Site C Clean Energy Project

Baseline Peace River (2010–2020) Fish Mercury

FINAL

Prepared for:

BC Hydro

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EXECUTIVE SUMMARY

Azimuth Consulting Group Inc. (Azimuth) has prepared this report on behalf of BC Hydro to characterize baseline fish mercury concentrations in the Peace River, as part of the Site C Clean Energy Project (Site C). Unless specified otherwise, use of the term "mercury" throughout this document refers to methylmercury, the form most commonly found in fish and of most concern from a human health perspective.

Azimuth has been working with BC Hydro for over a decade to help address concerns regarding potential changes in fish mercury concentrations stemming from the development of Site C. To support the environmental assessment process, initial efforts were directed at understanding the magnitude and timing of changes in fish mercury levels. More recently, we have worked with BC Hydro to develop the Methylmercury Monitoring Plan (MMP) for Site C. The purpose of the MMP is to guide the monitoring of fish mercury concentrations over time, in relation to the construction and subsequent operation of Site C, to provide timely information upon which to base advice for consuming fish.

Baseline fish sampling efforts to support the MMP have been integrated into other Site C fish-related monitoring programs, to avoid duplicating efforts to collect fish. Sampling conducted to support the environmental assessment process was paired with the baseline fish community sampling in 2010/2011 (considered the *early* baseline period), and more recent sampling was conducted as part of the Fisheries and Aquatic Habitat Monitoring and Follow-up Program (FAHMFP), from 2017 to 2020 (considered the *recent* baseline period). Data collected include fish biology (e.g., species, size, age etc.), tissue mercury (measured as "total" but assumed to be exclusively methylmercury) and tissue stable isotope analysis (SIA; used to provide insights into feeding ecology). Collectively, these data are considered the baseline fish mercury dataset to support the MMP.

Eleven fish species have been sampled for mercury concentrations to date, as part of baseline monitoring in the Peace River. A subset of these have been selected as *targeted* species, as described in the MMP (BC Hydro 2021). Their selection was based on their importance from a consumption perspective, such as having cultural or sporting value, or from an ecological perspective, such as being an important prey species. These are:

- Bull Trout (BT)
- Mountain Whitefish (MW)
- Rainbow Trout (RB)
- Longnose Sucker (LSU)

- Redside Shiner (RSC)
- Walleye (WP)

The baseline dataset includes tissue mercury results from fish caught at select locations in the Peace River, upstream and downstream of the Site C dam (**Figure ES-1**). The upstream end of the baseline dataset is represented by Dinosaur Reservoir. The downstream end of the baseline dataset, through 2020, is Many Islands.

Mercury or methylmercury data are available for 1,371 individual fish representing 12 different species. Statistical analyses were used to test for patterns over time and across space. Temporal differences were seen between the early and recent baseline periods for most species, with mercury concentrations approximately twice as high in the recent period. These changes are unlikely to be related to Site C given that substantial inundation of organic-rich terrestrial habitat, which is the primary driver of methylmercury increases in fish tissues in reservoirs, will only begin in 2023. Where spatial differences were identified, the most common pattern was higher mercury concentrations downstream of Site C.

A summary of estimated mercury concentrations for specific standardized sizes of the target species in the Peace River for the recent (2017–2020) baseline period is presented in **Table ES-1**. These results are considered representative of current conditions in the river.

Figure ES-1. Baseline fish mercury monitoring locations.

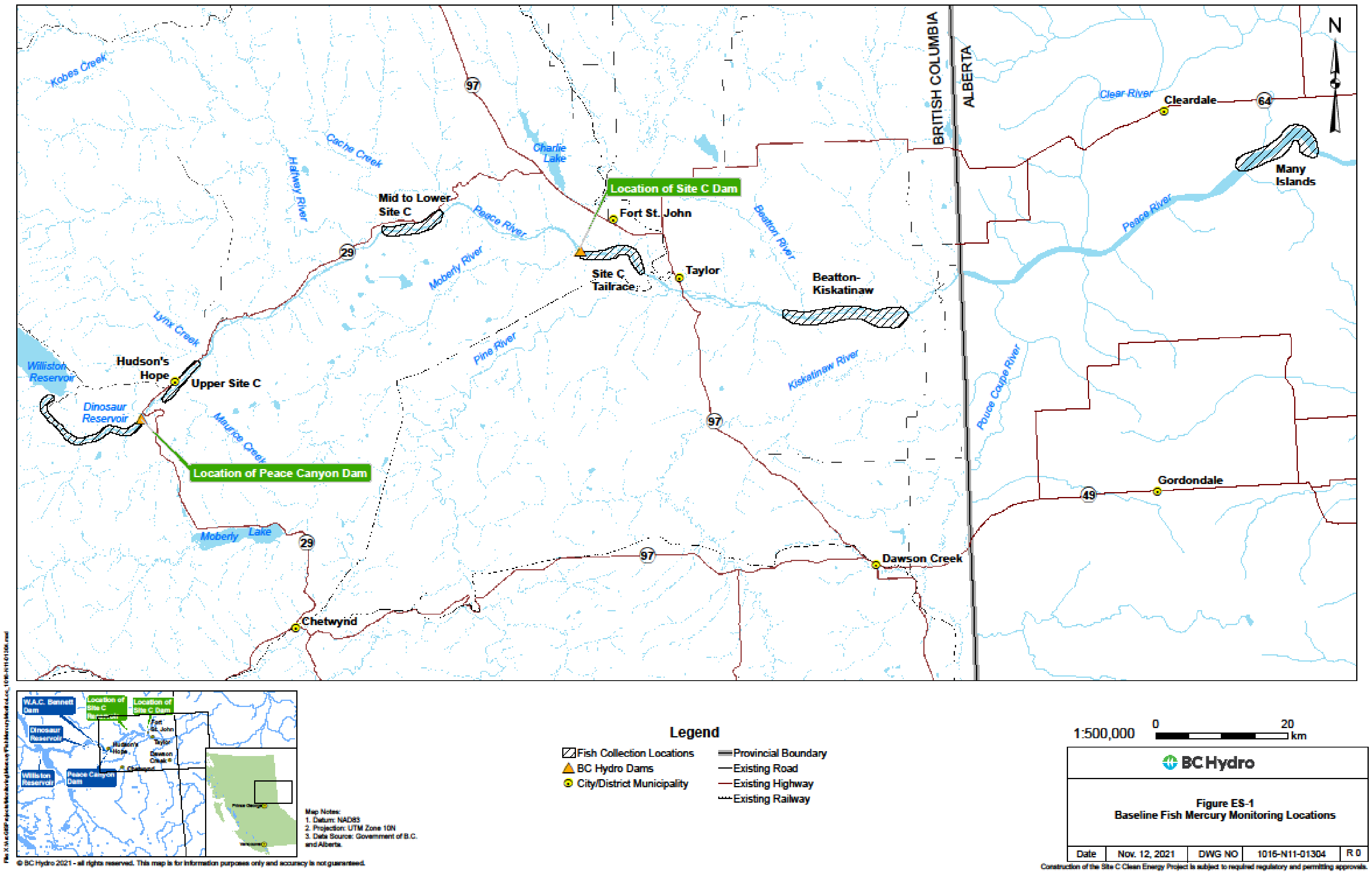

Table ES-1. Summary of fish mercury concentrations for select sizes of target species in the Peace River for the recent (2017–2020) baseline sampling period.

Species	Temporal/ Period Trends?	Spatial Trends?	Model Used	Data Overview	Location	Size	Mercury (mg/kg ww)
Bull Trout	Yes; recent > early period	No	Fit for recent period	2017-2020 (n=148; pooled); Sect 1,3,5,6,7 (pooled); one outlier removed	All	400 mm	0.091
					All	550 mm	0.15
					All	700 mm	0.24
Mountain Whitefish	Yes; recent > early period	Yes; generally higher concentrations further downstream	Fit for spatial using recent data	2017-2020 (n=280; pooled); fish > 200 mm only; Sect 1,3,5,6,7,9; one outlier removed	Sec 1	200 mm	0.013
					Sec 3	200 mm	0.016
					Sec 5	200 mm	0.025
					Sec 6	200 mm	0.023
					Sec 7	200 mm	0.022
					Sec 9	200 mm	0.019
					Sec 1	350 mm	0.045
					Sec 3	350 mm	0.045
					Sec 5	350 mm	0.054
					Sec 6	350 mm	0.055
					Sec 7	350 mm	0.067
					Sec 9	350 mm	0.054
					Sec 1	500 mm	0.16
					Sec 3	500 mm	0.13
					Sec 5	500 mm	0.12
					Sec 6	500 mm	0.13
					Sec 7	500 mm	0.21
					Sec 9	500 mm	0.15
Rainbow Trout	No	No	Fit for recent period	2017, 2018, 2020 (n=53; pooled); Sect 1,3 (pooled); no outliers to remove	All	200 mm	0.018
					All	300 mm	0.028
					All	400 mm	0.042
Longnose Sucker	Yes; recent > early period	Yes; generally higher concentrations further downstream	Fit for spatial using recent data	2017-2020 (n=262; pooled); Sect 1,3,5,6,7,9; no outliers to remove	Sec 1	250 mm	NA*
					Sec 3	250 mm	0.028
					Sec 5	250 mm	0.027
					Sec 6	250 mm	0.027
					Sec 7	250 mm	0.035
					Sec 9	250 mm	0.036
					Sec 1	350 mm	0.047
					Sec 3	350 mm	0.049
					Sec 5	350 mm	0.048
					Sec 6	350 mm	0.047
					Sec 7	350 mm	0.061
					Sec 9	350 mm	0.063
					Sec 1	450 mm	0.1
					Sec 3	450 mm	0.11
					Sec 5	450 mm	0.1
					Sec 6	450 mm	0.1
					Sec 7	450 mm	0.13
					Sec 9	450 mm	0.14
Walleye	Yes; recent > early period	Yes; generally higher concentrations further downstream	Fit for spatial using recent data	2017-2019 (n=129; pooled); Sect 5,6,7,9; no outliers to remove	Sec 5	300 mm	0.11
					Sec 6	300 mm	0.11
					Sec 7	300 mm	0.13
					Sec 9	300 mm	0.17
					Sec 5	400 mm	0.18
					Sec 6	400 mm	0.19
					Sec 7	400 mm	0.22
					Sec 9	400 mm	0.28
					Sec 5	500 mm	0.3
					Sec 6	500 mm	0.31
					Sec 7	500 mm	0.36
					Sec 9	500 mm	0.46

*NA = estimate not made due to lack of data for this fish size.

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ACKNOWLEDGEMENTS

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We gratefully acknowledge the following support:

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- Dustin Ford and the Golder Associates team that conducted the Peace River Large Fish Indexing Survey (Mon-2a) under Site C's Fisheries and Aquatic Habitat Monitoring and Follow-up Program (FAHMFP; Mon-2, Task 2a), which has provided the bulk of the fish samples analyzed for mercury since 2017. Dustin also built the database used to house the fish mercury dataset.
- Mark Le Ruez and the Triton Environmental Consultants team that conducted the Peace River Fish Composition and Abundance Survey (Mon-2b) under Site C's FAHMFP, which provided the Redside Shiner fish mercury data.
- Site C's Methylmercury Sub-committee provided input through discussions on the baseline data and analysis results.

ACRONYMS

BB	Burbot
BT	Bull Trout
FAHMFP	Fisheries and Aquatic Habitat Monitoring Follow-up Program
FWCP	Fish and Wildlife Compensation Program
GE	Goldeye
GR	Grayling
Hg	Mercury
LC	Length "centered"
LSU	Longnose Sucker
LT	Lake Trout
LW	Lake Whitefish
MMP	Methylmercury Monitoring Program
MW	Mountain Whitefish
NP	Northern Pike
RB	Rainbow Trout
RSC	Redside Shiner
SD	Standard Deviation
SIA	Stable Isotope Analysis
TSA	Timber Supply Area
WP	Walleye

1 INTRODUCTION

1.1 Background

Azimuth Consulting Group Inc. (Azimuth) prepared this report on behalf of BC Hydro to characterize baseline fish mercury concentrations in the Peace River, as part of the Site C Clean Energy Project (Site C). Azimuth has been working with BC Hydro for over a decade to help address concerns regarding potential changes in fish mercury concentrations stemming from the development of Site C. To support the environmental assessment process, initial efforts were directed at understanding the magnitude and timing of changes in fish mercury levels. More recently, we have worked with BC Hydro to develop the Methylmercury Monitoring Plan (MMP) for Site C. The purpose of the plan is to guide the monitoring of fish mercury concentrations over time, in relation to the construction and subsequent operation of the Site C dam, to provide timely information upon which to base advice for consuming fish.

Background information on mercury in aquatic ecosystems, including expected changes associated with Site C, is provided elsewhere (BC Hydro 2021). Characterizing baseline fish mercury levels is important because it will support the development of fish consumption advice for current conditions and it will help better establish a reference point to which future monitoring results will be compared.

Mercury Measurements in Fish

Mercury can exist in several forms in the environment. These include elemental mercury (metallic; liquid "quicksilver" at 20°C), inorganic mercury compounds, such as cinnabar (HgS), and organic mercury compounds, such as methylmercury (CH_3Hg).

In fish tissue, most mercury is present as methylmercury (Bloom, 1992), which is also the most toxic form. Measuring methylmercury directly is considerably more expensive than measuring "total mercury," which includes methylmercury. Consequently, most fish mercury studies rely on total mercury measurements and assume that it is all present as methylmercury.

In this document, unless specified otherwise, both "total mercury" and "mercury" are assumed to refer to methylmercury in the context of fish tissue.

1.2 Objectives

Baseline fish mercury sampling started in 2010/2011 to support the environmental impact assessment for Site C, and it continued from 2017 to 2020 as part of the Site C Fisheries and Aquatic Habitat Monitoring and Follow-up Program (FAHMFP). The objectives of this baseline analysis were to:

- Summarize available monitoring data by species.
- Summarize fish mercury concentrations by species.
- Summarize fish stable isotope analysis (SIA) data to understanding general feeding relationships.
- Provide the following information for target species (see **Section 2.2**):
  - Present catch by location/year and by location/size class.
  - Present fish length and age by location (across years).
  - Explore key mercury relationships.
  - Characterize length-mercury relationships (see **Section 4.1** for details) and explore patterns over time (across years or between periods) and space (across locations).
  - Estimate tissue mercury concentrations for specific, standardized sizes.

1.3 Report Organization

The remainder of this report is organized as follows:

- **Overview of Baseline Fish Mercury Data** (**Section 2**), which summarizes the baseline data sources, targeted fish species and sampling locations.
- **Summary of Baseline Catch, Fish Mercury Concentrations and Feeding Relationships** (**Section 3**), which presents catch, fish mercury and stable isotope results across species.
- **Fish Mercury Results by Species** (**Section 4**), which summarizes key results regarding patterns in fish mercury concentrations over time and space for each target species.
- **Summary of Recent Baseline Results** (**Section 5**)

Terminology note: To differentiate sections of this report from Peace River sections at the Site C location, the report sections are written in bold, navy font, e.g., **Section 1**, and the Peace River sections are written in plain text, e.g., Section 1.

2 OVERVIEW OF BASELINE FISH MERCURY DATA

2.1 Baseline Data Collection

Sampling efforts for mercury analysis have been integrated into other Site C fish-related monitoring programs, to avoid duplicating efforts to collect fish tissue samples. Sampling conducted to support the environmental assessment process was paired with the baseline fish community sampling in 2010/2011 (considered the *early* baseline period), and more recent sampling was conducted as part of the FAHMFP, from 2017 to 2020 (considered the *recent* baseline period). Collectively, these baseline fish mercury data are considered the baseline dataset to support the MMP.

2.2 Targeted Fish Species

Eleven fish species have been sampled for fish mercury concentrations to date, as part of baseline monitoring in the Peace River. A subset of these have been selected as *targeted* species, as described in the MMP. Their selection was based on their importance from a consumption perspective, such as having cultural or sporting value, or from an ecological perspective, such as being an important prey species. These are:

- Bull Trout (BT)
- Mountain Whitefish (MW)
- Rainbow Trout (RB)
- Longnose Sucker (LSU)
- Redside Shiner (RSC)
- Walleye (WP)

After Site C has been constructed and the fish community shifts in response to the change in habitat from river habitat to more lacustrine (lake-like) habitat, the targeted MMP species may need to be adjusted. For now, the statistical analyses presented here focus on the targeted species, and results for non-target species are included for completeness.

2.3 Sampling Locations

The baseline dataset includes tissue mercury results from fish caught at select locations in the Peace River, upstream and downstream of the Site C dam (**Figure 2-1**). The upstream end of the baseline dataset is represented by Dinosaur Reservoir. The downstream end of the baseline dataset, through 2020, is Many Islands. The Peace River sampling locations are referred to as *Sections* in the FAHMFP, and Many Islands is Section 9.

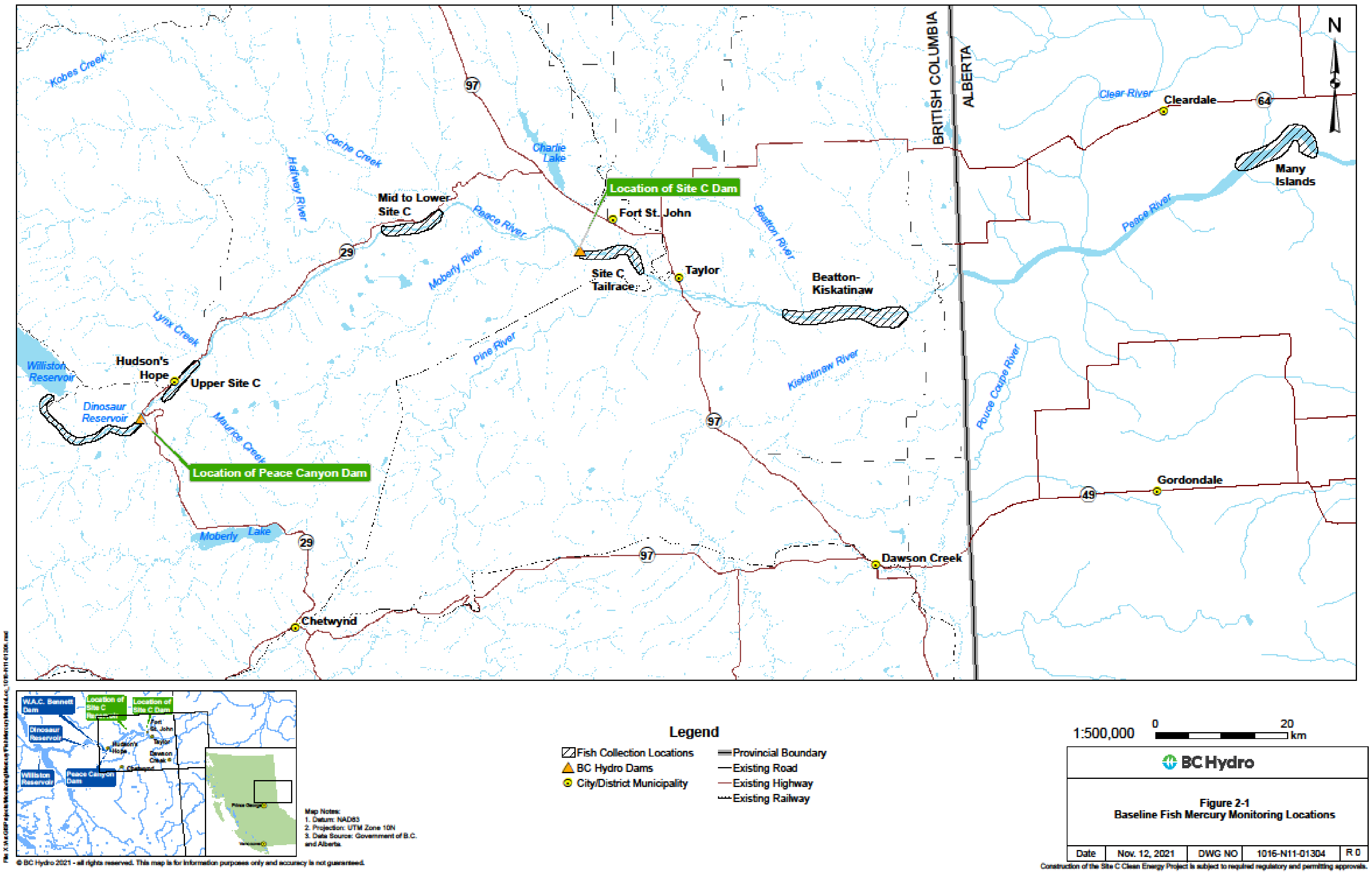
The primary baseline MMP fish sampling locations in the Peace River were as follows:

- *Upper Site C (Section 1)* on the Peace River mainstem, 5 km downstream of Peace-Canyon Dam.
- *Mid to Lower Site C (Section 3)* on the Peace River mainstem, immediately downstream of the Halfway River but upstream of the Moberly River and the site of the Site C dam.
- *Site C Tailrace (Section 5), immediately downstream of Site C dam*. This location is on the Peace River mainstem, immediately downstream of future Site C dam but upstream the Pine River.
- *Beatton-Kiskatinaw (Section 7), approximately 45 km downstream of Site C dam.* This location is on the Peace River mainstem, downstream of the Beatton River but upstream of the Kiskatinaw River.
- *Many Islands (Section 9), approximately 120 km downstream of Site C dam.* This location is on the Peace River mainstem, in the vicinity of Many Islands, AB. This location is the expected downstream terminus of Project-related mercury impacts.

In addition to sampling at these locations, a limited number of samples were collected from Sections 6 and 8. They were included in the general summaries and plotting, but were excluded from the detailed analysis due to low sample numbers.

Dinosaur Reservoir is not part of any current Site C fish monitoring programs, so there are no recent (2017–2020) samples from the Reservoir. However, some additional data from 2016 and 2017 were sourced from the Fish and Wildlife Compensation Program (FWCP) Peace Region's Williston-Dinosaur Watershed Fish Mercury Investigation (Azimuth, 2019b). While this location was included in some general summary tables and plotting, it was not included in any of the length-mercury relationship modelling.

Figure 2-1. Baseline fish mercury monitoring locations.



3 SUMMARY OF BASELINE CATCH, FISH MERCURY, AND FEEDING RELATIONSHIPS

3.1 Baseline Fish Catch

Mercury or methylmercury data are available for 1,371 individual fish, representing 12 different species, in at least one baseline year (**Table 3-1**). All six targeted species (see **Section 2.2**) were caught at one or more monitoring locations over at least two baseline years (details provided in **Section 4**), and six non-target species were caught at one or more monitoring location. Analysis of results for non-target species focused mainly on Goldeye, Lake Trout, Burbot and Northern Pike. The sample size for Arctic Grayling was low (n = 4), so they were only included in limited analyses. The sample size for Lake Whitefish was also low (n = 2) and they were caught only at Dinosaur Reservoir, so they were excluded from further analysis.

3.2 Fish Mercury Concentrations

Fish mercury concentrations are strongly influenced by diet. As a result, mercury is generally lower in species that consume zooplankton and benthic invertebrates, like Mountain Whitefish and Rainbow Trout, and higher in species that feed higher in the food web, like piscivorous (fish-eating) Bull Trout. In addition, larger, older fish tend to have higher mercury concentrations than smaller fish of the same species.

Fish mercury concentrations for all fish caught between 2010 and 2020, by species and waterbody zone (upper panel) or time period (lower panel), are shown in **Figure 3-1**. Note that at this stage of the assessment fish size is not considered, although size is an important factor when comparing fish mercury concentrations over time or space; this is explored further in **Section 4**. A detailed assessment of data quality for the baseline MMP dataset is provided in **Appendix A**.

3.3 Feeding Relationships

Insights into the feeding relationships among and within species and across waterbody zones can be obtained from stable isotope analysis (SIA; see text box).

Results from SIA are shown by waterbody zone and baseline period in **Figure 3-2**. These results confirm the patterns expected, based on general feeding ecology, with primarily piscivorous species such as Bull Trout, Lake Trout, Burbot, Northern Pike and Walleye having higher $\delta^{15}N$ values than species that are generally non-piscivorous in the Peace River such as Rainbow Trout, Mountain Whitefish and Longnose Sucker. Variability of results within a species largely reflects changes in the fish feeding preferences as they grow (e.g., smaller fish may feed on invertebrates and switch to increasingly larger fish as they get bigger). The SIA results also highlight the difference between the lacustrine Dinosaur Reservoir and the two Peace River zones, which is reflected in the spread of $\delta^{13}C$ values. The difference is due mainly to the influence of the pelagic (water column) food chain in the reservoir and the important role of the benthic (bottom) food web in the two riverine zones.

Stable Isotopes & Feeding Ecology

Stable isotopes are slightly different types of the same element (light & heavy) that are stable in the environment. Both types participate in chemical and biological reactions, but at different rates, which leads to patterns in the ratios of these isotopes in the environment. The ratios of carbon and nitrogen, two principal elements in biological tissue, can be used to quantify "you are what you eat."

***Nitrogen isotopes ($\delta^{15}N$)** are used to determine the trophic position of consumers in aquatic systems (i.e., where they sit within the food chain). With each increasing trophic level in the food chain organisms become more enriched in the stable isotope nitrogen-15. For example, the $\delta^{15}N$ value in a mature Bull Trout that eats other fish will be higher than in Rainbow Trout or Mountain Whitefish that eat invertebrates.*

***Carbon isotopes ($\delta^{13}C$)** trace the flow of energy, and therefore the flow of mercury (methylmercury: CH_3Hg), through food webs. Carbon isotopes can be used to determine whether fish are feeding more from the benthic or pelagic food webs.*

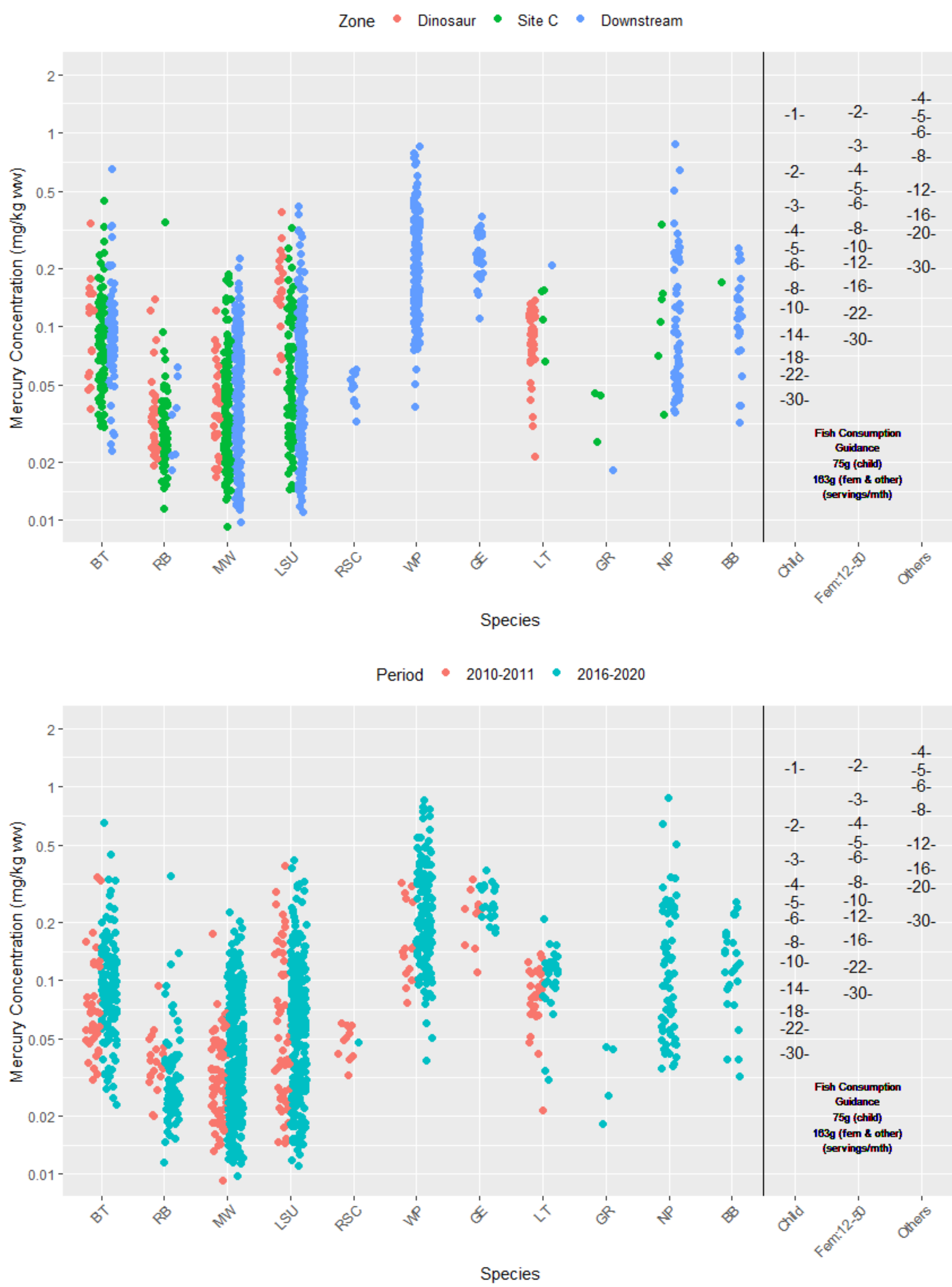
Note: the symbol "δ" is the Greek letter delta, which is often used to signify difference. In this case, delta refers to the isotopic ratio of sample relative to that of a standard reference material. Units are "‰", which is "per mil" or parts per thousand.

Table 3-1. Number of fish by species, captured during baseline years from all Project areas and Dinosaur Reservoir, sampled for tissue mercury (total) concentrations.

Species Name	Species Code	Fish N
Bull Trout	BT	186
Rainbow Trout	RB	101
Mountain Whitefish	MW	385
Longnose Sucker	LSU	324
Redside Shiner	RSC	12
Walleye	WP	166
Goldeye	GE	31
Lake Trout	LT	57
Arctic Grayling	GR	4
Northern Pike	NP	65
Burbot	BB	27
Lake Whitefish	LW	2

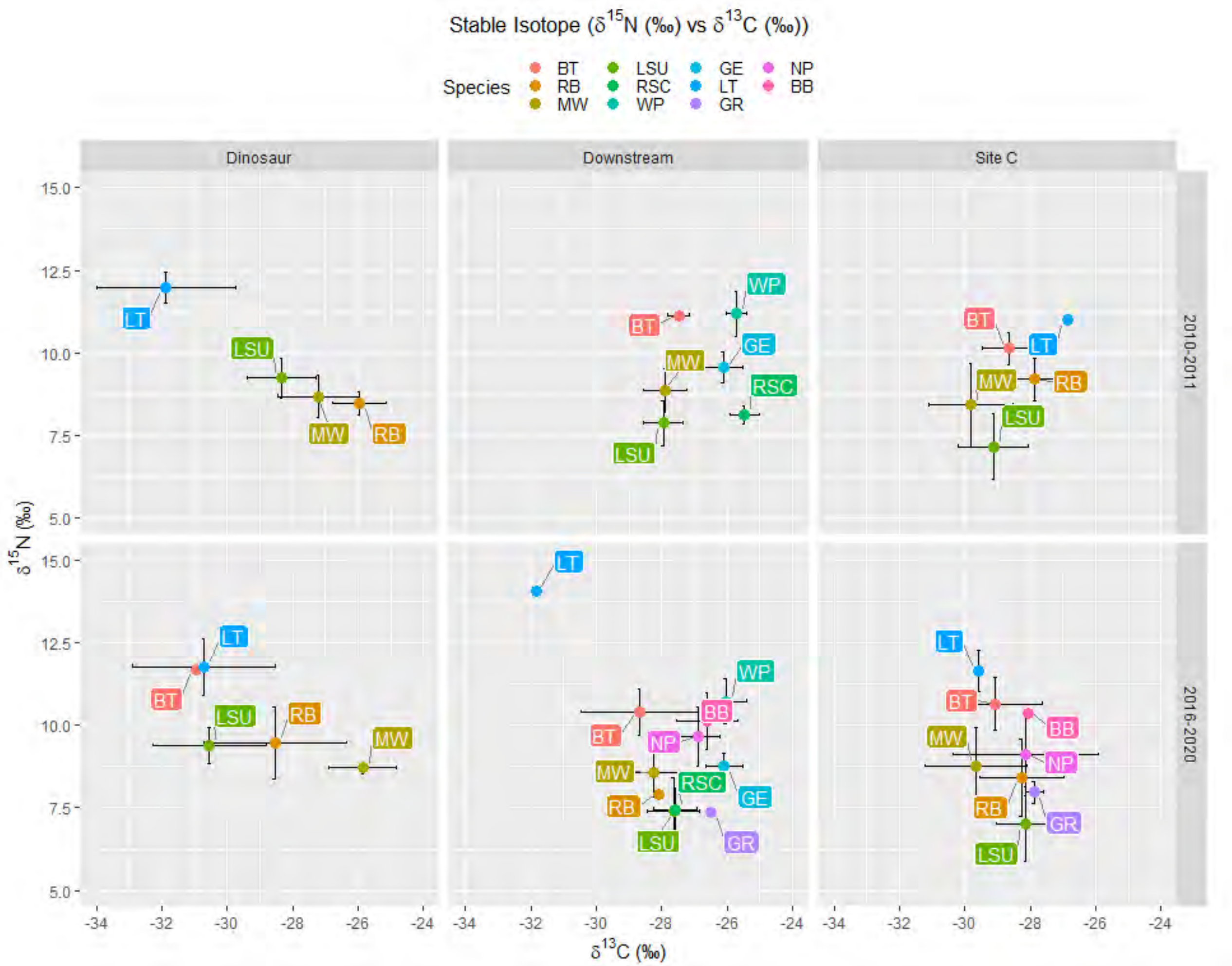
*Note that for RSC there are an additional 11 fish with methylmercury concentrations.

Figure 3-1. Tissue mercury concentrations for all fish species collected from 2010–2020, by waterbody zone (upper panel) or time period (lower panel). For interest, fish mercury consumption guidance is plotted on the right.



Species Codes: BT = Bull Trout, RB = Rainbow Trout, MW = Mountain Whitefish, LSU = Longnose Sucker, RSC = Redside Shiner, LT = Lake Trout, GR = grayling, NP = Northern Pike, BB = Burbot

Figure 3-2. Stable isotope results (mean ±SD for $\delta^{15}N$ and $\delta^{13}C$ values) by fish species, waterbody zone and time period.



Species Codes: BT = Bull Trout, RB = Rainbow Trout, MW = Mountain Whitefish, LSU = Longnose Sucker, RSC = Redside Shiner, LT = Lake Trout, GR = grayling, NP = Northern Pike, BB = Burbot

4 FISH MERCURY RESULTS BY SPECIES

4.1 Analysis Overview

For this analysis of the baseline fish mercury dataset, we considered the following elements: catch and data, length and age, general mercury relationships and length-mercury relationships. These are described below.

Catch and Data Summary. *Catch* refers to the fish that were caught and sampled for mercury analysis. Because sampling for mercury analysis is conducted to characterize a range of fish sizes, the focus is on sampling evenly across the relevant size range of a species, rather than randomly sampling from all fish caught (see **Length-Mercury Relationships** below for more details). The catch and data summary presents the sample size, mean and range for length, weight, condition[1], age, mercury concentration and the stable isotopes $\delta^{13}C$ and $\delta^{15}N$.

Length and Age. These two variables provide information on the size and age.

General Mercury Relationships. Length, weight, age and feeding preferences can all influence fish mercury concentrations. Plots are used to explore the following key relationships:

- *Length-Weight.* The length-weight relationship shows how weight increases as fish get longer. This relationship is usually "tight" in that the range of observed weights for a given fish length is narrow relative to the other relationships. Consequently, this plot is useful to identify outliers such as incorrectly entered data or unhealthy fish.
- *Age-Length.* Age-length relationships show how fish length increases as fish get older. These relationships are typically variable and show a wide range of length values for each age. This variability makes it harder to identify outliers, but the plots can still provide useful insights into growth patterns and how they influence mercury concentrations.
- *Length-Mercury.* Length-mercury is the classic mercury relationship, because concentrations increase as fish length increases. Length is simple to measure and highly repeatable, so measurement error tends to be low. Mercury concentrations are also positively correlated to weight and age, but measurement error for both those variables relative to length is higher (e.g., being off by a year for age could be a 100% error for a

[1] Condition is a measure of the weight of a fish relative to its length. It is calculated as ($weight/length^3 \times 100$) and is represented by the letter K. Higher condition fish weigh more for their size than lower condition fish.

year-old fish, and the time since a fish's last meal can influence weight). This makes weight and age correlations less useful than length, particularly for comparing patterns over time or space.

- *Length-δ^{15}N.* Fish are known to change their diet as they get bigger, and this leads to their feeding at higher trophic positions as they get larger.
- *δ^{15}N-Mercury.* As trophic levels increase, i.e., as the relative position of a fish in the food chain increases, so δ^{15}N values increase, as described in **Section 3.3**. This relationship essentially shows how feeding preferences affect mercury concentrations in fish tissue. The expectation is for higher tissue mercury concentrations in fish that feed higher in the food chain.

Length-Mercury Relationships (target species only). When looking at patterns in fish mercury concentrations over time or space, fish size (length) must be considered. Failing to do so can lead to biased results, as described in the text box. The approach we used to characterize (or "model") the length-mercury relationships is presented in detail in **Appendix B**. Using Bull Trout as an example (**Figure 4-1**), the results for the early and recent baseline periods highlight the following:

- The *upper left panel* shows the length-mercury relationship for Bull Trout for each period. The solid line is the best estimate of the relationship, and the dashed lines are the 95% confidence limits of that estimate. The more closely that the best estimate fits the data, the closer the confidence limits will be to the best estimate.
- The *upper right panel* shows how the length-mercury relationship relates to the estimate of mercury concentration for a 550 mm Bull Trout. Start at 550 mm on the x axis of the early period plot and move up until you intersect the best fit (solid) line, then move horizontally to the y axis to find the corresponding best estimate mercury concentration for that fish size. The same process applies for the confidence limits (dashed lines). Then repeat this process for the recent baseline period on the left plot.

Size Matters for Fish Mercury Concentrations

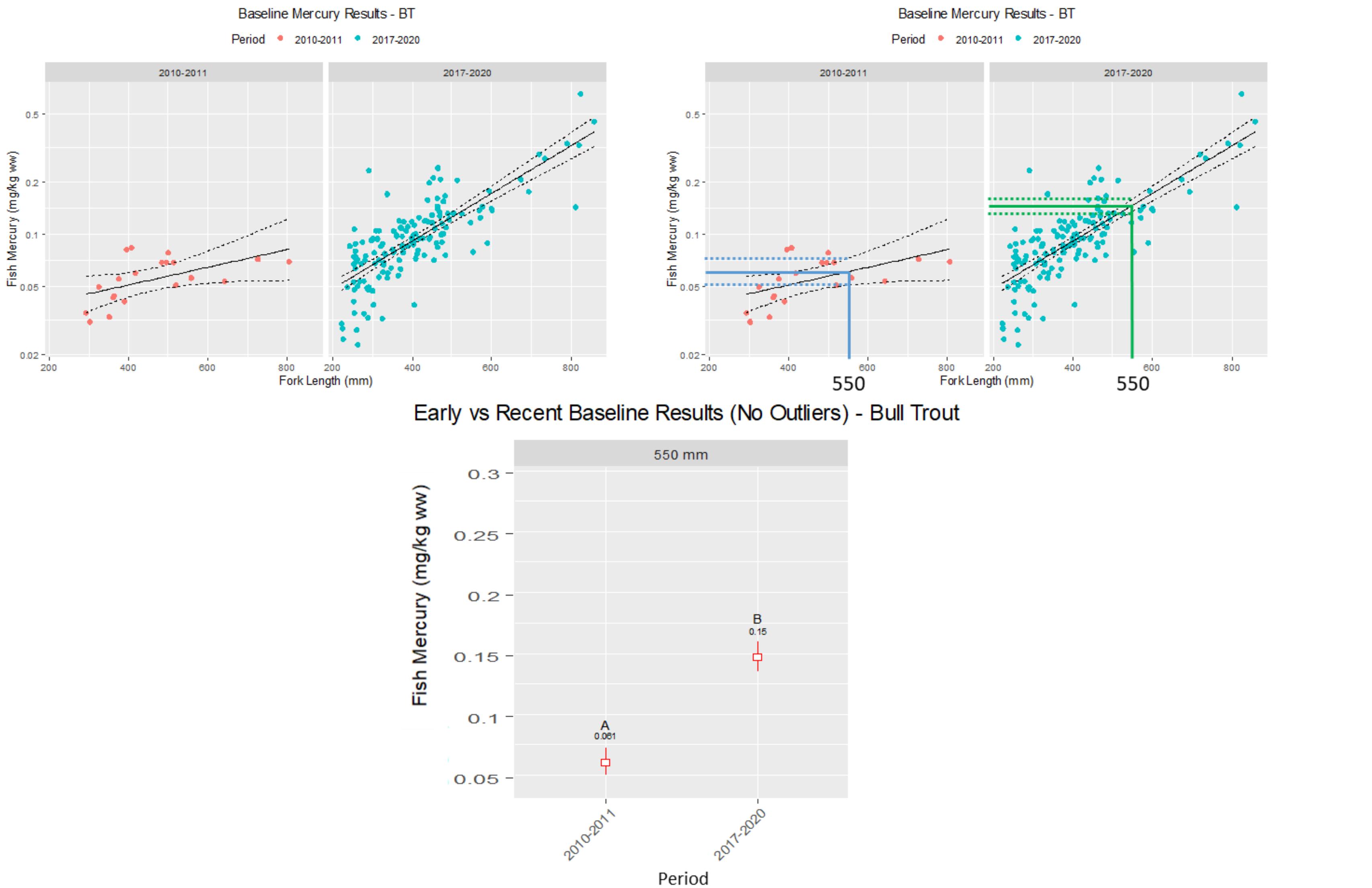
Within a species, tissue mercury concentrations are known to increase as fish length increases. Sampling efforts attempted to target similar numbers of fish in each of a range of size classes, for each species, at each location/year combination, but differences in the sizes of fish caught almost always exist. This can result in biased results if mean tissue mercury concentrations are used to represent a location-year combination for a species. The best way to remove this bias is to first characterize the length-mercury relationship, then use it to estimate mercury concentrations for one or more specific fish sizes (i.e., "standardized" sizes).

- The *lower panel* shows the estimates (square box) and 95% confidence limits (vertical red lines) for a 550-mm Bull Trout in the early period (0.061 mg/kg ww) and recent period (0.15 mg/kg ww).

Azimuth explored the patterns in the baseline data using three main model types:

- *Temporal trends.* The temporal trends model was used to determine if tissue mercury concentrations were different across sampling years. The presence or absence of temporal trends informed the options for treating baseline data, such as the appropriateness of pooling across all or certain years (see *baseline sampling periods* below).
- *Spatial trends.* The spatial trends model was used to determine if tissue mercury concentrations differed among sampling locations during a specific time period (i.e., during a period when no temporal patterns were identified). The presence or absence of spatial patterns informed options for pooling across locations.
- *Baseline sampling periods.* The baseline sampling periods model tested for differences between the early and recent baseline sampling periods to characterize past and current conditions in terms of fish mercury concentrations. The current conditions characterization was used to inform fish consumption guidance.

Figure 4-1. Example using Bull Trout and the baseline period assessment of deriving mercury concentration estimates for a 550-mm fish.



4.2 Bull Trout

Catch and Data Overview

The baseline fish mercury dataset (2010–2020) contains 186 tissue mercury samples for Bull Trout. Catch details are provided by year and location (**Table 4-10**) and by location and size class (**Table 4-2**). These results show that while samples were collected throughout the Peace River, most samples came from fish caught in Sections 1, 3 and 5.

The data overview for Bull Trout is presented by location across all years in **Table 4-3**. The results show that despite efforts to keep fish size consistent across locations, there were differences among sites that could bias the mercury (Hg) results. This highlights the need to use the length-mercury relationships as the foundation for making comparisons across time or space.

Length and Age

To compare the distribution of fish samples from each location, length frequency plots (**Figure 4-2**, left panel) and age frequency plots (**Figure 4-2**, right panel) were used. In general, the ranges of length and age were similar across locations. Also of note, larger or older individuals (i.e., > 500 mm) were sampled less frequently throughout the Peace River locations. Additional sampling is being conducted in 2021 to obtain larger Bull Trout.

General Mercury Relationships

Key mercury relationships are shown in **Figure 4-3**. The length-weight and age-length relationships are as expected for Bull Trout, with much less variability in length-weight relative to age-length. Overall, there are strong positive relationships for length-mercury, δ15N-mercury and δ15N-length, indicating that larger Bull Trout feed higher in the food chain and have higher tissue mercury concentrations than smaller Bull Trout. While there is some variability in the relationships, none of the data stand out as outliers.

Length-Mercury Relationships

Key results are summarized below, and detailed modelling results are provided in **Appendix B**.

- In the temporal assessment, statistically significant differences in Bull Trout mercury concentrations were identified, but only for early years relative to recent years. This means that data can be pooled within each period (i.e., 2010 and 2011 for the early period and 2017, 2018, 2019 and 2020 for the recent period).
- In the spatial assessment, no statistically significant differences in Bull Trout mercury concentrations were identified among locations for the recent period. This means (1) that

fish mercury concentrations were generally similar regardless of where the samples were collected, and (2) that samples can be pooled across locations. This result generally reflects the migratory nature of this species in the Peace River, with major annual movements in and out of the Halfway River watershed.

- In the baseline period assessment, which tested for differences in the length-mercury relationships between the early and recent sampling period (**Figure 4-4**), the results showed that tissue mercury concentrations for a 550-mm Bull Trout in the recent period (0.15 mg/kg wet) were more than twice as high than in the early period (0.061 mg/kg wet) (**Figure 4-5**). Results for the recent baseline period are considered representative of current conditions in the Peace River.

Table 4-1. Bull Trout catch by location and year.

Waterbody Zone	Section	N	2010	2011	2016	2017	2018	2019	2020
Dinosaur	Dinosaur	17	14	2	0	1	0	0	0
Site C	Section 1	31	0	0	0	7	15	5	4
Site C	Section 3	63	15	4	0	26	18	0	0
Downstream	Section 5	38	0	0	0	15	22	1	0
Downstream	Section 6	21	0	0	0	10	7	4	0
Downstream	Section 7	16	0	2	0	5	2	7	0

Table 4-2. Bull Trout sample sizes by length interval (fork length in mm) and location across all years (2010–2020).

Section	N	201-300	301-400	401-500	501-600	601-700	701-800	801-900
Dinosaur	17	2	1	2	0	1	7	4
Section 1	31	5	8	8	5	2	1	2
Section 3	63	10	24	20	5	1	2	1
Section 5	38	11	7	17	2	0	1	0
Section 6	21	3	8	5	1	1	1	2
Section 7	16	8	5	2	1	0	0	0

Table 4-3. Bull Trout size, age, mercury and stable isotope data summary by location across all years (2010–2020).

Section	Length (mm)	Weight (g)	Condition (K)	Age (yrs)	Hg (ppm ww)	d13C (‰)	d15N (‰)
Dinosaur	n=17; 645 (285-835)	n=7; 2273 (262-7775)	n=7; 1.18 (0.94-1.5)	n=16; 7 (3-10)	n=17; 0.114 (0.038-0.341)	n=16; -33.8 (-36.2--29.3)	n=16; 11.4 (10.4-12.4)
Section 1	n=31; 462 (222-860)	n=29; 1146 (110-4195)	n=29; 1.06 (0.89-1.46)	n=17; 5 (3-7)	n=31; 0.121 (0.03-0.449)	n=24; -29.9 (-33.2--28.2)	n=24; 11.1 (9.5-12.3)
Section 3	n=63; 408 (251-806)	n=63; 936 (153-7160)	n=63; 1.02 (0.84-1.37)	n=48; 4 (1-11)	n=63; 0.087 (0.031-0.328)	n=39; -28.3 (-30.3--27)	n=39; 10.1 (8.7-11.1)
Section 5	n=38; 390 (223-720)	n=38; 730 (105-4381)	n=38; 0.99 (0.82-1.17)	n=28; 5 (2-11)	n=38; 0.097 (0.023-0.293)	n=27; -28.6 (-33.1--26.5)	n=27; 10.3 (8.9-11.1)
Section 6	n=21; 455 (254-825)	n=20; 1355 (165-5273)	n=20; 0.95 (0.76-1.25)	n=13; 5 (3-8)	n=21; 0.154 (0.049-0.649)	n=11; -27.9 (-31.1--26.3)	n=11; 11 (9.7-11.9)
Section 7	n=16; 325 (225-558)	n=16; 468 (114-1822)	n=16; 0.99 (0.86-1.15)	n=9; 4 (2-8)	n=16; 0.079 (0.025-0.131)	n=11; -29.4 (-31.1--27.2)	n=11; 10.1 (8.6-11.2)

Figure 4-2. Length frequency and age frequency for Bull Trout (BT) by location across all years (2010–2020).

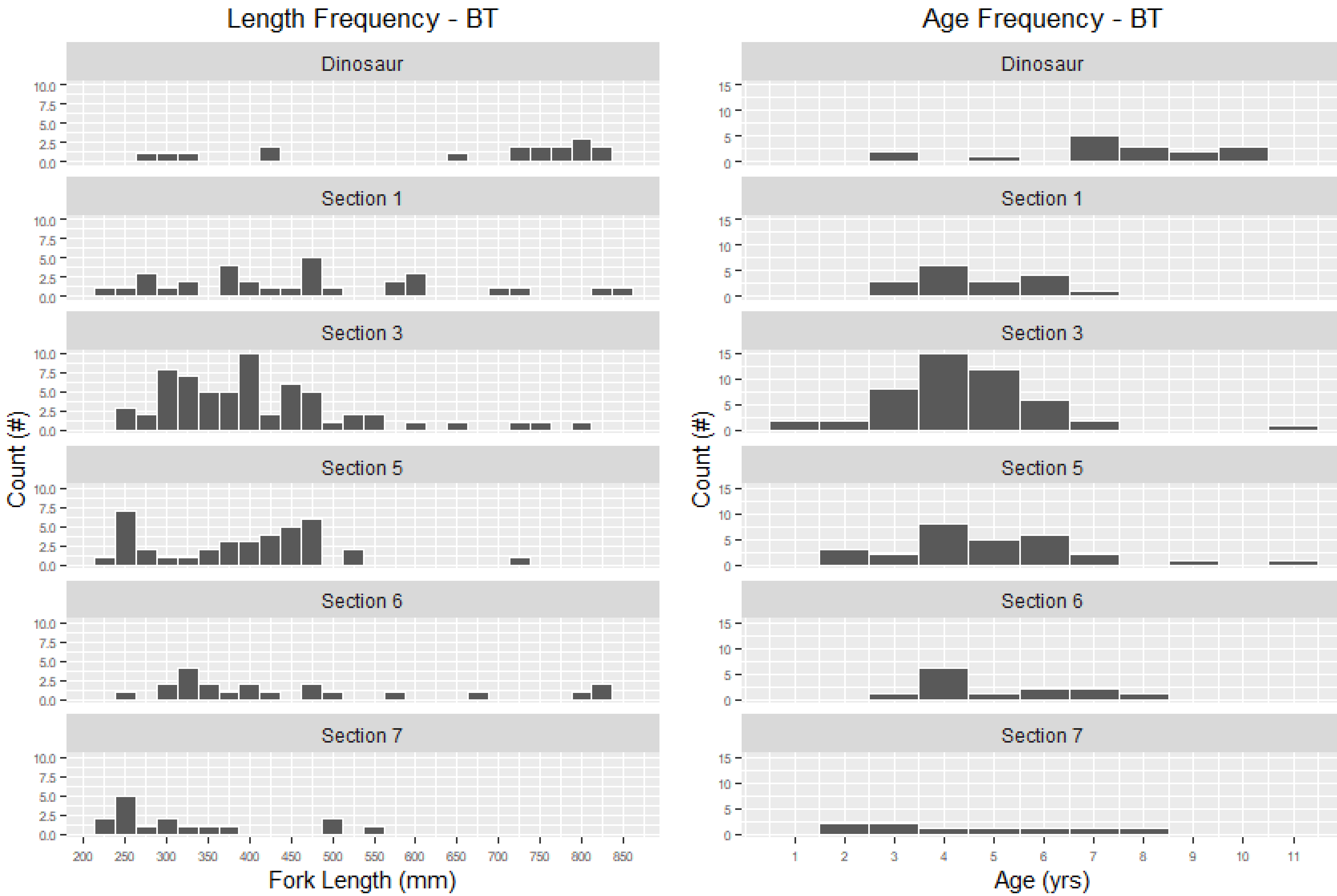


Figure 4-3. Key mercury relationships for Bull Trout (BT) across all years (2010–2020).

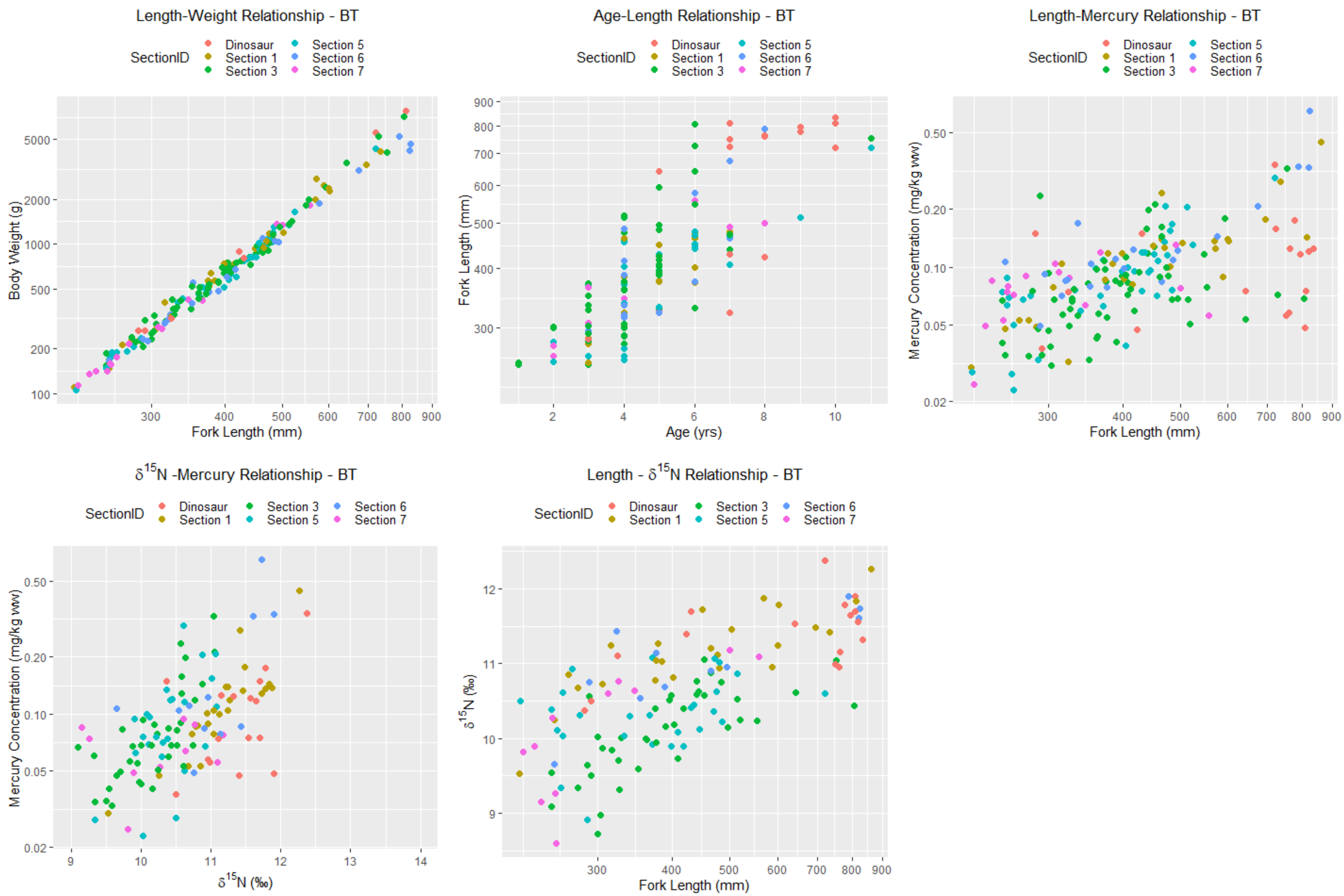
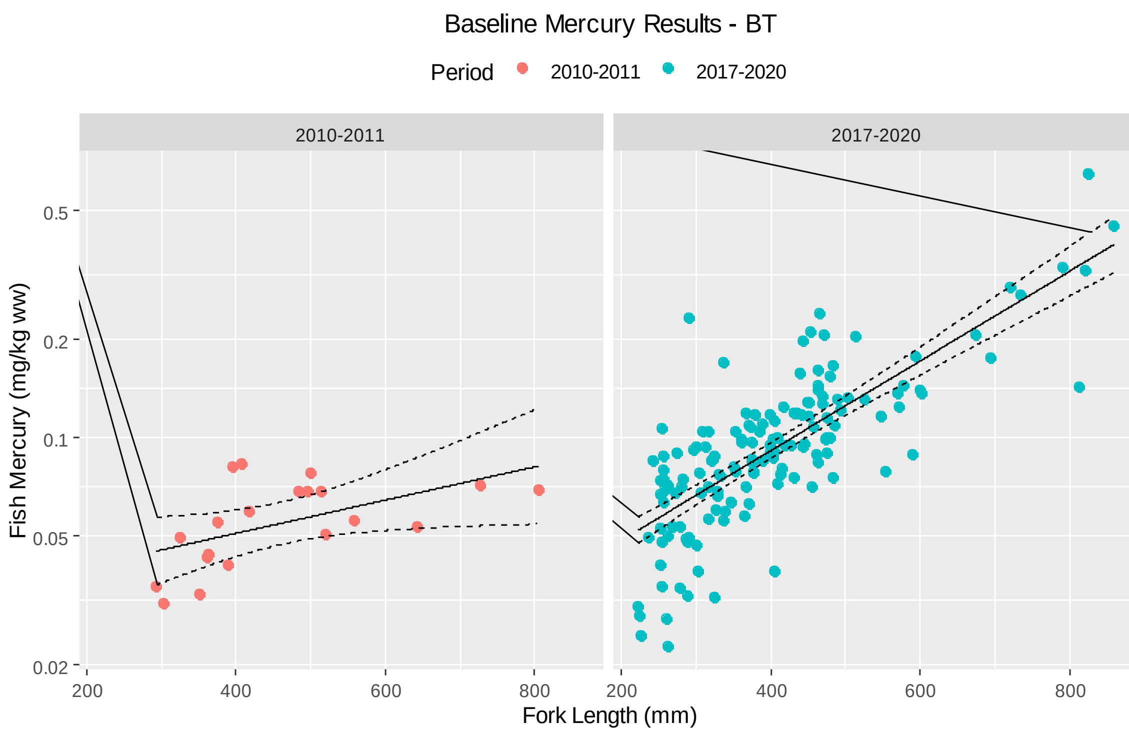
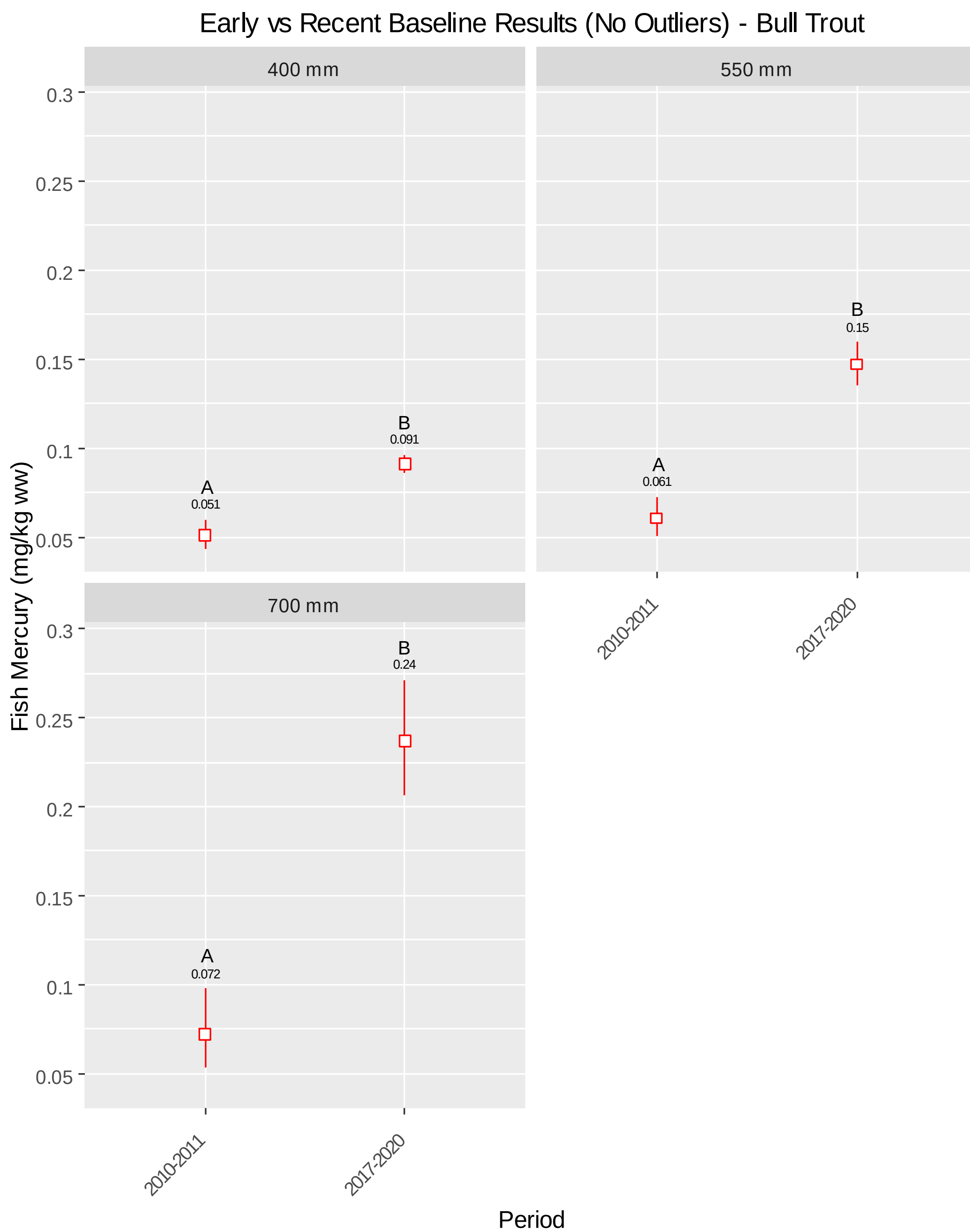


Figure 4-4. Comparison of length-mercury relationships for Peace River Bull Trout between the early and recent baseline periods.



