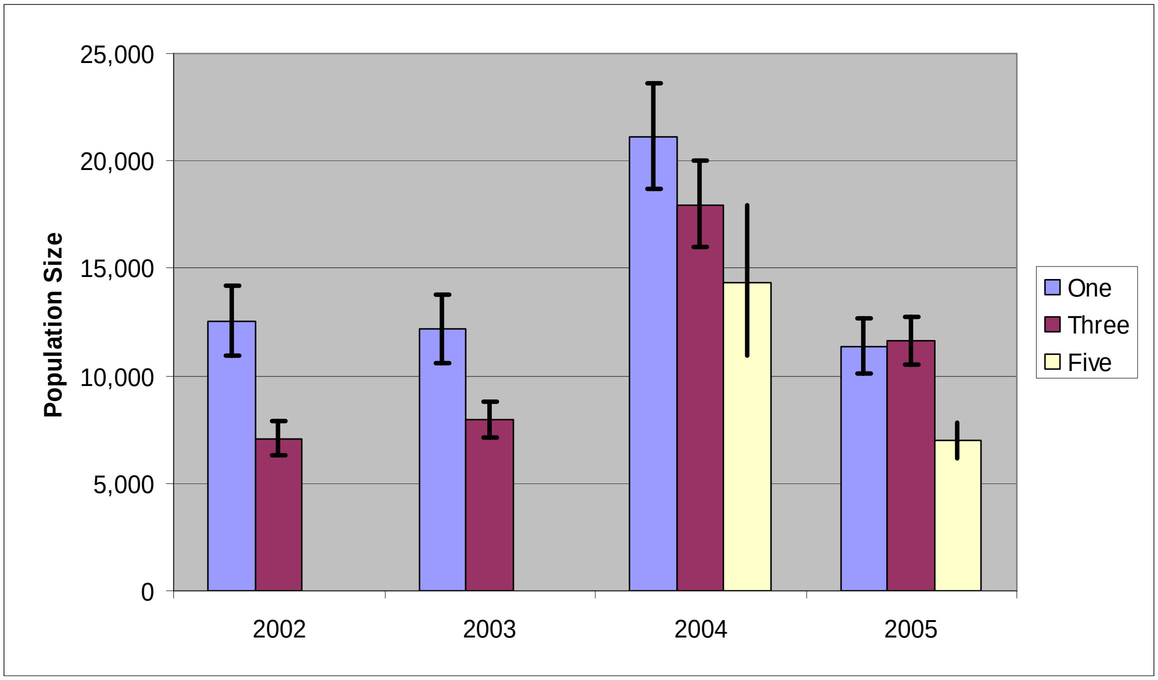


Figure 3.44 Mountain whitefish population estimates by section for 2002 to 2005 during the Peace River Fish Community Indexing Program, 2002 to 2005. The error bars represent the 95% confidence interval.

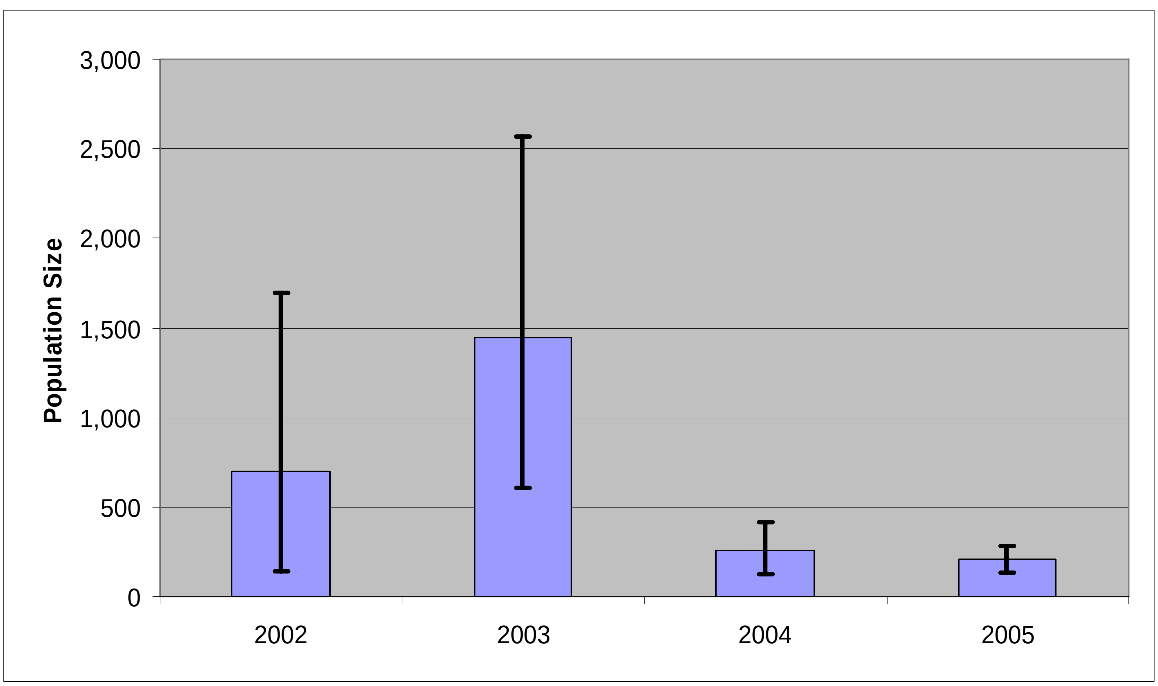


Figure 3.45 Bull trout population estimates for Section 3 for 2002 to 2005 during the Peace River Fish Community Indexing Program, 2002 to 2005. The error bars represent the 95% confidence interval.

