PEACE RIVER
FISH COMMUNITY INDEXING PROGRAM
– PHASE 3 STUDIES –

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Cover: Peace River near Cache Creek

PEACE RIVER FISH COMMUNITY INDEXING PROGRAM - PHASE 3 STUDIES

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March 2004

Citation: Mainstream Aquatics Ltd. and W.J. Gazey Research. 2004. Peace River Fish Community Indexing Program - Phase 3 Studies. Prepared for BC Hydro. Report No. 03008F: 104 p. + Appendices.

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 of this program is to develop monitoring tools that provide a reliable index of the fish community status in each of these watersheds. Activities during Phases 1 and 2 of the Peace River Fish Community Indexing Program focused on development of suitable monitoring tools. The primary objectives of Phase 3 were to test whether the results were repeatable using the recommended approach and to extend time series data.

<u>Biological Characteristics</u>

There were spatial differences in biological characteristics of target fish populations, which was consistent with results of Phase 2. Smaller, younger Arctic grayling accounted for a greater percentage of the sample in Zone 2 compared to Zone 1. Results for bull trout were not as distinct, which likely reflected the large natural variation in the data. Mountain whitefish in Zone 1 exhibited a condensed bi-modal size distribution, whereas sampled fish in Zone 2 exhibited a broader multi-modal size distribution. There also were yearly differences in biological characteristics of sampled mountain whitefish. There was a general increase in length-at-age and body condition between 2002 and 2003.

As a check of the accuracy of the length-at-age estimates, information derived from age data were compared to incremental growth data from marked fish tagged in 2002 and recaptured in 2003. Incremental growth of mountain whitefish was lower then expected and was below the age derived growth estimates. Additional analyses established that body condition of mountain whitefish tagged in 2002 also was lower than expected. The results suggested that project activities may have had a detrimental effect on fish. Direct mortality of mountain whitefish associated with boat electrofisher capture was negligible and potential delayed mortality was low. As such, the tagging system rather than boat electrofishing effects may have been the primary mechanism causing reduced growth and body condition of 2002 fish.

<u>Relative Abundance</u>

Sampling Protocols

Adjustments to boat operation protocols were not sufficient to remove all apparent bias identified during Phase 2. Crew differences in catch rates for bull trout and Arctic grayling still differed. However, the adjustment in boat operation was sufficient to reduce crew bias to acceptable levels to allow the individual crew catch data to be combined for analyses.

The Phase 3 observer results were consistent with findings during Phase 2. The ability to identify difficult target fish species (Arctic grayling and bull trout) was dependent on experience. In contrast, sampler experience did not improve counts of the more numerous species, mountain whitefish. Use of observed fish affected the precision of the catch rate estimate. For Arctic grayling and bull trout, inclusion of observed fish increased precision whereas use of observed mountain whitefish decreased precision. Based on the results, use of observed fish in estimation of catch rate depends on the target species. Arctic grayling and bull trout counts should be included in the catch enumeration. Use of observed mountain whitefish, which is a very abundant species is not recommended.

Similar to results for Phase 2, mean catch rates of the three target species exhibited spatial differences between habitats and sections. Arctic grayling and bull trout catch rates were higher in SFC habitats compared to SFN habitats. Catch rates of mountain whitefish tended to be higher in SFN habitats compared to SFC. Mean catch rates also differed between sampled sections. Arctic grayling were more numerous in Sections 3 and 4, but bull trout mean catch rates tended to be constant. Mountain whitefish exhibited distinct spatial differences in abundance relative to the Halfway River confluence. Mean catch rates were higher in Sections 1 and 2 compared to Sections 3 and 4.

Confounding Factors

Peace River discharge during the present field program was lower and tended to be more variable than in 2002. One basic flow pattern was recorded, which was depicted by rapid changes in water level followed by short periods of high or low stable flow based on a 24-hour cycle.

Several water level parameters were examined to ascertain whether discharge affected catch rate. The evaluation provided only limited evidence that catch rates of target species were influenced by flow patterns of the Peace River, which is similar to findings during Phase 2.

Water clarity in the Peace River during the sampling period was high (> 170 cm). Given the high values recorded during Phase 2 there likely was no influence of water clarity on catch rate.

Effort Required to Detect Change

Standard deviations associated with catch rate estimates for the majority of target species remained stable between 2002 and 2003. Also, the size of the standard deviation did not differ substantially between the SFC and SFN habitat categories. Coefficient of variation was very high for Arctic grayling and bull trout, but remained low and stable for mountain whitefish. Because the standard deviations associated with the estimates remained stable, the differences were due to changes in fish abundance.

Power analysis indicated that sample sizes needed to detect a 25% change in abundance for Arctic grayling and bull trout were greater than 100, while sample sizes needed for mountain whitefish were less than 12. The results were similar to findings made during Phase 2.

Comparison to Previous Studies

In general, catch rates of the target species populations differed between years and sections. Overall, Arctic grayling mean catch rates in the SFC were higher in 2003 compared to 2002. The opposite trend was recorded for bull trout; however, the decrease may have been an artifact of using catch data from both crews in 2003 compared to using only the catch rates of the more efficient crew in 2002. Small changes in mountain whitefish mean catch rates were recorded between years. Decreases occurred in Sections 1 and 2, while the opposite was true for Sections 3 and 4.

<u>Population Estimates</u>

Overall, the program was highly successful for mountain whitefish, but much less so for Arctic grayling and bull trout. The results were repeatable. Population estimates were made using a Bayesian sequential closed population model. The replication of the mark-recapture experiment revealed that the recapture probabilities were heterogeneous which usually leads to an overestimation of population size. However, the consistency of the catchability coefficient across various population sizes and flow conditions argues that the impact was 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. The structured sequential sampling design was the same as 2002 and had similar efficiency.
4. Highly precise population (CV = 3.3%) and catchability (CV = 7.5%) estimates for mountain whitefish.
5. Verification that catchability is constant between river sections and years (thus catch-per-unit effort indices are comparable and representative of the population).

The very sparse recoveries for Arctic grayling made any point estimates of population size highly unreliable. For bull trout, population estimates are available, but the precision is poor (CV = 39%).

Relative Abundance as an Index of Population Size

Mountain whitefish data from two years of study demonstrated a strong positive relationship weighted relative abundance and population size. In addition, catchability was stable across sections and years and exhibited good precision (CV < 8%). Therefore, catch rate data for mountain whitefish are suitable to monitor trends in mountain whitefish abundance in the Peace River study area.

Recommendations

The results of the Phase 2 program indicated that the monitoring protocols were suitable to meet the objective of the program, particularly for mountain whitefish. The Phase 3 results confirmed these findings. Adjustments can be incorporated into future monitoring to improve the reliability of the data for other target species, but the basic strategy and effort employed by Phase 3 are sufficient to meet the overall objective of the Large River Program.

Recommendations to improve the monitoring program are as follows:

1. Maintain the present study design and sampling protocol with the following adjustments.
    a. There is no need to repeat the entire experiment to assess inter-annual variation in catchability. However, replication of the study in at least two sections would enable the application of multi-year open mark-recapture population models.
    b. Expand the program to include one or more downstream sections in the study area.
    c. Quantify recruitment by targeting younger mountain whitefish by modifying the present fish capture methodology.
    d. Quantify fecundity and sexual differences in growth of mountain whitefish.
2. Employ an alternate marking system (pit tags) to address the potential issue of detrimental effects caused by the current marking system (T-bar anchor tags).
3. Build an age-structured model that will serve to synthesize catch-per-unit-of-effort, age and abundance information. If such models are to be maintained and used for the evaluation of dam operation impacts there will be a need to collect long term information on population dynamics. The application of long-lasting marks such as pit tags would assist in this endeavor.
4. Investigate alternative sampling protocols for Arctic grayling and bull trout. This should include use of dedicated angling by qualified individuals.

ACKNOWLEDGEMENTS

Mainstream Aquatics Ltd. would like to thank Paul Higgins of BC Hydro for initiating the study and for providing timely assistance. We also thank the following persons who participated during the field program. Their hard work and interest in the program is appreciated.

Darren Sherbot	BC Hydro
David Hunter	BC Hydro

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

Rick Pattenden	Senior Biologist and Coauthor
Scott Millar	Project Biologist
Chantal Pattenden	Senior Technician
Charlene Williamson	Technician
Ash McKone	Technician
David Winarski	Freestone Fishing Systems
Alicia Goddard	Local Assistant

The individuals of W.J. Gazey Research responsible for the population estimate component 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 interpreting the water level data were as follows:

Mike Miles	Fluvial Geomorphologist
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1.0 INTRODUCTION

1.1 BACKGROUND

In 2001, BC 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 is to establish a cost-effective monitoring protocol for the Columbia River and Peace River systems to provide a reliable index of fish population characteristics. The scope of the program is to:

1. Develop standardized fish sampling protocols for trends in abundance, distribution, and biological characteristics of fish populations.
2. Advance the analytical framework to assess trends in the monitoring data and understanding how changes in habitat influence the fish populations.
3. Assess the costs and benefits of the implementation of a monitoring program in each watershed.
4. Provide recommendations for the long-term monitoring protocols in each watershed.

The program is designed to proceed in three phases over 3 to 5 years. In Phase 1 (2001/2002) sampling was undertaken to update basic information on fish populations and to test methodological assumptions. Phase 2 (2002/2003) efforts built on findings of Phase 1 to refine sampling and analytical strategies. Phase 3 (2003/2004) investigations were to continue to develop the time series data, refine sampling and analytical protocols, and provide recommendations on implementation of the index monitoring programs.

Mainstream Aquatics Ltd. (formerly P&E Environmental Consultants Ltd.) and its study team completed Phases 1 and 2 of the Peace River component of the Large River Program. The findings of the Phase 1 program were sufficient to recommend monitoring protocols in order to provide a reliable index of fish populations (P&E 2002). Phase 2, which evaluated the recommended protocols, established that reliable data could be generated for at least one target species (mountain whitefish) and made recommendations to further improve the study design (P&E and Gazey 2003). In May 2004, Mainstream Aquatics Ltd. was contracted by BC Hydro to complete Phase 3 of the Peace River component of the program.

The Mainstream study team employed during Phase 3 consisted of three members. Mainstream Aquatics Ltd. was the overall managing consultant and was responsible for the field program, the biological characteristics, and relative abundance components of the study. W.J. Gazey Research was responsible for the population estimate component. M. Miles and Associates Ltd. was responsible for the water level monitoring program used to ascertain whether discharge influenced fish sampling effectiveness.

1.2 APPROACH AND OBJECTIVES

At the recommendation of BC Hydro, the Phase 3 approach was essentially identical to that of Phase 2. The rationale for this was as follows:

1) To ensure continuity with Phase 2 sampling protocols.
2) To ascertain whether the results generated during Phase 2 are repeatable.
3) To assess inter-annual variation in catchability and other study parameters.

Because the sampling protocols remained unchanged, recommendations presented in the Phase 2 report were not incorporated into the Phase 3 program. The primary objectives of Phase 3 were as follows:

1) To extend the time series data on the biological characteristics, abundance, and distribution of nearshore fish populations.
2) To build on past investigations to further refine the sampling strategy, methodology, and analytical procedures.
3) To update the existing electronic storage and retrieval system for fish population and habitat monitoring data for the Peace River.
4) To identify gaps in our current knowledge of the fish populations and procedures for sampling and provide recommendations for future monitoring and fisheries investigations.

Two objectives were added to the Phase 3 program as follows:

1. Boat electrofisher operation protocols were standardized in an attempt to remove biases identified during Phase 2.
2. Attempts also were made to examine sexual differences in growth rate and maturity of mountain whitefish using incidental fish mortalities. This objective was not achieved because the number of incidental mortalities was too low to generate an adequate sample for investigation (<1% of the catch).

1.3 TARGET SPECIES

Three target species were investigated during Phase 3:

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

1.4 STUDY AREA

The study area was similar to that of Phase 2 (Figure 1.1). It encompassed a 75 km section of the Peace River from just upstream of the Moberly River confluence (Km 70) to just downstream of the PCN Dam (Km 145). As for Phase 2, this river portion represents 50% of the total study area targeted by the Large River Program on the Peace River.

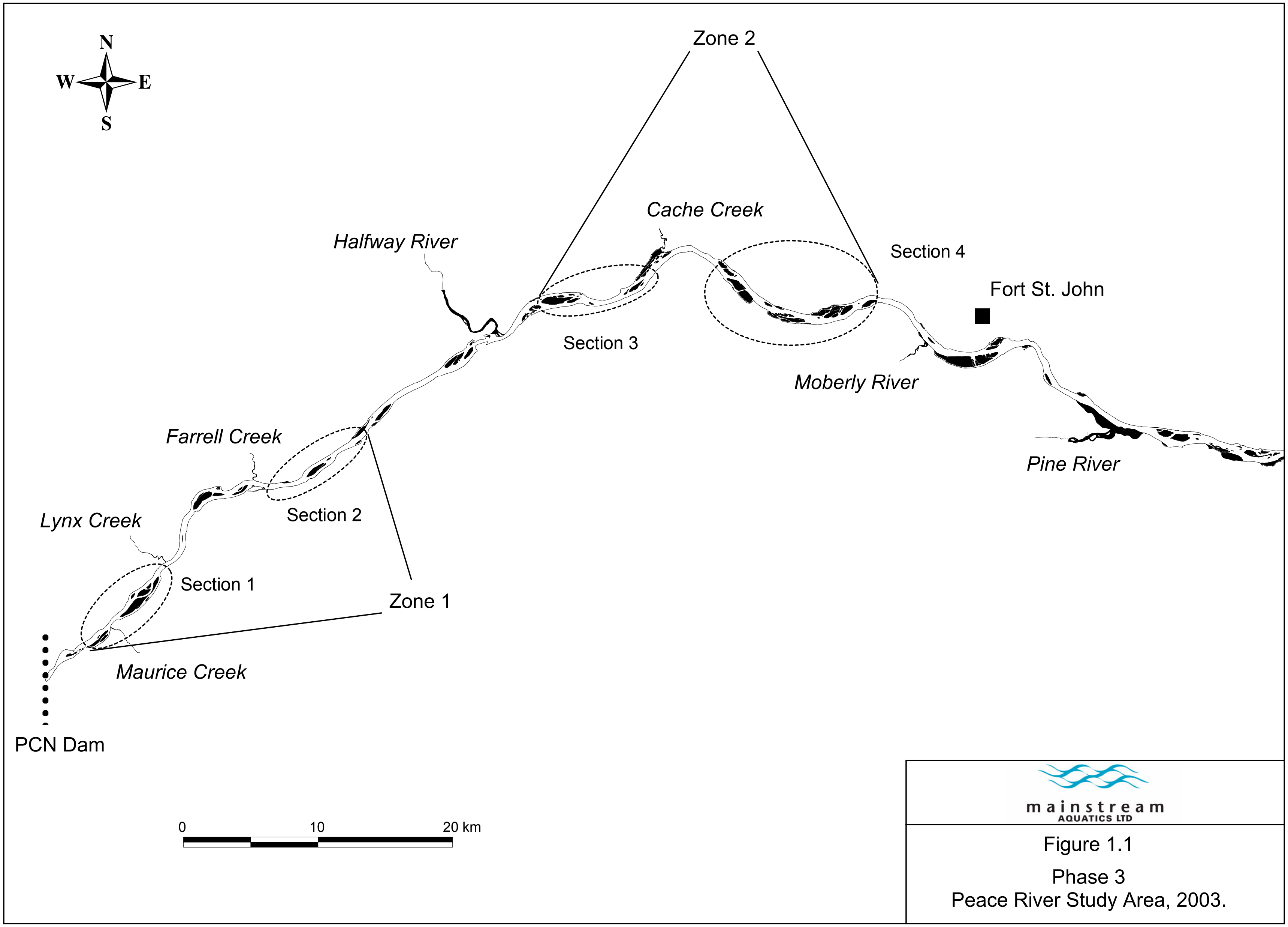

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Figure 1.1

Phase 3
Peace River Study Area, 2003.

Sampling was stratified into two zones (upstream and downstream of the Halfway River) each of which contained two sample sections (Table 1.1). This approach allowed an assessment of spatial differences in target fish population characteristics (differences between zones or sections). Based on this design, between 53% and 66% of the available nearshore habitats were sampled within each section. Each section was separated by at least 6 km to minimize the potential for mixing of fish.

Table 1.1 Locations of sections sampled during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Zone	**Section**	**Location**	**Section Length (km)**	**Sampled Length (m)[a]**	**Percent of Section Sampled[b]**
Upstream of Halfway River	1	Km 145.2 to 137.9	7.3	12 418	55.8
	2	Km 124.4 to 117.0	7.4	14 365	65.1
Downstream of Halfway River	3	Km 99.2 to 89.8	9.4	19 467	65.5
	4	Km 83.9 to 70.3	13.6	18 707	52.7

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

The number of sites sampled during the present study was reduced by one compared to Phase 2 (from 16 to 15 sites) as a way to reduce the work load of field crews. This represented a 7.5% to 5.0% reduction in sampling effort.

1.5 SAMPLE PERIOD

Phase 3 sampling occurred during a 42-day period from 22 August to 2 October 2003.

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 3 was to generate reliable population estimates for target fish species, the overall approach concentrated on achieving this goal. As such, the specific approach used for each of the other study components was adjusted to accommodate this requirement.

The basic study design involved repeated sampling of discrete sites located in defined river sections using a boat electrofisher (Table 2.1; Appendix A). Fifteen sites were sampled within each study section and each site represented one of two distinct habitat categories: nearshore habitat with physical cover (SFC) and nearshore habitat without physical cover (SFN). Sampling effort within each section was distributed as follows: eight SFC sites and seven SFN sites. Each site was sampled six times during the field program.

Table 2.1 Distribution of sampling effort (hours sampled) during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Zone	Section	Sampling Sequence						Total
		1	2	3	4	5	6	
Upstream of Halfway R.	1	2.1	2.1	2.1	1.9	2.2	2.0	12.4
	2	2.4	2.6	2.8	2.2	2.6	2.7	15.3
Downstream Halfway R.	3	3.3	3.4	3.2	2.8	3.3	3.4	19.4
	4	3.0	3.2	2.9	3.0	3.3	3.3	18.7
Total		**10.8**	**11.3**	**11.0**	**9.9**	**11.4**	**11.4**	**65.8**

Each of the first four sessions required two days to completely sample each section (7 to 8 sites per day). These sessions were used to collect information on all fish species encountered, to mark and recapture target fish species, and to collect data on biological characteristics from 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). During each of the last two sessions, attempts were made to completely sample each section in one day (15 sites). Using this approach, there was generally an eight-day rest period between sample events during sessions one to four and a four-day rest period between sessions five and six.

Sampling focused on two discrete habitat categories (SFC and SFN) rather than using a uniform, nonselective sampling method 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 3 of the Peace River Fish Community Indexing Program, 2003.

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.

In general, the length of each site sampled during the present study was identical to that sampled during Phase 2. The only exception occurred for Site 0304, which was shortened from 1357 m to 1257 m due to shallow water. The boundaries of each site were geo-referenced and marked with stakes prior to sampling. Site lengths ranged between 445 m and 1840 m (Appendix A).

2.1.2 Fish Capture Methods

A boat electrofisher was used to capture fish in near-shore habitats. Larger-sized fish were targeted (> 150 mm fork length) in water depths ranging from 0.5 to 2.0 m. Sampling was restricted to areas ≤ 2.0 m deep because 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 3.3 A, pulsed DC current, and a frequency of 60 Hz. These settings were sufficient to capture all three target species using the boat electrofisher and minimize injury rates of susceptible species such as mountain whitefish. The electrofisher settings used during Phase 3 were identical to those employed during the Phase 2 study.

The boat electrofisher 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 by monitoring 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 within the backwater 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. Netters were equipped with nets having a diameter of 45 cm and 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 and to net no more than one fish at a time.

The only exception to this 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, fish were released several hundred metres upstream in the same section.

2.1.3 Observed Fish

To ascertain the value of using observed fish to calculate catch rate, the field program used a standardized approach to enumerate observed fish. Each netter was instructed to count only 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. One inexperienced netter did not follow the sampling protocols; therefore, these data were excluded.

2.1.4 Processing Fish

All captured fish were held in a holding tank until processing. Data recorded for each fish included species, fork length (to the nearest 1 mm), weight (to the nearest 2 g), sexual maturity (stage of gonad development), 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 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.

2.1.5 Measured Parameters

In addition to fish capture and information on biological characteristics, other parameters measured for each site 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 for analysis during Phase 3 or stored for future reference as instructed by the Terms of Reference.

2.1.6 Measurement of Water Levels

Four instruments, the 8007WDP water depth logger manufactured by Unidata, that were purchased for the Phase 1 study were used to monitor water levels in each section. 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.

All four instruments were tested prior to being shipped to the field. During the field program, the water level gauge in Section 1 was destroyed because the data logger became flooded when a beaver severed the polyethylene tube. As such, data from the Water Survey of Canada (WSC) station at Hudson's Hope was used in its place.

The locations of the WSC station at Hudson's Hope and the four installed gauges are listed in Table 2.3.

Table 2.3 Water level gauge locations relative to fish sample sections during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Gauge	River Kilometre	Fish Sample Section
Instrument 1	145.3	1
WSC at Hudson's Hope	142.3	1
Instrument 2	117.2	2
Instrument 3	98.9	3
Instrument 4	73.6	4

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 3 findings were consistent with trends documented during Phase 2.

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 $P < 0.05$. To meet the assumptions required for parametric statistical analyses data were log-transformed where appropriate.

2.2.2 Biological Characteristics

Biological characteristics examined included size and age distribution, body condition, and growth rate. The analyses focused on whether samples from the entire study area could be combined, or whether the sample should be stratified by zone. Data collected from individual sections within each zone were grouped for the analysis. This was deemed appropriate because of the short distance separating the sections.

Size and Age Distribution

Fish of the three target species were measured for length. All collected Arctic grayling and bull trout were aged; however, the large numbers of mountain whitefish processed required use of a random subsample of ageing structures. A random number generator was used to select a minimum of 400 ageing structures from fish processed in each of the two zones.

Ageing procedures followed those described in Mackay *et al.* (1990). Fin rays were fixed in epoxy, sectioned with a jeweller'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. An experienced individual aged each structure. A second experienced individual randomly aged 20% of the sample as a quality control check.

Body Condition

The relationship between weight and length of fish can be used to monitor fish vigour. Fulton's Condition index (K) was used for this purpose. To minimize problems associated with correlations between fish length and body condition (Cone 1989), samples were stratified by age class for analyses. It should be noted that Relative Condition Factor (Kn) was employed in Phase 2. These values were changed to K in order to ascertain annual differences in fish condition.

Growth Rate

Age-at-length was used to assess whether growth rates of sampled populations differed spatially. The age-length relationship was described using a best-fit curvilinear regression based on a two-parameter logarithmic equation 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.

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 discussed in Section 3.2.2.

The approach used for statistical analyses of catch rate data was dependent on the questions asked and the characteristics of the data. For all analysis, it was assumed that catch rates differed between habitats; therefore, the data were stratified by habitat type. In general, data collected during each session were grouped prior to analysis, but in some instances a repeated measure design was employed.

Most procedures used to evaluate the influence of factors on catch rate are described in the results section for each assessment. Those requiring detailed descriptions are discussed as follows.

2.2.4 Water Levels

Water level data collected at gauging stations were corrected to account for the lag time between conditions at the gauge and a fish sample site using data generated during Phase 2 (Table 2.4).

Table 2.4 Summary of Phase 2 hydrographic information used to generate travel time between sample sections during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Section	Section Length (km)	Peak Discharge			Base Discharge			Adjustment (min)
		n	Travel Time[a] (h)	Water Velocity[b] (km/h)	*n*	Travel Time (h)	Water Velocity (km/h)	
1	8.2	21	0.68	12.0	36	0.90	9.13	0
2	8.2	21	0.68	12.0	36	0.90	9.13	30
3	9.4	20	0.85	11.2	35	1.07	8.78	30
4	13.6	20	1.23	11.2	35	1.54	8.78	15

[a] Estimate of time required for water to pass through sample section.
[b] Estimate based on distance between sections; Section 1 results based on comparison to WSC Station data.

Based on the distance travelled, the water level sample interval was adjusted to match that of the fish sample interval. Given the high water velocities in the sample sections (> 8.5 km/h) the midpoint of each sample section was used.

Scaled Water Levels

Water level readings from Instruments 2, 3 and 4 were first corrected to facilitate yearly comparisons. The readings of the present study were adjusted by comparing the vertical distances (i.e., bench mark to instrument) measured during Phase 2 and Phase 3.

Water level readings from Hudson's Hope and Instruments 2, 3 and 4 were standardized to facilitate comparison between sample sections. This was undertaken on the basis of the following formula:

$$SC = \frac{x_1 - x_2}{x_{\max} - x_{\min}} \times 20$$

Where:

SC =	standardized water depth (m)
x_1 =	observed water depth at Time 1 (m)
x_2 =	median water depth (m)
x_{max} =	maximum observed water depth (m)
x_{min} =	minimum observed water depth (m)

The standardized water depth was scaled to values between 10 and -10 by multiplying by 20.

Water Level Variability

An index of water level variability was calculated for various periods preceding fish sampling. This was undertaken by calculating the standard deviation of the scaled water depths over the periods of the preceding 6, 12, 24, 36 and 48 hours.

Water Level Trend Analysis

Trends in water level (i.e., rising or falling) identified by calculating the difference between 2 consecutive readings and determining the direction and magnitude of change, positive and negative values indicate rising or falling levels, respectively.

Categorizing Water Level

Water level data were categorized to facilitate comparisons with the catch rate data. Categories included water level, rate of change, and magnitude of variation. Categories were based on the distribution of the individual data points as follows:

Low	- < 25% quartile
Medium	- 25% ≤ and ≥ 75% quartile
High	- > 75% quartile

2.2.5 Power Analysis

The Z-value power equation illustrated below and described in Environment Canada and Department of Fisheries and Oceans (1995) was used to estimate the sample size (*n*) needed to detect a specified difference (δ) in catch rate (i.e., 10, 25, and 50% difference). Catch rate estimates and standard deviations (SD) used for the calculations were derived using the following steps. Catch rate estimates and standard deviations were calculated for a specified group (e.g., Arctic grayling in Section 1). The estimates and standard deviations were then pooled and an average calculated for each parameter. The test was based on a comparison of two independent samples and assumed a significance level (α) of 0.1 and a power ($1-\beta$) of 0.8; therefore, $Z_\alpha = 1.960$ and $Z_\beta = 1.282$ and:

$$n \geq \frac{2(Z_\alpha + Z_\beta)^2\, SD^2}{\delta^2} + \frac{Z_\alpha^2}{4}$$

2.2.6 Population Estimates and Catchability

A mark-recapture program was conducted on mountain whitefish, Arctic grayling and bull trout over the period August 22, 2003 to October 2, 2003 (duration of 42 days). Four 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 on fish encountered. As such, during the latter two sessions marks were applied only on scarce species (Arctic grayling and bull trout). Overall, the program was highly successful in terms of the number of 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.

The tagging program has some characteristics that must be considered with reference to the population estimation methodology and limitations of the subsequent 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. To the best of our knowledge, all potential candidates for population estimation for this mark-recapture study design assume homogeneous capture probabilities. Second, marks were applied only to fish ≥ 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 ≥ 250 mm when the study commenced. 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 past studies on the Peace River (P&E 2002, Pattenden at al. 1990 and 1991, P&E and Gazey 2003) sparse recoveries precluded the application of open population models (births and losses to the population are accommodated) suggested by Schwarz and Arnason (1996).

Table 2.5 Sampling dates by section and session and the study days used for the Jolly-Seber model during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Session	**Section**			
	One	**Two**	**Three**	**Four**
Actual Sampling Date				
1	22, 23 Aug	24, 25 Aug	25, 26, 27 Aug	27, 28, 29 Aug
2	30, 31 Aug	1, 2 Sep	3, 4 Sep	4, 5, 7 Sep
3	6, 8 Sep	9, 10 Sep	11, 12 Sep	13, 14 Sep
4	15, 16 Sep	17, 18 Sep	19, 20 Sep	21, 22 Sep
5	23 Sep	24 Sep	25, 26 Sep	26, 27 Sep
6	28 Sep	29 Sep	30 Sep, 1 Oct	1, 2 Oct
Mid or Study Day				
1	1	3	5	7
2	9	11	13	15
3	17	19	21	23
4	25	27	29	31
5	33	34	35	36

In order to address these characteristics, we first examined the capture behavior of the marked fish. Because a substantial number of mountain whitefish were marked in 2002 and were available for recapture in 2003, we compared (Exact Fisher test; Sokal and Rohlf 1969) the recapture rate and the time at large for releases made in 2002 and 2003. 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; Sokal and Rohlf 1969) for each section. Growth over the period of the 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). The movement of fish between sections within 2003 and over a year (marked in 2002 and recaptured in 2003) 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 all sections, the model selection was for a closed population (no change in population size over the period of the study). Therefore, a Bayesian mark-recapture model for closed populations (Gazey and Staley 1986, and Gazey 1994) was 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 2003 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 ≥ 250 mm to be a member of m_{ti}. For mountain whitefish, marks applied were also compiled as only newly marked fish in 2003 in order to calculate alternative population estimates. 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 and if it was a member of the recaptures (r_{ti}).

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

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

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

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

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.,

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

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

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

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

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

The corrected marks available, sample and recaptures (equations 3, 4 and 5) are the input information required by Gazey and Staley (1986) to form the population estimates.