Note: Data pool

Figure 4-5. Estimated tissue mercury concentrations (and 95% confidence intervals) for select sizes (400 mm, 550 mm, 700 mm) of Bull Trout in the Peace River (across locations) for the early (2010–2011) and recent (2017–2020) baseline periods.



Note: Letters above estimates show which are not statistically different from one another (same letters) or which are statistically different (different letters); combinations (e.g., “AB”) show estimates that are not statistically different from other groups that are different (e.g., “A” and “B”).

4.3 Mountain Whitefish

Catch and Data Overview

The 2010–2020 dataset contains 385 tissue mercury samples for Mountain Whitefish, which are broken down by year and location in **Table 4-4**. Catch details by location and size class are provided in **Table 4-5**. These results show that while Mountain Whitefish were collected in good numbers throughout the Peace River, and that nearly half the samples were collected in Section 3 and Section 9.

The data overview for Mountain Whitefish across all years and locations is presented in **Table 4-6**. The results show that despite consistent sampling efforts, there is variability in fish size among sites that could bias the mercury (Hg) results. This highlights the need to use the length-mercury relationships as the foundation for making comparisons across time or space.

Length and Age

To compare the distribution of fish samples from each location, frequency plots for length (**Figure 4-6**, left panel) and age (**Figure 4-6**, right panel) were used. Generally, the ranges of length and age were similar across locations.

General Mercury Relationships

Key mercury relationships are shown in **Figure 4-7**. The length-weight and age-length relationships are as expected, with somewhat less variability in length-weight than age-length. Overall, there are strong, positive, length-mercury, δ15N-mercury and δ15N-length relationships, which indicates that larger Mountain Whitefish feed higher on the food chain and accumulate higher tissue mercury concentrations than smaller Mountain Whitefish. While the length-weight and age-length relationships show limited variability, increased variability exists in the length-mercury, δ15N-mercury and length-δ15N relationships. Two outliers are present in all relationships and are denoted.

Length-Mercury Relationships

Detailed modelling results are included in **Appendix B**. Key results are summarized here:

- In the temporal assessment, significant differences in Mountain Whitefish mercury concentrations were present among years, but only between the early years (2010 and 2011) and recent years (2017–2020). This means that data may be pooled within each period.

- Because of the temporal differences discussed above, the spatial assessment was done using only recent (2017–2020) baseline data. Statistically significant differences in the mercury concentrations of Mountain Whitefish were identified among sampling locations in the recent baseline assessment (2017–2020), so sampling data were not pooled across locations (**Figure 4-8**). Mercury concentrations were generally highest in fish sampled from Section 7 of the Peace River (**Figure 4-9**). The recent baseline results are considered representative of current conditions in the Peace River.
- The baseline period assessment tested for differences in length-mercury relationships between the early and recent sampling periods (**Figure 4-10**). The results show that tissue-mercury concentrations for a 550-mm Mountain Whitefish nearly doubled between the early (0.079 mg/kg wet) and recent baseline periods (0.13 mg/kg wet).

Table 4-4. Mountain Whitefish catch by location and year.

Waterbody	Section	N	2010	2011	2016	2017	2018	2019	2020
Dinosaur	Dinosaur	29	15	11	3	0	0	0	0
Site C	Section 1	52	0	10	0	12	16	10	4
Site C	Section 3	87	17	12	0	15	14	18	11
Downstream	Section 5	48	0	0	0	7	12	18	11
Downstream	Section 6	51	0	0	0	11	12	22	6
Downstream	Section 7	44	0	10	0	8	7	7	12
Downstream	Section 9	74	0	0	0	32	38	1	3

Note: 2016 data from the FWCP Williston-Dinosaur Fish Mercury Investigation study.

Table 4-5. Mountain Whitefish sample sizes by length interval (fork length in mm) and location across all years (2010–2020).

SectionID	N	51-100	101-150	151-200	201-250	251-300	301-350	351-400	401-450	451-500	501-550
Dinosaur	29	0	0	0	5	6	13	5	0	0	0
Section 1	52	0	0	3	3	11	9	13	7	5	1
Section 3	87	0	1	1	10	18	25	12	13	7	0
Section 5	48	1	0	0	6	6	11	10	8	6	0
Section 6	51	4	0	1	7	10	8	7	6	8	0
Section 7	44	1	0	0	7	9	10	8	7	2	0
Section 9	74	0	1	14	10	11	14	17	6	1	0

Table 4-6. Mountain Whitefish size, age, mercury, and stable isotope data summary by location across all years (2010–2020).

Section	Length (mm)	Weight (g)	Condition (K)	Age (yrs)	Hg (ppm ww)	d13C (‰)	d15N (‰)
Dinosaur	n=29; 307 (218-395)	n=29; 334 (70-692)	n=29; 1.06 (0.546-2.385)	n=26; 6 (2-15)	n=29; 0.044 (0.017-0.121)	n=29; -27.1 (-29.5--23.4)	n=29; 8.7 (7.8-10.8)
Section 1	n=52; 342 (160-502)	n=52; 472 (41-1130)	n=52; 1.05 (0.826-1.342)	n=12; 6 (2-11)	n=52; 0.052 (0.013-0.185)	n=43; -30.1 (-35.9--27.9)	n=43; 9.5 (6.8-11.8)
Section 3	n=87; 334 (145-490)	n=86; 461 (27-1346)	n=86; 1.09 (0.853-1.411)	n=35; 6 (2-12)	n=87; 0.042 (0.009-0.18)	n=82; -29.5 (-35.2--26.6)	n=82; 8.2 (6.5-11.3)
Section 5	n=48; 344 (97-473)	n=48; 482 (10-1248)	n=48; 1.01 (0.742-1.221)	n=8; 5 (4-8)	n=48; 0.06 (0.013-0.109)	n=41; -28.6 (-33.2--26.6)	n=41; 8.6 (6.6-11.2)
Section 6	n=51; 321 (73-485)	n=51; 427 (4-1137)	n=51; 1 (0.752-1.195)	n=2; 6 (5-7)	n=51; 0.058 (0.012-0.202)	n=41; -28.2 (-30.8--26.4)	n=41; 8.5 (6.9-9.7)
Section 7	n=44; 326 (91-470)	n=44; 392 (9-926)	n=44; 1.01 (0.828-1.306)	n=7; 5 (3-9)	n=44; 0.06 (0.014-0.154)	n=39; -28 (-29.4--26.4)	n=39; 8.8 (7.5-10.3)
Section 9	n=74; 295 (145-460)	n=73; 310 (35-992)	n=73; 0.99 (0.688-1.244)	n=21; 5 (1-9)	n=74; 0.048 (0.01-0.227)	n=50; -28.2 (-32.3--25.5)	n=50; 8.4 (7.3-10.2)

Figure 4-6. Length frequency and age frequency for Mountain Whitefish (MW) by location across all years (2010–2020).

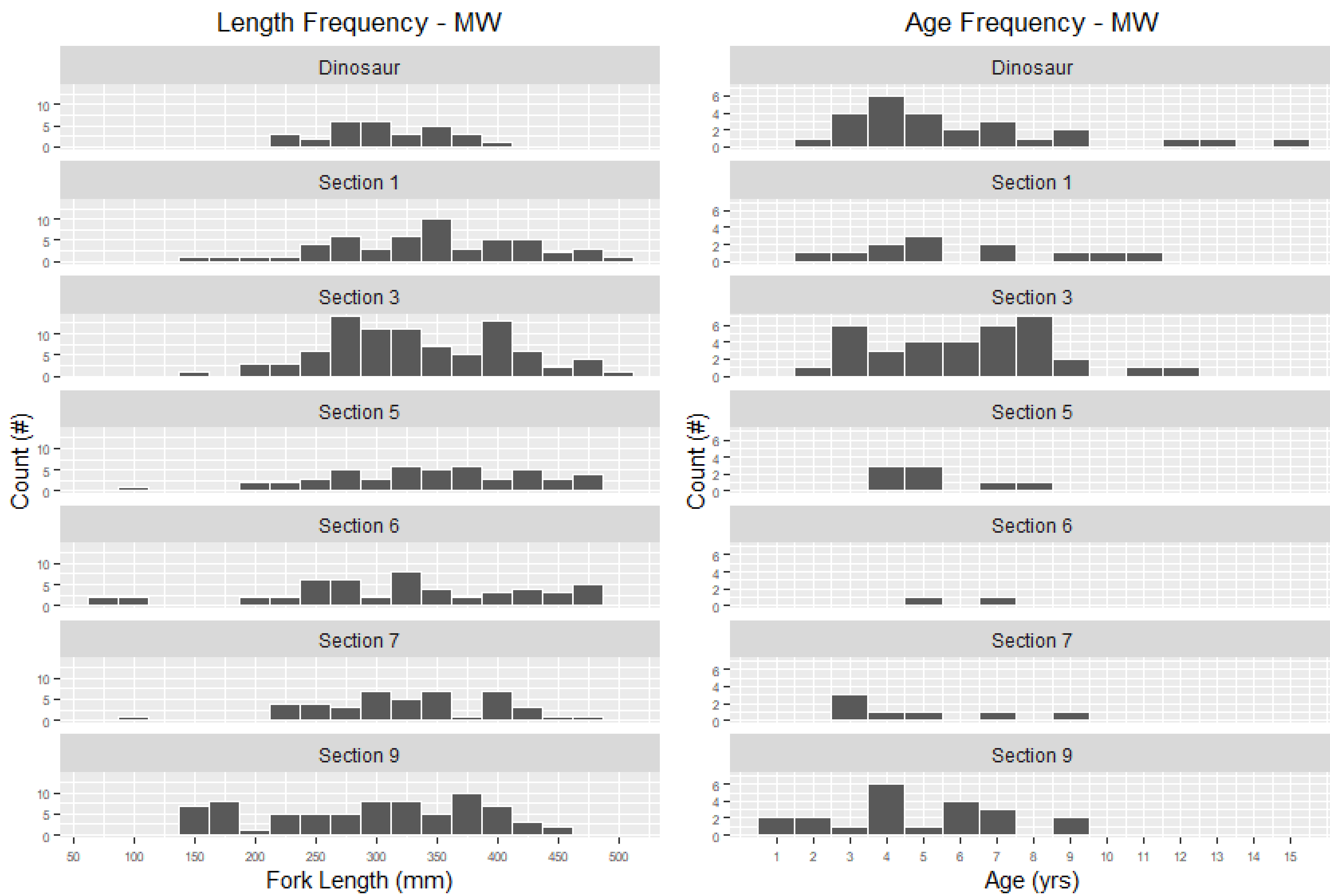
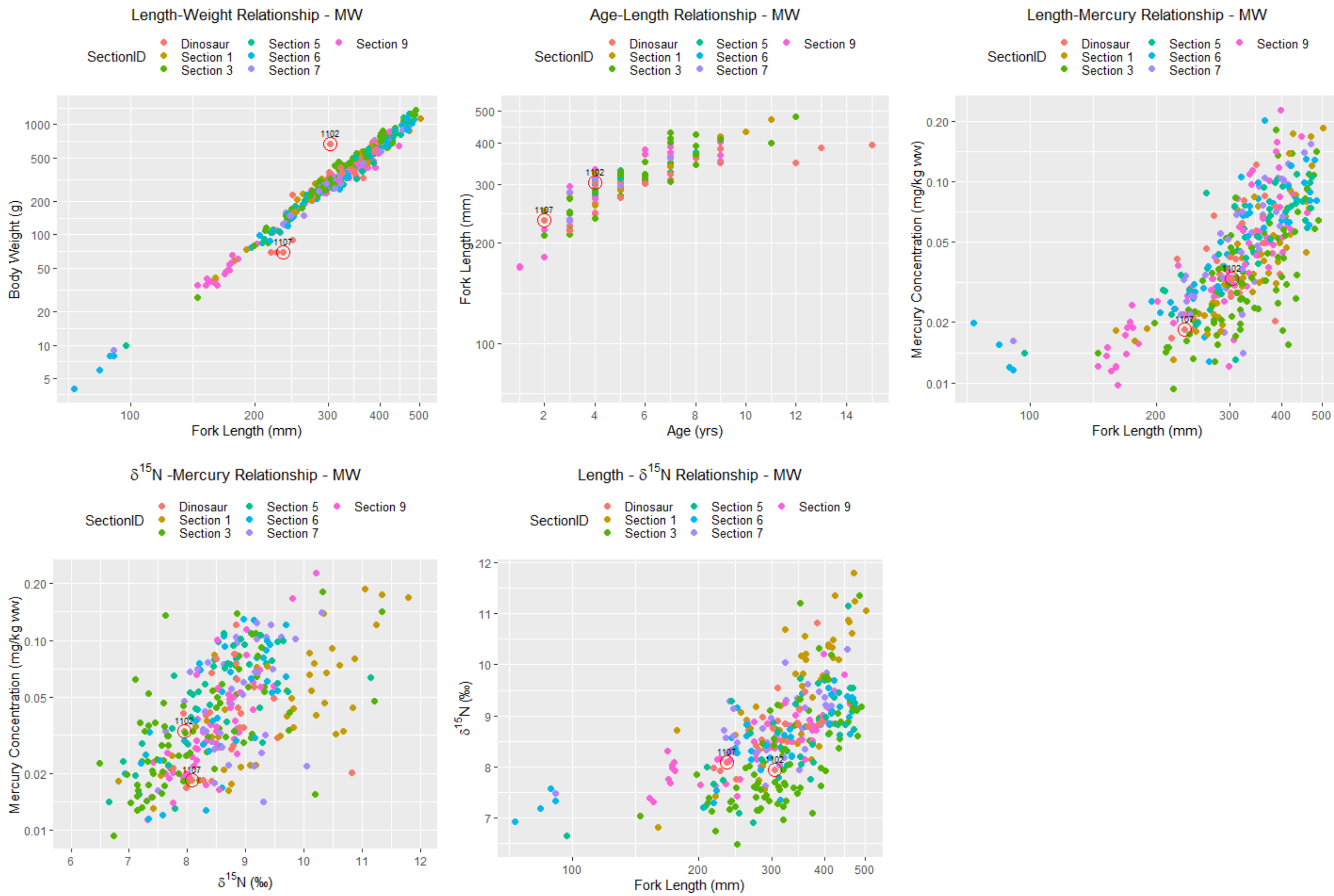


Figure 4-7. Key mercury relationships for Mountain Whitefish (MW) across all years (2010–2020).



Note: Red circles indicate length-weight outliers

Figure 4-8. Comparison of length-mercury relationships for Mountain Whitefish (MW) among Peace River sampling locations for the recent baseline period (2017–2020).

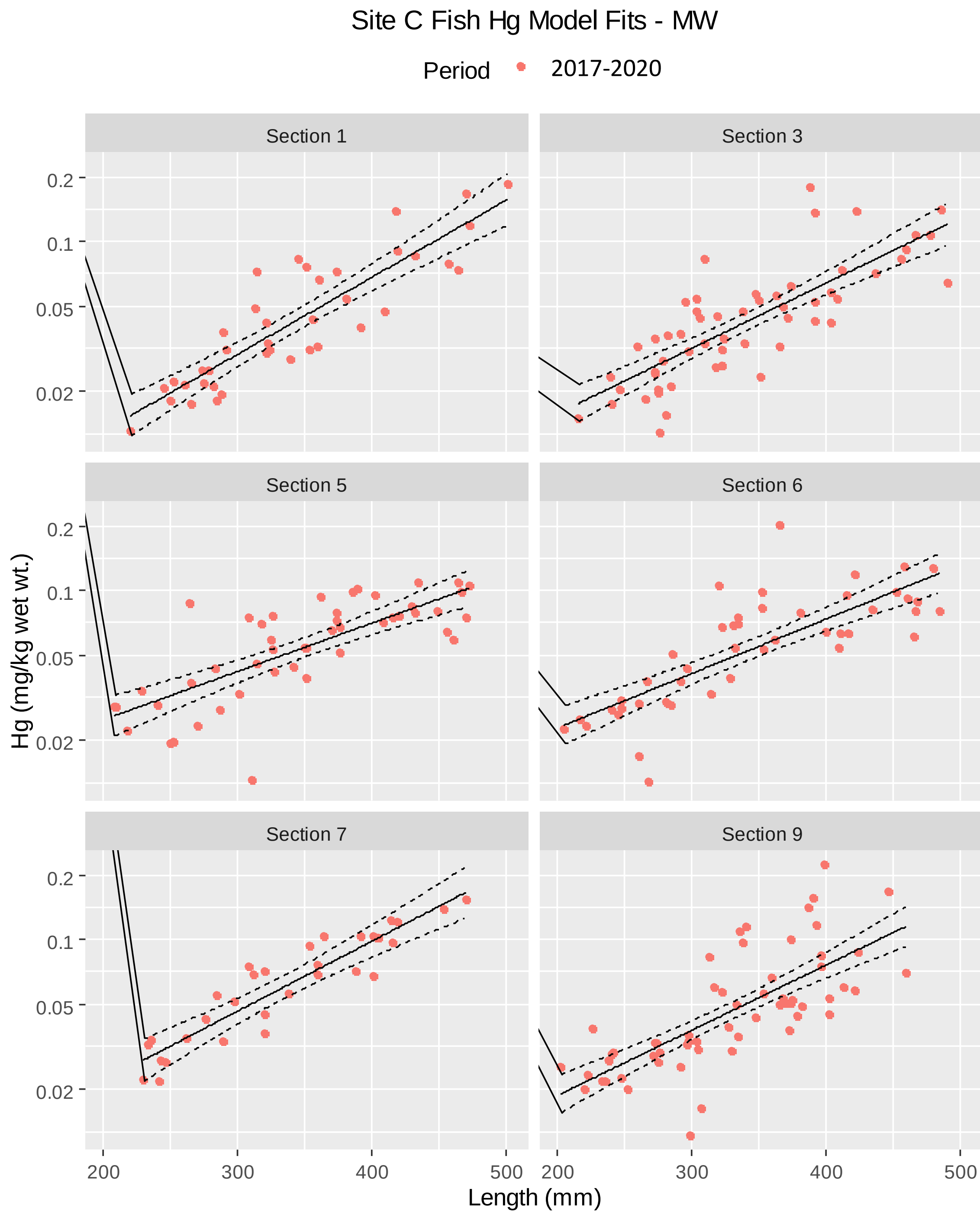
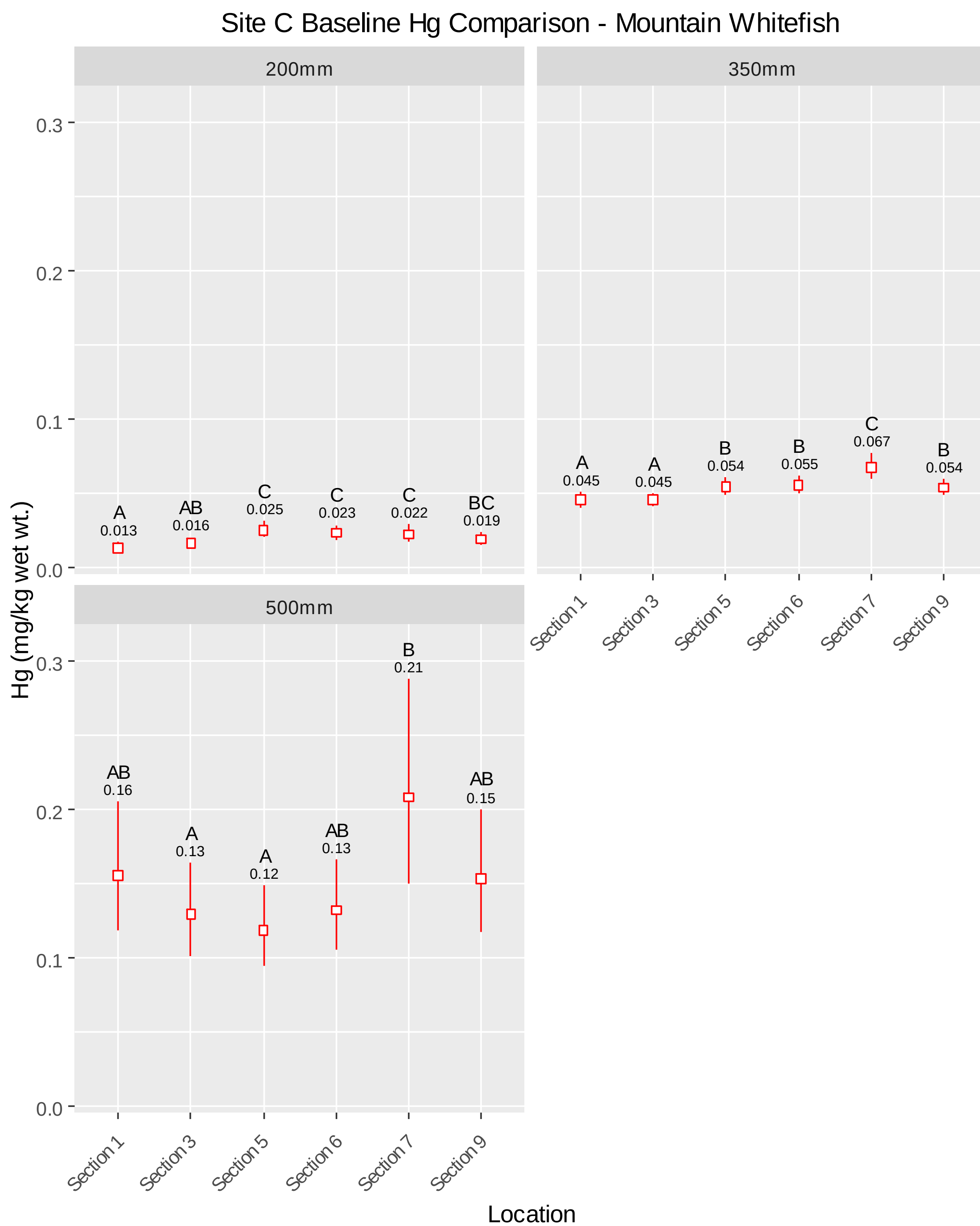
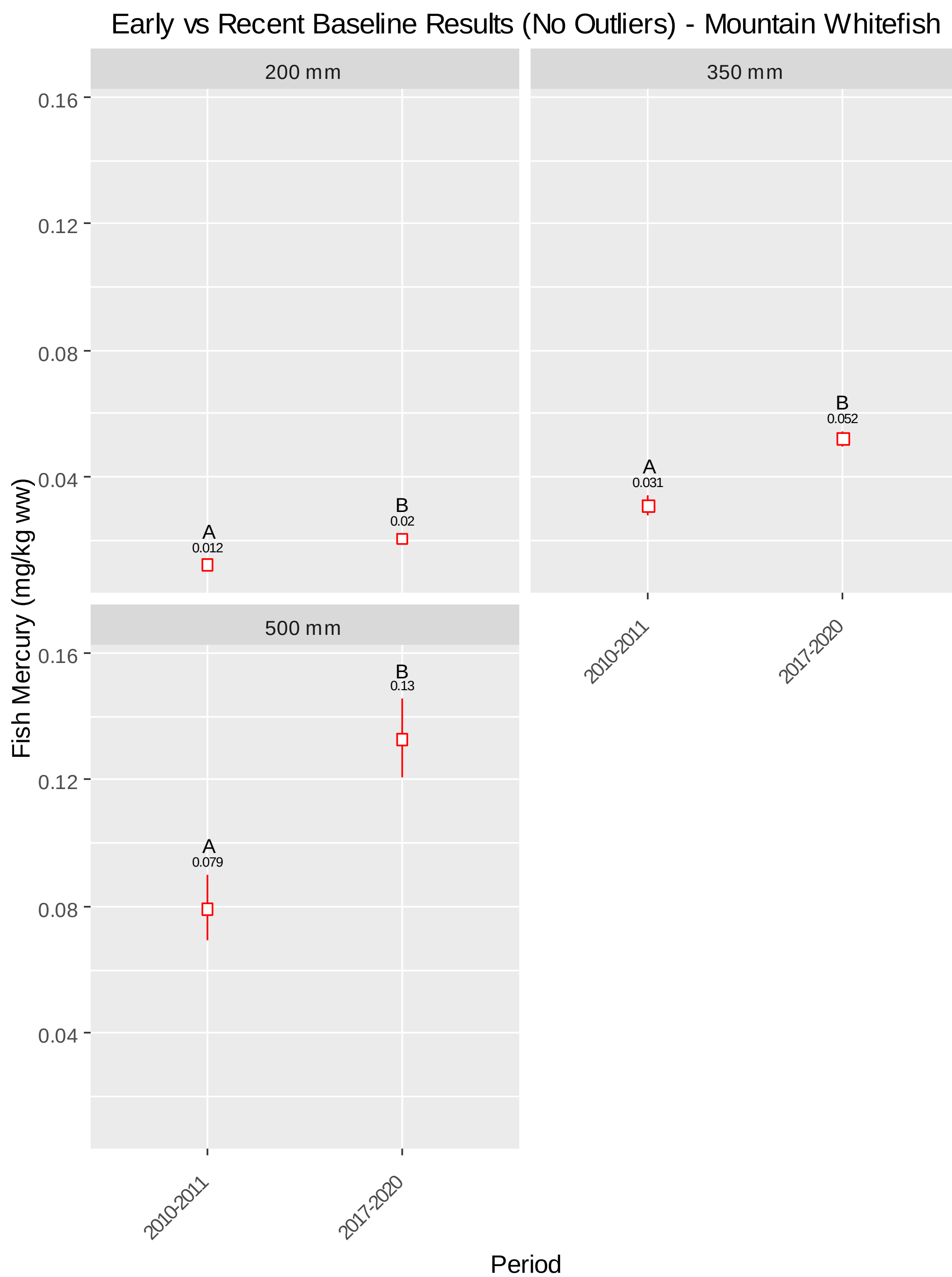


Figure 4-9. Estimated mercury concentrations (and 95% confidence intervals) for select sizes (200 mm, 350 mm, 500 mm) of Mountain Whitefish for Peace River sampling locations for the recent baseline period (2017–2020).



Note: Letters above estimates show which are not statistically different from one another (same letters) or which are statistically different (different letters); combinations (e.g., "AB") show estimates that are not statistically different from other groups that are different (e.g., "A" and "B").

Figure 4-10. Estimated mercury concentrations (and 95% confidence intervals) for select sizes (200 mm, 350 mm, 500 mm) for each year in the baseline period assessment of Mountain Whitefish mercury concentrations across Peace River locations.



Note: Letters above estimates show which are not statistically different from one another (same letters) or which are statistically different (different letters); combinations (e.g., "AB") show estimates that are not statistically different from other groups that are different (e.g., "A" and "B").

4.4 Rainbow Trout

Catch and Data Overview

The baseline fish mercury dataset for Rainbow Trout includes years 2011–2020 (no catch in 2010) and contains a total of 101 tissue mercury samples. Catch results are provided by year and location in **Table 4-7** and by location and size class in **Table 4-8**. These results show that while at least one Rainbow Trout was caught in each Section, the majority were caught in the Dinosaur Reservoir, Section 1 and Section 3 of the Peace River.

The data overview for Rainbow Trout is presented by location across all years in **Table 4-9**. The results show that despite efforts to maintain consistent fish size between locations, there was variability that could bias the mercury (Hg) results. Low sampling numbers from Sections 5, 6 and 7 may also bias results. This highlights the need to use the length-mercury relationships as the foundation for making comparisons across time.

Length and Age

To compare the distribution of fish samples across locations frequency plots for length (**Figure 4-11**; left panel) and age (**Figure 4-11**; right panel) were used. Generally, the ranges of age and length were similar across locations.

General Mercury Relationships

Key mercury relationships are shown in **Figure 4-12**. The length-weight and age-length relationships are as expected, although relative variability in the age-length relationship increased. There are moderately positive length-mercury, δ15N-mercury and δ15N-length relationships overall. These results indicate a relative increase in trophic level and tissue mercury accumulation in larger Rainbow Trout compared to smaller Rainbow Trout. While the length-weight relationship shows limited variability, the variability in all other relationships is increased. Outliers were identified and denoted in all relationships except age-length; these values were excluded from the length-mercury relationship modelling analyses.

Length-Mercury Relationships

Key results are summarized here and detailed modelling results are included in **Appendix B**.

- In the temporal assessment, no statistically significant differences in Rainbow Trout mercury concentrations were found between years or between the early (2010, 2011) and recent period (2017–2020). This means that data may be pooled across sampling years, regardless of the sampling period.

- In the spatial assessment for the recent period, no statistically significant differences in Rainbow Trout mercury concentrations were identified between locations. This means that fish tissue mercury concentrations were generally similar across all sampling locations and, therefore, may be pooled (**Figure 4-13**).
- In the baseline assessment, differences in tissue mercury concentration between select sizes of Rainbow Trout were investigated (**Figure 4-14**). The results show that tissue mercury concentrations for a 400-mm Rainbow Trout (0.042 mg/kg wet) are more than double the concentrations for a 200-mm Rainbow Trout (0.018 mg/kg wet). The results collected across all sampling years are considered representative of current conditions in the Peace River.

Table 4-7. Rainbow Trout catch by location and year.

Waterbody	Section	N	2010	2011	2016	2017	2018	2019	2020
Dinosaur Reservoir	Dinosaur	29	0	10	6	13	0	0	0
Peace River	Section 1	27	0	10	0	5	11	0	1
Peace River	Section 3	38	0	0	0	15	12	0	11
Peace River	Section 5	5	0	0	0	5	0	0	0
Peace River	Section 6	1	0	0	0	1	0	0	0
Peace River	Section 7	1	0	0	0	1	0	0	0

Table 4-8. Rainbow Trout sample sizes by length interval (fork length in mm) and location across all years (2010–2020).

Section	N	151-200	201-250	251-300	301-350	351-400	401-450
Dinosaur	29	0	2	14	9	3	1
Section 1	27	0	2	9	7	4	5
Section 3	38	1	8	7	10	9	3
Section 5	5	0	0	3	0	2	0
Section 6	1	0	0	0	0	1	0
Section 7	1	0	0	0	0	0	1

Table 4-9. Rainbow Trout size, age, mercury, and stable isotope data summary by location across all years (2010–2020).

Section	Length (mm)	Weight (g)	Condition (K)	Age (yrs)	Hg (ppm ww)	d13C (‰)	d15N (‰)
Dinosaur	n=29; 306 (234-411)	n=29; 283 (50-600)	n=29; 0.93 (0.39-1.412)	n=22; 4 (3-6)	n=29; 0.042 (0.019-0.138)	n=29; -27.6 (-32.3--25)	n=29; 9.1 (7.8-12.2)
Section 1	n=27; 320 (215-440)	n=27; 399 (109-984)	n=27; 1.12 (0.861-1.288)	n=15; 3 (1-5)	n=27; 0.046 (0.019-0.348)	n=25; -28.8 (-32.2--25.8)	n=25; 9.4 (8.4-10.5)
Section 3	n=38; 308 (200-430)	n=38; 368 (80-1039)	n=38; 1.12 (0.908-1.335)	n=33; 3 (1-7)	n=38; 0.03 (0.004-0.094)	n=26; -27.6 (-30--26.2)	n=26; 7.8 (5.8-9.1)
Section 5	n=5; 314 (265-363)	n=5; 381 (232-595)	n=5; 1.18 (1.085-1.247)	n=5; 2 (2-3)	n=5; 0.032 (0.018-0.062)	n=1; -28.1 (-28.1--28.1)	n=1; 7.9 (7.9-7.9)
Section 6	n=1; 395 (395-395)	n=1; 730 (730-730)	n=1; 1.18 (1.184-1.184)	n=1; 3 (3-3)	n=1; 0.038 (0.038-0.038)	n=0; NA (NA)	n=0; NA (NA)
Section 7	n=1; 415 (415-415)	n=1; 711 (711-711)	n=1; 1 (0.995-0.995)	n=1; 4 (4-4)	n=1; 0.056 (0.056-0.056)	n=0; NA (NA)	n=0; NA (NA)

Figure 4-11. Length frequency and age frequency for Rainbow Trout (RB) by location across all years (2010–2020).

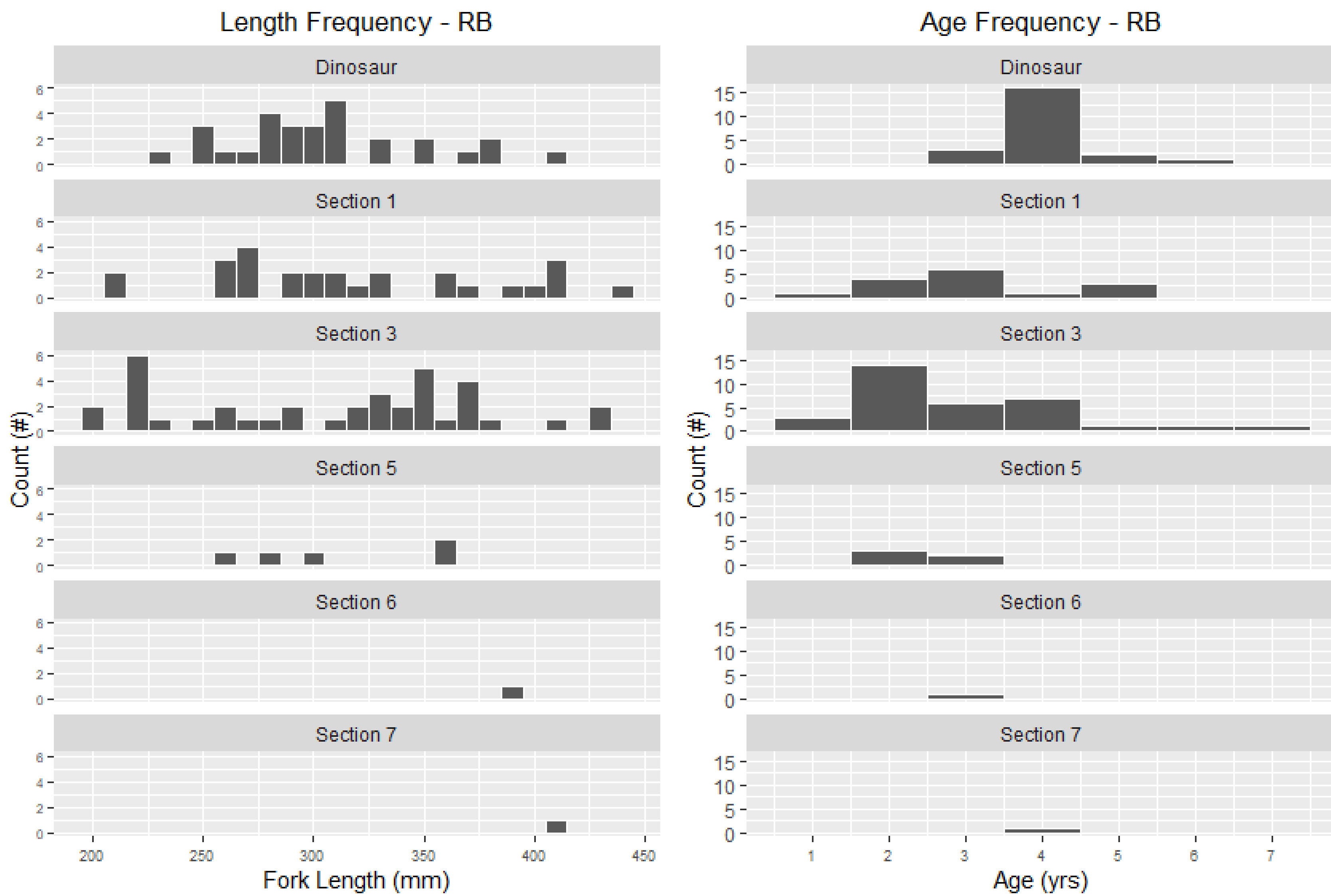
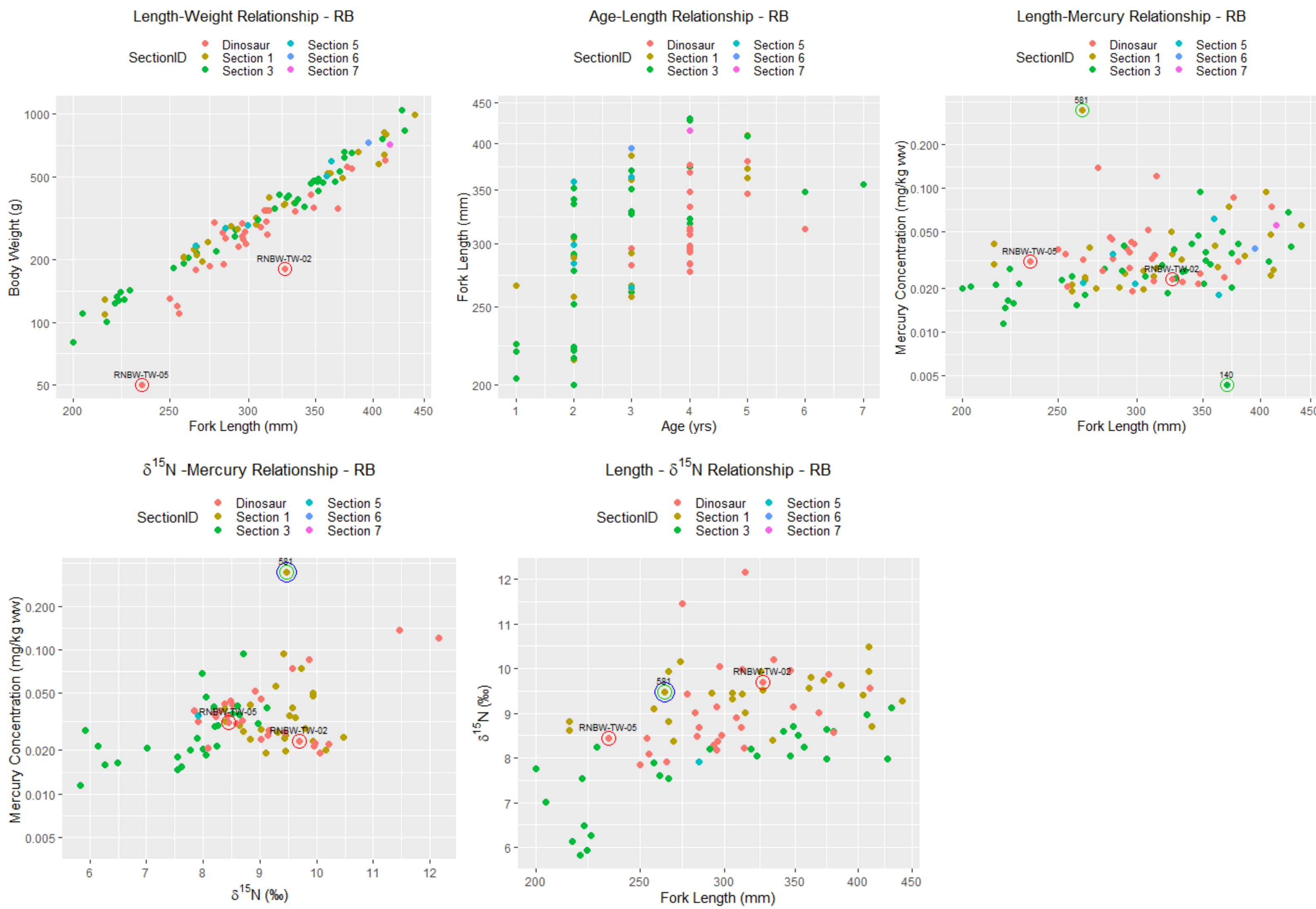


Figure 4-12. Key mercury relationships for Rainbow Trout (RB) across all years (2010–2020).



Note: Red circles indicate length-weight outliers, green circles indicate length-mercury outliers, and blue circles indicate δ15N-mercury outliers.

Figure 4-13. Comparison of length-mercury relationships for Peace River Rainbow Trout between the early (2010–2011) and recent (2017–2020) baseline periods.

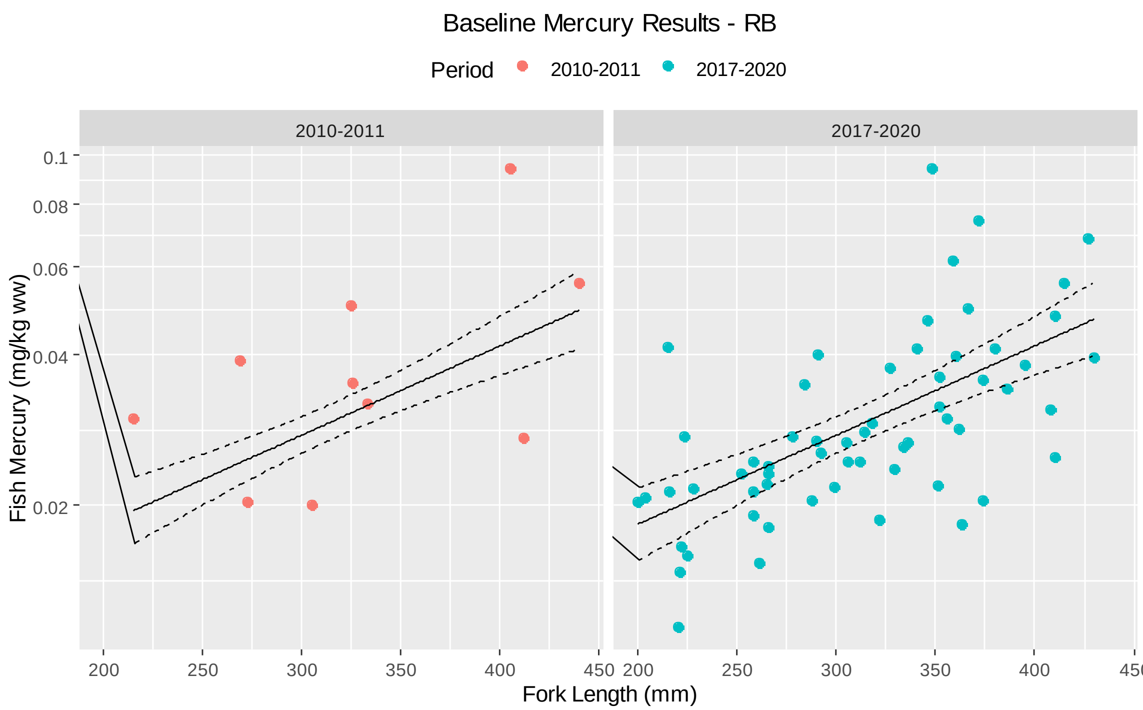
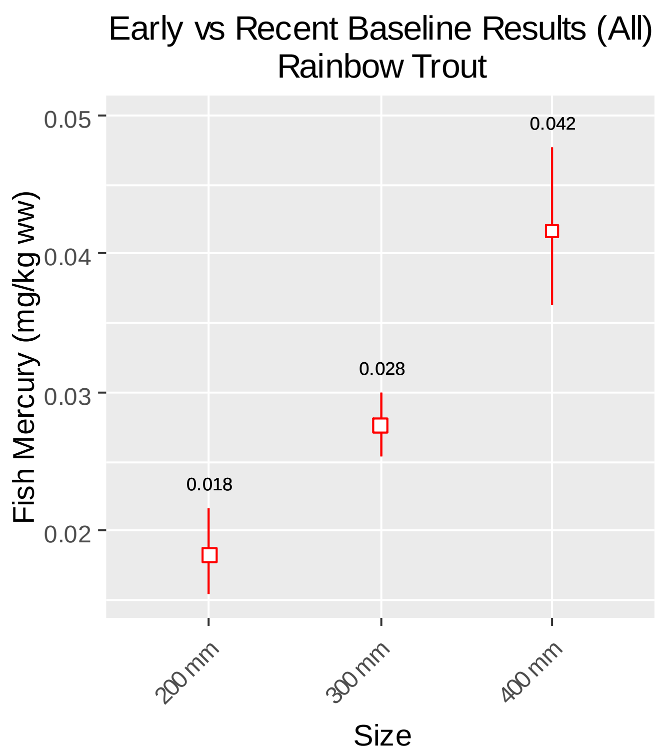


Figure 4-14. Estimated tissue mercury concentrations (and 95% confidence intervals) for select sizes (200 mm, 300 mm, 400 mm) of Rainbow Trout in the Peace River (across locations) for the early (2010–2011) and recent (2017–2020) baseline periods.



Note: No statistically significant differences were identified between the two periods, so the results shown above are applicable to both periods.

4.5 Longnose Sucker

Catch and Data Overview

The baseline fish mercury dataset (2010–2020) contains 324 tissue mercury samples for Longnose Sucker. The breakdown of the catch results by year and location is provided in (**Table 4-10**), and the breakdown by location and size class is provided in **Table 4-11**. These results show that while Longnose Sucker were collected throughout the Peace River, approximately half of all samples were collected in Section 3 and Section 9.

The data overview for Longnose Sucker is presented by locations and across years in **Table 4-12**. Fish size was generally similar across sampling locations.

Length and Age

To compare the distribution of fish samples between locations and across years, frequency histogram plots for length (**Figure 4-15**; left panel) and age (**Figure 4-15**; right panel) were used. While the length distributions look generally similar across all locations, age data were more limited.

General Mercury Relationships

Key mercury relationships are shown in **Figure 4-16**. The length-weight relationship is as expected for Longnose Sucker, except for one outlier. No conclusions can be made for the age-length relationship because there are too few age data. Length-mercury and δ15N-mercury show strong positive relationships, while the length-δ15N relationship displays no distinct trend. One outlier was identified and denoted in all relationships excluding age-length, which had few data; this outlier was removed from the length-mercury relationship modelling analyses.

Length-Mercury Relationships

Key results are summarized here and detailed modelling results are provided in **Appendix B**:

- In the temporal assessment, statistically significant differences in Longnose Sucker mercury concentrations were identified among years, but only for early years relative to the recent years. This means that data can be pooled for each period (i.e., 2010 and 2011 for the early period and 2017–2020 for the recent period).
- Because of the temporal differences discussed above, the spatial assessment was done using recent (2017–2020) baseline data only. Statistically significant differences in Longnose Sucker mercury concentrations were identified among sampling locations in the recent baseline assessment (2017–2020), and sampling data were therefore not

pooled across locations (**Figure 4-17**). Mercury concentrations were generally highest in fish sampled from Sections 7 and 9 of the Peace River (**Figure 4-18**). The recent baseline period results are considered representative of current conditions in the Peace River.

- The baseline period assessment tested for differences in the length-mercury relationships between the early and recent sampling period (**Figure 4-19**). The results showed that tissue mercury concentrations for a 450-mm Longnose Sucker in the recent period (0.12 mg/kg wet) are nearly twice as high than in the early period (0.066 mg/kg wet).

Table 4-10. Longnose Sucker catch by location and year.

Waterbody	Section	N	2010	2011	2016	2017	2018	2019	2020
Dinosaur Reservoir	Dinosaur	21	1	11	9	0	0	0	0
Peace River	Section 1	21	0	11	0	7	0	3	0
Peace River	Section 3	76	10	10	0	21	29	0	6
Peace River	Section 5	42	0	0	0	13	21	3	5
Peace River	Section 6	37	0	0	0	12	3	17	5
Peace River	Section 7	48	0	10	0	10	4	10	14
Peace River	Section 9	79	0	0	0	40	39	0	0

Table 4-11. Longnose Sucker sample sizes by length interval (fork length in mm) and location across all years (2010–2020).

Section	N	101-200	201-300	301-400	401-500	501-600
Dinosaur	21	0	1	14	6	0
Section 1	21	0	1	11	9	0
Section 3	76	0	19	34	22	0
Section 5	42	0	12	14	16	0
Section 6	37	1	12	9	12	0
Section 7	48	0	13	18	16	1
Section 9	79	10	24	24	21	0

Table 4-12. Longnose Sucker size, age, mercury and stable isotope data summary by location across all years (2010–2020).

Section	Length (mm)	Weight (g)	Condition (K)	Age (yrs)	Hg (ppm ww)	d13C (‰)	d15N (‰)
Dinosaur	n=21; 378 (268-434)	n=21; 615 (240-1074)	n=21; 1.09 (0.79-1.356)	n=12; 17 (5-22)	n=21; 0.169 (0.059-0.388)	n=20; -29.2 (-33.9--26.1)	n=20; 9.3 (7.9-10.3)
Section 1	n=21; 397 (285-486)	n=21; 823 (232-1461)	n=21; 1.27 (1.002-1.431)	n=0; NA (NA)	n=21; 0.071 (0.018-0.227)	n=15; -28.9 (-31.3--26.3)	n=15; 7.8 (6.2-9)
Section 3	n=76; 359 (221-470)	n=76; 638 (138-1449)	n=76; 1.26 (0.986-1.541)	n=9; 8 (7-10)	n=76; 0.062 (0.014-0.326)	n=59; -28.5 (-30.7--26.7)	n=59; 6.9 (5.6-10.3)
Section 5	n=42; 363 (219-481)	n=42; 660 (114-1389)	n=42; 1.22 (1.067-1.35)	n=0; NA (NA)	n=42; 0.065 (0.014-0.173)	n=29; -27.6 (-29.6--25.9)	n=29; 6.9 (5.6-9)
Section 6	n=37; 341 (185-462)	n=37; 561 (91-1253)	n=37; 1.18 (0.941-1.564)	n=0; NA (NA)	n=37; 0.057 (0.016-0.157)	n=26; -27.7 (-29.2--26.3)	n=26; 7.4 (6.3-10.6)
Section 7	n=48; 358 (206-524)	n=48; 631 (115-1675)	n=48; 1.2 (1.014-1.351)	n=0; NA (NA)	n=48; 0.078 (0.014-0.214)	n=39; -27.8 (-29.4--25.9)	n=39; 8 (6.6-13.8)
Section 9	n=79; 323 (130-495)	n=79; 511 (22-1479)	n=79; 1.18 (0.943-1.409)	n=0; NA (NA)	n=79; 0.088 (0.011-0.416)	n=53; -27.6 (-29.4--26.2)	n=53; 7.3 (5.9-9.3)

Figure 4-15. Length frequency and age frequency for Longnose Sucker (LSU) by location across all years (2010–2020).

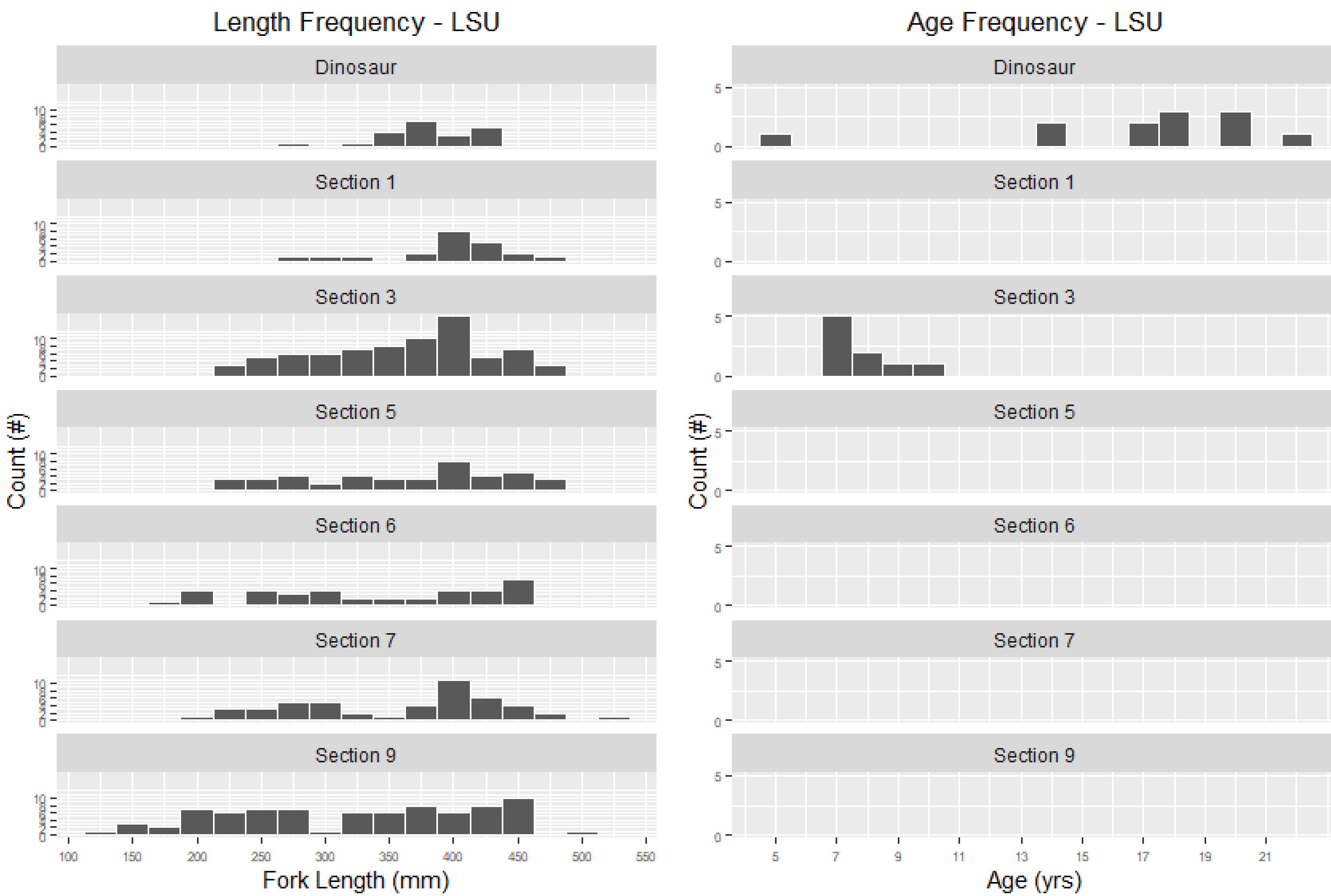
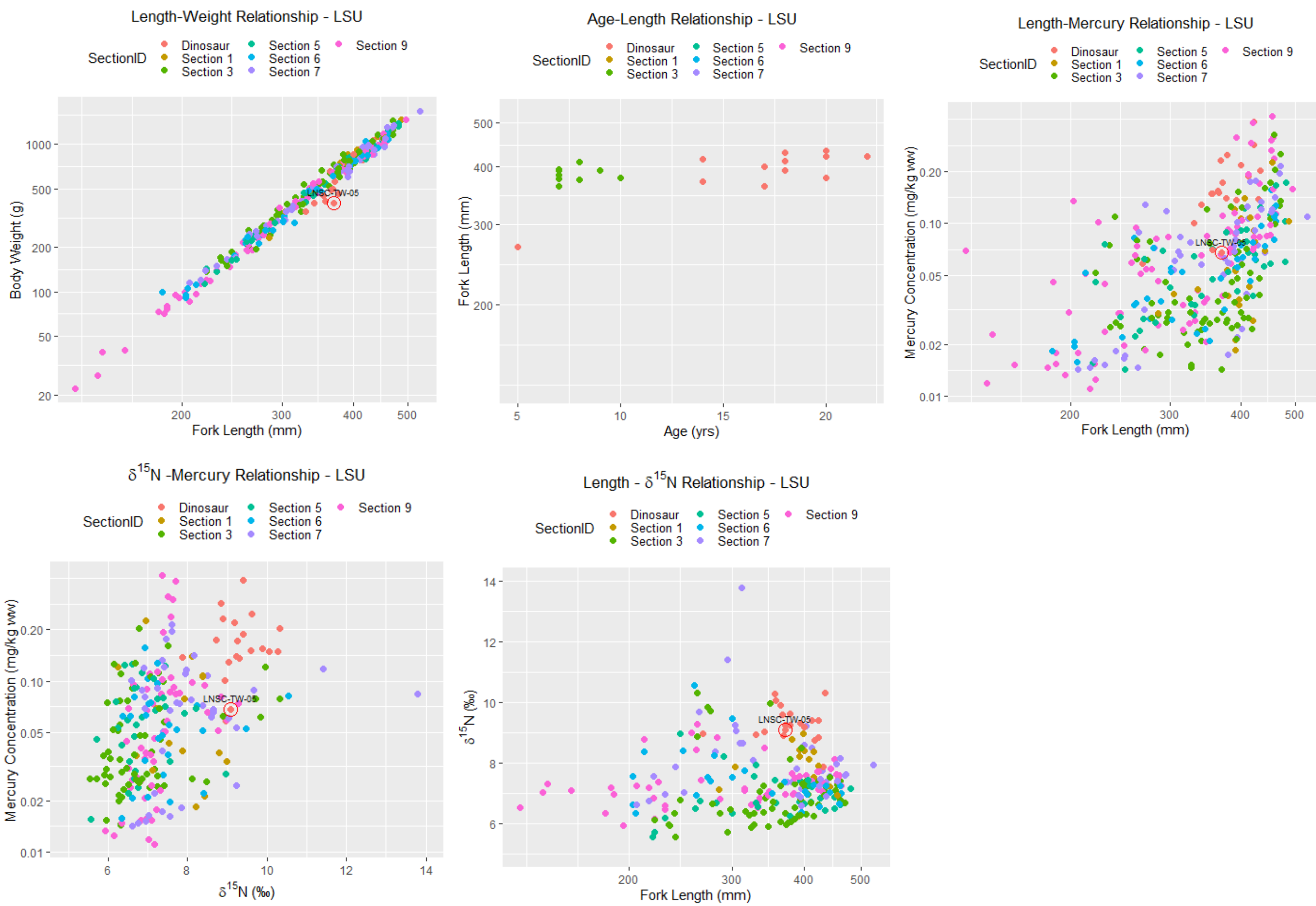


Figure 4-16. Key mercury relationships for Longnose Sucker (LSU) across all years (2010–2020).