3.6.6 Multi-Year Open Population Estimates

The mountain whitefish closed population estimates for Section 1 made for 2002 to 2005 are defensible. As pointed out by Mainstream and Gazey (2005), the increase in population size in 2004 from the stable levels in 2002 and 2003 (Figure 3.44) is too large to be due to recruitment into the plus 250 mm size group. Therefore, a different population was sampled in 2004. Perhaps the low water levels served to concentrate the fish. Second, the effects of Floy marked fish on growth and condition will lead to differential vulnerability of marked and unmarked fish to electrofishing because of size differences. Behaviour, survival and movement may also be affected because the marked fish are expending more energy and/or the mark obstructs the intake of food. The high incidence of tag loss of marks one year or older will also confound survival and population estimates.

A long term objective of the annual mark-recapture design could be to employ a “robust model” where the closed population estimates from each study year can be combined with the open population estimates from between year recaptures (e.g., Kendall *et al*. 1995). In order to execute this approach mountain whitefish need to be sampled and marked for a minimum of four years. The mark or project effects cannot impede the fish and the same population must be vulnerable each year or covariates (e.g., water level, water clarity) are available that allow estimation of the proportion of the population available each year. While the PIT tag looks to be an attractive prospect, a better understanding of mountain whitefish movement and reaction to water conditions are needed before an empirical “robust model” can be implemented.

3.7 CATCH RATE AS INDEX OF ABSOLUTE ABUNDANCE

Catchabilty during 2005 remained consistent among sample years and sections (Figure 3.38), which suggests that the catchability estimate is fairly robust despite a range of conditions. The one caveat is that water clarity must be high in order to eliminate the apparent effects on capture efficiency as evidenced by the results for Sections 3 and 5 in 2004.

The relationship between catch rate and absolute abundance for ten data points is presented in Figure 3.46. Weighted catch rates were generated using the procedures described in Mainstream and Gazey (2004). For 2005, the weighted catch rate for Section 1 was based on data from capture sessions 1 to 5, because session 6 catch rates demonstrated a strong increase that likely was related to in-migration (Figure 3.18 and Appendix E, Figure E1). The relationship explains 96% of the observed variation.

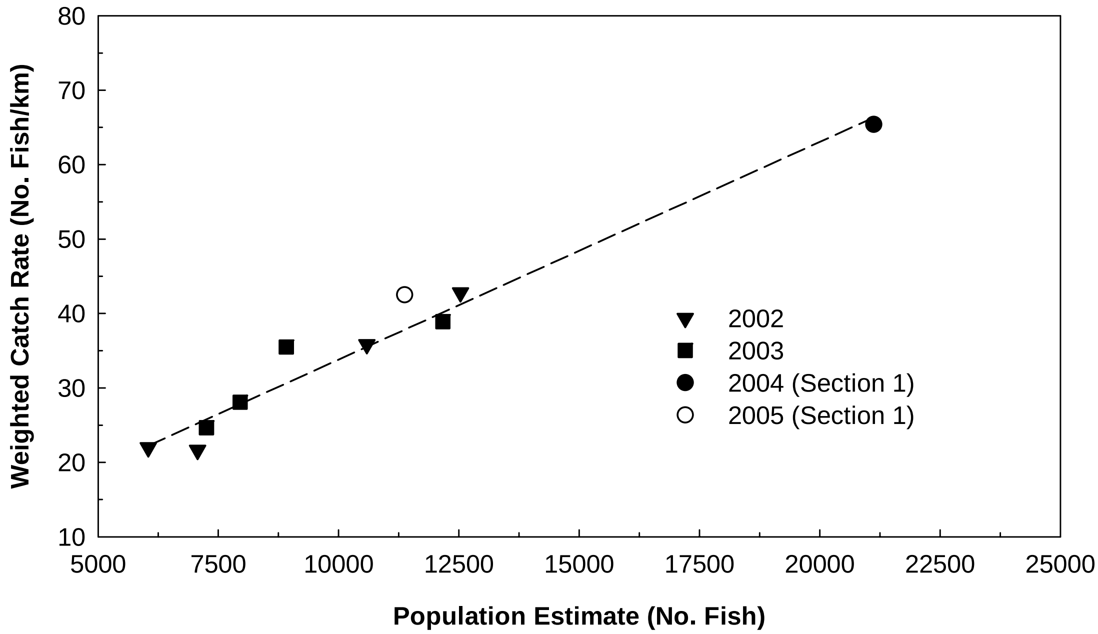


Figure 3.46 Linear relationship between population estimate and weighted catch rate of mountain whitefish during the Peace River Fish Community Indexing Program, 2002 to 2005 (2005 weight catch rated based on data from sessions 1 to 5).

3.8 PILOT SMALL FISH PROGRAM

The pilot small fish program was initiated to ascertain whether sampling protocols could be developed to effectively capture small sized fish (< 220 mm length). This was deemed a worthwhile exercise because the Peace River Fish Community Indexing Program provided little information regarding recruitment of younger age classes of target species populations.

Standard boat electrofishing protocols were modified during the pilot study to maximize the probability of small fish capture as follows:

- Sampling occurred in shallow water areas immediately adjacent to the channel margin (10 cm to 50 cm depth).
- The intensity of the electrofisher field was increased by reducing the surface area of the anode arrays and by increasing the amperage output.
- Sampling was restricted to suspected high quality small fish habitats, which were SFN habitat with physical instream cover at the water-bank interface.

The results of the pilot small fish program are presented in terms of general small fish community characteristics, relative abundance of target species, and size distribution. Where appropriate, comparisons are made with results of the standard large fish program to evaluate whether the collected data adds value to the existing Peace River Fish Community Indexing Program.

3.8.1 General Characteristics

In total, 2 199 fish representing 18 species were recorded during small fish sampling (Table 3.36). This included 9 sportfish species, 3 sucker species, 5 cyprinid species, and 2 sculpin species. The three target species Arctic grayling, bull trout, and mountain whitefish were well represented in the catch.