The estimation of population size was accomplished with a Microsoft Excel© spreadsheet model that consists of macros coded in Visual Basic. The procedure requires the execution of two passes (macros update and estimate). First (execute macro update), the mark-recapture data are 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 user must specify the sections to be included in the estimate (coined a region), annual instantaneous removal rate, the proportion of undetected marks and the confidence interval percentage desired for the output. The model then assembles the adjusted mark-recapture data (equations 3, 4 and 5) and follows Gazey and Staley (1986) using the replacement model to compute the population estimates. Output includes 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 four sections using marks applied in 2002 and 2003, a start date of 21 August 2003, 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%. Other parameter values were tried in order to reveal the sensitivity of the population estimates to failures in the closed model assumptions. Population estimates for mountain whitefish were also generated for only newly marked fish in 2003. 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 for Arctic grayling 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.,

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

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 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

$$\hat{q}_i = \frac{\sum_t C_{ti}}{E_i \cdot N_i} \tag{7}$$

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

$$Var(\hat{q}_i) = \left(\frac{\sum_t C_{ti}}{E_i} \right)^2 Var\left(\frac{1}{N_i} \right) \tag{8}$$

where the reciprocal of estimated abundance is distributed normally and can be estimated using the following expression (Ricker 1975, p97):

$$Var\left(\frac{1}{N_i} \right) = \frac{\sum_t R_{ti}}{\left(\sum_t M_{ti} C_{ti} \right)^2} \tag{9}$$

In order to explore the precision that may be obtained under alternative sampling intensities, a simple power analysis was conducted on the Arctic grayling results from 1989 and 1990 studies and on mountain whitefish from 1989 and this 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:

$$M'_t = \left[1 - \left(1 - \frac{M_t}{\overline{N}} \right)^f \right] \cdot \overline{N} \tag{10}$$

$$C'_t = \left[1 - \left(1 - \frac{C_t}{\overline{N}} \right)^f \right] \cdot \overline{N} \tag{11}$$

$$R'_t = R_t \cdot \frac{M'_t}{M_t} \cdot \frac{C'_t}{C_t} \tag{12}$$

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 or fish examined is small in relation to the population size, a sampling factor of 2 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.

2.2.7 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 3. This information was used to update the Peace River database developed during Phase 2.

3.0 RESULTS AND DISCUSSION

Two primary objectives of Phase 3 were to extend the time series data describing nearshore fish populations in the Peace River and to ascertain whether the Phase 2 results were repeatable. The section provides a summary of the general characteristics of the fish community, an evaluation of the recommended monitoring protocols, and a comparison to Phase 2 results. The materials have been presented for the three principal monitoring components: biological characteristics, relative abundance, and population estimates. Raw data used for the analyses are provided in Appendices B, C, D, and E.

3.1 PEACE RIVER CONDITIONS

Peace River discharge during the 2003 field program differed from discharge recorded during 2002. Mean daily discharge was 20% lower during the majority of the sampling period (Figure 3.1). Hourly discharge within a 24-hour period also was more variable during the first half of the 2003 program. The coefficient of variation was 39 versus 23. In addition, river discharge tended to fall to lower levels (450 m^3/s) more often (22 sample days in 2003 versus 6 sample days in 2002).

These differences potentially affected the Phase 3 results. Changes in environmental conditions caused by lower and more variable discharge could influence fish biological characteristics. Also, more variable discharge could alter the effectiveness of fish capture by electrofishing and resulting in changes in catchability.

3.2 GENERAL CHARACTERISTICS OF THE FISH COMMUNITY

In total 13 104 fish representing 13 fish species were recorded from the Peace River study area in 2003 (Table 3.1). The species included 9 sportfish, 3 suckers, and 1 cyprinid. Mountain whitefish, which was one of the target species were very numerous and dominated the sample (11 949 fish or 91.2% of the sample). The two other target species were not abundant. Arctic grayling contributed only 1.1% to the sample, while bull trout accounted for 1.3%. After mountain whitefish, longnose sucker was the most prominent species (3.7%). The results were very similar to findings of the large-fish sampling component of Phase 1 in 2001 (P&E 2002) and Phase 2 in 2002 (P&E and Gazey 2003). Mountain whitefish was the dominant species followed by much lower numbers of all other species including sportfish. Longnose sucker was typically the second most numerous species recorded.

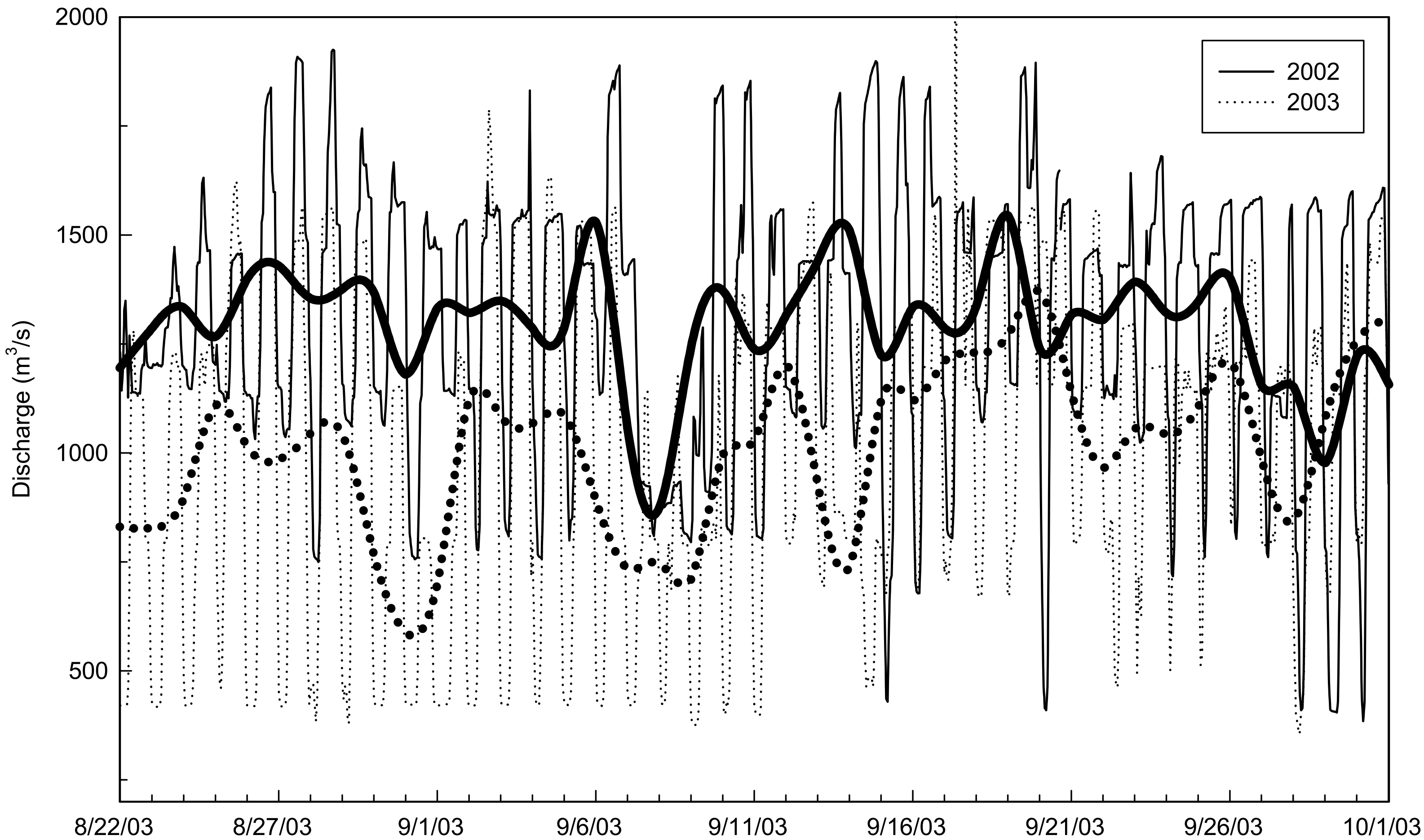


Figure 3.1 Comparisons of Peace River discharge during Phase 2 (2002) and Phase 3 (2003) of the Peace River Fish Community Indexing Program (Patterns represent daily means (thick lines) or meaurements at 15 minute intervals (thin lines). (Data from Water Survey of Canada Hudson Hope Station).

Table 3.1 Number and percent composition of fish species recorded during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Family	Common Name	Scientific Name	Composition	
			Number	Percent
Salmonidae	Arctic grayling	*Thymallus arcticus* (Pallas)	142	1.1
	Bull trout	*Salvelinus confluentus* (Suckley)	174	1.3
	Kokanee	*Oncorhynchus nerka* (Walbaum)	7	0.1
	Lake whitefish	*Coregonus clupeaformis* (Mitchill)	2	0.0
	Mountain whitefish	*Prosopium williamsoni* (Girard)	11 949	91.2
	Rainbow trout	*Oncorhynchus mykiss* (Walbaum)	133	1.0
Gadidae	Burbot	*Lota lota* (Linnaeus)	2	0.0
Esocidae	Northern pike	*Esox lucius* Linnaeus	5	0.0
Percidae	Walleye	*Stizostedion vitreum vitreum* (Mitchill)	4	0.0
Catostomidae	Largescale sucker	*Catostomus macrocheilus* Girard	170	1.3
	Longnose sucker	*Catostomus catostomus* (Forster)	481	3.7
	White sucker	*Catostomus commersoni* (Lacépède)	1	0.0
Cyprinidae	Northern pikeminnow	*Ptychocheilus oregonensis* (Richardson)	34	0.3
Total			**13 104**	**100.0**

The majority of the 13 fish species were widely distributed throughout the study area (Table 3.2). The exceptions were lake whitefish, burbot, northern pike, walleye, and white sucker, which were recorded in two or one section. As for the percent composition results, these findings were very similar to those of Phases 1 and 2.

Table 3.2 Spatial distribution of fish species recorded during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Name	Zone[a] 1		Zone 2	
	Section 1	Section 2	Section 3	Section 4
Arctic grayling	*	*	*	*
Bull trout	*	*	*	*
Kokanee	*	*	*	
Lake whitefish	*			
Mountain whitefish	*	*	*	*
Rainbow trout	*	*	*	*
Burbot			*	*
Northern pike				*
Walleye				*
Largescale sucker	*	*	*	*
Longnose sucker	*	*	*	*
White sucker				*
Northern pikeminnow	*	*	*	*

[a] Zone 1 upstream of the Halfway River; Zone 2 downstream of the Halfway River.

3.3 MONITORING COMPONENTS

3.3.1 Biological Characteristics

3.3.1.1 Arctic grayling

In total, 142 Arctic grayling were sampled for biological characteristics. When stratified by zone, sample sizes available for analyses were 18 and 124 fish in Zones 1 and 2, respectively. The low number of fish encountered in Zone 1 limits the value of the data in terms of describing the characteristics of the Arctic grayling population.

There were spatial differences in length and age distributions of Arctic grayling (Figure 3.2). Smaller fish < 250 mm fork length accounted for a greater percentage of the sample in Zone 2 compared to Zone 1. The difference was related primarily to the absence of Age 1 fish from Zone 1. Few Age 0 fish were encountered; a single individual was recorded in Zone 2. The results were consistent with the findings of Phase 2, which suggested that monitoring should be spatially stratified.

Predicted length-at-age curves for fish from each zone were generally similar (Figure 3.2). The slight difference in length-at-age for Age 1 fish may have been a reflection of the small sample size in Zone 1 (n=5), rather then a real difference in growth. Mean length-at-age results for Arctic grayling from each zone were similar (Table 3.3). Significant or near significant differences were recorded for Age 2 and Age 1 fish, respectively, but the results were contradictory.

Body condition-at-age of fish sampled from each zone also was similar (Table 3.4). The mean condition factor was approximately 1.30 for all age classes.

The results for length-at-age and body condition suggested that there were no spatial differences in the samples for these two parameters. This was similar to the results of Phase 2 and was expected. Arctic grayling are a migratory species; therefore, the Peace River population probably consists of mobile individuals that continually mix within the 75 km study area.

There were some yearly differences in biological characteristics of Arctic grayling (Figure 3.3). The strong Age 3 class recorded in Zone 1 in 2002 resulted in a strong Age 4 class the following year. Age 1 fish also were more prevalent in the Zone 2 sample in 2003 compared to 2002. This may result in a strong Age 2 class in 2004. Few differences in Arctic grayling age-class growth were recorded between years. Age 2 fish were the only group to exhibit a significantly greater length-at-age in 2003 compared to 2002. The body condition of sampled Arctic grayling tended to be greater in 2003 compared to 2002. This was apparent for Ages 1 to 4, but the differences were not significant.

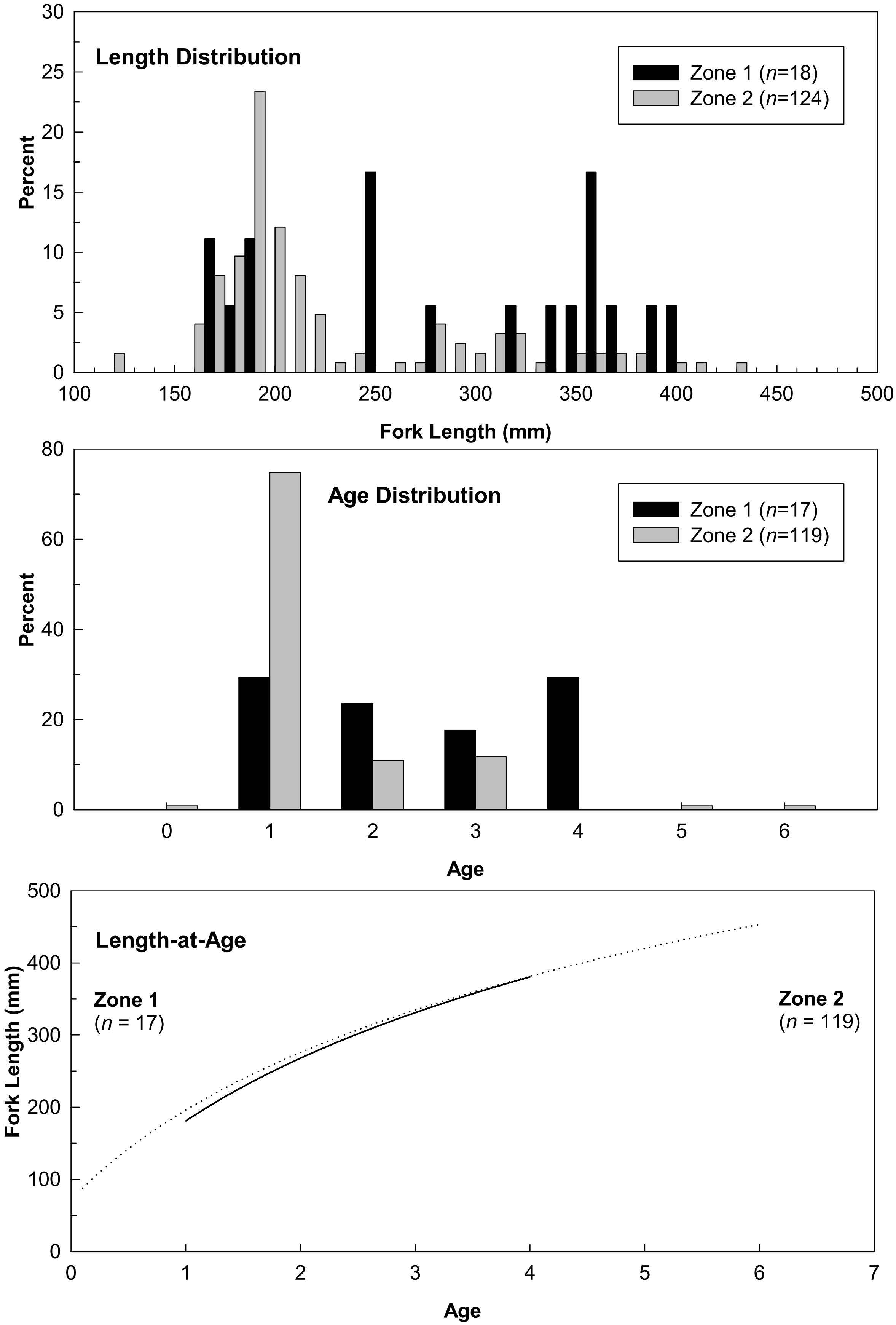


Figure 3.2 Length and age distributions and length-at-age relationships for Arctic grayling sampled during Phase 3 of the Peace River Fish Community Indexing Program, 2003. Best fit regression curve for age-length relationship generated using a two-parameter logrithmic equation [$y=a*\ln(x-x_o)$].

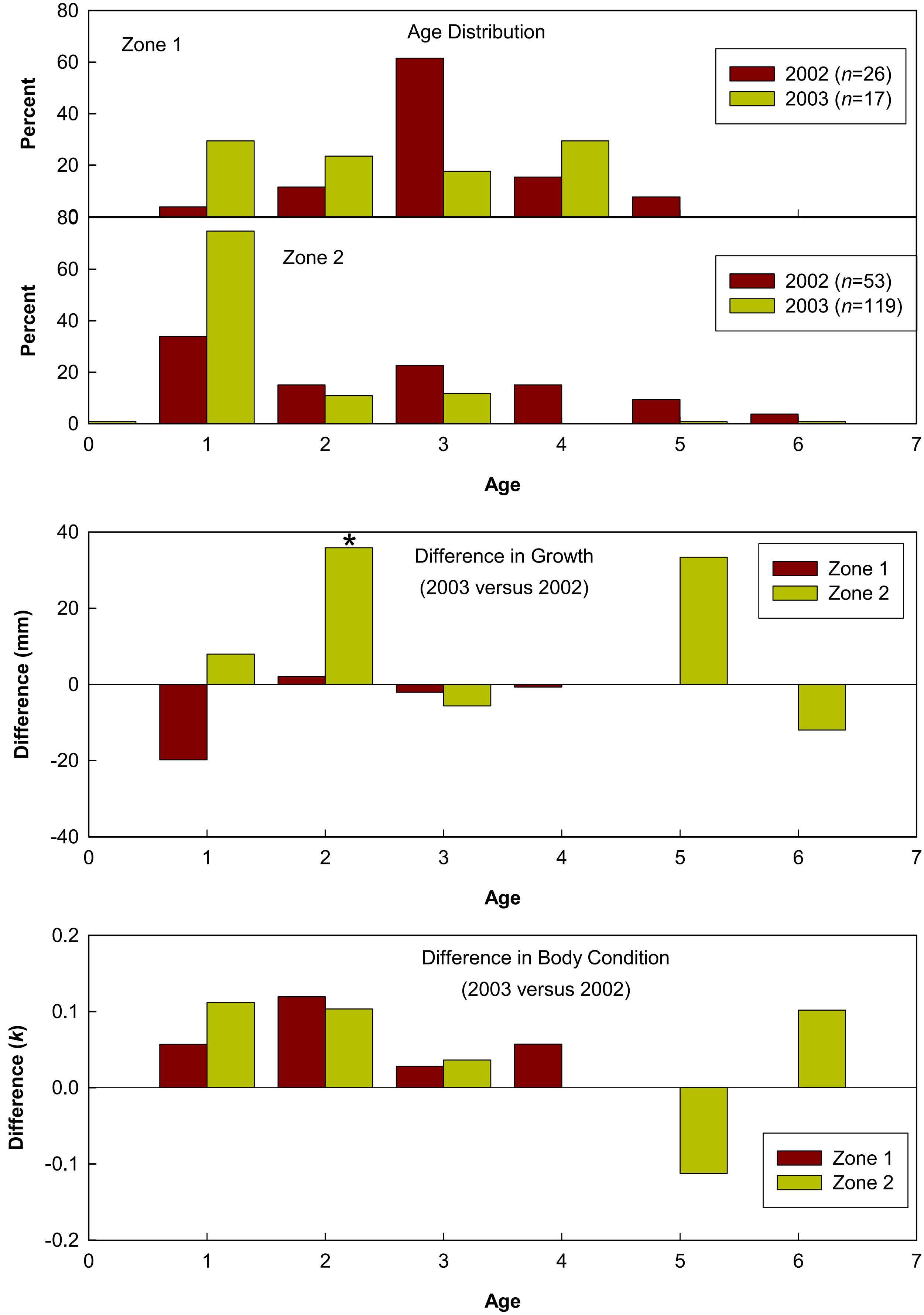


Figure 3.3 Yearly comparisons of age distribution, growth, and body condition of Arctic grayling sampled during the Peace River Fish Community Indexing Program, 2002 and 2003 (Asterix represents statistical difference between years at $P < 0.05$; Independent samples t-test).

Table 3.3 Mean length-at-age of Arctic grayling sampled during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Age	Zone 1		Zone 2		P-value[a]
	n	Mean Fork Length (± SE)	*n*	Mean Fork Length (± SE)	
0	-	-	1	120.0	-
1	5	183.2 ± 4.3	89	194.4 ± 1.7	0.117
2	4	259.8 ± 7.5	13	286.0 ± 5.4	0.027
3	3	339.3 ± 9.8	14	335.6 ± 7.4	0.830
4	5	379.8 ± 8.1	-	-	-
5	-	-	1	431.0	-
6	-	-	1	408.0	-

[a] Based on Independent samples t-test.

Table 3.4 Mean body condition-at-age of Arctic grayling sampled during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Age	Zone 1		Zone 2		P-value[a]
	n	Mean Body Condition (± SE)	*n*	Mean Body Condition (± SE)	
0	-	-	1	1.16	-
1	5	1.25 ± 0.03	87	1.30 ± 0.01	0.460
2	4	1.36 ± 0.05	13	1.38 ± 0.02	0.814
3	3	1.34 ± 0.04	14	1.37 ± 0.03	0.736
4	5	1.38 ± 0.06	-	-	-
5	-	-	1	1.16	-
6	-	-	1	1.35	-

[a] Based on Independent samples t-test.

3.3.1.2 Bull trout

In total, 174 bull trout were sampled for biological characteristics. When stratified by zone, sample sizes available for analysis were 72 and 102 fish in Zones 1 and 2, respectively.

Length and age distributions of the bull trout sample suggested that there were spatial differences in the population structure (Figure 3.4). Smaller fish < 300 mm fork length were more prominent in Zone 1 compared to Zone 2 due to the prevalence of Age 2 and Age 3 fish. No Age 0 or Age 1 fish were recorded from the sample. The absence of Age 6 bull trout from Zone 1 was unexpected. This also was a weak age class in 2002. It is possible that Age 6 fish belong to a spawning cohort that had not returned from streams in the Halfway River system, or this age class simply did not use the upper Peace River system. Overall, the results were consistent with findings during Phase 2.

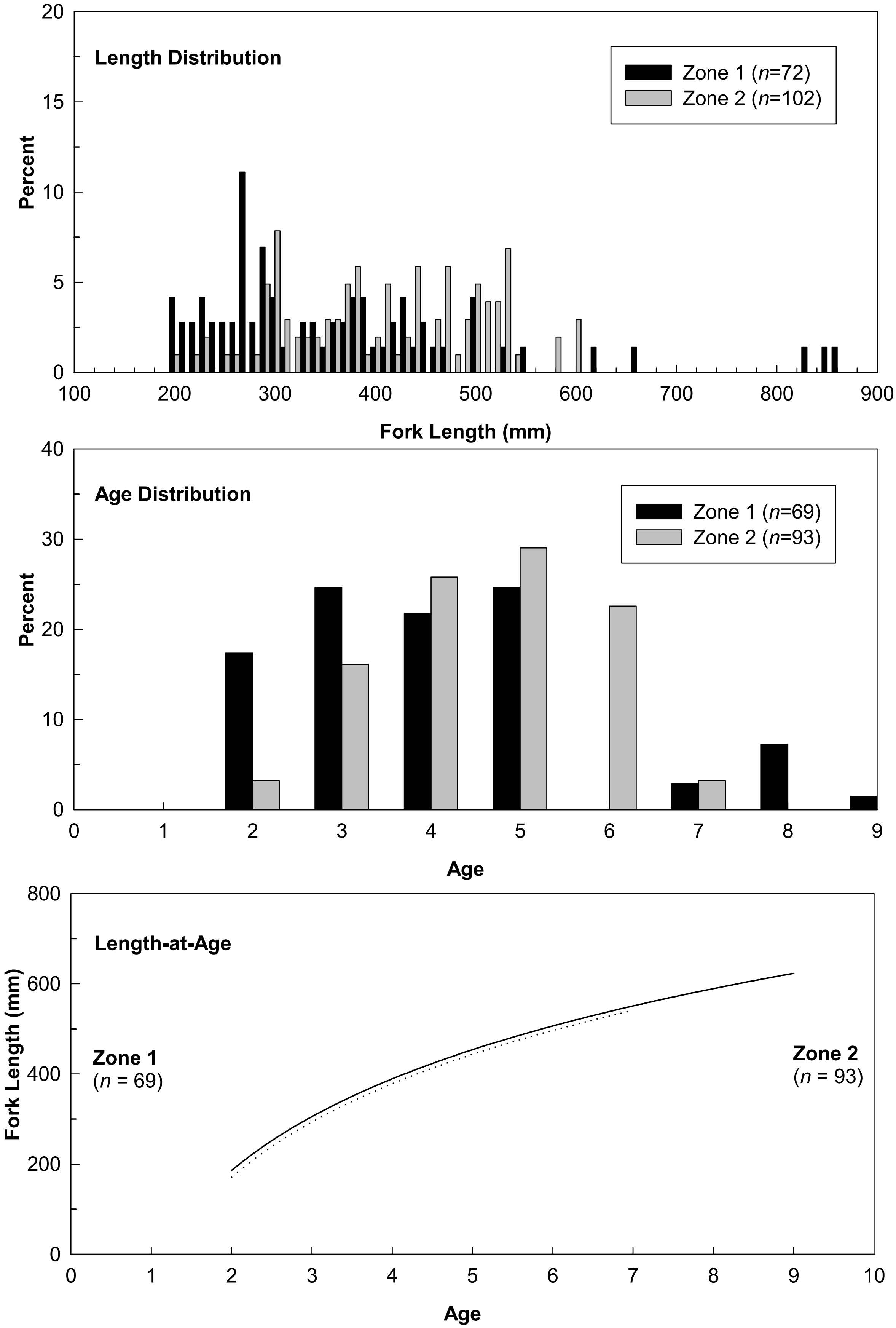


Figure 3.4 Length and age distributions and length-at-age relationships for bull trout sampled during Phase 3 of the Peace River Fish Community Indexing Program, 2003. Best fit regression curve for age-length relationship generated using a two-parameter logrithmic equation [$y=a*\ln(x-x_o)$].

A visual assessment of length-at-age data suggested that growth rates of bull trout in Zones 1 and 2 were similar. However, mean length-at-age data did not support this observation (Table 3.5). Bull trout sampled from Zone 2 tended to be larger at a given age than bull trout in Zone 1 (all except Ages 2 and 4); however, the differences were not significant. Although the fit of each curvilinear regression line was considered good ($r^2 \geq 0.750$), there is too much variation to establish whether there are spatial differences in growth. The results were consistent with Phase 2 findings.

Table 3.5 Mean length-at-age of bull trout sampled during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Age	**Zone 1**		**Zone 2**		**P-value**[a]
	n	**Mean Fork Length (± SE)**	***n***	**Mean Fork Length (± SE)**	
1	-	-	-	-	-
2	12	233.3 ± 7.1	3	226.7 ± 12.9	0.676
3	17	278.7 ± 5.3	15	295.7 ± 8.8	0.099
4	15	354.2 ± 11.9	24	351.6 ± 7.5	0.848
5	17	425.7 ± 12.2	27	440.4 ± 9.2	0.331
6	-	-	21	514.0 ± 10.5	-
7	2	519.0 ± 12.0	3	572.3 ± 21.5	0.164
8	5	62.8 ± 62.8	-	-	-
9	1	835	-	-	-

[a] Based on Independent samples t-test.

The body condition of bull trout sampled from each zone was similar (Table 3.6). The mean condition factor was approximately 1.00 for all age classes.

Table 3.6 Mean body condition-at-age of bull trout sampled during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Age	**Zone 1**		**Zone 2**		**P-value**[a]
	N	**Mean Fork Length (± SE)**	***n***	**Mean Fork Length (± SE)**	
1	-	-	-	-	-
2	12	1.04 ± 0.02	2	0.96 ± 0.03	0.194
3	16	0.01 ± 0.03	15	1.03 ± 0.02	0.586
4	14	1.00 ± 0.02	24	1.03 ± 0.02	0.419
5	17	1.03 ± 0.01	25	1.00. ± 0.02	0.145
6	-	-	20	0.99 ± 0.02	-
7	2	0.94 ± 0.05	3	1.03 ± 0.03	-
8	5	1.12 ± 0.06	-	-	-
9	1	0.91	-	-	-

[a] Based on Independent samples t-test.

Some yearly differences in biological characteristics were recorded for sampled bull trout (Figure 3.5). As indicated earlier, the weak Age 6 bull trout class in Zone 1 during 2002 was entirely absent in 2003. The Age 2 class in Zone 1 also was stronger compared to 2002.

Bull trout tended to exhibit a smaller mean length-at-age in 2003 compared to 2002 in both zones. Age 5 fish in Zone 2 was the only group that exhibited a significant difference in mean length-at-age. No significant yearly difference in body condition was recorded, but fish condition tended to be lower in 2003.