Note: Red circles indicate length-weight outliers.

Figure 4-17. Comparison of length-mercury relationships for Longnose Sucker (LSU) among Peace River sampling locations for the recent baseline period (2017–2020).

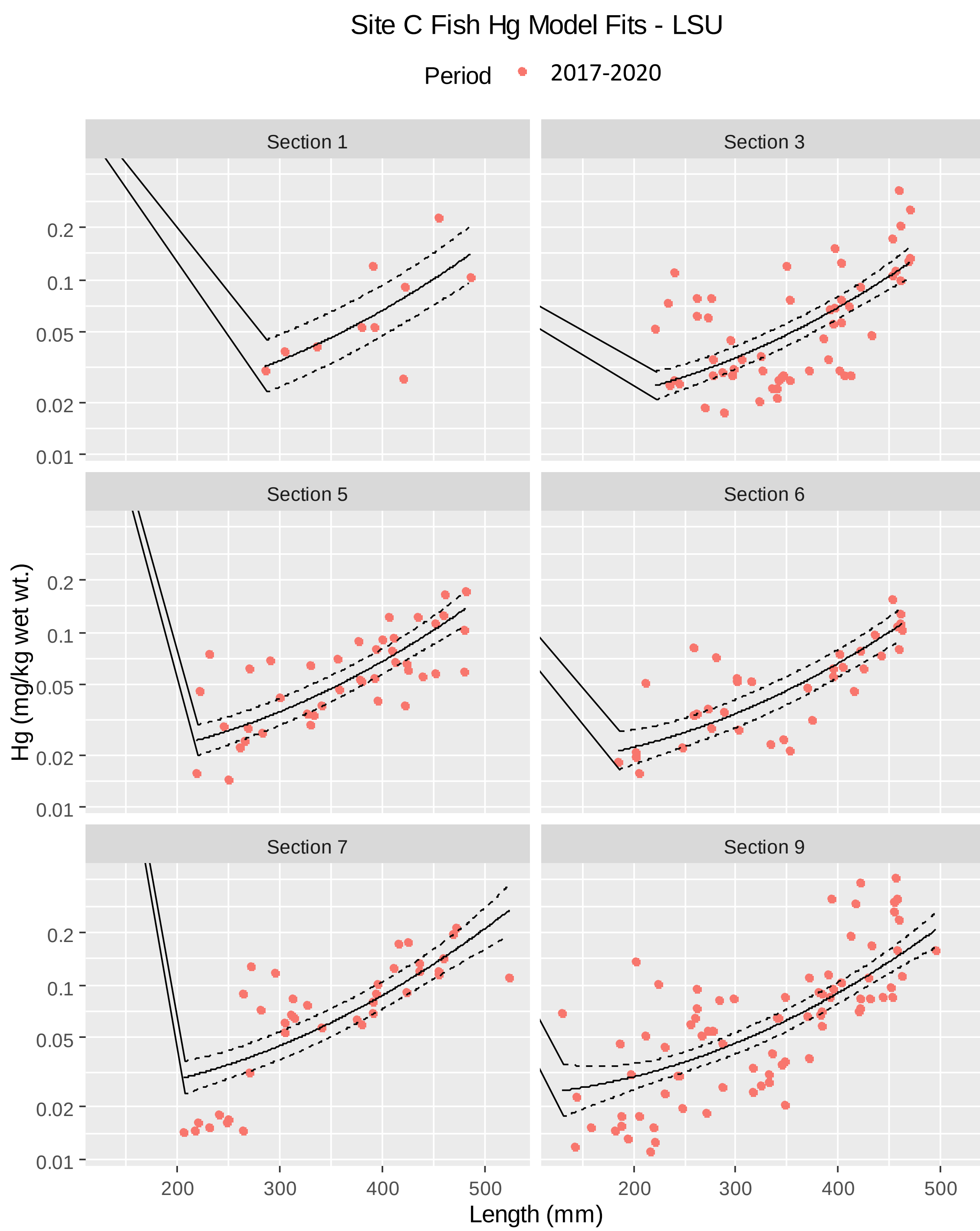
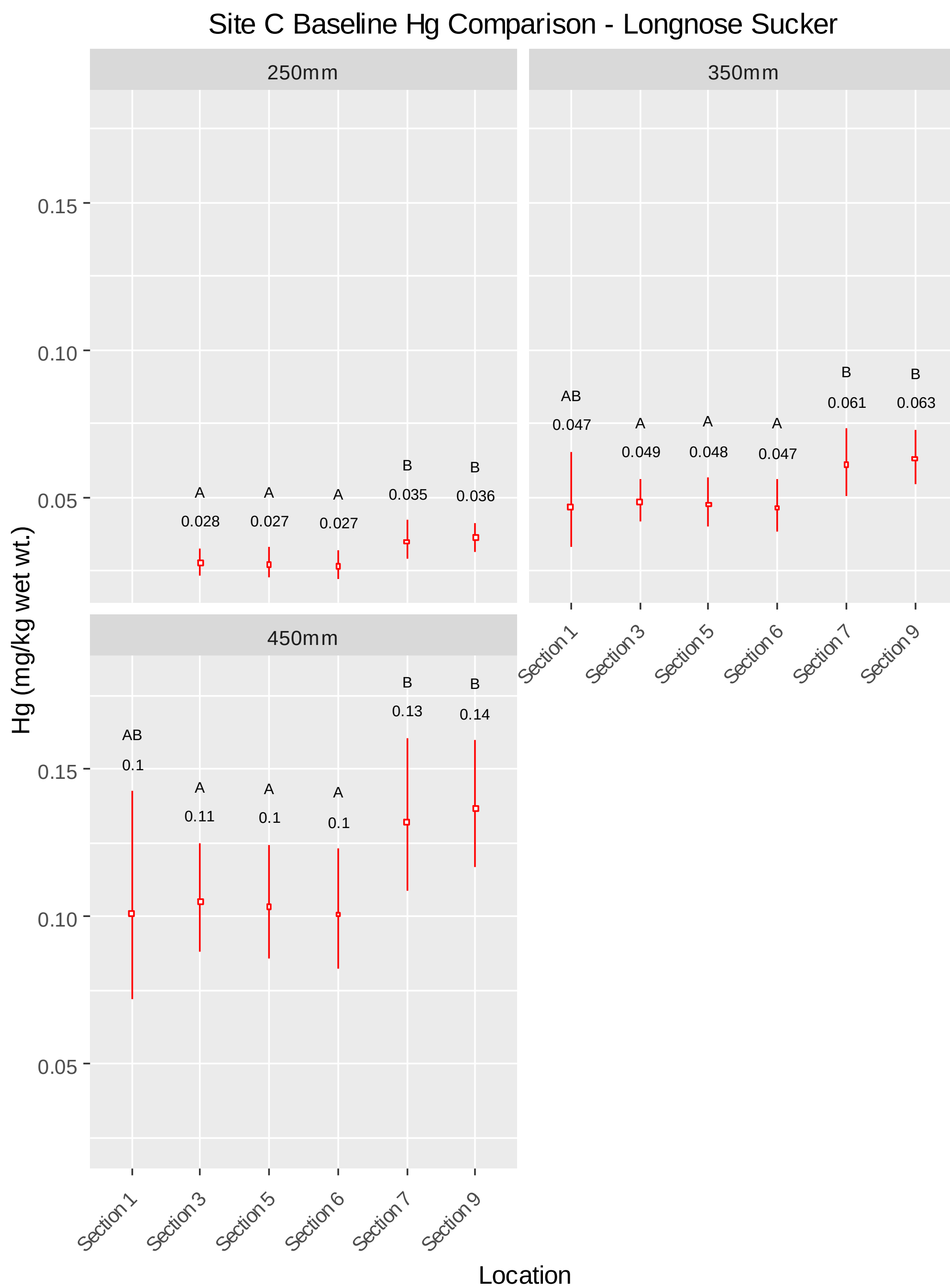
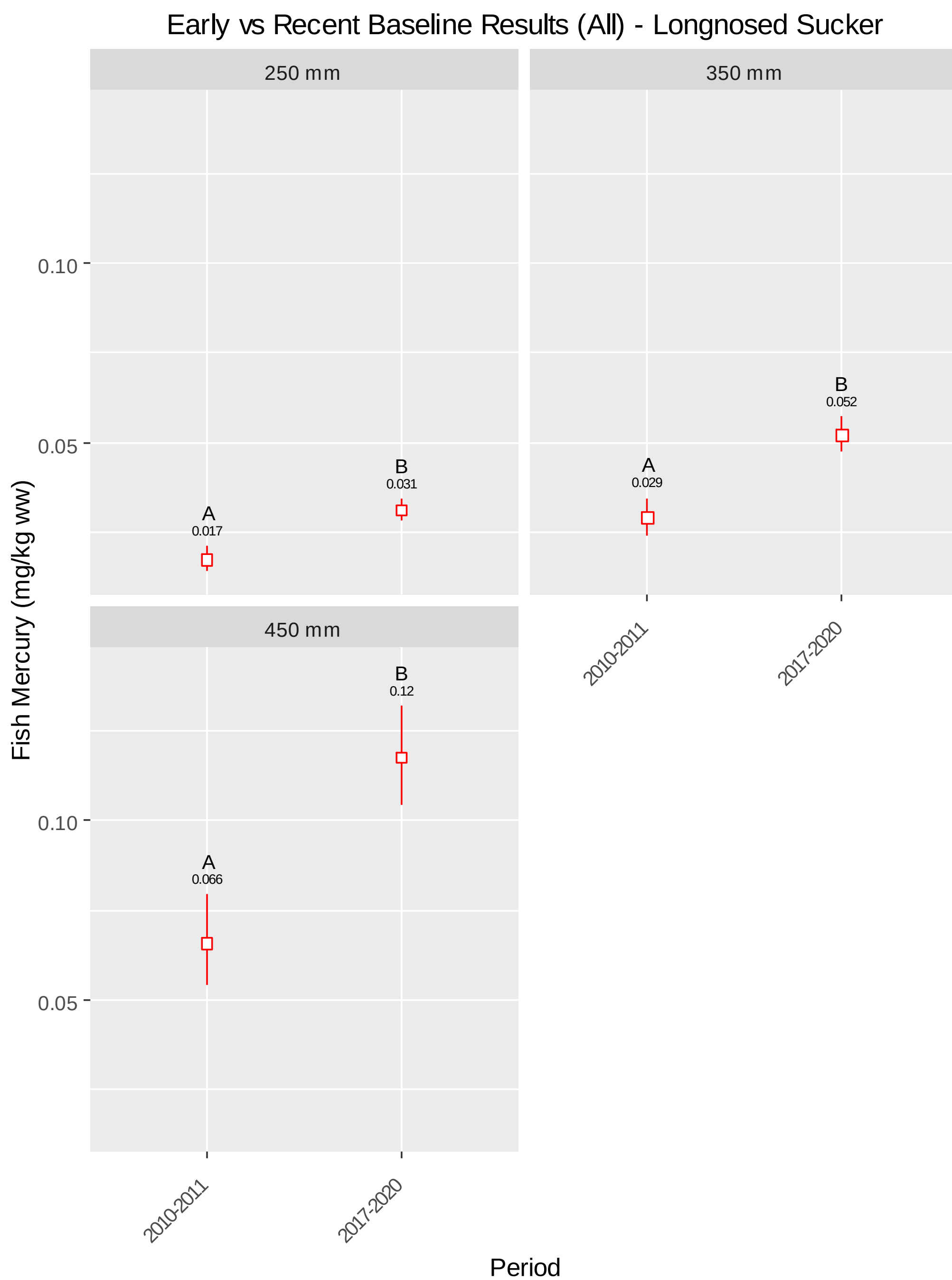


Figure 4-18. Estimated mercury concentrations (and 95% confidence intervals) for select sizes (250 mm, 350 mm, 450 mm) of Longnose Sucker for Peace River sampling locations for the recent baseline period (2017–2020).



Note: Letters above estimates show which are not statistically different from one another (same letters) or which are statistically different (different letters); combinations (e.g., "AB") show estimates that are not statistically different from other groups that are different (e.g., "A" and "B"). No results are shown for the 250-mm size class in Section 1 as fish that small were not caught there.

Figure 4-19. Estimated mercury concentrations (and 95% confidence intervals) for Longnose Sucker for select sizes (250 mm, 350 mm, 450 mm) across periods in the baseline sampling period assessment across Peace River locations.



Note: Letters above estimates show which are not statistically different from one another (same letters) or which are statistically different (different letters); combinations (e.g., "AB") show estimates that are not statistically different from other groups that are different (e.g., "A" and "B").

4.6 Walleye

Catch and Data Overview

The baseline fish mercury dataset for Walleye includes years 2011–2020 (no catch in 2010) and contains 166 tissue mercury samples. The breakdown of the catch results by year and location is shown in **Table 4-13**, and the breakdown by size-class is shown in **Table 4-14**. These results show that while Walleye were collected in good numbers throughout the Peace River, over half of all samples were collected in Section 7 and Section 9.

The data overview for Walleye across all years and locations is presented in **Table 4-15**. The results show that despite consistent sampling effort, there is variability in fish size among sites that may bias the mercury results. This highlights the need to use length-mercury relationships to make accurate comparisons across time and space.

Length and Age

Length results for fish sampled for mercury are shown for each location (Section) as a frequency histogram plot for both length (**Figure 4-20**, left panel) and age (**Figure 4-20**, right panel). Age samples were collected from a subset of Walleye, except for 2011 when no age samples were collected. Generally, the distributions of length and age were similar across locations.

General Mercury Relationships

Key mercury relationships for Walleye are shown in **Figure 4-21**. The length-weight and age-weight relationships are as expected for Walleye, with somewhat less variability in length-weight than in age-weight. The length-mercury relationship is slightly positive, while the δ15N-mercury and δ15N-length relationships are generally ambiguous. No outliers were identified in the data.

Length-Mercury Relationships

Key results are summarized below and detailed modelling results are provided in **Appendix B**:

- In the temporal assessment, statistically significant differences in Walleye tissue mercury concentrations were identified among years, but only for early years relative to recent years. This means that data can be pooled for each period (i.e., 2010–2011 for the early period and 2017–2020 for the recent period). However, the early baseline period had only six Walleye tissue samples, and fish sizes generally had limited range and displayed minimal overlap across years.
- Because of the temporal limitations discussed above, the spatial assessment was done using recent (2017–2020) baseline data only. Statistically significant differences in Walleye tissue

mercury concentrations were identified among sampling locations, and sampling data were therefore not pooled across locations (**Figure 4-22**). Mercury concentrations were generally highest in fish sampled in Section 9 of the Peace River (**Figure 4-23**).

- Based on the data limitations discussed above, no formal assessment of potential differences in tissue mercury concentrations between baseline sampling periods was conducted.

Table 4-13. Walleye catch by location and year.

Waterbody	Section	N	2011	2017	2018	2019	2020
Peace River	Section 5	33	0	6	13	4	10
Peace River	Section 6	28	0	14	7	7	0
Peace River	Section 7	40	6	14	6	5	9
Peace River	Section 8	10	10	0	0	0	0
Peace River	Section 9	55	0	31	23	0	1

Table 4-14. Walleye sample sizes by length interval (fork length in mm) and location across all years (2010–2020).

Section	N	201-300	301-400	401-500	501-600	601-700
Section 5	33	1	11	15	4	1
Section 6	28	4	11	8	2	1
Section 7	40	8	11	13	7	1
Section 8	10	0	0	10	0	0
Section 9	55	8	28	17	0	0

Table 4-15. Walleye size, age, mercury, and stable isotope data summary by location across all years (2010–2020).

Section	Length (mm)	Weight (g)	Condition (K)	Age (yrs)	Hg (ppm ww)	d13C (‰)	d15N (‰)
Section 5	n=33; 431 (284-635)	n=32; 1029 (263-3177)	n=32; 1.14 (0.98-1.32)	n=13; 5 (3-8)	n=33; 0.252 (0.084-0.768)	n=28; -26.2 (-28.2--25.3)	n=28; 11 (9.7-12.3)
Section 6	n=28; 406 (233-693)	n=28; 920 (119-4191)	n=28; 1.1 (0.94-1.33)	n=5; 4 (3-6)	n=28; 0.214 (0.038-0.55)	n=16; -25.9 (-26.7--25.2)	n=16; 10.5 (9.7-12)
Section 7	n=40; 403 (249-621)	n=40; 902 (154-2772)	n=40; 1.14 (0.99-1.31)	n=15; 5 (2-9)	n=40; 0.248 (0.076-0.854)	n=27; -26.2 (-27.5--25.1)	n=27; 10.9 (9-12)
Section 8	n=10; 435 (411-479)	n=10; 874 (640-1204)	n=10; 1.05 (0.92-1.19)	n=0; NA (NA)	n=10; 0.21 (0.109-0.321)	n=10; -25.8 (-26.3--25.4)	n=10; 11.5 (10.4-12.7)
Section 9	n=55; 368 (222-499)	n=55; 568 (134-1334)	n=55; 1.06 (0.87-1.23)	n=25; 5 (1-7)	n=55; 0.266 (0.104-0.79)	n=29; -25.7 (-27.4--24.2)	n=29; 10.4 (9.1-11.6)

Figure 4-20. Length frequency and age frequency for Walleye (WP) by location across all years (2010–2020).

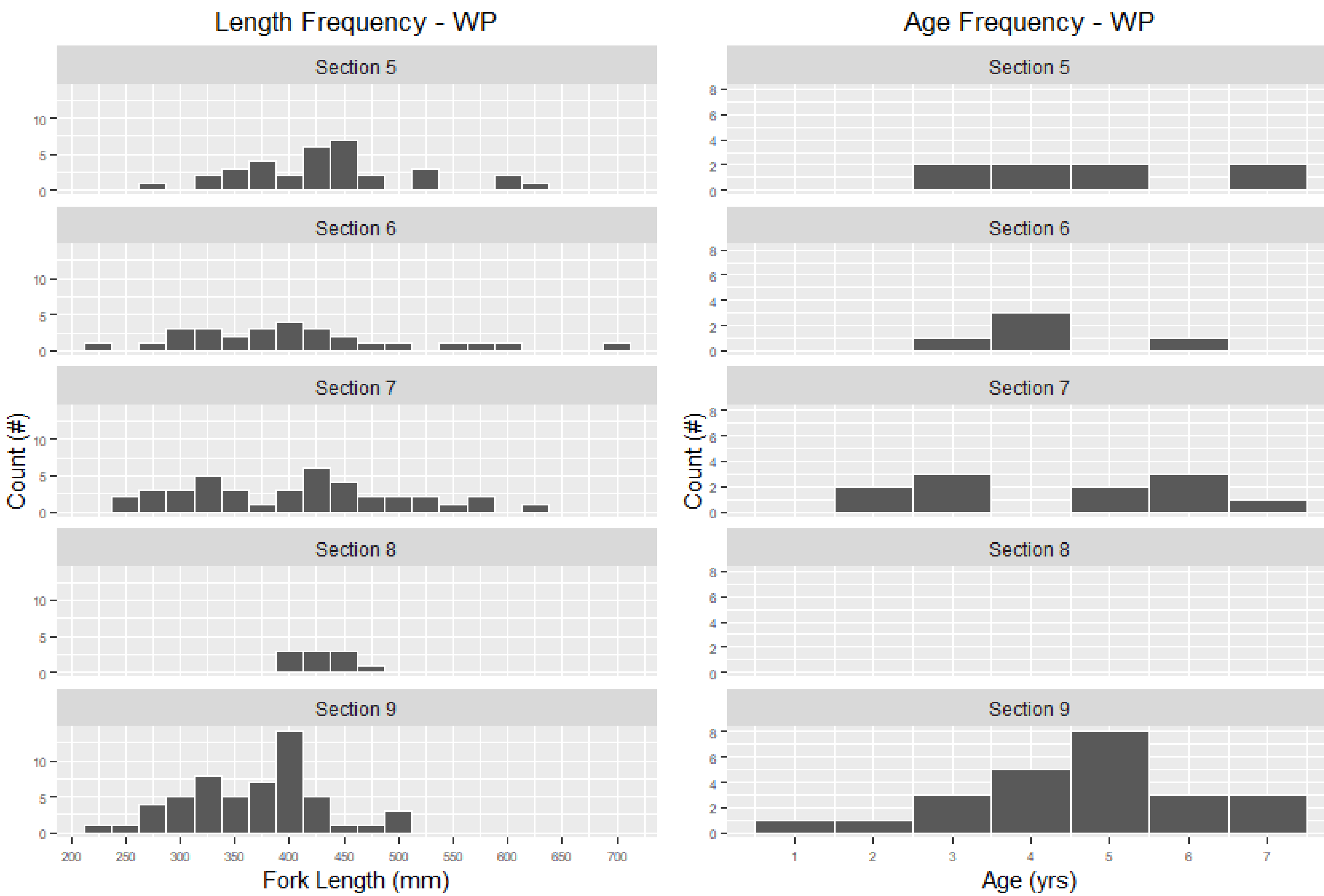
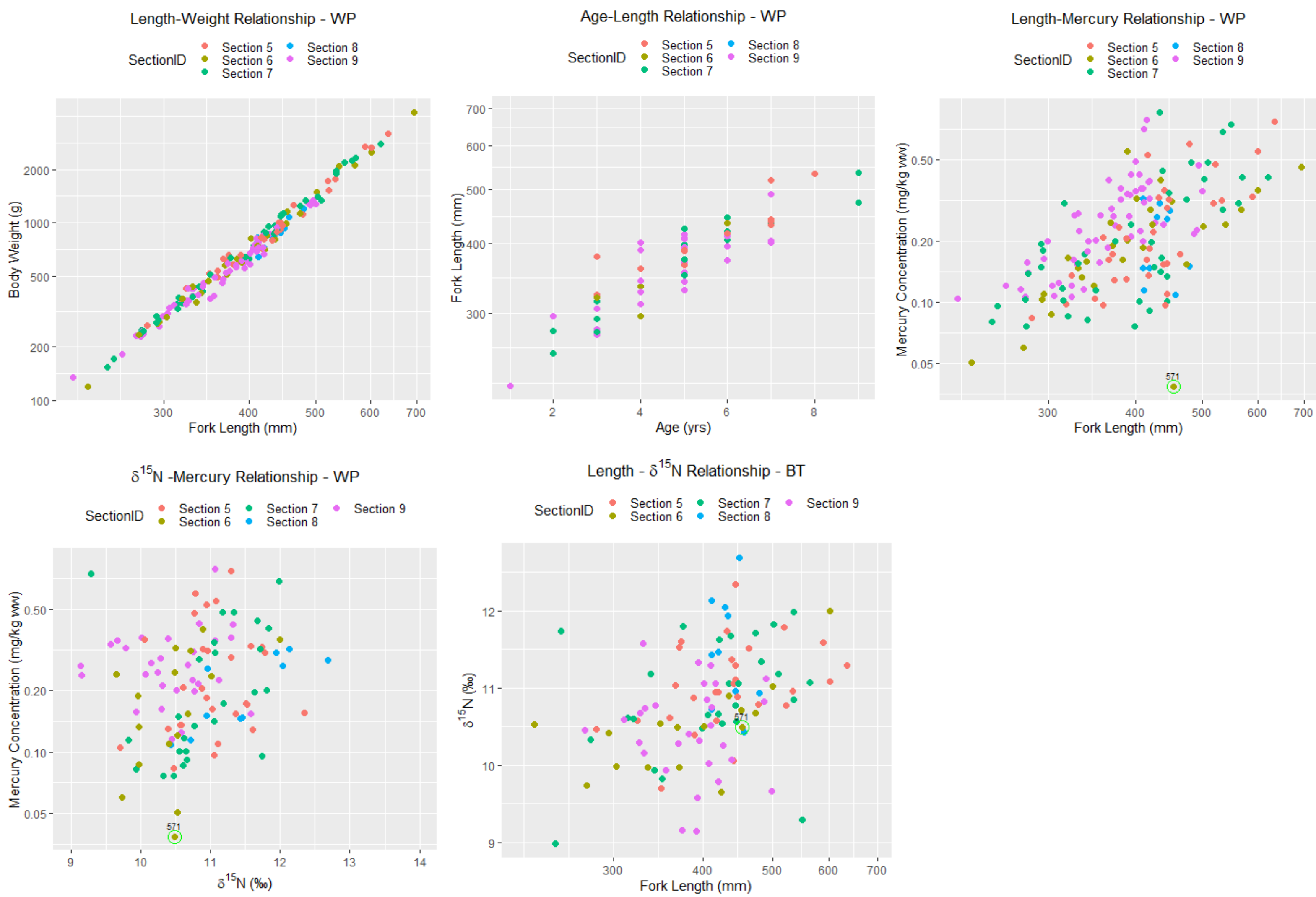


Figure 4-21. Key mercury relationships for Walleye (WP) across all years (2010–2020).



Note: Green circle indicates length-mercury outliers (not carried through as no SIA data).

Figure 4-22. Comparison of length-mercury relationships for Walleye (WP) among Peace River sampling locations for the recent baseline period (2017–2020).

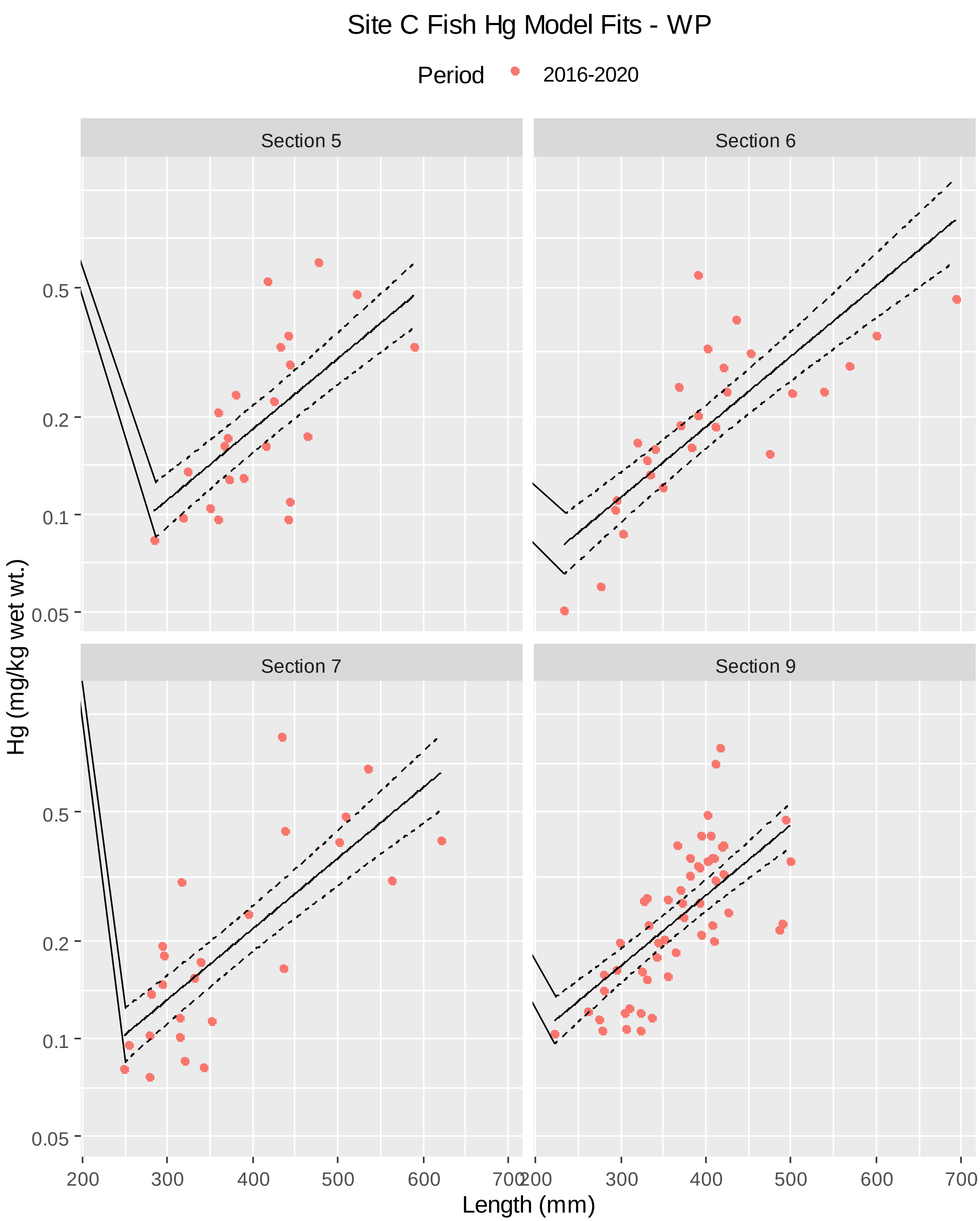
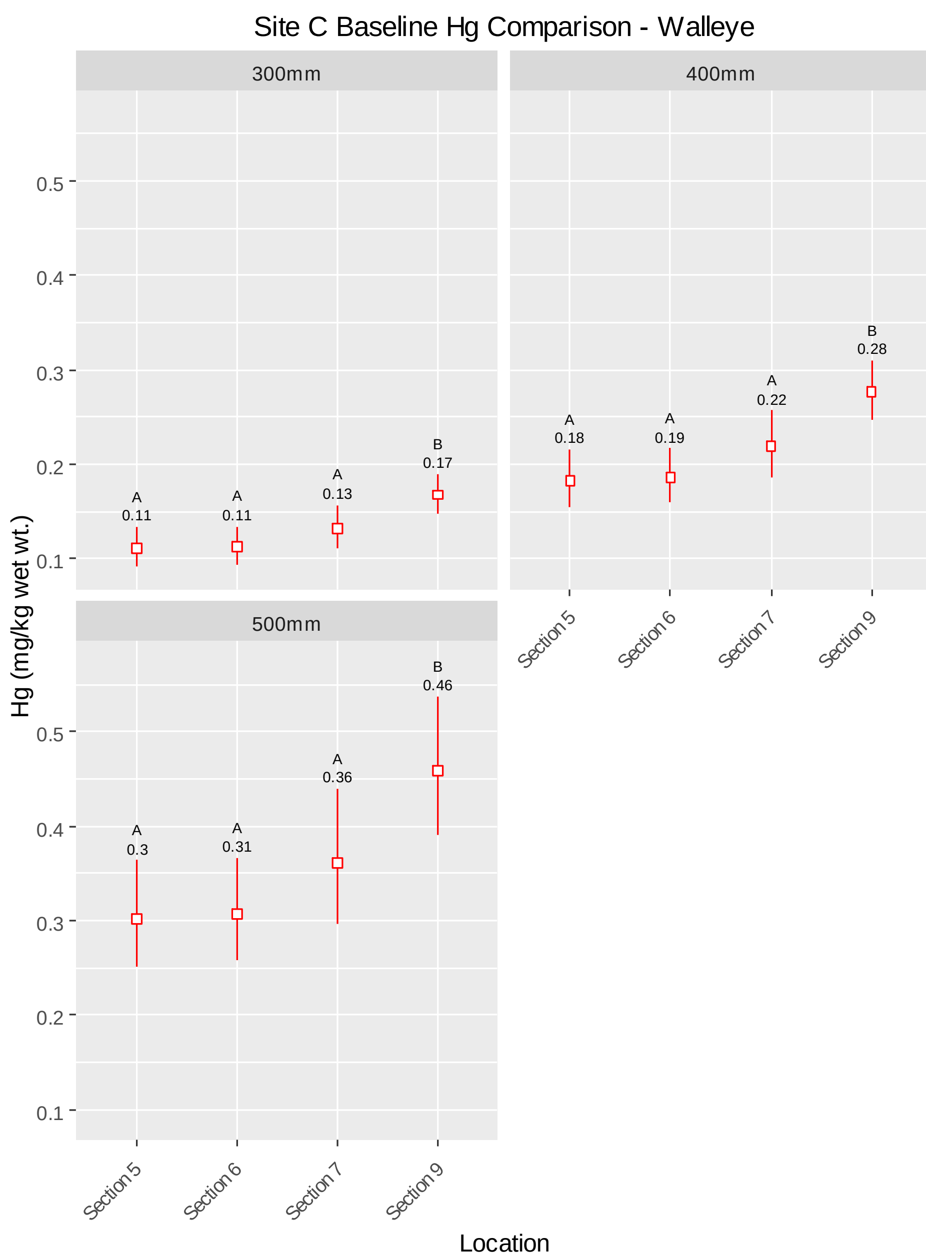


Figure 4-23. Estimated mercury concentrations (and 95% confidence intervals) for select sizes (250 mm, 350 mm, 450 mm) for each location in the spatial assessment of Walleye mercury concentrations for Peace River Sections 5, 6, 7 and 9 across the recent baseline period (2017–2020).



Note: Letters above estimates show which are not statistically different from one another (same letters) or which are statistically different (different letters); combinations (e.g., "AB") show estimates that are not statistically different from other groups that are different (e.g., "A" and "B").

4.7 Redside Shiner

Catch and Data Overview

A total of 23 Redside Shiner tissue samples have been assessed for either total mercury (n = 12) or methylmercury (n = 11) in the baseline dataset. The breakdown by year and location are shown in Error! Reference source not found.. These results show that in all three sampling years, most Redside Shiners were collected in Section 5.

Length and Age

Length results for fish sampled for mercury are shown by location as a length-frequency histogram plot (**Figure 4-24**). Age samples were not collected from Redside Shiners sampled for tissue mercury in baseline years.

General Mercury Relationships

Key mercury relationships are shown in **Figure 4-25** (note that some axes are log-transformed). The relationships exclude age-length, because there are no age data for Redside Shiner. The Redside Shiner length-mercury relationship does not have any clear patterns, likely due to the small range of fish sizes.

Length-Mercury Relationships

Due to the low overall catch numbers of Redside Shiner (n = 23), coupled with a lack of length-mercury relationship, modelling was not carried out for this target species.

Table 4-16. Redside Shiner size, age, mercury (total mercury in top panel; methylmercury in bottom panel), and stable isotope data summary by location across all years (2010–2020).

Section	Year	Length (mm)	Weight (g)	Condition (K)	Hg (ppm ww)	d13C (‰)	d15N (‰)
Section 5	2010	n=11; 99 (85-119)	n=11; 14 (6-26)	n=11; 1.3 (0.977-1.543)	n=11; 0.049 (0.032-0.06)	n=11; -25.5 (-26--24.3)	n=11; 8.1 (7.6-8.6)
Section 5	2017	n=1; 90 (90-90)	n=1; 9 (9-9)	n=1; 1.24 (1.235-1.235)	n=1; 0.048 (0.048-0.048)	n=1; -26.1 (-26.1--26.1)	n=1; 8.6 (8.6-8.6)

Section	Year	Length (mm)	Weight (g)	Condition (K)	MeHg (ppm ww)	d13C (‰)	d15N (‰)
Section 5	2020	n=7; 72 (46-106)	n=7; 5 (0.4-15)	n=7; 0.97 (0.302-1.259)	n=7; 0.049 (0.027-0.091)	n=7; -27.8 (-28.3--27.2)	n=7; 7.4 (6.9-7.9)
Section 7	2020	n=4; 45 (33-53)	n=2; 1 (0.2-1.3)	n=2; 0.8 (0.557-1.04)	n=4; 0.04 (0.024-0.076)	n=4; -27.5 (-28.1--26.8)	n=4; 7.2 (6.6-8.5)

Note: Mercury analyses for Redside Shiner to date have either total mercury or methylmercury. Both should be equivalent (i.e., as discussed in Section 1.1, total mercury is assumed to be comprised completely of the methylmercury form).

Figure 4-24. Length frequency and age frequency for Redside Shiner (RSC) by location across all years (2010–2020).

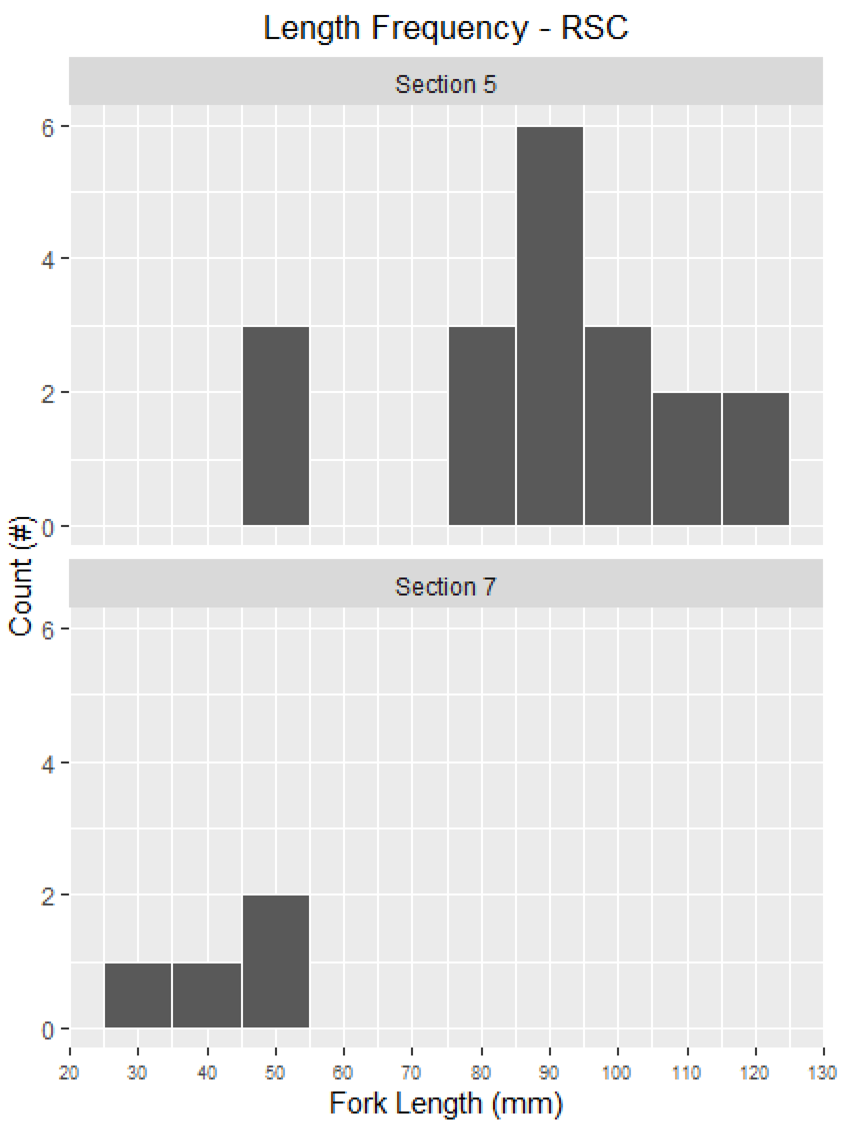
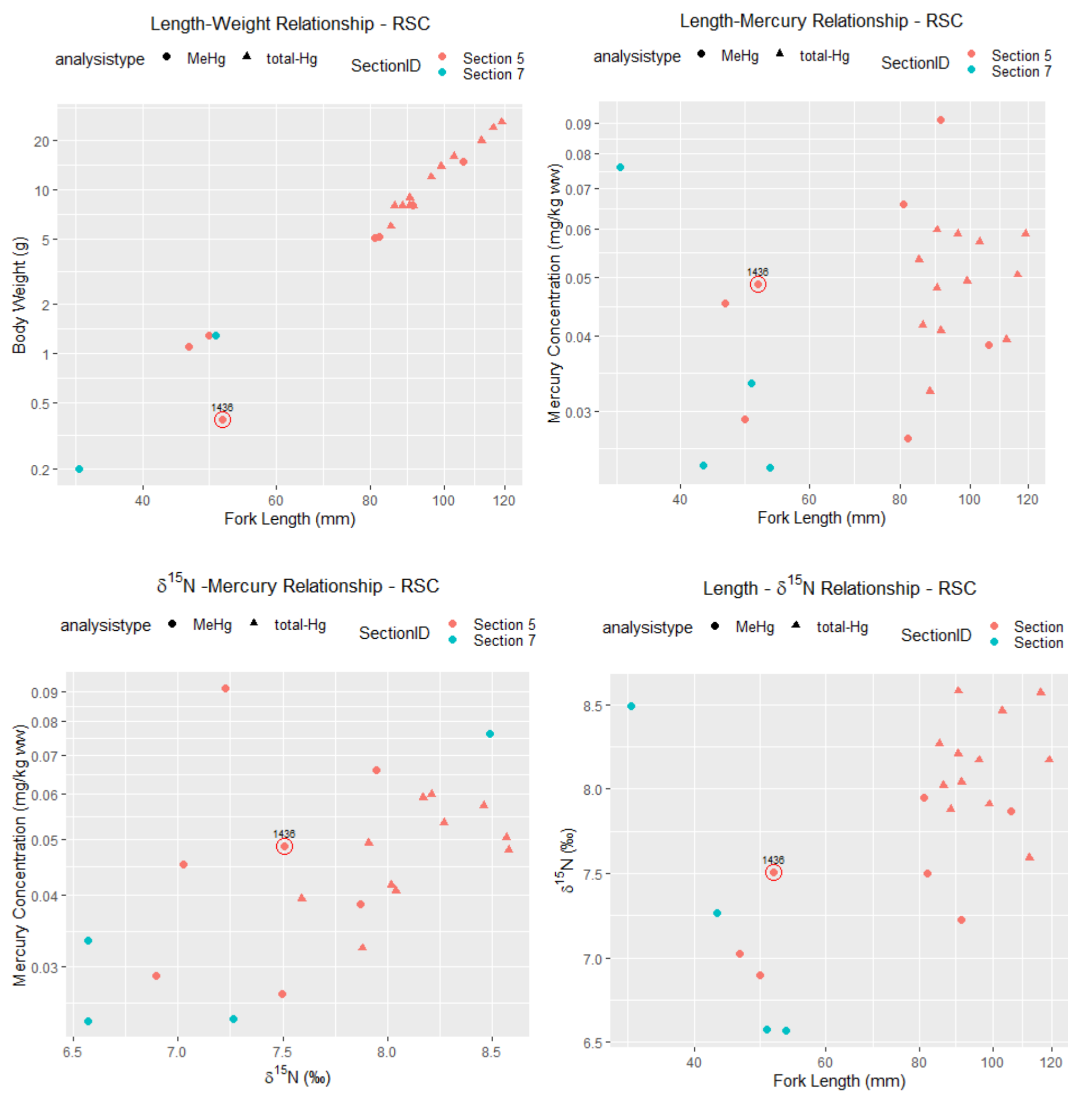


Figure 4-25. Key mercury relationships for Redside Shiner (RSC) across all years (2010–2020).



Note: Red circle indicates length-weight outlier. Methylmercury (MeHg) and total mercury (total Hg) are plotted together.

4.8 Non-Target Species

Catch and Data Overview

Tissue mercury samples were collected from non-target species on an opportunistic basis over baseline years. The breakdown by species, year and location is shown in **Table 4-17**.

Catch details by location/size class are provided in **Table 4-18**. The results show that over all sampling years:

- Most Goldeneye were collected in Section 9
- Most Lake Trout were collected in Dinosaur
- Most Arctic Grayling were collected in Section 3
- Most Northern Pike were collected in Sections 5 and 6
- Most Burbot were collected in Section 9.

Length and Age

The frequency plot for length compares the distribution of fish samples from each location (**Figure 4-26**). Distributions were generally too sparse to determine or compare trends.

General Mercury Relationships

Mercury relationships were plotted for species with more than five data points: Goldeye (GE; n=31), Lake Trout (LT, n=57), Northern Pike (NP, n=65) and Burbot (BB, n=27). The length-weight relationships for each of the plotted species were as expected and demonstrated minimal variability (**Figure 4-27**). Key mercury relationships (excluding age-length because age data were generally sparce for non-target species) are shown in **Figure 4-28**, **Figure 4-29** and **Figure 4-30**. Except for Goldeye, the non-target species generally had good representation across their size ranges (**Figure 4-26**). The Lake Trout dataset consists mainly of fish caught in Dinosaur Reservoir, and there is a surprisingly weak length-mercury relationship for this species. Northern Pike and Burbot both have positive mercury relationships.

Length-Mercury Relationships

Analysis of the non-target species' datasets was limited to plotting key mercury relationships, and no formal outlier assessment or characterization of size-mercury relationships was conducted.

Table 4-17. Non-target species catch by location and year.

Species	Section ID	N	2010	2011	2016	2017	2018	2019	2020
GE	Section 7	3	0	3	0	0	0	0	0
GE	Section 8	7	0	7	0	0	0	0	0
GE	Section 9	21	0	0	0	3	0	14	4
LT	Dinosaur	52	20	10	0	22	0	0	0
LT	Section 1	1	0	0	0	0	0	0	1
LT	Section 3	3	1	0	0	0	0	2	0
LT	Section 7	1	0	0	0	0	1	0	0
GR	Section 3	3	0	0	0	0	0	3	0
GR	Section 7	1	0	0	0	1	0	0	0
NP	Section 1	2	0	0	0	0	1	0	1
NP	Section 3	4	0	0	0	1	3	0	0
NP	Section 5	21	0	0	0	2	8	6	5
NP	Section 6	20	0	0	0	3	4	6	7
NP	Section 7	12	0	0	0	1	6	2	3
NP	Section 9	6	0	0	0	3	1	1	1
BB	Section 3	1	0	0	0	0	0	0	1
BB	Section 5	4	0	0	0	2	1	1	0
BB	Section 6	5	0	0	0	0	4	1	0
BB	Section 7	4	0	0	0	0	2	2	0
BB	Section 9	13	0	0	0	1	2	9	1

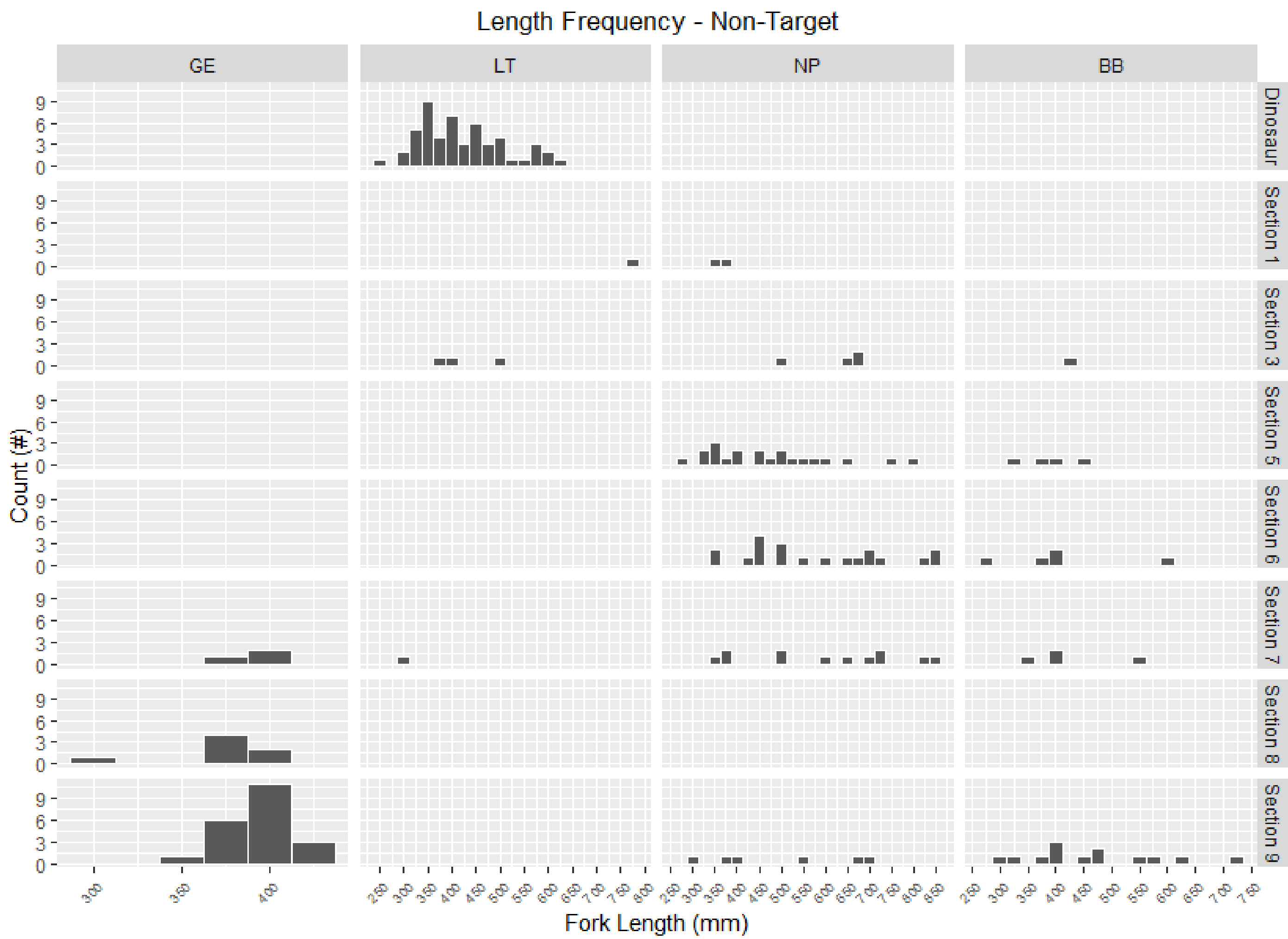
Note: GE = Goldeye, LT = Lake Trout, GR = Arctic Grayling, NP = Northern Pike, BB = Burbot

Table 4-18. Non-target species size, age, mercury, and stable isotope data summary by location across all years (2010–2020).

Species	Section ID	Length (mm)	Weight (g)	Condition (K)	Age (yrs)	Hg (ppm ww)	d13C (‰)	d15N (‰)
GE	Section 7	n=3; 391 (366-410)	n=3; 721 (600-854)	n=3; 1.2 (1.14-1.24)	n=3; 12 (11-12)	n=3; 0.159 (0.11-0.221)	n=3; -26.3 (-26.6--25.8)	n=3; 9 (8.7-9.2)
GE	Section 8	n=7; 374 (310-404)	n=7; 549 (314-702)	n=7; 1.03 (0.78-1.26)	n=7; 10 (9-11)	n=7; 0.247 (0.153-0.334)	n=7; -26 (-26.8--25.2)	n=7; 9.8 (9.4-10.1)
GE	Section 9	n=21; 395 (352-430)	n=21; 793 (525-1036)	n=21; 1.27 (1.06-1.55)	n=2; 16 (15-16)	n=21; 0.252 (0.177-0.37)	n=19; -26.1 (-27.3--25.2)	n=19; 8.8 (8.2-9.5)
LT	Dinosaur	n=52; 424 (260-630)	n=51; 922 (141-2676)	n=51; 1.04 (0.27-2.89)	n=45; 7 (4-13)	n=52; 0.092 (0.021-0.137)	n=52; -31.4 (-35.4--25.4)	n=52; 11.9 (9.3-13.1)
LT	Section 1	n=1; 780 (780-780)	n=0; NA (NA)	n=0; NA (NA)	n=0; NA (NA)	n=1; 0.109 (0.109-0.109)	n=1; -34.9 (-34.9--34.9)	n=1; 12.3 (12.3-12.3)
LT	Section 3	n=3; 421 (376-495)	n=3; 680 (485-985)	n=3; 0.89 (0.81-0.95)	n=1; 4 (4-4)	n=3; 0.124 (0.066-0.154)	n=3; -26.9 (-27--26.9)	n=3; 11.2 (11-11.6)
LT	Section 7	n=1; 306 (306-306)	n=1; 272 (272-272)	n=1; 0.95 (0.95-0.95)	n=1; 3 (3-3)	n=1; 0.207 (0.207-0.207)	n=1; -31.8 (-31.8--31.8)	n=1; 14.1 (14.1-14.1)
GR	Section 3	n=3; 353 (337-362)	n=3; 565 (473-646)	n=3; 1.27 (1.22-1.36)	n=0; NA (NA)	n=3; 0.038 (0.026-0.046)	n=3; -27.9 (-28.1--27.6)	n=3; 8 (7.8-8.4)
GR	Section 7	n=1; 336 (336-336)	n=1; 482 (482-482)	n=1; 1.27 (1.27-1.27)	n=1; 3 (3-3)	n=1; 0.018 (0.018-0.018)	n=1; -26.5 (-26.5--26.5)	n=1; 7.4 (7.4-7.4)
NP	Section 1	n=2; 362 (348-375)	n=2; 454 (345-563)	n=2; 0.94 (0.82-1.07)	n=0; NA (NA)	n=2; 0.053 (0.035-0.071)	n=2; -30.8 (-31.5--30.1)	n=2; 7.7 (7.3-8)
NP	Section 3	n=4; 628 (505-684)	n=3; 2435 (1897-2737)	n=3; 0.81 (0.73-0.86)	n=1; 4 (4-4)	n=4; 0.182 (0.106-0.337)	n=4; -26.8 (-28--25.9)	n=4; 9.9 (9.1-10.6)
NP	Section 5	n=21; 475 (284-800)	n=21; 992 (159-4139)	n=21; 0.71 (0.61-0.81)	n=2; 3 (3-3)	n=21; 0.119 (0.04-0.508)	n=20; -27.2 (-28.7--25.1)	n=20; 9 (7.9-10.3)
NP	Section 6	n=20; 575 (340-860)	n=20; 1801 (284-5260)	n=20; 0.78 (0.57-1.4)	n=3; 4 (2-5)	n=20; 0.166 (0.036-0.873)	n=17; -26.7 (-27.3--26)	n=17; 10.1 (9.1-11)
NP	Section 7	n=12; 598 (351-850)	n=12; 2177 (305-5470)	n=12; 0.78 (0.55-0.95)	n=0; NA (NA)	n=12; 0.209 (0.037-0.64)	n=10; -26.7 (-27.6--26.3)	n=10; 10.2 (9-11.4)
NP	Section 9	n=6; 501 (310-696)	n=6; 1217 (221-2595)	n=6; 0.73 (0.64-0.83)	n=3; 4 (1-6)	n=6; 0.106 (0.042-0.244)	n=4; -26.4 (-26.6--26.1)	n=4; 9.7 (8.4-10.6)
BB	Section 3	n=1; 420 (420-420)	n=1; 367 (367-367)	n=1; 0.5 (0.5-0.5)	n=0; NA (NA)	n=1; 0.17 (0.17-0.17)	n=1; -28.1 (-28.1--28.1)	n=1; 10.4 (10.4-10.4)
BB	Section 5	n=4; 384 (326-454)	n=4; 351 (186-485)	n=4; 0.6 (0.52-0.78)	n=0; NA (NA)	n=4; 0.076 (0.039-0.099)	n=2; -27.1 (-27.4--26.9)	n=2; 8.7 (8.1-9.2)
BB	Section 6	n=5; 412 (283-601)	n=5; 415 (131-889)	n=5; 0.55 (0.41-0.6)	n=0; NA (NA)	n=5; 0.094 (0.032-0.117)	n=5; -27 (-27.7--26)	n=5; 10.1 (9.1-11.4)
BB	Section 7	n=4; 422 (341-550)	n=4; 480 (216-1000)	n=4; 0.57 (0.55-0.6)	n=0; NA (NA)	n=4; 0.129 (0.075-0.16)	n=4; -27 (-29.6--24.6)	n=4; 10.2 (8.7-11.2)
BB	Section 9	n=13; 469 (302-725)	n=13; 650 (170-2310)	n=13; 0.53 (0.44-0.62)	n=0; NA (NA)	n=13; 0.157 (0.039-0.255)	n=12; -26.2 (-26.7--25.8)	n=12; 10.3 (8.8-11.2)

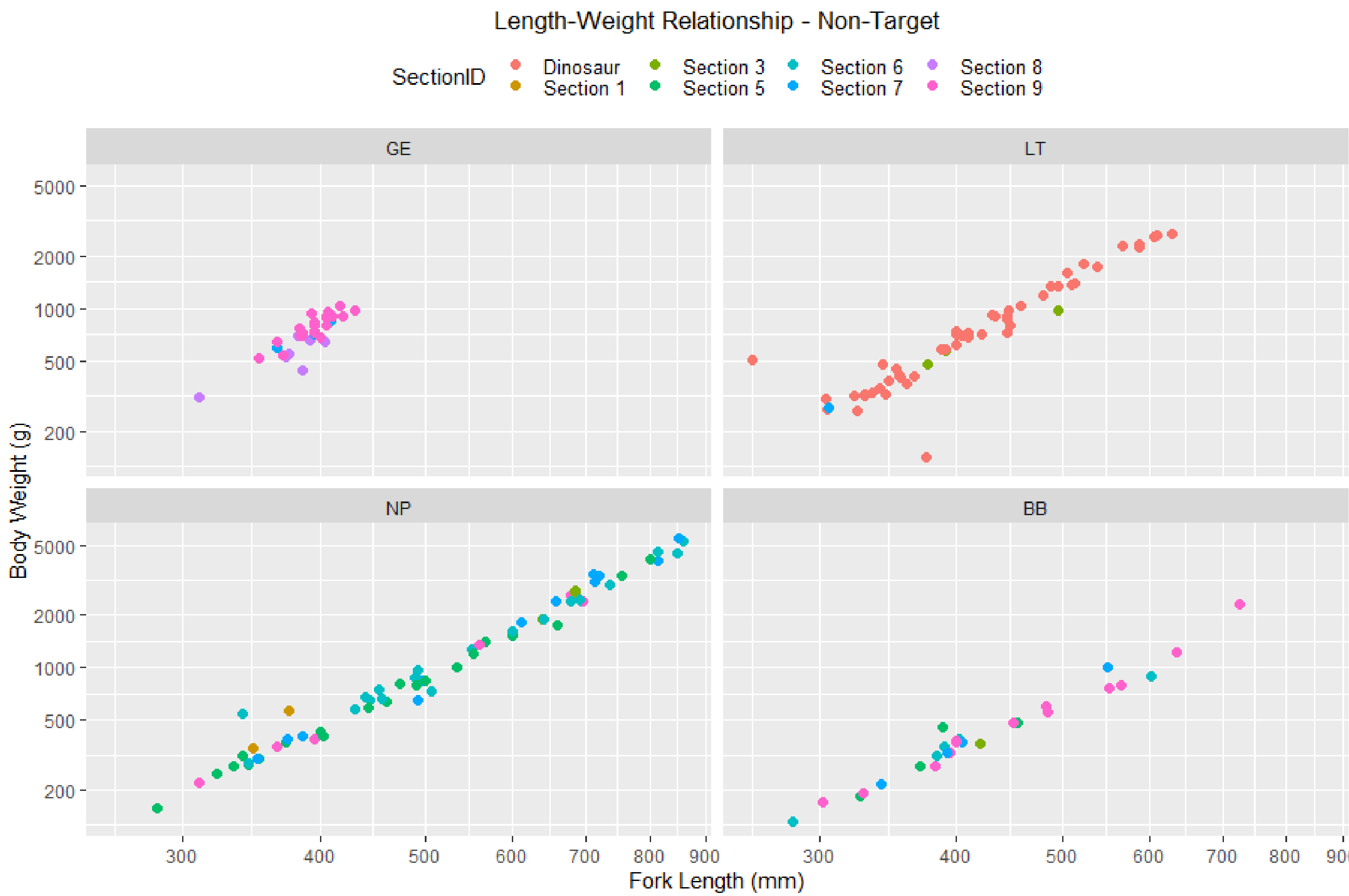
Note: GE = Goldeye, LT = Lake Trout, GR = Arctic Grayling, NP = Northern Pike, BB = Burbot

Figure 4-26. Length frequency results for non-target species by location across all years (2010–2020).