Table 3.36 Number and percent composition of fish species recorded during the pilot small fish program and comparison to large-fish results during Phase 5 of the Peace River Fish Community Indexing Program, 2005.

Family	Common Name	Scientific Name	Small Fish		Large Fish
			No.	%	%
Salmonidae	Arctic grayling	*Thymallus arcticus* (Pallas)	86	3.9	2.1
	Bull trout	*Salvelinus confluentus* (Suckley)	30	1.4	1.5
	Kokanee	*Oncorhynchus nerka* (Walbaum)	99	4.5	0.3
	Lake trout	*Salvelinus namaycush* (Walbaum)	-	-	<0.1
	Mountain whitefish	*Prosopium williamsoni* (Girard)	1 485	67.5	86.8
	Pygmy whitefish	*Prosopium coulteri* (Eigenmann)	1	<0.1	-
	Rainbow trout	*Oncorhynchus mykiss* (Walbaum)	12	0.5	0.7
Gadidae	Burbot	*Lota lota* (Linnaeus)	1	<0.1	<0.1
Esocidae	Northern pike	*Esox lucius* Linnaeus	3	0.1	<0.1
Percidae	Walleye	*Sander vitreus* (Mitchell)	-	-	<0.1
	Yellow perch	*Perca flavescens* (Mitchell)	2	0.1	-
Catostomidae	Largescale sucker	*Catostomus macrocheilus* Girard	23	1.0	1.4
	Longnose sucker	*Catostomus catostomus* (Forster)	52	2.4	6.8
	White sucker	*Catostomus commersoni* (Lacépède)	-	-	<0.1
Cyprinidae	Lake chub	*Couesius plumbeus* (Agassiz)	14	0.6	-
	Longnose dace	*Rhinicthys cataractae* (Valenciennes)	5	0.2	-
	Northern pikeminnow	*Ptychocheilus oregonensis* (Richardson)	8	0.4	0.4
	Redside shiner	*Richardsonius balteatus* (Richardson)	92	4.2	-
	Spottail shiner	*Notropis hudsonius* (Clinton)	23	1.0	-
Cottidae	Prickly sculpin	*Cottus asper* Richardson	203	9.2	-
	Spoonhead sculpin	*Cottus cognatus* Richardson	60	2.7	-
Total			**2 199**	**100.0**	**100.0**

The pilot study encountered eight species not recorded during the standard sampling program. These included small-sized species (4 cyprinid and 2 sculpins) yellow perch, and a suspected pygmy whitefish.

The suspected pygmy whitefish was recorded in Section 3. A voucher specimen was not collected due to possible restrictions associated with the fish collection permit issues for the project. If the species identification was correct, this is the first record of pygmy whitefish in the Peace River downstream of the PCN Dam. The small fish catch was dominated by mountain whitefish (68%), with lower numbers of other species. Sculpin species (prickly and spoonhead) were an important component of the sample (13%). Arctic grayling and kokanee also were present (3.9 and 4.5%, respectively), as were redside shiners (4%) and longnose suckers (2%). The results differed from findings of the standard sampling program that focused on large fish. As expected the contribution of small-sized species increased, which included six new species. In addition the relative importance of target species changed. Mountain whitefish decreased from 87% to 68%, while Arctic grayling increased from 2% to 4%. Bull trout remained unchanged at 1.5%. These data indicated that the small fish program accessed a different, more diverse species assemblage than the standard large-fish program.

Figure 3.47 illustrates the spatial changes in species groups within the small fish sample. Mountain whitefish importance remained above 60% in all three sections. Coldwater sportfish species were dominant only in Section 1 (35%). This was due to the presence of kokanee. Cyprinids were absent from Section 1, but accounted for approximately 6% of the sample in each of Sections 3 and 5. Of interest was the increasing importance of large nonsportfish species (suckers and northern pikeminnow) and sculpins from upstream to downstream. It is unclear whether this shift was related to physical changes in habitat or higher water temperatures. The results indicated that the pilot study was able to document spatial differences in the small fish species assemblage.

3.8.2 Relative Abundance

The primary objective of the pilot small fish program was to effectively capture younger age-classes of the target species populations. Mean catch rates for the three target species in each of the study sections are presented in Figure 3.48. Arctic grayling were scarce in Section 3 (0.44 fish/km), but were abundant in Section 5 (4.83 fish/km). It should be noted that the small fish catch rates for this species in Section 5 were approximately 2 times higher than catch rates recorded during standard large fish sampling.

Bull trout were not abundant in the catch. Catch rates did not exceed 0.68 fish/km. Despite the low number of fish recorded a distinct trend of decreasing abundance was recorded between Sections 1 and 5. Section differences were significant (P = 0.038 one way analysis of variance).