The results for bull trout suggested that the population structure (size and age distributions) differed between zones and this was consistent with findings of Phase 2. There were also apparent yearly differences in growth and body condition, but the differences were not significant. As for Phase 2, the findings highlight two issues. First, spatial differences in the bull trout population indicate that monitoring should incorporate spatial stratification. Second, the variation in length-at-age data will necessitate collection of larger sample sizes in order to detect statistical differences in biological characteristics.

3.3.1.3 Mountain whitefish

In total, 8798 fish were measured for length and weight. In all, 828 fish or 9.4% of the sample were aged.

A comparison of length and age frequency distributions of mountain whitefish indicated that there were spatial differences in the population structure (Figure 3.6). Fish in Zone 1 exhibited a condensed bi-modal size distribution (modal peaks at 260 mm and 320 mm fork length). Fish < 175 mm fork length and > 360 mm fork length were largely absent from Zone 1. The results can be explained by the scarcity of fish in age classes 1, 7 and 8, and the preponderance of fish aged 3, 4 and 5. Mountain whitefish in Zone 2 exhibited a much broader multi-modal size distribution. Modal peaks occurred at 160 mm, 210 mm, 300 mm, and 340 mm fork length. As expected, the age distribution of sampled mountain whitefish in Zone 2 also was more evenly distributed (Ages 1 to 9), where as Ages 3 to 5 dominated in Zone 1. The results were similar to Phase 2. There were spatial differences in the size and age structure of the mountain whitefish population.

Length-at-age data also suggested spatial differences in growth (Figure 3.6; Table 3.7). Fish Age 4 and older in Zone 2 were larger at a given age and several of the differences were significant. The findings were similar to the results of Phase 2.

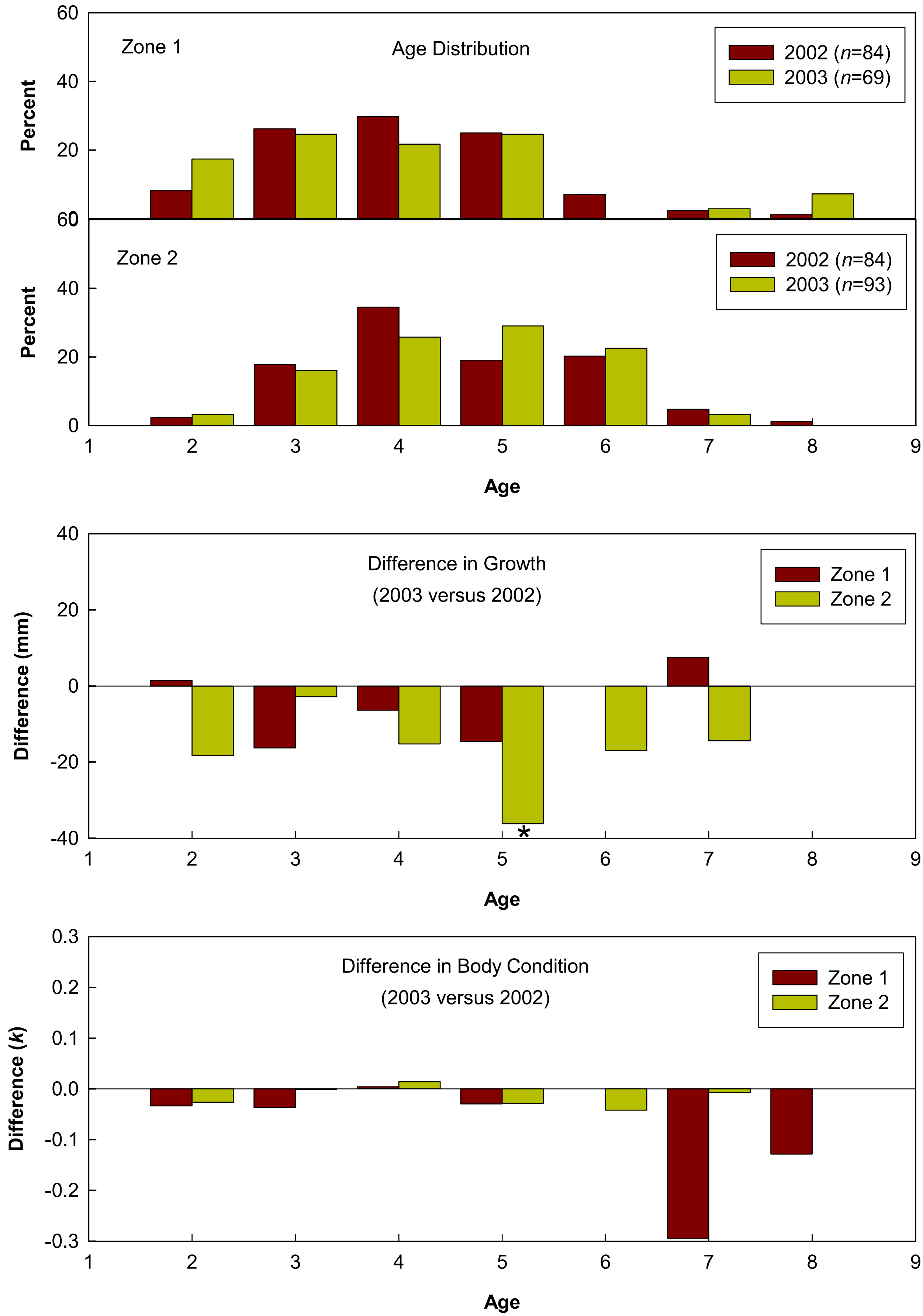


Figure 3.5 Yearly comparisons of age distribution, growth, and body condition of Bull trout sampled during the Peace River Fish Community Indexing Program, 2002 and 2003 (Asterix represents statistical difference between years at P < 0.05; Independent samples t-test).

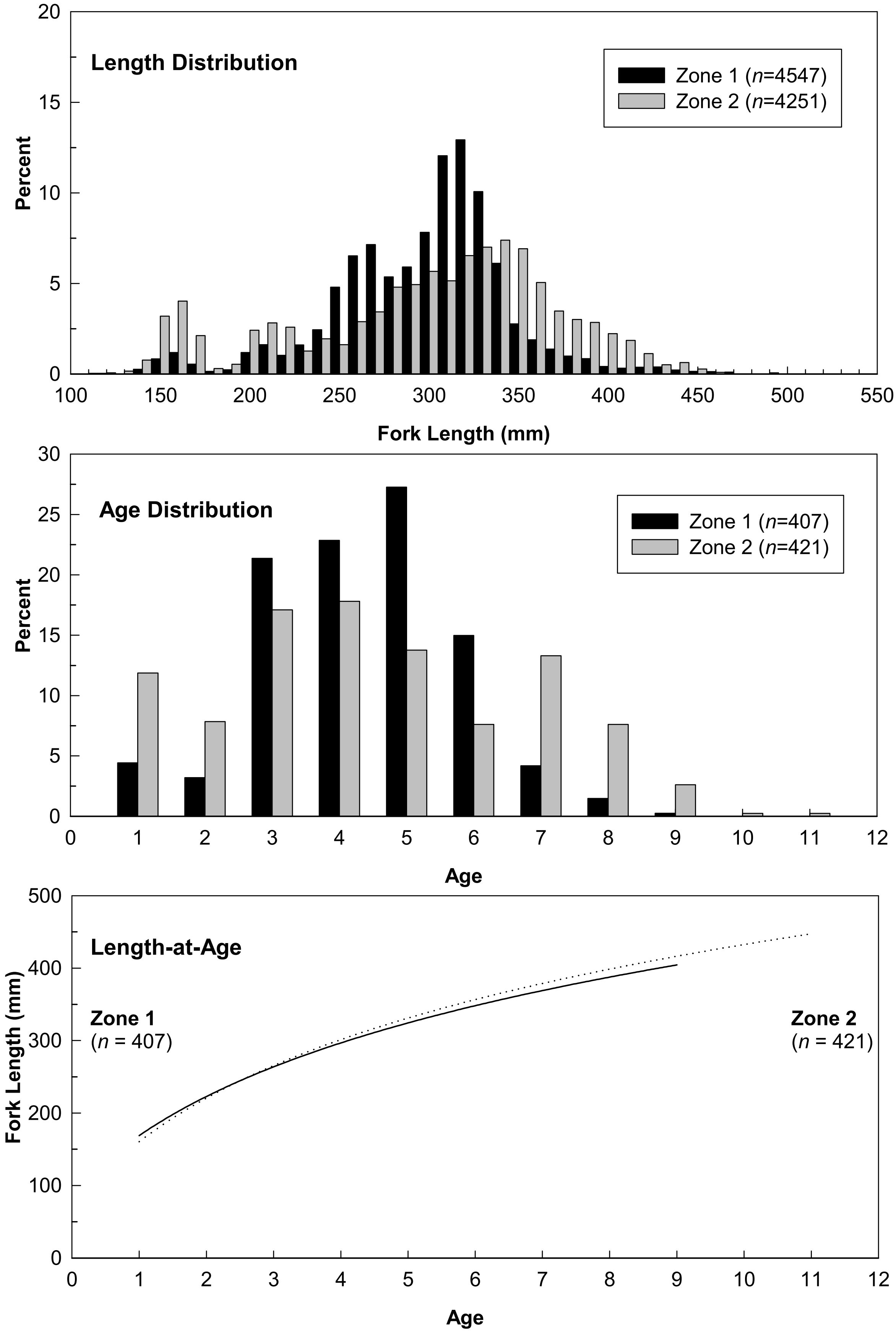


Figure 3.6 Length and age distributions and length-at-age relationships for mountain whitefish sampled during Phase 3 of the Peace River Fish Community Indexing Program, 2003. Best fit regression curve for age-length relationship generated using a two-parameter logrithmic equation [$y=a*\ln(x-x_o)$].

Table 3.7 Mean length-at-age of mountain whitefish sampled during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Age	Zone 1		Zone 2		P-value[a]
	n	Mean Fork Length (± SE)	*n*	Mean Fork Length (± SE)	
1	18	160.7 ± 1.8	50	161.2 ± 1.5	0.843
2	13	210.2 ± 2.3	33	213.3 ± 1.7	0.297
3	87	270.7 ± 2.2	72	264.0 ± 2.4	0.042
4	93	298.8 ± 2.4	74	308.0 ± 1.7	0.001
5	110	324.9 ± 1.6	59	335.0 ± 1.5	0.000
6	62	339.1 ± 2.1	31	354.5 ± 3.6	0.000
7	17	360.2 ± 5.9	56	371.2 ± 2.2	0.038
8	6	406.3 ± 13.8	33	392.8 ± 3.4	0.415
9	1	478.0	11	431.0 ± 4.8	-
10	-	-	1	447.0	-
11	-	-	1	475.0	-

[a] Based on Independent samples t-test.

Body condition of mountain whitefish sampled from each zone were not statistically different for all but Age 3 fish (Table 3.8). In general, the mean condition factor was approximately 1.10. The results were contrary to findings of Phase 2, where mountain whitefish body condition tended to be greater in Zone 1 compared to Zone 2.

Table 3.8 Mean body condition-at-age of mountain whitefish sampled during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Age	Zone 1		Zone 2		P-value[a]
	n	Mean Body Condition (± SE)	*n*	Mean Body Condition (± SE)	
1	18	1.06 ± 0.04	49	1.14 ± 0.01	0.072
2	13	1.14 ± 0.02	31	1.10 ± 0.02	0.170
3	86	1.19 ± 0.01	68	1.11 ± 0.01	0.000
4	92	1.12 ± 0.01	74	1.12 ± 0.01	0.846
5	108	1.09 ± 0.01	57	1.08 ± 0.01	0.423
6	60	1.08 ± 0.01	29	1.07 ± 0.01	0.498
7	17	1.08 ± 0.03	52	1.06 ± 0.01	0.585
8	6	1.01 ± 0.03	31	1.07 ± 0.02	0.216
9	1	1.35	10	0.99 ± 0.03	-
10	-	-	1	0.80	-
11	-	-	1	1.10	-

[a] Based on Independent samples t-test.

There were yearly differences in biological characteristics of sampled mountain whitefish (Figure 3.7). The strong Age 3 class recorded in Zone 1 in 2002 resulted in a strong Age 4 class the following year. Also, Age 1 fish were more prevalent in Zone 2 in 2003, which could result in an increase of Age 2 fish in 2004. The majority of age classes in both zones demonstrated an increase in mean length between 2002 and 2003. The difference in growth was significant for the majority of comparisons. A similar pattern also was observed for mean body condition-at-age. Sampled mountain whitefish body condition in Zones 1 and 2 were greater in 2003 compared to 2002. The differences also were significant for the majority of comparisons.

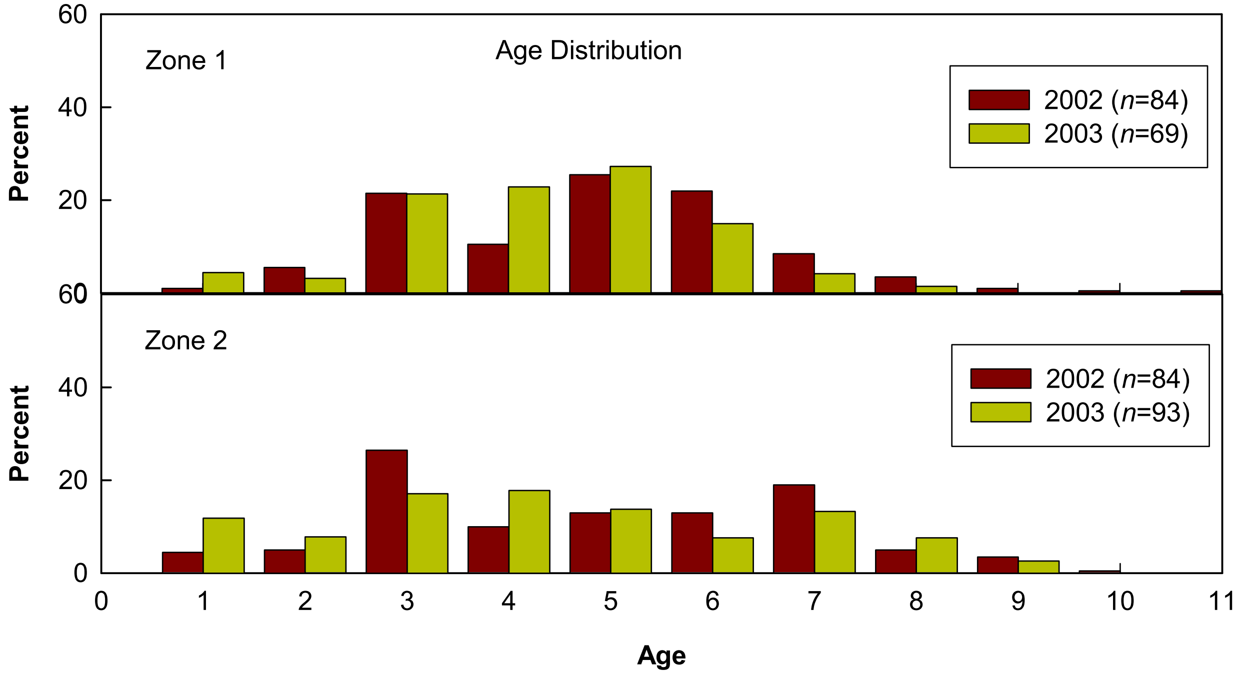
Overall, the Phase 3 data suggests that the mountain whitefish population in the Peace River study area exhibited spatial differences in biological characteristics and the results were consistent with Phase 2. As such, monitoring should continue to be stratified. The results also suggested yearly differences in growth and body condition. The mechanism(s) driving the differences are unknown, but factors such as discharge, water temperature, and primary productivity may play a role.

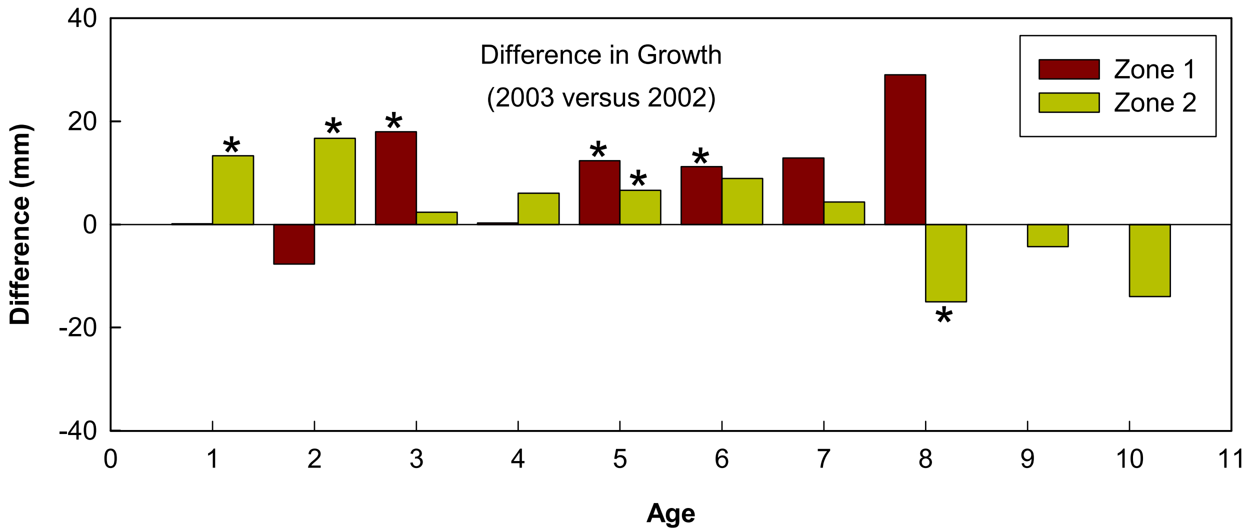
3.3.1.4 Incremental Growth and Project Effects

As a check of the accuracy of the length-at-age estimates, information derived from age data were compared to incremental growth data from marked fish tagged in 2002 and recaptured in 2003. It was assumed that the incremental growth of these fish was representative of the actual growth of the sample population. If growth among the two groups was similar, this would confirm the accuracy of the length-at-age estimates and the fish ages on which the estimates were based.

The assessment was restricted to mountain whitefish because sample sizes for other target species were limited (n = 1 for Arctic grayling and n < 5 for bull trout). Incremental growth of mountain whitefish ranged from 13.1 to 1.0 mm (Table 3.9). Most sample sizes available for analysis in each age class (fish Aged 2 to 7) were greater than ten; therefore, the estimates should be representative of incremental growth of individuals in the sample population.

Incremental growth of mountain whitefish was much lower then expected and was well below the age derived growth estimates. Differences ranged from 47% to more than 95% and these findings were consistent in both Zones 1 and 2. The results suggested that either the age growth data or the incremental growth data were not representative of actual growth.





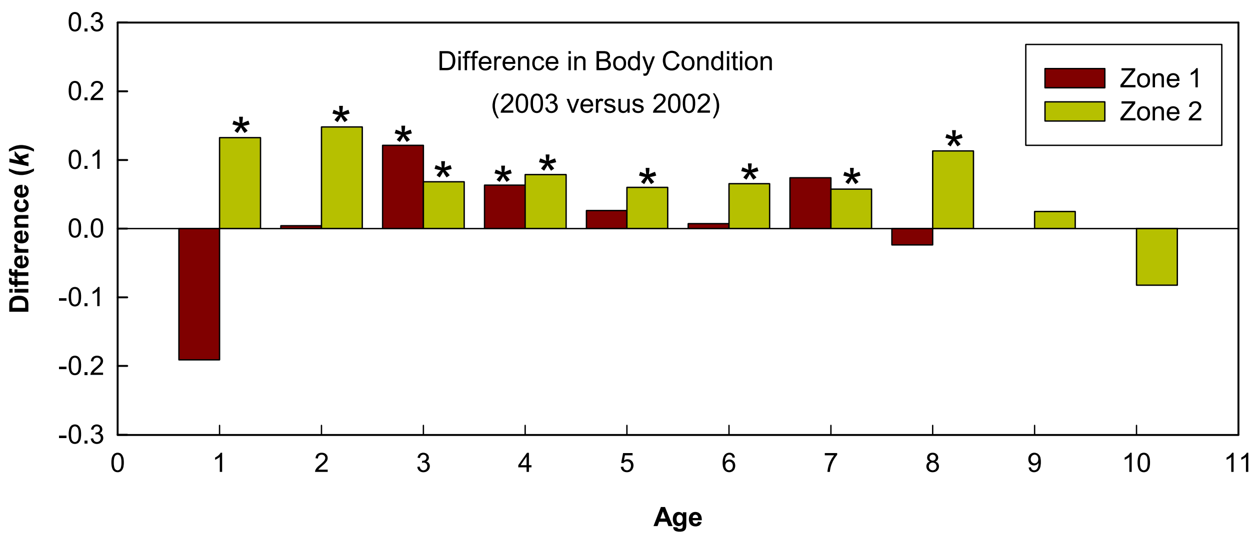


Figure 3.7 Yearly comparisons of age distribution, growth, and body condition of Mountain whitefish sampled during the Peace River Fish Community Indexing Program, 2002 and 2003 (Asterix represents statistical difference between years at P < 0.05; Independent samples t-test).

Table 3.9 Comparison of mountain whitefish growth estimates derived from aged fish and from tagged fish during the Peace River Fish Community Indexing Program, 2003.

Age	Zone 1				Zone 2			
	Age Growth		Incremental Growth		Age Growth		Incremental Growth	
	n	Millimeters (± SE)	*n*	Millimeters (± SE)	*n*	Millimeters (± SE)	*n*	Millimeters (± SE)
1	18	49.5 ± 1.49			50	52.1 ± 0.71		
2	13	60.6 ± 1.98			33	50.6 ± 1.00	9	9.8 ± 2.28
3	87	28.1 ± 0.69	11	13.1 ± 1.62	72	44.1 ± 0.69	23	4.0 ± 1.38
4	93	26.1 ± 0.56	6	9.5 ± 4.03	74	27.0 ± 0.56	35	2.6 ± 1.19
5	110	14.2 ± 0.59	19	2.4 ± 1.26	59	19.5 ± 1.14	23	2.4 ± 1.09
6	62	21.2 ± 2.22	22	4.7 ± 1.33	31	16.4 ± 1.32	14	2.8 ± 1.06
7	17	46.1 ± 9.40	16	2.5 ± 2.04	56	22.0 ± 1.24	10	3.5 ± 1.83
8			3	1.0 ± 2.52	33	38.2 ± 3.03	4	-0.25 ± 1.03

Growth estimates generated from the age data ranged from 61 mm (Age 2 fish in Zone 1) to 14 mm (Age 5 fish in Zone 1), which was expected for this population. As an alternative check for accuracy, comparisons were made to size intervals between modal peaks that were depicted by mountain whitefish length distributions (Figure 3.6). Age 1 fish in Zones 1 and 2 exhibited growths of 49.5 and 52.1 mm, respectively (Table 3.9). The size interval between Age 1 and Age 2 fish was 50 mm in both zones. Similarly, the 60 mm size interval for fish between Age 2 and Age 3 fish in Zone 1 was similar to the growth estimate of 60.6 mm. Comparisons for older fish could not be undertaken because of obscured age-specific modal peaks in the length distributions. Based on this information, the growth estimates derived from the age data, at least for younger fish, were deemed to be accurate.

One should conclude from this assessment that the incremental growth data were not valid. Therefore, the data should not be used as a check of the accuracy of the length-at-age estimates or the ages on which estimates were based.

An important issue that should be examined further is the reason (s) why the incremental growth data were not valid. Incremental growth data of marked fish was less then expected, which suggested that project activities may have had a detrimental effect on fish. Mountain whitefish were captured using a boat electrofisher, processed, and marked with uniquely numbered T-bar anchor Floy tag (FD-94). Each or a combination of these activities had the potential to adversely affect fish growth. The effect of project activities was evaluated by examining body condition, which is an indicator of fish health. This was accomplished by comparing two groups of tagged fish: fish marked in 2002 and recaptured in 2003 and fish marked in 2003 and recaptured in 2003.

Both groups received the same treatment (i.e., captured by boat electrofisher, processed, and tagged), but the 2002 fish were at large for a longer time period (approximately 365 days).

The body condition of mountain whitefish tagged in 2002 and recaptured in 2003 was lower than the body condition of fish that had been tagged and recaptured in 2003 (Table 3.10). The difference was highly significant for samples in both Zones 1 and 2. Similar to results for incremental growth, the body condition of sampled mountain whitefish appeared to be adversely affected by project activities.

Table 3.10 Mean body condition of mountain whitefish groups[a] during the Peace River Fish Community Indexing Program, 2003.

Zone	Group 1 (2002 Tags)		Group 2 (2003 Tags)		P-value[b]
	n	**Body Condition (± SE)**	***n***	**Body Condition (± SE)**	
1	100	1.057 ± 0.010	42	1.136 ± 0.022	0.000
2	116	1.047 ± 0.008	26	1.121 ± 0.019	0.000

[a] Group 1 - Fish marked in 2002 and recaptured in 2003; Group 2 - Fish marked in 2003 and recaptured in 2003.
[b] Based on Independent samples t-test of aged sample.

Several mechanisms have the potential to cause an adverse effect on fish. Tagging can reduce fish growth in a number of ways (Manire and Gruber 1991; Mourning *et al.* 1994). These include low-grade bacterial infections facilitated by the open wound that surrounds the tag insertion point, electrolyte loss through the tag wound, and increased energetic costs associated with increased swimming drag. Inappropriate boat electrofishing also can be detrimental to fish by causing injury or death (Gatz *et al.* 1986; Hollender and Carline 1994; Dwyer and White 1997, Thompson et al. 1997).

Direct mortality of mountain whitefish associated with boat electrofisher capture was negligible during Phase 3. In total, 32 mountain whitefish suffered accidental mortality during the program, which represented 0.38% of the catch. This value does not account for delayed mortality or reduced growth associated with nonlethal injuries. This effect was examined indirectly by comparing the percentage of sample that had the potential to be tagged (≥ 250 mm), but that were not marked. Fish that were excluded from tagging exhibited at least one condition: abnormal swimming behaviour, lethargy, evidence of blood vessel rupture in the fins, or physical injury. The percentage of the sample consisting of fish deemed unsuitable for tagging represented a conservative estimate of the number of fish that may have suffered delayed mortality caused by boat electrofisher capture.

Less than 5% of mountain whitefish captured by boat electrofisher were deemed unsuitable for tagging (Table 3.11). Values ranged from 4.4% in Section 1 to 2.2% in Section 4. In addition, a large number of samples contained no fish that fit this category (44% to 64%). These data indicated that a low percentage of the sample may have suffered delayed mortality caused by boat electrofisher capture.

Table 3.11 Percentage of mountain whitefish sample that suffered potential injury during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Section	Percentage of Fish in Sample Demonstrating Potential Injury		95% C.I.		Percentage of Samples Containing No Fish that Demonstrated Potential Injury
	n	Mean	Lower	Upper	
1	85	4.4	3.2	5.7	43.5
2	83	2.4	1.5	3.2	62.7
3	89	2.9	1.6	4.1	64.0
4	89	2.2	1.5	2.8	61.8

In summary, project activities may have adversely affected the mountain whitefish sample population (i.e., reduced growth and body condition). It appears that use of the T-bar anchor tag rather than effects of boat electrofisher capture may have been the primary mechanism that adversely affected mountain whitefish.

3.3.2 Relative Abundance

Results of Phase 1 and Phase 2 indicated that relative abundance, or catch rate, was a suitable monitoring tool for the Peace River Fish Community Indexing Program; however, a number of factors influenced the reliability of the data. First, a structured sampling protocol was needed to increase sample precision and help stabilize catchability. Second, the variable nature of the data necessitated use of stratified sampling. An objective of Phase 3 was to establish whether the Phase 2 results were repeatable. This would provide evidence to support the recommended approach regarding use of relative abundance as a monitoring tool.

3.3.2.1 Sampling Protocols

Influence of Boat Operation

Two crews were used to sample fish during the field program, each of which consisted of two netters and an experienced boat operator. The results of Phase 2 suggested that catch rates for Arctic grayling and bull trout were influenced by boat operation. Indirect evidence suggested that differences in sampling effort (time) was an important factor. During Phase 3, attempts were made to eliminate this bias by further standardizing operation of the boat electrofisher by each crew.