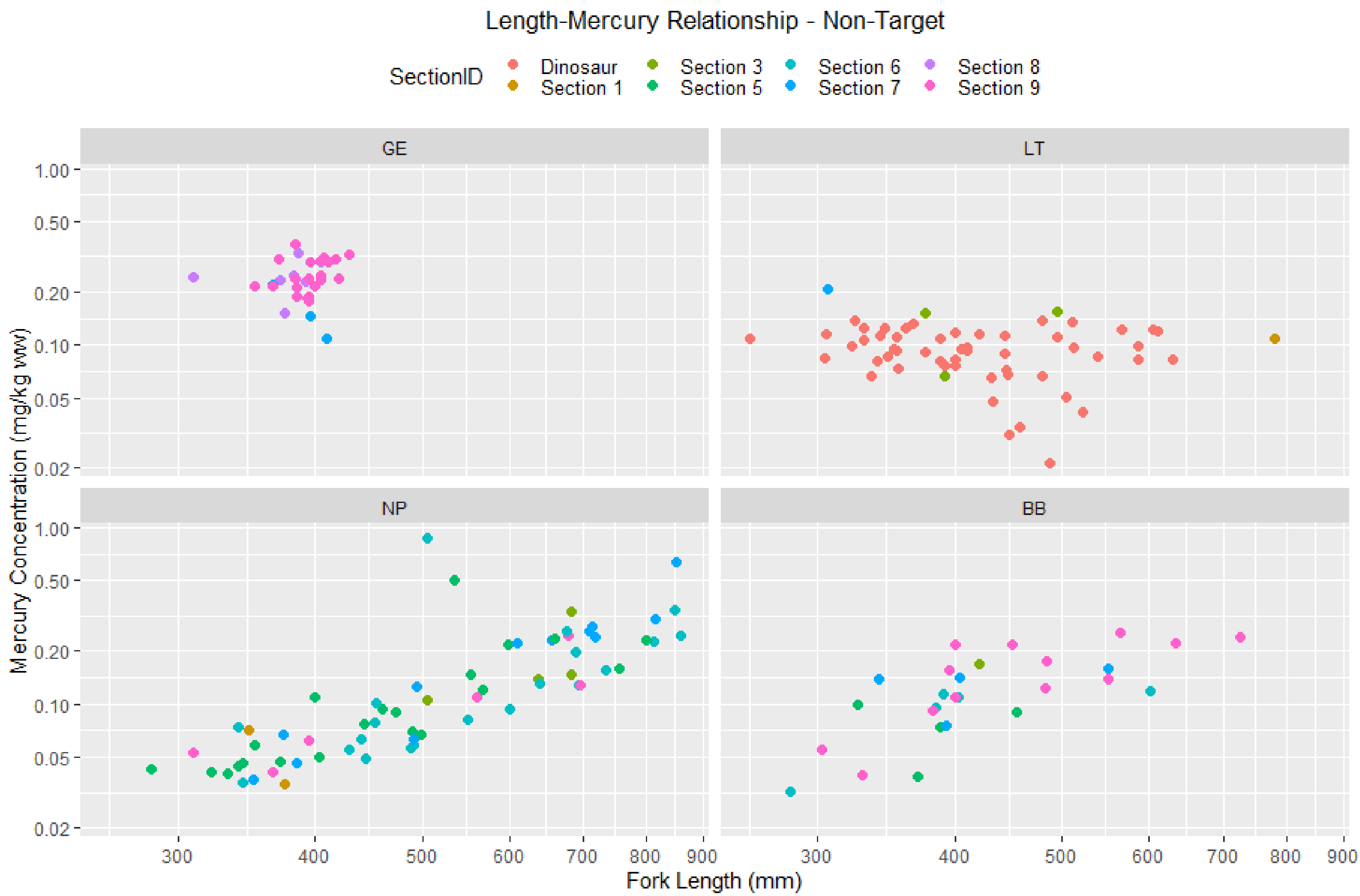
Note: LT = Lake Trout, GR = Arctic Grayling, NP = Northern Pike, BB = Burbot, LW = Lake Whitefish

Figure 4-27. Length-weight relationships for select non-target species showing location (colour) across sampling years (2010–2020).



GE = Goldeye, LT = Lake Trout, NP = Northern Pike, BB = Burbot

Figure 4-28. Length-mercury relationships for select non-target species showing location (colour) across sampling years (2010–2020).

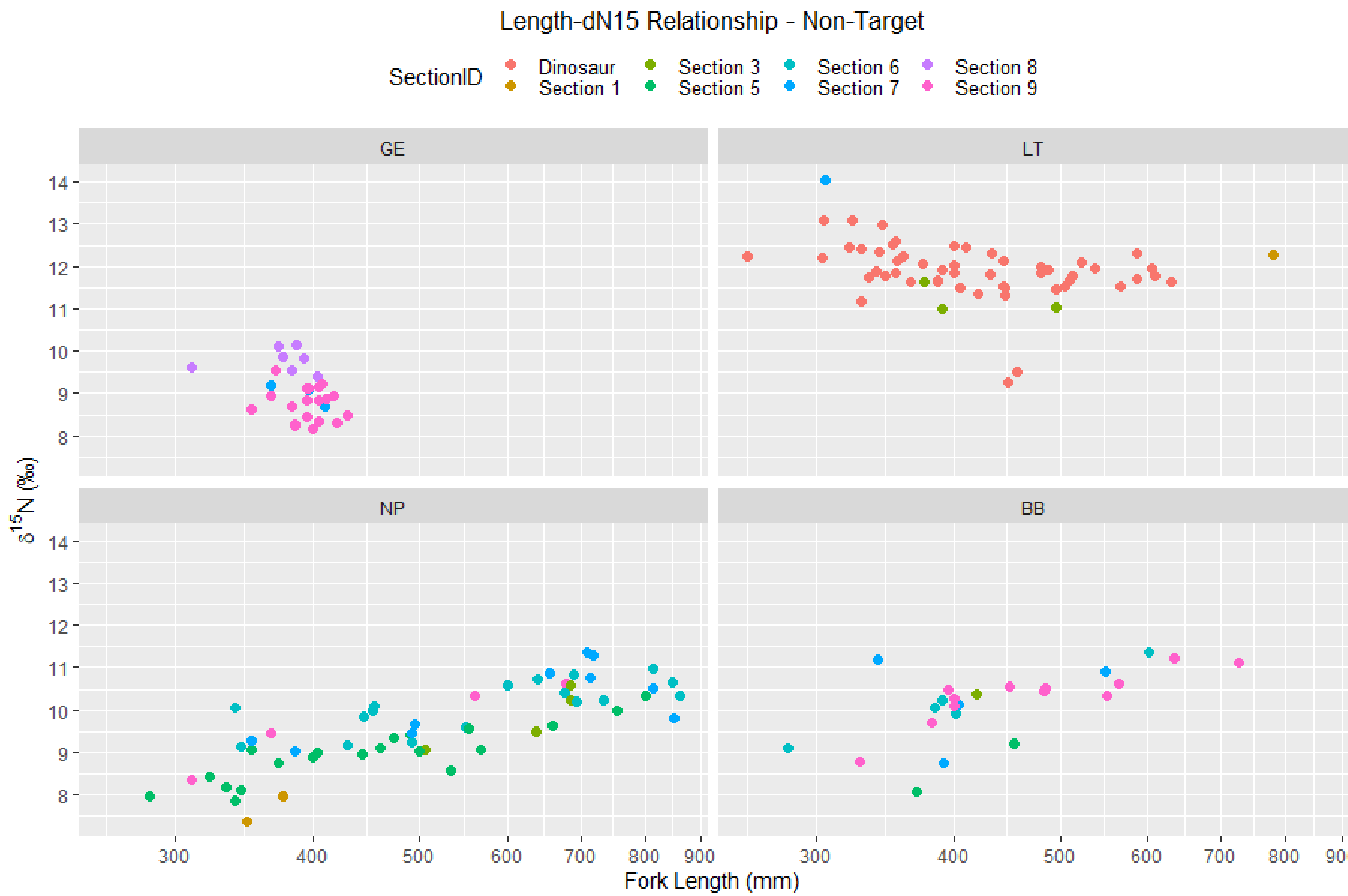


Note: GE = Goldeye, LT = Lake Trout, NP = Northern Pike, BB = Burbot

Figure 4-29. δ15N-mercury relationships for select non-target species showing location (colour) across sampling years (2010–2020).

Note: GE = Goldeye, LT = Lake Trout, NP = Northern Pike, BB = Burbot

Figure 4-30. Length-δ15N relationships for select non-target species showing location (colour) across sampling years (2010–2020).



Note: GE = Goldeye, LT = Lake Trout, NP = Northern Pike, BB = Burbot

5 SUMMARY OF RECENT RESULTS

A summary of estimated mercury concentrations for specific standardized sizes of the target species in the Peace River for the recent (2017–2020) baseline period (originally presented individually in **Section 4**) is presented in **Table 5-1**. These results are considered representative of current conditions in the river.

This baseline fish mercury analysis identified substantial increases in mercury concentrations (around two-fold depending on the selected fish size) between the early (2010–2011) and recent (2017–2020) baseline periods for Bull Trout (**Section 4.2**), Mountain Whitefish (**Section 4.3**) and Longnose Sucker (**Section 4.5**). There were apparent temporal differences for Walleye (**Section 4.6**), but the dataset was limited and precluded a more formal statistical analysis. For Rainbow Trout, no significant differences in mercury concentrations were found between the periods (**Section 4.4**), but data were also limited. Data for Redside Shiner were too limited (**Section 4.7**) to characterize either baseline period.

The data quality assessment for tissue chemistry (see Section 3.3.2 in **Appendix A** for details) examined field and laboratory quality control samples by year. No apparent systematic differences were identified in the analytical results for mercury between the early and recent baseline periods, suggesting that the changes observed were not due to any changes in field or laboratory processes.

Given that construction of the Site C dam has yet to lead to any appreciable inundation of organic-rich soils, which is the main driver of increased mercury methylation in newly constructed reservoirs, these temporal changes appear to be related to other factors affecting the Peace River watershed. Possible options include logging activities, forest fires and/or climate change. Each of these is described below:

- **Logging.** Forestry is a major industry within the region. In a study on the influence of logging and wildfires on fish mercury concentrations, Garcia and Carignan (2005) found fish mercury concentrations to be significantly higher in lakes within logged watersheds than in watersheds without logging. Temporal trends in timber harvest details for the region are likely available, but efforts to find relevant data were unsuccessful.
- **Forest Fires.** Timber loss due to forest fires is tracked by the BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development. A recent report (2019) categorizes the cumulative percentage of merchantable timber loss since 1999 in the Fort St. John and Dawson Creek Timber Supply Areas (TSAs) as “low” (< 14%). In the

Mackenzie and Prince George District TSAs it was "moderate" (14–30%). These TSAs all have at least some overlap with the Peace River watershed. Studies have shown mixed results of the impacts of forest fires on fish mercury concentrations. Kelly et al. (2006) found a five-fold increase in Rainbow Trout mercury concentrations after a forest fire in Alberta, and Garcia and Carignan (2005) found evidence of increased fish mercury concentrations in Quebec. In contrast, Riggs et al. (2017) found no increase in Yellow Perch mercury concentrations following wildfires in northern Minnesota. More recently, Sever (2021) reports that big wildfires generally do not result in substantial increases in methylmercury. She notes, however, that when heavy rainfall events occur shortly after fires, extreme runoff that includes both organic matter and mercury can lead to higher methylmercury production.

- **Climate Change.** Both precipitation (+14% increase) and temperatures (+1.7 C) have increased in the region over the last century, according to the BC Ministry of Environment and Climate Change Strategy (links below[2]). Despite declining mercury emissions in North America over the last few decades, when Gandhi et al. (2014) assessed 40 years of monitoring data for Ontario they found mercury concentrations in northern Ontario have been increasing since around 2000, particularly for Walleye and Northern Pike. They hypothesized that climate change may have been one of the factors driving these changes.

In summary, the results of this baseline fish mercury data analysis indicate that fish mercury concentrations in the Peace River have increased over the past decade. Unfortunately, we can only speculate as to why these changes may have occurred. Regardless, the results for the recent baseline period are considered the most representative of current conditions should be used for comparing future changes related to Site C after impoundment.

[2] https://www.env.gov.bc.ca/soe/indicators/climate-change/temp.html; https://www.env.gov.bc.ca/soe/indicators/climate-change/precip.html

Table 5-1. Summary of fish mercury concentrations for select sizes of target species in the Peace River for the recent (2017–2020) baseline sampling period.

Species	Temporal/ Period Trends?	Spatial Trends?	Model Used	Data Overview	Location	Size	Mercury (mg/kg ww)
Bull Trout	Yes; recent > early period	No	Fit for recent period	2017-2020 (n=148; pooled); Sect 1,3,5,6,7 (pooled); one outlier removed	All	400 mm	0.091
					All	550 mm	0.15
					All	700 mm	0.24
Mountain Whitefish	Yes; recent > early period	Yes; generally higher concentrations further downstream	Fit for spatial using recent data	2017-2020 (n=280; pooled); fish > 200 mm only; Sect 1,3,5,6,7,9; one outlier removed	Sec 1	200 mm	0.013
					Sec 3	200 mm	0.016
					Sec 5	200 mm	0.025
					Sec 6	200 mm	0.023
					Sec 7	200 mm	0.022
					Sec 9	200 mm	0.019
					Sec 1	350 mm	0.045
					Sec 3	350 mm	0.045
					Sec 5	350 mm	0.054
					Sec 6	350 mm	0.055
					Sec 7	350 mm	0.067
					Sec 9	350 mm	0.054
					Sec 1	500 mm	0.16
					Sec 3	500 mm	0.13
					Sec 5	500 mm	0.12
					Sec 6	500 mm	0.13
					Sec 7	500 mm	0.21
					Sec 9	500 mm	0.15
Rainbow Trout	No	No	Fit for recent period	2017, 2018, 2020 (n=53; pooled); Sect 1,3 (pooled); no outliers to remove	All	200 mm	0.018
					All	300 mm	0.028
					All	400 mm	0.042
Longnose Sucker	Yes; recent > early period	Yes; generally higher concentrations further downstream	Fit for spatial using recent data	2017-2020 (n=262; pooled); Sect 1,3,5,6,7,9; no outliers to remove	Sec 1	250 mm	NA*
					Sec 3	250 mm	0.028
					Sec 5	250 mm	0.027
					Sec 6	250 mm	0.027
					Sec 7	250 mm	0.035
					Sec 9	250 mm	0.036
					Sec 1	350 mm	0.047
					Sec 3	350 mm	0.049
					Sec 5	350 mm	0.048
					Sec 6	350 mm	0.047
					Sec 7	350 mm	0.061
					Sec 9	350 mm	0.063
					Sec 1	450 mm	0.1
					Sec 3	450 mm	0.11
					Sec 5	450 mm	0.1
					Sec 6	450 mm	0.1
					Sec 7	450 mm	0.13
					Sec 9	450 mm	0.14
Walleye	Yes; recent > early period	Yes; generally higher concentrations further downstream	Fit for spatial using recent data	2017-2019 (n=129; pooled); Sect 5,6,7,9; no outliers to remove	Sec 5	300 mm	0.11
					Sec 6	300 mm	0.11
					Sec 7	300 mm	0.13
					Sec 9	300 mm	0.17
					Sec 5	400 mm	0.18
					Sec 6	400 mm	0.19
					Sec 7	400 mm	0.22
					Sec 9	400 mm	0.28
					Sec 5	500 mm	0.3
					Sec 6	500 mm	0.31
					Sec 7	500 mm	0.36
					Sec 9	500 mm	0.46

*NA = estimate not made due to lack of data for this fish size.

6 REFERENCES

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Garcia, E. and Carignan, R. 2005. Mercury concentrations in fish from forest harvesting and fire-impacted Canadian Boreal lakes compared using stable isotopes of nitrogen. *Environmental Toxicology and Chemistry,* 24(3): 685-693.

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Riggs C.E., Kolka, R.K., Nater, E.A., Witt, E.L., Wickman, T.R., Woodruff, L.G., and Butcher, J.T. 2017. Yellow Perch (*Perca Flavescens*) Mercury Unaffected By Wildland Fires in Northern Minnesota. *Journal of Environmental Quality, 46*:623-631.

APPENDICES

APPENDIX A:
DATA QUALITY ASSESSMENT OF BASELINE FISH MERCURY DATASET (2010-2020)

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TABLES

APPENDICES

Appendix A1: SINLAB Interpretation Guide

1 INTRODUCTION

BC Hydro has committed to undertaking a broad range of environmental monitoring programs to collect information integral to understanding, and managing if appropriate, environmental changes related to the construction and operations of BC Hydro's Site C Clean Energy Project (Site C). The Site C Methylmercury Monitoring Plan (MMP; see *text box*) is one of these commitments, and spans the baseline, diversion and operations phases of Site C. Baseline sampling for Site C has been ongoing for a decade, starting initially in 2010 through 2011 ("early" baseline period) to support the environmental assessment process, then continuing more recently in 2017 through 2020 ("recent" baseline period) to characterize conditions prior to impoundment. Collectively, these efforts have resulted in the current fish mercury baseline dataset[1]; data and sources for the MMP dataset are summarized in **Table 1-1**.

MMP Background

The MMP is being developed by BC Hydro to meet the methylmercury-related conditions of the provincial Environmental Assessment Certificate (EAC) and the Federal Decision Statement (FDS). To that end, the MMP is being designed in consultation with Indigenous Groups to characterize mercury concentrations in fish, to understand Project-related mercury changes over time and, working with Health Authorities, to effectively communicate potential health risks associated with consuming fish from the Site C Reservoir and downstream in the Peace River.

While the MMP is technically a new program, we use the term "MMP" to collectively refer to past and future fish mercury monitoring efforts for Site C.

The MMP dataset is comprised of the following key data:

- *Fish morphometrics* (i.e., size and shape) –measured in the field and limited to length and weight.

[1] Additional baseline data were sourced from the Fish and Wildlife Compensation Program (FWCP) Peace Region's Williston-Dinosaur Watershed Fish Mercury Investigation (Azimuth 2019), which included mercury data from fish collected in the Dinosaur reservoir (upstream of Site C, and a possible reference waterbody for the MMP) in 2016 and 2017. However, data quality results for these samples are reported elsewhere (Azimuth 2019) and the data are not stored in the MMP database.

- *Tissue chemistry* – typically focusing on mercury (and moisture), but other metals were occasionally assessed too; analyzed in an analytical laboratory using a tissue sample. Tissue preferentially obtained using non-destructive techniques (Baker et al. 2004).
- *Tissue stable isotopes analysis (SIA)* – typically limited to carbon and nitrogen only; analyzed in an analytical laboratory using a tissue sample. Tissue preferentially obtained using non-destructive techniques (Baker et al. 2004).
- *Fish age* – a combination of methods used including capture history and aging structures (otoliths [destructive], fin rays [non-destructive] and scales [non-destructive]). Where available capture history and aging results are used together to refine age estimates (Golder and Gazey 2018, 2019, 2020).

Recognizing the advantages of developing a single repository for the growing mercury dataset, BC Hydro commissioned Golder Associates Inc. (Golder), in collaboration with Azimuth Consulting Group Inc. (Azimuth), to develop an Access database for the MMP (Golder 2020), to house all Site C generated mercury-related data.

In working through the MMP design process (starting in 2019), a number of MMP study design (now in draft, BC Hydro 2021) questions were raised internally that were difficult to answer without the benefit of statistical analysis of the baseline data collected to-date so Azimuth was commissioned to produce the *Preliminary Analysis of Site C Baseline Fish Mercury Data: Site C Methylmercury Monitoring Plan (MMP)* (Azimuth 2021). In the interest of time, this effort did not include an assessment of the data quality, but it was recognized that a full assessment of the baseline data (as well as the Access Database itself) was of high importance to ensure data quality now and into the future of the MMP (which is expected to be a ~25+ year program). This technical memorandum is a companion document to Azimuth 2021, presenting the QA/QC assessment for the Site C baseline fish mercury dataset.

1.1 Quality Assurance/Quality Control

A Quality Assurance/Quality Control (QA/QC) program helps to ensure that the chemical and biological data collected for the MMP are representative of the material or populations being sampled, are of known quality, have sufficient laboratory precision to be highly repeatable, are properly documented, and are scientifically defensible.

- *Quality Assurance* (QA) are the practices employed (e.g., use of experienced field staff, Standard Operating Procedures [SOPs], field data sheets, and certified laboratories) to collect scientifically defensible data meeting data quality objectives (DQOs).

- *Quality Control* (QC) are the measures taken to verify that the specific DQOs (e.g., limits for bias and precision) are met. QC measures can be based in the field (e.g., field duplicates, equipment blanks, and travel blanks) or laboratory (e.g., lab duplicates, method blanks, certified reference materials [CRMs], and lab standards).

The Site C baseline fish mercury data collection to-date has been integrated into other monitoring programs and therefore has not had a dedicated QA/QC program; however, each of the monitoring programs that the mercury data are sourced from have had their own QA/QC program. QA/QC by year/program are summarized in **Table 1-2**.

This technical memorandum presents a centralized QA/QC assessment conducted by Azimuth for the Site C baseline fish mercury dataset. Broadly this assessment supports two MMP-related efforts:

- *MMP Database* - Golder, in collaboration with Azimuth, developed an Access database for the MMP (Golder 2020), to house all MMP-related data. Data are continually added to the database, on a roughly annual basis. Presently, the database includes data up to and including 2020 data.
- *Preliminary Baseline Fish Mercury Analysis* – To support development of the MMP, statistical analyses were conducted by Azimuth (2021) to better understand temporal and spatial trends in the baseline dataset.

While mercury (and other parameters) has been and will be monitored in other environmental media (e.g., water, sediment and invertebrates) as part of the MMP, this QA/QC assessment is limited to fish at this time.

1.2 Document Structure

The remainder of this document is structured as follows:

- *MMP Database Quality* (**Section 2**) – assesses the functionality of database structure and verifies that the stored MMP fish-related data matches the original sources.
- *Data Quality* (**Section 3**) – assesses the actual quality of the MMP fish-related data.

Table 1-1. Summary of mercury and supporting data compiled for MMP.

Program	Year Data Collected	Locations (MMP Specific)	Species (MMP Target)[1]	Data Type[2]	Analysis	Lab Report	Data Report
Site C EA	2010	Dinosaur, Section 3 and 5	BT, MW, LSU, RSC	Field	Mainstream	NA	Azimuth 2011
				Hg	ALS	L937092	
				Hg	ALS	L937091	
				SIA	SINLAB	SINLAB 2010 Fish and Benthos RBA 001-126-1	
				Age	Golder[3]	none located	
	2011	Dinosaur, Section 1, 3, 7 and 8	BT, RB, MW, LSU, WP, GE	Field	Mainstream	NA	Mainstream 2013 / Azimuth 2014
				Hg	ALS	L1085007	
				SIA	SINLAB	SINLAB 2011 Fish RBA 222-390	
				Age	Golder[3]	none located	
FWCP	2016	Dinosaur	RB, LSU	Field	Azimuth	NA	Azimuth 2019
				Hg	ALS	L1864020	
				SIA	SINLAB	Si Data Report	
	2017	Dinosaur	BT, RB	Hg	ALS	L1987923	
				SIA	SINLAB	Dinosaur Derby 17AZ 001-212	
				Age	North/South	Azimuth-PeaceR-R.Baker_QAQC	
FAHMFP	2017	Section 1, 3, 5, 6, 7 and 9	BT, RB, MW, LSU, RSC, WP, GE	Field	Golder	NA	Golder & Gazey 2018
				Hg	ALS	L2212785[4]	Azimuth 2020
						L2212694[4]	Azimuth 2020
						L2023871	Azimuth 2020
				SIA	SINLAB	18 Golder 001-452	Azimuth 2020
				Age	Golder	Digital deliverable to BCH[3]	Golder & Gazey 2018
	2018	Section 1, 3, 5, 6, 7 and 9	BT, RB, MW, LSU, WP, GE	Field	Golder	NA	Golder & Gazey 2019
				Hg	ALS	L2212624	Azimuth 2020
						L2212391	Azimuth 2020
				SIA	SINLAB	18 Golder 001-452	Azimuth 2020
				Age	Golder	Digital deliverable to BCH[3]	Golder & Gazey 2019
	2019	Section 1, 3, 5, 6, 7 and 9	BT, MW, LSU, WP, GE	Field	Golder	NA	Golder & Gazey 2020
				Hg	ALS	L2395235	Azimuth 2020
				SIA	SINLAB	19 GOLD 001 - 189	Azimuth 2020
				Age	Golder	Digital deliverable to BCH[3]	Golder & Gazey 2020
	2020	Section 1, 3, 5, 6, 7 and 9	BT, RB, MW, LSU, RSC, WP, GE, LT, NP, BB	Field	Golder	NA	in prep.
					Triton	NA	in prep.
				Hg	ALS	VA20C3662	in prep.
				MeHg	ALS	VA20B7317	in prep.
				SIA	SINLAB	21Gold 001-151	in prep.
						20TRI 001-011	in prep.
				Age	Golder	Digital deliverable to BCH[3]	in prep.

Notes:

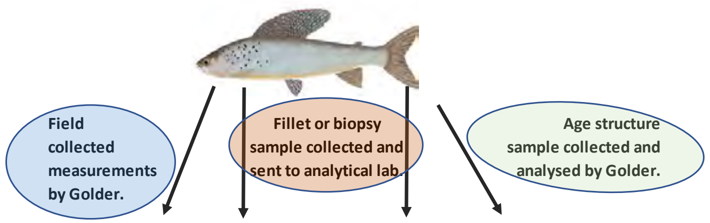
[1] Species Codes: BT = Bull Trout, MW = Mountain Whitefish, RB = Rainbow Trout, LSU = Longnose Sucker, RSC = Redside Shiner, WP = Walleye, GE = Goldeye

[2] Analysis Codes: Hg = Mercury, MeHg = Methylmercury, SIA = Carbon and Nitrogen Stable Isotope Analysis.

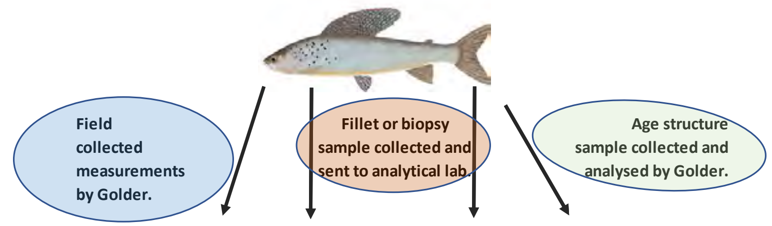
[3] Raw data are included with annual report as digital attachment.

[4] Collected in 2017 but analysed in 2019.

Table 1-2. Summary of QA/QC workflow for recent (2017-2020) and early (2010-2011) baseline Site C mercury and supporting data.



Year Fish Caught	Step in Process	Length (L) & Weight (W)	Mercury (Hg)	Stable Isotope Analysis (SIA)	Age
Recent Period (2017-2020, FAHMFP)	Field	Qualfied professionals conduct field program. Electronic entry with QA features built in.	Baker et al., 2004 sampling procedures. Field duplicate samples (collected in 2017 and 2020 only).	Baker et al., 2004 sampling procedures. Field duplicate samples (collected in 2020 only).	Age structure collected: Finray (GR, GE, MW, RB), Scales (GE, NP, LT, BT, WE).[1] Otoliths where fish succumbed to sampling only.
	Laboratory	n/a	Lab (ALS) QC: lab duplicates, lab control samples, method blanks and certified reference materials.	Lab (SINLAB) QC: laboratory duplicates, secondary standards and check standards.	Two experienced personnel independently age each structure. Aging methods evaluated annually and adjusted based on lessons learned and lit review.
	Database	Electronic entry completed in the field.	Direct electronic import from lab report(s). Some years have multiple ALS lab reports.	Direct electronic import from lab report.	Direct electronic import (append query from FAHFMP database to MMP database).
	Statistical Analysis	L vs W outlier assessment (Azimuth 2021).	L vs Hg & dN vs Hg outlier assessments (Azimuth 2021).	dN vs Hg outlier assessment (Azimuth 2021).	None, less precise measurement than length



Year Fish Caught	Step in Process	Length (L) & Weight (W)	Mercury (Hg)	Stable Isotope Analysis (SIA)	Age
Early Period (2010-2011, Site C Baseline)	Field	Qualfied professionals conduct field program. Hardcopy datasheet entry in field, transcribed to Excel database, 10% QA check.	Baker et al., 2004 sampling procedures. Field duplicate samples.	Baker et al., 2004 sampling procedures.	Age structure collected: Otolith (MW), Finray (LSU, RB, BT), Scales (RSC).[1]
	Laboratory	n/a	Lab (ALS) QC: lab duplicates, lab control samples, method blanks and certified reference materials.	Lab (SINLAB) QC: laboratory duplicates, secondary standards and check standards.	Two experienced personnel independently aged each structure.
	Database	Electronic transfer from Excel database to Access database.	Direct electronic import from lab report(s). Some years have multiple reports.	Direct electronic import from lab report.	Electronic transfer from 2011 database (Excel) to Access database.
	Statistical Analysis	L vs W outlier assessment (Azimuth 2021).	L vs Hg & dN vs Hg outlier assessments (Azimuth 2021).	dN vs Hg outlier assessment (Azimuth 2021).	None, less precise measurement than length

Notes:

The FWCP data from Dinosaur Reservoir is not included in this table. Readers are directed to Azimuth (2019) for information on field and laboratory QA/QC. These data were merged with the Site C data prior to conducting the statistical analyses.

[1] Species Codes: BT = Bull Trout, MW = Mountain Whitefish, RB = Rainbow Trout, LSU = Longnose Sucker, RSC = Redside Shiner, WP = Walleye, GE = Goldeye

Azimuth 2021 = Preliminary Analysis of Site C Baseline Fish Mercury Data Report

2 DATABASE QUALITY

An Access database for the MMP that centralizes all mercury-related data for Site C, has been developed and maintained by Golder and Associates (Golder). For details on the contents and organization of the baseline Access database, see the metadata summary report (Golder 2020). Here we document the process undertaken by Azimuth, with the assistance of Golder, to ensure through compiling and centralizing various data sources into a database, data quality is maintained. That is, documenting how the information is transcribed from source into the database, and reviewing data systematically to ensure from a structural perspective, it matches the information from the original sources.

Data Transfer to Access Database

Early period fish morphometric data (and other field-collected data) were manually entered into Excel from hardcopy datasheets by an experienced professional. This Excel data had at a minimum 10% of transcribed e-data reviewed independently by a second experienced professional to check for completeness and accuracy. Excel data were bulk transferred to the Access database and spot checked from accuracy (i.e., the correct data type was transferred to the correct Access table/column).

Recent period fish morphometric data (and other field-collected data) were input to the Access database by direct transfer from the electronic FAHMFP database and spot checked for accuracy.

Chemistry and SIA lab data (including select laboratory QC data[2]) was directly transferred from electronic lab reports (copies of reports also stored in the database).

Age data was either input from Excel (early period) or from FAHMFP database (recent period).

Database Assessment

The assessment of the database looked at two main aspects:

[2] Chemistry and SIA laboratory QC data was input to the Access database with the exception of the results for SIA check standards and secondary standards, which was reported in a format not easily electronically transferred. These QC components are tracked manually, outside of the database.

1. That the database design (i.e., collection of tables/fields) allowed for the inclusion of all relevant MMP information.
2. That the data were imported completely and accurately from the sources into the appropriate tables/fields in the database.

Thus, the database assessment did not focus on the quality of the specific data being housed (see **Section 3** for details), but rather on the completeness and accuracy of the data in bulk and the structure of the database itself. Ultimately, the database needs to provide unambiguous linkages across information types: fish-related information (e.g., date, species, catch location, and morphometric data), tissue mercury (and other metals) data, tissue SIA data, and age data in order to function as intended. The following checks/modifications were conducted on the database to assess/improve this functionality:

- *Verification of number of mercury samples by year* – this provided a direct comparison of data with original sources, particularly for the early period data (summarized previously; Azimuth 2014). Note that the year the samples was collected, rather than the sample laboratory reporting date, was used to determine the year for a given sample.

  Accounting for samples was challenging for the 2017 data, where some tissue samples were erroneously discarded by the chemistry laboratory prior to analysis and records related to the incident were incomplete. This effort was also hampered by

  - Inconsistent naming conventions employed by the field team (e.g., fish IDs used as sample labels rather than listed mercury sample IDs).
  - In response to the chemistry lab mistake, samples originally destined for SIA were redirected for mercury analysis, but without updating the sampling records; the redirected samples were analyzed and reported in 2019.
  - Due to the redirect (see above bullet), multiple tissue samples from the same fish were inadvertently analyzed (termed “inadvertent duplicates” to reflect their status accurately).
  - Cases where fish recorded in the database were without an associated tissue mercury result (due to sample throw-away); these fish records were removed from the database.

- *Identification/verification of mercury data measurement units* – this is a common error in fish mercury studies, but is easy to verify. Units are generally mg/kg, but can be reported on a wet weight or dry weight basis. The convention for tissue mercury concentrations is on a wet weight basis, but concentrations reported in dry weight can be converted using moisture content (measured or assumed). Results were verified against the original lab reports.

- *Identification of tissue sample type* – the two options are biopsy and fillet; the former is generally associated with non-lethal sampling and the latter with lethal sampling. This is important to know only as it relates to laboratory analytical methods and tissue chemistry results reporting (i.e., biopsy samples reported on a dry weight basis).
- *Standardization of species names* – this is important to ensure consistency across sampling periods and correctly associate sample results to a particular fish species.
- *Unique identifiers for fish and fish/year* – non-lethal sampling allows for the possibility of catching the same fish in different years (note that any fish caught more than once in the same year would not be sampled again). Unique identifiers for the fish in general and for each capture event for that fish facilitates individual records for each capture (e.g., to accommodate different results for location, morphometric measures, etc.) while allowing easy identification of capture history, and hence evolution of tissue mercury concentrations for that particular fish.
- *Identification of age structures used* – methods for aging fish have been modified over the years at Site C to obtain more accurate estimates of age (see **Section 3.2**). Confidence in the age estimates differs according to the aging structure used and species. A database field was added to document the aging structure type.
- *Identification of Field Quality Control Samples* – there were inconsistencies in the collection of field duplicate samples across years, including the 2017 situation (see first bullet above). Field duplicate samples are submitted "blind" (i.e., the lab does not know which samples are duplicates) to verify the precision of the laboratory. The results are provided alongside the rest of the samples, so additional information (recorded in the field) is needed to pair the duplicate sample to the original sample. Consequently, a table (tble2TissueSample) was added to the database to provide information on sample QC type, explicitly identifying all samples as an original sample (SAMP) or a duplicate (DUP) sample with pairing information. Note that cases where multiple duplicates were found (e.g., as occurred with the inadvertent duplicates from 2017), the duplicates were numbered (e.g., DUP1, DUP2, etc.) and the first in the series used for QC purposes.

3 DATA QUALITY

3.1 Assessment Overview

A summary of the QA/QC workflow for each of the two Site C baseline sampling periods is presented for the field and laboratory, database, and statistical analyses in **Table 1-2**. Database quality was discussed in **Section 2**. Details on QA/QC for the statistical analysis (e.g., outlier assessment, etc.) of the MMP baseline dataset is reported in the companion document *Preliminary Analysis of Site C Baseline Fish Mercury Data: Site C Methylmercury Monitoring Plan (MMP)* (Azimuth 2021). This section focuses on the assessment of the overall quality of the MMP data, with subsections on Quality Assurance (**Section 3.2**) and Quality Control (**Section 3.3**) for the field and laboratory components.

3.2 Quality Assurance

Careful collection, documentation and handling of all samples and data, regardless of media, data type, or frequency is a key component of QA on a field program. Below is an assessment of the QA component of the Site C baseline fish mercury data.

For all data sources, field programs were carried out by experienced field crews that follow standard field procedures, as described in each program's reports (see **Table 1-1** for list of reports).

Field Datasheets

The 2010 and 2011 Site C EA sampling programs (Azimuth 2011, Azimuth 2014) relied on recording field-collected information and data in field data sheets initially, followed by scanning the data sheets and transcribing the data into Excel after returning from the field. In the field, data entry included two or more of the field crew to ensure that all data were logged correctly. At a minimum, 10% of transcribed e-data were reviewed independently by a second experienced professional to check for completeness and accuracy.

As of 2015[3], BC Hydro implemented a system of electronic entry of all FAHMFP field data, which has a number of benefits from a data quality perspective. 1) there is no extra data-handling required as is the case with field hard copy to office electronic copy transcription. 2) the

[3] While the FAHMFP has been collecting data since 2015, mercury data collection under this program began in 2017.

FAHFMP database has built-in QC features. For example, a warning prompt if the fish body condition measure is outside an acceptable range. For further information see the FAHMFP study design document (BC Hydro 2015).

Standard Operating Procedures (SOPs)

Tissue sampling methods (mercury and SIA) for both the early and recent MMP baseline periods were based on Baker et al. (2004). A brief synopsis of these procedures is as follows:

A sample of dorsal muscle tissue is acquired from all fish. Fish captured alive are anesthetized, biopsied, then released alive. Tissue plugs are collected from anaesthetized fish using single-use tissue biopsy sampler. The tissue sample is placed into sterile, individually-labeled vials, kept on ice, and frozen at the end of the field day. Fish that succumb to capture have fillet tissue removed, samples placed into labelled bag, kept on ice, and frozen at the end of the field day. All fish collected (whether biopsied or filleted) also have a small piece of tissue (either a single biopsy plug or fillet) collected for stable carbon and nitrogen isotope analysis (SIA).

For ageing structure collection methods, see annual FAMHFP reports (recent period; Golder & Gazey, 2018, 2019, and 2020) and Azimuth reports (early period; Azimuth 2011 and 2014).

Certified Laboratories

The certified laboratories contracted to analyze field samples for baseline mercury-related data are named in **Table 1-1**.

Shipments of samples to the analytical laboratories were accompanied by chain-of-custody (CoC) forms detailing sample identification, reporting requirements, and sample handling information. CoC forms not only inform the laboratory of sample details, they also help ensure that sample handling instructions are followed, sample hold-times are met, and that all samples are accounted for.

Mercury and Moisture (Chemistry) Analysis

All tissue analyses for mercury and moisture in the MMP dataset have been conducted by ALS Environmental (ALS), a CALA-accredited lab in Burnaby, BC. The BC environmental laboratory QA/QC procedures are detailed in Austin (2020).

Carbon and Nitrogen Stable Isotopes Analysis (SIA)

All SIA analyses were completed by the University of New Brunswick's (UNB) Stable Isotopes in Nature lab (SINLAB). SINLAB was established in 1999 as part of UNB's Canadian Rivers Institute under the direction of Dr. Rick Cunjak. They specialize in SIA in environmental samples to support academic, private and government researchers.

Age Analysis

Golder has conducted all the fish ageing analysis for the FAHFMP data sourced for the MMP. QA/QC procedures for all MMP baseline data sources include independently assessing ageing structures by two or more experienced individuals.

To continually increase the accuracy of ages assigned using aging structures, specifically fin rays, FAMHFP ageing methods are modified relative to previous study years based on lessons learned and literature reviews. Aging methods, including changes, are described in the annual FAHFMP Mon-2, Task 2a reports, the most recent of which is particularly thorough (Golder and Gazey 2020).

Through years of experience with Site C fish age data, Golder has gathered evidence that not all age data are created equal, with some ageing structures and methods of ageing producing higher quality (more accurate) data than others. Age data methods have been modified and updated over the baseline years in an effort to produce high quality data.

Generalizing across species, the hierarchy of the quality of aging methods is: encounter history & years at-large > otoliths > fin rays > scales (Golder and Gazey, 2020). However, rather than assign a qualitative value to the data (i.e., good, moderate, poor), the MMP Database instead provides the method that was used for ageing, thereby leaving the decision of whether or not to include the ages in an analysis up to the user (i.e., does the user consider fin rays, as an example, to be accurate enough for their purposes).

To-date, the MMP has utilized age and weight data as supporting variables, not primary variables like length, in the assessment of size-mercury relationships in fish. For this reason, all age data have been deemed acceptable for the MMP assessments and included in analysis, recognizing that there is known bias in subsets of the data. To ensure full transparency for future MMP data assessments involving fish age, aging data and aging methods have been carefully documented in the MMP database.

3.3 Quality Control

This section provides the results of QC samples for the field and lab, where appropriate, followed by an overall statement of data quality for each of the four main data types.

3.3.1 Fish ID and Morphometrics

Fish identification and morphometric data for the Site C MMP are comprised of species, maturity, body length, and body weight measurements.

Field

As noted in **Section 3.2**, in the recent baseline period (FAHMFP sampling), fish identification and morphometric data were recorded directly into an electronic FAHMFP database in the field. This electronic system included instantaneous QC checks of length and weight by calculating condition (K) and comparing the results for each fish to expected norms.

Lab

There is no laboratory QC component for these data.

Overall

These data meet the data quality needs of the MMP.

3.3.2 Tissue Chemistry

Field

Field Duplicates (FD)

FDs were collected as a QC measure to provide insights into (a) within-fish variability in tissue mercury and (b) the precision of laboratory analyses. FD samples are collected from the same fish and treated independently through the sampling and analysis process; they are submitted "blind" to the lab. Data quality objectives (DQOs) are based on relative percent difference (RPD) between the original and duplicate samples (see calculation below) or the absolute difference (DIFFx) between the original and duplicate samples; the specific DQO values are set at 1.5x higher than those used by ALS for laboratory duplicates (i.e., RPD = 45% and DIFFx = 3x the method detection limit [MDL]). This approach is consistent with the Canadian Council of Ministers of the Environment (CCME) (2016) approach for field QC samples, which acknowledges that DQOs should be set to recognize the higher variability expected when a sample is processed through the whole laboratory analysis process (i.e., not just post-homogenization process as is done in laboratory duplicates).

RPDs are calculated as follows:

$$RPD = \frac{(A - B)}{(\frac{A + B}{2})} x\ 100$$

where: A = original sample result; B = duplicate sample result; both samples need to be measured above the MDL. The calculated RPD is compared to the DQO.

FD samples pass if either the RPD or DIFFx meets their respective DQO.

Field QC results across sampling years are summarized in **Table 3-1**. A total of 50 field duplicate samples were analyzed in the baseline dataset. Field duplicates were explicitly included in the 2010, 2011 and 2020 monitoring events, but were not collected in 2017 through 2019. However, there were some inadvertent FDs in 2017 that stem from a laboratory error[4]. Six (12%) of the 50 FD samples across the baseline dataset did not meet the FD DQO (**Table 3-2**). These results suggest that while the majority of samples met the precision-related DQOs, the absolute results of individual sample results should be interpreted with some caution due to the variability in precision.

Lab

ALS' laboratory QC results are summarized in **Table 3-3**; details on each QC sample type and their respective results are described below.

Laboratory Duplicates (LD)

LD samples provide insights into the precision of laboratory analyses. Duplicate aliquots are taken from the samples and run through part (aliquots taken post digestion) or all (aliquots taken from the sample tissue) the laboratory analytical process. DQOs are based on RPD between the original and duplicate samples or the DIFFx between the original and duplicate samples. The mercury laboratory RPD DQO for precision is 30% and the laboratory DIFFx DQO for mercury is 2 x MDL.

Twenty-six of 27 laboratory duplicates met ALS' DQOs for LC samples (**Table 3-3**). Details regarding the only sample not meeting the DQO are provided in **Table 3-4**. These results show that ALS' analytical process was working as intended, providing good precision in the mercury analyses.

Laboratory Control Samples (LCS)

LC samples provide insights into whether the laboratory systems are working as intended. They are comprised of a mixture of analyte-free water to which known amounts of the method analytes are added. They are essentially an internal version of a certified reference material. The DQO for LCSs for tissue mercury are 30% (i.e., recovery of 70 to 130%).

[4] The laboratory discarded a number of the original tissue samples submitted for mercury analysis. Samples originally destined for stable isotope analysis (SIA) were redirected to ALS for mercury analysis. As some of the original samples were already analyzed, this led to multiple results from the same fish, or an "inadvertent" field duplicate.

Only two of 69 LCS samples failed to meet the DQOs (**Table 3-3**). Details regarding the two samples that failed to meet DQOs are provided in **Table 3-5**. Overall, these results indicate good accuracy and precision in ALS' mercury analyses.

Matrix Blanks (MB)

MB samples are analyzed to assess background interference or contamination that exists in the analytical system that could lead to elevated concentrations or false positive data. These samples are comprised of analyte-free water. The DQO for method blanks is that the results are <MDL (i.e., no detectable concentrations found).

None of the 116 MB samples analyzed over the years contained detectable amounts of mercury (**Table 3-3**), suggesting that the sensitivity of the analytical instruments were set appropriately.

Certified Reference Materials or Reference Materials (CRM or RM)

CRMs (aka RMs) are similar to LCS samples, but the dried tissue media are purchased from external suppliers. CRMs have a known concentration against which the lab must achieve a precision of within 10% either side of the CRM.

All 117 CRM samples met the DQOs (**Table 3-3**). These results confirm the accuracy and precision of ALS' tissue mercury analyses.

Overall

A total of 382 field and lab QC checks related to tissue mercury were conducted across sampling years. Only 9 (2%) of those checks failed to meet their respective DQOs, 6 of which were field duplicates. Four of those 6 cases were in 2011. Given the lab duplicates results (96% met DQOs), the field duplicate results suggest possible incomplete homogenization of some tissues in 2011, warranting some caution in putting too much emphasis on the results of individual fish that year. Overall, the QC results verify that the accuracy and precision of tissue mercury analyses meet the data quality needs of the MMP.

3.3.3 Tissue Stable Isotopes

Field

Field Duplicates (FD)

FD samples are collected from the same fish and treated independently through the sampling and analysis process; they are submitted "blind" to the lab. DQOs are based on relative percent difference (RPD) between the original and duplicate samples (see **Section 3.3.2** for calculation).

FDs provide insights into (a) within-fish variability in tissue and (b) the precision of laboratory analyses. Due to the general high precision and accuracy of SIA, FDs were not included as a QC measure prior to 2020.

Generally, FD DQO values are set at 1.5x higher than those used for laboratory (see **Section 3.3.2** for further discussion). However, SINLAB does not provide laboratory duplicate DQOs (see next sub-section for further discussion), so FD DQOs were not developed in advance for SIA. Rather, FD RPD results for SIA were evaluated based on their magnitude alone, with consideration as to how they provide insights into laboratory precision. RPDs for the FD samples are provided in **Table 3-6**. The RPD results for most samples were less than 5%, with many (24 of 30; 80%) of the results at or below 2%. The highest RPD was still only 9%. These results verify high precision for FDs.

Lab

SINLAB provides an Interpretation Guide (**Appendix A1**) with all laboratory data results, which includes discussion of QC standards and is updated occasionally to reflect updated acceptability values for standards. The types of QC samples that SINLAB uses to ensure their laboratory processes are working properly are described below, along with their results.

Laboratory Duplicates (LD)

LDs provide insights into the precision of laboratory analyses. Duplicate aliquots are taken from the samples and run through part (aliquots taken post digestion) or all (aliquots taken from the sample tissue) the laboratory analytical process. DQOs are based on RPD between the original and duplicate samples. LDs are identified in SINLAB analytical results by an "R" appended to the end of the sample ID. SINLAB does not have a set acceptability range for LDs, based on the following rationale:

> *"Different tissues have different matrices and things such as lipid content, how finely ground, residual shells, to name a few, can make the replicates more variable. As such, a "set" acceptable range* [for LDs] *does not exist. Typically, a duplicate sample with a difference of greater than 0.5 per mil is flagged, and when possible, run again."* (Anne McGeachy, pers. comm. 2021).

To our knowledge, none of the laboratory duplicates were flagged, or re-run by the lab. Calculated RPDs for LDs (**Table 3-7**) were all at or below 4%.

Secondary Standards and Check Standards (Standards)

Secondary standards[5] are SINLAB's internal working standards (i.e., created by SINLAB). They are calibrated against and traceable to International Atomic Energy Agency (IAEA) primary standards (CH6, CH7, N1, and N2) and are subjected to round robin testing for verification as a part of SINLAB's QA/QC protocol. Check standards are commercially available standards and are analyzed in each SINLAB run (batch of samples).

Results for secondary and check standards (**Table 3-7**) were generally within the acceptable range. The only exception was in the 2020 results for Redside Shiner (lab report 20TRI 001-011; submitted by Triton), where the mean results for USGS61 (secondary standard), CH7 (check standard) and nicotinamide (check standard) were outside the acceptable range. The lab provided the following explanation:

> *"If any of our standards, on a given day, have a deviation of greater than 0.2* [per mil] *we will take extra time to review traces and see if the data are acceptable. The Interpretation Guide is just a "guide" to give you an idea of the results we see in the lab. I am not sure when this guide was last updated, given our restricted access to campus during COVID. In 2020, close to 300 USGS61 samples were run: the average value for the year was -34.96 and the standard deviation of 0.12. Although your samples land at the edge of this range, we felt the data were acceptable.*
>
> *There are typically 13 points that make up the regression line used to bring the observed values to the international scale. If one standard is slightly off, it does not usually change the regression line by much. In the case of the Triton data (run in October 2020) the equipment was stable throughout the run and the traces looked good. Only the standards around -30 were slightly off from the expected values and none of your samples were in this range. Again, we felt this was not a difference worth holding up the data and running it a second time. Following your inquiry, I was curious as to what the results for your samples would have looked like if the values in the -30 range were a little tighter. The difference in the slope and intercept are so slight that the resulting delta values for the Triton samples change by less than 0.2 per mil…"* (Anne McGeachy, pers. comm. 2021)

[5] SINLABs secondary standards are analogous to ALS' laboratory control samples.

After our request for more information, SINLAB offered to re-run the samples, but Azimuth and Triton agreed with SINLAB's interpretation that the data were acceptable as-is, and there was no need to re-run the analysis.

Overall

SIA data are used in the MMP to provide ecological context to the tissue mercury results. SIA data can be used to provide high-level insights into why tissue mercury concentrations might be different among species, locations or time periods, or to help understand the results for individual fish (e.g., those with different feeding strategies than their cohorts).

Overall, the field and lab QC checks provide confirmation that SINLAB's laboratory processes are resulting in high quality SIA data that meets the needs of the Site C MMP.

3.3.4 Fish Age

Field

For information on the age data field QC procedure, see each program's reports (see **Table 1-1** for list of reports).

Lab

For information on the age data lab QC procedure, see each program's reports (see **Table 1-1** for list of reports).

Overall

The relative variability of fish age data are typically much higher than either fish length or weight. Golder has introduced methods meant to improve the accuracy and precision of estimates, but not to a level where the results would be similar to fish length from a measurement variability perspective. As discussed in **Section 3.2**, the magnitude of variability, and hence confidence in the aging results, depends on the aging structures used.

Age is used in the MMP to help inform fish growth rates, which can affect tissue mercury concentrations (e.g., faster growing fish tend to "dilute" tissue mercury concentrations relative to slower growing fish). While fish mercury programs are usually limited to the ages of fish sampled in the program, the MMP has the added benefit of the full FAHMFP dataset to make inferences about different growth rates among locations, populations or time periods. In addition, both the MMP and FAHMFP databases include a field identifying the aging structure used, providing a means of understanding the degree of confidence associated with each age estimate.

Overall, the aging data meets the needs of the MMP.

Table 3-1. Summary of field quality control results for the Site C baseline fish mercury dataset, 2010 through 2020.

Event(s): 2010 to 2020			
	Pass	Fail	ND
Field Duplicate			
2010	7	1	0
2011	16	4	0
2017	8	1	0
2018	0	0	0
2019	0	0	0
2020	13	0	0
Totals	44	6	0

Table 3-2. Details for field duplicate samples not meeting data quality objectives.

Event(s): 2010 to 2020

Year	Group	Analyte	Units	DL	Samp	Dup	RPD	DIFFx	FD.QC
2011	20	Mercury (Hg)-Total	mg/kg wwt	0.001	0.0188	0.0437	79.7	24.9	Fail
2011	4	Mercury (Hg)-Total	mg/kg wwt	0.001	0.0282	0.0720	87.4	43.8	Fail
2011	18	Mercury (Hg)-Total	mg/kg wwt	0.001	0.0457	0.0063	151.5	39.4	Fail
2011	17	Mercury (Hg)-Total	mg/kg wwt	0.001	0.0331	0.1040	103.4	70.9	Fail
2017	22	Mercury (Hg)-Total	mg/kg wwt	0.001	0.0210	0.0550	89.5	34.0	Fail
2010	8	Mercury (Hg)-Total	mg/kg	0.005	0.3390	0.1650	69.0	34.8	Fail

Table 3-3. Summary of laboratory quality control results for the Site C baseline fish mercury dataset, 2010 through 2020.

Event(s): 2010 to 2020	Pass	Fail	ND	Event(s): 2010 to 2020	Pass	Fail	ND
Lab Duplicate				*Lab Control Sample*			
2010	4	0	0	2010	0	0	0
2011	11	1	0	2011	0	0	0
2017	4	0	0	2017	26	0	0
2018	4	0	0	2018	19	2	0
2019	2	0	0	2019	15	0	0
2020	2	0	0	2020	9	0	0
Totals	27	1	0	Totals	69	2	0
Matrix Blank				*Certified Reference Material*			
2010	22	0	0	2010	29	0	0
2011	23	0	0	2011	17	0	0
2017	26	0	0	2017	26	0	0
2018	21	0	0	2018	21	0	0
2019	15	0	0	2019	15	0	0
2020	9	0	0	2020	9	0	0
Totals	116	0	0	Totals	117	0	0

Table 3-4. Details for laboratory duplicates not meeting data quality objectives.

Event(s): 2010 to 2020						
Year	**Reference**	**QC_Lot**	**Analyte**	**RPD**	**DIFFx**	**LD.QC**
2011	L1085007-137	NA	Mercury (Hg)-Total	66.7	58.5	Fail

Table 3-5. Details for laboratory control samples not meeting data quality objectives.

Event(s): 2010 to 2020						
Year	**ALS_QC_ID**	**QC_Lot**	**Analyte**	**Percent**	**Limit**	**LCS.QC**
2018	WG2970096-3	1026173	Mercury (Hg)-Total	147.7	70-130	Fail
2018	WG2970099-3	1026174	Mercury (Hg)-Total	163.4	70-130	Fail

Table 3-6. Stable Isotope field duplicate sample quality control results.

Site C 2020 SIA Field Dupicates

Parameter	Fish ID 1294				Fish ID 1295				TL-LKTR-10			Fish ID 1296			
	dw or ww	Original	Duplicate	RPD (%)	dw or ww	Original	Duplicate	RPD (%)	Original	Duplicate	RPD (%)	dw or ww	Original	Duplicate	RPD (%)
d13C		-29.44	-30.74	-4		-31.0518	-30.1223	3					-29.6283	-29.5165	0
d15N	ww	7.39568	7.260208	2	ww	7.605076	7.455435	2	4.11	4.02	2	ww	9.32347	9.469147	-2

Parameter	Fish ID 1297				Fish ID 1298				TL-LKTR-10			Fish ID 1299			
	dw or ww	Original	Duplicate	RPD (%)	dw or ww	Original	Duplicate	RPD (%)	Original	Duplicate	RPD (%)	dw or ww	Original	Duplicate	RPD (%)
d13C		-27.5416	-27.7515	-1		-29.0314	-28.578	2					-29.3957	-29.4986	0
d15N	ww	7.969764	7.907331	1	ww	7.328587	7.34147	0	4.11	4.02	2	ww	8.424633	8.349317	1

Parameter	Fish ID 1300				Fish ID 1301				TL-LKTR-10			Fish ID 1302			
	dw or ww	Original	Duplicate	RPD (%)	dw or ww	Original	Duplicate	RPD (%)	Original	Duplicate	RPD (%)	dw or ww	Original	Duplicate	RPD (%)
d13C		-31.5923	-29.9401	5		-28.9483	-28.8879	0					-30.0124	-29.8609	1
d15N	ww	8.556436	7.789402	9	ww	9.210496	8.787339	5	4.11	4.02	2	ww	9.711942	9.70005	0

Parameter	Fish ID 1303				Fish ID 1304				TL-LKTR-10			Fish ID 1305			
	dw or ww	Original	Duplicate	RPD (%)	dw or ww	Original	Duplicate	RPD (%)	Original	Duplicate	RPD (%)	dw or ww	Original	Duplicate	RPD (%)
d13C		-26.2191	-26.2419	0		-26.133	-26.233	0					-25.9479	-25.8261	0
d15N	ww	11.2916	11.29556	0	ww	10.96457	10.89321	1	4.11	4.02	2	ww	11.05673	11.10925	0

Parameter	Fish ID 1306			
	dw or ww	Original	Duplicate	RPD (%)
d13C		-25.5133	-25.3789	1
d15N	ww	11.08554	11.4361	-3

Note: samples from 2020 only

Table 3-7. Stable Isotope laboratory quality control results, 2010 to 2020.

Lab	Year Caught	Lab ID	# of Samples	Analytes	Laboratory Duplicates		Check Standards (N2, CH7, Nicotinamide	Secondary Standards (USGS61, LBS, MLS)
					# of duplicate samples	RPD Range (%)		
SINLAB	2010	SINLAB 2010 Fish and Benthos RBA 001-126-1	126	C and N SIA	6	RPD = 0 - 3% (+/-)	Met Lab DQO	Met Lab DQO
SINLAB	2011	SINLAB 2011 Fish RBA 222-390	169	C and N SIA	8	RPD = 0 - 2% (+/-)	Met Lab DQO	Met Lab DQO
SINLAB	2017	18 Golder 001-452	58	C and N SIA	5	RPD = 0 - 3% (+/-)	Met Lab DQO	Met Lab DQO
SINLAB	2018	18 Golder 001-452	86	C and N SIA	20	RPD = 0 - 2% (+/-)	Met Lab DQO	Met Lab DQO
SINLAB	2019	19 GOLD 001 - 189	58	C and N SIA	14	RPD = 0 - 4% (+/-)	Met Lab DQO	Met Lab DQO
SINLAB	2020	20 TRI 001-011	11	C and N SIA	1	RPD = 0 -1% (+/-)	CH7 and Nicotinamide mean results outside the acceptable range.	USGS61 mean result outside the acceptable range.
SINLAB	2020	21Gold 001-151	152	C and N SIA	10	RPD = 0 - 2% (+/-)	Met Lab DQO	Met Lab DQO

Notes:
RPD = Relative Percent Difference
DQO = Data Quality Objective

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Stable Isotopes in Nature Lab (SINLAB). Undated. Interpretation Guide.