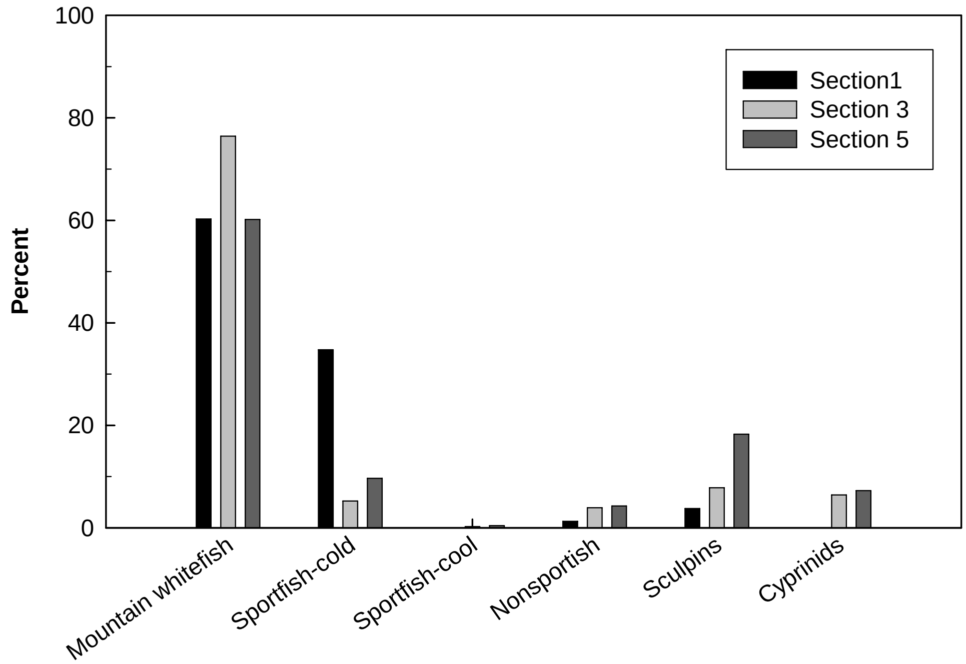


Figure 3.47 Percent composition of fish species groups in the pilot small fish sample during the Phase 5 Peace River Fish Indexing Program, 2005.

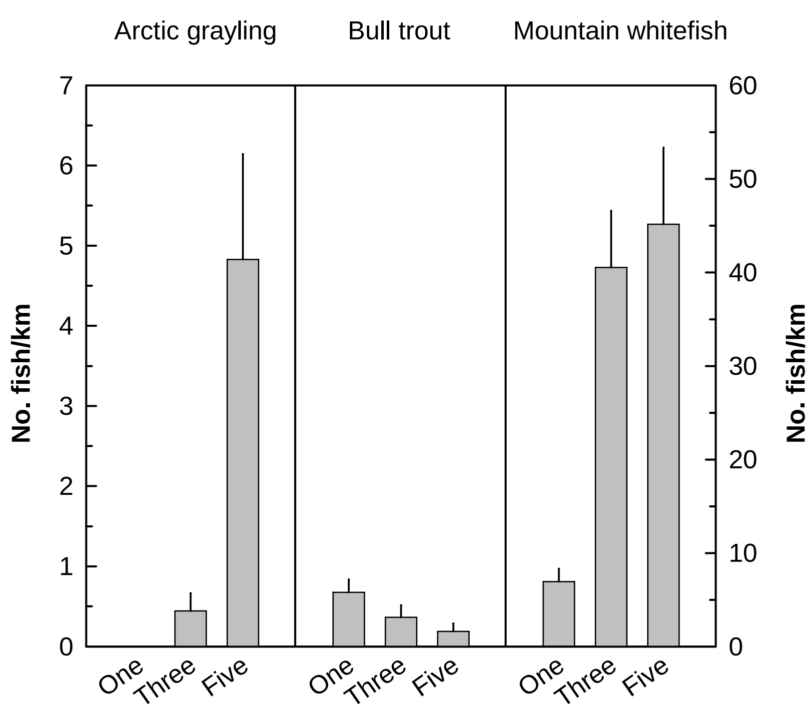


Figure 3.48 Mean catch rate of target species by section during the pilot small fish program of the Phase 5 Peace River Fish Community Indexing Program, 2005.

This trend is of interest because small bull trout were encountered in low numbers during the standard program (see Section 3.3.2). It was unclear from the results of that study component whether small bull trout were originating from upstream or downstream sources. It was hypothesized that fish originated from the Halfway River system because this was the primary spawning area for the population. The pilot study results refute this idea. If the Halfway River system was the source, bull trout mean catch rate should have been highest in Section 3. Instead mean catch rate was highest in Section 1, which suggests the possibility that fish originated from upstream of the PCN Dam (i.e., were entrained). If so, recruitment may not be based solely on reproductive potential of the population that resides downstream of the dam.

Mean catch rate of small mountain whitefish ranged from 6.9 fish/km to over 40 fish/km in Sections 3 and 5. The low abundance of small mountain whitefish in Section 1 indicates that the area is not an important rearing area, which contrasts to findings for Sections 3 and 5.

In general, the relative abundance of the three target species are similar to the results of the standard large fish program. Differences include the higher catch rates for Arctic grayling in Section 5 and the scarcity of mountain whitefish in Section 1. The results indicate that there are spatial differences in habitat selection based on fish size (rearing areas versus adult feeding).

3.8.3 Biological Characteristics

Length distributions of sampled fish for the three target species are presented in Figure 3.49. The length distribution of Arctic grayling indicated the presence of two modal peaks: 100 mm and 190 mm fork length. These modal peaks represent Age 0 and Age 1 fish, respectively based on length-at-age data presented in Section 3.3. In terms of relative importance, Age 0 fish (90 mm to 120 mm accounted for 21% of the sample.

The presence of Age 0 fish in the Peace River was not expected. During their first year, Arctic grayling typically rear in tributaries until late fall, when a portion or all of the Age 0 fish disperse downstream. The results of the present study indicated that young Arctic grayling enter the Peace River as early as September. The timing of dispersal could be specific to the tributary. Age 0 Arctic grayling originating from the smaller Moberly River would not have traveled as far as Arctic grayling originating from the larger Halfway River. The origin of the fish and dispersal timing may explain the scarcity of young Arctic grayling in Section 3. Sampling later in the fall after dispersal from rearing streams may have resulted in larger numbers of fish, which was a finding by Pattenden *et al.* (1990).