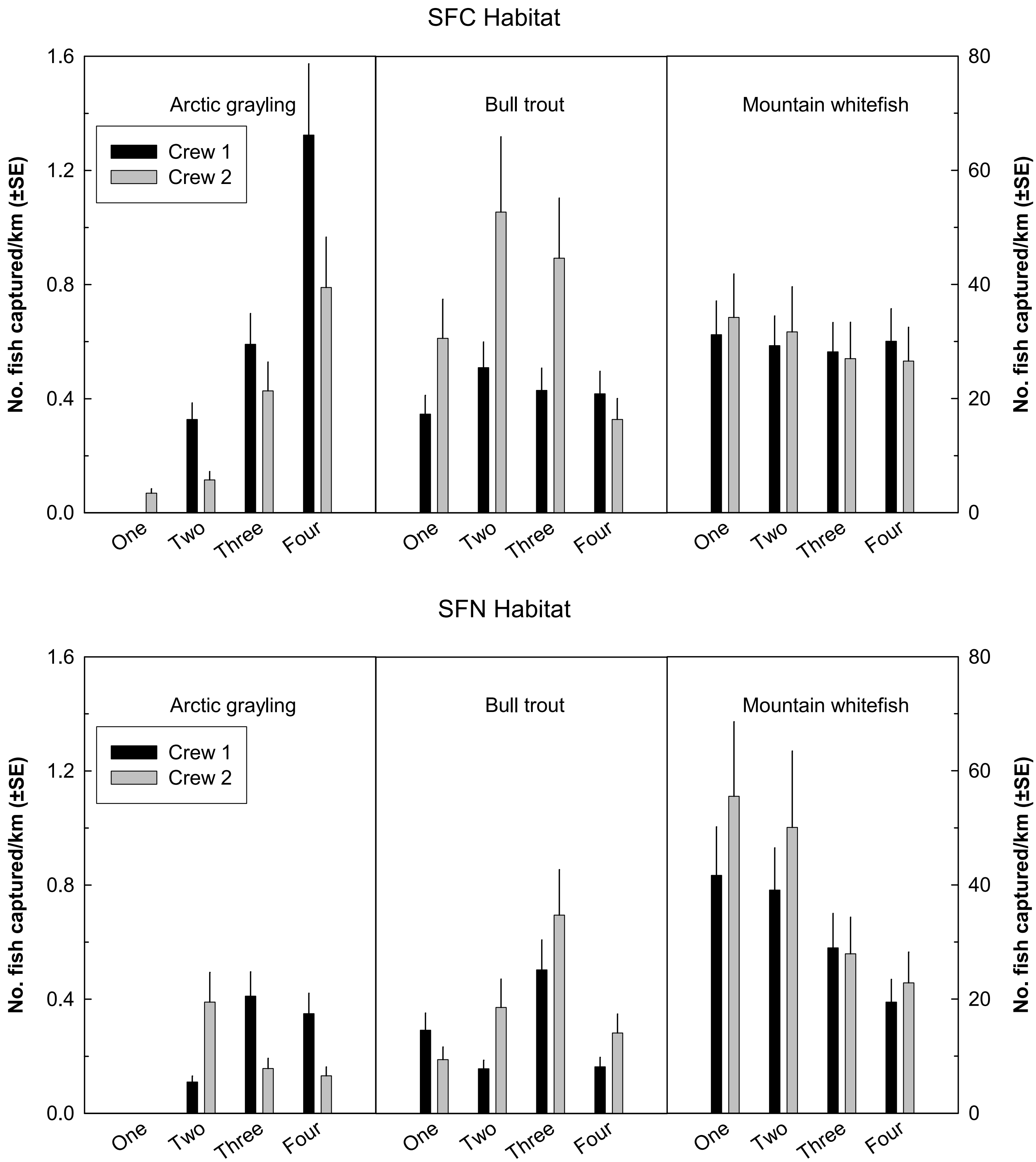


Figure 3.8 Relationship between mean catch rate of target fish species and crew in two habitat categories during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Crew catch rates for some species differed during the present study (Figure 3.8). For Arctic grayling the mean catch rate for Crew 1 tended to be higher than the mean catch rate for Crew 2 in both SFC and SFN habitats. The opposite trend occurred for bull trout. Crew 2 tended to have higher mean catch rates then Crew 1. The variable nature of the data and low values for these two species precluded statistical analyses. For mountain whitefish, the differences in crew catch rate were small and they were not significant (SFC habitat P = 0.835; SFN habitat P = 0.673) (Results based on Repeated Measures Analysis using log-transformed data from sites that were equally sampled by Crews 1 and 2 [*n* = 26 for SFC and *n* = 18 for SFN]; each site sampled 3 times).

In terms of sampling effort, Crew 1 expended significantly more sampling time than Crew 2 (Table 3.12). The percent difference in mean sampling time between the two crews was 14.7% in SFC and 7.5% in SFN habitats.

Table 3.12 Mean sampling effort (seconds) expended by Crews 1 and 2 during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Habitat	Crew 1		Crew 2		P-value[b]
	n	**Mean Effort (± SE)**	***n***	**Mean Effort (± SE)**	
SFC	27	710 ± 38	27	606 ± 30	0.000
SFN	39	640 ± 34	39	592 ± 33	0.015

[a] Based on Analysis of covariance using meters as covariate.

The results of the present study were not consistent with findings made during Phase 2. In 2002, Crew 1 consistently captured fewer Arctic grayling and bull trout in SFC habitat. Also, Crew 1 expended less sampling effort then Crew 2. The Phase 3 results indicated that the boat operation protocols of Crew 1 had changed in terms of time spent sampling, but the adjustment was not sufficient to remove all apparent bias. Crew 1 catch rates for bull trout were lower and Crew 1 catch rates for Arctic grayling were higher than for Crew 2.

Although not absolute, the adjustment in boat operation was sufficient to reduce crew bias to acceptable levels (Figure 3.9). The proportional difference in crew catch rates was reduced for each of the target species in SFC habitat, particularly for Arctic grayling. The 2003 values ranged from 0.65 for bull trout to 0.10 for mountain whitefish. Large changes between Phase 3 and Phase 2 in proportional difference were not recorded in the SFN habitat category, but the bull trout value decreased to 0.53.

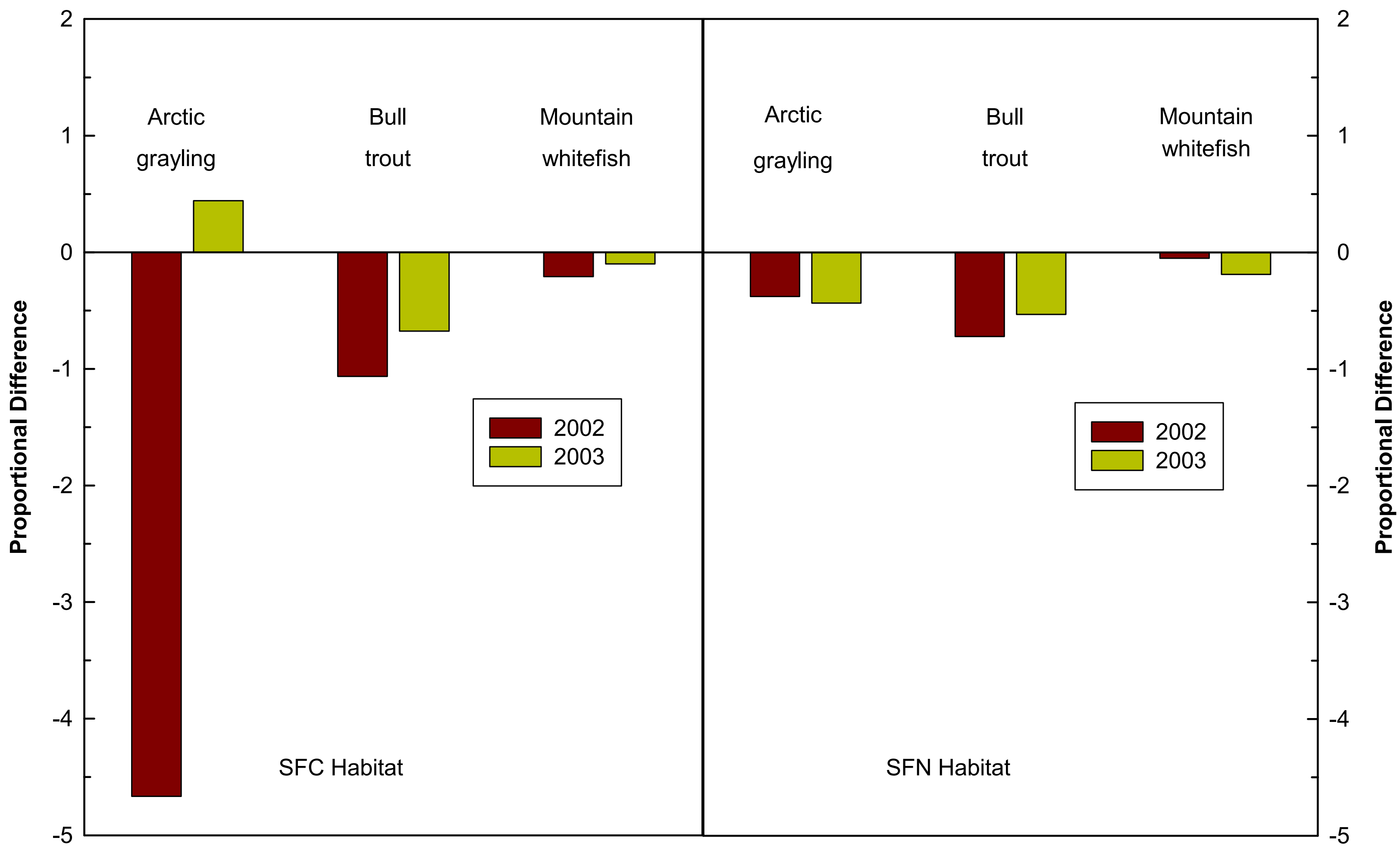


Figure 3.9 Comparisons of the proportional difference in Crew 1 and Crew 2 mean catch rates between 2002 and 2003 during the Peace River Fish Community Indexing Program.

The results of the evaluation indicated that crew bias likely associated with boat operation identified during Phase 2 could not be entirely eliminated by further adjustment to sampling protocols. However, the difference in crew catch rates was reduced for the two problem species bull trout and Arctic grayling. This change was deemed sufficient to allow analysis of catch data collected by both crews.

Use of Observed Fish

Results of Phase 2 indicated that observed fish of the more abundant species (mountain whitefish) should not be included in the enumeration data because it could affect the precision of the estimate (P&E and Gazey 2003). The conclusion was reached because factors such as observer experience and observer bias affected the investigator's ability to correctly count fish. To confirm this, observed data collected by experienced and inexperienced netters during the present study were evaluated to ascertain whether there was an effect on sample precision and whether there was observer bias.

The ability of experienced and inexperienced samplers to identify difficult target fish species was examined by comparing the correlation between the number of fish captured and the number observed (Table 3.13). Inexperienced samplers showed weak correlations for Arctic grayling and bull trout. In contrast, experienced samplers demonstrated a significant positive correlation between number of fish observed and captured (0.347 for Arctic grayling and 0.129 for bull trout). The results support the position that sampler experience affected the ability to enumerate difficult species.

Table 3.13 Correlation between number of fish captured and number observed for experienced and inexperienced samplers during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Species	**Pearson's Correlation Coefficient**	
	Experienced (*n* = 555)	**Inexperienced (*n* = 165)**
Arctic grayling	0.347**	0.078
Bull trout	0.129**	0.025

** $P < 0.01$; Two-tailed Pearson Correlation test.

Sampler experience did not improve the reliability of counts for the numerous target species mountain whitefish (Figure 3.10). The amount of variation explained by the relationship between observed and captured fish was only 54% for experienced and 37% for inexperienced groups. Sampler experience did not affect the ability to maintain the precision of the count. This was illustrated by the increased spread of the data points in relation to the number of captured fish. Both experienced and inexperienced samplers tended to underestimate the number of mountain whitefish present. The slope of each relationship was less than 1 (0.473 for experienced samplers and 0.288 for inexperienced samplers).

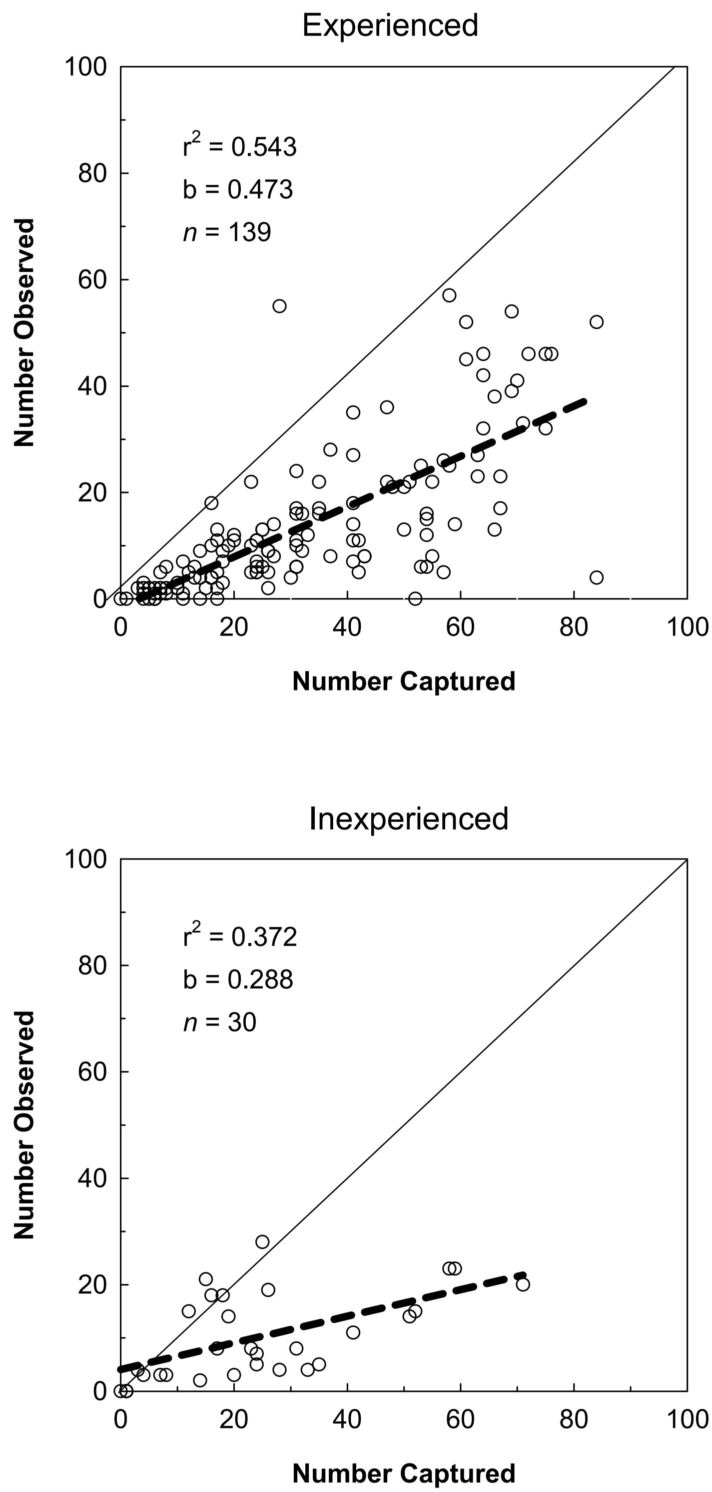


Figure 3.10 Relationship between number captured and number observed of mountain whitefish sampled from Section One during Phase 3 of the Peace River Fish Community Indexing Program, 2003 (solid line represents slope = 1).

In theory, the number of fish observed should exhibit exponential growth because there is a finite ability to physically net fish, but there is no physical limitation on the ability to count fish. Similar to findings of Phase 2, experience did not improve the sampler's ability to count a numerous species such as mountain whitefish, it did not substantially increase the precision of the count, and most importantly, it did not eliminate sampler bias.

Use of observed fish affected the precision of the catch rate estimate (Table 3.14). The coefficient of variation generated with and without observed fish indicated that the effect depended on the target species.

Table 3.14 Effects of observed fish on the precision of catch rate estimates during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Species	**Habitat**	**Coefficient of Variation**[a]		**Percent Change in Variation**
		Captured	**Captured + Observed**	
Arctic grayling	SFC	1.79	1.71	-5.2
	SFN	2.74	2.35	-16.6
Bull trout	SFC	1.37	1.35	-1.3
	SFN	2.04	1.89	-7.9
Mountain whitefish	SFC	0.59	0.62	+4.2
	SFN	0.77	0.99	+22.6

[a] Estimates for each section pooled for the analysis.

For Arctic grayling, inclusion of observed fish decreased the coefficient of variation in each of the SFC and SFN habitats (-5.2% and -16.6%, respectively), which indicated an improvement in precision. The results for bull trout were similar. Inclusion of observed fish decreased the coefficient of variation in the SFC habitat (-1.3%) and in the SFN habitat (-7.9%). Use of observed fish in catch rate estimates for mountain whitefish had the opposite effect. Variation increased for samples collected from both the SFC and SFN habitat categories (4.2% and 22.6%, respectively).

The results of the present study were consistent with findings of Phase 2. The target species of interest should dictate whether observed fish are used to calculate catch rate. Observed Arctic grayling and bull trout should be included in the catch rate analyses because these species were scarce and use of observed fish increased the precision of the estimate. For the abundant target species mountain whitefish, observed fish should not be used to calculate catch rate because inclusion of these data bias the results and decreases sample precision.

Stratification by Section and Habitat

Findings during Phases 1 and 2 indicated that spatial distributions of target fish species were influenced by habitat and river section. Arctic grayling were less abundant upstream of the Halfway River, while the opposite was true for bull trout and mountain whitefish. In terms of habitat, catch rates for Arctic grayling and bull trout were higher in areas containing physical cover (SFC habitat), while mountain whitefish were more abundant in areas without physical cover (SFN habitat). Based on these findings, it was recommended that sampling should be stratified by river section and habitat type as a way to reduce catch rate variation and to help stabilize catchability.

In 2003 mean catch rates differed between species, section, and habitat (Figure 3.11 and Table 3.15). In general, catch rates for Arctic grayling and bull trout were low in all sections. Values ranged from zero to 1.78 fish/km. Catch rates for mountain whitefish were much greater than for the other two target species. Mean values exceeded 20 fish/km.

Table 3.15 Mean catch rates of the three target species stratified by section and habitat during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Species	Section	SFC Habitat		SFN Habitat		P-value[a]
		n	Mean (± SE)	*n*	Mean (± SE)	
Arctic grayling	1	48	0.11 ± 0.07 (A)	42	0.02 ± 0.02 (A)	0.274
	2	48	0.43 ± 0.12 (AB)	42	0.55 ± 0.18 (B)	0.834
	3	48	0.73 ± 0.14 (B)	42	0.39 ± 0.11 (B)	0.032
	4	48	1.78 ± 0.27 (C)	42	0.31 ± 0.07 (B)	0.000
P-value[b]		0.000		0.010		
Bull trout	1	48	0.72 ± 0.17	42	0.52 ± 0.16	0.246
	2	48	0.86 ± 0.17	42	0.71 ± 0.26	0.269
	3	48	0.90 ± 0.14	42	0.72 ± 0.15	0.279
	4	48	0.50 ± 0.08	42	0.42 ± 0.08	0.512
P-value		0.232		0.494		
Mountain whitefish	1	48	32.5 ± 3.0	42	47.6 ± 5.4 (A)	0.299
	2	48	30.1 ± 2.6	42	42.8 ± 3.6 (A)	0.006
	3	48	27.8 ± 1.9	42	28.5 ± 3.7 (B)	0.195
	4	48	28.6 ± 2.6	42	20.9 ± 1.4 (B)	0.105
P-value		0.860		0.000		

[a] Based on Independent samples t-test using log-transformed data.
[b] Based on Repeated measures analysis using log-transformed data. Different letters designate significantly different ($P < 0.05$) values using the Tukey B means test.

Arctic grayling catch rates were higher in SFC habitats compared to SFN habitats in three of four sections; however, the differences were significant only in Sections 3 and 4. Bull trout catch rates also were higher in SFC habitats in all four sections, but none were significant. Catch rates of mountain

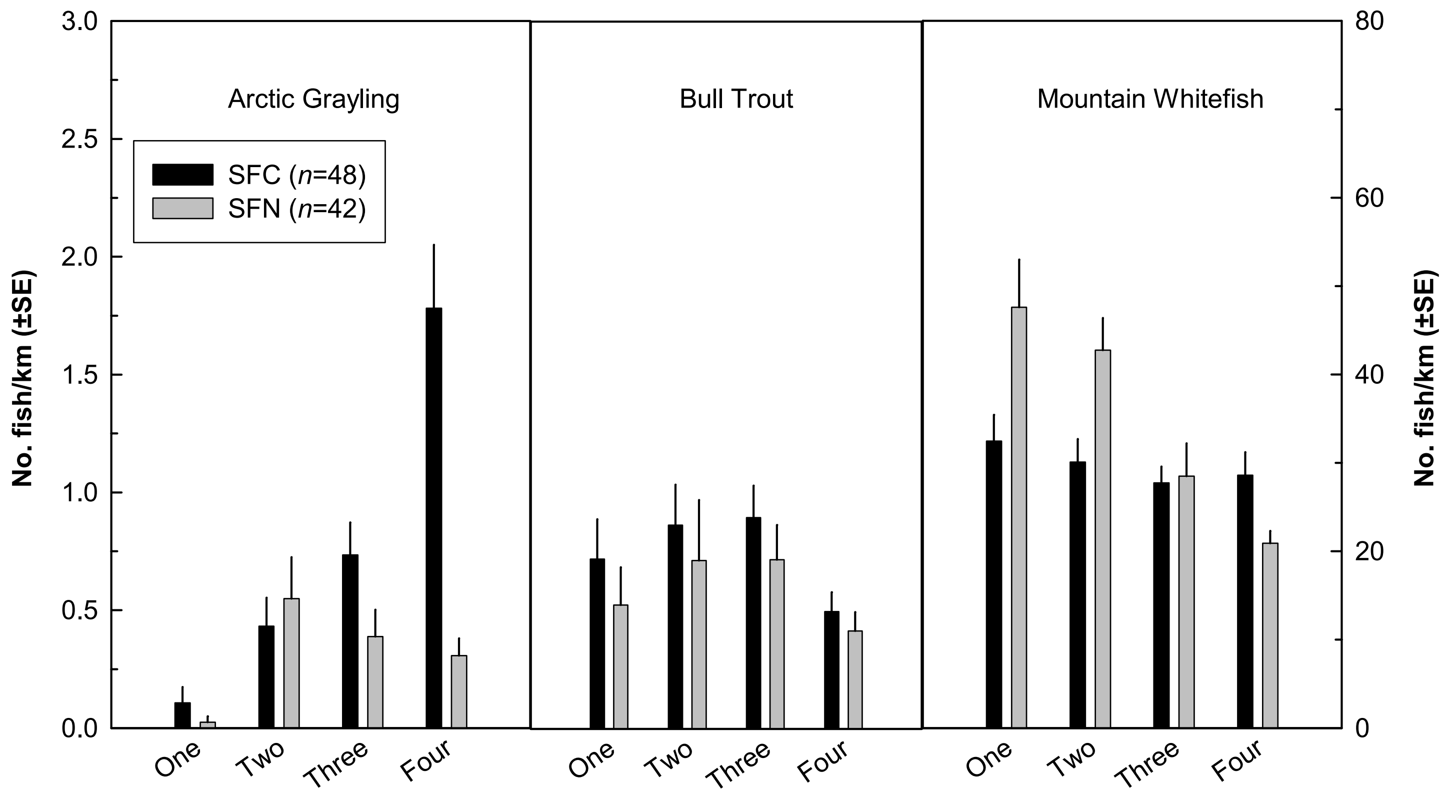


Figure 3.11 Mean catch rate of three target species stratified by section and habitat during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

whitefish were higher in SFN compared to SFC habitats in three sections, but the difference was significant only for Section 2. The results were generally consistent with the findings from Phase 2, but the habitat differences were not as distinct. A possible explanation for this difference could be a change in fish abundance or river discharge patterns.

Mean catch rates differed between sampled sections. Arctic grayling catch rates increased from Sections 1 to 4 in SFC habitat. The high catch rate recorded in Section 4 was due to the prevalence of Age 1 fish in the sample. Bull trout mean catch rates were similar between sections, but fish abundance in both SFC and SFN habitats were lowest in Section 4.

In SFN habitat mountain whitefish exhibited distinct spatial differences in abundance relative to the Halfway River confluence. Mean catch rates were approximately 20% higher in Sections 1 and 2 compared to Sections 3 and 4. Statistical analysis of the mountain whitefish catch rates confirmed these groupings. In contrast, catch rates in the SFC habitat did not differ statistically.

Similar to findings for Phase 2, there were spatial differences in catch rates. Depending on species, fish abundance varied with river section and habitat. As such, stratification by habitat and river section is deemed to be an appropriate strategy.

<u>Effect of Repeated Sampling on Catch Rate</u>

The field program was structured to collect information for calculation of population estimates. As such, sampling was repeated six times in each section. During Phase 2, catch rates decreased slightly over time, which indicated that the level of sampling intensity may have affected the target fish species.

This apparent effect also occurred during Phase 3 for some species (Table 3.16). The majority of correlations between catch rate and session were negative for Arctic grayling and bull trout in SFC habitat. Only two of the correlations were significant. There were no trends identified for mountain whitefish in SFC habitat or any of the three species in SFN habitat. Although there was an indication that repeated sampling may have influenced Arctic grayling and bull trout catch rates, no definitive conclusions could be made because other factors could have affected catch rate (e.g., changes in discharge). However, the findings should be acknowledged when developing future monitoring programs for Arctic grayling and bull trout.

Table 3.16 Correlation[a] between catch rate and session during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Species	Habitat (*n*)	Section			
		One	Two	Three	Four
Arctic grayling	SFC (48)	+0.051	-0.175	-0.307*	-0.211
	SFN (42)	-0.137	+0.150	+0.180	+0.296*
Bull trout	SFC (48)	-0.159	-0.405*	-0.068	-0.129
	SFN (40)	+0.168	+0.003	+0.031	+0.060
Mountain whitefish	SFC (48)	-0.260*	-0.210	+0.408	+0.096
	SFN (42)	-0.131	-0.370*	+0.020	-0.345

[a] Pearson Correlation Coefficient (* $P < 0.05$; One-tailed test).

3.3.2.2 Confounding Factors

<u>Discharge</u>

Phase 2 examined the potential effect of discharge on catch rates and found no clear relationship (P&E and Gazey 2003). There was limited evidence that water levels at the time of sampling and water level stability during periods immediately preceding sampling may have influenced catch rate, but the effect was weak and was not consistent among target species and sections.

Discharge during the Phase 3 program was lower and more variable (see Section 3.1), which may have resulted in a greater influence on catch rate then what was observed in 2002. To ascertain whether discharges during the Phase 3 field program affected catch rate, water level recorder stations were established in the study area. The water level data provided an index of discharge and allowed calculation of water travel times between sample sites. It should be noted that the station at the upstream end of Section 1 failed during the program; therefore, data from the Water Survey of Canada station was used in its place.

One basic flow pattern was recorded during the entire field program (Figure 3.12). Rapid changes in water level followed by short periods of high or low stable flow occurred during a 24-hour cycle. Also, the distinct fluctuation at Station 1 progressively attenuated as the distance from the PCN Dam increased.

The time required to record a change in water flow was dependant on distance traveled and discharge from the PCN Dam (Figure 3.12; Table 3.17). The travel time and water velocity results from Phase 2 indicated that the duration of a particular flow effect was short-lived within each section. Therefore, the

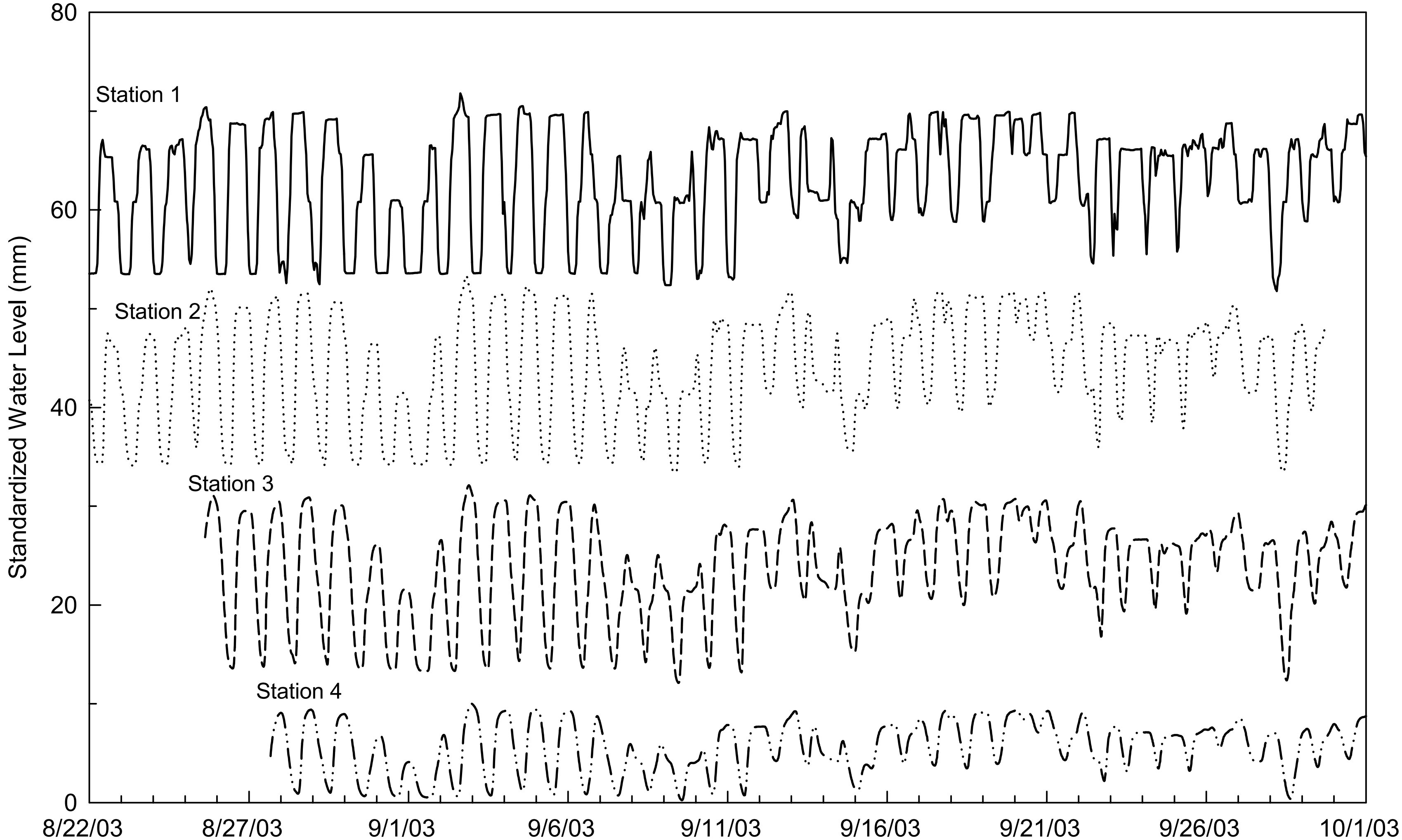


Figure 3.12 Standardized water levels at monitoring stations during Phase 3 of the Peace River Fish Community Indexing Program, 2003 (Patterns represent meaurements at 15 minute intervals; see Section 2.16 regarding Station 1).

data collected at each station accurately reflected real-time flow conditions at a particular fish sample site within a section with only minor adjustments (± 0.5 h).