APPENDIX A1:
SINLAB INTERPRETATION GUIDE

SINLAB

Stable Isotopes in Nature Laboratory

UNB

UNIVERSITY OF NEW BRUNSWICK

SINLAB INTERPRETATION GUIDE

For further information please visit our website:

https://www.isotopeecology.com/

Instrumentation

Continuous Flow-Isotope Ratio Mass Spectrometry (CF-IRMS) is used for stable isotope analysis of $\delta^{13}C$, $\delta^{15}N$ and $\delta^{2}H$. The SINLAB currently operates the following mass spectrometer/conflo combinations:

- $Delta^{Plus}$ XP – Conflo III
- Delta V Plus – Conflo IV

(All manufactured by Thermo Finnigan; Bremen, Germany)

Carbon & Nitrogen Methodology

Dried, ground and homogeneous samples are weighed into tin capsules and analyzed for $\delta^{13}C$ and $\delta^{15}N$ by an Elemental Analyzer (EA) coupled to one of the IRMS/Conflo combinations listed above. Samples are introduced into the EA by an autosampler where complete combustion occurs in the presence of oxygen to generate CO_2 and nitrogen oxide (N_xO_x) gases. Combustion occurs in a quartz tube filled with chromium oxide and silvered cobaltous oxide. A second quartz tube filled with fine copper wire is used for the reduction of nitrogen oxides (N_xO_x) to N_2 gas. Gas Chromatography (GC) is used to separate CO2 and N2 peaks with helium as a carrier gas. A water trap of magnesium perchlorate & silica chips is located before the GC column to remove water.

The SINLAB currently utilizes two elemental analyzers for $\delta^{13}C$ and $\delta^{15}N$ analyses.

Elemental Analyzer	Autosampler	Combustion Temperature	Reduction Temperature	GC Length	GC Temperature
CE NC2500 (Carlo Erba; Milan, Italy)	PN150	1050ºC	650ºC	4m	50ºC
Costech 4010 (Costech; California, USA)	Zero Blank	1000ºC	650ºC	3m	40ºC

Stable isotope measurements are reported as isotope delta δ in parts per thousand (‰) relative to the international standard: Vienna Pee Dee Belemnite (VPDB) for carbon, and atmospheric air (AIR) for nitrogen. Isotope values are normalized using secondary standards: USGS61, BLS, and MLS for animal tissues; and CMS, SPS, SPL and EPS for sediments and plant material. All of these standards were calibrated against IAEA standards. See below for standard descriptions.

Hydrogen Methodology

Samples are weighed into silver capsules and loaded into a Costech Zeroblank autosampler. Samples are converted to hydrogen (H_2) gas by pyrolysis using a Thermo-Finnigan High Temperature Conversion Elemental Analyzer (TC/EA). Pyrolysis occurs in a ceramic tube lined with a glassy carbon reactor and filled with glassy carbon chips at a temperature of 1400ºC. Helium is used as the carrier gas and a 1.5m GC column held at 100ºC separates H_2 sample gas and other interfering gases produced

Stable-hydrogen isotope (δ^2H) measurements for keratin tissues are normalized to the international standard VSMOW (Vienna Standard Mean Ocean Water). We determine the non-exchangeable δ^2H of samples using the comparative equilibration approach (Wassenaar and Hobson 2003) with two secondary keratin standards (EC1 and EC2). These standards were previously calibrated to account for the H exchangeability between the H atoms of ambient water vapor and tissues (Wassenaar and Hobson 2000, 2003). This technique requires that samples along with these standards of known H isotope ratios are left to exchange with local atmospheric hydrogen for 72 hours prior to analysis. See below for standard descriptions.

Standards

Secondary Standards **–** These are SINLAB working standards used to bring data to the international scale. They are calibrated against and traceable to IAEA primary standards (CH6, CH7, N1, and N2). These standards are subjected to round robin testing for verification as a part of our QA/QC protocol. Values below- used as check standards within a run

USGS61 = commercially available pure compound (caffeine)
$\delta^2H_{(VSMOW)}$ = 96.9 ‰ +/- 0.9
$\delta^{13}C_{(VPDB)}$ = –35.05‰ +/- 0.04
$\delta^{15}N_{(AIR)}$ = -2.87 ‰ +/- 0.04

BLS = Bovine Liver Standard developed by SINLAB
$\delta^{13}C_{(VPDB)}$ = –18.76 ‰ +/- 0.14
$\delta^{15}N_{(AIR)}$ = 7.17 ‰ +/- 0.17

MLS = Muskellunge muscle standard developed by SINLAB
$\delta^{13}C_{(VPDB)}$ = –22.30 ‰ +/- 0.18
$\delta^{15}N_{(AIR)}$ = 14.00 ‰ +/- 0.11

CMS = Corn Meal Standard developed by SINLAB
$\delta^{13}C_{(VPDB)}$ = –13.25 ‰ +/- 0.11
$\delta^{15}N_{(AIR)}$ = 4.42 ‰ +/- 0.12

EPS = Ephedra Plant Standard developed by SINLAB
$\delta^{13}C_{(VPDB)}$ = -30.96 ‰ +/- 0.09
$\delta^{15}N_{(AIR)}$ = 0.35 ‰ +/- 0.12

SPL = Spirulina standard developed by SINLAB
$\delta^{13}C_{(VPDB)}$ = -24.97 ‰ +/- 0.12
$\delta^{15}N_{(AIR)}$ = 12.94 ‰ +/- 0.09

SPS = Seaweed plant standard developed by SINLAB
$\delta^{13}C_{(VPDB)}$ = -28.40 ‰ +/- 0.10
$\delta^{15}N_{(AIR)}$ = 21.10 ‰ +/- 0.10

EC1 = caribou hoof keratin standard- Environment Canada, Saskatoon, Canada
$\delta^{2}H_{(VSMOW)}$ = –197.00 ‰ +/- 1.8
$\delta^{18}O_{(VSMOW)}$ = 2.40 ‰ +/- 0.6

EC2 = kudu horn keratin standard - Environment Canada, Saskatoon, Canada
$\delta^{2}H_{(VSMOW)}$ = –54.10 ‰ +/- 0.6
$\delta^{18}O_{(VSMOW)}$ = 21.20 ‰ +/- 0.6

KERATIN STANDARD = Keratin powder purchased from Spectrum. B/N SJ1400
$\delta^{2}H_{(VSMOW)}$ = –121.60 ‰ +/- 2.0
$\delta^{18}O_{(VSMOW)}$ = 10.60 ‰ +/- 0.6

THS = Topi horn keratin standard developed by SINLAB, $\delta^{18}O$ unverified
$\delta^{2}H_{(VSMOW)}$ = –40.60 ‰ +/- 2.0
$\delta^{18}O_{(VSMOW)}$ = 20.28 ‰ +/- 0.6 (unverified)

<u>Check Standards</u> – These standards are analyzed in each analytical run as part of SINLAB's QA/QC protocol to assess the analytical accuracy.

ACETANILIDE = commercially available pure compound
Batch 2880 (Feb 2010 – Apr 2011) - $\delta^{13}C_{(VPDB)}$ = –27.87 ‰ +/- 0.12
$\delta^{15}N_{(AIR)}$ = –2.05 ‰ +/- 0.13

Batch 149699 (Apr 2011-Aug 2012) - $\delta^{13}C_{(VPDB)}$ = –31.59 ‰ +/- 0.12
$\delta^{15}N_{(AIR)}$ = –2.32 ‰ +/- 0.23

Costech (Aug 2012 – July 2020) - $\delta^{13}C_{(VPDB)}$ = –33.81 ‰ +/- 0.14
$\delta^{15}N_{(AIR)}$ = –0.92 ‰ +/- 0.23

Batch 317490 (July 2020 – Present) - $\delta_{13}C_{(VPDB)}$ = –26.54 ‰ +/- 0.06
$\delta_{15}N_{(AIR)}$ = –5.09 ‰ +/- 0.37

NICOTINAMIDE = commercially available pure compound
Batch 237264 (Mar 2018 – Present) - $\delta^{13}C_{(VPDB)}$ = –32.50 ‰ +/-0.1
$\delta^{15}N_{(AIR)}$ = –2.00 ‰ +/- 0.1

BENZOIC ACID = commercially available pure compound, $\delta^{18}O$ unverified
HEKAtech (Feb 2010 – Present) $\delta^{2}H_{(VSMOW)}$ = -76‰ +/- 2.0 (unverified)
$\delta^{18}O_{(VSMOW)}$ = 25.7‰ +/- 0.6 (unverified)

N2 = ammonium sulfate – Primary standard certified by IAEA.
$\delta^{15}N_{(AIR)}$ = 20.3 ‰ +/- 0.14

CH7 = polyethylene foil – Primary standard certified by IAEA.
$\delta^{13}C_{(VPDB)}$ = –32.2 ‰ +/- 0.1
$\delta^{2}H_{(VSMOW)}$ = 100.3 ‰ +/- 2.0

PROTEIN = casein – Certified by Elemental Microanalysis Ltd.
$\delta^{13}C_{(VPDB)}$ = –26.98 ‰ +/- 0.13
$\delta^{15}N_{(AIR)}$ = 5.94 ‰ +/- 0.08

HIGH ORGANIC SEDIMENT **=** Certified by Elemental Microanalysis Ltd.
$\delta^{13}C_{(VPDB)}$ = –26.27 ‰ +/- 0.15
$\delta^{15}N_{(AIR)}$ = 4.42 ‰ +/- 0.2

SORGHUM FLOUR **=** Certified by Elemental Microanalysis Ltd.
$\delta^{13}C_{(VPDB)}$ = –13.68 ‰ +/- 0.19
$\delta^{15}N_{(AIR)}$ = 1.58 ‰ +/- 0.15

PEACH LEAF = NIST 1547 peach leaves - not certified
$\delta^{13}C_{(VPDB)}$ = –26.17 ‰ +/- 0.08
$\delta^{15}N_{(AIR)}$ = 1.94 ‰ +/- 0.12

ATS = Atlantic salmon standard developed by SINLAB
$\delta^{2}H_{(VSMOW)}$ = –113.8 ‰ +/- 2.0
$\delta^{18}O_{(VSMOW)}$ = 17.50 ‰ +/- 0.6 (unverified)

LAT = Lake trout standard developed by SINLAB, $\delta^{18}O$ unverified
$\delta^{2}H_{(VSMOW)}$ = –165.60 ‰ +/- 2.0
$\delta^{18}O_{(VSMOW)}$ = 4.70 ‰ +/- 0.6 (unverified)

Column Headings

CLIENT ID = ID code assigned to sample by the client.

SINLAB ID = ID code assigned to the client's samples; starting with the year, each client is given a two or three letter identifier and samples numbered sequentially; ex, 15ABC 001.

Date = date sample was analyzed.

Position = position in the analytical run for that particular day; samples are weighed into 96-well ELISA trays, a typical animal tissue run will consist of approximately 73 samples, 22 standards, and 1 blank.

Weight = weight of the tissue analyzed; animal tissues are weighed at 1.000 ± 0.100 milligrams and plant tissues are weighed at 3.100 ± 0.100 milligrams for C and N isotope analysis. Keratin tissues are weighed at 0.200 ± 0.020mg for H isotope analysis.

CO2 ampl = the relative amount of CO_2 gas measured by the mass spectrometer in volts (V), a function of the weight of tissue used and the total amount of carbon (%C) it contains.

N2 ampl = the relative amount of N_2 gas measured by the mass spectrometer in volts (V), a function of the weight of tissue used and the total amount of nitrogen (%N) it contains.

H2 ampl = the relative amount of H_2 gas measured by the mass spectrometer in volts (V), a function of the weight of tissue used and the total amount of hydrogen (%H) it contains.

δ^{13}C = the relative isotope ratio difference between the sample and the international standard (VPDB) according to the formula:

$\delta^{13}C = [(R_{sample}/R_{standard})-1]*1000$ where R is the isotopic ratio of the heavy to light ($^{13}C/^{12}C$)

δ^{15}N = the relative isotope ratio difference between the sample and the international standard (AIR) according to the formula:

$\delta^{15}N = [(R_{sample}/R_{standard})-1]*1000$ where R is the isotopic ratio of the heavy to light ($^{15}N/^{14}N$)

δ^{2}H = the relative isotope ratio difference between the sample and the international standard (VSMOW) according to the formula:

$\delta^{2}H = [(R_{sample}/R_{standard})-1]*1000$ where R is the isotopic ratio of the heavy to light ($^{2}H/^{1}H$)

%C = percent of carbon in the sample by weight; calculated with NICOTINIMIDE for animals and ACETANILIDE for plants

%N = percent of nitrogen in the sample by weight; calculated with NICOTINIMIDE for animals and ACETANILIDE for plants

C/N = ratio of carbon to nitrogen in the sample; simple division of %C by %N.

%H= percent of hydrogen in the sample by weight; calculated with BENZOIC ACID

%O= percent of oxygen in the sample by weight; calculated with BENZOIC ACID

Comment Codes

NR = no repeat; not enough sample tissue to allow another analysis

No drop = equipment malfunction wherein autosampler fails to turn; often leads to a “double-up” with the following sample

Double-up = two samples drop together

LR = lipid-rich. Samples may contain high lipid content according to the C/N ratio (Logan et al. 2008)

Whole bug = individual analyzed without grinding

1/4, 1/8, 1/16, 1/32 = indicates the size of a filter paper sample that was cut into a “pie-slice” for analysis

Scraped from paper = filtered material was scraped from the top of filter rather than analyzed as a “pie slice”

LE = Lipid extracted, a common technique to remove lipids from tissues such as liver, eggs, and muscle of some fishes. Lipids have different δ^{13}C than proteins and carbohydrates.

AT = Acid treated, a common technique to remove carbonates (that have different δ^{13}C values than organic tissues) from organisms such as crustaceans.

Colours

Gray shading = repeated sample as part of regular QA/QC routine (four of every 73 samples)
Red text = highlights low amplitude peaks or a poor repeat

Please address any questions about this document to:

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APPENDIX B:
CHARACTERIZATION OF LENGTH-MERCURY RELATIONSHIPS

Table of Contents

1 INTRODUCTION

The Site C Methylmercury Monitoring Plan (MMP) is designed based on the assumption that catch is similar across the fish size distribution for a given species at each location/year combination. However, there are often discrepancies in size distributions that would affect the analysis if they were based on mean mercury concentrations for each location/event combination. Modelling length-mercury relationships facilitates removing potential bias related to catching larger or smaller fish relative to other locations/year sampled. While length-mercury relationships are characterized across the full size range of fish sampled (within a given species), numerical presentation of results is simplified by focusing on one or more key sizes (sometimes referred to as "standardized" sizes[1]).

As described in Section 2 of the main report, the baseline fish mercury dataset is comprised of fish mercury results for a number of species caught in various locations over a number of sampling events from 2010 to 2020. The following sections present details on the methods and results of statistical analyses conducted to characterize baseline fish mercury concentrations.

1.1 Length-Mercury Relationship Modelling

Three main model types were used to determine patterns in the data that needed to be taken into consideration for characterizing baseline conditions. There were:

1. **Temporal trends** – this focused on looking at data for specific locations over time to determine if tissue mercury concentrations were different across sampling years. The presence or absence of temporal trends will inform options for treating baseline data (e.g., appropriateness of pooling across all or certain years).
2. **Spatial trends** – this focused on looking at data for a specific time period (i.e., during which no temporal patterns were identified) to determine if tissue mercury

[1] Historically, fish mercury data were often simplified to means per species-location-year of interest. The major limitation of that approach is that tissue mercury concentrations are often positively correlated to fish size, so random differences in the size of fish caught can impart a bias in the mean. This potential bias was overcome by using the length-mercury relationship to estimate mercury concentrations for a specific sized fish. The "standardized" size (i.e., a single size per species) was used to allow comparisons both within and among studies. The main limitation of using a single size to represent tissue concentrations for a species is that information about other size classes is lost. Consequently, we try to use more than one size class (up to four or five) to provide a more complete understanding of fish mercury concentrations.

concentrations differed among sampling locations. The presence or absence of spatial patterns will inform options for pooling across locations.

3. **Baseline sampling periods** – this focused on testing for differences between the early and recent baseline sampling periods to characterize past and current conditions in terms of fish mercury concentrations, with the latter being used to inform fish consumption guidance.

Note that due to data limitations for Dinosaur Reservoir there was insufficient data to include that location in either the temporal or spatial trend assessments. Consequently, data from that location were also excluded from the baseline period assessment.

The general process for the statistical analysis for each of the main model types followed the following steps:

- **Variables** – the following primary variables were included in the various model fits:
  - *Mercury* (Hg; FishHg in model fits) – measured total mercury concentrations in fish muscle tissue (mg/kg dw); assumed to all be present as methylmercury (Bloom 1992).
  - *Length* – fish length (generally fork length) was used to help account for the known influence of fish size on tissue mercury concentrations. Length was "centered" (LC) on the standardized size for each species, which allows direct interpretation of the regression coefficients from the output. Note that the quadratic model fits also include length squared (LC2; LC2 in model fits).
  - *Site* (see above) - this was included to account for variability related to site-specific factors.
  - *Year* – based on the sampling year (Year.Caught in model fits).
  - *Period* – refers to the early (2010/2011) or recent (2017-2020) baseline time periods.
- **Transformations** – Length-mercury data were plotted using various transformations to determine which was most suitable.
- **Model Fitting** – A set of nine models were used to fit the data used to assess temporal (**Table 1-1**), spatial (**Table 1-2**) or period (**Table 1-3**) trends in the dataset; these models ranged from simple year/location/period-specific intercepts through linear forms (with and without length-year/location/period interaction terms) to quadratic polynomials (with/without various interaction terms). From a size-mercury relationship characterization perspective, this array of models covers the spectrum from no relationship with size (fit0) through general size-dependent relationships to more complex models capable of characterizing more site-specific relationships. In our

experience, no single model form adequately characterizes fish mercury relationships across all species and conditions. Each of the model forms included have been used in to describe fish length-mercury relationships. While the linear fits are more commonly used, the quadratic models were included as they can better characterize size-mercury relationships in some situations. For example, a quadratic fit best characterized the length-mercury relationship for Lake Trout in Williston Reservoir (Azimuth 2019b), where the relationship changed in response to reduced growth rates in larger fish. Quadratic fits provide more flexibility to fit different slopes and intercepts, which we anticipate will be useful when mercury concentrations in the environment are dynamic (e.g., in a newly created reservoir) and affect smaller fish more rapidly than larger fish.

- **Model Over-fitting** – One drawback of polynomial models is that they can over-fit data. Over-fitting occurs when a model is sufficiently parameterized to allow it to respond too closely to the underlying data, essentially describing random error rather than the underlying length-mercury relationship. For length-mercury relationships, the general expectation is that mercury concentrations increase with fish size, often more sharply when fish growth slows down later in life. Consequently, key signs of model over-fitting in these relationships is when the curve shape shows a decrease in slope of the relationship, or even a reversal (negative slope) of the relationship, across the size range. A good example of model over-fitting comes from the analysis of temporal trends in mercury concentrations in Bull Trout, where fit7 (**Table 1-1, Figure 1-1**) is clearly over-fitting the data (e.g., model fit reasonably characterizes the 2017 data, but predicts decreasing mercury concentrations in larger fish) relative to fit5 (**Table 1-1**, **Figure 1-1**). Cases of model over-fitting are noted in the results, but details for each fit are not included in the results.
- **Model Selection** – A variant of Akaike's Information Criterion (AIC), corrected for bias in small sample sizes (AICc), was used to compare models (Burnham and Anderson 2002). Models with the lowest AICc values were considered first, by examining model coefficients, plotting the fit along with the data and viewing model diagnostics (e.g., residuals, Q-Q plot, Cook's distance, and residual distribution). In cases where models over-fitted the data (see previous bullet), the next best model, generally more parsimonious, was selected.
- **Outlier Identification** – Formal assessment of outliers was conducted for selected models. This involved identifying data that were clear outliers (studentized residuals > 4) or had high leverage (Cook's distance > 0.5) values. For simplicity, these are collectively referred to as "outliers" hereafter, but any instances are documented along with the

driver for their categorization. The models were run with and without the outliers, but only results with outliers removed are reported.

- **Mercury Concentration Estimates and Confidence Limits** – Selected models were used to estimate mercury concentrations, and associated confidence intervals, for one or more selected fish sizes for each year/location/period modelled. Given that the models could have not only different intercepts, but also different slopes (linear models) or polynomial curve shapes (quadratic models) for the various locations (e.g., lakes or reaches), up to three standard sizes were selected for each species to facilitate comparisons among locations (Sections) and among years.

Table 1-1. Models fit to fish length and tissue mercury concentrations to assess temporal trends in the Site C baseline data.

Fit	Model[1]	Comments
fit0	FishHg ~ Year.Caught	simple means by Year.Caught
fit1	FishHg ~ LC	linear - all Year.Caughts same
fit2	FishHg ~ LC + LC2	quadratic - all Year.Caughts same
fit3	FishHg ~ Year.Caught + LC	linear - Year.Caught-specific intercepts
fit4	FishHg ~ Year.Caught + LC + LC2	quadratic - Year.Caught-specific intercepts
fit5	FishHg ~ Year.Caught + LC + Year.Caught:LC	linear - Year.Caught-specific intercepts/slopes
fit6	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC	quadratic - Year.Caught-specific intercepts/slopes (length)
fit7	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC2	quadratic - Year.Caught-specific intercepts/quadratics (length^2)
fit8	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC + Year.Caught:LC2	quadratic - Year.Caught-specific intercepts/slopes/quadratics

[1] LC=length centered on standard length (varies by species); LC2=LC^2

Table 1-2. Models fit to fish length and tissue mercury concentrations to assess spatial trends in the Site C baseline data.

Fit	Model[1]	Comments
fit0	FishHg ~ Location	simple means by location
fit1	FishHg ~ LC	linear - all locations same
fit2	FishHg ~ LC + LC2	quadratic - all locations same
fit3	FishHg ~ Location + LC	linear - location-specific intercepts
fit4	FishHg ~ Location + LC + LC2	quadratic - location-specific intercepts
fit5	FishHg ~ Location + LC + Location:LC	linear - location-specific intercepts/slopes
fit6	FishHg ~ Location + LC + LC2 + Location:LC	quadratic - location-specific intercepts/slopes (length)
fit7	FishHg ~ Location + LC + LC2 + Location:LC2	quadratic - location-specific intercepts/quadratics (length^2)
fit8	FishHg ~ Location + LC + LC2 + Location:LC + Location:LC2	quadratic - location-specific intercepts/slopes/quadratics

[1] LC=length centered on standard length (varies by species); LC2=LC^2

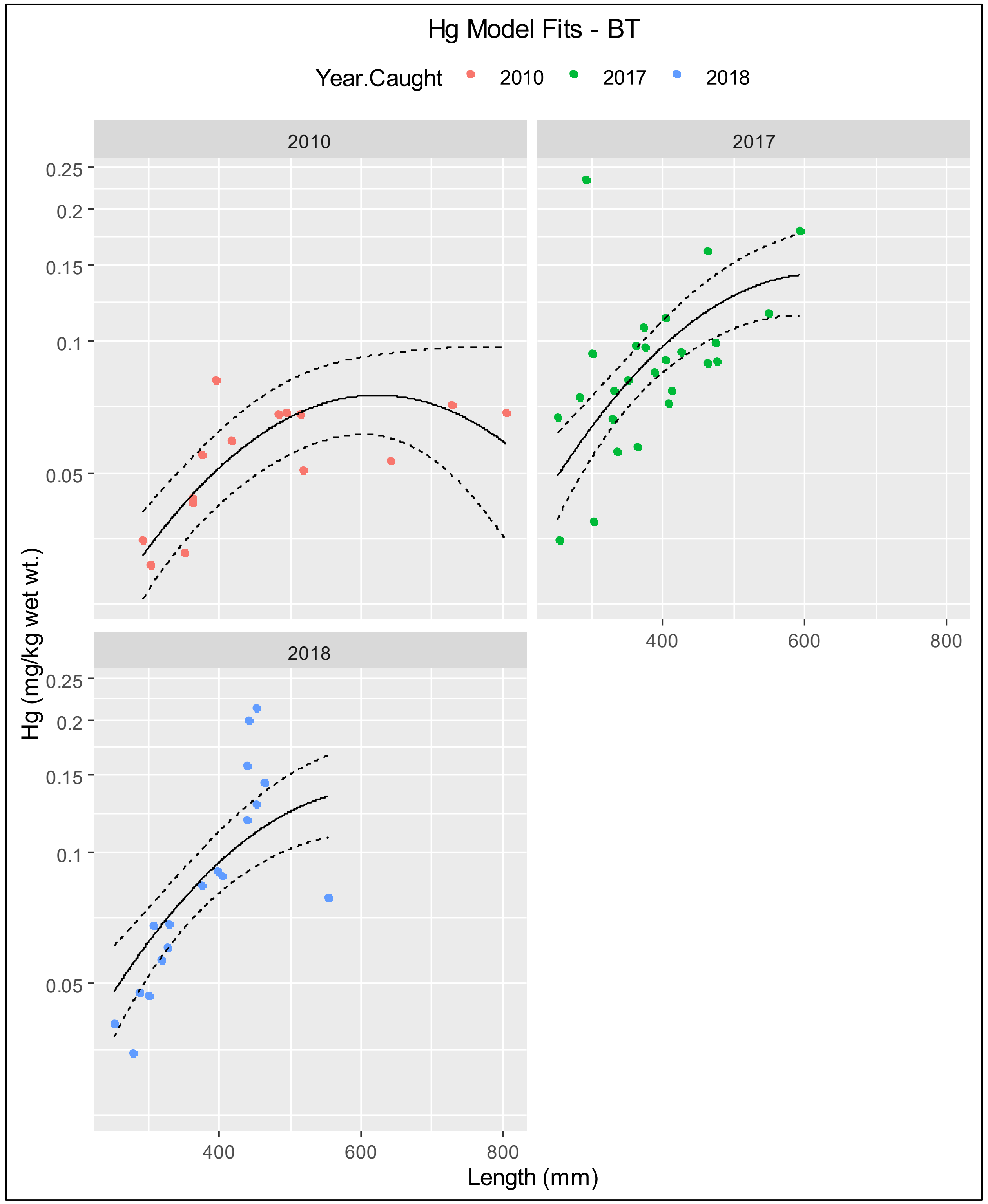
Table 1-3. Models fit to fish length and tissue mercury concentrations to characterize the early and recent baseline periods in the Site C baseline data.

Fit	Model[1]	Comments
fit0	FishHg ~ Period	simple means by period
fit1	FishHg ~ LC	linear - all periods same
fit2	FishHg ~ LC + LC2	quadratic - all periods same
fit3	FishHg ~ Period + LC	linear - period-specific intercepts
fit4	FishHg ~ Period + LC + LC2	quadratic - period-specific intercepts
fit5	FishHg ~ Period + LC + Period:LC	linear - period-specific intercepts/slopes
fit6	FishHg ~ Period + LC + LC2 + Period:LC	quadratic - period-specific intercepts/slopes (length)
fit7	FishHg ~ Period + LC + LC2 + Period:LC2	quadratic - period-specific intercepts/quadratics (length^2)
fit8	FishHg ~ Period + LC + LC2 + Period:LC + Period:LC2	quadratic - period-specific intercepts/slopes/quadratics

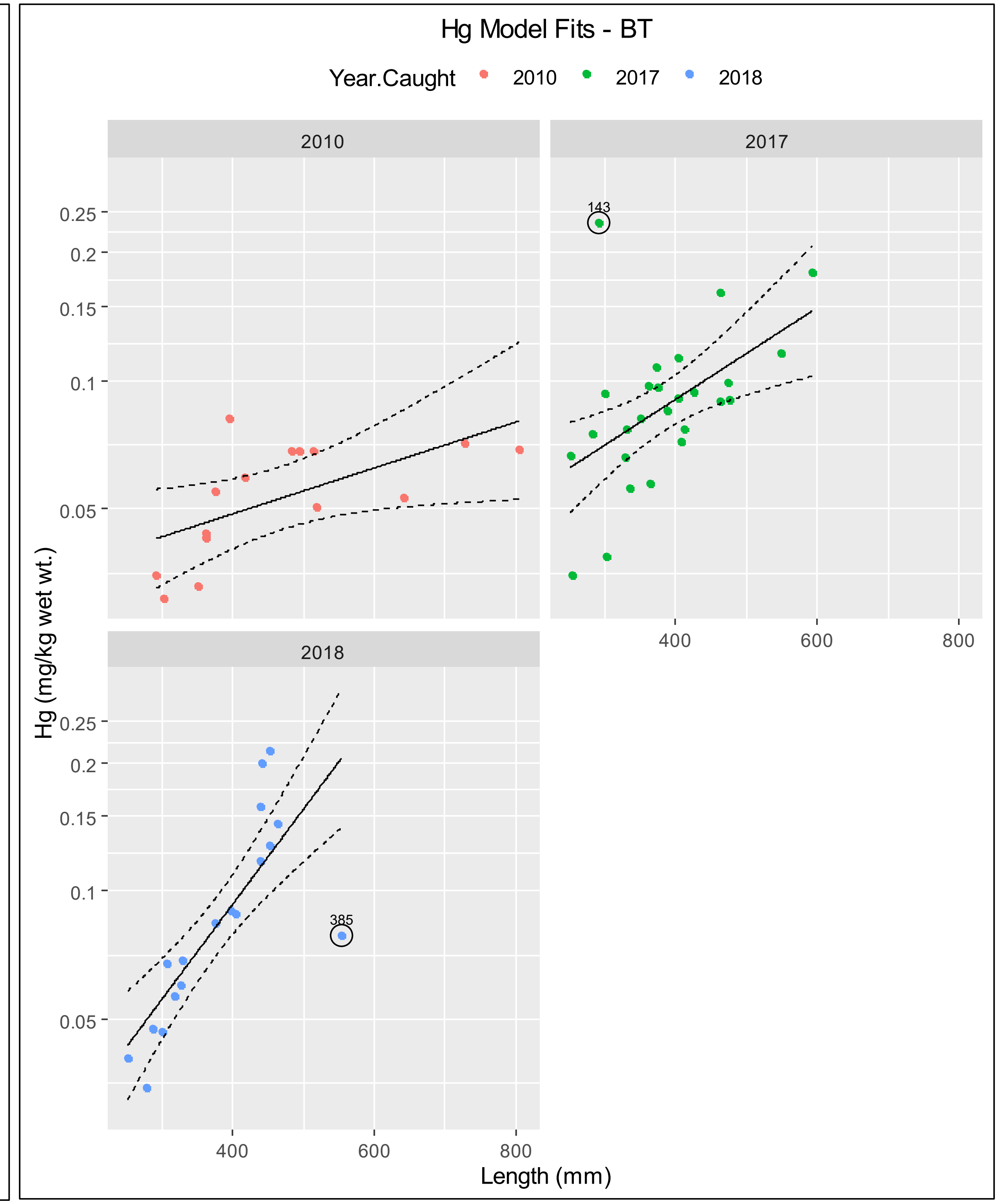
[1] LC=length centered on standard length (varies by species); LC2=LC^2

Figure 1-1 Example of model over-fitting (panel a) and parsimonious model-fitting (panel b) from the analysis of temporal trends in mercury concentrations in Bull Trout.

a) model over-fit to data



b) model appropriately fit to data



2 BULL TROUT

Temporal Assessment

The temporal assessment was conducted to determine whether there were any changes in the length-mercury relationship for Bull Trout across sampling years. To control for spatial trends, the analysis was limited to **Section 3**, which had three years (2010, 2017 and 2018) with 15 or more samples (see Bull Trout section of main report for catch details by location/year).

Key information on the modelling and associated results were as follows:

- *Transformations* – Total mercury concentrations in fish tissue were log-transformed.
- *Initial Model Selection* – The suite of temporal models (**Table 1-1**) was initially run with all the data. Fits 7, 8, 4 and 6, all quadratic model forms, had the lowest AICc values (**Table 2-1**), but all over-fit the data (see **Section 1.1** for details on over-fitting). The model selected for the analysis was fit5, which had the following structure (linear model with year-specific intercepts and slopes):

  *Log Hg ~ Year + Length + Year*Length*

- *Outliers/High Leverage Data* – Formal outlier assessment of the initial fit5 run (with all data) identified two points (**Figure 2-3**) as outliers and/or having high leverage (**Table 2-2**); these were removed ("trimmed") from the dataset.
- *Final Model Selection* – Given the potential for outliers or high-leverage data to influence the model fits, the model selection process was repeated with the trimmed dataset. This time, fit6 (over-fit the data) had the lowest AICc (**Table 2-6**), followed by fit5, which was used to characterize the length-mercury relationship.
- *Fitted length-mercury Relationships* – Final model results are shown in **Figure 2-4** and summarized in **Table 2-4**. The model fits generally show strong positive relationships between length and mercury concentrations. Model residuals were visually examined and indicated that the fit was good. The model had an adjusted R2 of 0.76 and showed statistically significant differences in Bull Trout mercury concentrations among years.
- *Predicted Mercury Concentrations for Standard Sized Fish by Year* – Using the length-mercury model shown above, and where the underlying data supported making a prediction (e.g., predictions were not made for 700-mm Bull Trout in 2017 or 2018), tissue mercury concentrations were estimated for three standard fish sizes: 400 mm, 550 mm and 700 mm. The predictions (and their 95% confidence limits) were used to compare fish tissue mercury concentrations among years (**Figure 2-5**); statistical

differences among year-size combinations determined using the selected model were annotated on the plot. The results show that Bull Trout mercury concentrations were generally lower in 2010 than in 2017 and 2018.

Spatial Assessment

The spatial assessment was conducted to determine whether there are differences in the length-mercury relationship for Bull Trout among Peace River sampling locations. Given the temporal changes identified previously, the spatial assessment was limited to the recent time period only. Five sampling locations (Sections 1, 3, 5, 6, and 7) had 14 or more samples across the recent sampling period (2017 to 2020), with a total of 148 samples (see Bull Trout section of main report for catch details by location/year).

Key information on the spatial modelling and associated results were as follows:

- *Transformations* – Mercury concentrations were log-transformed.
- *Initial Model Selection* – The suite of spatial models (**Table 1-2**) was initially run with all the data. Fit4, a quadratic model form, had the lowest AICc values (**Table 2-5**), but over-fit the data (see **Section 1.1** for details on over-fitting). The model selected for the analysis (fit1) had the following structure (linear model with no location-specific differences):

  Log Hg ~ Length

- *Outliers/High Leverage Data* – No outliers or high leverage points were identified.
- *Final Model Selection* – As no outliers or high-leverage points were identified, fit1 using all data was used to characterize the length-mercury relationship.
- *Fitted length-mercury Relationships* – Final model results are shown in **Figure 2-6** and summarized in **Table 2-6**. The model fits generally show strong positive relationships between length and mercury concentrations. Model residuals were visually examined and indicated that the fit was good. The model had an adjusted R2 of 0.59 and showed no statistically significant differences in Bull Trout mercury concentrations among locations.
- *Predicted Mercury Concentrations for Standard Sized Fish by Year* – Using the length-mercury model shown above, tissue mercury concentrations were estimated for three standard fish sizes: 400 mm, 550 mm and 700 mm. Given that location did not improve model fit (i.e., mercury concentrations did not differ significantly among Sections), the single set of predictions (and their 95% confidence limits) is valid for all modelled locations for the recent period (2017 – 2020) (**Figure 2-7**).

Baseline Period Assessment

This analysis was conducted to characterize potential differences between the early and recent baseline monitoring periods for Peace River locations (i.e., excluding Dinosaur Reservoir), with the recent period results used to support the development of fish consumption advice based on current conditions. The analysis included 169 samples, with 21 from the early baseline period and 148 from the recent period (see Bull Trout section of main report for catch details by location/year).

Key information on the modelling and associated results were as follows:

- *Transformations* – Mercury concentrations were log-transformed.
- *Initial Model Selection* – The suite of baseline period models (**Table 1-3**) was initially run with all the data. Fit5 had the lowest AICc value (**Table 2-7**) and was the initial model selection; it has the following structure (linear model with year-specific intercepts and slopes):

  *Log Hg ~ Period + Length + Period*Length*

- *Outliers/High Leverage Data* – Formal outlier assessment of the initial fit5 run (with all data) identified one point (**Figure 2-8**) as having high leverage (**Table 2-8**); this was removed ("trimmed") from the dataset.
- *Final Model Selection* – Given the potential for outliers or high-leverage data to influence the model fits, the model selection process was repeated with the trimmed dataset. Fit5 once again had the lowest AICc (**Table 2-9**), so was used to characterize the length-mercury relationship.
- *Fitted length-mercury Relationships* – Final model results are shown in **Figure 2-9** and summarized in **Table 2-10.** The model fits generally show strong positive relationships between length and mercury concentrations. Model residuals were visually examined and indicated that the fit was good. The model had an adjusted R2 of 0.62 and showed statistically significant differences in Bull Trout mercury concentrations among periods.
- *Predicted Mercury Concentrations for Standard Sized Fish by Period* – Using the length-mercury model shown above, and where the underlying data supported making a prediction, tissue mercury concentrations were estimated for three standard fish sizes: 400 mm, 550 mm and 700 mm. The predictions (and their 95% confidence limits) were used to compare fish tissue mercury concentrations between the two baseline sampling periods (**Figure 2-10**); statistical differences between periods for each standard size were determined using the selected model and were annotated on the plot. The results show

that Bull Trout mercury concentrations, when adjusted for fish size, increased more than two-fold between the early and the recent baseline period.

Table 2-1. Comparison of initial model fit results for the temporal assessment of length-mercury relationship by year for Bull Trout.

Fit	Model[1]	Df	AICc	Delta
fit7	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC2	8	37.1	0.0
fit8	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC + Year.Caught:LC2	10	41.8	4.7
fit4	FishHg ~ Year.Caught + LC + LC2	6	44.4	7.4
fit6	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC	8	45.3	8.2
fit5	FishHg ~ Year.Caught + LC + Year.Caught:LC	7	47.1	10.0
fit3	FishHg ~ Year.Caught + LC	5	54.0	16.9
fit2	FishHg ~ LC + LC2	4	69.2	32.1
fit0	FishHg ~ Year.Caught	4	74.5	37.4
fit1	FishHg ~ LC	3	78.5	41.4

[1] LC=length centered on standard size; LC2=LC^2

Table 2-2. Outlier and/or high leverage data points excluded from the temporal assessment of Bull Trout fish mercury concentrations.

Waterbody	Year.Caught	FishID	SectionID	Sp	FL.mm	Wt.g	Hg.ppm.ww	StudRes	CooksD	OutType[1]
Peace River	2017	143	Section 3	BT	290	205	0.23540	4.527	0.235	Outlier
Peace River	2018	385	Section 3	BT	554	1977	0.07854	3.975	0.967	High Leverage

[1] Outlier types: 'Outlier' = studentized residual > 4; 'High Leverage' = Cook's distance > 0.5.

Table 2-3. Comparison of final model fit results for the temporal assessment of length-mercury relationship by year for Bull Trout.

Fit	Model[1]	Df	AICc	Delta
fit6	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC	8	5.1	0.0
fit5	FishHg ~ Year.Caught + LC + Year.Caught:LC	7	6.8	1.7
fit7	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC2	8	9.0	4.0
fit8	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC + Year.Caught:LC2	10	9.6	4.5
fit4	FishHg ~ Year.Caught + LC + LC2	6	16.1	11.0
fit3	FishHg ~ Year.Caught + LC	5	37.7	32.6
fit2	FishHg ~ LC + LC2	4	53.3	48.3
fit0	FishHg ~ Year.Caught	4	68.3	63.3
fit1	FishHg ~ LC	3	68.7	63.7

[1] LC=length centered on standard size; LC2=LC^2

Table 2-4. Final model results for the temporal assessment of Bull Trout fish mercury concentrations.

Predictor	Estimate	95% CI[1]	p-value
(Intercept)	-2.960	-3.083, -2.837	<0.001
Year.Caught			
2010	—	—	
2017	0.6769	0.5058, 0.8480	<0.001
2018	1.074	0.8591, 1.288	<0.001
LC	0.0012	0.0004, 0.0021	0.004
Year.Caught * LC			
2017 * LC	0.0019	0.0005, 0.0033	0.008
2018 * LC	0.0060	0.0042, 0.0079	<0.001

[1] CI = Confidence Interval

Model: FishHg ~ Year.Caught + LC + Year.Caught:LC

Overall Results: $F(5,51)=32$; Adjusted $R^2 = 0.760$; N = 57.0

Table 2-5. Comparison of final model fit results for the spatial assessment of length-mercury relationship by Peace River sampling location for Bull Trout (2017 – 2020).

Fit	Model[1]	Df	AICc	Delta
fit4	FishHg ~ Location + LC + LC2	8	112.9	0.0
fit1	FishHg ~ LC	3	113.0	0.2
fit2	FishHg ~ LC + LC2	4	113.7	0.8
fit3	FishHg ~ Location + LC	7	114.0	1.1
fit7	FishHg ~ Location + LC + LC2 + Location:LC2	12	114.8	2.0
fit5	FishHg ~ Location + LC + Location:LC	11	118.5	5.6
fit8	FishHg ~ Location + LC + LC2 + Location:LC + Location:LC2	16	120.0	7.2
fit6	FishHg ~ Location + LC + LC2 + Location:LC	12	120.1	7.3
fit0	FishHg ~ Location	6	240.3	127.4

[1] LC=length centered on standard size; LC2=LC^2

Note: as there were no outliers, there are no initial fit results.

Table 2-6. Final model results for the spatial assessment of Bull Trout fish mercury concentrations (2017 – 2020).

Predictor	Estimate	95% CI[1]	p-value
(Intercept)	-1.917	-2.002, -1.832	<0.001
LC	0.0032	0.0027, 0.0036	<0.001

[1] CI = Confidence Interval

Model: FishHg ~ LC

Overall Results: F(1,146)=212; Adjusted R^2 = 0.592; N = 148

Table 2-7. Comparison of initial model fit results for the baseline period assessment of length-mercury relationship by year for Bull Trout.

Fit	Model[1]	Df	AICc	Delta
fit5	FishHg ~ Period + LC + Period:LC	5	135.2	0.0
fit6	FishHg ~ Period + LC + LC2 + Period:LC	6	135.6	0.4
fit4	FishHg ~ Period + LC + LC2	5	136.2	1.0
fit3	FishHg ~ Period + LC	4	136.8	1.6
fit8	FishHg ~ Period + LC + LC2 + Period:LC + Period:LC2	7	137.7	2.6
fit7	FishHg ~ Period + LC + LC2 + Period:LC2	6	138.4	3.2
fit1	FishHg ~ LC	3	187.1	51.9
fit2	FishHg ~ LC + LC2	4	188.1	52.9
fit0	FishHg ~ Period	3	275.0	139.8

[1] LC=length centered on standard size; LC2=LC^2

Table 2-8. Outlier and high leverage data points excluded from the baseline period assessment of Bull Trout fish mercury concentrations.

Waterbody	Year.Caught	FishID	SectionID	Sp	FL.mm	Wt.g	Hg.ppm.ww	StudRes	CooksD	OutType[1]
Peace River	2011	1246	Section 3	BT	754	4120	0.3280702	3.752	0.923	High Leverage

[1] Outlier types: 'Outlier' = studentized residual > 4; 'High Leverage' = Cook's distance > 0.5.

Table 2-9. Comparison of final model fit results for the baseline period assessment of length-mercury relationship by year for Bull Trout.

Fit	Model[1]	Df	AICc	Delta
fit6	FishHg ~ Period + LC + LC2 + Period:LC	6	121.1	0.0
fit5	FishHg ~ Period + LC + Period:LC	5	121.6	0.5
fit8	FishHg ~ Period + LC + LC2 + Period:LC + Period:LC2	7	121.8	0.7
fit4	FishHg ~ Period + LC + LC2	5	128.3	7.2
fit7	FishHg ~ Period + LC + LC2 + Period:LC2	6	130.4	9.3
fit3	FishHg ~ Period + LC	4	130.4	9.3
fit1	FishHg ~ LC	3	186.1	65.0
fit2	FishHg ~ LC + LC2	4	186.8	65.7
fit0	FishHg ~ Period	3	263.5	142.4

[1] LC=length centered on standard size; $LC2=LC^2$

Table 2-10. Final model results for the baseline period assessment of Bull Trout fish mercury concentrations.

Predictor	Estimate	95% CI[1]	p-value
(Intercept)	-2.804	-2.984, -2.624	<0.001
Period			
2010-2011	—	—	
2017-2020	0.8872	0.6890, 1.085	<0.001
LC	0.0012	0.0001, 0.0023	0.038
Period * LC			
2017-2020 * LC	0.0020	0.0008, 0.0032	0.001

[1] CI = Confidence Interval

Model: FishHg ~ Period + LC + Period:LC

Overall Results: $F(3,164)=90$; Adjusted $R^2 = 0.621$; N = 168

Figure 2-1. Length frequency and age frequency for Bull Trout (BT) by location across all years (2010–2020).

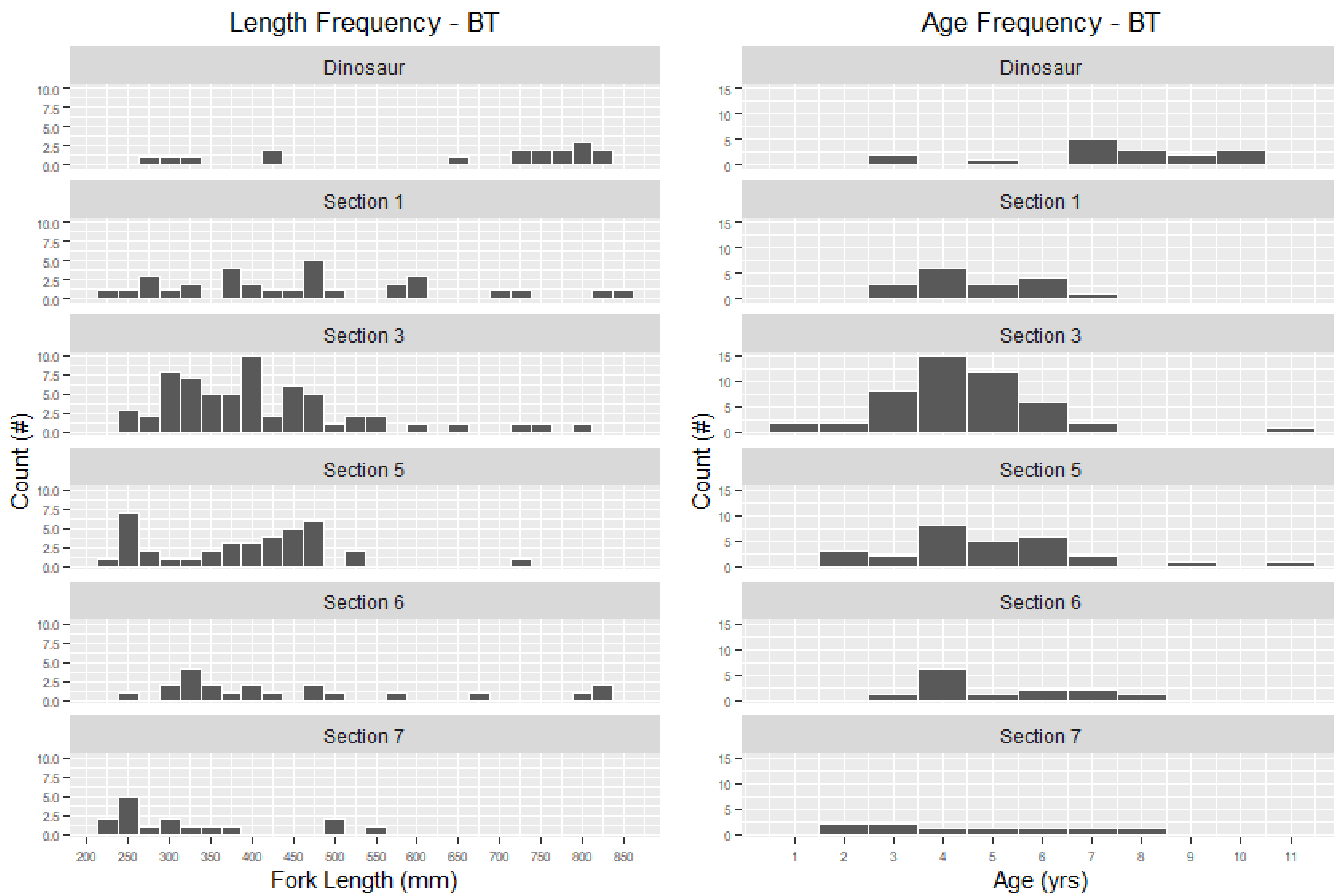


Figure 2-2. Key mercury relationships for Bull Trout (BT) across all years (2010–2020).

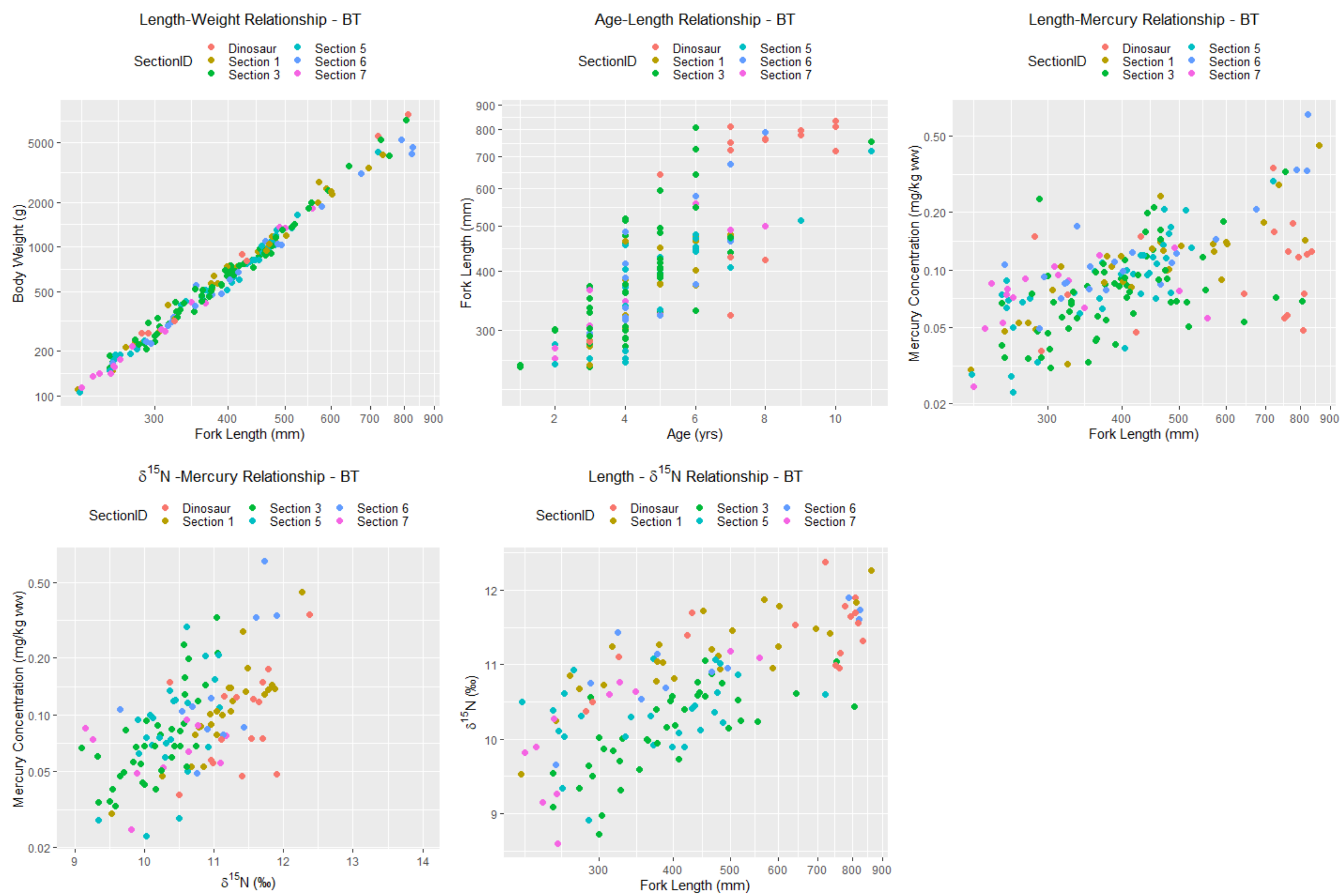
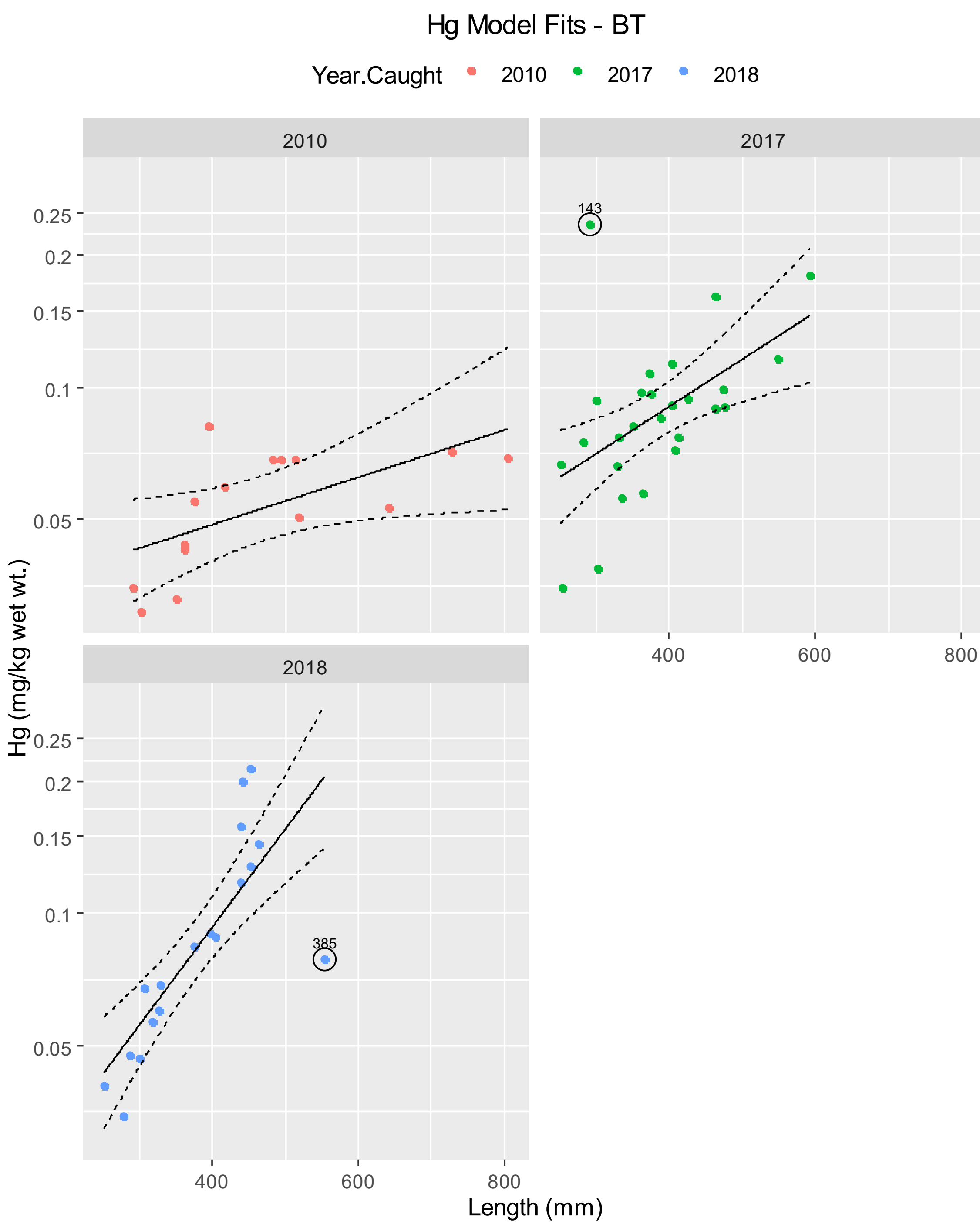
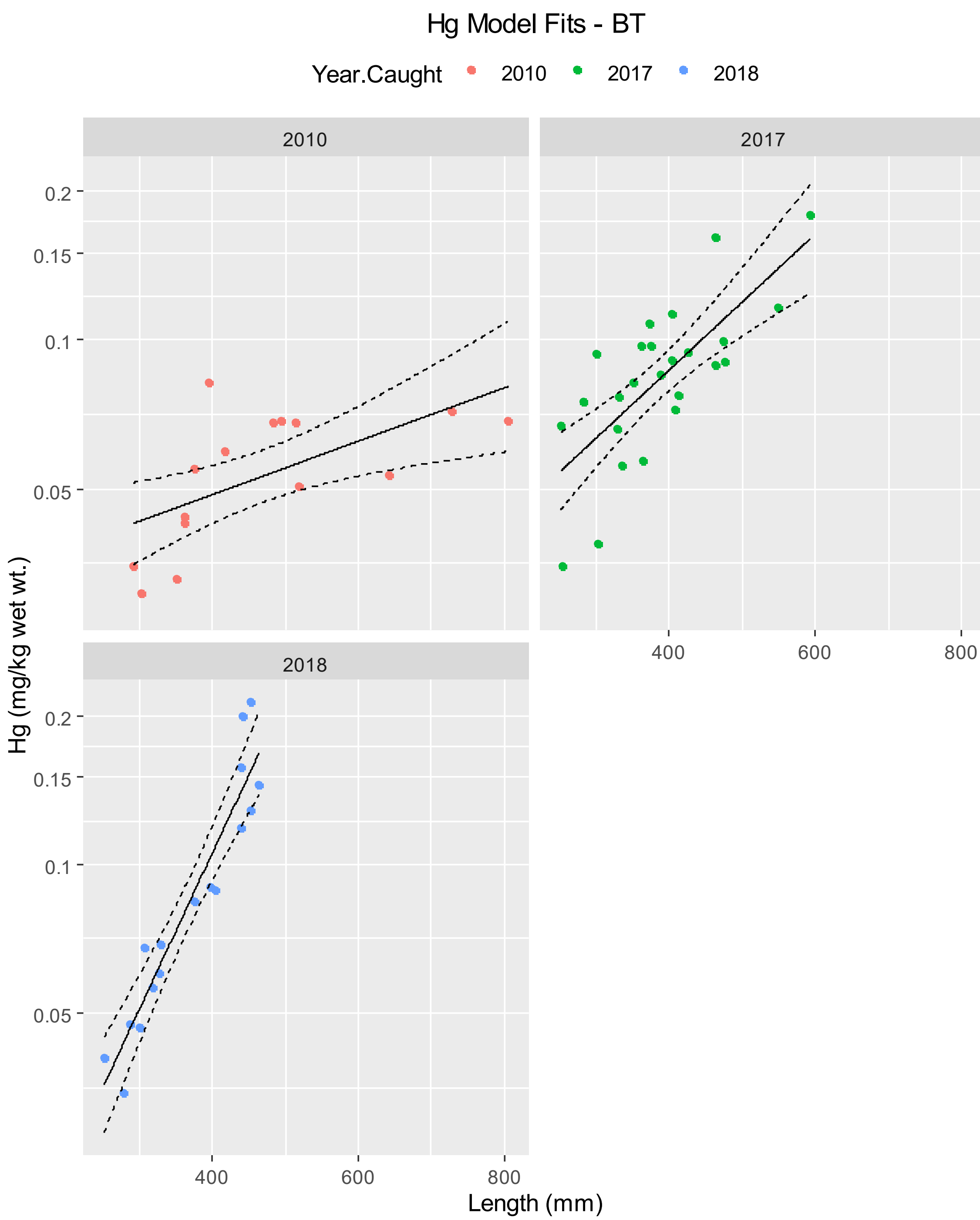


Figure 2-3. Initial model fit results and identified outliers for the temporal assessment of Bull Trout mercury concentrations for Section 3 (2010, 2017 and 2018 [see note]).