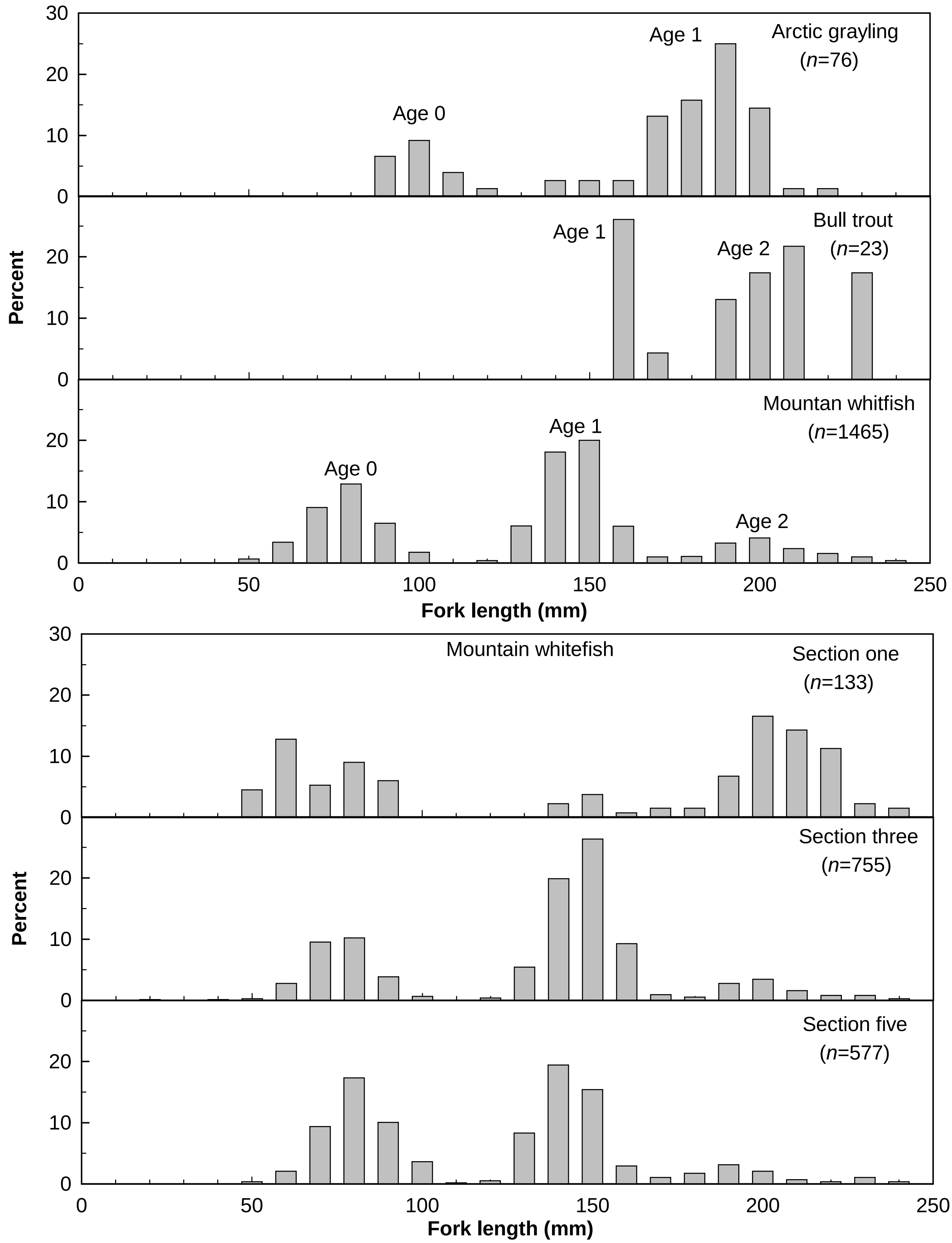


Figure 3.49 Comparisons of length distributions of arctic grayling, bull trout, and mountain whitefish sampled, and comparisons of mountain whitefish from Sections 1, 3, and 5 during the Phase 5 Peace River Fish Community Indexing Program, 2005.

The sample size for bull trout was small (*n* = 23), but based on length-at-age data one or two age groups were represented. These were Age 1 and possibly Age 2 fish. Similar to the rearing ecology of Arctic grayling, bull trout typically rear in tributaries for 2 to 3 years prior to dispersal to large systems. As such, the presence of young bull trout in the Peace River was not expected.

The large sample size of small mountain whitefish provided good information that described the general population length distribution as well as section differences. Three distinct modal peaks were represented in the combined sample. These were Age 0 fish (50 to 100 mm), Age 1 fish (120 to 160 mm), and Age 2 fish (170 to 220 mm). In terms of relative importance, the Age 0 group 35% of the sample, Age 1 fish accounted for 52% of the sample, and Age 2 fish 13% of the sample. Fish Aged 0 accounted for < 1% of the standard sample, while Age 1 fish accounted for approximately 8%. As such, the pilot small fish study accessed younger fish that were not available to the standard program.

There were apparent spatial differences in length distributions of mountain whitefish. In Section 1, fish between 120 mm and 160 mm (Age 1) were largely absent, but in Sections 3 and 5 fish > 170 mm (Age 2) were scarce. The results for Section 1 are representative of the actual length distributions of mountain whitefish; however, data for the other to sections are biased for the following reason. Netters were instructed to target fish < 200 mm in length. Low catch rates in Section 1 allowed netters to sample for larger fish because fish in the target size range were not abundant. In Sections 3 and 5 higher catch rates forced netters restrict sampling to target fish < 200 mm. This bias in sampling can be avoided in the future by adhering to the sampling protocols.

3.8.4 Evaluation as a Monitoring Tool

The results of the pilot small fish program established the following regarding its value as a monitoring tool:

1. The modified boat electrofisher can effectively capture small fish (< 200 mm) in shallow water habitats in the Peace River.
2. The small fish program accessed a different species assemblage and age classes of target species populations that were not previously available using the standard large fish capture method.
3. The data collected during the small fish program provided useful information that described the abundance, distribution, and biological characteristics of younger age classes of target species populations.