Table 3.17 Summary of hydrographic information[a] and sample sizes available for analysis during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Section	Section Length (km)	Peak Discharge[a]		Base Discharge[a]		No. Samples per Flow Pattern and Habitat Category							
		Travel Time[b] (h)	Water Velocity[c] (km/h)	Travel Time (h)	Water Velocity (km/h)	Falling		Stable-Low		Rising		Stable-High	
						SFC	SFN	SFC	SFN	SFC	SFN	SFC	SFN
1	8.2	0.68	12.0	0.90	9.1	10	12	0	0	18	20	6	3
2	8.2	0.68	12.0	0.90	9.1	4	5	4	0	35	32	5	5
3	9.4	0.85	11.2	1.07	8.8	9	11	2	1	34	29	3	1
4	13.6	1.23	11.2	1.54	8.8	12	17	9	8	25	17	0	0

[a] Based on data collected during Phase 2.
[b] Estimate of time required for water to pass through section.
[c] Estimate based on distance between sections; Station 1 results based on comparison to WSC Station data.

The variable flow pattern during the entire field program dictated that the majority of sampling occurred during rising or falling conditions (Table 3.17). Limited data were available during stable water flows. The spatial location of the sections also caused inconsistent flow conditions among sections. Rising water levels dominated throughout, while falling water levels were prevalent only in Section 4. Based on these conditions, limited sample sizes were available to examine the effect of stable water levels on catch rate and samples used to examine the effect of changing water levels had to be stratified by section.

Several water level parameters were examined to ascertain whether discharge affected catch rate. These included changes in water levels, the rate or magnitude of change, and water level variability prior to sampling.

The effects of changing water levels (rising) were examined by comparing the correlations between standardized values and catch rates. The results indicated that there was no relationship between a change in water level and catch rate (Table 3.18). Correlations were generally very weak and the direction of the effect was not consistent. Only one significant negative correlation was recorded.

Table 3.18 Correlations between catch rates and standardized water levels during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Direction	Section	Species	Habitat Category	
			SFC	SFN
Rising	1	Arctic grayling	-0.375	-0.211
		Bull trout	+0.011	+0.072
		Mountain whitefish	-0.473*	+0.389
	2	Arctic grayling	-0.062	+0.139
		Bull trout	-0.229	-0.207
		Mountain whitefish	-0.048	-0.146
	3	Arctic grayling	-0.091	+0.148
		Bull trout	+0.039	-0.213
		Mountain whitefish	+0.335	+0.047
	4	Arctic grayling	-0.247	+0.038
		Bull trout	-0.106	+0.397
		Mountain whitefish	+0.041	-0.283

[a] Pearson's Correlation Coefficient (* $P < 0.05$; Two-tailed test); see Table 3.14 for sample sizes.

Although change in water level had no effect, the rate of change could have had an influence. A similar approach was used for this analysis, but the magnitude of change, which was the difference in water level from the previous measure, was used for the analysis. Again, the results indicated that there was no relationship between rate of change and catch rate for each of the target species (Table 3.19). Correlations were weak and there was no consistent direction of effect. Similar to the results for changing water level, the rate of change had no apparent influence on catch rates of the target species.

Water level at the time of sampling (low versus high) could also affect catch rate. The evaluation could not be completed due to insufficient sample sizes.

The final parameter examined was the effect of water level stability on catch rate. The analysis compared mean catch rates associated with periods of stable water levels to those associated with variable levels. This was accomplished by calculating the standard deviation of the water level measurements for a 12 h period immediately preceding the boat electrofishing sample. A 12 h period was chosen for the following reasons. First, it encompassed a time window that was potentially influenced by the normal operational flow regime of the BC Hydro facilities. Second, it provided sufficient time for fish to respond to the change or lack of change in water level. The standard deviation values were then categorized in two groups: stable (low variation) versus variable (high variation). The catch data were grouped into zones to maximize sample sizes (Zone 1 = Sections 1 and 2; Zone 2 = Sections 3 and 4). Also, analyses of

Arctic grayling and bull trout catch rates were restricted to the SFC habitat category because catch rates were too low in SFN habitats to be able to show a pattern.

Table 3.19 Correlations between catch rates and changes in water level during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Direction	Section	Species	Habitat Category	
			SFC	SFN
Rising	1	Arctic grayling	+0.017	-0.226
		Bull trout	-0.072	-0.297
		Mountain whitefish	+0.270	-0.344
	2	Arctic grayling	+0.172	-0.050
		Bull trout	+0.089	+0.101
		Mountain whitefish	+0.044	+0.474*
	3	Arctic grayling	+0.045	-0.023
		Bull trout	+0.038	-0.071
		Mountain whitefish	-0.110	+0.054
	4	Arctic grayling	+0.153	-0.332
		Bull trout	-0.149	-0.051
		Mountain whitefish	-0.123	+0.098

[a] Pearson's Correlation Coefficient (* P < 0.05; Two-tailed test); see Table 3.14 for sample sizes.

Water level stability may have affected catch rate, but the influence was weak (Table 3.20). Arctic grayling and mountain whitefish mean catch rates were higher for stable versus variable flows. However, the difference was significant only for Arctic grayling in Zone 1. Unlike the two other target species, mean catch rates of bull trout were higher following a period of variable flow.

Table 3.20 Comparison of mean catch rates following a 12 hour period of stable versus variable water levels during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Zone	Species	Habitat Category	Stable		Variable		P-value[a]
			n	Mean (± SE)	*n*	Mean (± SE)	
1	Arctic grayling	SFC	4	1.49 ± 0.53	25	0.15 ± 0.12	0.000
	Bull trout	SFC	4	0.84 ± 0.56	25	0.94 ± 0.34	0.892
	Mountain whitefish	SFC	4	54.7 ± 14.0	25	33.3 ± 4.0	0.182
		SFN	3	70.4 ± 13.4	32	49.1 ± 5.7	0.265
2	Arctic grayling	SFC	44	1.23 ± 0.20	19	1.14 ± 0.27	0.882
	Bull trout	SFC	44	0.61 ± 0.09	19	0.80 ± 0.23	0.724
	Mountain whitefish	SFC	44	30.5 ± 2.8	19	22.3 ± 1.7	0.198
		SFN	38	18.6 ± 1.3	15	27.7 ± 5.4	0.166

[a] Based on Independent samples t-test using log-transformed data.

In summary, the findings provided little evidence that catch rates of target species were affected by discharge. The absence of a strong relationship between water level and catch rate suggested that discharge did not have a strong effect during the 2003 sampling period. The results were similar to the findings of Phase 2.

Water Clarity

Water clarity in the Peace River during the sampling period was high (Table 3.21). Mean water clarity ranged from 195 cm in Section 3 to 220 cm in Section 1. Measurements did not fall below the lower 50 cm threshold for effective sampling identified by P&E (2002). Section 3 was the only area affected by lower water clarity due to the influence of the Halfway River. Even in this section, only 3% of the samples were less than 100 cm. Similar to the results of Phase 2, the high values recorded during Phase 3 indicated little potential effect of water clarity on catch rate.

Table 3.21 Water clarity (cm) during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Section	Mean (± SE)	Sample	Range		
			Minimum		Maximum[a]
1	220	90	220	-	220
2	215 ± 1.0	90	180	-	220
3	195 ± 3.6	77	80	-	220
4	209 ± 1.8	82	130	-	220

[a] Value of 220 cm used when clarity exceeded instrument capacity (215 cm).

3.3.2.3 Effort Required to Detect Change

An objective of the Peace River Fish Community Indexing Program was to monitor change in fish abundance; therefore, it was important to establish whether catch rate estimates were sufficiently precise to detect a certain magnitude of change.

To ascertain whether the target species populations were suitable candidates for monitoring, the relationship between catch rate variation (standard deviation) and a measure of the magnitude of difference needed between samples (coefficient of variation) was examined (Figure 3.13).

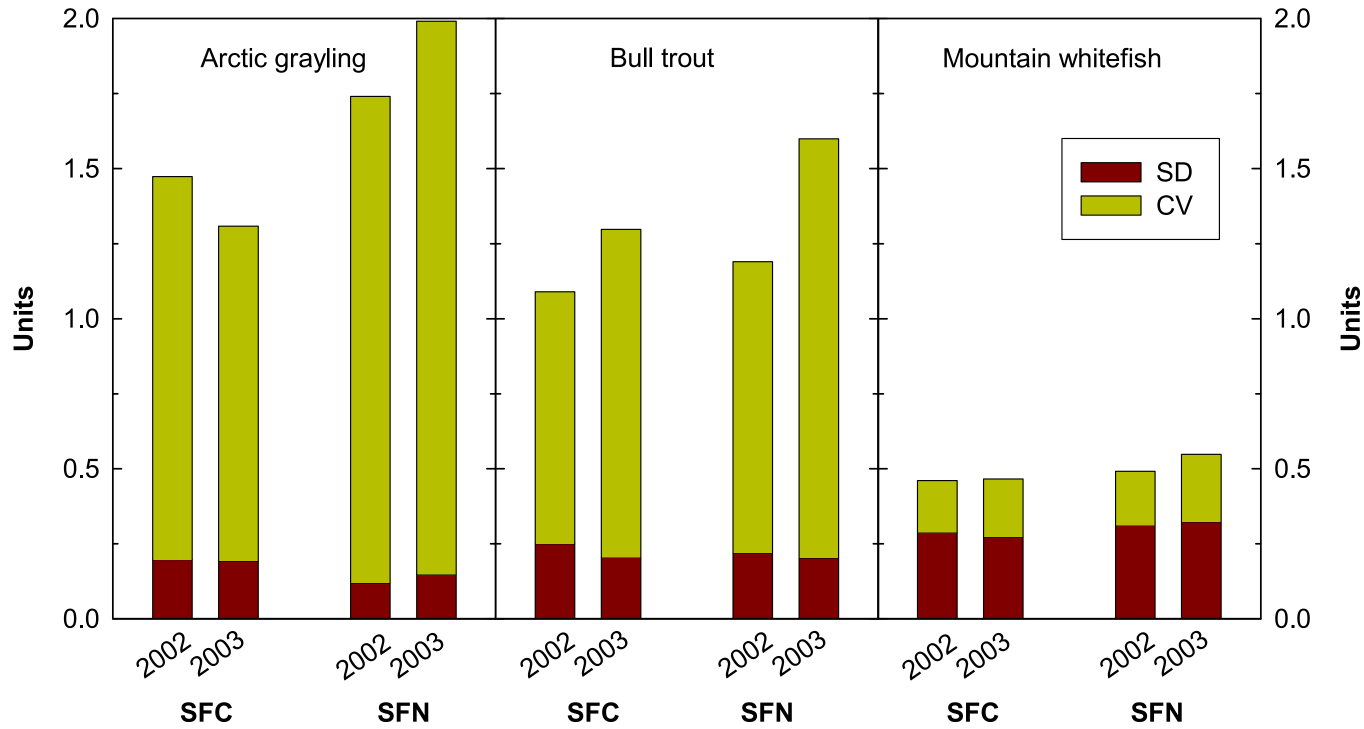


Figure 3.13 Relationship between standard deviation (SD) and coefficient of variation (CV) for mean catch rates of target fish species sampled in two habitat categories during 2002 and 2003 of the Peace River Fish Community Indexing Program.

Standard deviations associated with catch rate estimates for the majority of target species remained stable between the two years, although slight decreases were recorded for bull trout in SFC and SFN habitats (18% and 8%, respectively). Also, the size of the standard deviation did not differ substantially betweenthe two habitat categories. The results indicated that the sampling protocols used during both Phase 2 and Phase 3 maintained the stability of the catch rate variation.

The coefficient of variation did vary between sample years for two of the target species. Values decreased in the SFC habitat and increased in the SFN habitat by approximately 15% for Arctic grayling. Bull trout values increased at least 30% in both habitat categories. The coefficient of variation for mountain whitefish remained similar between years (approximately 19%). Because the standard deviations associated with the estimates remained stable, the differences were due to changes in fish abundance. As such, decreased fish abundance would reduce the ability to detect a specified change, or the power of the test.

Assuming a Type I error of 0.1 and a Type II error of 0.2, power analysis of data collected during Phase 3 indicated that catch rates and the associated variation for Arctic grayling and bull trout would not be suitable to allow detection of a 25% change in fish abundance (Table 3.22). In contrast, mountain whitefish would require a sample size of eleven or less, which was well within the effort expended during Phase 3 ($n \geq 42$). The Phase 3 sampling effort also would be almost sufficient to detect a 10% change in mountain whitefish abundance in the SFC habitat. The results of the power analyses were similar to those of Phase 2: mountain whitefish would be the only suitable target population for monitoring changes in catch rate.

Table 3.22 Sample sizes required to detect change in catch rates during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Species	Habitat	Mean (± SD)	Sample Size[a]		
			10% Difference	25% Difference	50% Difference
Arctic grayling	SFC	0.17 ± 0.19	>100	>100	63
	SFN	0.08 ± 0.15	>100	>100	>100
Bull trout	SFC	0.19 ± 0.21	>100	>100	62
	SFN	0.15 ± 0.20	>100	>100	89
Mountain whitefish	SFC	1.41 ± 0.27	47	8	3
	SFN	1.43 ± 0.32	63	11	4

[a] Based on power analysis of two independent samples using log-transformed data ($\alpha = 0.1$, $\beta = 0.2$); estimates for individual sections pooled for the analysis.

3.3.2.4 Comparison to Previous Studies

An objective of Phase 3 was to extend time series data of the abundance of nearshore fish populations in the Peace River. Catch rates of the target species populations differed between years and sections (Figure 3.14). Overall, Arctic grayling mean catch rates in the SFC were higher in 2003 compared to 2002 ($P = 0.002$; Two-way Anova using log-transformed data with year and section as fixed effects); however, no statistical differences were detected in the SFN habitat ($P = 0.383$). This likely was caused by decreases in Arctic grayling catch rates in Sections 1 and 2 in combination with increases in Sections 3 and 4. Despite these changes there were no statistical groupings.

The opposite trend was recorded for bull trout. For both habitat categories overall catch rates decreased between 2002 and 2003 ($P = 0.010$ and $P = 0.025$, respectively). The change was greatest in Section 2 for the SFC habitat and Section 1 for the SFN habitat. The decreases may be an artifact of using catch data from both crews in 2003 compared to using only the catch rates of the more efficient crew in 2002. Therefore, the data should be interpreted with caution. There were no statistical groupings of the sample sections.

Mountain whitefish mean catch rates changed slightly between years in the SFC and SFN habitats. Decreases were recorded in Sections 1 and 2, while the opposite was true for Sections 3 and 4. In both cases the differences were not significant ($P = 0.124$ and $P = 0.847$, respectively). In the SFC habitat category, the statistical groupings of Sections 1 and 2 versus 3 and 4 that occurred in 2002 disappeared in 2003. This likely was due to the increase in catch rates in Sections 3 and 4. The results for the SFN habitat category were consistent between years. Catch rates of mountain whitefish in Sections 1 and 2 were significantly higher then catch rates in Sections 3 and 4. Although not significant, catch rates in this habitat category decreased in Section 1 and increased in Sections 2 and 3.

The results indicated that there were changes in fish abundance within the study area. Arctic grayling numbers increased between 2002 and 2003. The change was likely due to an influx of Age 1 fish in Sections 3 and 4. The results for bull trout were difficult to interpret because they could have represented a change in the analysis protocol. Continued monitoring should establish whether the downward trend recorded in bull trout abundance is real. The catch rate data for mountain whitefish demonstrated temporal and spatial patterns of abundance. Mountain whitefish catch rates in the SFC habitat category in Sections 3 and 4 demonstrated a slight nonsignificant increase between 2002 and 2003.

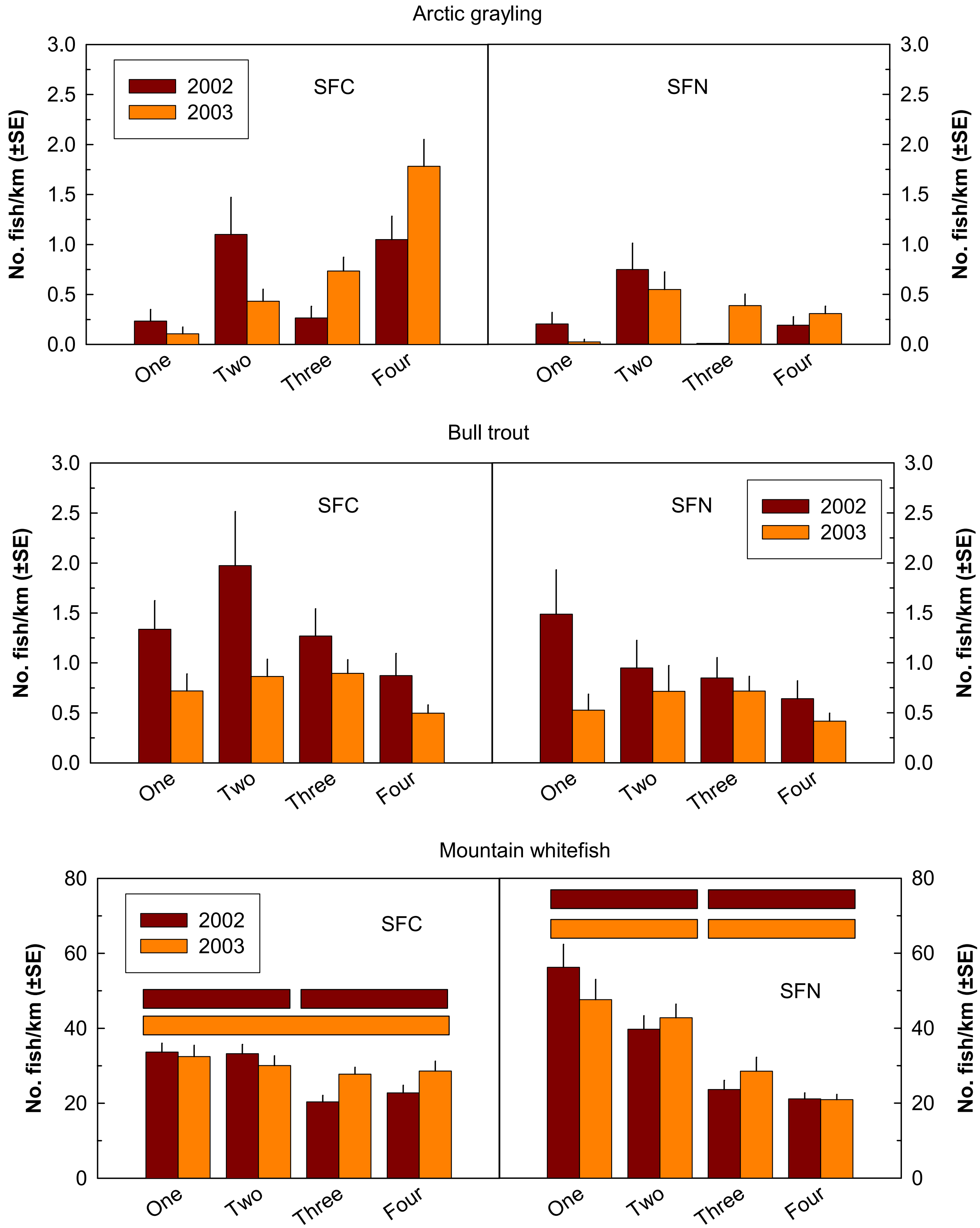


Figure 3.14 Comparisons of mean catch rates of target fish species recorded during the Peace River Fish Community Indexing Program, 2002 and 2003 (Bars denote statistical groupings at P<0.05; Tukey B means test).

3.3.3 Population Estimate

3.3.3.1 Mountain whitefish

A comparison of mountain whitefish recaptured in 2003 but originally marked in 2002 with those fish newly marked in 2003 is recorded in Table 3.23. Fish that were marked in 2002 were significantly more likely to be recaptured in Sections 2, 3 and 4. Figure 3.15 plots the proportion of available marked fish (i.e., recaptured in previous sessions) of 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 3.15 should be the same. Note that the confidence bounds on the three-times recapture proportions, assuming a binomial distribution, overlap all other points. Similarly, inspection of the time-at-large plots (Figure 3.16) does not reveal any obvious differences for the 2002 and 2003 derived releases.

Table 3.23 A comparison of mountain whitefish recaptured in 2003 that were originally marked in 2002 with those fish newly marked in 2003, Peace River Fish Community Indexing Program, 2003.

Details	**Section**				
	One	**Two**	**Three**	**Four**	**Total**
2002 Releases:					
Recapures	26	55	74	64	219
Marks	213	243	303	224	983
Percent	12.2	22.7	24.4	28.5	22.3
Time-at-large (days)	20.3	15.4	18.0	15.2	16.8
2003 Releases:					
Recapures	174	168	222	118	682
Marks	1428	1284	1195	1030	4937
Percent	12.2	13.1	18.6	11.5	13.8
Time-at-large (days)	18.0	16.5	17.6	15.1	17.0
Fisher Exact Test:					
Probability	0.996	<0.001	0.029	<0.001	<0.001

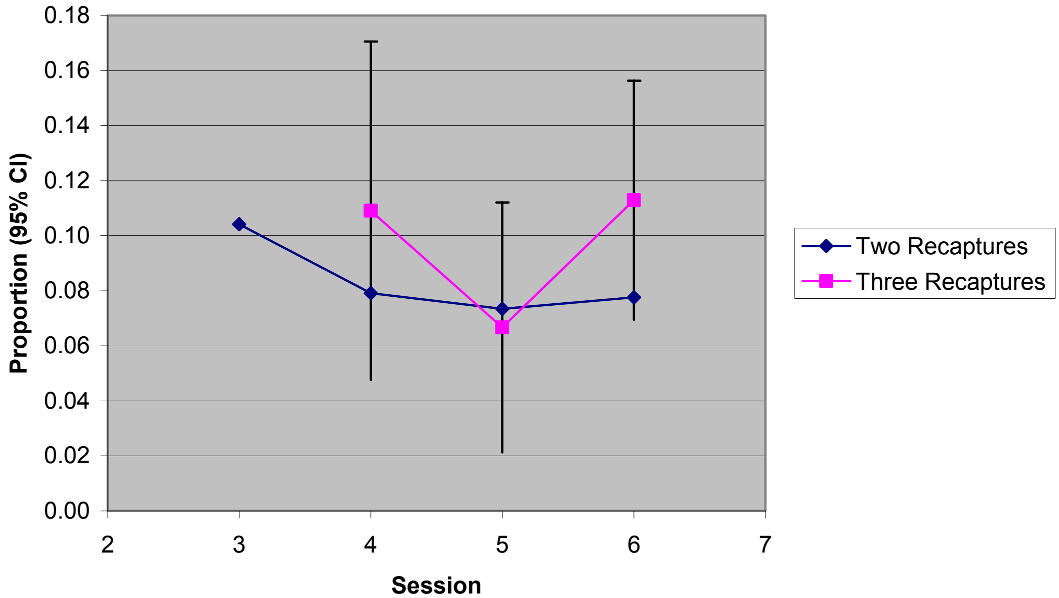


Figure 3.15 Proportion of multiple recaptures by sampling session for mountain whitefish captured during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

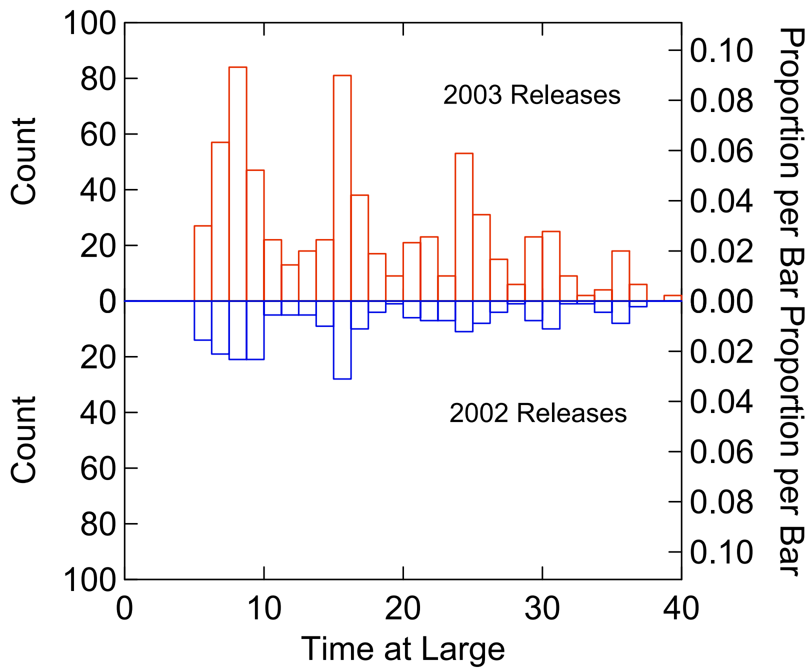


Figure 3.16 Comparison of time-at-large for mountain whitefish releases made in 2002 and 2003, Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Histograms of the mountain whitefish lengths at release and recapture are plotted in Figures 3.17 and 3.18, 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 3.24. Note that significant differences ($P < 0.05$) were observed in Sections 1 and 3. Time at large of recaptured mountain whitefish regressed on the growth increment (length at release minus length at recapture) is plotted in Figure 3.19. There was significant growth ($P = 0.004$ for zero slope); however, the fish only gained 1.5 mm, approximately, over a 39 day period (maximum time-at-large).