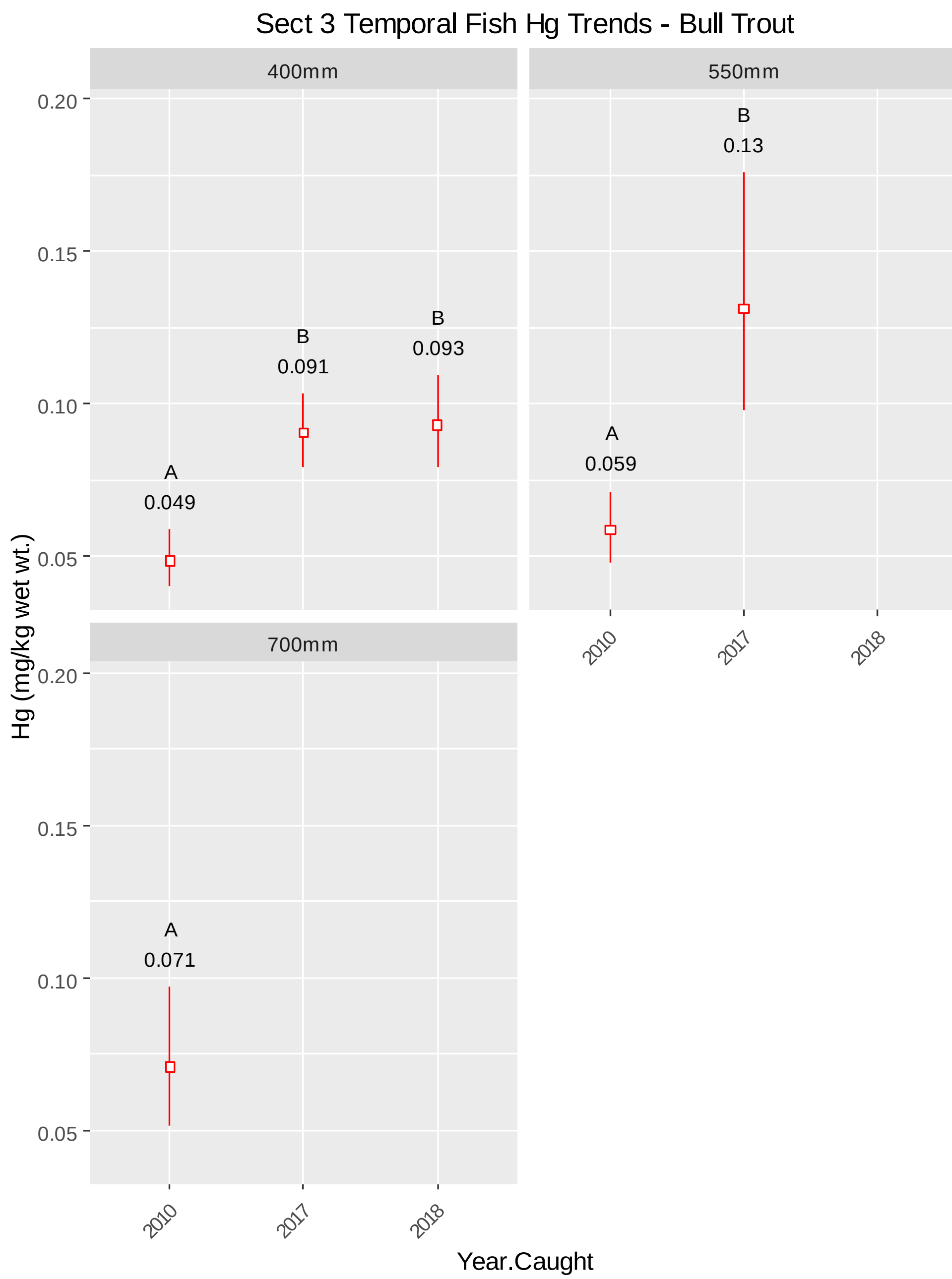
Note: Only years with 15 or more samples were included.

Figure 2-4. Final model fit results for the temporal assessment of Bull Trout mercury concentrations for Section 3.



Note: Only years with 15 or more samples were included.

Figure 2-5. Estimated mercury concentrations (and 95% confidence intervals) for select sizes (400 mm, 550 mm, 700 mm) for each year in the temporal assessment of Bull Trout mercury concentrations for Section 3.



Note: Letters above estimates show which are not statistically different from one another (same letters) or which are statistically different (different letters); combinations (e.g., “AB”) show estimates that are not statistically different from other groups that are different (e.g., “A” and “B”). Only years with more than 15 samples were included.

Figure 2-6. Final model fit results for the spatial assessment of Bull Trout fish mercury concentrations across Peace River locations for the recent baseline period (2017 – 2020).

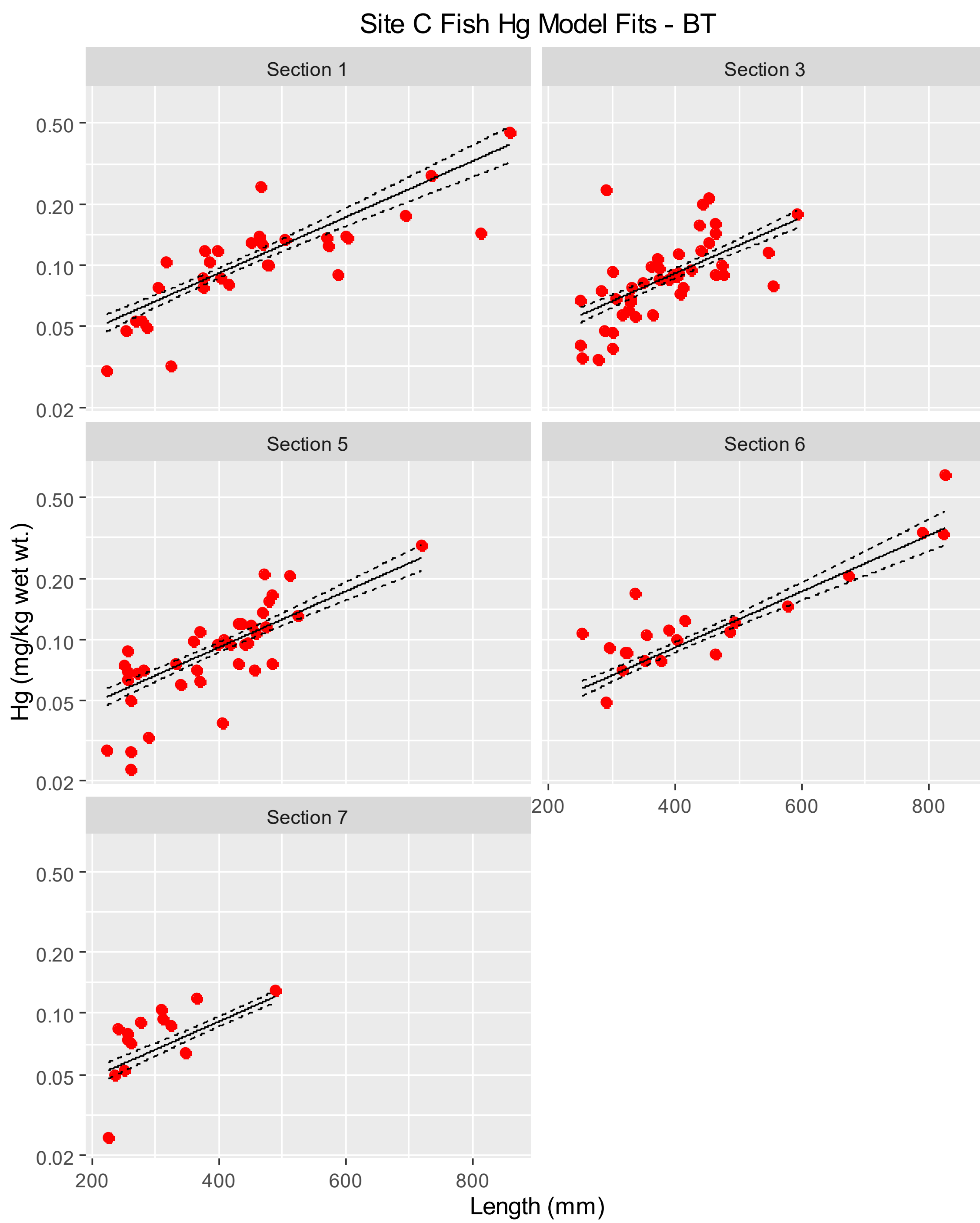
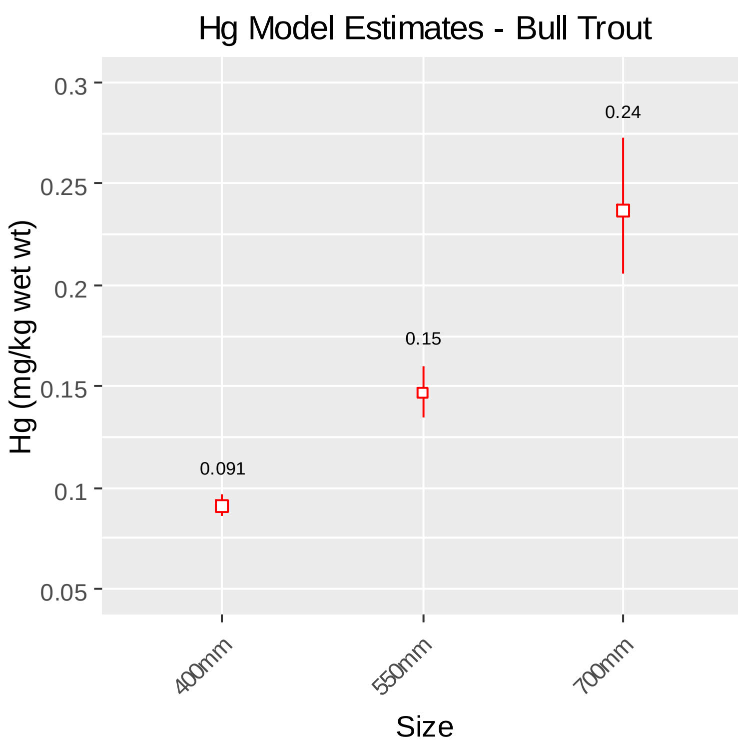


Figure 2-7. Estimated mercury concentrations (and 95% confidence intervals) for Bull Trout for select sizes (400 mm, 550 mm, 700 mm) across Peace River locations in the spatial assessment using recent baseline data (2017 – 2020).



Note: The location (Section) parameter did not improve the length-mercury model, indicating no statistically significant differences in BT mercury concentrations across river sections.

Figure 2-8. Initial model fit results and identified outliers for the baseline period assessment of Bull Trout fish mercury concentrations across Peace River locations.

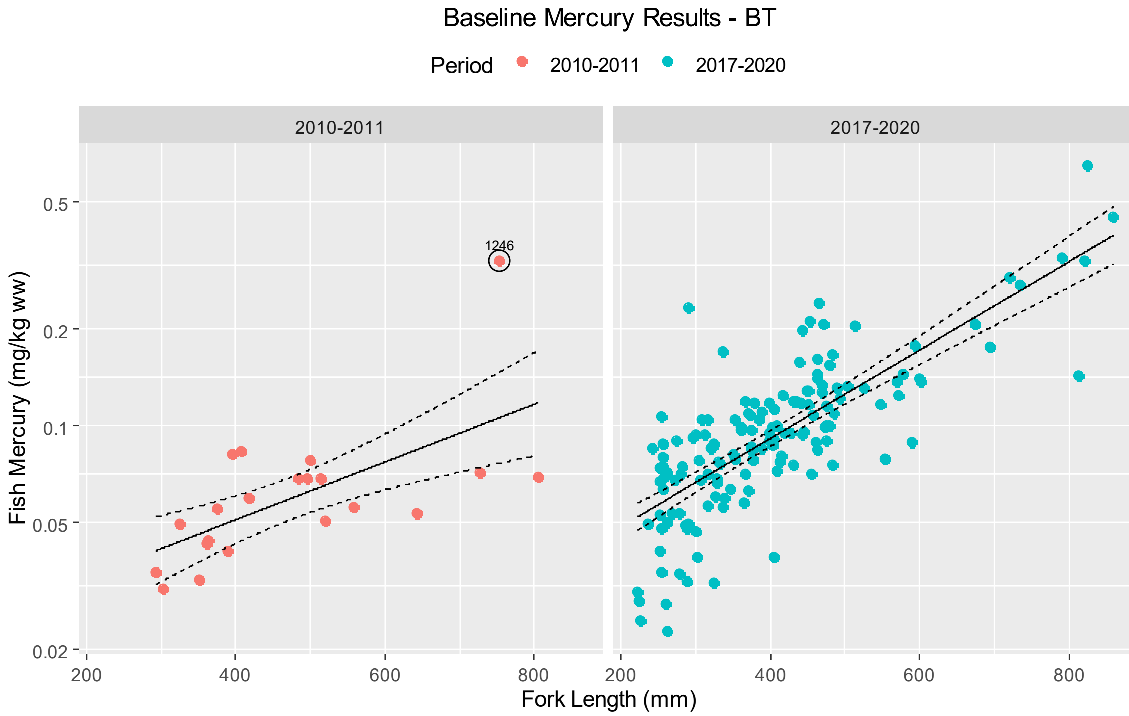


Figure 2-9. Final model fit results for the baseline period assessment of Bull Trout fish mercury concentrations across Peace River locations.

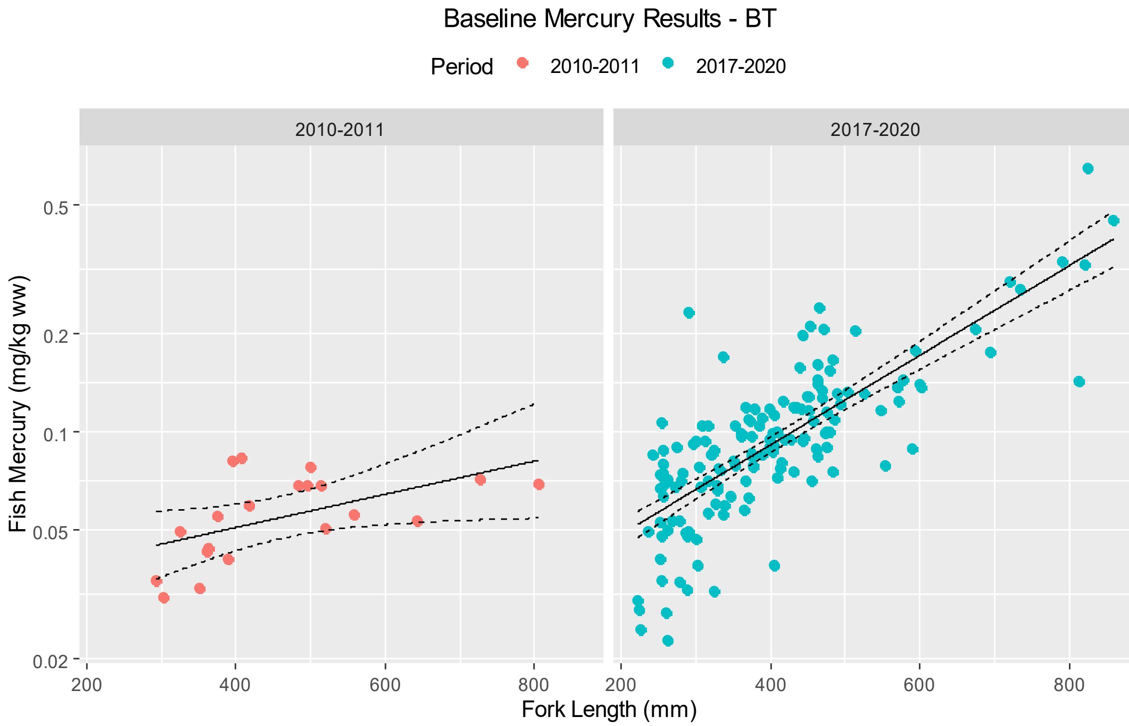
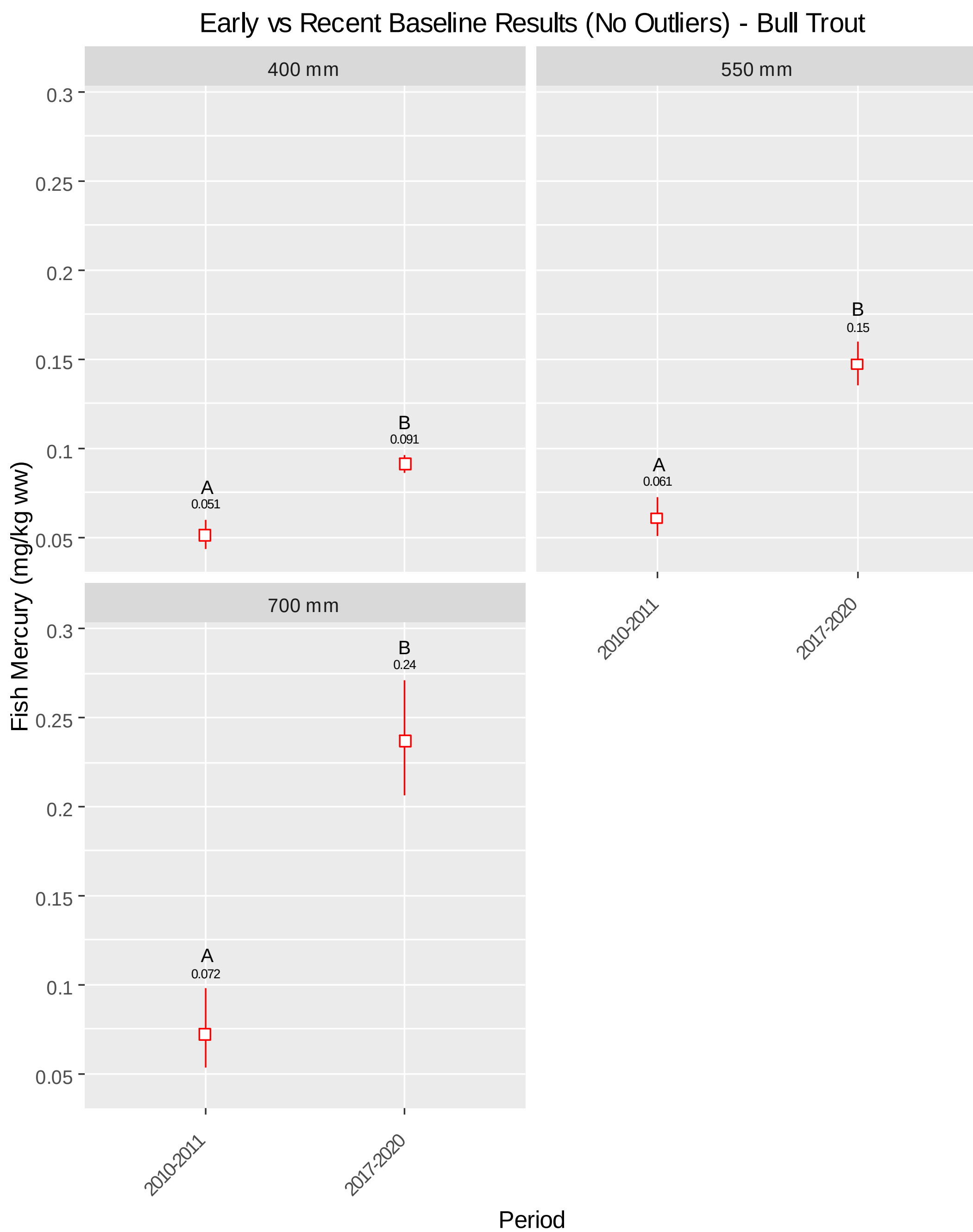


Figure 2-10. Estimated mercury concentrations (and 95% confidence intervals) for select sizes (400 mm, 550 mm, 700 mm) for each period in the baseline period assessment of Bull Trout fish mercury concentrations across Peace River locations.



Note: Letters above estimates show which are not statistically different from one another (same letters) or which are statistically different (different letters); combinations (e.g., “AB”) show estimates that are not statistically different from other groups that are different (e.g., “A” and “B”).

3 MOUNTAIN WHITEFISH

Temporal Assessment

The temporal assessment was conducted to determine whether there were any changes in the length-mercury relationship for Mountain Whitefish across sampling years. To control for potential spatial trends the analysis was limited to Section 3, which had six years (2010, 2011, 2017, 2018, 2019, and 2020) with 11 or more samples, with a total of 87 samples across all years (see Mountain Whitefish section of main report for catch details by location/year).

Key information on the modelling and associated results were as follows:

- *Transformations* – Mercury concentrations were log-transformed.
- *Initial Model Selection* – The suite of temporal models (**Table 1-1**) was initially run with all the data. Fit5 had the lowest AICc value (**Table 3-2**), was selected for use, and has the following structure (linear model with year-specific intercepts and slopes):

  *Log Hg ~ Year + Length + Year*Length*

- *Outliers/High Leverage Data* – Formal outlier assessment of the initial fit5 run (with all data) identified one point (**Figure 3-3**) as an outlier (**Table 3-3**); this was removed ("trimmed") from the dataset.
- *Final Model Selection* – Given the potential for outliers or high-leverage data to influence the model fits, the model selection process was repeated with the trimmed dataset. Fit5 still had the lowest AICc (**Table 3-4**), and so was used to characterize the length-mercury relationship.
- *Fitted length-mercury Relationships* – Final model results are shown in **Figure 3-4** and summarized in **Table 3-5**. The model fits generally show strong positive relationships between length and mercury concentrations. Model residuals were visually examined and confirmed a reasonable fit. The model had an adjusted R2 of 0.78 and showed statistically significant differences in Mountain Whitefish mercury concentrations among years.
- *Predicted Mercury Concentrations for Standard Sized Fish by Year* – Using the length-mercury model shown above, and where the underlying data supported making a prediction, tissue mercury concentrations were estimated for three standard fish sizes: 200 mm, 350 mm and 500 mm. The predictions (and their 95% confidence limits) were used to compare fish tissue mercury concentrations among years (**Figure 3-5**); statistical differences among year-size combinations determined using the selected model were

annotated on the plot. The results show that Mountain Whitefish mercury concentrations were generally lower in 2010/2011 than in 2017 through 2020.

Spatial Assessment

The spatial assessment was conducted to determine whether there are differences in the length-mercury relationship for Mountain Whitefish among sampling locations. Given the temporal changes identified previously, the spatial assessment was limited to the recent time period only. Six sampling locations (Sections 1, 3, 5, 6, 7, and 9) had 34 or more samples across the recent sampling period (2017 to 2020), with a total of 307 samples; (see Mountain Whitefish section of main report for catch details by location/year). However, 27 of these fish were smaller than 200 mm, which had quite low mercury concentrations, so the dataset was trimmed to remove these very small fish, resulting in 280 samples. This adjustment allowed the models to more accurately characterize mercury concentrations in MW between 200 and 300 mm.

Key information on the spatial modelling and associated results were as follows:

- *Transformations* – Mercury concentrations were log-transformed.
- *Initial Model Selection* – The suite of spatial models (**Table 1-2**) was initially run with all the data. Fits 6 and 4, both quadratic model forms, had the lowest AICc values (Table 3-6), but over-fit the data (see **Section 1.1** for details on over-fitting). The model selected for the analysis was fit3, which had the following structure (linear model with no location-specific differences):

  Log Hg ~ Location + Length

- *Outliers/High Leverage Data* – Formal outlier assessment of the initial fit3 run (with all data) identified one point (**Figure 3-6**) as an outlier (**Table 3-7**); this was removed ("trimmed") from the dataset.
- *Final Model Selection* – Given the potential for outliers or high-leverage data to influence the model fits, the model selection process was repeated with the trimmed dataset. Fits 6 and 4 still had the lowest AICc values (**Table 3-8**), but as both still over-fit the data, fit3 was used to characterize the length-mercury relationship.
- *Fitted length-mercury Relationships* – Final model results are shown in **Figure 3-7** and summarized in **Table 3-9**. The model fits generally show strong positive relationships between length and mercury concentrations. Model residuals were visually examined and indicated that the fit was good. The model had an adjusted R2 of 0.66 and showed statistically significant differences in Mountain Whitefish mercury concentrations among locations.

- *Predicted Mercury Concentrations for Standard Sized Fish by Year* – Using the length-mercury model shown above, and where the underlying data supported making a prediction, tissue mercury concentrations were estimated for three standard fish sizes: 200 mm, 350 mm and 500 mm. The predictions (and their 95% confidence limits) were used to compare fish tissue mercury concentrations among locations for the recent period (2017 – 2020) (**Figure 3-8**). The results suggest that Mountain Whitefish mercury concentrations generally increase downstream.

Baseline Period Assessment

This analysis was conducted to characterize potential differences between the early and recent baseline monitoring periods, with the latter information being used to support the development of fish consumption advice based on current conditions. The analysis included 356 samples, with 49 from the early baseline period and 307 from the recent period (see Mountain Whitefish section of main report for catch details by location/year).

Key information on the modelling and associated results were as follows:

- *Transformations* – Mercury concentrations were log-transformed.
- *Initial Model Selection* – The suite of baseline period models (**Table 1-3**) was initially run with all the data. Fit3 had the lowest AICc value (**Table 3-10**) and was the initial model selection; it has the following structure (linear model with period-specific intercepts):

  Log Hg ~ Period + Length

- *Outliers/High Leverage Data* – Formal outlier assessment of the initial fit3 run (with all data) identified one point (**Figure 3-9**) as an outlier (**Table 3-11**); this was removed ("trimmed") from the dataset.
- *Final Model Selection* – Given the potential for outliers or high-leverage data to influence the model fits, the model selection process was repeated with the trimmed dataset. Fit3 once again had the lowest AICc (**Table 3-12**), so was used to characterize the length-mercury relationship.
- *Fitted length-mercury Relationships* – Final model results are shown in **Figure 3-10** and summarized in . The model fits generally show strong positive relationships between length and mercury concentrations. Model residuals were visually examined and indicated that the fit was good. The model had an adjusted R2 of 0.68 and showed statistically significant differences in Mountain Whitefish mercury concentrations among periods.

- *Predicted Mercury Concentrations for Standard Sized Fish by Period* – Using the length-mercury model shown above, and where the underlying data supported making a prediction, tissue mercury concentrations were estimated for three standard fish sizes: 400 mm, 550 mm and 700 mm. The predictions (and their 95% confidence limits) were used to compare fish tissue mercury concentrations between the two baseline sampling periods (**Figure 3-11**); statistical differences between periods for each standardized size were determined using the selected model and were annotated on the plot. The results show that Mountain Whitefish mercury concentrations nearly doubled between the early period (2010-2011) and the recent baseline period (2017 – 2020)

Table 3-1. Potential mercury-related outliers and assessment outcome for Mountain Whitefish.

Waterbody	Year.Caught	FishID	SectionID	Sp	FL.mm	Wt.g	Hg.ppm.ww	Relationship	Outcome
Dinosaur Reservoir	2010	1102	Dinosaur	MW	304	670	0.03311	L-W	retained
Dinosaur Reservoir	2010	1107	Dinosaur	MW	234	70	0.01848	L-W	retained

Table 3-2. Comparison of initial model fit results for the temporal assessment of length-mercury relationship by year for Mountain Whitefish.

Fit	Model[1]	Df	AICc	Delta
fit5	FishHg ~ Year.Caught + LC + Year.Caught:LC	13	83.2	0.0
fit6	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC	14	85.9	2.7
fit3	FishHg ~ Year.Caught + LC	8	91.5	8.2
fit4	FishHg ~ Year.Caught + LC + LC2	9	93.9	10.7
fit8	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC + Year.Caught:LC2	19	97.6	14.4
fit7	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC2	14	101.2	18.0
fit1	FishHg ~ LC	3	110.0	26.8
fit2	FishHg ~ LC + LC2	4	112.2	29.0
fit0	FishHg ~ Year.Caught	7	160.5	77.3

[1] LC=length centered on standard size; $LC2=LC^2$

Table 3-3. Outlier and high leverage data points excluded from the temporal assessment of Mountain Whitefish mercury concentrations.

Waterbody	Year.Caught	FishID	SectionID	Sp	FL.mm	Wt.g	Hg.ppm.ww	rstud	cooks	OutType[1]
Peace River	2018	426	Section 3	MW	415	772	0.015554	4.443	0.432	Outlier

[1] Outlier types: 'Outlier' = studentized residual > 4; 'High Leverage' = Cook's distance > 0.5.

Table 3-4. Comparison of final model fit results for the temporal assessment of length-mercury relationship by year for Mountain Whitefish.

Fit	Model[1]	Df	AICc	Delta
fit5	FishHg ~ Year.Caught + LC + Year.Caught:LC	13	63.3	0.0
fit6	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC	14	65.9	2.5
fit3	FishHg ~ Year.Caught + LC	8	77.8	14.5
fit8	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC + Year.Caught:LC2	19	78.7	15.4
fit4	FishHg ~ Year.Caught + LC + LC2	9	80.1	16.7
fit7	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC2	14	87.1	23.7
fit1	FishHg ~ LC	3	101.1	37.8
fit2	FishHg ~ LC + LC2	4	103.3	40.0
fit0	FishHg ~ Year.Caught	7	157.7	94.3

[1] LC=length centered on standard size; LC2=LC^2

Table 3-5. Model results for the temporal assessment of Mountain Whitefish mercury concentrations.

Predictor	Estimate	95% CI[1]	p-value
(Intercept)	-3.650	-3.813, -3.487	<0.001
Year.Caught			
2010	—	—	
2011	0.0426	-0.2018, 0.2871	0.7
2017	0.5546	0.3244, 0.7848	<0.001
2018	0.5490	0.2959, 0.8021	<0.001
2019	0.4846	0.2623, 0.7069	<0.001
2020	0.5599	0.2977, 0.8221	<0.001
LC	0.0049	0.0031, 0.0068	<0.001
Year.Caught * LC			
2011 * LC	-0.0032	-0.0071, 0.0008	0.11
2017 * LC	0.0065	0.0027, 0.0103	0.001
2018 * LC	0.0035	-0.0005, 0.0075	0.084
2019 * LC	0.0015	-0.0008, 0.0038	0.2
2020 * LC	-0.0045	-0.0088, -0.0001	0.043

[1] CI = Confidence Interval

Model: FishHg ~ Year.Caught + LC + Year.Caught:LC

Overall Results: F(11,74)=23; Adjusted R^2 = 0.776; N = 86.0

Table 3-6. Comparison of initial model fit results for the spatial assessment of length-mercury relationship by Peace River sampling location for Mountain Whitefish (2017 – 2020).

Fit	Model[1]	Df	AICc	Delta
fit6	FishHg ~ Location + LC + LC2 + Location:LC	14	255.1	0.0
fit4	FishHg ~ Location + LC + LC2	9	255.7	0.6
fit3	FishHg ~ Location + LC	8	258.5	3.4
fit5	FishHg ~ Location + LC + Location:LC	13	258.7	3.6
fit7	FishHg ~ Location + LC + LC2 + Location:LC2	14	262.1	7.0
fit8	FishHg ~ Location + LC + LC2 + Location:LC + Location:LC2	19	262.3	7.2
fit2	FishHg ~ LC + LC2	4	279.6	24.5
fit1	FishHg ~ LC	3	281.4	26.3
fit0	FishHg ~ Location	7	524.5	269.4

[1] LC=length centered on standard size; LC2=LC^2

Table 3-7. Outlier and high leverage data points excluded from the temporal assessment of Mountain Whitefish mercury concentrations.

Waterbody	Year.Caught	FishID	SectionID	Sp	FL.mm	Wt.g	Hg.ppm.ww	rstud	cooks	OutType[1]
Peace River	2018	426	Section 3	MW	415	772	0.015554	4.017	0.048	Outlier

[1] Outlier types: 'Outlier' = studentized residual > 4; 'High Leverage' = Cook's distance > 0.5.

Table 3-8. Comparison of final model fit results for the spatial assessment of length-mercury relationship by Peace River sampling location for Mountain Whitefish (2017 – 2020).

Fit	Model[1]	Df	AICc	Delta
fit6	FishHg ~ Location + LC + LC2 + Location:LC	14	237.4	0.0
fit4	FishHg ~ Location + LC + LC2	9	239.4	2.0
fit5	FishHg ~ Location + LC + Location:LC	13	241.8	4.3
fit3	FishHg ~ Location + LC	8	242.5	5.1
fit8	FishHg ~ Location + LC + LC2 + Location:LC + Location:LC2	19	244.4	7.0
fit7	FishHg ~ Location + LC + LC2 + Location:LC2	14	245.5	8.0
fit2	FishHg ~ LC + LC2	4	261.8	24.4
fit1	FishHg ~ LC	3	264.0	26.5
fit0	FishHg ~ Location	7	521.0	283.6

[1] LC=length centered on standard size; LC2=LC^2

Table 3-9. Model results for the spatial assessment of Mountain Whitefish mercury concentrations (2017 – 2020).

Predictor	Estimate	95% CI[1]	p-value
(Intercept)	-3.103	-3.219, -2.988	<0.001
Location			
Section 1	—	—	
Section 3	0.0029	-0.1479, 0.1538	>0.9
Section 5	0.1889	0.0335, 0.3444	0.017
Section 6	0.2012	0.0448, 0.3575	0.012
Section 7	0.4047	0.2328, 0.5765	<0.001
Section 9	0.1755	0.0240, 0.3270	0.023
LC	0.0083	0.0067, 0.0099	<0.001
Location * LC			
Section 3 * LC	-0.0013	-0.0034, 0.0008	0.2
Section 5 * LC	-0.0031	-0.0052, -0.0010	0.004
Section 6 * LC	-0.0024	-0.0045, -0.0004	0.020
Section 7 * LC	-0.0008	-0.0032, 0.0017	0.5
Section 9 * LC	-0.0013	-0.0034, 0.0009	0.2

[1] CI = Confidence Interval

Model: FishHg ~ Location + LC + Location:LC

Overall Results: $F(11,267)=48$; Adjusted $R^2 = 0.664$; N = 279

Table 3-10. Comparison of initial model fit results for the baseline period assessment of length-mercury relationship by year for Mountain Whitefish.

Fit	Model[1]	Df	AICc	Delta
fit3	FishHg ~ Period + LC	4	337.9	0.0
fit5	FishHg ~ Period + LC + Period:LC	5	339.2	1.2
fit4	FishHg ~ Period + LC + LC2	5	339.8	1.9
fit6	FishHg ~ Period + LC + LC2 + Period:LC	6	340.9	3.0
fit7	FishHg ~ Period + LC + LC2 + Period:LC2	6	341.8	3.9
fit8	FishHg ~ Period + LC + LC2 + Period:LC + Period:LC2	7	342.7	4.8
fit1	FishHg ~ LC	3	403.7	65.7
fit2	FishHg ~ LC + LC2	4	404.4	66.4
fit0	FishHg ~ Period	3	713.0	375.0

[1] LC=length centered on standard size; LC2=LC^2

Table 3-11. Outlier and high leverage data points excluded from the baseline period assessment of Mountain Whitefish mercury concentrations.

Waterbody	Year.Caught	FishID	SectionID	Sp	FL.mm	Wt.g	Hg.ppm.ww	StudRes	CooksD	OutType[1]
Peace River	2018	426	Section 3	MW	415	772	0.015554	4.262	0.038	Outlier

[1] Outlier types: 'Outlier' = studentized residual > 4; 'High Leverage' = Cook's distance > 0.5.

Table 3-12. Comparison of final model fit results for the baseline period assessment of length-mercury relationship by year for Mountain Whitefish.

Fit	Model[1]	Df	AICc	Delta
fit3	FishHg ~ Period + LC	4	320.2	0.0
fit5	FishHg ~ Period + LC + Period:LC	5	321.2	1.0
fit4	FishHg ~ Period + LC + LC2	5	321.9	1.8
fit6	FishHg ~ Period + LC + LC2 + Period:LC	6	322.8	2.7
fit7	FishHg ~ Period + LC + LC2 + Period:LC2	6	324.0	3.8
fit8	FishHg ~ Period + LC + LC2 + Period:LC + Period:LC2	7	324.6	4.4
fit1	FishHg ~ LC	3	390.4	70.2
fit2	FishHg ~ LC + LC2	4	390.9	70.7
fit0	FishHg ~ Period	3	709.5	389.3

[1] LC=length centered on standard size; LC2=LC^2

Table 3-13. Model results for the baseline period assessment of Mountain Whitefish mercury concentrations.

Predictor	Estimate	95% CI[1]	p-value
(Intercept)	-3.476	-3.582, -3.370	<0.001
Period			
2010-2011	—	—	
2017-2020	0.5185	0.4041, 0.6329	<0.001
LC	0.0062	0.0058, 0.0067	<0.001

[1] CI = Confidence Interval

Model: FishHg ~ Period + LC

Overall Results: $F(2,352)=379$; Adjusted $R^2 = 0.683$; N = 355

Figure 3-1. Length Frequency and age frequency for Mountain Whitefish (MW) by location across all years (2010 – 2020)

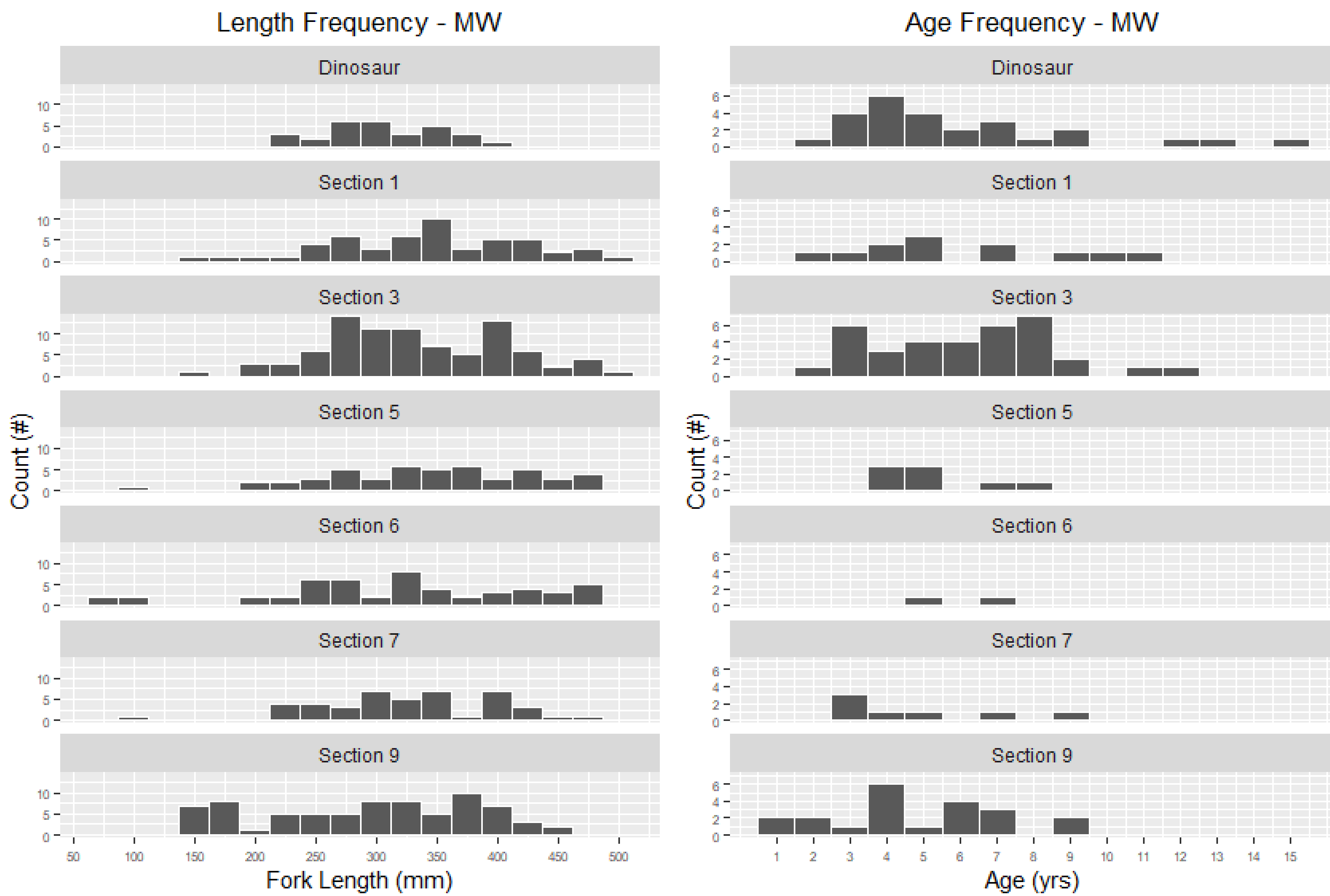


Figure 3-2. Key mercury-related relationships for Mountain Whitefish (MW) across all years (2010 – 2020). Red circles indicate length-weight outliers.

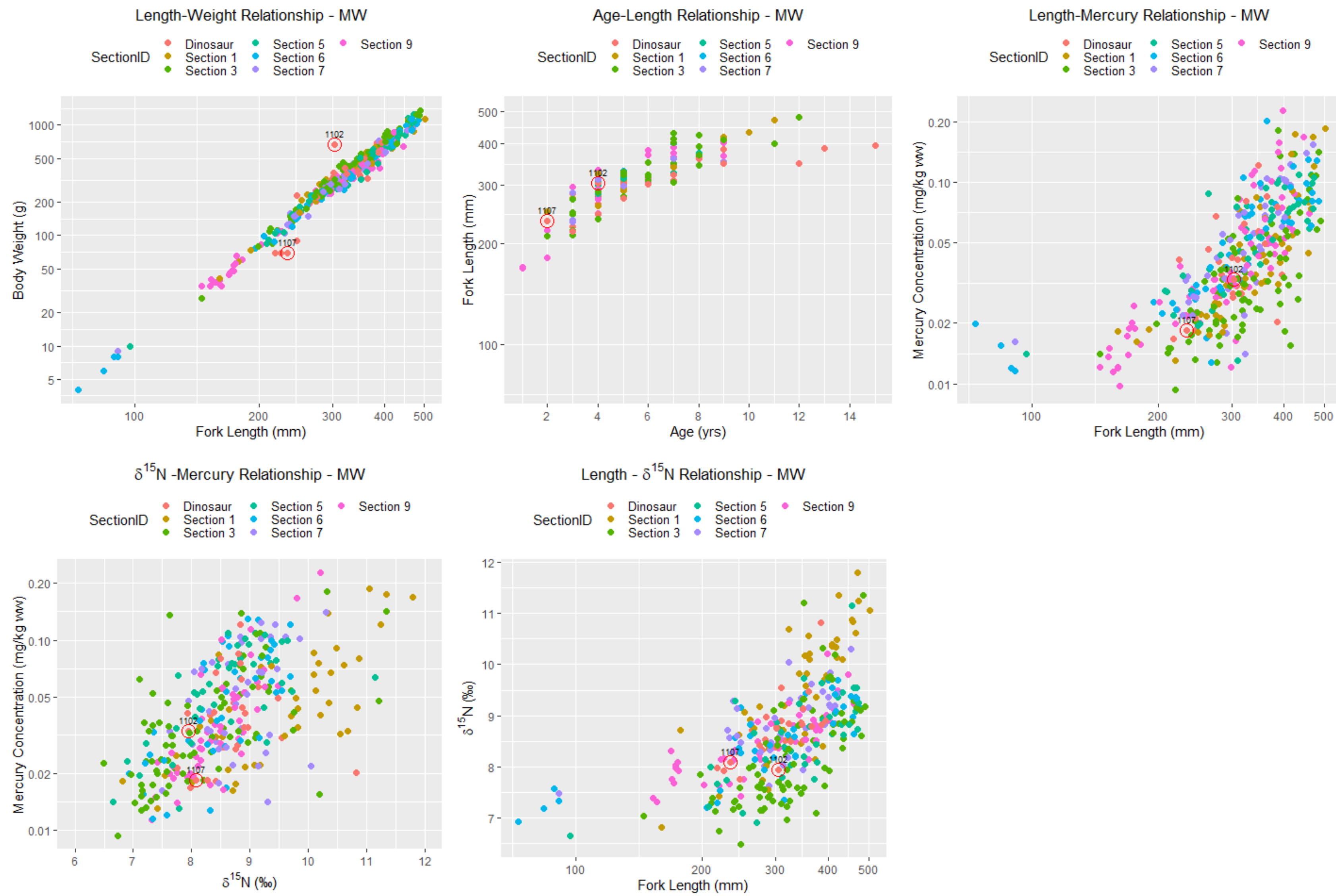


Figure 3-3. Initial model fit results and identified outliers for the temporal assessment of Mountain Whitefish mercury concentrations for Section 3 (2010 – 2020)

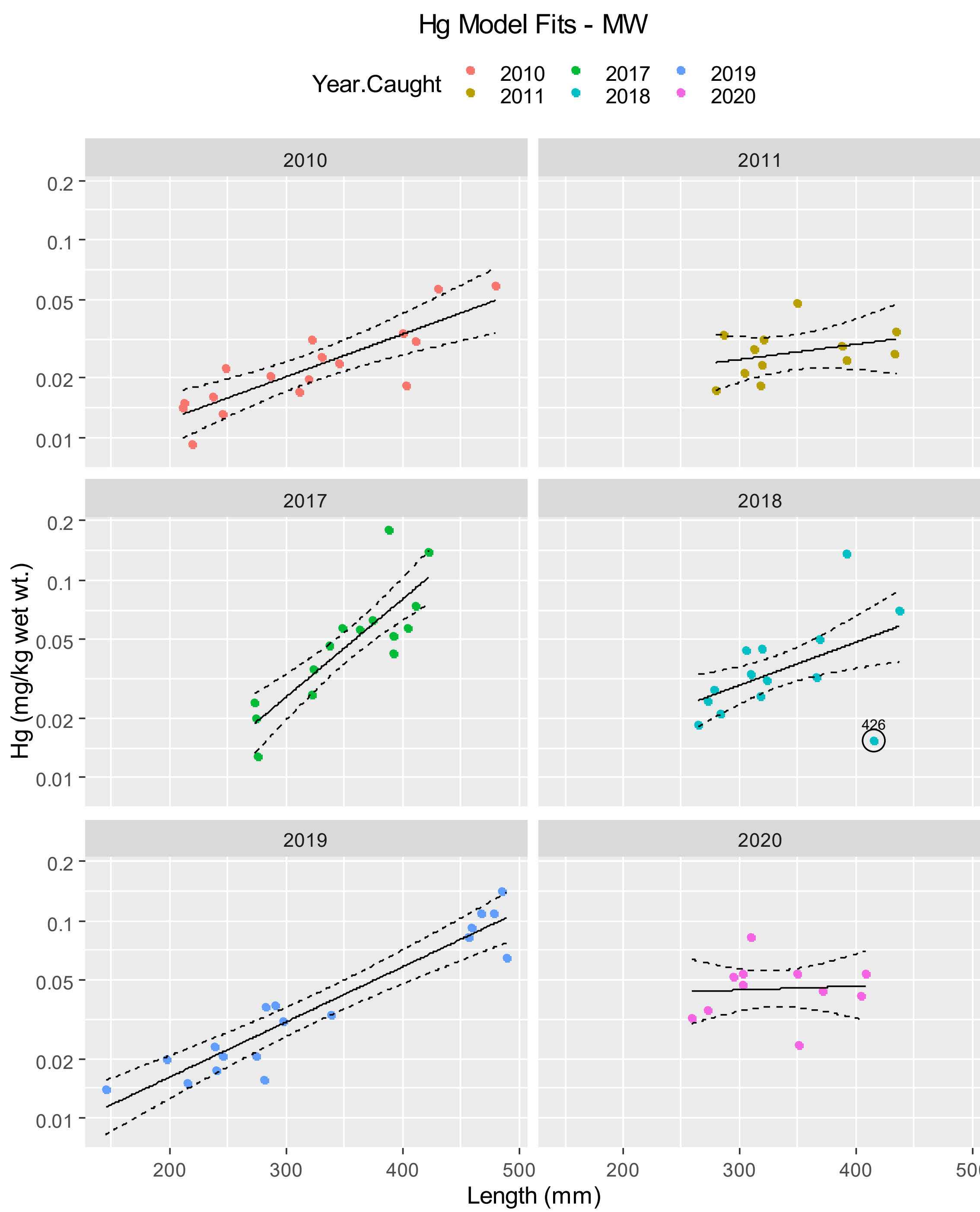


Figure 3-4. Final model fit results for the temporal assessment of Mountain Whitefish mercury concentrations for Section 3.

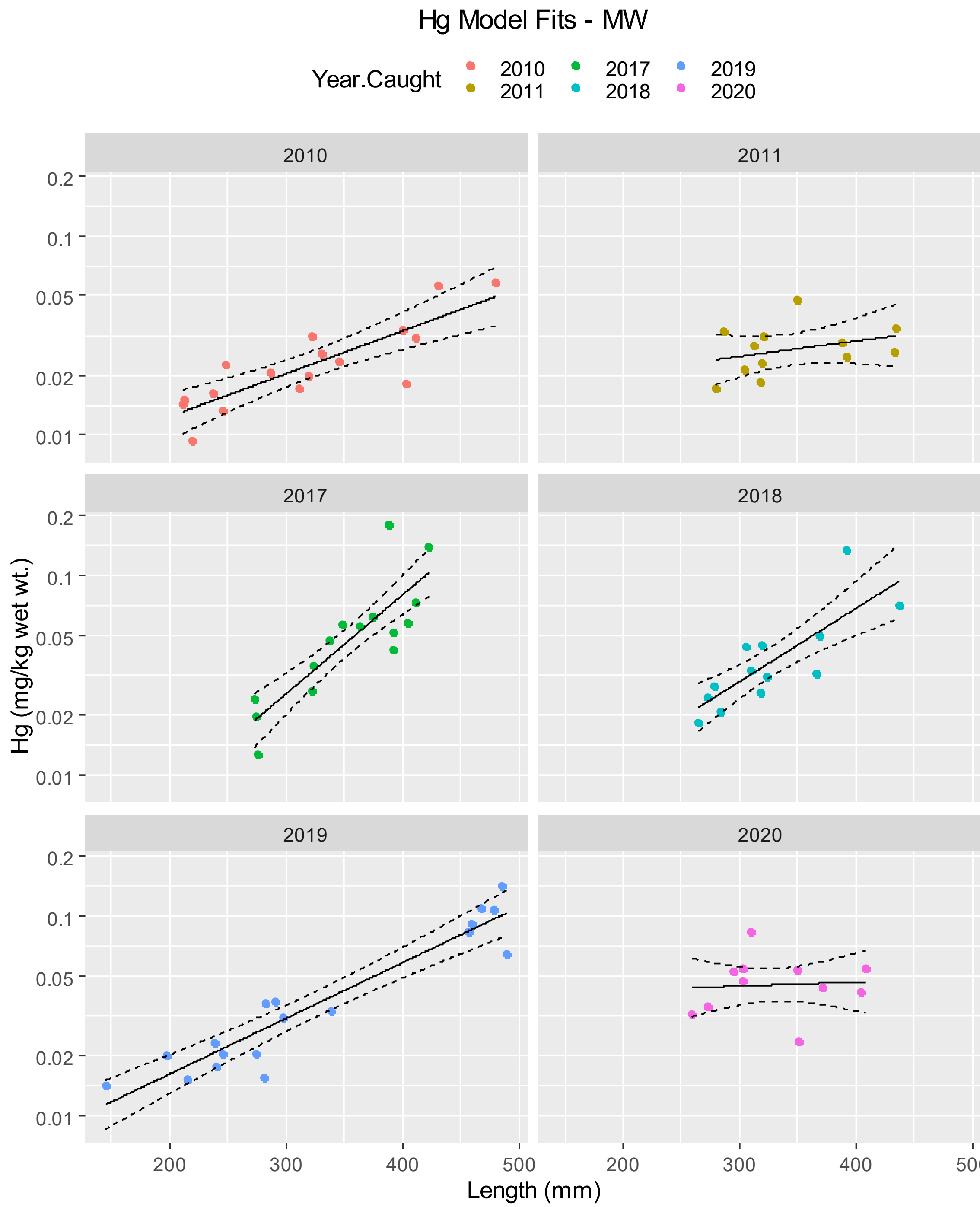
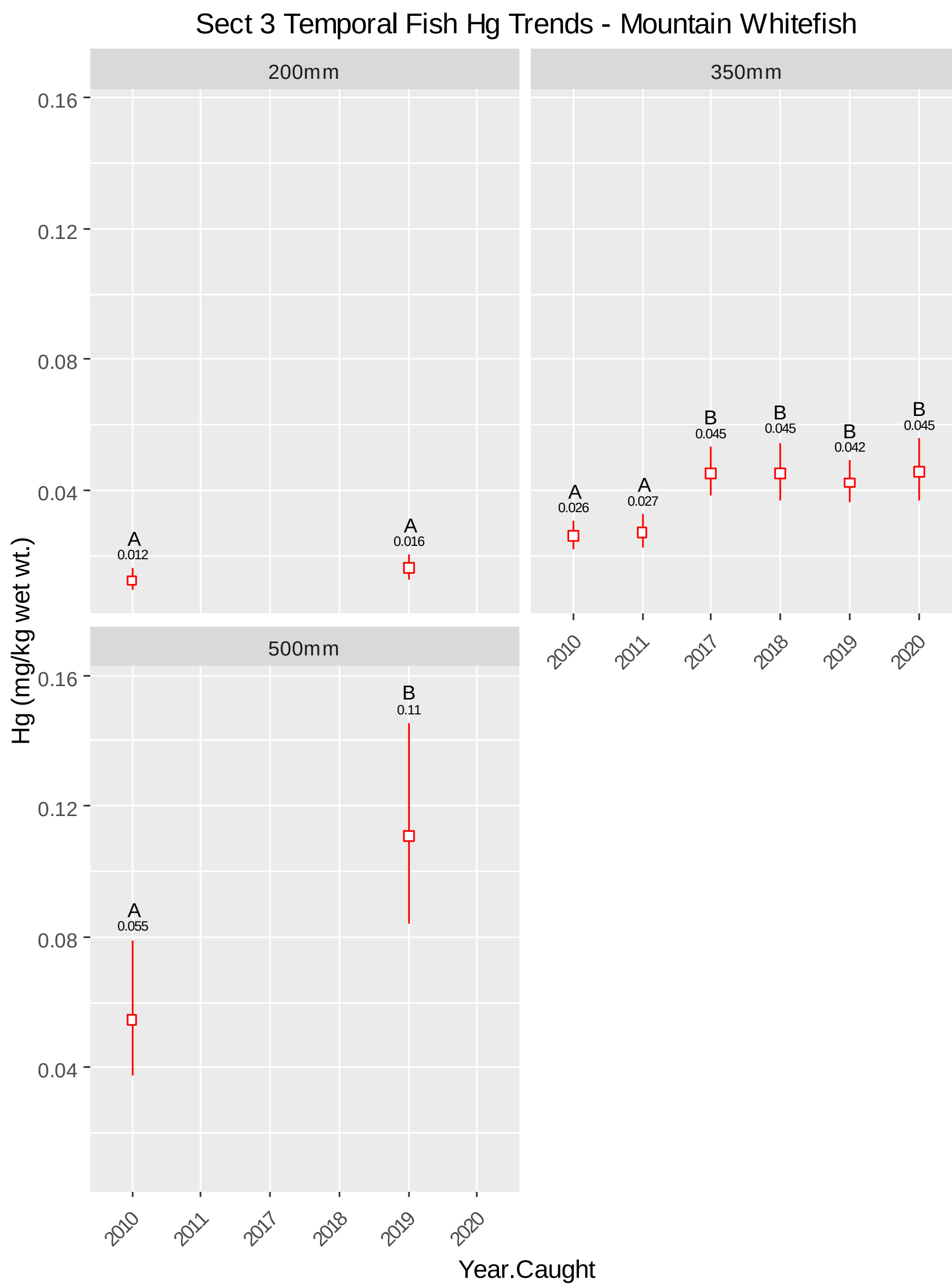


Figure 3-5. Estimated mercury concentrations (and 95% confidence intervals) for select sizes (200 mm, 350 mm, 500 mm) for each year in the temporal assessment of Mountain Whitefish mercury concentrations for Section 3.



Note: Letters above estimates show which are not statistically different from one another (same letters) or which are statistically different (different letters); combinations (e.g., "AB") show estimates that are not statistically different from other groups that are different (e.g., "A" and "B").

Figure 3-6. Initial model fit results and identified outliers for the spatial assessment of Mountain Whitefish mercury concentrations across Peace River locations for the recent baseline period (2017 – 2020).

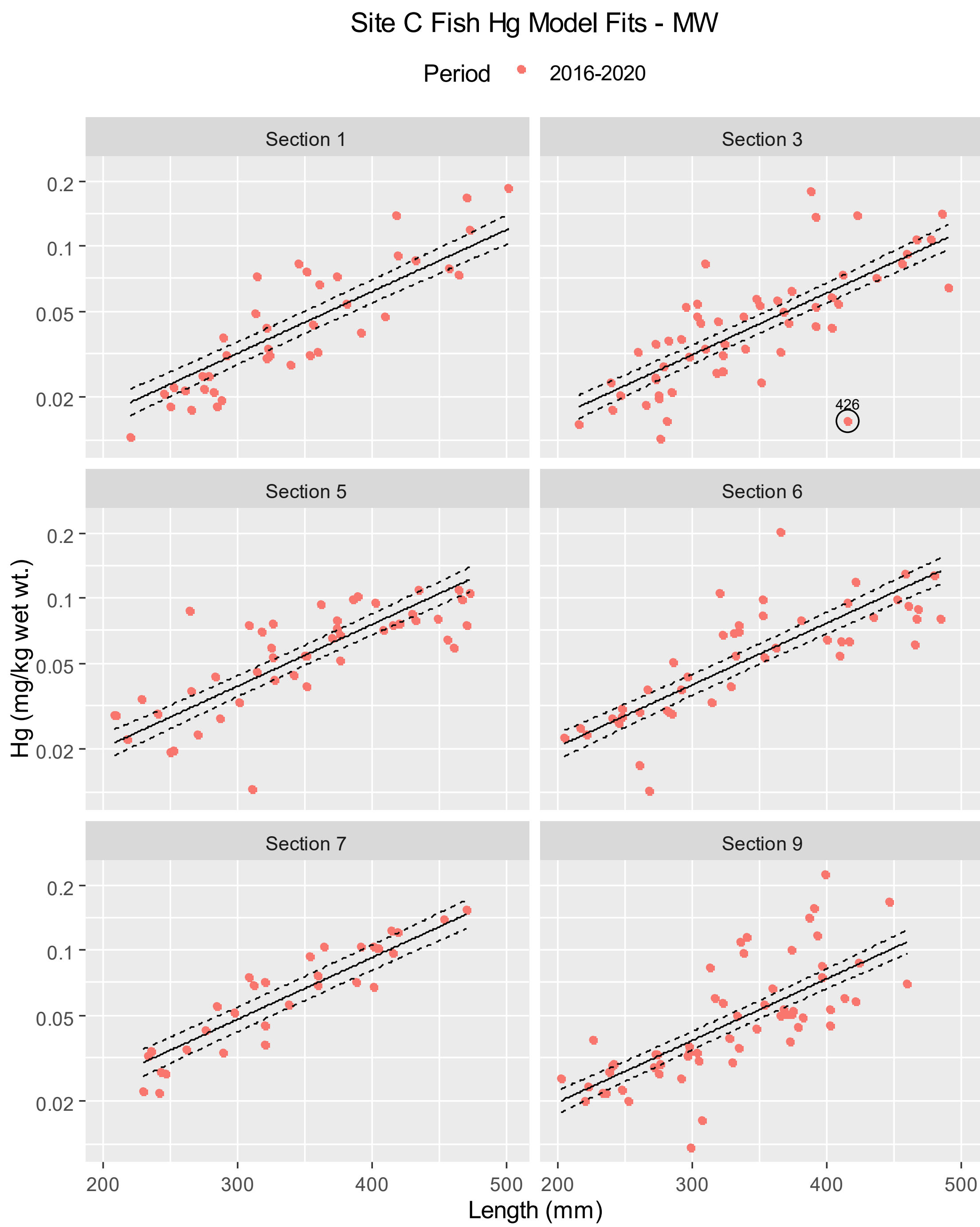


Figure 3-7. Final model fit results for the spatial assessment of Mountain Whitefish mercury concentrations across Peace River locations for the recent baseline period (2017 – 2020).