Based on this information we can conclude that the small fish program has good potential to be an effective monitoring tool for the Peace River Fish Community Indexing Program.

The 2005 pilot small fish program was not designed to provide a detailed evaluation of sampling protocols. Several aspects need to be examined in more detail before it is incorporated as an integral part of the indexing program. As a corollary, the small fish program should be viewed the same way as the standard program during its initial stages of development (P&E 2002).

Further evaluations are required in several areas as follows:

1. What is the spatial and temporal distribution of the target species populations (e.g., season, river section, and habitat)?
2. What sampling protocols maximize sampling efficiency and minimize variability?
3. Is hyperstability an issue that would compromise use of catch rate as an index of abundance?
4. Are small fish populations open or closed?
5. Is it logistically feasible to generate population estimates for small fish?
6. Can an unbiased sample be collected for description of population biological characteristics?

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4.0 SUMMARY

4.1 SAMPLING CONDITIONS

In 2005, the discharge regime of the Peace River during the field program differed from previous investigations. Discharge decreased during the first half of the study and then increased gradually until the end of the program. In 2004, discharge from the PCN Dam was low and stable during most of the program, but inputs from the Halfway River and Moberly River caused spatial differences between upstream and downstream sections. During 2002 and 2003, discharge was high and variable at all times. Based on findings in 2004, the discharge regime of the Peace River during the present study had the potential to affect fish catch rate.

In 2005, water clarity was high and remained above the 50 cm threshold that potentially affected capture efficiency. In addition, water temperatures remained above the threshold that initiates mountain whitefish spawning activity (7.5^{o}C). As such, these factors did not have a strong influence on fish catch rates during the present study.

4.2 FISH COMMUNITY CHARACTERISTICS

Fish community characteristics documented in 2005 were similar to findings of previous investigations. There was a spatial shift in the relative importance of major fish species and groups. The percentage of mountain whitefish decreased from upstream to downstream and there was a corresponding increase in the percentage of nonsportfish species. A similar pattern was recorded for coldwater sportfish versus coolwater sportfish.

4.3 BIOLOGICAL CHARACTERISTICS

The results for the present study were consistent with those of previous investigations. The program design was sufficient to document spatial and temporal trends in the biological characteristics of the target species populations. The following highlights key findings.

4.3.1 Arctic grayling

Few Arctic grayling were recorded in Section 1. In Sections 3 and 5 the sample population consisted primarily of fish Aged 1 to 3. Age 0 fish were largely absent. Of interest was the scarcity of fish older than Age 3, despite the recruitment of younger fish starting in 2002. This finding was consistent with previous investigations. The absence of older, larger fish may be caused by recreational angler harvest. The importance of this factor on the Arctic grayling population apparent mortality rate, which was at least 75% in 2005, cannot be addressed until quantitative data are collected that characterizes angler harvest.

Biological characteristics of Arctic grayling examined during the present study (length distribution, age distribution, growth rate, length-at-age, and body condition) indicated that sample populations in Sections 3 and 5 were similar. And, there were no major differences from results of previous studies.

4.3.2 Bull trout

Length and age distributions of bull trout suggested that there were spatial differences in population structure. In Section 1 the age distribution was dominated by Age 2 and 3 fish and no fish older than Age 5 were recorded. A broader range of ages were encountered in Sections 3 and 5 (Ages 1 to 10). Spatial differences in age distribution also occurred during previous investigations, but the pattern was not consistent. The results indicate that the annual changes in population structure within a section may be an artifact of the timing of spawning activity by the adult cohort in tributaries and the subsequent absence of these fish from study sections, rather than real differences in population structure. Assuming that sample populations in Sections 3 and 5 were representative of the study area population, apparent mortality rate was 24%.

Of note was the presence of Age 1 and Age 2 fish within each section during 2005, which was not recorded during previous investigations. The presence of these fish was an indication of either increased reproductive success of the study area population, or atypical dispersal of fish from rearing tributaries.

There were spatial differences in growth rate. Section 1 bull trout grew at a lower rate than fish in Sections 3 and 5. Comparisons of age-specific lengths indicated that the difference was statistically significant for Age 4 fish. There was no distinct change in growth or body condition between years.

4.3.3 Mountain whitefish

There were spatial and temporal differences in length and age distributions of mountain whitefish in 2005, which was consistent with findings by previous investigations. Fish in Section 1 exhibited a truncated length distribution caused by the preponderance of Age 4 and Age 5 fish. Younger fish (Ages 0 and 1) and older fish (> Age 6) were largely absent. In contrast, mountain whitefish in Sections 3 and 5 exhibited multi-modal length distributions represented by multiple ages. Age 0 and Age 1 fish accounted for a substantial proportion of these sample populations, which indicated good recruitment.

Mountain whitefish in Section 1 had a lower growth rate than mountain whitefish in Sections 3 and 5. Age-specific comparisons indicated significant differences for fish Aged 5 to 8.

Large annual differences in age structure were not recorded. Apparent mortality rate remained above 40% in Section 1, while in Sections 3 and 5 it was approximately 34%.

Mountain whitefish were smaller and had a lower body condition at a given age during the present study compared to mountain whitefish in 2004. These differences were consistent among the three sections and were statistically significant for most age classes. The causal mechanisms of reduced mountain whitefish vigour are not known. Potential factors could include perturbations associated with weather or river discharge.

4.4 RELATIVE ABUNDANCE

4.4.1 General

The results of Phase 5 demonstrated that established sampling protocols were appropriate to generate reliable data and findings were consistent with previous investigations. In general, catch rates differed between species, section, and habitat. Catch rates for Arctic grayling and bull trout were low in all sections and were much less than those of mountain whitefish. Arctic grayling and bull trout catch rates were higher in SFC habitats compared to SFN habitats, while the reverse was true for mountain whitefish.