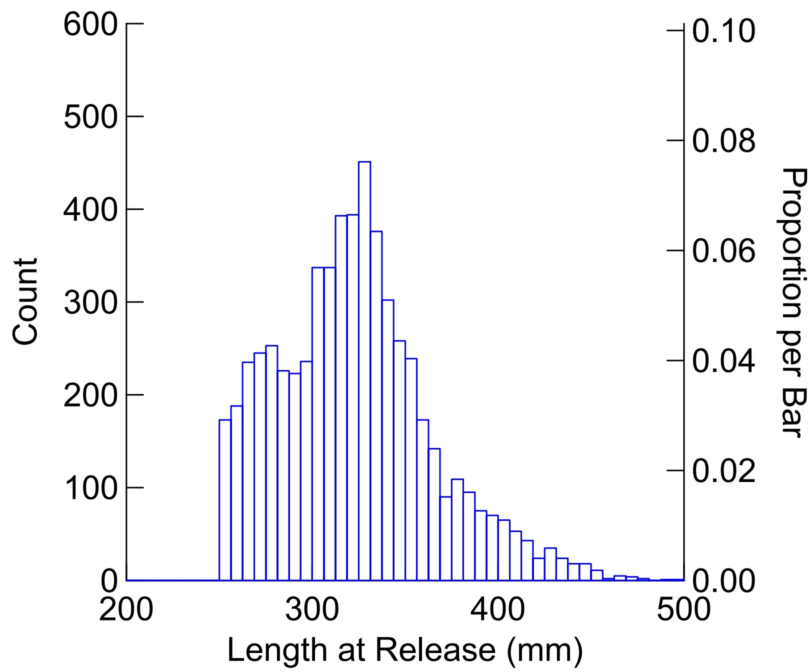


Figure 3.17 Histogram of mountain whitefish lengths at release during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

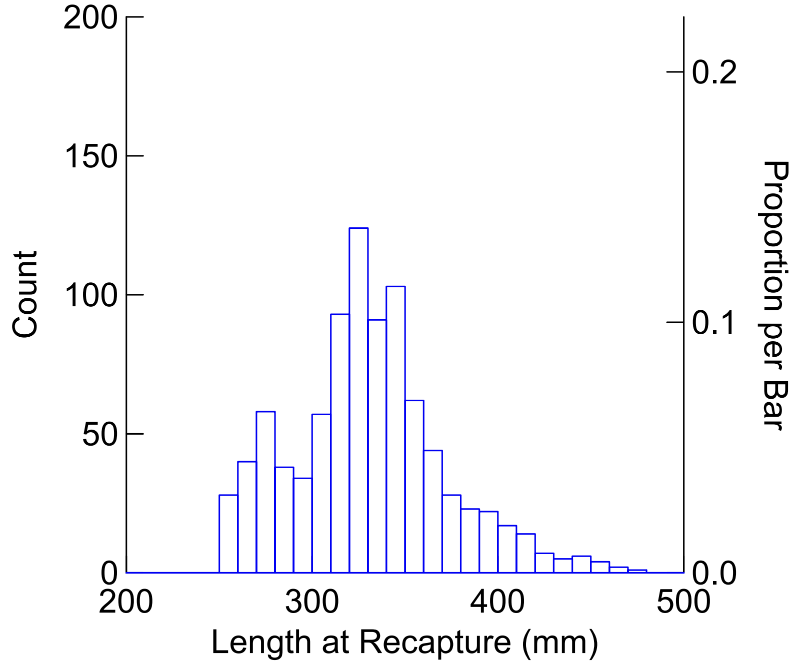


Figure 3.18 Histogram of mountain whitefish lengths at recapture during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Table 3.24 Comparison of mountain whitefish lengths at release and recapture by section during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Length Interval (mm)	Section								Total	
	One		Two		Three		Four			
	Count	Percent	Count	Percent	Count	Percent	Count	Percent	Count	Percent
Recaptures										
250-275	52	26.0	19	8.8	14	4.8	12	6.9	97	11.0
275-300	18	9.0	33	15.3	27	9.3	23	13.2	101	11.5
300-325	58	29.0	61	28.2	65	22.5	27	15.5	211	24.0
325-350	65	32.5	63	29.2	91	31.5	38	21.8	257	29.2
350-375	4	2.0	26	12.0	47	16.3	39	22.4	116	13.2
375-400	3	1.5	12	5.6	28	9.7	20	11.5	63	7.2
400-425			2	0.9	17	5.9	15	8.6	34	3.9
Total	**200**	**100.0**	**216**	**100.0**	**289**	**100.0**	**174**	**100.0**	**879**	**100.0**
Releases										
250-275	399	23.3	207	13.2	122	9.0	113	9.6	841	14.5
275-300	293	17.1	251	16.0	201	14.9	193	16.4	938	16.2
300-325	497	29.0	488	31.2	271	20.1	205	17.4	1461	25.2
325-350	420	24.5	394	25.2	345	25.5	228	19.4	1387	23.9
350-375	68	4.0	124	7.9	223	16.5	229	19.5	644	11.1
375-400	23	1.3	78	5.0	126	9.3	122	10.4	349	6.0
400-425	12	0.7	24	1.5	63	4.7	86	7.3	185	3.2
Total	**1712**	**100.0**	**1566**	**100.0**	**1351**	**100.0**	**1176**	**100.0**	**5805**	**100.0**
Like Ratio Chi-Square	18.07		9.08		15.97		4.25		32.9	
Probability	0.001		0.169		0.014		0.643		0.000	

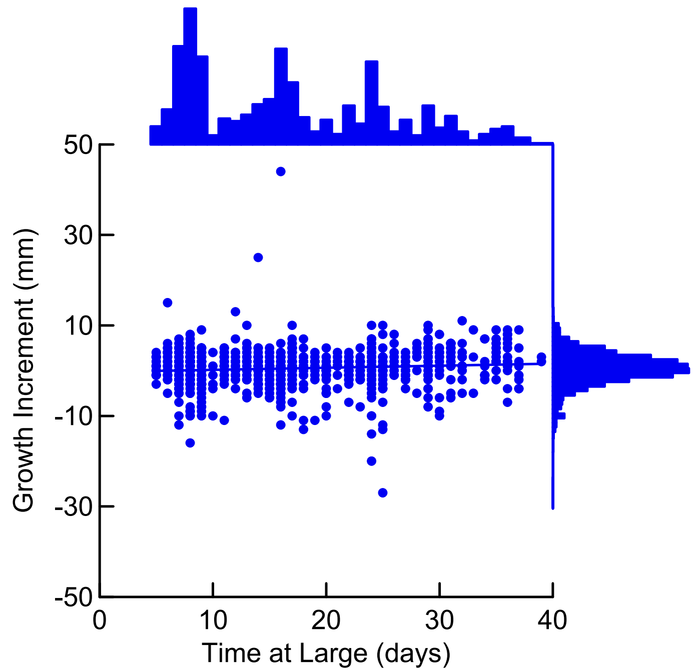


Figure 3.19 Growth over the study period of mountain whitefish with border histograms of time at large and growth increment, during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

The movement of recaptured mountain whitefish between sections during 2003 is listed in Table 3.25 along with the estimates of the migration proportions adjusted for the number of fish examined (Equation 1). These proportions are plotted in Figure 3.20. Similarly, the movement of recaptured whitefish between 2002 and 2003 is listed in Table 3.26 and the migration proportions weighted for sampling are plotted in Figure 3.21. The percent of recaptured marks in each section are not constant (they range from 7.03% to 12.53%, see Tables 3.25 and 3.26) and are significantly different ($P < 0.05$, weighted likelihood ratio test, Fleiss 1981). Since there is little movement between river sections (i.e., little mixing) within and between years and the probability of recapturing a mark is different between sections, population estimates should be stratified by section.

Table 3.25 Mountain whitefish recaptures and migration proportions adjusted (inverse weight) for fish examined by section during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Release Section	Recapture Section				
	One	**Two**	**Three**	**Four**	**Total**
Recaptures					
One	200	0	7	1	208
Two	0	223	8	3	234
Three	0	0	276	3	279
Four	0	0	5	175	180
Sample	2688	2419	2546	1883	9536
Percent Recaptured	7.44	9.22	11.63	9.67	
Proportions					
One	0.958	0.000	0.035	0.007	1.000
Two	0.000	0.951	0.032	0.016	1.000
Three	0.000	0.000	0.986	0.014	1.000
Four	0.000	0.000	0.021	0.979	1.000

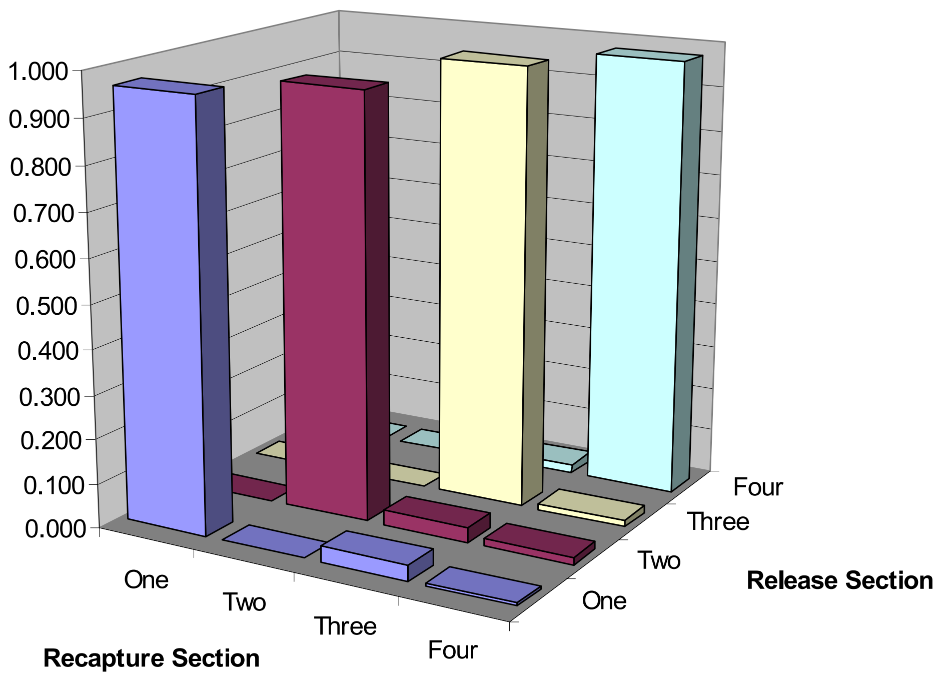


Figure 3.20 Distribution of recaptured marks standardized for sampling effort by section of release for mountain whitefish during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Table 3.26 Mountain whitefish recaptures and migration proportions adjusted (inverse weight) for fish examined by section during 2003 but released during 2003, Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Release Section	Recapture Section				
	One	Two	Three	Four	Total
Recaptures					
One	210	1	4	0	215
Two	3	258	2	1	264
Three	0	2	282	5	289
Four	0	1	6	222	229
Sample	2688	2419	2546	1883	9536
Percent Recaptured	7.92	10.83	11.55	12.11	
Proportions					
One	0.975	0.005	0.020	0.000	1.000
Two	0.010	0.978	0.007	0.005	1.000
Three	0.000	0.007	0.970	0.023	1.000
Four	0.000	0.003	0.020	0.977	1.000

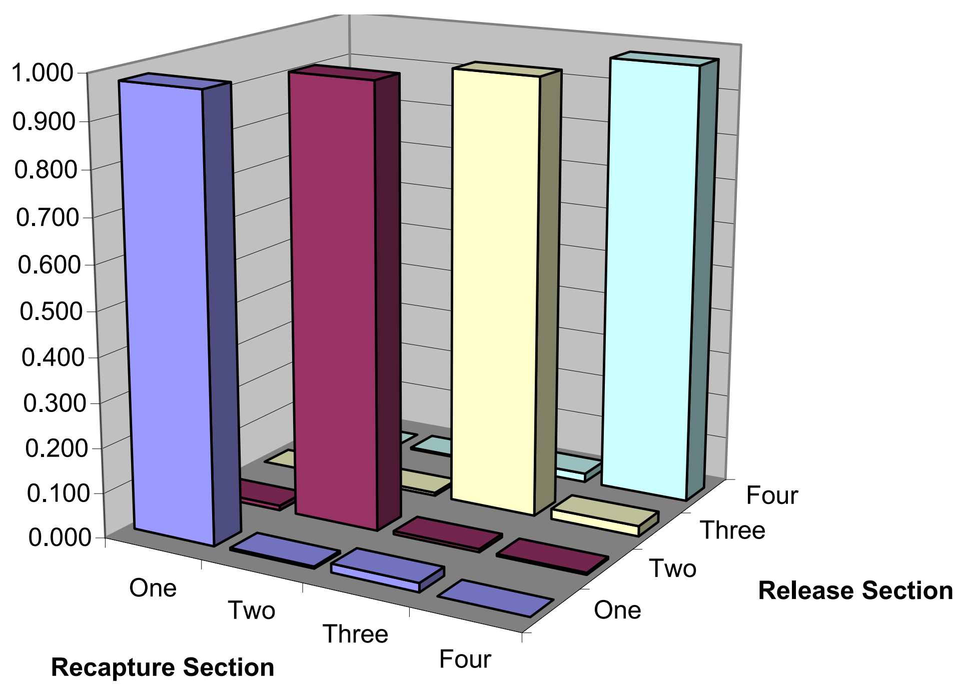


Figure 3.21 Distribution of recaptured marks in 2003 standardized for sampling effort by section of release for mountain whitefish released in 2002, during Phase 3 of the Peace River Fish Community Indexing Study, 2003.

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 3.27. 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 and the 95% interval for births included 0.

Table 3.27 Jolly-Seber population estimates by river section for mountain whitefish during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Session	Marks	Sample	Recapture of Fish Marked at Session					Total	Abundance	Survival	Births
			1	2	3	4	5				
Section One											
1	499										
2	524	587	21					21	12626	1.201	-850
3	309	377	14	22				36	12002	0.997	63
4	341	435	23	24	5			52	11837		
5	15	247	9	11	9	8		37			
6		499	14	16	13	10	1	54			
Total			**81**	**73**	**27**	**18**	**1**		**12155**	**1.086**	**-787**
Section Two											
1	496										
2	466	525	23					23	10758	0.946	-113
3	246	300	22	16				38	8317	1.238	507
4	350	450	25	22	21			68	6184		
5	33	336	17	13	17	18		65			
6		285	5	9	6	9		29			
Total			**92**	**60**	**44**	**27**	**0**		**8419**	**1.059**	**393**
Section Three											
1	390										
2	300	356	25					25	5494	1.191	479
3	310	380	22	21				43	6955	0.986	240
4	309	399	29	16	14			59	7026		
5	34	430	20	21	18	20		79			
6		558	18	16	18	15	3				
Total			**114**	**74**	**50**	**35**	**3**		**6492**	**1.096**	**718**
Section Four											
1	300										
2	336	392	27					27	7686	0.924	384
3	318	382	14	20				34	6200	1.081	280
4	229	280	10	14	13			37	7371		
5	29	304	12	9	16	8		45			
6		211	6	11	9	4	2	32			
Total			**69**	**54**	**38**	**12**	**2**		**7086**	**1.003**	**665**

The mark-recapture data were extracted by section from the database using marks applied during 2003 and marks that were observed during 2003 that were applied in 2002 and a minimum length of 250 mm. Table 3.28 lists mountain whitefish examined for marks and recaptures by date and section. The releases, adjusted for movement between sections (Equation 1) by section and date, are given in Table 3.29. The compilations of marks available (Equation 3), fish examined (Equation 4), and recaptures (Equation 5) assuming 0.0 removal and 0% undetected mark rate are listed in Table 3.30. The subsequent population estimates using the Bayesian closed model are given in Table 3.31. The posterior probability plots by section are provided in Appendix E (Figures E1 to E4) and the final posterior distributions for the four sections are drawn in Figure 3.22.

Table 3.28 Sample size and recaptures of mountain whitefish by section and date, Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Date (2003)	Section								Total	
	One		Two		Three		Four			
	Sample	Recap.	Sample	Recap.	Sample	Recap.	Sample	Recap.	Sample	Recap.
22-Aug	292	0	0	0	0	0	0	0	292	0
23-Aug	251	0	64	0	0	0	0	0	315	0
24-Aug	0	0	345	0	0	0	0	0	345	0
25-Aug	0	0	114	0	62	0	0	0	176	0
26-Aug	0	0	0	0	242	0	0	0	242	0
27-Aug	0	0	0	0	119	0	17	0	136	0
28-Aug	0	0	0	0	0	0	176	0	176	0
29-Aug	0	0	0	0	0	0	121	0	121	0
30-Aug	284	6	0	0	0	0	0	0	284	6
31-Aug	303	15	0	0	0	0	0	0	303	15
1-Sep	0	0	253	16	0	0	0	0	253	16
2-Sep	0	0	272	7	0	0	0	0	272	7
3-Sep	0	0	0	0	258	17	0	0	258	17
4-Sep	0	0	0	0	98	8	48	0	146	8
5-Sep	0	0	0	0	0	0	169	10	169	10
6-Sep	155	11	0	0	0	0	0	0	155	11
7-Sep	0	0	0	0	0	0	175	18	175	18
8-Sep	222	25	0	0	0	0	0	0	222	25
9-Sep	0	0	78	14	0	0	0	0	78	14
10-Sep	0	0	222	24	0	0	0	0	222	24
11-Sep	0	0	0	0	160	16	0	0	160	16
12-Sep	0	0	0	0	220	28	0	0	220	28
13-Sep	0	0	0	0	0	0	196	14	196	14
14-Sep	0	0	0	0	0	0	186	22	186	22
15-Sep	183	24	0	0	0	0	0	0	183	24
16-Sep	252	28	0	0	0	0	0	0	252	28
17-Sep	0	0	271	42	0	0	0	0	271	42
18-Sep	0	0	179	26	0	0	0	0	179	26
19-Sep	0	0	0	0	258	40	0	0	258	40
20-Sep	0	0	0	0	141	21	0	0	141	21
21-Sep	0	0	0	0	0	0	191	24	191	24
22-Sep	0	0	0	0	0	0	89	13	89	13
23-Sep	247	37	0	0	0	0	0	0	247	37
24-Sep	0	0	336	65	0	0	0	0	336	65
25-Sep	0	0	0	0	361	81	0	0	361	81
26-Sep	0	0	0	0	69	5	179	27	248	32
27-Sep	0	0	0	0	0	0	125	21	125	21
28-Sep	499	54	0	0	0	0	0	0	499	54
29-Sep	0	0	285	29	0	0	0	0	285	29
30-Sep	0	0	0	0	470	66	0	0	470	66
1-Oct	0	0	0	0	88	14	115	20	203	34
2-Oct	0	0	0	0	0	0	96	13	96	13
3-Oct	0	0	0	0	0	0	0	0	0	0
Total	**2688**	**200**	**2419**	**223**	**2546**	**296**	**1883**	**182**	**9536**	**901**

Table 3.29 Mountain whitefish marks applied by section adjusted for migration during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Date (2003)	Section				Total
	One	Two	Three	Four	
22-Aug	252.9	0.0	9.3	1.8	264
23-Aug	225.1	58.0	10.3	2.6	296
24-Aug	0.0	306.3	10.4	5.3	322
25-Aug	0.0	107.5	58.9	2.7	169
26-Aug	0.0	0.0	224.7	3.3	228
27-Aug	0.0	0.0	104.8	17.2	122
28-Aug	0.0	0.0	3.4	161.6	165
29-Aug	0.0	0.0	2.5	116.5	119
30-Aug	246.1	0.0	9.1	1.8	257
31-Aug	255.7	0.0	9.4	1.8	267
1-Sep	0.0	211.2	7.2	3.6	222
2-Sep	0.0	232.1	7.9	4.0	244
3-Sep	0.0	0.0	215.8	3.2	219
4-Sep	0.0	0.0	80.7	44.3	125
5-Sep	0.0	0.0	3.0	141.0	144
6-Sep	125.5	0.0	4.6	0.9	131
7-Sep	0.0	0.0	3.1	144.9	148
8-Sep	170.5	0.0	6.3	1.2	178
9-Sep	0.0	55.2	1.9	1.0	58
10-Sep	0.0	178.8	6.1	3.1	188
11-Sep	0.0	0.0	131.1	1.9	133
12-Sep	0.0	0.0	174.4	2.6	177
13-Sep	0.0	0.0	3.4	158.6	162
14-Sep	0.0	0.0	3.2	151.8	155
15-Sep	132.2	0.0	4.9	0.9	138
16-Sep	193.5	0.0	7.1	1.4	202
17-Sep	0.0	201.6	6.9	3.5	212
18-Sep	0.0	129.4	4.4	2.2	136
19-Sep	0.0	0.0	200.1	2.9	203
20-Sep	0.0	0.0	104.5	1.5	106
21-Sep	0.0	0.0	3.3	154.7	158
22-Sep	0.0	0.0	1.4	68.6	70
23-Sep	14.4	0.0	0.5	0.1	15
24-Sep	0.0	31.4	1.1	0.5	33
25-Sep	0.0	0.0	24.6	0.4	25
26-Sep	0.0	0.0	8.2	16.8	25
27-Sep	0.0	0.0	0.2	11.8	12
28-Sep	24.9	0.0	0.9	0.2	26
29-Sep	0.0	15.2	0.5	0.3	16
30-Sep	0.0	0.0	32.5	0.5	33
1-Oct	0.0	0.0	5.0	3.0	8
2-Oct	0.0	0.0	0.2	8.8	9
3-Oct	0.0	0.0	0.0	0.0	0
Total	**1640.7**	**1526.6**	**1498.0**	**1254.8**	**5920**

Table 3.30 Mountain whitefish sample, cumulative marks available for recapture and recaptures by section, during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Date (2003)	Sample	Marks	Recap.
Section One			
30-Aug	284	478	6
31-Aug	303	478	15
6-Sep	155	980	11
8-Sep	222	980	25
15-Sep	183	1276	24
16-Sep	252	1276	28
23-Sep	247	1601	37
28-Sep	499	1616	54
Section Two			
1-Sep	253	472	16
2-Sep	272	472	7
9-Sep	78	915	14
10-Sep	222	915	24
17-Sep	271	1149	42
18-Sep	179	1149	26
24-Sep	336	1480	65
29-Sep	285	1511	29
Section Three			
25-Aug	62	9	
26-Aug	242	20	
27-Aug	119	30	
3-Sep	258	443	17
4-Sep	98	450	8
11-Sep	160	771	16
12-Sep	220	773	28
19-Sep	258	1104	40
20-Sep	141	1110	21
25-Sep	361	1424	81
26-Sep	69	1425	5
30-Sep	470	1459	66
1-Oct	88	1460	14
Section Four			
27-Aug	17	10	
28-Aug	176	12	
29-Aug	121	16	
4-Sep	48	318	
5-Sep	169	322	10
7-Sep	175	370	18
13-Sep	196	662	14
14-Sep	186	664	22
21-Sep	191	985	24
22-Sep	89	988	13
26-Sep	179	1213	27
27-Sep	125	1213	21
1-Oct	115	1242	20
2-Oct	96	1242	13

Table 3.31 Population estimates by section for mountain whitefish during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Section	Bayesian Mean	MLE	95% HPD		Standard Deviation	CV (%)
			Low	High		
One	12 165	12 050	10 590	13 800	818	6.7
Two	8 911	8 840	7 840	10 030	558	6.3
Three	7 955	7 910	7 130	8 810	427	5.4
Four	7 252	7 180	6 280	8 260	504	6.9
Total	**36 283**		**33 949**	**38 617**	**1 191**	**3.3**

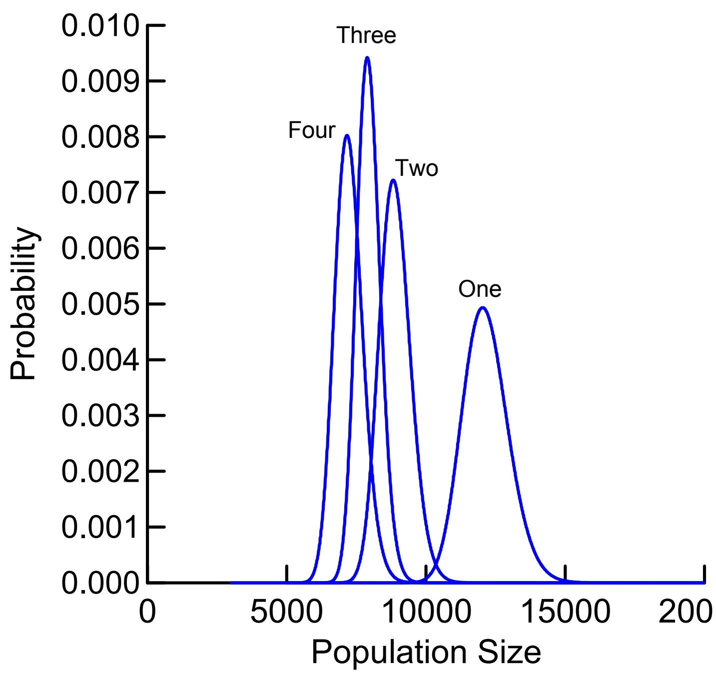


Figure 3.22 Final posterior distributions by section for mountain whitefish, during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

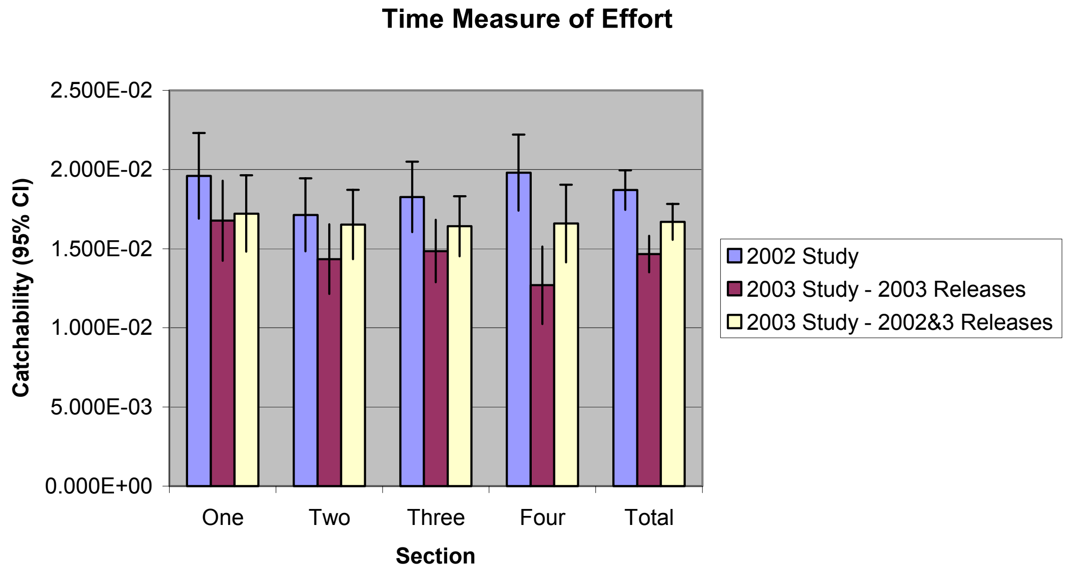
The catchability coefficients and associated 95% confidence intervals (Equations 7 to 9) by section are listed in Tables 3.32 and 3.33, and are plotted in Figure 3.23 using effort derived from time fished (hours) or distance traveled (km), respectively. Each table and figure presents the catchability coefficients from the 2002 study, the 2003 study using 2003 releases and the 2003 study using both the 2002 and 2003 releases.

Table 3.32 Catchability of mountain whitefish by section (effort in kilometers) during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Statistic	Section				Total
	One	Two	Three	Four	
2002 Study:					
Sample	2845	2611	2363	2105	9924
Effort (E)	78.13	90.90	124.85	119.34	413.22
Abundance (N)	12534	10587	7066	6045	36232
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 Using 2003 Releases:					
Sample	2145	1896	2546	1883	8470
Effort	74.51	86.98	116.80	112.24	390.53
Abundance (N)	12494	10269	8797	9478	41038
SD(1/N)	6.150E-06	7.608E-06	7.715E-06	1.039E-05	4.055E-06
Catchability (q)	2.304E-03	2.123E-03	2.478E-03	1.770E-03	2.169E-03
SD(q)	1.771E-04	1.658E-04	1.682E-04	1.743E-04	8.795E-05
CV(q)	7.7%	7.8%	6.8%	9.8%	4.1%
2003 Study Using 2002 and 2003 Releases:					
Sample	2145	1896	2546	1883	8470
Effort	74.51	86.98	116.80	112.24	390.53
Abundance (N)	12165	8911	7955	7252	36283
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%

Table 3.33 Catchability of mountain whitefish by section (effort in hours) during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Statistic	Section				Total
	One	Two	Three	Four	
2002 Study:					
Sample	2845	2611	2363	2105	9924
Effort (E)	11.58	14.39	18.31	17.59	61.86
Abundance (N)	12534	10587	7066	6045	36232
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 Using 2003 Releases:					
Sample	2145	1896	2546	1883	8470
Effort	12.29	15.31	19.49	18.67	65.76
Abundance (N)	12494	10269	8797	9478	41038
SD(1/N)	6.150E-06	7.608E-06	7.715E-06	1.039E-05	4.055E-06
Catchability (q)	1.677E-02	1.434E-02	1.485E-02	1.269E-02	1.466E-02
SD(q)	1.288E-03	1.120E-03	1.008E-03	1.249E-03	5.896E-04
CV(q)	7.7%	7.8%	6.8%	9.8%	4.0%
2003 Study Using 2002 and 2003 Releases:					
Sample	2145	1896	2546	1883	8470
Effort	12.29	15.31	19.49	18.67	65.76
Abundance (N)	12165	8911	7955	7252	36283
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%



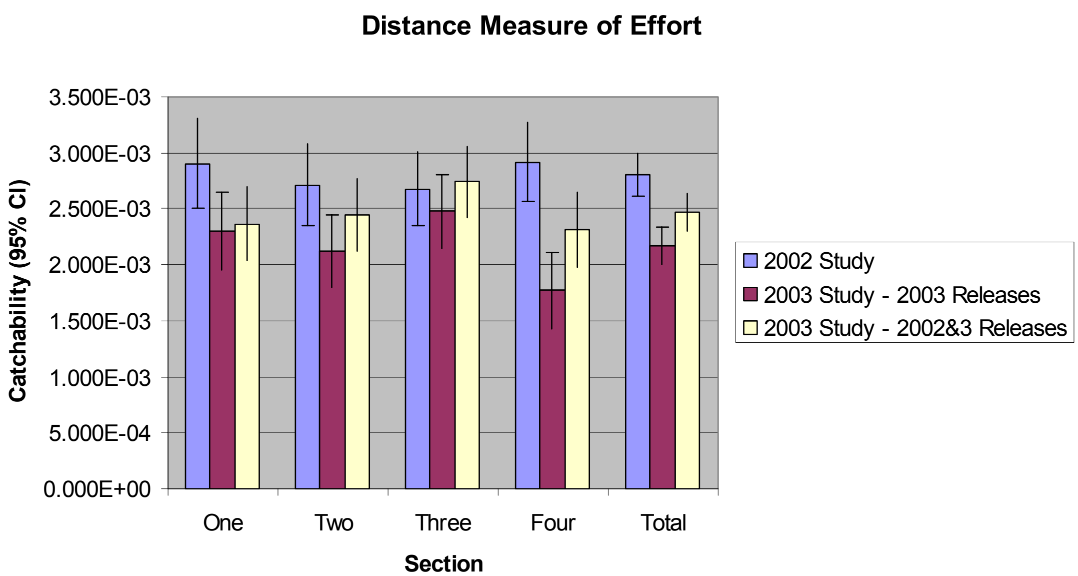


Figure 3.23 Catchability of mountain whitefish using time (in hours – upper graph) and distance (in kilometres – lower graph) by section during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

3.3.3.2 Arctic grayling

The mark-recapture data were extracted by section from the database using marks applied during 2003 and marks that were observed during 2003 that were applied in 2002 and a minimum length of 250 mm. Table 3.34 lists Arctic grayling examined for marks and recaptures by date and section. Only two recaptures were observed, one in Section 2 and the other in Section 4. No movement between sections was observed. Given the sparse recoveries, length histograms and a growth regression were not conducted. The releases by section and date are given in Table 3.35. The compilations of marks available

(Equation 3), fish examined (Equation 4), and recaptures (Equation 5) assuming 0.0 removal and 0% undetected mark rate are listed in Table 3.36 (all sections combined). Because only two recaptures were recorded we combined all sections (termed "total"). The subsequent population estimates using the Bayesian closed model are given in Table 3.37, the associated final posterior probability plots are provided in Appendix E (Figure E5) and the final posterior distribution is drawn in Figure 3.24. Figure 3.26 presents the minimum population estimates and their associated precision for Arctic grayling. For example, from Figure 3.25 it can be determined with 95% probability that the population size is at least 250 for all sections combined.