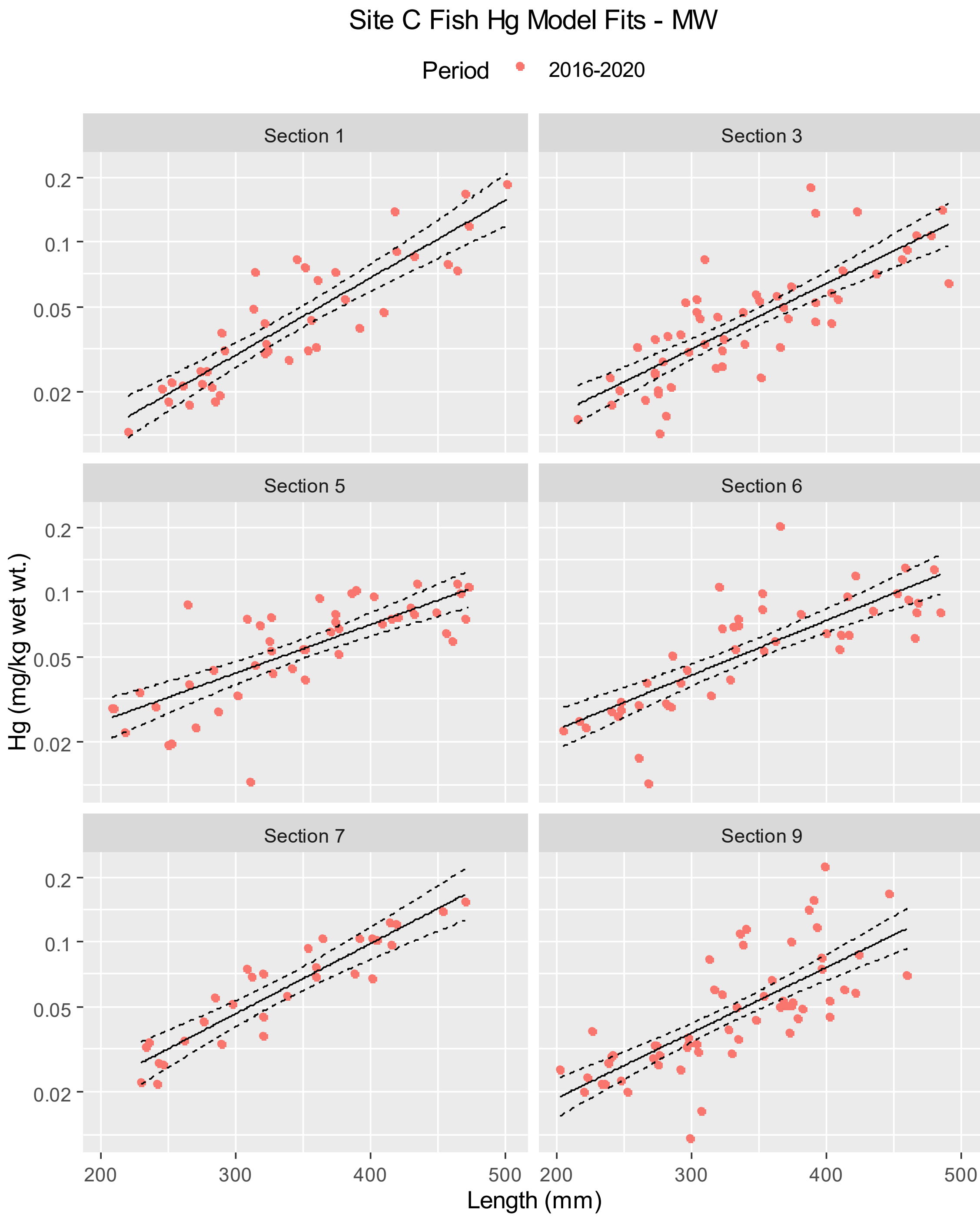
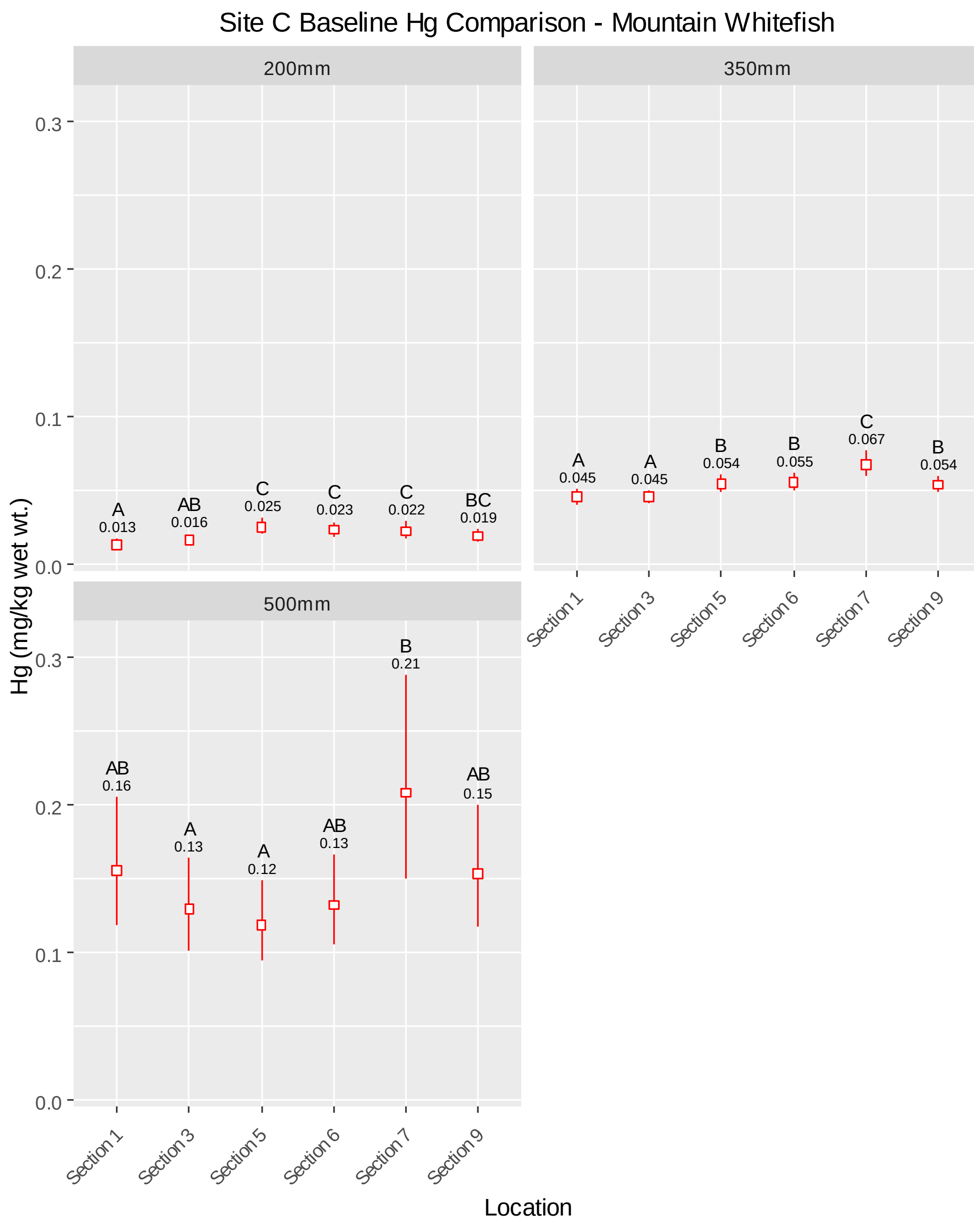


Figure 3-8. Estimated mercury concentrations (and 95% confidence intervals) for select sizes (200 mm, 350 mm, 500 mm) across Peace River sites in the spatial assessment of Mountain Whitefish mercury concentrations across the recent baseline period (2017 – 2020)



Note: Letters above estimates show which are not statistically different from one another (same letters) or which are statistically different (different letters); combinations (e.g., "AB") show estimates that are not statistically different from other groups that are different (e.g., "A" and "B").

Figure 3-9. Initial model fit results and identified outliers for the baseline period assessment of Mountain Whitefish mercury concentrations across Peace River locations.

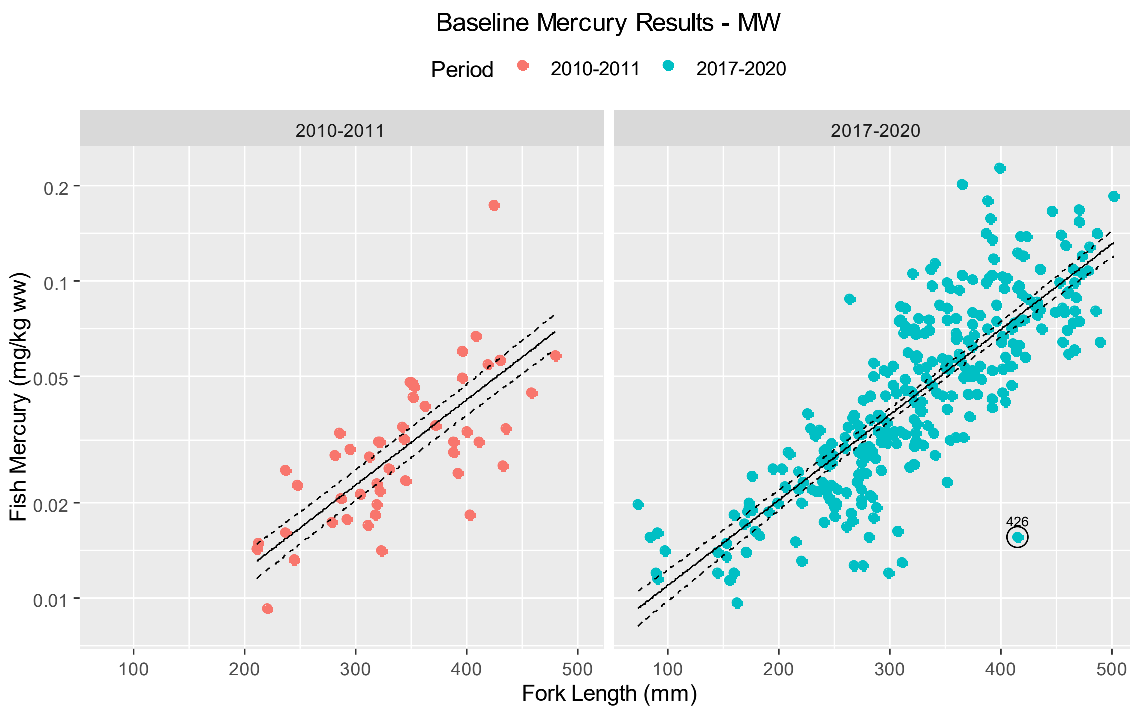


Figure 3-10. Final model fit results for the baseline period assessment of Mountain Whitefish mercury concentrations across Peace River locations.

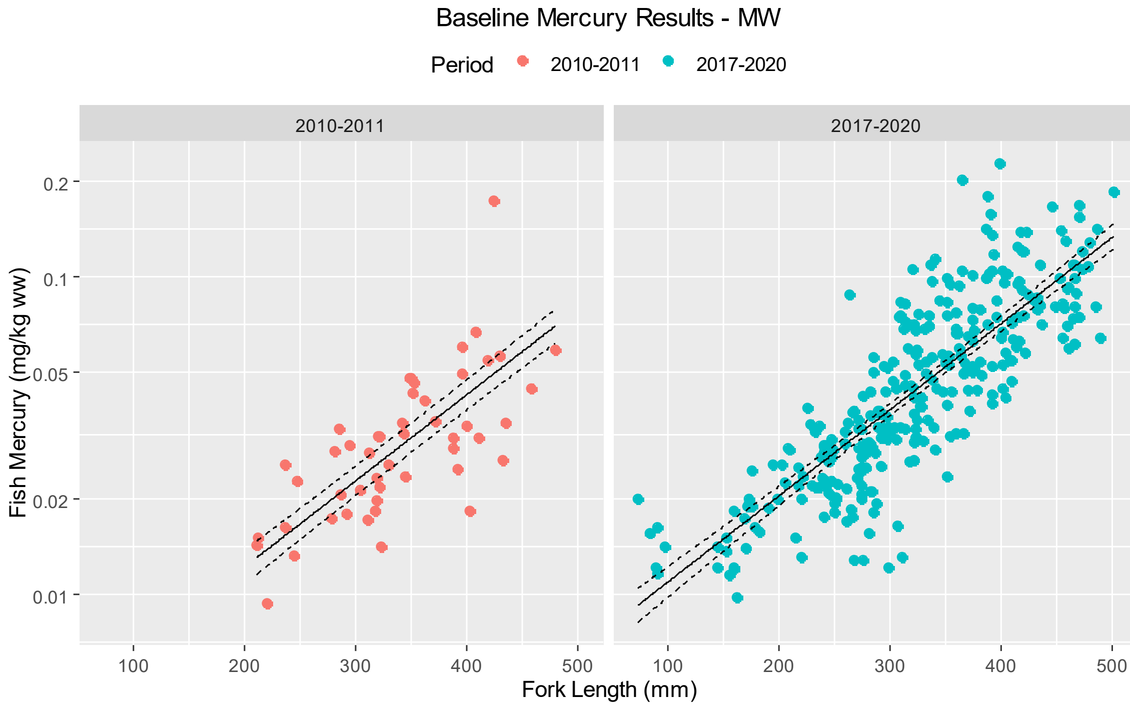
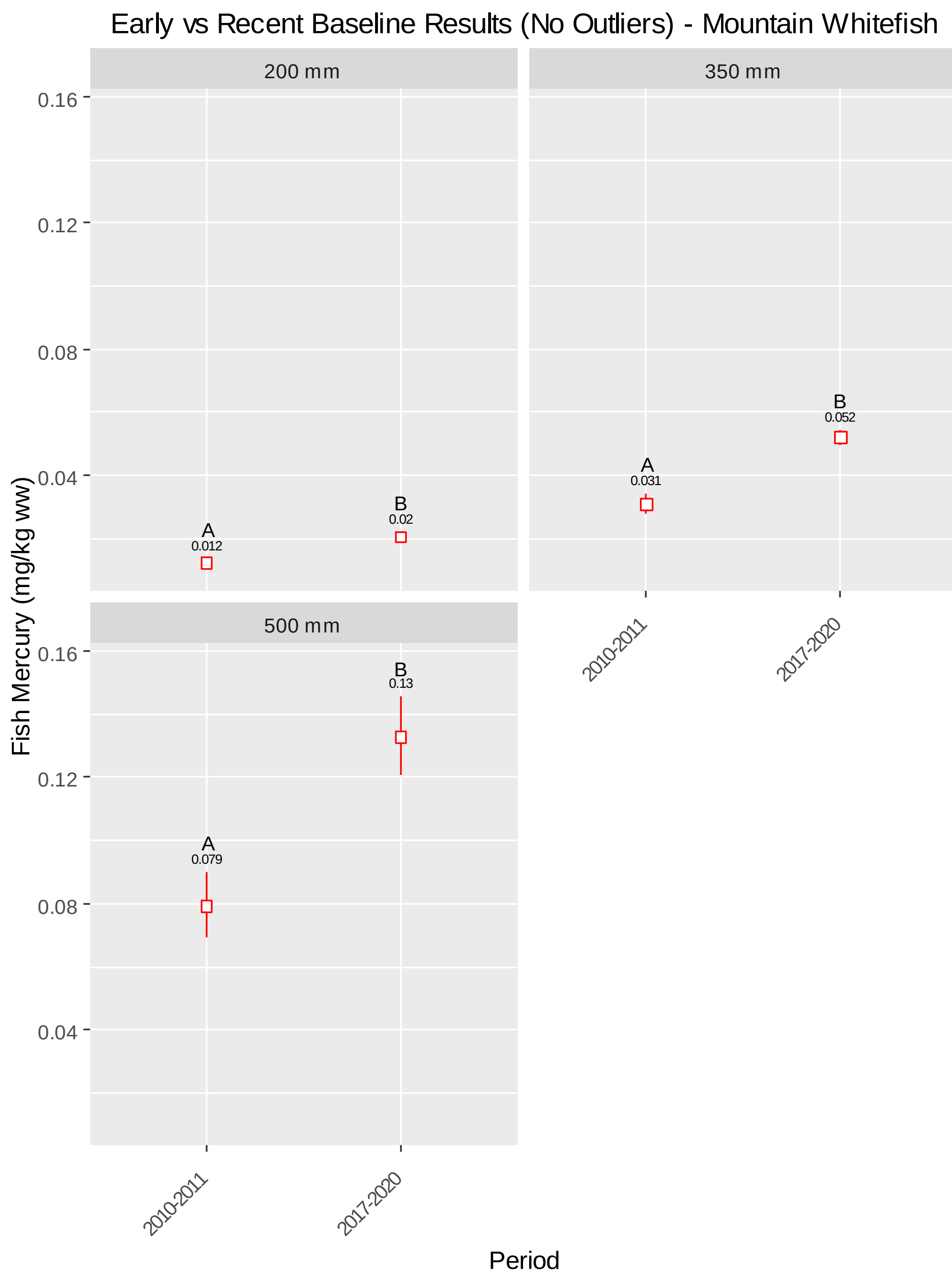


Figure 3-11. Estimated mercury concentrations (and 95% confidence intervals) for select sizes (200 mm, 350 mm, 500 mm) for each year in the baseline period assessment of Mountain Whitefish mercury concentrations across Peace River locations.



Note: Letters above estimates show which are not statistically different from one another (same letters) or which are statistically different (different letters); combinations (e.g., “AB”) show estimates that are not statistically different from other groups that are different (e.g., “A” and “B”).

4 RAINBOW TROUT

Temporal Assessment

The temporal assessment was conducted to determine whether there were any changes in the length-mercury relationship for Rainbow Trout across sampling years. To control for potential spatial trends the analysis was limited to Section 1, which had three years (2010, 2017, and 2018) with 5 or more samples, with a total of 26 samples across all years (see Rainbow Trout section of main report for catch details by location/year). While Dinosaur Reservoir and Section 3 also had three years of data each, Section 1 was the only location that was in the Peace River and had data spanning the early and recent baseline sampling periods.

Key information on the modelling and associated results were as follows:

- *Transformations* – Mercury concentrations were log-transformed.
- *Initial Model Selection* – The suite of temporal models (**Table 1-1**) was initially run with all the data. Fit1 had the lowest AICc value (**Table 4-2**), was selected for use, and has the following structure (linear model with year-specific intercepts and slopes):

  Log Hg ~ Length

- *Outliers/High Leverage Data* – No outliers or high leverage points were identified.
- *Final Model Selection* – As no outliers or high-leverage points were identified, fit1 using all data was used to characterize the length-mercury relationship.
- *Fitted length-mercury Relationships* – Final model results are shown in **Figure 4-3** and summarized in **Table 4-3**. The model fits generally show positive relationships between length and mercury concentrations. Model residuals were visually examined and confirmed a reasonable fit. The model had an adjusted R2 of 0.35 and showed no statistically significant differences in Rainbow Trout mercury concentrations among years.
- *Predicted Mercury Concentrations for Standard Sized Fish by Year* – Using the length-mercury model shown above, and where the underlying data supported making a prediction, tissue mercury concentrations were estimated for three standard fish sizes: 200 mm, 350 mm and 500 mm. The predictions (and their 95% confidence limits) were made for fish size only as year caught was not in the final model (**Figure 4-4**). The results show that Rainbow Trout mercury concentrations have a positive relationship with length, but that concentrations were generally similar across years.

Spatial Assessment

The spatial assessment was conducted to determine whether there are differences in the length-mercury relationship for Rainbow Trout among sampling locations. While no temporal changes were identified in the previous analysis, the spatial assessment was limited to the recent time period only. Two sampling locations (Sections 1 and 3) had 16 or more samples across the recent sampling period (2017 to 2020), with a total of 53 samples; (see Rainbow Trout section of main report for catch details by location/year).

Key information on the spatial modelling and associated results were as follows:

- *Transformations* – Mercury concentrations were log-transformed.
- *Initial Model Selection* – The suite of spatial models (**Table 1-2**) was initially run with all the data. Fit1 had the lowest AICc value (**Table 4-4**), was selected for use, and has the following structure (linear model with year-specific intercepts and slopes):

  Log Hg ~ Length

- *Outliers/High Leverage Data* – No outliers or high leverage points were identified.
- *Final Model Selection* – As no outliers or high-leverage points were identified, fit1 using all data was used to characterize the length-mercury relationship.
- *Fitted length-mercury Relationships* – Final model results are shown in **Figure 4-5** and summarized in **Table 4-5**. The model fits generally show strong positive relationships between length and mercury concentrations. Model residuals were visually examined and indicated that the fit was good. The model had an adjusted R2 of 0.40 and showed statistically significant differences in Rainbow Trout mercury concentrations among locations.
- *Predicted Mercury Concentrations for Standard Sized Fish by Year* – Using the length-mercury model shown above, and where the underlying data supported making a prediction, tissue mercury concentrations were estimated for three standard fish sizes: 200 mm, 350 mm and 500 mm. The predictions (and their 95% confidence limits) were only made for the three standard fish sizes as there were no differences predicted in fish tissue mercury concentrations among locations for the recent period (2017 – 2020) (**Figure 4-6**).

Baseline Period Assessment

This analysis was conducted to characterize potential differences between the early and recent baseline monitoring periods, with the latter information being used to support the development of fish consumption advice based on current conditions. The analysis included 70 samples, with 10 from the early baseline period and 60 from the recent period (see Rainbow Trout section of main report for catch details by location/year).

Key information on the modelling and associated results were as follows:

- *Transformations* – Mercury concentrations were log-transformed.
- *Initial Model Selection* – The suite of baseline period models (**Table 1-3**) was initially run with all the data. Fit1 had the lowest AICc value (**Table 4-6**), was selected for use, and has the following structure (linear model with year-specific intercepts and slopes):

  Log Hg ~ Length

- *Outliers/High Leverage Data* – No outliers or high leverage points were identified.
- *Final Model Selection* – As no outliers or high-leverage points were identified, fit1 using all data was used to characterize the length-mercury relationship.
- *Fitted length-mercury Relationships* – Final model results are shown in **Figure 4-7** and summarized in **Table 4-7**. The model fits generally show strong positive relationships between length and mercury concentrations. Model residuals were visually examined and indicated that the fit was good. The model had an adjusted R2 of 0.38 and showed statistically significant differences in Rainbow Trout mercury concentrations among periods.
- *Predicted Mercury Concentrations for Standard Sized Fish by Period* – Using the length-mercury model shown above, and where the underlying data supported making a prediction, tissue mercury concentrations were estimated for three standard fish sizes: 400 mm, 550 mm and 700 mm. As baseline sampling period did not prove to be a meaningful model parameter (i.e., no statistically significant differences were observed between periods), predictions (and their 95% confidence limits) were only made for the three standard fish sizes (**Figure 4-8**). Thus, the results show that Rainbow Trout mercury concentrations were similar between the early period (2010-2011) and the recent baseline period (2017 – 2020).

Table 4-1. Fish formally identified as outliers in length-weight (L-W), length-mercury (L-Hg) and/or mercury-nitrogen isotope (Hg-dN) relationships.

Waterbody	Year.Caught	FishID	SectionID	Sp	FL.mm	Wt.g	Hg.ppm.ww	Relationship	Outcome
Peace River	2018	581	Section 1	RB	264	224	0.3476000	NA,L-Hg,Hg-dN	excluded
Peace River	2017	140	Section 3	RB	370	528	0.0042900	NA,L-Hg,NA	excluded
Dinosaur Reservoir	2016	RNBW-TW-02	Dinosaur	RB	326	180	0.0233200	L-W,NA,NA	retained
Dinosaur Reservoir	2016	RNBW-TW-05	Dinosaur	RB	234	50	0.0311588	L-W,NA,NA	retained

Table 4-2. Comparison of final model fit results for the temporal assessment of length-mercury relationship by year for Rainbow Trout.

Fit	Model[1]	Df	AICc	Delta
fit1	FishHg ~ LC	3	22.6	0.0
fit2	FishHg ~ LC + LC2	4	25.2	2.6
fit3	FishHg ~ Year.Caught + LC	5	25.9	3.3
fit4	FishHg ~ Year.Caught + LC + LC2	6	29.4	6.8
fit0	FishHg ~ Year.Caught	4	33.0	10.5
fit5	FishHg ~ Year.Caught + LC + Year.Caught:LC	7	33.2	10.6
fit6	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC	8	37.6	15.0
fit7	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC2	8	37.6	15.0
fit8	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC + Year.Caught:LC2	10	46.9	24.3

[1] LC=length centered on standard size; LC2=LC^2

Table 4-3. Final model results for the temporal assessment of Rainbow Trout mercury concentrations.

Predictor	Estimate	95% CI[1]	p-value
(Intercept)	-3.568	-3.724, -3.412	<0.001
LC	0.0041	0.0017, 0.0065	0.002

[1] CI = Confidence Interval

Model: FishHg ~ LC

Overall Results: $F(1,23)=12$; Adjusted R^2 = 0.348; N = 25.0

Table 4-4. Comparison of final model fit results for the spatial assessment of length-mercury relationship by location for Rainbow Trout.

Fit	Model[1]	Df	AICc	Delta
fit1	FishHg ~ LC	3	34.7	0.0
fit3	FishHg ~ Location + LC	4	36.9	2.3
fit2	FishHg ~ LC + LC2	4	37.0	2.3
fit5	FishHg ~ Location + LC + Location:LC	5	38.3	3.7
fit4	FishHg ~ Location + LC + LC2	5	39.3	4.7
fit6	FishHg ~ Location + LC + LC2 + Location:LC	6	40.6	6.0
fit7	FishHg ~ Location + LC + LC2 + Location:LC2	6	41.7	7.1
fit8	FishHg ~ Location + LC + LC2 + Location:LC + Location:LC2	7	42.0	7.3
fit0	FishHg ~ Location	3	61.1	26.4

[1] LC=length centered on standard size; LC2=LC^2

Table 4-5. Final model results for the spatial assessment of Rainbow Trout fish mercury concentrations.

Predictor	Estimate	95% CI[1]	p-value
(Intercept)	-3.617	-3.707, -3.527	<0.001
LC	0.0041	0.0027, 0.0055	<0.001

[1] CI = Confidence Interval

Model: FishHg ~ LC

Overall Results: $F(1,51)=34$; Adjusted $R^2 = 0.397$; N = 53.0

Table 4-6. Comparison of final model fit results for the baseline period assessment of length-mercury relationship by sampling period for Rainbow Trout.

Fit	Model[1]	Df	AICc	Delta
fit1	FishHg ~ LC	3	53.1	0.0
fit3	FishHg ~ Period + LC	4	53.2	0.1
fit2	FishHg ~ LC + LC2	4	55.0	2.0
fit4	FishHg ~ Period + LC + LC2	5	55.3	2.2
fit5	FishHg ~ Period + LC + Period:LC	5	55.4	2.3
fit7	FishHg ~ Period + LC + LC2 + Period:LC2	6	57.3	4.3
fit6	FishHg ~ Period + LC + LC2 + Period:LC	6	57.5	4.4
fit8	FishHg ~ Period + LC + LC2 + Period:LC + Period:LC2	7	59.8	6.7
fit0	FishHg ~ Period	3	83.3	30.3

[1] LC=length centered on standard size; LC2=LC^2

Table 4-7. Final model results for the baseline period assessment of Rainbow Trout fish mercury concentrations.

Predictor	Estimate	95% CI[1]	p-value
(Intercept)	-3.384	-3.477, -3.291	<0.001
LC	0.0041	0.0028, 0.0054	<0.001

[1] CI = Confidence Interval

Model: FishHg ~ LC

Overall Results: $F(1,68)=41$; Adjusted $R^2 = 0.376$; N = 70.0

Figure 4-1. Length Frequency and age frequency for Rainbow Trout (RB) by location across all years (2010 – 2020).

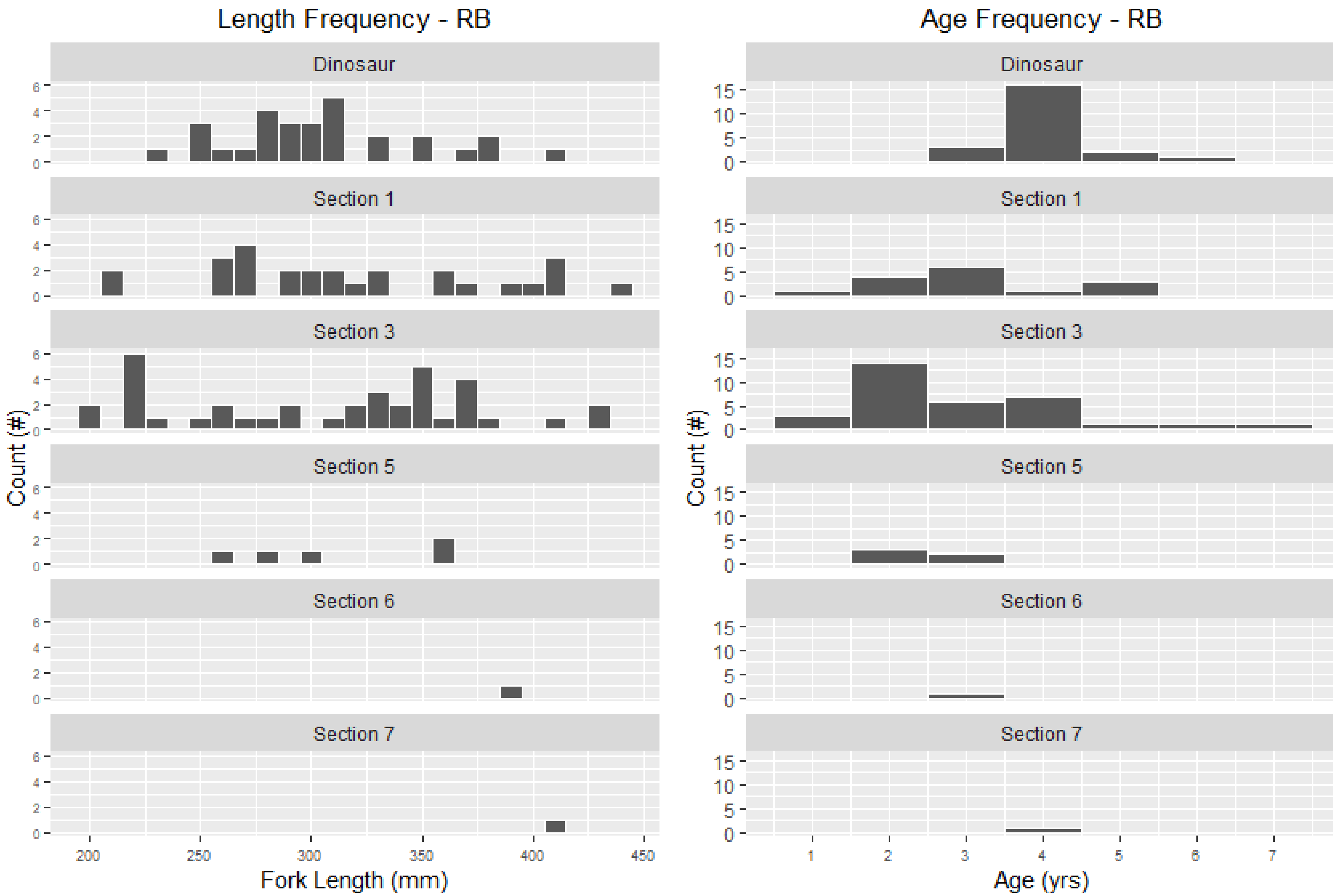


Figure 4-2. Key mercury-related relationships for Rainbow Trout (RB) across all years (2010 – 2020). Red circles indicate length-weight outliers, green circles indicate length-mercury outliers, and blue circles indicate δ15N-mercury outliers.

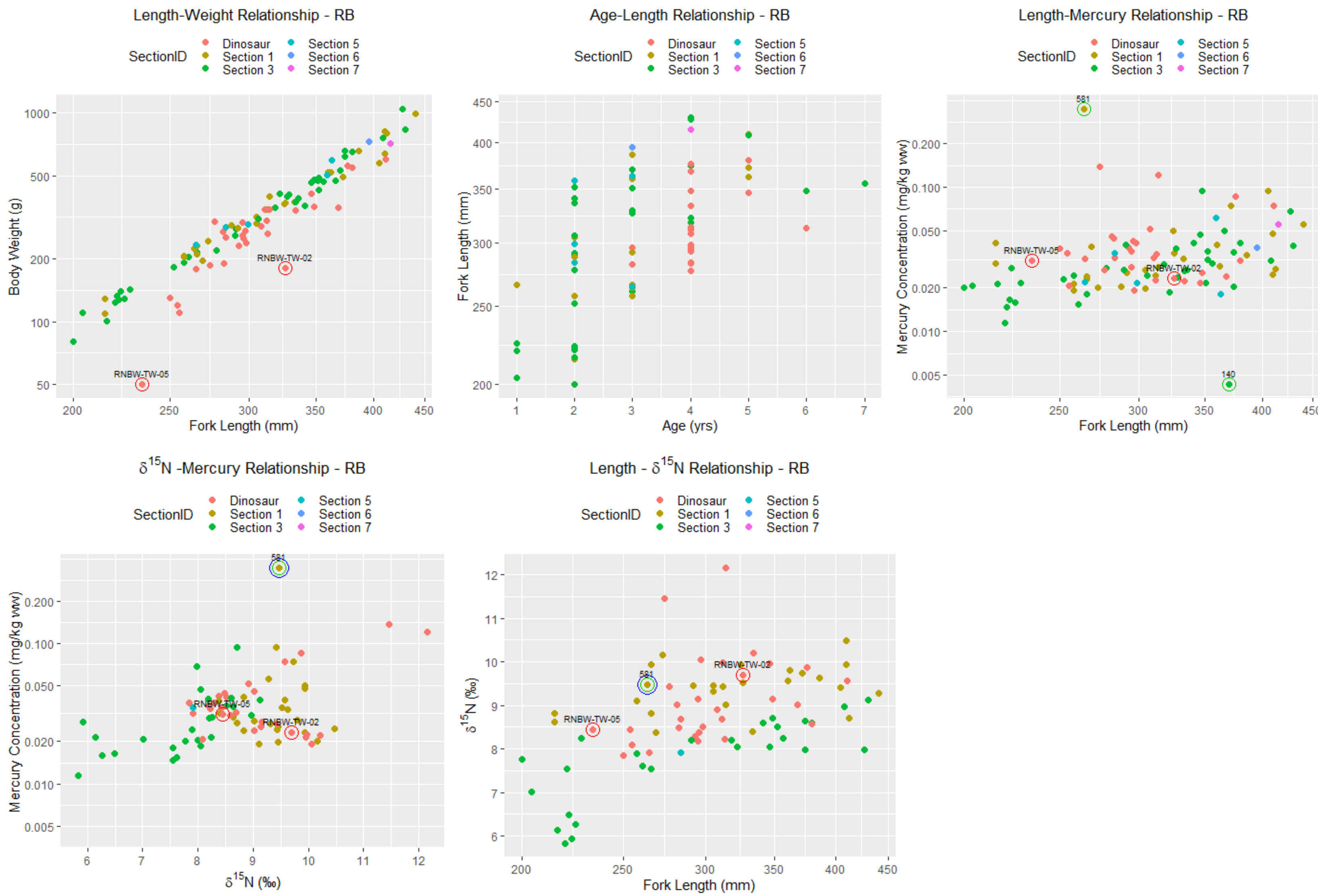
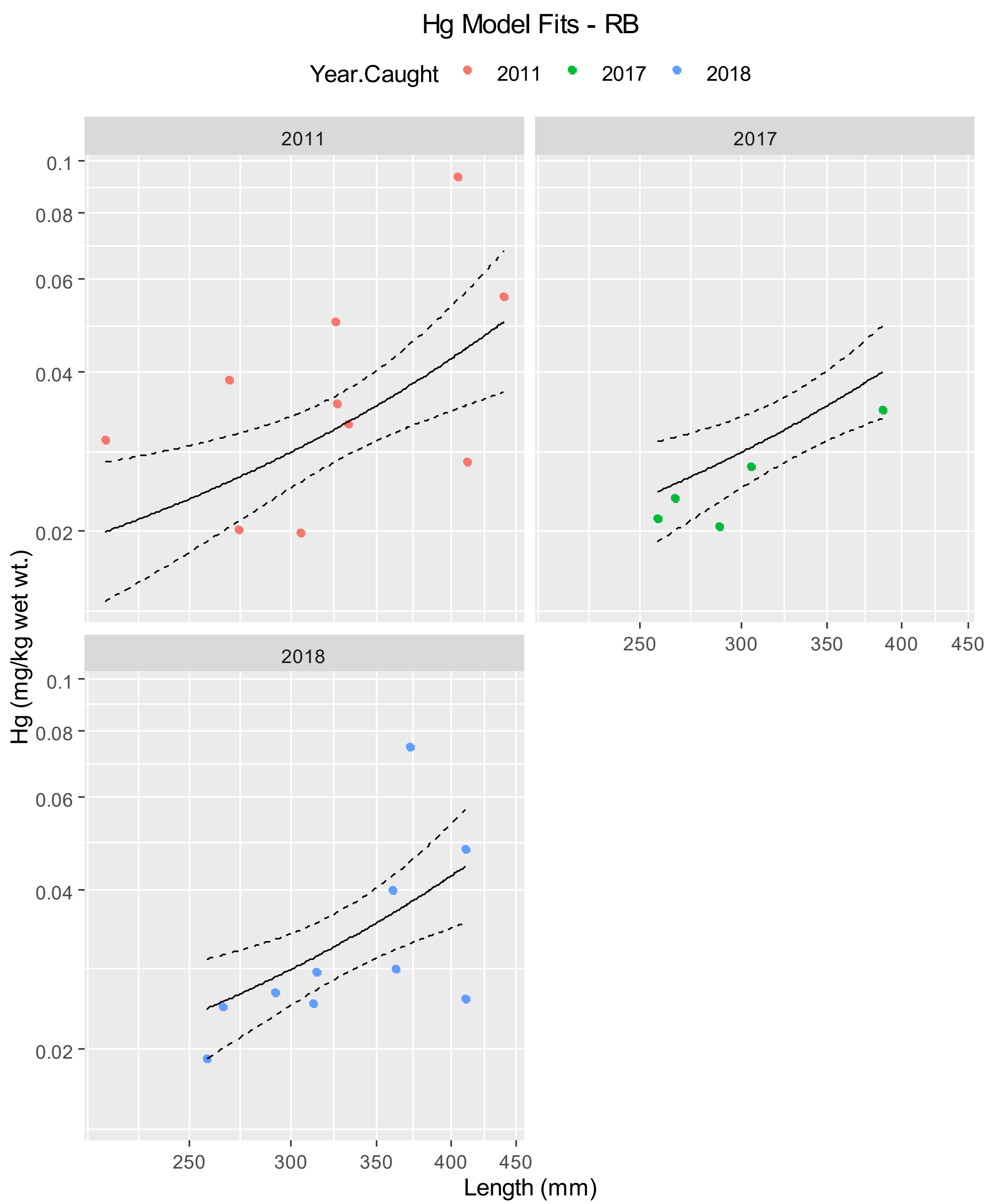
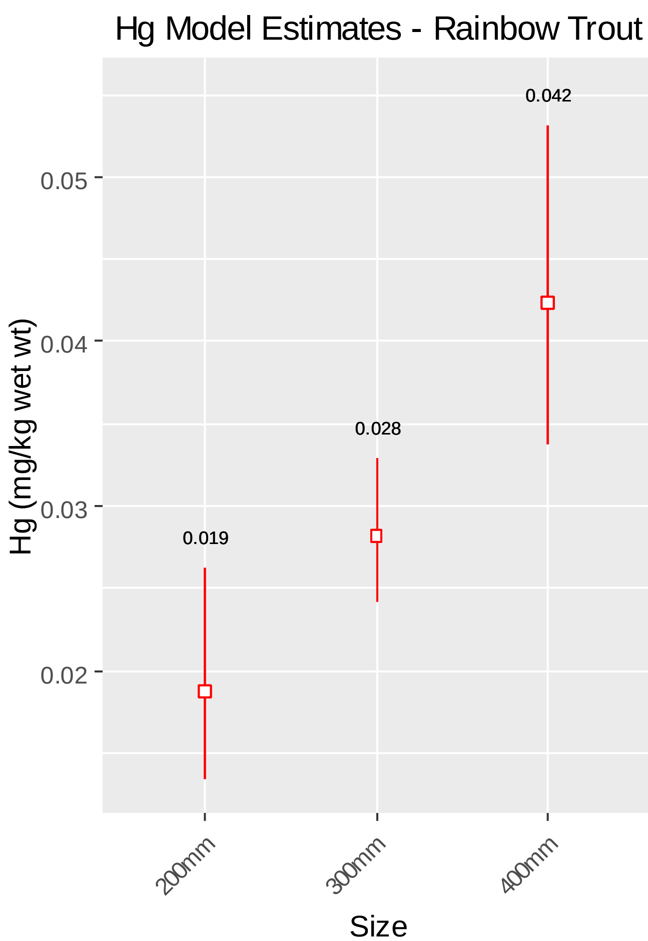


Figure 4-3. Final model fit results for the temporal assessment of Rainbow Trout mercury concentrations for Section 1 (2010, 2017, and 2018 [see note]).



Note: The best model fit (fit1) for Rainbow Trout is dependent on length only and is not improved by considering each year separately. Therefore, the linear model remains consistent across years (i.e., with the same slope and intercept across years). Only years with 5 or more samples were included

Figure 4-4. Estimated mercury concentrations (and 95% confidence intervals) for select sizes (200 mm, 300 mm, 400 mm) for each year in the temporal assessment of Rainbow Trout mercury concentrations for Section 1.



Note: The year parameter did not improve the length-mercury model, indicating no statistically significant differences in Rainbow Trout mercury concentrations across years.

Figure 4-5. Final model fit results for the spatial assessment of Rainbow Trout mercury concentrations for Sections 1 and 3 across the recent baseline period (2017 – 2020).

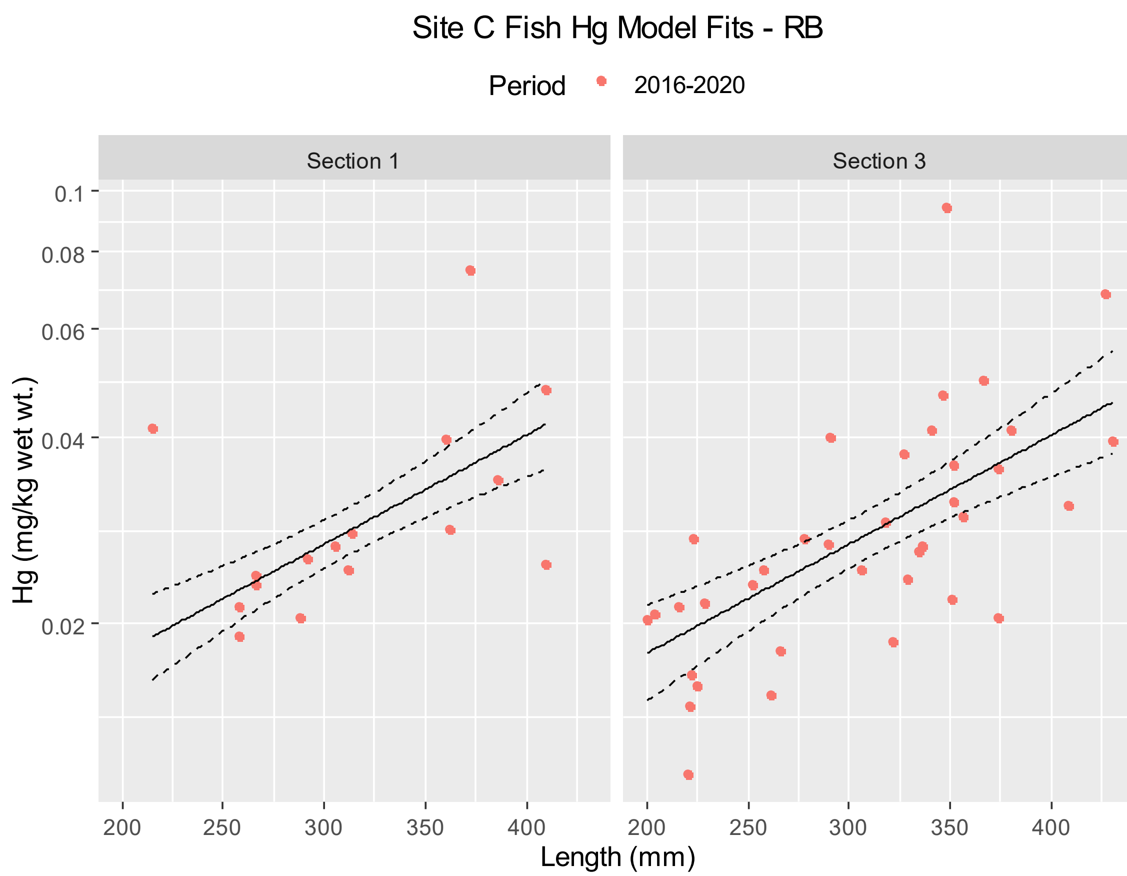
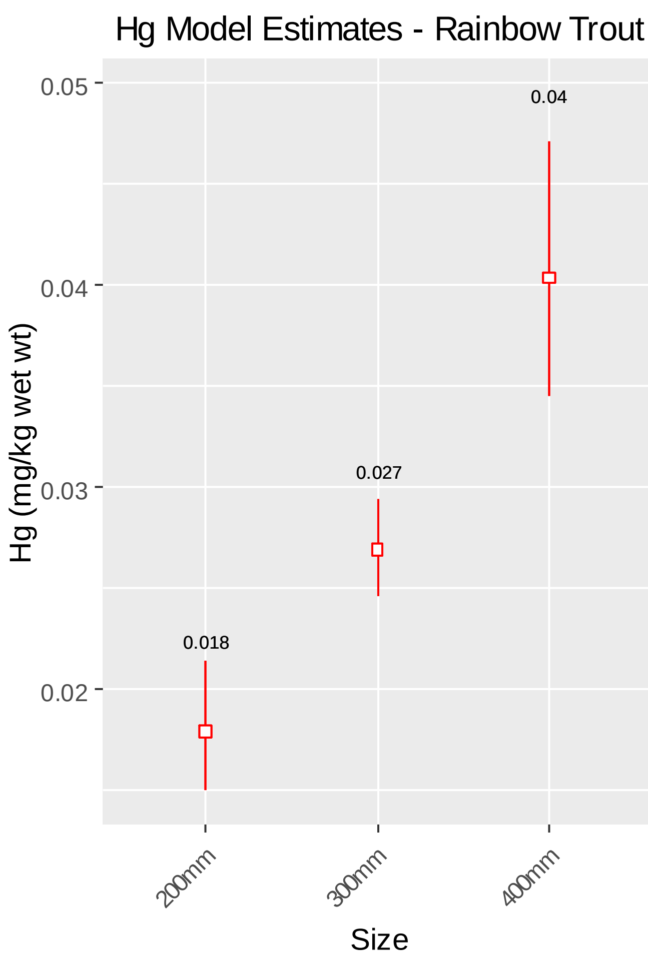


Figure 4-6. Estimated mercury concentrations (and 95% confidence intervals) for select sizes (200 mm, 300 mm, 400 mm) for Sites 1 and 3 in the spatial assessment of Rainbow Trout mercury concentrations using recent baseline data (2017 – 2020).



Note: The location (Section) parameter did not improve the length-mercury model, indicating no statistically significant differences in RB mercury concentrations across river sections.

Figure 4-7. Final model fit results for the baseline period assessment of Rainbow Trout mercury concentrations across Peace River locations.

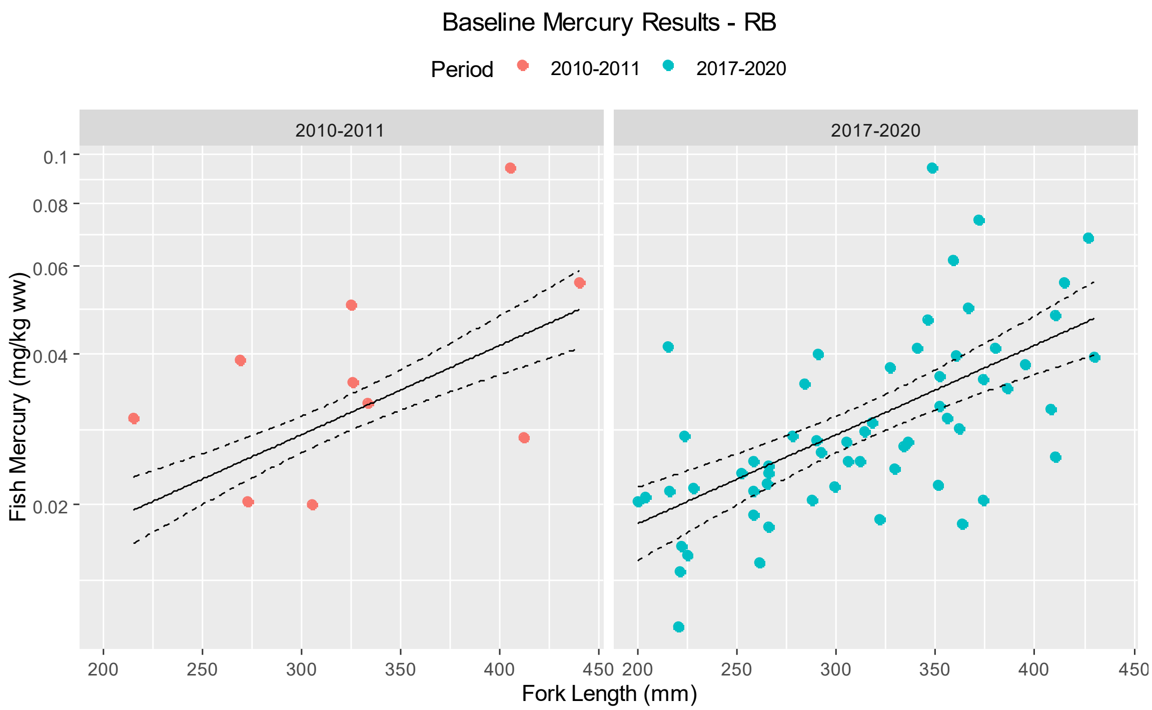
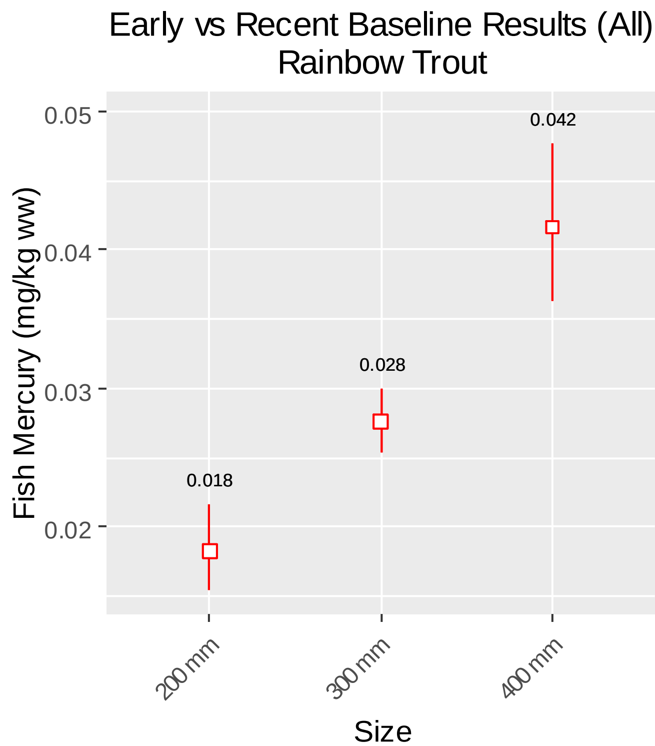


Figure 4-8. Estimated mercury concentrations (and 95% confidence intervals) for select sizes (200 mm, 300 mm, 400 mm) for each period in the baseline period assessment of Rainbow Trout mercury concentrations across Peace River locations.



Note: The period parameter did not improve the length-mercury model, indicating no statistically significant differences in RB mercury concentrations between baseline sampling periods.

5 LONGNOSE SUCKER

Temporal Assessment

The temporal assessment was conducted to determine whether there were any changes in the length-mercury relationship for Longnose Sucker across sampling years. To control for potential spatial trends the analysis was limited to Section 3, which had four years (2010, 2011, 2017, and 2018) with 10 or more samples, with a total of 70 samples across all years (see Longnose Sucker section of main report for catch details by location/year).

Key information on the modelling and associated results were as follows:

- *Transformations* – Mercury concentrations were log-transformed.
- *Initial Model Selection* – The suite of temporal models (**Table 1-1**) was initially run with all the data. Fits 4, 6, 7, 2 and 8 (all quadratic model forms) had the lowest AICc values, respectively, but all over-fit the data. Fit3 had the next lowest AICc value (**Table 5-2**), was selected for use, and has the following structure (linear model with year-specific intercepts and slopes):

  Log Hg ~ Year + Length

- *Outliers/High Leverage Data* – Formal outlier assessment of the initial fit3 run (with all data) did not identify any outliers or high leverage points in the dataset.
- *Final Model Selection* – As no outliers or high-leverage points were identified, fit3 using all data was used to characterize the length-mercury relationship.
- *Fitted length-mercury Relationships* – Final model results are shown in **Figure 5-3** and summarized in **Table 5-3**. The model fits generally show strong positive relationships between length and mercury concentrations. Model residuals were visually examined and confirmed a reasonable fit. The model had an adjusted R2 of 0.45 and showed statistically significant differences in Longnose Sucker mercury concentrations among years.

Predicted Mercury Concentrations for Standard Sized Fish by Year – Using the length-mercury model shown above, and where the underlying data supported making a prediction, tissue mercury concentrations were estimated for three standard fish sizes: 200 mm, 350 mm and 500 mm. The predictions (and their 95% confidence limits) were used to compare fish tissue mercury concentrations among years (**Figure 5-4**); statistical differences among year-size combinations determined using the selected model were annotated on the plot. The results show that

Longnose Sucker mercury concentrations were generally lower in 2010/2011 than in 2017 through 2020.

Spatial Assessment

The spatial assessment was conducted to determine whether there are differences in the length-mercury relationship for Longnose Sucker among sampling locations. Given the temporal changes identified previously, the spatial assessment was limited to the recent time period only. Six sampling locations (Sections 1, 3, 5, 6, 7, and 9) had 10 or more samples across the recent sampling period (2017 to 2020), with a total of 262 samples; (see Longnose Sucker section of main report for catch details by location/year**)**.

Key information on the spatial modelling and associated results were as follows:

- *Transformations* – Mercury concentrations were log-transformed.
- *Initial Model Selection* – The suite of spatial models (**Table 1-2**) was initially run with all the data. Fits 7 and 8, both quadratic model forms, had the lowest AICc values (**Table 5-4**), but over-fit the data (see **Section 1.1** for details on over-fitting). The next lowest AICc value was for fit4, which had the following model structure (quadratic model with location-specific differences in intercept):

  Log Hg ~ Location + Length + Length2

- *Outliers/High Leverage Data* – Formal outlier assessment of the initial fit4 run (with all data) identified no points as outliers or as having high leverage.
- *Final Model Selection* – Given the lack of outliers/high leverage data points, fit4 was retained to characterize the length-mercury relationship.
- *Fitted length-mercury Relationships* – Final model results are shown in **Figure 5-5** and summarized in **Table 5-5**. The model fits generally show strong positive relationships between length and mercury concentrations. Model residuals were visually examined and indicated that the fit was good. The model had an adjusted R2 of 0.52 and showed statistically significant differences in Longnose Sucker mercury concentrations among locations.
- *Predicted Mercury Concentrations for Standard Sized Fish by Year* – Using the length-mercury model shown above, and where the underlying data supported making a prediction, tissue mercury concentrations were estimated for three standard fish sizes: 200 mm, 350 mm and 500 mm. The predictions (and their 95% confidence limits) were used to compare fish tissue mercury concentrations among locations for the recent

period (2017 – 2020) (**Figure 5-6**). The results suggest that Longnose Sucker mercury concentrations are generally higher in Sections 7 and 9 relative to the upstream sections.

Baseline Period Assessment

This analysis was conducted to characterize potential differences between the early and recent baseline monitoring periods, with the latter information being used to support the development of fish consumption advice based on current conditions. The analysis included 303 samples, with 41 from the early baseline period and 262 from the recent period (see Longnose Sucker section of main report for catch details by location/year).

Key information on the modelling and associated results were as follows:

- *Transformations* – Mercury concentrations were log-transformed.
- *Initial Model Selection* – The suite of baseline period models (**Table 1-3**) was initially run with all the data. Fits 7 and 6 had the lowest AICc values, but over-fit the data (see **Section 1.1** for details on over-fitting). The next lowest AICc value was for fit4, which had the following model structure (quadratic model with period-specific differences in intercept):

Log Hg ~ Period + Length + Length2

- *Outliers/High Leverage Data* – Formal outlier assessment of the initial fit4 run (with all data) identified no outlier or high leverage points in the dataset.
- *Final Model Selection* – Given that no outliers or high-leverage data were identified, fit4 was retained to characterize the length-mercury relationship.
- *Fitted length-mercury Relationships* – Final model results are shown in **Figure 5-7** and summarized in **Table 5-7**. The model fits generally show strong positive relationships between length and mercury concentrations. Model residuals were visually examined and indicated that the fit was good. The model had an adjusted R2 of 0.48 and showed statistically significant differences in Longnose Sucker mercury concentrations among periods.
- *Predicted Mercury Concentrations for Standard Sized Fish by Period* – Using the length-mercury model shown above, and where the underlying data supported making a prediction, tissue mercury concentrations were estimated for three standard fish sizes: 400 mm, 550 mm and 700 mm. The predictions (and their 95% confidence limits) were used to compare fish tissue mercury concentrations between the two baseline sampling periods (**Figure 5-8**); statistical differences between periods for each standardized size were determined using the selected model and were annotated on the plot. The results show that Longnose Sucker mercury concentrations nearly doubled between the early period (2010-2011) and the recent baseline period (2017 – 2020).