Mean catch rates differed between sections. Arctic grayling were scarce in Section 1, moderately abundant in Section 3, and most abundant in Section 5. These differences were caused by the relative contribution of young fish to the samples. Bull trout tended to be least abundant in Section 5. Catch rates of mountain whitefish were higher in Sections 1 and 3 compared to Section 5.

4.4.2 Confounding Factors

In 2005, discharge declined during the first half of the field program and then remained relatively constant for the latter half of the program. Bull trout and mountain whitefish catch rates also changed during the study. Catch rates for all three target species were negatively correlated with water level. These correlations were strongest and were statistically significant for mountain whitefish. These results were similar to the 2004 findings. Large changes in discharge during the field program appear to influence catch rate. The causal mechanisms of this relationship are not known. Lower discharge over an extended period, or diurnal fluctuations, may concentrate fish. For bull trout the observed changes in catch rate may have been related to an influx of post-spawning adults from tributaries. The catch rate results will remain difficult to interpret without empirical data that describes fish movement in relation to discharge.

4.4.3 Comparison to Previous Investigations

Arctic grayling and bull trout catch rates remained low during the present study, which is consistent to findings during previous investigations. Changes to Arctic grayling catch rates that occurred relative to 2004 were due to increases in numbers of younger aged fish. Mountain whitefish catch rates in Section 1 declined in 2005 compared to 2004. There has been a continuous upward trend in catch rate in Section 3 since the first year of standardized sampling in 2002. Values are approaching those recorded in Section 1, which historically has been the section with the highest number of mountain whitefish. No distinct change was recorded in Section 5.

4.5 SAMPLING EFFECTS

Floy tag effects on growth and condition have been shown to be statistically significant by the current study and previously in the Phase 4 study. Because the absolute biological impacts are also large in terms of growth and condition we should expect significant impacts on survival and vulnerability to recapture over the long term. Comparisons of unaffected control fish to unmarked study fish provided initial results suggesting no detrimental effect of sampling activities (boat electrofishing) on mountain whitefish growth and health.

The short term impact of Floy tags on fish is not known; however, since the study was conducted over a short period (41 days) and most fish were marked with PIT tags, we believe the impact to be small. Immediate mortality of mountain whitefish associated with capture by boat electrofishing was negligible.

4.6 POPULATION ESTIMATES

Overall, the program was highly successful for mountain whitefish but much less so for Arctic grayling and bull trout. Population estimates were made using a Bayesian sequential closed population model and with an open Jolly-Seber model for mountain whitefish. Since marks were applied only to fish greater than 250 mm, estimates are only applicable to that portion of the population. Population estimates were generated for three river sections (1, 3, and 5) using minimum time-at-large of five days, a minimum length of 250 mm, an annual instantaneous removal rate (represents natural mortality, unobserved removals and emigration) of 0.0 and an undetected mark rate of 0%. The population estimates were defensible for Section 1 but Sections 3 and 5 had a serious closure violation and the closed population model estimates are not valid. Unlike the pervious studies (Mainstream and Gazey 2004 and 2005) significant heterogeneous capture probabilities were not observed during the present study. The consistency of the catchability coefficient across various population sizes and flow conditions in Section 1 argues that any impact from heterogeneous capture should be small.

For mountain whitefish, the large number of marks applied and recaptured and the structured sequential sampling design allowed the following findings:

1. Empirical evaluation of the assumptions required for population estimation.
2. Population estimates must be stratified by river section.
3. Verification that catchability is constant between river sections and years (thus catch-per-unit effort indices are comparable and representative of the vulnerable population) where compliance with the closed population assumption allows for rigorous comparison.
4. The population vulnerable to sampling in 2004 was different than that in 2002, 2003, and 2005.
5. Sampling effort should be standardized (sample with same array of sites, intensity and period) if high precision is required.
6. Application of Floy tags affected growth and condition.
7. Application of PIT tags did not affect growth and condition.

For Arctic grayling and bull trout, population estimates are available, but the overall precision is poor (CV = 44.7% and 44.2%, respectively). On the other hand, the precision for bull trout in Section 3 was acceptable (19.4%). There is insufficient data to forecast effort levels needed for reliable population estimates for either species.

4.7 CATCH RATE AS AN INDEX OF ABSOLUTE ABUNDANCE

The catchability estimate remained fairly robust despite a range of conditions encountered among sample years and sections. As such catch rate can be used as an index of absolute abundance. Ten data points are now available for mountain whitefish to quantify the relationship. This relationship explains 96% of the apparent variation.

Three caveats should be acknowledged as follows:

1. Sampling protocols (methods, equipment, and approach) must be consistent.
2. Water clarity must remain above 50 cm in order to eliminate the apparent effects on catchability.
3. The target population must remain closed during the period used to generate the catch rate value.

4.8 PILOT SMALL FISH PROGRAM

4.8.1 General Characteristics

In total 18 species were recorded during the pilot small fish program, which included 9 sportfish, 3 sucker, 5 cyprinid, and 2 sculpin species. Arctic grayling, bull trout, and mountain whitefish were well represented in the catch. Eight of these species, which included small-sized fish were not previously encountered during the standard program. One suspected pygmy whitefish was recorded, which was the first record of pygmy whitefish in the Peace River downstream of the PCN Dam. These data indicated that the pilot small fish program accessed a different, more diverse species assemblage than the standard program.

Coldwater sportfish species were dominant only in Section 1, while cyprinids were absent. Nonsportfish species and sculpins increased in relative importance from upstream to downstream. These results indicated that the pilot study was able to document spatial differences in the small fish species assemblage.