Table 3.34 Sample size and recaptures of Arctic grayling by section and date, Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Date (2003)	Section								Total	
	One		Two		Three		Four			
	Sample	Recap.	Sample	Recap.	Sample	Recap.	Sample	Recap.	Sample	Recap.
23-Aug	1	0	0	0	0	0	0	0	1	0
24-Aug	0	0	1	0	0	0	0	0	1	0
25-Aug	0	0	0	0	0	0	0	0	0	0
26-Aug	0	0	0	0	2	0	0	0	2	0
27-Aug	0	0	0	0	1	0	0	0	1	0
28-Aug	0	0	0	0	0	0	4	0	4	0
29-Aug	0	0	0	0	0	0	4	0	4	0
30-Aug	0	0	0	0	0	0	0	0	0	0
31-Aug	0	0	0	0	0	0	0	0	0	0
1-Sep	0	0	3	0	0	0	0	0	3	0
2-Sep	0	0	0	0	0	0	0	0	0	0
3-Sep	0	0	0	0	3	0	0	0	3	0
4-Sep	0	0	0	0	0	0	0	0	0	0
5-Sep	0	0	0	0	0	0	3	0	3	0
6-Sep	0	0	0	0	0	0	0	0	0	0
7-Sep	0	0	0	0	0	0	2	0	2	0
8-Sep	0	0	0	0	0	0	0	0	0	0
9-Sep	0	0	1	0	0	0	0	0	1	0
10-Sep	0	0	1	0	0	0	0	0	1	0
11-Sep	0	0	0	0	2	0	0	0	2	0
12-Sep	0	0	0	0	0	0	0	0	0	0
13-Sep	0	0	0	0	0	0	1	0	1	0
14-Sep	0	0	0	0	0	0	0	0	0	0
15-Sep	0	0	0	0	0	0	0	0	0	0
16-Sep	0	0	0	0	0	0	0	0	0	0
17-Sep	0	0	2	1	0	0	0	0	2	1
18-Sep	0	0	2	0	0	0	0	0	2	0
19-Sep	0	0	0	0	0	0	0	0	0	0
20-Sep	0	0	0	0	0	0	0	0	0	0
21-Sep	0	0	0	0	0	0	1	0	1	0
22-Sep	0	0	0	0	0	0	0	0	0	0
23-Sep	0	0	0	0	0	0	0	0	0	0
24-Sep	0	0	1	0	0	0	0	0	1	0
25-Sep	0	0	0	0	0	0	0	0	0	0
26-Sep	0	0	0	0	0	0	1	0	1	0
27-Sep	0	0	0	0	0	0	2	0	2	0
28-Sep	0	0	0	0	0	0	0	0	0	0
29-Sep	0	0	1	0	0	0	0	0	1	0
30-Sep	0	0	0	0	1	0	0	0	1	0
1-Oct	0	0	0	0	1	0	3	1	4	1
2-Oct	0	0	0	0	0	0	1	0	1	0
Total	**1**	**0**	**12**	**1**	**10**	**0**	**22**	**1**	**45**	**2**

Table 3.35 Arctic grayling marks applied by section and date during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Date (2003)	Section				Total
	One	Two	Three	Four	
23-Aug	1.0	0.0	0.0	0.0	1
24-Aug	0.0	1.0	0.0	0.0	1
25-Aug	0.0	0.0	0.0	0.0	0
26-Aug	0.0	0.0	1.0	0.0	1
27-Aug	0.0	0.0	1.0	0.0	1
28-Aug	0.0	0.0	0.0	4.0	4
29-Aug	0.0	0.0	0.0	4.0	4
30-Aug	0.0	0.0	0.0	0.0	0
31-Aug	0.0	0.0	0.0	0.0	0
1-Sep	0.0	3.0	0.0	0.0	3
2-Sep	0.0	0.0	0.0	0.0	0
3-Sep	0.0	0.0	2.0	0.0	2
4-Sep	0.0	0.0	0.0	0.0	0
5-Sep	0.0	0.0	0.0	3.0	3
6-Sep	0.0	0.0	0.0	0.0	0
7-Sep	0.0	0.0	0.0	2.0	2
8-Sep	0.0	0.0	0.0	0.0	0
9-Sep	0.0	1.0	0.0	0.0	1
10-Sep	0.0	1.0	0.0	0.0	1
11-Sep	0.0	0.0	2.0	0.0	2
12-Sep	0.0	0.0	0.0	0.0	0
13-Sep	0.0	0.0	0.0	0.0	0
14-Sep	0.0	0.0	0.0	0.0	0
15-Sep	0.0	0.0	0.0	0.0	0
16-Sep	0.0	0.0	0.0	0.0	0
17-Sep	0.0	1.0	0.0	0.0	1
18-Sep	0.0	2.0	0.0	0.0	2
19-Sep	0.0	0.0	0.0	0.0	0
20-Sep	0.0	0.0	0.0	0.0	0
21-Sep	0.0	0.0	0.0	1.0	1
22-Sep	0.0	0.0	0.0	0.0	0
23-Sep	0.0	0.0	0.0	0.0	0
24-Sep	0.0	1.0	0.0	0.0	1
25-Sep	0.0	0.0	0.0	0.0	0
26-Sep	0.0	0.0	0.0	1.0	1
27-Sep	0.0	0.0	0.0	2.0	2
28-Sep	0.0	0.0	0.0	0.0	0
29-Sep	0.0	1.0	0.0	0.0	1
30-Sep	0.0	0.0	1.0	0.0	1
1-Oct	0.0	0.0	0.0	2.0	2
2-Oct	0.0	0.0	0.0	1.0	1
Total	**1.0**	**11.0**	**7.0**	**20.0**	**39**

Table 3.36 Arctic grayling sample, cumulative marks available for recapture and recaptures by section, during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Date (2003)	Sample	Marks	Recap.
All Sections			
26-Aug	2	1	
27-Aug	1	2	
28-Aug	4	2	
29-Aug	4	3	
1-Sep	3	12	
3-Sep	3	12	
5-Sep	3	15	
7-Sep	2	17	
9-Sep	1	20	
10-Sep	1	22	
11-Sep	2	22	
13-Sep	1	24	
17-Sep	2	26	1
18-Sep	2	26	
21-Sep	1	29	
24-Sep	1	30	
26-Sep	1	30	
27-Sep	2	31	
29-Sep	1	32	
30-Sep	1	34	
1-Oct	4	34	1
2-Oct	1	35	

Table 3.37 Population estimates by section for Arctic grayling during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Section	Bayesian Mean	MLE	95% HPD		Standard Deviation	CV (%)
			Low	High		
Total	**2136**	**375**	**75**	**8450**	**2967**	**138.9**

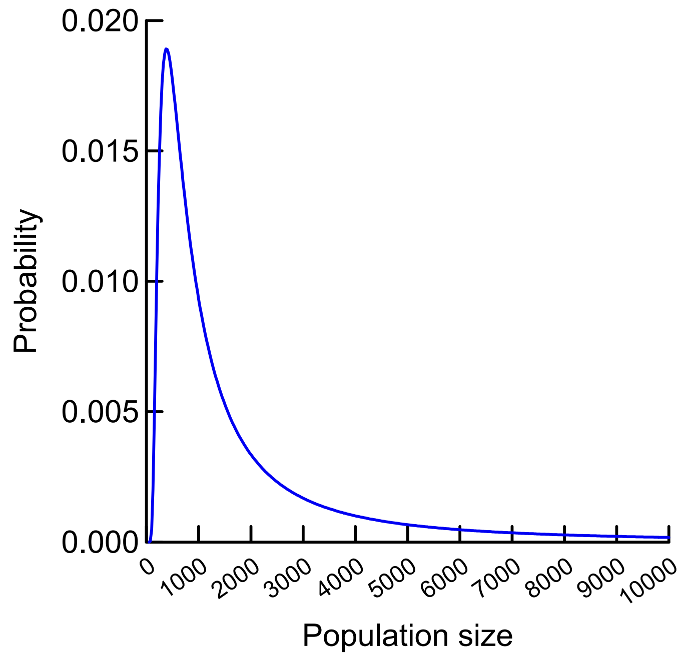


Figure 3.24 Final posterior distributions all sections combined for Arctic grayling during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

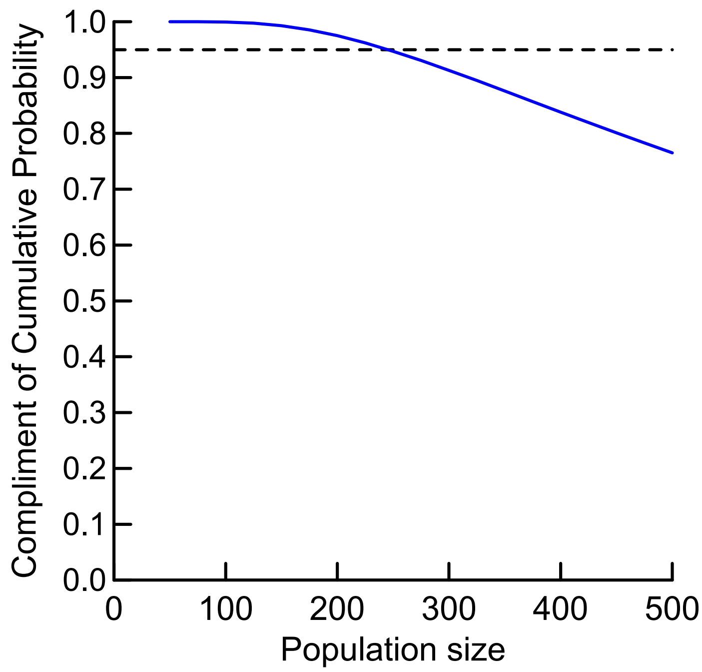


Figure 3.25 Minimum population estimates (compliment of cumulative probability) for Arctic grayling during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

3.3.3.3 Bull trout

The mark-recapture data were extracted by section from the database using marks applied during 2003 and marks that were observed during 2003 that were applied in 2002 and a minimum length of 250 mm. Table 3.38 lists bull trout examined for marks and recaptures by date and section. Only 9 recaptures were observed and no movement between sections was noted. The releases by section and date are given in Table 3.39. The compilations of marks available (Equation 3), fish examined (Equation 4), and recaptures (Equation 5) assuming 0.0 removal and 0% undetected mark rate are listed in Table 3.40 (all sections combined). Because 9 recaptures were recorded we combined all sections (termed “total”). The subsequent population estimates using the Bayesian closed model are given in Table 3.41, the associated final posterior probability plots are provided in Appendix E (Figure E6) and the final posterior distribution is drawn in Figure 3.26.

Table 3.38 Sample size and recaptures of bull trout by section and date, Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Date (2003)	Section								Total	
	One		Two		Three		Four			
	Sample	Recap.	Sample	Recap.	Sample	Recap.	Sample	Recap.	Sample	Recap.
22-Aug	3	0	0	0	0	0	0	0	3	0
23-Aug	0	0	4	0	0	0	0	0	4	0
24-Aug	0	0	8	0	0	0	0	0	8	0
25-Aug	0	0	0	0	3	0	0	0	3	0
26-Aug	0	0	0	0	7	0	0	0	7	0
27-Aug	0	0	0	0	8	0	1	0	9	0
28-Aug	0	0	0	0	0	0	0	0	0	0
29-Aug	0	0	0	0	0	0	3	0	3	0
30-Aug	2	0	0	0	0	0	0	0	2	0
31-Aug	5	0	0	0	0	0	0	0	5	0
1-Sep	0	0	4	0	0	0	0	0	4	0
2-Sep	0	0	2	1	0	0	0	0	2	1
3-Sep	0	0	0	0	3	0	0	0	3	0
4-Sep	0	0	0	0	2	0	1	0	3	0
5-Sep	0	0	0	0	0	0	2	0	2	0
6-Sep	0	0	0	0	0	0	0	0	0	0
7-Sep	0	0	0	0	0	0	4	0	4	0
8-Sep	0	0	0	0	0	0	0	0	0	0
9-Sep	0	0	4	0	0	0	0	0	4	0
10-Sep	0	0	3	0	0	0	0	0	3	0
11-Sep	0	0	0	0	4	1	0	0	4	1
12-Sep	0	0	0	0	5	0	0	0	5	0
13-Sep	0	0	0	0	0	0	4	0	4	0
14-Sep	0	0	0	0	0	0	1	0	1	0
15-Sep	2	0	0	0	0	0	0	0	2	0
16-Sep	3	0	0	0	0	0	0	0	3	0
17-Sep	0	0	4	0	0	0	0	0	4	0
18-Sep	0	0	4	1	0	0	0	0	4	1
19-Sep	0	0	0	0	8	2	0	0	8	2
20-Sep	0	0	0	0	5	0	0	0	5	0
21-Sep	0	0	0	0	0	0	5	0	5	0
22-Sep	0	0	0	0	0	0	3	0	3	0
23-Sep	3	0	0	0	0	0	0	0	3	0
24-Sep	0	0	5	0	0	0	0	0	5	0
25-Sep	0	0	0	0	8	1	0	0	8	1
26-Sep	0	0	0	0	0	0	4	0	4	0
27-Sep	0	0	0	0	0	0	2	0	2	0
28-Sep	3	0	0	0	0	0	0	0	3	0
29-Sep	0	0	1	0	0	0	0	0	1	0
30-Sep	0	0	0	0	7	1	0	0	7	1
1-Oct	0	0	0	0	6	1	1	0	7	1
2-Oct	0	0	0	0	0	0	1	1	1	1
Total	**21**	**0**	**39**	**2**	**66**	**6**	**32**	**1**	**158**	**9**

Table 3.39 Bull trout marks applied by section and date during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Date (2003)	Section				Total
	One	Two	Three	Four	
22-Aug	3.0	0.0	0.0	0.0	3
23-Aug	0.0	4.0	0.0	0.0	4
24-Aug	0.0	8.0	0.0	0.0	8
25-Aug	0.0	0.0	3.0	0.0	3
26-Aug	0.0	0.0	7.0	0.0	7
27-Aug	0.0	0.0	8.0	1.0	9
28-Aug	0.0	0.0	0.0	0.0	0
29-Aug	0.0	0.0	0.0	3.0	3
30-Aug	1.0	0.0	0.0	0.0	1
31-Aug	5.0	0.0	0.0	0.0	5
1-Sep	0.0	4.0	0.0	0.0	4
2-Sep	0.0	1.0	0.0	0.0	1
3-Sep	0.0	0.0	3.0	0.0	3
4-Sep	0.0	0.0	2.0	1.0	3
5-Sep	0.0	0.0	0.0	2.0	2
6-Sep	0.0	0.0	0.0	0.0	0
7-Sep	0.0	0.0	0.0	4.0	4
8-Sep	0.0	0.0	0.0	0.0	0
9-Sep	0.0	3.0	0.0	0.0	3
10-Sep	0.0	3.0	0.0	0.0	3
11-Sep	0.0	0.0	3.0	0.0	3
12-Sep	0.0	0.0	3.0	0.0	3
13-Sep	0.0	0.0	0.0	4.0	4
14-Sep	0.0	0.0	0.0	1.0	1
15-Sep	2.0	0.0	0.0	0.0	2
16-Sep	3.0	0.0	0.0	0.0	3
17-Sep	0.0	5.0	0.0	0.0	5
18-Sep	0.0	3.0	0.0	0.0	3
19-Sep	0.0	0.0	6.0	0.0	6
20-Sep	0.0	0.0	5.0	0.0	5
21-Sep	0.0	0.0	0.0	5.0	5
22-Sep	0.0	0.0	0.0	2.0	2
23-Sep	3.0	0.0	0.0	0.0	3
24-Sep	0.0	5.0	0.0	0.0	5
25-Sep	0.0	0.0	7.0	0.0	7
26-Sep	0.0	0.0	0.0	3.0	3
27-Sep	0.0	0.0	0.0	2.0	2
28-Sep	3.0	0.0	0.0	0.0	3
29-Sep	0.0	1.0	0.0	0.0	1
30-Sep	0.0	0.0	6.0	0.0	6
1-Oct	0.0	0.0	4.0	1.0	5
2-Oct	0.0	0.0	0.0	1.0	1
Total	**20.0**	**37.0**	**57.0**	**30.0**	**144**

Table 3.40 Bull trout sample, cumulative marks available for recapture and recaptures by section, during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Date (2003)	Sample	Marks	Recap.
All Sections			
25-Aug	3	3	
26-Aug	7	7	
27-Aug	9	15	
29-Aug	3	25	
30-Aug	2	34	
31-Aug	5	34	
1-Sep	4	37	
2-Sep	2	38	1
3-Sep	3	43	
4-Sep	3	47	
5-Sep	2	48	
7-Sep	4	54	
9-Sep	4	56	
10-Sep	3	60	
11-Sep	4	60	1
12-Sep	5	63	
13-Sep	4	66	
14-Sep	1	69	
15-Sep	2	72	
16-Sep	3	76	
17-Sep	4	77	
18-Sep	4	79	1
19-Sep	8	82	2
20-Sep	5	87	
21-Sep	5	90	
22-Sep	3	96	
23-Sep	3	101	
24-Sep	5	106	
25-Sep	8	108	1
26-Sep	4	111	
27-Sep	2	116	
28-Sep	3	123	
29-Sep	1	126	
30-Sep	7	128	1
1-Oct	7	131	1
2-Oct	1	132	1

Table 3.41 Population estimates by section for bull trout during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Section	Bayesian Mean	MLE	95% HPD		Standard Deviation	CV (%)
			Low	High		
Total	**1447**	**1140**	**610**	**2570**	**570**	**39.4**

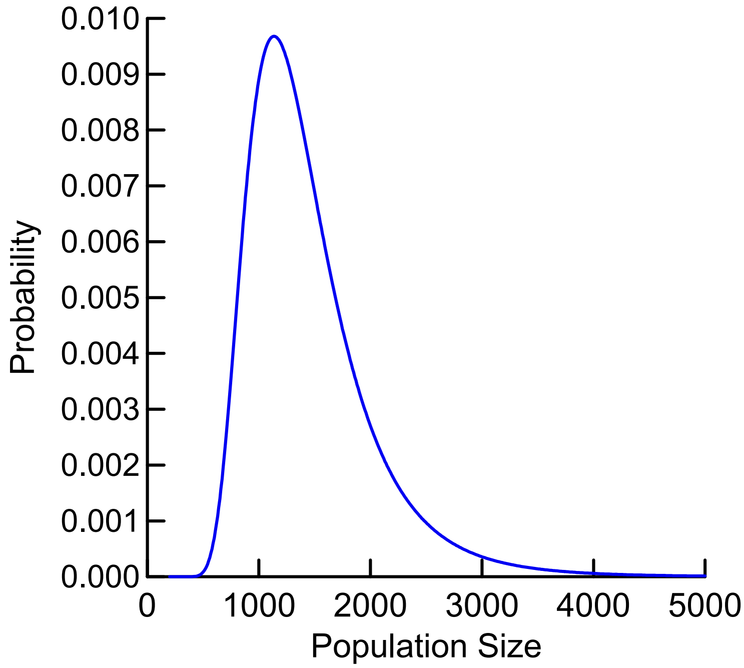


Figure 3.26 Final posterior distribution all sections combined for bull trout during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

3.3.3.4 Summary

Adjustments to the Bayesian population estimation methodology were made through the mark-recapture information to account for the movement of fish (only mountain whitefish moved between sections) within the study area and the potential to account for removals (natural mortality, unobserved removals and emigration from the study area) or for undetected marks (lost or missed). Also, the methodology allowed for a daily resolution of the mark-recapture information; thus, daily increments to the number of marked fish in the population and daily sampling for recaptures were accommodated.

The sensitivity of mountain whitefish for undetected mortality and marks is explored in Table 3.42. Because the study was conducted over a short period of time the impact of an instantaneous annual mortality of 0.2 on population estimates is slight (1%, approximately). The potential impact from undetected marks is more severe (6%, approximately, change in the estimate from a 5% rate of not detecting marks); however, as discussed below, the observed level of a scaring (from the loss of a mark) implies that a 5% non-detection rate is arguably extreme.

Table 3.42 Sensitivity of mountain whitefish estimates to mortality and undetected marks during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Section	**Mortality = 0.0**		**Mortality = 0.2**	
	Undetected Marks			
	0%	**5%**	**0%**	**5%**
One	12 165	11 581	12 058	11 479
Two	8 911	8 484	8 837	8 413
Three	7 955	7 576	7 887	7 511
Four	7 252	6 906	7 199	6 855
Total	**36 283**	**34 547**	35 981	34 258

The population estimates do not include small (≤ 250 mm) fish. The precision for mountain whitefish population estimates was very high (CV = 3.3%). However, the disappearance of some small (250-275 mm) mountain whitefish in Sections 1 and 3 in the recapture length profile may introduce a small unevaluated bias into the population estimates. A more serious problem is the heterogeneous capture probability demonstrated by the higher rate of recapture of fish marked in 2002 over that of fish marked in 2003 in Sections 2, 3 and 4 (Table 3.23). The following four observations may be pertinent for the formation of hypothesis to explain the heterogeneous behavior:

Section 1 is unique from the other four sections in that the recapture rates are homogeneous (Table 3.23), the recapture rates are the smallest (Tables 3.25 and 3.26), the population size is the largest (Table 3.31), fish length is the smallest (Table 3.24) and the time-at-large of recovered marks is the longest.

Analysis of multiple recaptures suggests that electrofishing does not make mountain whitefish more or less prone to subsequent recapture (Figure 3.15). However, note that the discrimination power is small (e.g., few fish are recaptured three or more times) so the chance of type II error (accepting the null hypothesis of homogeneous recapture probability when false) is large.

The Jolly-Seber survival estimates (Table 3.27) suggest that mountain whitefish do not die, loose their marks or leave the area over the period of the study in large numbers. However, as noted by Seber (1982), initial tag mortality is difficult to detect because any two groups of fish (e.g., the 2002 and 2003 releases) are buffered by a similar common mortality experience over most of their history.

The time-at-large profile (Figure 3.16) suggests that marked fish have similar behavior with respect to the likelihood of recapture. More rigorous examination of log-transformed time-at-large (to make the distribution more symmetrical) can be conducted through a two-way analysis of variance with release type and section as factors (Table 3.43). The ANOVA results reveal that release type (2002 or 2003) is not significant but section is significant with Section 1 declared more different than the other sections using a *post-hoc* Bonferroni multiple means test at the 95% confidence level.

Table 3.43 Two-way analysis of variance on log-transformed time-at-large with categorical variables release type and section, during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
Section	4.128	3	1.376	4.724	0.003
Type	0.014	1	0.014	0.048	0.827
Section*Type	0.398	3	0.133	0.455	0.714
Error	260.094	893	0.291		

Bonferroni Multiple means test on Section (homogeneous means are underlined): One <u>Two Three Four</u>

We are not aware of any hypothesis that is entirely consistent with the above observations. One or both of the following arguments could explain the heterogeneous capture rates:

Some mountain whitefish in Sections 2, 3 and 4 might be more vulnerable to electrofishing. These fish are marked in 2002 and are not available for marking in 2003 (because they already carry the 2002 tag). Results in Section 3.3.1.4 provided evidence that fish marked in 2002 had a lower body condition, suggesting that they may have been physically weaker, and therefore, more vulnerable to capture. The number of these vulnerable fish is not sufficient to trigger multiple recapture or time-at-large statistical differences between the 2002 and 2003 releases groups.

Mountain whitefish may experience initial tagging mortality. Further, perhaps the tagging mortality is size related and that the initial tagging mortality was smaller in Section 1 (fish recaptured in Section 1 were smaller than the other sections).

Population estimates for bull trout are available, but the precision is poor (CV = 39%). Because of very sparse recoveries of Arctic grayling, population estimates should not be quoted. Statements of minimum population size (e.g., 0.95 probability that there is at least 250 Arctic grayling) should be valid.

3.3.3.5 Evaluation as a Monitoring Tool

A key objective of this study was to establish an index to use as a monitoring tool for the second 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 2003 results using both the 2002 and 2003 releases should be used. We argue that a tag would have been applied to a fish but for the presence of the 2002 tag. For mountain whitefish, this proportionality constant (the catchability coefficient) was demonstrated to be constant in the four sampled river sections and the two years sampled (see Tables 3.34, 3.35 and Figure 3.23) even though there was a two-fold difference in the population size, different flow regimes between the years and there was a substantial ability (high power) to differentiate small changes in catchability (a CV of less than 7.5% for river sections and 4% total area each study year).

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.* Only a very few mountain whitefish were recaptured in river sections other than the section of release (approximately 1%). Therefore, the number of mountain whitefish leaving the study area (the four sections sampled) 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 different river sections. 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 issues because the study period was short (see Table 3.26 and Figure 3.19). Other empirical evidence of closure includes the selection of the closed model for mountain whitefish by POPAN-5 (UFIT module) and the stability of the sequence of daily posterior distributions displayed in Appendix E for all species.
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 four river sections to account for any differences in catchability, lack of mixing, marks applied, or population size. The heterogeneous capture probabilities illustrated by the 2002 and 2003 releases are an assumption violation. The amount of bias for population estimates will depend on the unknown amount of skewness in the distributions of capture probabilities for marked and unmarked fish. Usually, heterogeneous capture probabilities result in over-estimation of population size (Seber 1982). The consistency of the catchability coefficient across various population sizes and flow conditions argues that the 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 one mountain whitefish out of 682 captures was observed to have scars consistent with tagging in 2003.
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.

<u>Effort Needed to Detect Change</u>

Figure 3.27 plots the precision as a function of electrofishing effort (hours) using Equations 10, 11 and 12 for mountain whitefish. For reference, the 2002 and 2003 level of efforts expended are also plotted. Note that the mountain whitefish power curve for this study was very similar to the 2002 curve but was substantially more efficient than the 1989 study. We attribute the increased efficiency to the structured stratified sequential sampling design employed by the 2002 and 2003 studies.

For Arctic grayling and bull trout there was not sufficient data to generate a power curve for 2003.

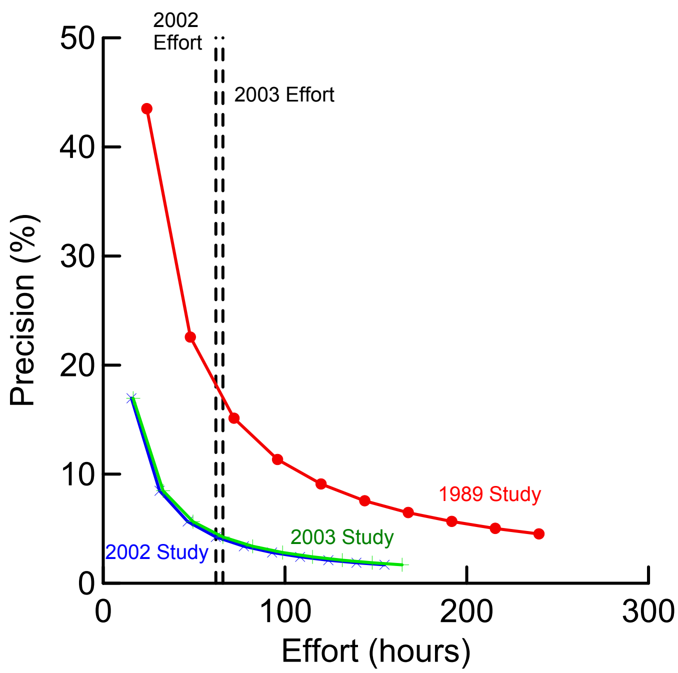


Figure 3.27 Precision (percentage of the mean) of the population estimate at various efforts for mountain whitefish during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

3.3.3.6 Comparison to Previous Studies

Table 3.44 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 here as half the 95% HPD expressed as a percentage of the Bayesian mean. Note the very large precision values (e.g., greater than 100%) implies that any point estimates are highly unreliable. Also, direct comparison of population estimates between years, other than 2002 and 2003, is difficult because different sections were sampled.

Table 3.44 Historical population estimates during Phase 3 of the Peace River Fish Community Indexing Program, 2003.

Year	Effort (h)	Arctic grayling	Mountain whitefish	Lake whitefish	Rainbow trout	Walleye	Bull trout
1989[a]	95.9						
Recoveries		18	126	3	19	6	
Mean		4359	117 593	33 814	1418	2591	
Precision (%)		47.1	17.4	136.6	41.3	86.1	
1990[b]	110.9						
Recoveries		37		7	19	7	
Mean		4160		82 012	5995	2881	
Precision (%)		32.9		65.5	39	64.7	
2001[c]	26.2						
Recoveries		2	3				
Mean		7700	560 000				
Precision (%)		175.0	140.0				
2002[d]	61.9						
Recoveries		3	954				12
Mean		1283	36 232				2049
Precision (%)		137.6	6.5				105.4
2003[e]	65.8						
Recoveries		2	901				9
Mean		2136	36 283				1447
Precision (%)		196.0	6.4				67.7

[a] Pattenden *et al.* (1990); [b] Pattenden *et al.* (1991); [c] Phase 1; [d] Phase 2; [e] Phase 3.

3.4 RELATIVE ABUNDANCE AS INDEX OF POPULATION SIZE

An important objective of the Peace River Fish Community Indexing Program was to establish whether catch rate, or relative abundance, could be used as an index of absolute abundance. In order for relative abundance to be a reliable monitoring tool, two conditions must be met. First, catch rates must have sufficient precision to allow detection of change. Second, catchability must be stable. The results of Phase 2 results indicated that both conditions were met for at least one target species: mountain whitefish. Standardized sampling protocols and stratified sampling generated precise estimates of catch rate. Precise estimates of population size were then used to establish that catchability was stable across sections. Based on these findings it was suggested that mountain whitefish catch rates were reliable monitoring tool. However, it was suggested that additional data points and inclusion of temporal differences were required to establish whether catchability was stable spatially and temporally.

Catch rate sampling protocols required stratification between two habitats within each section (SFC and SFN) as a way to improve precision. For assessment of catchability within each section, a combined catch rate estimate was generated by weighting the estimate and associated variation for each habitat category by the total length of the particular habitat sampled within each section. The combined values for Phase 2 and Phase 3 studies were then plotted against the appropriate population estimate for that section.

Weighted relative abundance indices exhibited a strong positive relationship with the population estimates generated during each year (Figure 3.28). When the data were combined (*n*=8) the relationship explained 92% of the observed variation (r^2 value; Linear regression analysis). Catchability was stable across sections and years (Table 3.45, Figure 3.29). In addition, catchability estimates exhibited a small coefficient of variation (<8%). These findings, which included within section variation (data generated using sites in a section), were similar to results presented using population estimate data (see Table 3.42), which did not address within section variation (data for all sites combined in a section).

Table 3.45 Catchability of mountain whitefish by section during the Peace River Fish Community Indexing Program, 2002 and 2003.

Statistic	Section			
	One	Two	Three	Four
2002				
Population Estimate (No. fish)	12534	10587	7066	6045
Weighted Catch Rate (No. fish/km)	42.8	35.8	21.7	22.0
Catchability (±95%CI)	3.235E-03	3.385E-03	3.064E-03	3.635E-03
Catchability Standard Deviation	2.403E-04	2.327E-04	1.904E-04	2.249E-04
Coefficient of variation	7.4%	6.9%	6.2%	6.2%
2003				
Population Estimate (No. fish)	12165	8911	7955	7252
Weighted Catch Rate (No. fish/km)	39.4	35.5	28.4	24.9
Catchability (±95%CI)	3.235E-03	3.987E-03	3.572E-03	3.434E-03
Catchability Standard Deviation	2.312E-04	2.6975E-04	2.099E-04	2.587E-04
Coefficient of variation	7.1%	6.8%	5.9%	7.5%

Two years of data indicate that catchability is stable both spatially and temporally. As such, catch rates for mountain whitefish are suitable to monitor trends in mountain whitefish abundance in the Peace River study area.

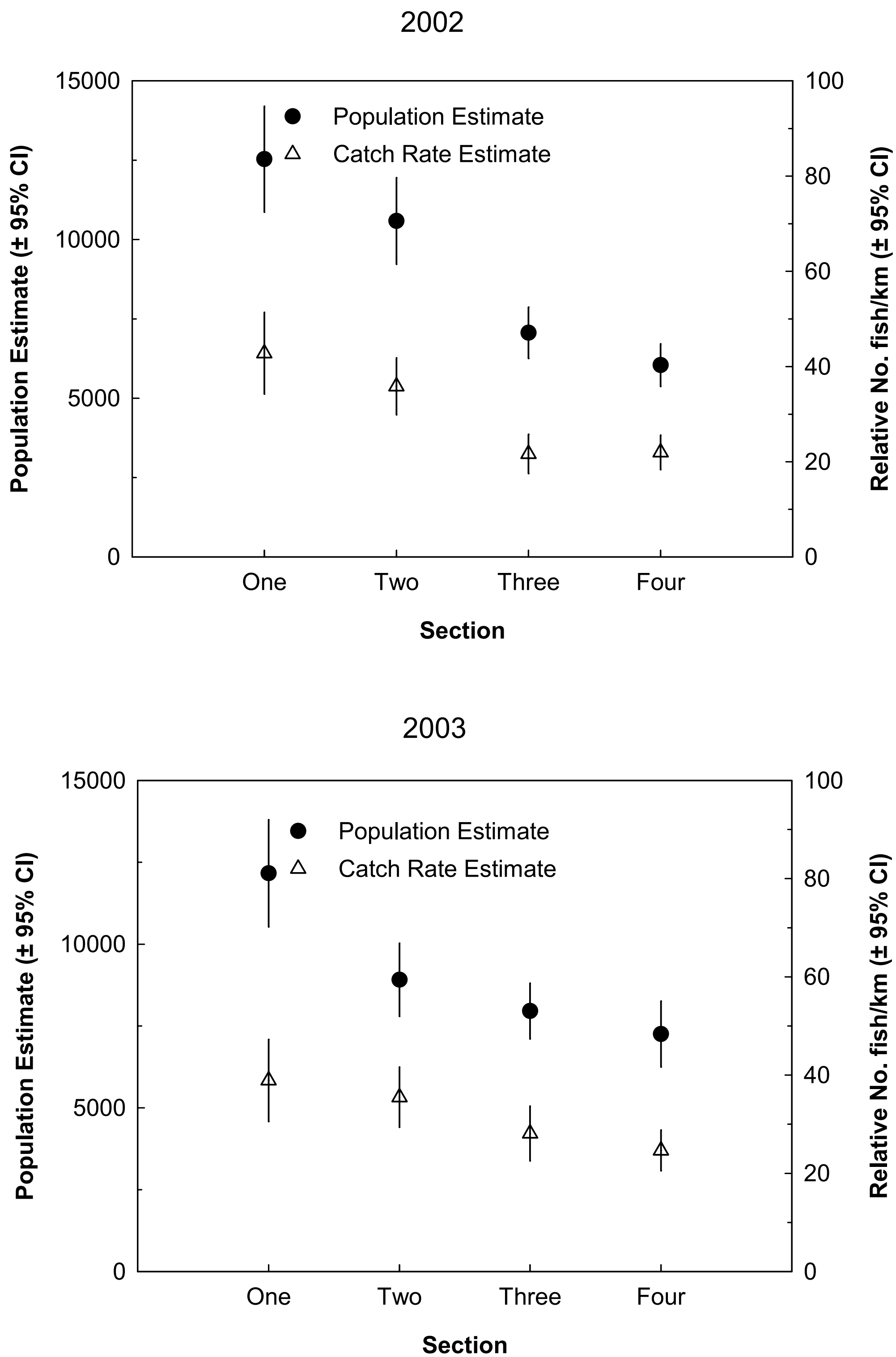


Figure 3.28 Relationship between population estimates and weighted catch rates of mountain whitefish during the Peace River Fish Community Indexing Program, 2002 and 2003.

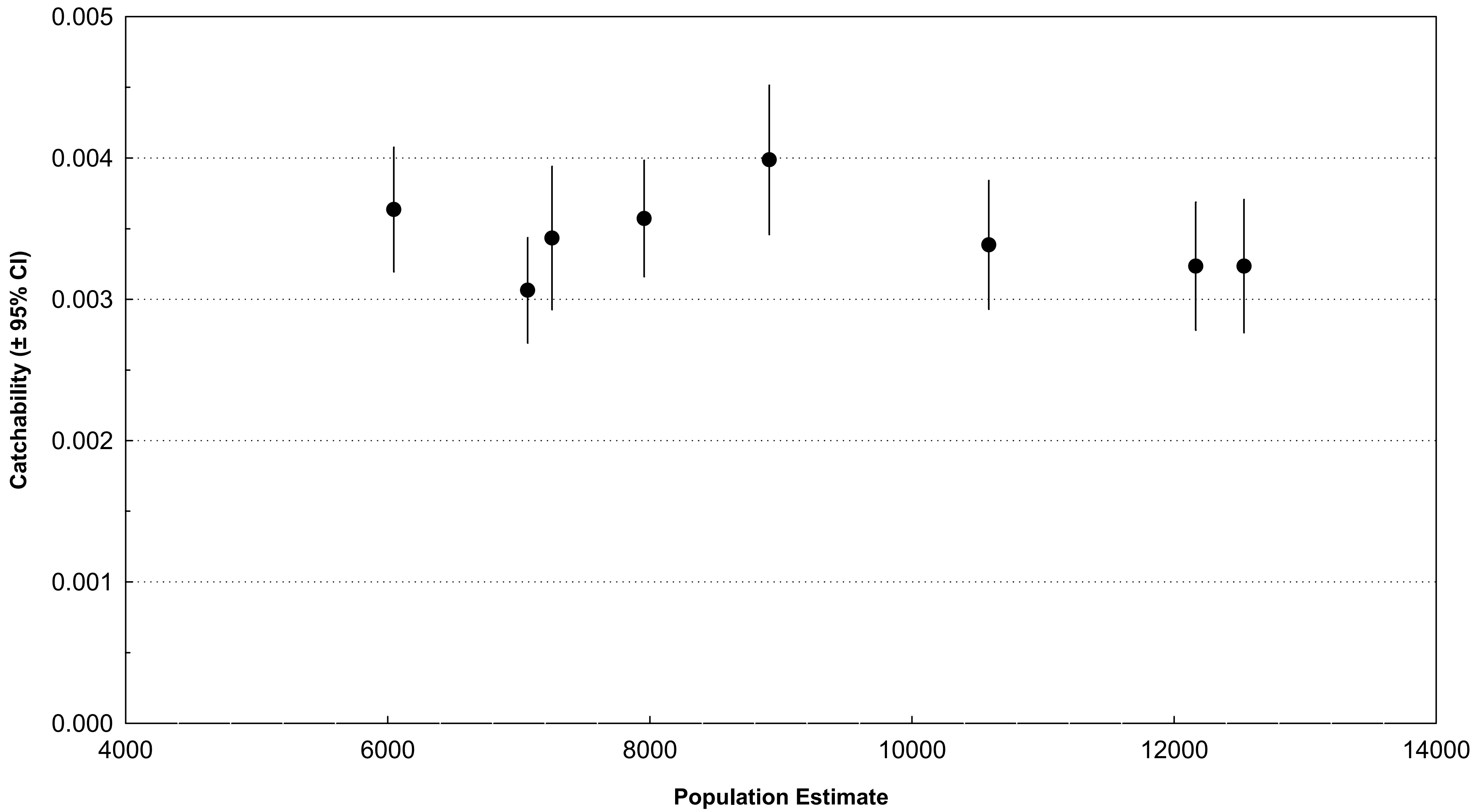


Figure 3.29 Catchability versus population estimate (using weighted catch rates) of mountain whitefish during the Peace River Fish Community Indexing Program, 2002 and 2003.

4.0 SUMMARY

4.1 BIOLOGICAL CHARACTERISTICS

4.1.1 Arctic grayling

In total, 142 Arctic grayling were sampled for biological characteristics; however, the low number of fish encountered in Zone 1 limits the value of the data in terms of describing the characteristics of the Arctic grayling population.

There were spatial differences in length and age distributions of Arctic grayling. Smaller, younger fish accounted for a greater percentage of the sample in Zone 2 compared to Zone 1. The difference was related primarily to the absence of Age 1 fish from Zone 1. The results for length-at-age and body condition suggested that there were no spatial differences in the population. The results were consistent with those of Phase 2.

There were some yearly differences in biological characteristics of Arctic grayling. The strong Age 3 class recorded in Zone 1 in 2002 resulted in a strong Age 4 class the following year. Age 1 fish also were more prevalent in the Zone 2 sample in 2003 compared to 2002. No difference in Arctic grayling age-class growth was recorded between years. But, body condition tended to be greater in 2003.

4.1.2 Bull trout

In total, 174 bull trout were sampled for biological characteristics. The results suggested that the population structure (size and age distributions) differed between zones and this was consistent with findings of Phase 2. There were also apparent yearly differences in growth and body condition, but the differences were not significant. As for Phase 2, the findings highlight two issues. First, spatial differences in the bull trout population indicate that monitoring should incorporate spatial stratification. Second, the variation in length-at-age data will necessitate collection of larger sample sizes in order to detect statistical differences in biological characteristics.

4.1.3 Mountain whitefish

In total, 8798 fish were measured for length and weight. Of these, 828 fish or 9.4% of the sample was aged. Length and age frequency distributions of mountain whitefish exhibited spatial differences in the population structure. Fish in Zone 1 exhibited a condensed bi-modal size distribution, which was explained by the scarcity of fish in age classes 1, 7 and 8. Mountain whitefish in Zone 2 exhibited a much broader multi-modal size distribution. The age distribution of these mountain whitefish was more evenly distributed between Ages 1 to 9. Length-at-age data suggested spatial differences in growth rate. Fish Age 4 and older fish in Zone 2 were larger at a given age and several of the differences were significant. Body condition of mountain whitefish sampled from each zone was not statistically different. In general, the findings were similar to the results of Phase 2.

There were yearly differences in biological characteristics of sampled mountain whitefish. A general increase in length-at-age occurred between 2002 and 2003. The majority of age classes in both zones demonstrated an increase in mean length. A similar pattern also was observed for mean body condition-at-age. The mechanism(s) driving the differences were unknown, but factors such as discharge, water temperature, and primary productivity could have played a role.

4.1.4 Biological Characteristics Summary

There were spatial differences in population structures of all three target species. Also, there was evidence that growth rate and body condition of mountain whitefish differed between the two sample zones. Based on these findings, future monitoring should incorporate spatial stratification in the study design. The large variation in length-at-age data for bull trout will necessitate collection of larger sample sizes in order to detect statistical differences in biological characteristics.

The present study also documented changes in biological characteristics of all three target species in terms of length and age distributions. The mountain whitefish population also demonstrated yearly differences in growth and body condition. As such, the monitoring program is able to document trends in biological characteristics of the target populations.

4.1.5 Incremental Growth and Project Effects

As a check of the accuracy of the length-at-age estimates, information derived from age data were compared to incremental growth data from marked fish tagged in 2002 and recaptured in 2003. If growth among the two groups was similar, this would confirm the accuracy of the length-at-age estimates and the fish ages on which the estimates were based.

Incremental growth of mountain whitefish was lower then expected and was below the age derived growth estimates. The results suggested that either the age growth data or the incremental growth data were not representative of actual growth rate. Comparisons made to size intervals between modal peaks depicted by mountain whitefish length distributions suggested that the growth estimates derived from the age data, at least for younger fish, were accurate. Based on these results, it was concluded that incremental growth data were not valid and should not be used as a check of the accuracy of the length-at-age estimates or the ages on which estimates were based.

The incremental growth of marked mountain whitefish was less then expected, which suggested that project activities may have had a detrimental effect. This issue was investigated be examining mountain whitefish body condition, as well as immediate and delayed mortality. The mean body condition of mountain whitefish tagged in 2002 and recaptured in 2003 was lower then the body condition of fish that had been tagged and recaptured in 2003. This indicated that project activities adversely affected mountain whitefish.

Direct mortality of mountain whitefish associated with boat electrofisher capture was negligible (< 1%). Also, less than 5% of mountain whitefish captured by boat electrofishing suffered potential injury and a large number of samples contained no fish that demonstrated potential injuries. The results provided evidence that immediate and delayed mortalities were low. As such, tags used for monitoring (T-bar anchor tags) may have been the primary mechanism causing the observed detrimental effects.

4.2 RELATIVE ABUNDANCE

4.2.1 Sampling Protocols

Boat Operation

The Phase 3 results indicated that the boat operation protocols of Crew 1 had changed in terms of time spent sampling, but the adjustment was not sufficient to remove all apparent bias. Crew 1 catch rates for bull trout were lower and Crew 1 catch rates for Arctic grayling were higher than for Crew 2. However, the adjustment in boat operation was sufficient to reduce crew bias to acceptable levels. The proportional difference in crew catch rates was lowered for each of the problem target species in SFC habitat. The change was deemed sufficient to allow analysis of catch data collected by both crews.

Observer Experience and Bias

The ability of experienced and inexperienced samplers to identify difficult target fish species (Arctic grayling and bull trout) was examined by comparing the correlation between the number of fish captured and the number observed. Inexperienced samplers showed a very weak correlation, while experienced observers showed a significant positive correlation. The results demonstrated that sampler experience affected the ability to enumerate difficult species.

Sampler experience did not improve counts of numerous species such as mountain whitefish. First, sampler experience did not improve the reliability of the count. Counts by experienced and inexperienced observers had the same variation. Second, sampler experience did not affect the ability to maintain the precision of the count. For both groups, the precision decreased as the number of fish counted increased. Third, both experienced and inexperienced samplers tended to underestimate the number of mountain whitefish counted.

Use of observed fish to calculate catch rate affected the precision of the estimate, but precision (measured as coefficient of variation) depended on the target species. For Arctic grayling and bull trout, inclusion of observed fish increased precision whereas use of observed mountain whitefish decreased precision.

Based on the results, use of observed fish in estimation of catch rate will depend on the target species of interest. Arctic grayling and bull trout counts, which are not abundant in the study area, should be included in the catch enumeration. Use of observed mountain whitefish, which is a very abundant species is not recommended because this will decrease sample precision and bias the catch rate downward.

<u>Stratification by Section and Habitat</u>

Mean catch rates of the three target species exhibited spatial differences between habitats. Arctic grayling and bull trout catch rates were higher in SFC habitats compared to SFN habitats. Catch rates of mountain whitefish tended to be higher in SFN habitats compared to SFC habitats in three sections. Mean catch rates differed between sampled sections for some target species. Arctic grayling were more numerous in Sections 3 and 4, but bull trout mean catch rates tended to be constant. Mountain whitefish exhibited distinct spatial differences in abundance relative to the Halfway River confluence. Mean catch rates were higher in Sections 1 and 2 compared to Sections 3 and 4.

Based on the findings, future monitoring should continue to stratify relative abundance sampling by habitat and river section.

<u>Effect of Repeated Sampling on Catch Rate</u>

Sampling during the field program was repeated six times in each section. This level of sampling intensity may have sensitized the target fish species to boat electrofishing, which could result in altered catchability. For Arctic grayling and bull trout the majority of correlations between catch rate and session were negative, which suggested that there was an effect. As such, this issue should be considered during future monitoring programs of these species.

4.2.2 Confounding Factors

Discharge

Peace River discharge during the present field program was lower and tended to be more variable than in 2002. One basic flow pattern was recorded, which was depicted by rapid changes in water level followed by short periods of high or low stable flow based on a 24-hour cycle.

Several water level parameters were examined to ascertain whether discharge affected catch rate. These included changes in water level, the rate or magnitude of change, high versus low water level, and water level variability prior to sampling. There was no relationship between a change in water level or the rate of change and catch rate for each of the target species. Water level stability may have affected catch rate, but the influence was weak. The evaluation provided only limited evidence that catch rates of target species were influenced by flow patterns of the Peace River during the study period, which is similar to findings during Phase 2.

Water Clarity

Water clarity in the Peace River during the sampling period was high (> 170 cm). Given the high values recorded during Phase 2 there likely was no influence of water clarity on catch rate.

4.2.3 Effort Required to Detect Change

To ascertain whether the target species populations were suitable candidates for monitoring, the relationship between sample variation (standard deviation) and a measure of the magnitude of difference needed between samples (coefficient of variation) was examined.

Standard deviations associated with catch rate estimates for the majority of target species remained stable between 2002 and 2003. Also, the size of the standard deviation did not differ substantially between the SFC and SFN habitat categories. The results indicated that the sampling protocols maintained the stability of the catch rate variation.

Coefficient of variation was very high for Arctic grayling and bull trout, but remained low and stable for mountain whitefish. Because the standard deviations associated with the estimates remained stable, the observed differences were due to changes in fish abundance.

Power analysis indicated that sample sizes required to detect a 25% change in abundance for Arctic grayling and bull trout were excessive (> 100), while sample sizes needed for mountain whitefish were achievable (< 12). The results were similar to findings made during Phase 2. Mountain whitefish catch rates were suitable for monitoring purposes. However, Arctic grayling and bull trout were not appropriate candidates for monitoring due to excessive catch rate variation.

4.2.4 Comparison to Previous Studies

An objective of Phase 3 was to extend the time series data of the abundance of nearshore fish populations in the Peace River. In general, catch rates of the target species populations differed between years and sections. Overall, Arctic grayling mean catch rates in the SFC were higher in 2003 compared to 2002. This likely was caused by decreases in Arctic grayling catch rates in Sections 1 and 2 in combination with increases in Sections 3 and 4. Despite these changes there were no statistical groupings of the sample sections.

The opposite trend was recorded for bull trout. Catch rates decreased between 2002 and 2003. The change was most pronounced in Section 2 (SFC habitat) and Section 1 (SFN habitat). The decreases may be an artifact of using catch data from both crews in 2003 compared to using only the catch rates of the more efficient crew in 2002. Therefore, the data should be interpreted with caution.

Small nonsignificant changes in mountain whitefish mean catch rates were recorded between years. Decreases occurred in Sections 1 and 2, while the opposite was true for Sections 3 and 4. In the SFC habitat category, the statistical groupings of Section 1 and 2 versus 3 and 4 that occurred in 2002 were not recorded in 2003. This likely was due to the increase in catch rates in Sections 3 and 4. The results for the SFN habitat category were consistent between years. Catch rates of mountain whitefish in Sections 1 and 2 were significantly higher then catch rates in Sections 3 and 4.

4.3 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.

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 four river sections using minimum time-at-large of six 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%. Other parameter values were tried in order to reveal the sensitivity of the population estimates to possible failures in the model assumptions. The replication of the mark-recapture experiment revealed that the recapture probabilities are heterogeneous which usually leads to an overestimation of population size. The consistency of the catchability coefficient across various population sizes and flow conditions argues that the impact was 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. The structured sequential sampling design was the same as 2002 and had similar efficiency.
4. Highly precise population (CV = 3.3%) and catchability (CV = 7.5%) estimates for mountain whitefish.
5. Verification that catchability is constant between river sections and years (thus catch-per-unit effort indices are comparable and representative of the population).

The very sparse recoveries for Arctic grayling made any point estimates of population size highly unreliable. Statements of minimum population size (e.g., 0.95 probability that there is at least 250 Arctic grayling) should be valid. For bull trout, population estimates are available, but the precision is poor (CV = 39%). There is not sufficient data to forecast effort levels needed for reliable population estimates for either Arctic grayling or bull trout.

4.4 RELATIVE ABUNDANCE AS INDEX OF POPULATION SIZE

An important objective of the Peace River Fish Community Indexing Program was to establish whether relative abundance could be used as an index of absolute abundance. The Peace River Fish Community Indexing Program has developed standardized sampling protocols and stratified sampling in order to generate precise estimates of catch rate and population size for at least one target species (mountain whitefish). Phase 2 established that catchability was stable across sections. More data points and inclusion of annual differences were required to establish whether catchability was stable both spatially and temporally.

Data from two years of study documented a strong positive relationship weighted between relative abundance and population size. The data also demonstrated stable catchability across sections and years. In addition, catchability estimates exhibited a small coefficient of variation (< 8%). From these data one can conclude that catchability is stable. Therefore, catch rates for mountain whitefish are suitable to monitor trends in mountain whitefish abundance in the Peace River study area.

5.0 RECOMMENDATIONS

5.1 APPROACH AND DESIGN

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 results of the Phase 2 program indicated that the monitoring protocols were suitable to meet the objective of the program, particularly for mountain whitefish. The Phase 3 results confirmed these findings. Adjustments can be incorporated into future monitoring to improve the reliability of the data for other target species, but the basic strategy and effort employed by Phase 3 are sufficient to meet the overall objective of the Large River Program.

Monitoring protocols should be based on a systematic assessment of the following factors:

1. The potential effects of the dam operation regimes on the fish community.
2. The best target species based on life history and catchability.
3. The best sampling locations or group of locations.
4. The optimal sampling time.

Phases 1, 2 and 3 focused efforts on developing and evaluating monitoring protocols designed to address these factors. The following provides general comments regarding the approach used to date and recommendations for future monitoring, if applicable.

<u>Monitoring Parameters</u>

The program targeted nearshore habitats that are effectively sampled by boat electrofishing. This approach focused on areas (channel margins) potentially influenced by changes to dam operation and used the most effective sampling method available for large river systems. Parameters chosen for monitoring (biological characteristics, relative abundance, and population estimates) were suitable for evaluating effects of the dam operation on the fish community.

Attempts should be made to monitor additional parameters. First, the contribution of younger age classes to the target populations, or recruitment should be quantified. Mountain whitefish would be the best candidate because younger-aged fish (Ages 0 and 1) are present in the mainstem river, which makes them vulnerable to capture (RL&L 2001). Second, sexual differences in growth and fecundity should be monitored to improve the ability of the program to detect changes in the biological characteristics of the target population. Again, mountain whitefish is the best candidate for this component because the population is abundant and widely distributed. Fish would need to be intentionally sacrificed in order to obtain useful information.

Target Species

The program results indicated that the low abundance of Arctic grayling and bull trout hindered collection of sufficient sample sizes to monitor changes in biological characteristics and relative abundance. Despite significant sampling effort, useful catch rate and population estimates were not developed for these two species. From a logistical perspective, Arctic grayling and bull trout are not suitable for monitoring because reliable data cannot be collected using the sampling techniques and effort employed. This likely is due to a number of factors including low fish number (Arctic grayling) and inefficiency of the capture method (bull trout).

From an ecological perspective, Arctic grayling and bull trout are suitable indicators. Both require distinct nearshore habitats (those with physical cover), which could make them susceptible to operational changes in flow regime. Each species uses a different ecological niche that is affected differently by flow alterations. Finally, bull trout may be an important species in the Peace River fish community from an ecological perspective, because they are a major predator.

If the Peace River Fish Community Indexing Program places a high importance on use of Arctic grayling and bull trout as target species, the efficacy of alternative sampling methods should be investigated. An alternate sampling method such as angling could be employed for the mark-recapture component of the program and to collect additional fish for assessment of biological characteristics. This technique has been used effectively for both species during population estimate studies on other river systems in Alberta and British Columbia.

Sample Location

The program has been designed to evaluate spatial differences in sample populations in the upper portion of the Peace River. This area encompasses the majority of the target species populations and represents the section of the Peace River that potentially would be most affected by alterations to the flow regime. However, the downstream half of the entire Peace River study area was not sampled during Phase 2 or Phase 3. Future monitoring should include the lower portion of the Peace River to eliminate this data gap.

Marking Effects

Mountain whitefish marked 2002 and recaptured in 2003 exhibited lower then expected growth and lowered body condition, which indicated that project activities such as use of T-bar anchor tags were having detrimental effects on fish. These effects may also explain heterogeneous capture probabilities of tagged mountain whitefish documented during Phase 3. To address this issue consideration should be given to use of a less intrusive tagging system (i.e., pit tags).

Recommendations

1. Maintain the present study design and sampling protocol with the following adjustments.
    a. There is no need to repeat the entire experiment to assess inter-annual variation in catchability. However, replication of the study in at least two sections would enable the application of multi-year open mark-recapture population models that would generate year-to-year survival estimates, population estimates and quantify growth recruitment into the population.
    b. Expand the program to include one or more downstream sections in the study area.
    c. Quantify recruitment by targeting younger mountain whitefish. This could be accomplished by modifying the present fish capture methodology to access shallow water habitats frequented by these fish.
    d. Quantify fecundity and sexual differences in growth of mountain whitefish. This would require intentional sacrifice of a random sample of fish.
2. Employ an alternate marking system (pit tags) to address the potential issue of detrimental effects caused by the current marking system (T-bar anchor tags).
3. Build an age-structured model that will serve to synthesize catch-per-unit-of-effort, age and abundance information. If such models are to be maintained and used for the evaluation of dam operation impacts there will be a need to collect long term information on population dynamics (e.g., mortality and stock-recruitment functional form). The application of long-lasting marks such as pit tags would assist in this endeavor.
4. Investigate alternative sampling protocols for Arctic grayling and bull trout. This should include use of dedicated angling by qualified individuals.

5.2 PROGRAM SCOPE

Results to date indicated that the monitoring protocols developed during Phases 1 to 3 were suitable to meet the objective of the program, particularly for mountain whitefish. However, establishing a causal relationship between flow alteration and a change in the fish community will be problematic until there is a good understanding of fish community response to flow alteration. In particular, effects outside the control of the program could hamper interpretation of the monitoring data.

The scope of the Peace River Fish Community Indexing Program should be expanded to collect information needed to interpret the monitoring data. The following are questions for consideration:

1. How does recreational sportfish harvest affect populations of the target species?
    - Are current harvest rates sufficient to depress the adult component of the Arctic grayling population?
    - Will development of improved boat access to the Peace River increase harvest rates?
2. What nearshore habitats are important to the target species populations?
    - What are the critical spawning areas for mountain whitefish?
    - Are Arctic grayling and bull trout restricted to nearshore habitats containing physical cover?
3. How does daily flow alteration affect fish use of important nearshore habitats?
    - What is the lateral and longitudinal extent of fish movement within the channel in response to flow alteration?
    - Are fish forced into suboptimal habitats that increase energy expenditures and the risk of predation?

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