4.8.2 Relative Abundance

Catch rates of the three target species recorded during the pilot small fish program varied among study sections. Small Arctic grayling were absent from Section 1, scarce in Section 3, and abundant in Section 5. Bull trout were not abundant, but a distinct trend of decreasing catch rate was recorded between Sections 1 and 5. The results for bull trout suggest the possibility that fish originated from upstream of the PCN Dam rather than from the study area population. Small mountain whitefish were not abundant in Section 1, but were very abundant in Sections 3 and 5. There were differences between the small fish program and the standard program, which indicated habitat selection based on fish size (rearing areas versus adult feeding). Overall, the pilot small fish program was effective at the capture of small fish including the three target species, and the data were sufficient to document species and section differences.

4.8.3 Biological Characteristics

Based on length distributions, samples of the three target species populations collected during the pilot small fish program were dominated by younger age classes. These were Age 0 and Age 1 fish for Arctic grayling and mountain whitefish and Age 1 and Age 2 fish for bull trout. Information collected from these fish provided length-at-age data that was largely unavailable during the standard program.

Sample sizes for mountain whitefish were sufficient to document section differences in population structure. In Section 1 Age 1 fish were largely absent, but this age class dominated in Sections 3 and 5.

4.8.4 Evaluation as a Monitoring Tool

The results of the pilot small fish program established the following regarding its value as a monitoring tool:

1. The modified boat electrofisher can effectively capture small fish (< 200 mm) in shallow water habitats in the Peace River.
2. The program accessed a different species assemblage and different age classes of the target species populations that were not previously available during the standard program.
3. The data provided useful information that described the abundance, distribution, and biological characteristics of younger age classes of target species populations.

Based on this information we can conclude that the small fish program has good potential to be used as a monitoring tool for the Peace River Fish Community Indexing Program.

The 2005 pilot small fish program was not designed to provide a detailed evaluation of sampling protocols. Several aspects need to be examined in more detail before it is incorporated as an integral part of the indexing program. As a corollary, the small fish program should be viewed the same way as the standard program during its initial stages of development (P&E 2002). If a small fish program is to be used evaluations of the following questions are required as follows:

1. What is the spatial and temporal distribution of the target species populations (e.g., season, river section, and habitat)?
2. What sampling protocols maximize sampling efficiency and minimize catch rate variability?
3. Is hyperstability an issue that would compromise use of catch rate as an index of abundance?
4. Are small fish populations open or closed?
5. Is it logistically feasible to generate small fish population estimates?
6. Can an unbiased sample be collected to describe population biological characteristics?

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5.0 RECOMMENDATIONS

The stated overall objective of the Large River Program is:

"to establish fish monitoring protocols that can be used reliably across the Peace River and Columbia River watersheds to provide an index of the general status of the fish community".

The findings of the Peace River Phase 2 and 3 programs indicated that the monitoring protocols were suitable to meet the objective of the program, particularly for mountain whitefish. Phase 4 and Phase 5 results have confirmed these findings with two exceptions. These exceptions are as follows:

1. Water clarity less than 50 cm reduces capture efficiency, thereby negating use of catch rate as an index of absolute abundance under these sampling conditions.
2. Certain flow regimes during the sampling program, (i.e., low stable flows or strong continuous decline in flow) apparently cause mountain whitefish movements that invalidate results of the closed population estimate model.

Because the program is aware of these confounding factors and has the sensitivity to identify these and other issues as they occur, the Peace River Fish Indexing Program as presently designed still meets the overall objective of the Large River Program.

After four years of standardized sampling we conclude that the program has become mature with diminishing returns with respect to the knowledge gained for the effort expended. A decision is now needed with respect to the future direction of the program. This is important for the following reasons:

1. The present scope of the program limits its ability to collect data that are needed to interpret the indexing results.
2. Adjustments to the program may be required in order to address monitoring needs of the Peace River Water Use Plan.

During each year of study, results were reviewed to identify issues of concern and recommendations were made to address those issues. The tasks of each subsequent study were limited to the main objective of refining sampling protocols. The Peace River Fish Community Program will continue to adhere to this overriding objective. To this end we recommend the following for the Phase 6 program:

1. Repeat the standard program to extend the time series data and to assess whether flow conditions influence target fish populations.
2. Maintain the current study design and sampling protocols with the following adjustments:
    a. Restrict the marking system to use of PIT tags to address the issue of detrimental effects caused by the current marking system (Floy T-bar anchor tags).

   b. Quantify fish movements into and out of Sections 1 and 3. This will be accomplished by reactivating Section 2 (sampled during the 2002 and 2003 programs). This spatial arrangement provides better coverage, which will allow an assessment of fish movement in the upper 60 km of the study area.
   c. Remove Section 5 from the sampling program to minimize potential effects of low water clarity on capture efficiency. Section 5 typically has the highest probability of having low water clarity because it is the furthest downstream section. Section 5 will be replaced by Section 2 (see Point b).
   d. Increase the number of marking sessions from four to five to examine use of open population estimate models and examine suspected violations of the closed population assumption.
   e. Expand and standardize the control fish program to provide a random sample of fish to evaluate non-tag effect sampling activities on target fish populations. Control sections would be established immediately upstream and downstream of standard sections. Information from these sections also would help assess fish movements (see point b).
3. Build an age-structured model that will serve to synthesize catch rate, age, and abundance information. If such models are to be maintained and used for the evaluation of dam operation effects there will be a need to collect long term information on population dynamics (e.g., mortality and stock-recruitment functional form). The continued application of long-lasting marks (PIT tags) will assist in this endeavor.

These recommendations do not address a number of data gaps identified during the present and previous investigations. These data gaps relate to:

1. Improvement of some aspects of the indexing program (e.g., development of catchability coefficients for low water clarity conditions).
2. Collection of data to assist in the interpretation of the indexing information (e.g., fish movements, angler harvest, and river productivity).
3. Expansion of the indexing program to allow collection of additional types of information (e.g., small fish recruitment).

As recommended during previous investigations, consideration should be given to expanding the scope of the Peace River Fish Community Indexing Program in order to address the data gaps.

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