Table 5-1. Potential general mercury-related outliers and assessment outcomes for Longnose Sucker.

Waterbody	Year.Caught	FishID	SectionID	Sp	FL.mm	Wt.g	Hg.ppm.ww	Relationship	Outcome
Dinosaur Reservoir	2016	LNSC-TW-05	Dinosaur	LSU	370	400	0.06823188	L-W	retained

Table 5-2. Comparison of final model fit results for the temporal assessment of length-mercury relationship by year for Longnose Sucker.

Fit	Model[1]	Df	AICc	Delta
fit4	FishHg ~ Year.Caught + LC + LC2	5	107.5	0.0
fit6	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC	6	109.2	1.7
fit7	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC2	6	109.8	2.3
fit2	FishHg ~ LC + LC2	4	111.4	3.9
fit8	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC + Year.Caught:LC2	7	111.5	4.0
fit3	FishHg ~ Year.Caught + LC	4	124.9	17.4
fit5	FishHg ~ Year.Caught + LC + Year.Caught:LC	5	126.3	18.8
fit1	FishHg ~ LC	3	136.1	28.6
fit0	FishHg ~ Year.Caught	3	155.1	47.6

[1] LC=length centered on standard size; LC2=LC^2

Table 5-3. Final model results for the temporal assessment of Longnose Sucker mercury concentrations.

Predictor	Estimate	95% CI[1]	p-value
(Intercept)	-3.627	-3.994, -3.259	<0.001
Year.Caught			
2010	—	—	
2011	-0.0394	-0.5465, 0.4676	0.9
2017	0.6645	0.2260, 1.103	0.004
2018	0.5113	0.0949, 0.9277	0.017
LC	0.0074	0.0051, 0.0098	<0.001

[1] CI = Confidence Interval

Model: FishHg ~ Year.Caught + LC

Overall Results: $F(4,65)=13$; Adjusted $R^2 = 0.446$; N = 70.0

Table 5-4. Comparison of final model fit results for the spatial assessment of length-mercury relationship by year for Longnose Sucker.

Fit	Model[1]	Df	AICc	Delta
fit7	FishHg ~ Location + LC + LC2 + Location:LC2	14	408.3	0.0
fit8	FishHg ~ Location + LC + LC2 + Location:LC + Location:LC2	19	410.0	1.7
fit4	FishHg ~ Location + LC + LC2	9	428.4	20.1
fit6	FishHg ~ Location + LC + LC2 + Location:LC	14	431.0	22.7
fit3	FishHg ~ Location + LC	8	432.0	23.7
fit2	FishHg ~ LC + LC2	4	433.7	25.3
fit5	FishHg ~ Location + LC + Location:LC	13	437.4	29.1
fit1	FishHg ~ LC	3	440.2	31.9
fit0	FishHg ~ Location	7	611.8	203.5

[1] LC=length centered on standard size; LC2=LC^2

Table 5-5. Final model results for the spatial assessment of Longnose Sucker mercury concentrations.

Predictor	Estimate	95% CI[1]	p-value
(Intercept)	-3.063	-3.403, -2.723	<0.001
Location			
Section 1	—	—	
Section 3	0.0388	-0.3254, 0.4030	0.8
Section 5	0.0210	-0.3517, 0.3936	>0.9
Section 6	-0.0037	-0.3825, 0.3751	>0.9
Section 7	0.2669	-0.1105, 0.6442	0.2
Section 9	0.2997	-0.0597, 0.6591	0.10
LC	0.0066	0.0058, 0.0074	<0.001
LC2	0.0000	0.0000, 0.0000	0.018

[1] CI = Confidence Interval

Model: FishHg ~ Location + LC + LC2

Overall Results: $F(7,254)=39$; Adjusted $R^2 = 0.519$; $N = 262$

Table 5-6. Comparison of final model fit results for the baseline sampling period assessment of length-mercury relationship by year for Longnose Sucker.

Fit	Model[1]	Df	AICc	Delta
fit7	FishHg ~ Period + LC + LC2 + Period:LC2	6	501.3	0.0
fit6	FishHg ~ Period + LC + LC2 + Period:LC	6	502.6	1.4
fit4	FishHg ~ Period + LC + LC2	5	502.7	1.4
fit8	FishHg ~ Period + LC + LC2 + Period:LC + Period:LC2	7	503.3	2.1
fit5	FishHg ~ Period + LC + Period:LC	5	509.9	8.6
fit3	FishHg ~ Period + LC	4	511.4	10.1
fit2	FishHg ~ LC + LC2	4	536.5	35.2
fit1	FishHg ~ LC	3	550.7	49.4
fit0	FishHg ~ Period	3	689.9	188.6

[1] LC=length centered on standard size; $LC2=LC^2$

Table 5-7. Final model results for the spatial assessment of Longnose Sucker mercury concentrations.

Predictor	Estimate	95% CI[1]	p-value
(Intercept)	-3.536	-3.712, -3.361	<0.001
Period			
2010-2011	—	—	
2017-2020	0.5834	0.3960, 0.7708	<0.001
LC	0.0066	0.0058, 0.0074	<0.001
LC2	0.0000	0.0000, 0.0000	0.001

[1] CI = Confidence Interval

Model: FishHg ~ Period + LC + LC2

Overall Results: F(3,299)=92; Adjusted R^2 = 0.481; N = 303

Figure 5-1. Length Frequency and age frequency for Longnose Sucker (LSU) by location across all years (2010 – 2020).

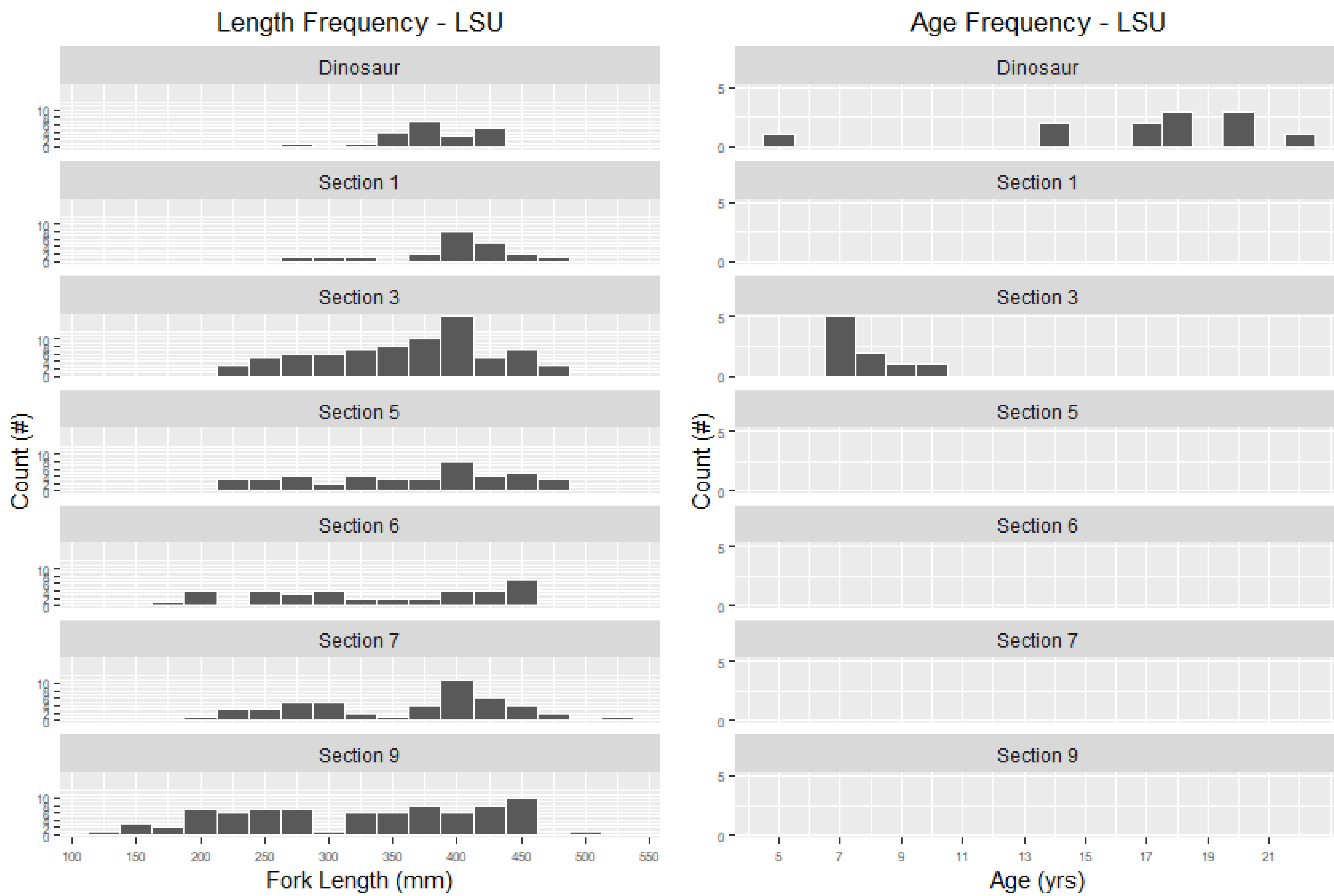


Figure 5-2. Key mercury-related relationships for Longnose Sucker (LSU) across all years (2010 – 2020). Red circles indicate length-weight outliers.

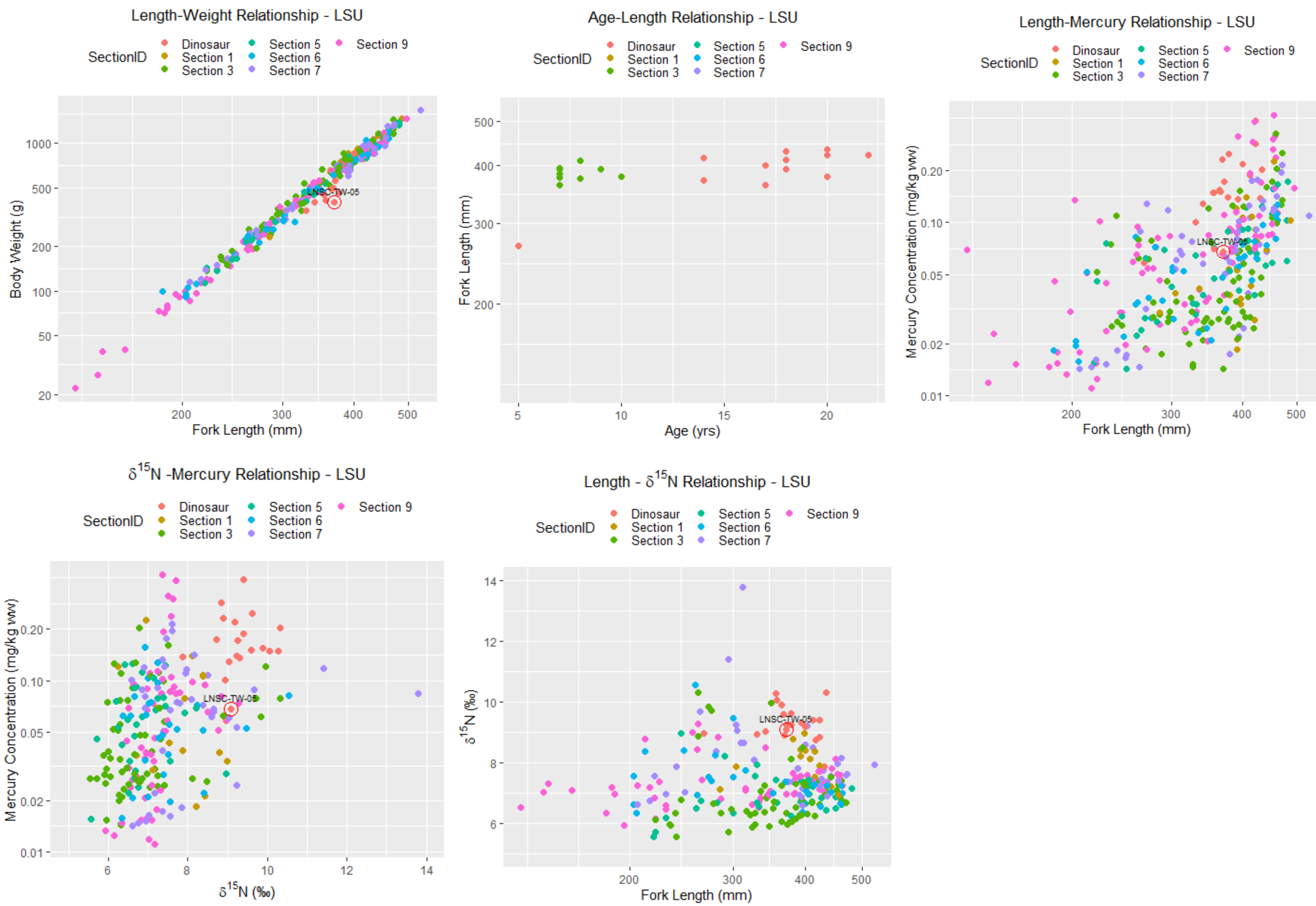
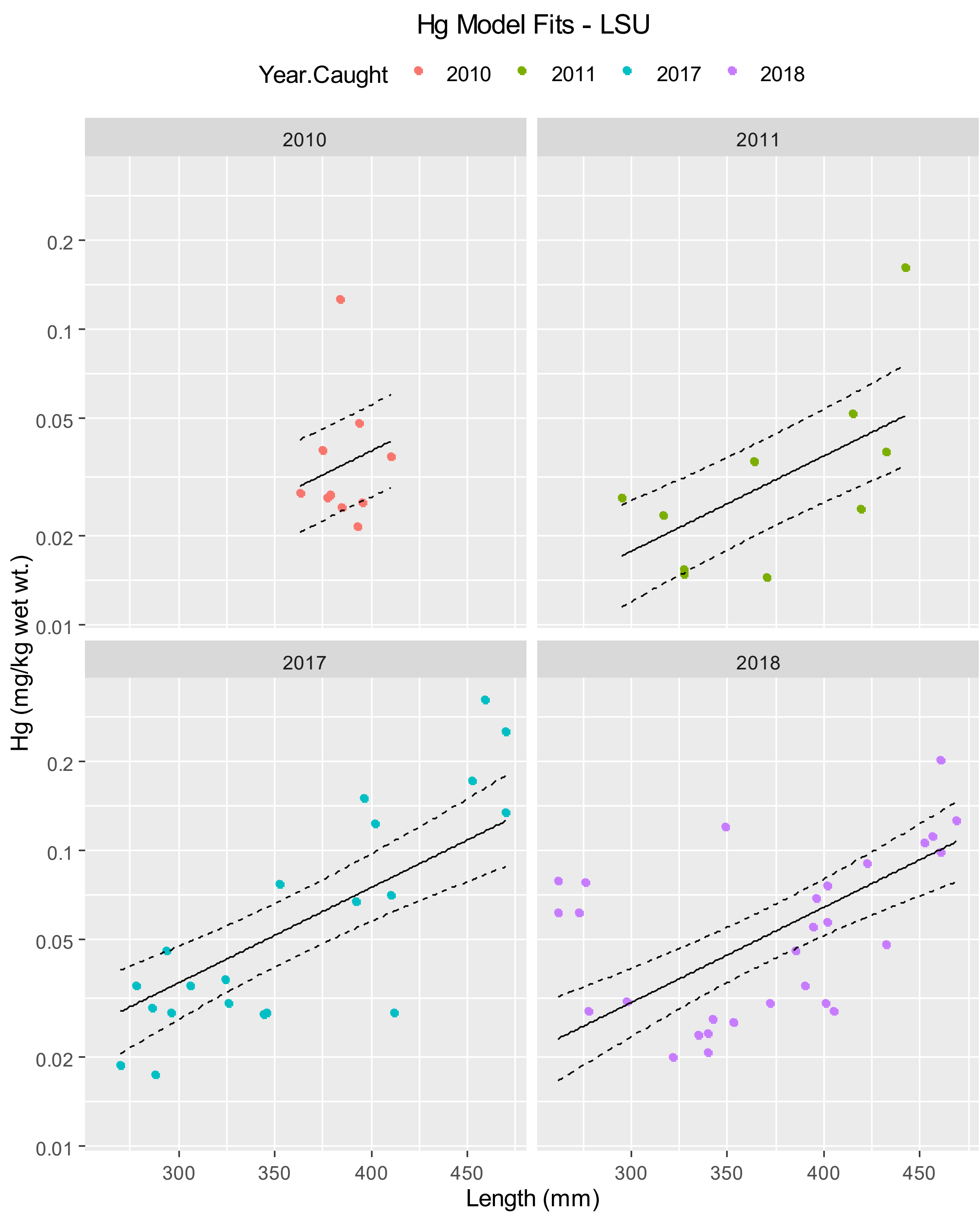
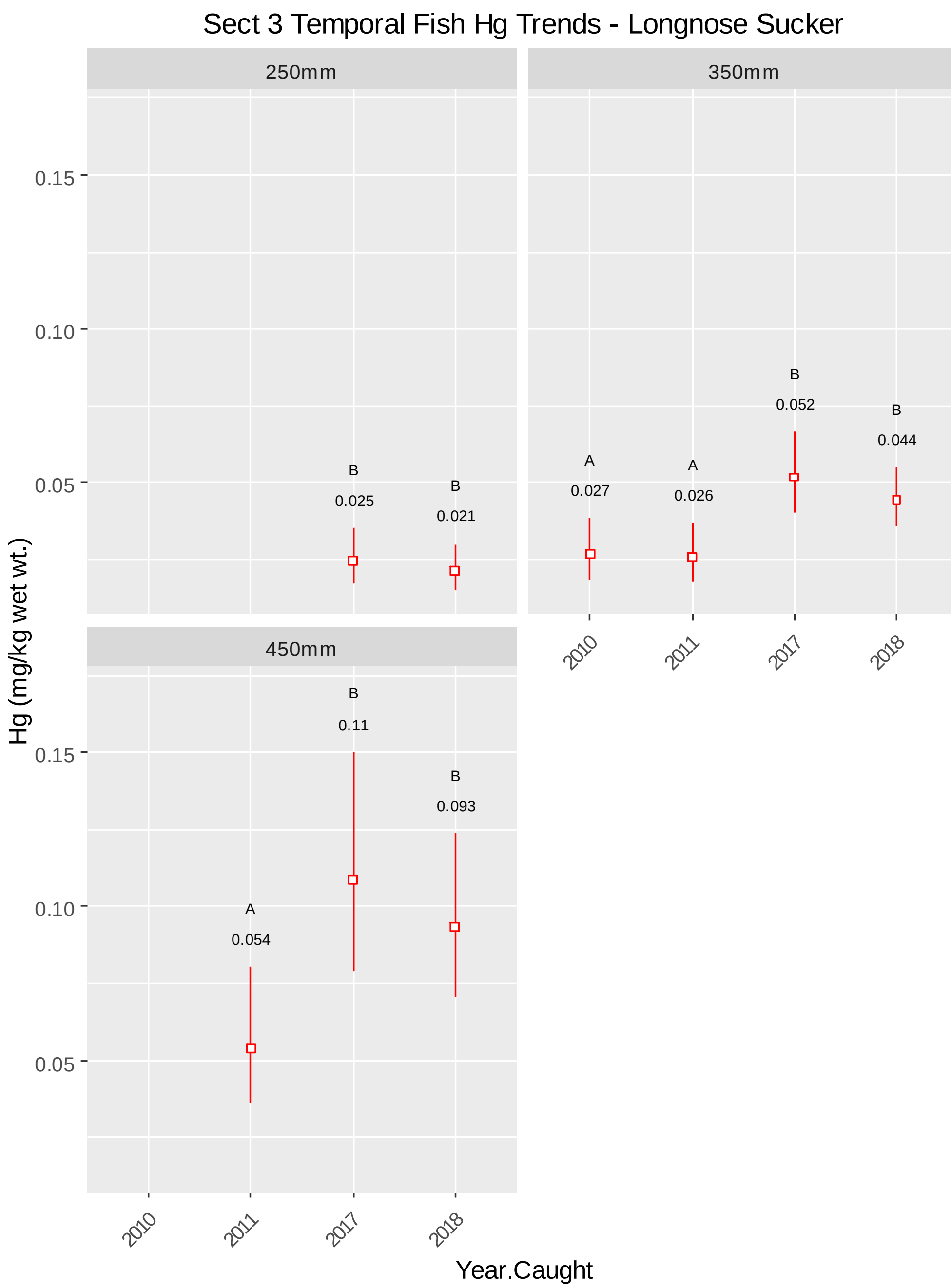


Figure 5-3. Final model fit results for the temporal assessment of Longnose Sucker mercury concentrations for Section 3 (2010, 2011, 2017, and 2018 [see note]).



Note: Only years with 10 or more samples were included.

Figure 5-4. Estimated mercury concentrations (and 95% confidence intervals) for select sizes (250 mm, 350 mm, 450 mm) for each year in the temporal assessment of Longnose Sucker mercury concentrations for Section 3.



Note: Letters above estimates show which are not statistically different from one another (same letters) or which are statistically different (different letters); combinations (e.g., “AB”) show estimates that are not statistically different from other groups that are different (e.g., “A” and “B”).

Figure 5-5. Final model fit results for the spatial assessment of Longnose Sucker mercury concentrations across Peace River locations for the recent baseline period (2017 – 2020).

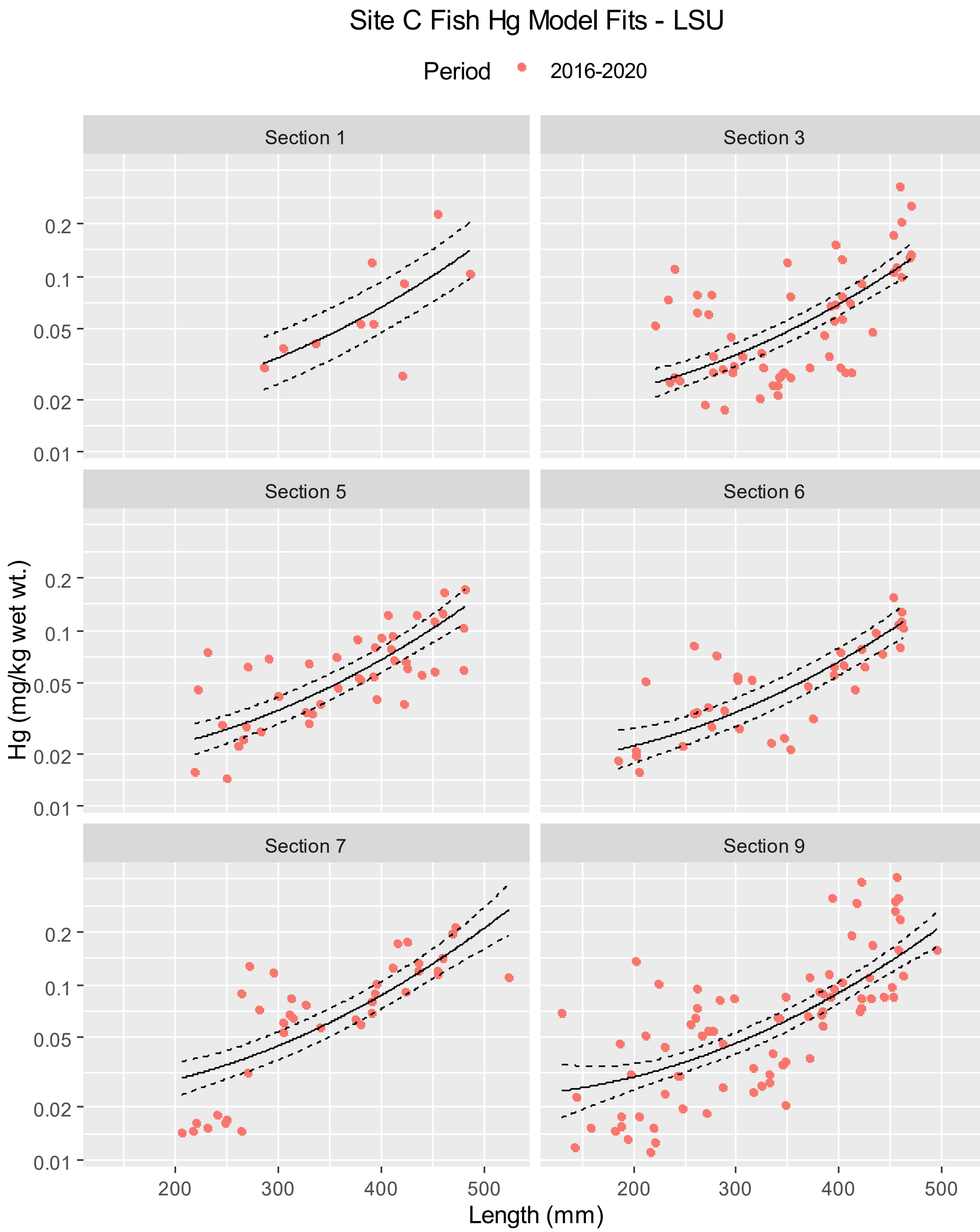


Figure 5-6. Estimated mercury concentrations (and 95% confidence intervals) for Longnose Sucker for select sizes (250 mm, 350 mm, 450 mm) across Peace River locations in the spatial assessment using recent baseline data (2017 – 2020).

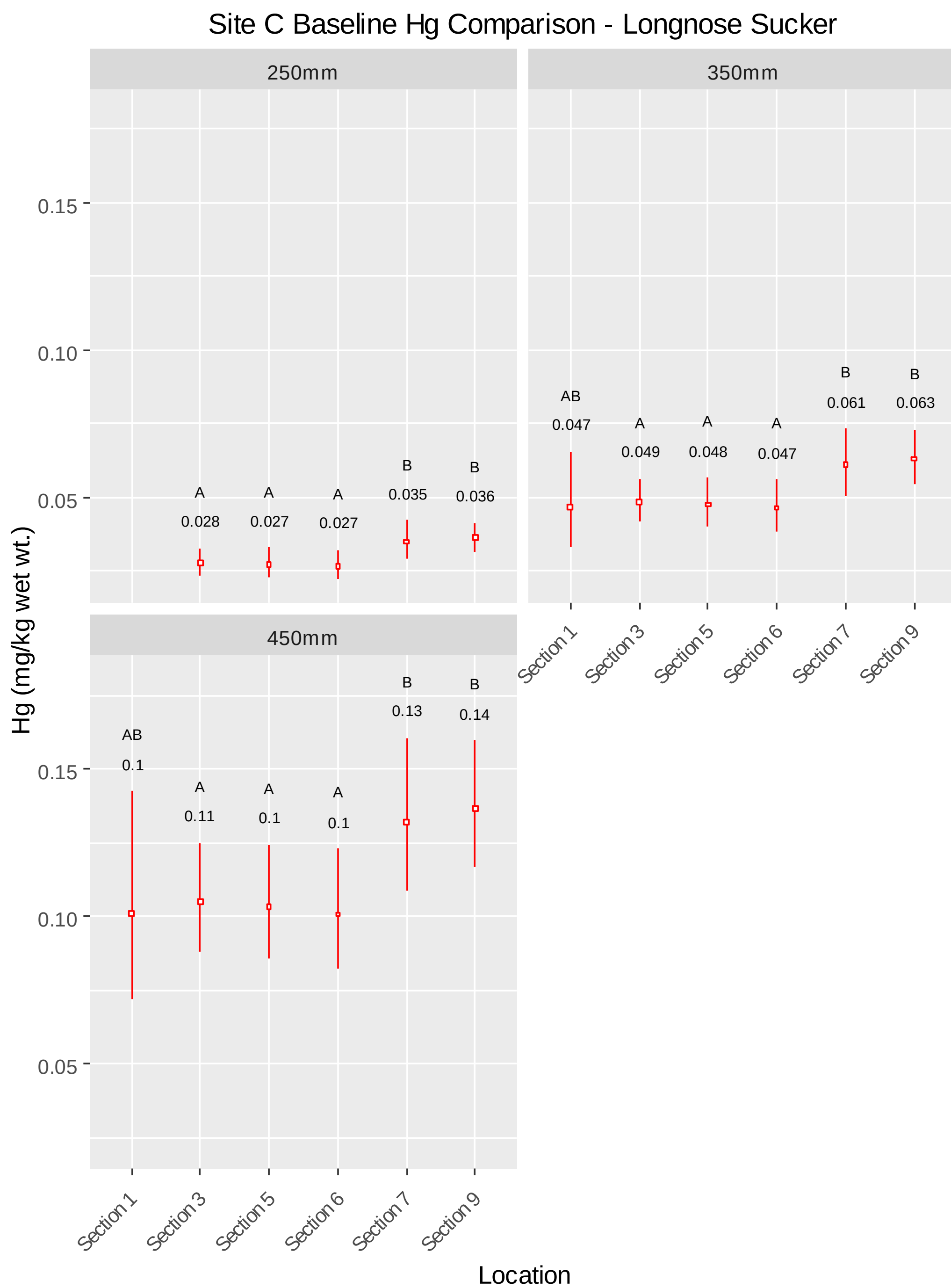


Figure 5-7. Final model fit results for the baseline sampling period assessment of Longnose Sucker mercury concentrations across Peace River locations.

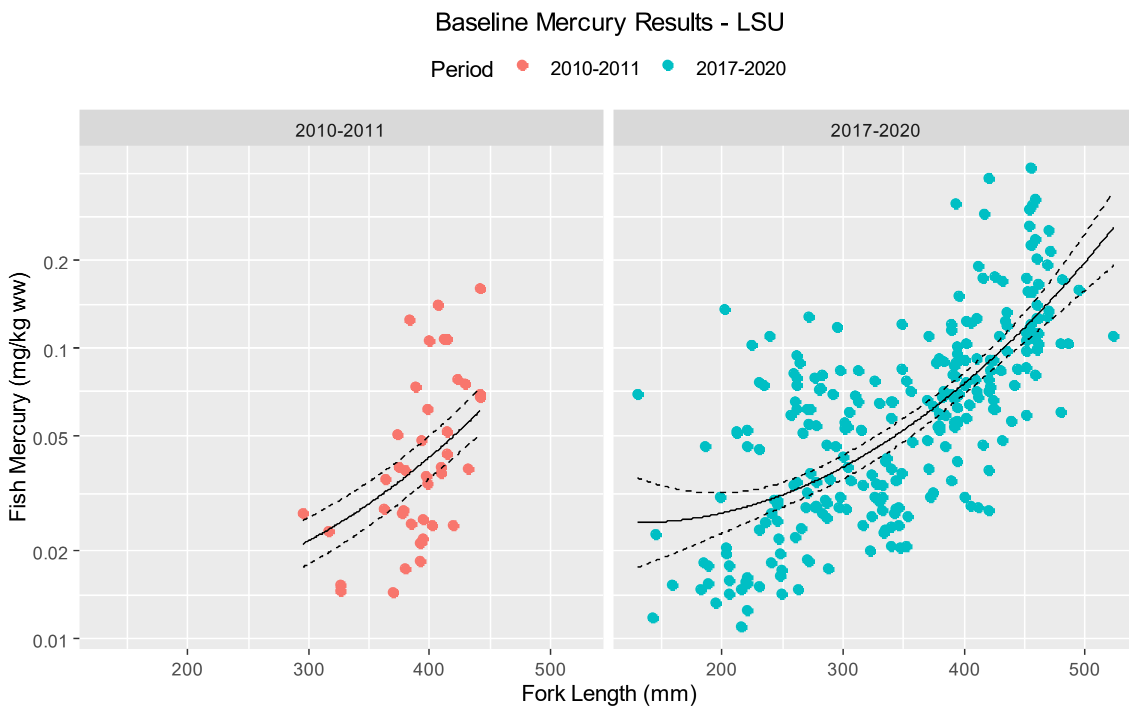
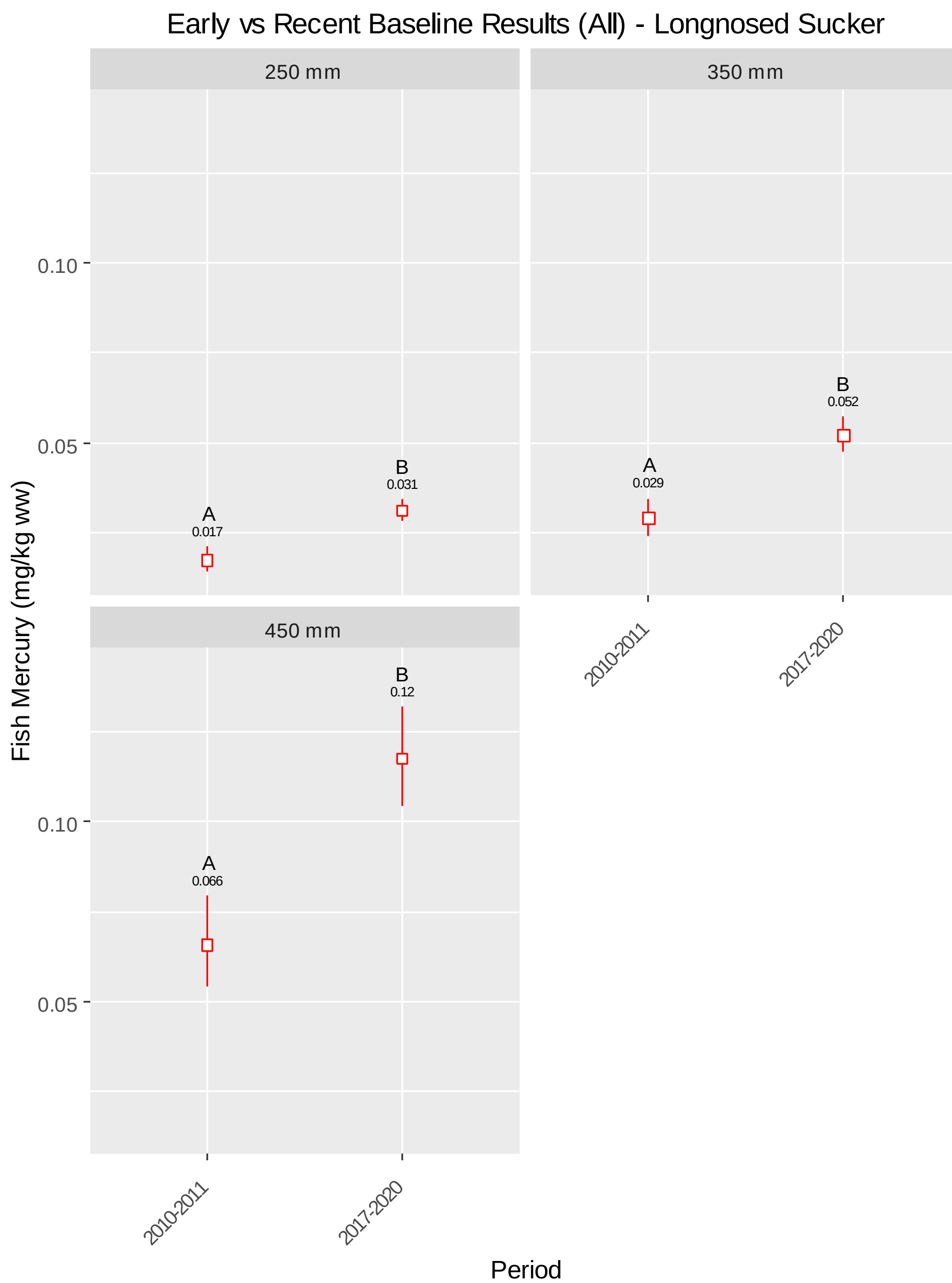


Figure 5-8. Estimated mercury concentrations (and 95% confidence intervals) for Longnose Sucker for select sizes (250 mm, 350 mm, 450 mm) across periods in the baseline sampling period assessment across Peace River locations.



Note: Letters above estimates show which are not statistically different from one another (same letters) or which are statistically different (different letters); combinations (e.g., “AB”) show estimates that are not statistically different from other groups that are different (e.g., “A” and “B”).

6 WALLEYE

Temporal Assessment

The temporal assessment was conducted to determine whether there were any changes in the length-mercury relationship for Walleye across sampling years. To control for potential spatial trends the analysis was limited to Section 7, which had five years (2011, 2017, 2018, 2019, and 2020) with 5 or more samples, with a total of 40 samples across all years (see Walleye section of main report for catch details by location/year).

Key information on the modelling and associated results were as follows:

- Transformations – Mercury concentrations were log-transformed.
- *Initial Model Selection* – The suite of temporal models (**Table 1-1**) was initially run with all the data. Fit3 had the lowest AICc value (**Table 6-2**), was selected for use, and has the following structure (linear model with year-specific intercepts):

  Log Hg ~ Year + Length

- *Outliers/High Leverage Data* – Formal outlier assessment of the initial fit3 run (with all data) did not identify any outliers or high leverage points in the dataset.
- *Final Model Selection* – As no outliers or high-leverage points were identified, fit3 using all data was used to characterize the length-mercury relationship.
- *Fitted length-mercury Relationships* – Final model results are shown in **Figure 6-3** and summarized in **Table 6-3**. The model fits generally show strong positive relationships between length and mercury concentrations. Model residuals were visually examined and confirmed a reasonable fit. The model had an adjusted R^2 of 0.73 and showed statistically significant differences in Walleye mercury concentrations among years. However, as seen in **Figure 6-5**, while the fits were generally good across years, there was little overlap in fish length across sampling years.
- *Predicted Mercury Concentrations for Standard Sized Fish by Year* – Given the lack of overlap across the size range among years, the length-mercury model shown above was not used to estimate tissue mercury concentrations for standard fish sizes. Thus, while the overall model identified statistically different concentrations among years, predictions for specific years were not made due to size range limitations across years.

Spatial Assessment

The spatial assessment was conducted to determine whether there are differences in the length-mercury relationship for Walleye among sampling locations. Given the temporal changes identified previously, the spatial assessment was limited to the recent time period only. Four sampling locations (Sections 5, 6, 7, and 9) had 23 or more samples across the recent sampling period (2017 to 2020), with a total of 54 samples; (see Walleye section of main report for catch details by location/year).

Key information on the spatial modelling and associated results were as follows:

- *Transformations* – Mercury concentrations were log-transformed.
- Initial Model Selection – The suite of spatial models (**Table 1-2**) was initially run with all the data. Fits 4, 6, 7 and 8, all quadratic model forms, had the lowest AICc values (**Table 6-4**), but over-fit the data (see **Section 1.1** for details on over-fitting). The next lowest AICc value was for fit3, which had the following model structure (linear model with location-specific differences in intercept):

Log Hg ~ Location + Length

- *Outliers/High Leverage Data* – Formal outlier assessment of the initial fit3 run (with all data) identified no points as outliers or as having high leverage.
- *Final Model Selection* – Given the lack of outliers/high leverage data points, fit3 was retained to characterize the length-mercury relationship.
- *Fitted length-mercury Relationships* – Final model results are shown in **Figure 6-5** and summarized in **Table 6-5**. The model fits generally show strong positive relationships between length and mercury concentrations. Model residuals were visually examined and indicated that the fit was good. The model had an adjusted R^2 of 0.53 and showed statistically significant differences in Walleye mercury concentrations among locations.
- *Predicted Mercury Concentrations for Standard Sized Fish by Year* – Using the length-mercury model shown above, and where the underlying data supported making a prediction, tissue mercury concentrations were estimated for three standard fish sizes: 300 mm, 400 mm and 500 mm. The predictions (and their 95% confidence limits) were used to compare fish tissue mercury concentrations among locations for the recent period (2017 – 2020) (**Figure 6-6**). The results suggest that Walleye mercury concentrations are generally higher in Sections 7 and 9, relative to the upstream sections.

Baseline Period Assessment

There were only 6 Walleye tissue samples for the early baseline period and fish sizes generally had limited range and little overlap across years. Consequently, no assessment of differences in tissue mercury concentrations between baseline sampling periods was conducted. However, it is noteworthy that the temporal assessment for Walleye did result in statistically significant differences in mercury concentrations among years, with 2011 generally being different than the recent baseline sampling period (**Figure 6-4**).

Table 6-1. Fish formally identified as outliers in length-weight (L-W), length-mercury (L-Hg) and/or mercury-nitrogen isotope (Hg-dN) relationship.

Waterbody	Year.Caught	FishID	SectionID	Sp	FL.mm	Wt.g	Hg.ppm.ww	Relationship	Outcome
Peace River	2018	571	Section 6	WP	454	1155	0.0385	L-Hg	retained

Table 6-2. Comparison of final model fit results for the temporal assessment of length-mercury relationship by year for Walleye.

Fit	Model[1]	Df	AICc	Delta
fit3	FishHg ~ Year.Caught + LC	7	48.5	0.0
fit4	FishHg ~ Year.Caught + LC + LC2	8	50.0	1.5
fit5	FishHg ~ Year.Caught + LC + Year.Caught:LC	11	59.6	11.1
fit7	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC2	12	59.7	11.1
fit6	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC	12	59.7	11.2
fit1	FishHg ~ LC	3	63.5	15.0
fit0	FishHg ~ Year.Caught	6	64.7	16.2
fit2	FishHg ~ LC + LC2	4	65.7	17.2
fit8	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC + Year.Caught:LC2	16	79.2	30.7

[1] LC=length centered on standard size; LC2=LC^2

Table 6-3. Final model results for the temporal assessment of Walley mercury concentrations.

Predictor	Estimate	95% CI[1]	p-value
(Intercept)	-2.360	-2.684, -2.036	<0.001
Year.Caught			
2011	—	—	
2017	0.8746	0.4650, 1.284	<0.001
2018	0.4552	-0.0484, 0.959	0.075
2019	1.094	0.5925, 1.596	<0.001
2020	0.8712	0.4459, 1.296	<0.001
LC	0.0042	0.0024, 0.0061	<0.001

[1] CI = Confidence Interval

Model: FishHg ~ Year.Caught + LC

Overall Results: $F(5,34)=18$; Adjusted $R^2 = 0.727$; N = 40.0

Table 6-4. Comparison of final model fit results for the spatial assessment of length-mercury relationship by year for Walleye.

Fit	Model[1]	Df	AICc	Delta
fit4	FishHg ~ Location + LC + LC2	7	123.9	0.0
fit6	FishHg ~ Location + LC + LC2 + Location:LC	10	129.8	5.9
fit7	FishHg ~ Location + LC + LC2 + Location:LC2	10	130.5	6.5
fit8	FishHg ~ Location + LC + LC2 + Location:LC + Location:LC2	13	136.3	12.3
fit3	FishHg ~ Location + LC	6	140.4	16.5
fit2	FishHg ~ LC + LC2	4	142.4	18.5
fit5	FishHg ~ Location + LC + Location:LC	9	144.2	20.3
fit1	FishHg ~ LC	3	157.9	34.0
fit0	FishHg ~ Location	5	231.2	107.3

[1] LC=length centered on standard size; LC2=LC^2

Table 6-5. Final model results for the spatial assessment of Walleye mercury concentrations.

Predictor	Estimate	95% CI[1]	p-value
(Intercept)	-1.698	-1.865, -1.531	<0.001
Location			
Section 5	—	—	
Section 6	0.0163	-0.2111, 0.2438	0.9
Section 7	0.1783	-0.0554, 0.4121	0.13
Section 9	0.4157	0.2130, 0.6185	<0.001
LC	0.0050	0.0041, 0.0059	<0.001

[1] CI = Confidence Interval

Model: FishHg ~ Location + LC

Overall Results: $F(4,124)=35$; Adjusted $R^2 = 0.530$; N = 129

Figure 6-1. Length Frequency and age frequency for Walleye (WP) by location across all years (2010 – 2020).

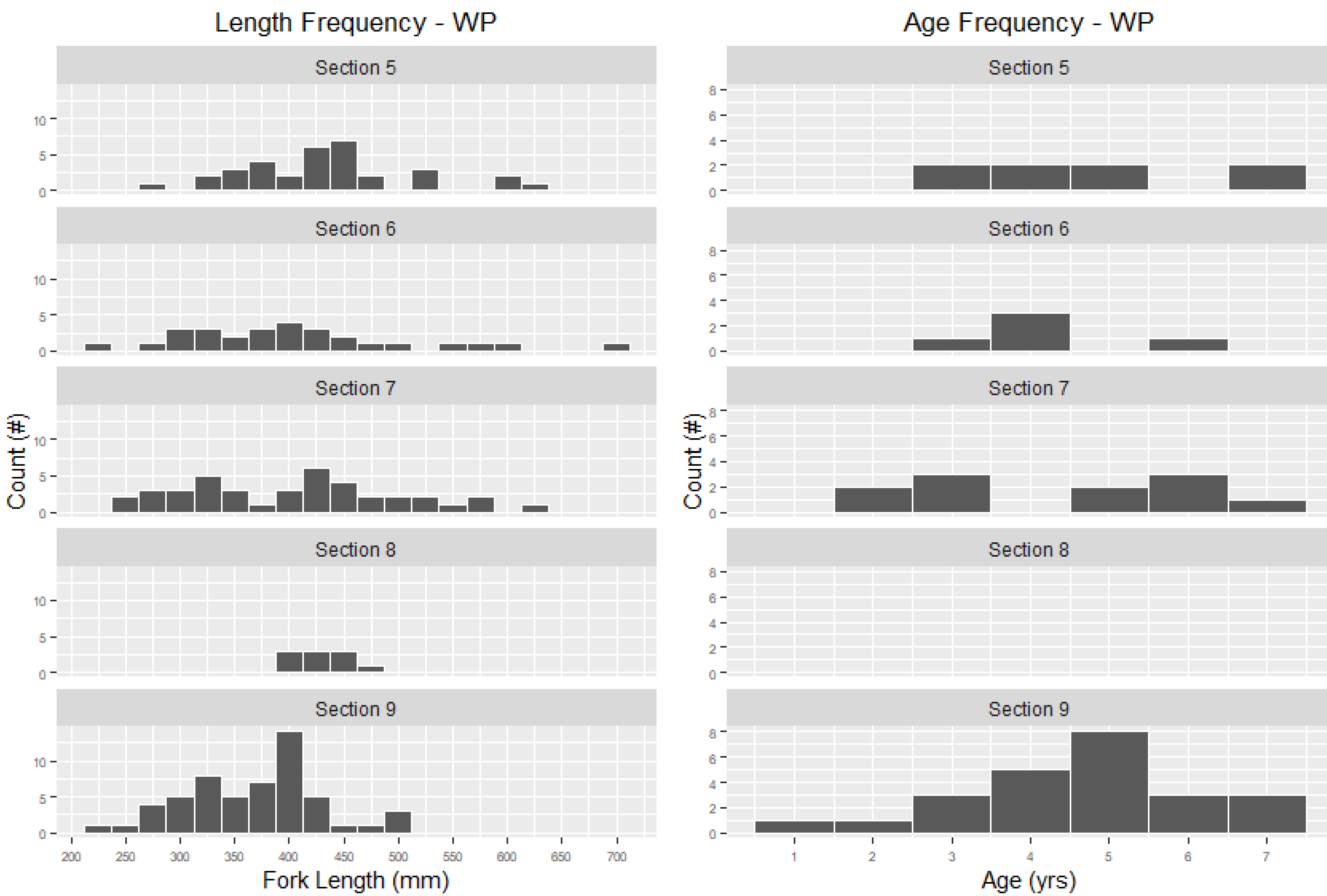


Figure 6-2. Key mercury-related relationships for Walleye (WP) across all years (2010 – 2020). Green circle indicates length-mercury outliers (not carried through as no SIA data).

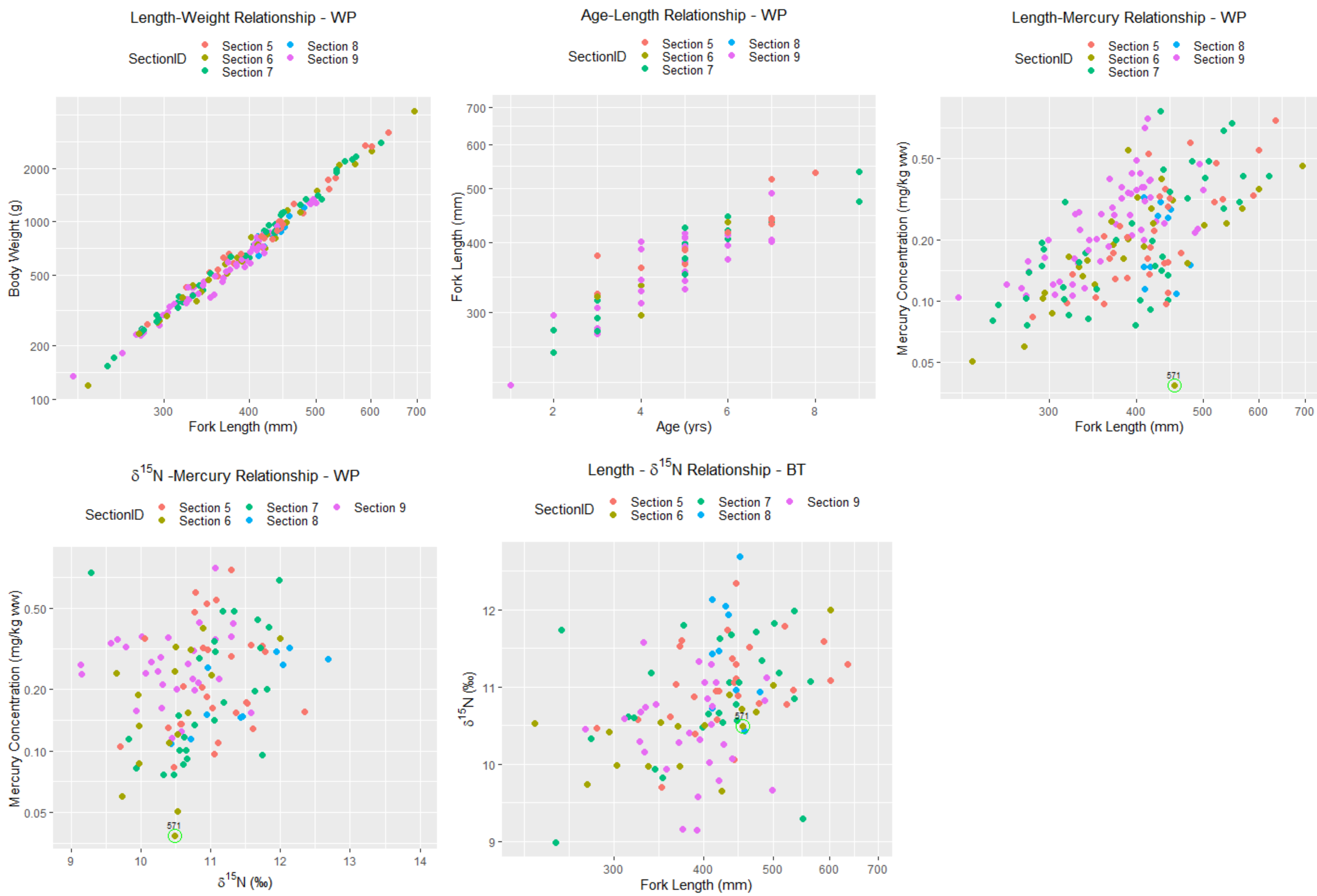
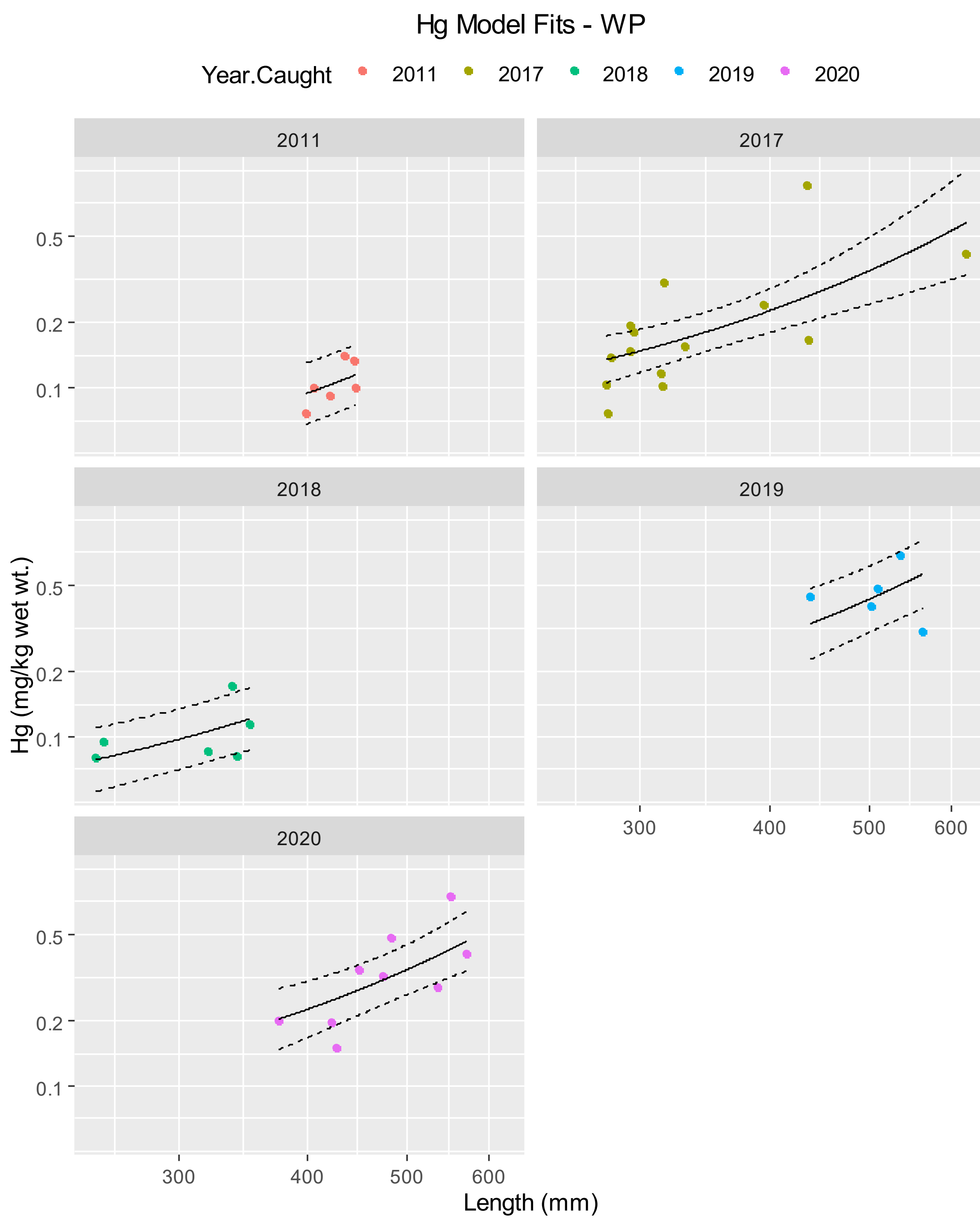


Figure 6-3. Final model fit results for the temporal assessment of Walleye mercury concentrations for Section 7 (2011, 2017 – 2020 [see note]).



Note: Only years with 5 or more samples were included.

Figure 6-4. Final model fit results for the temporal assessment of Walleye mercury concentrations, showing fits among years for Section7.

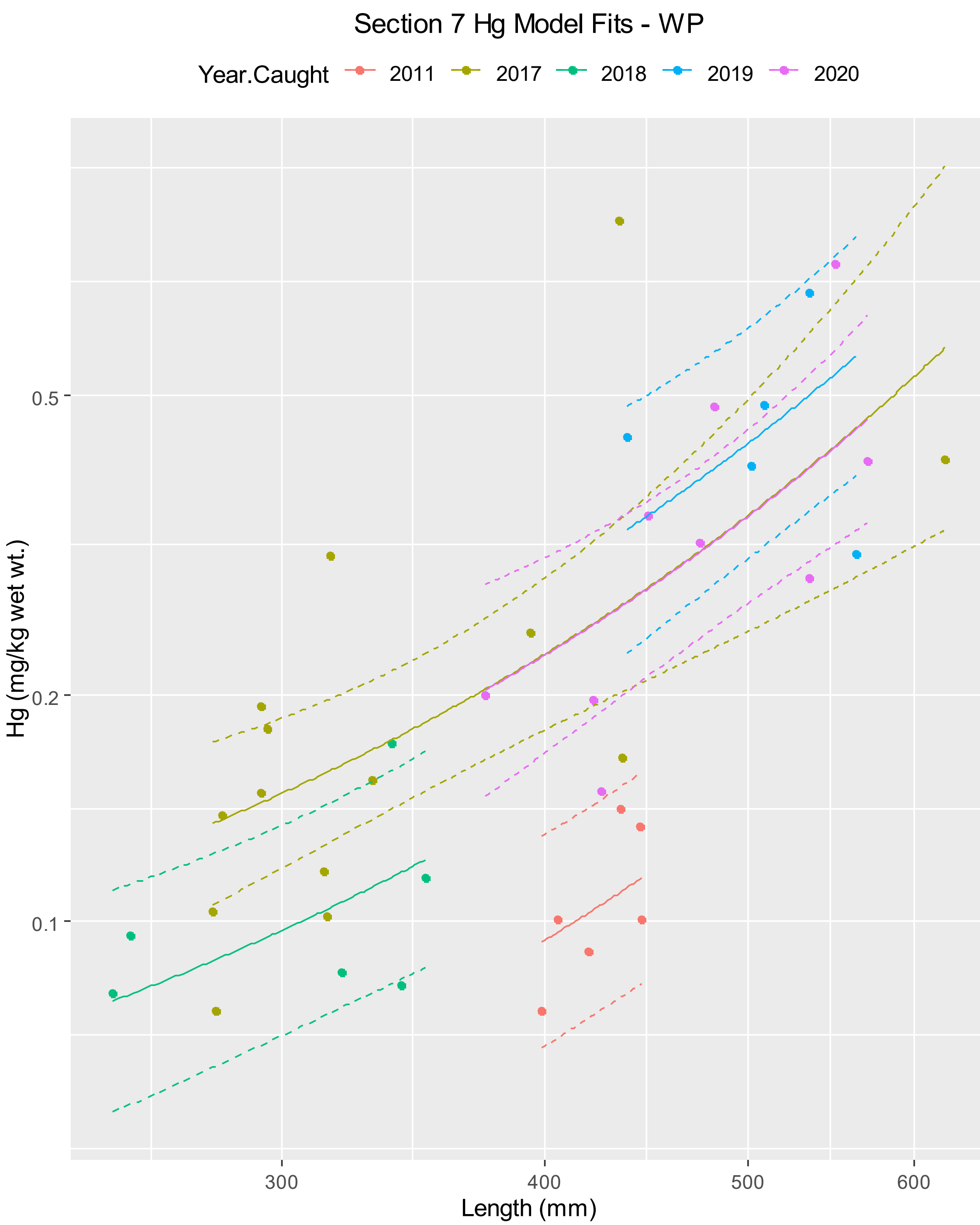


Figure 6-5. Final model fit results for the spatial assessment of Walleye mercury concentrations for Peace River Sections 5, 6, 7, and 9.

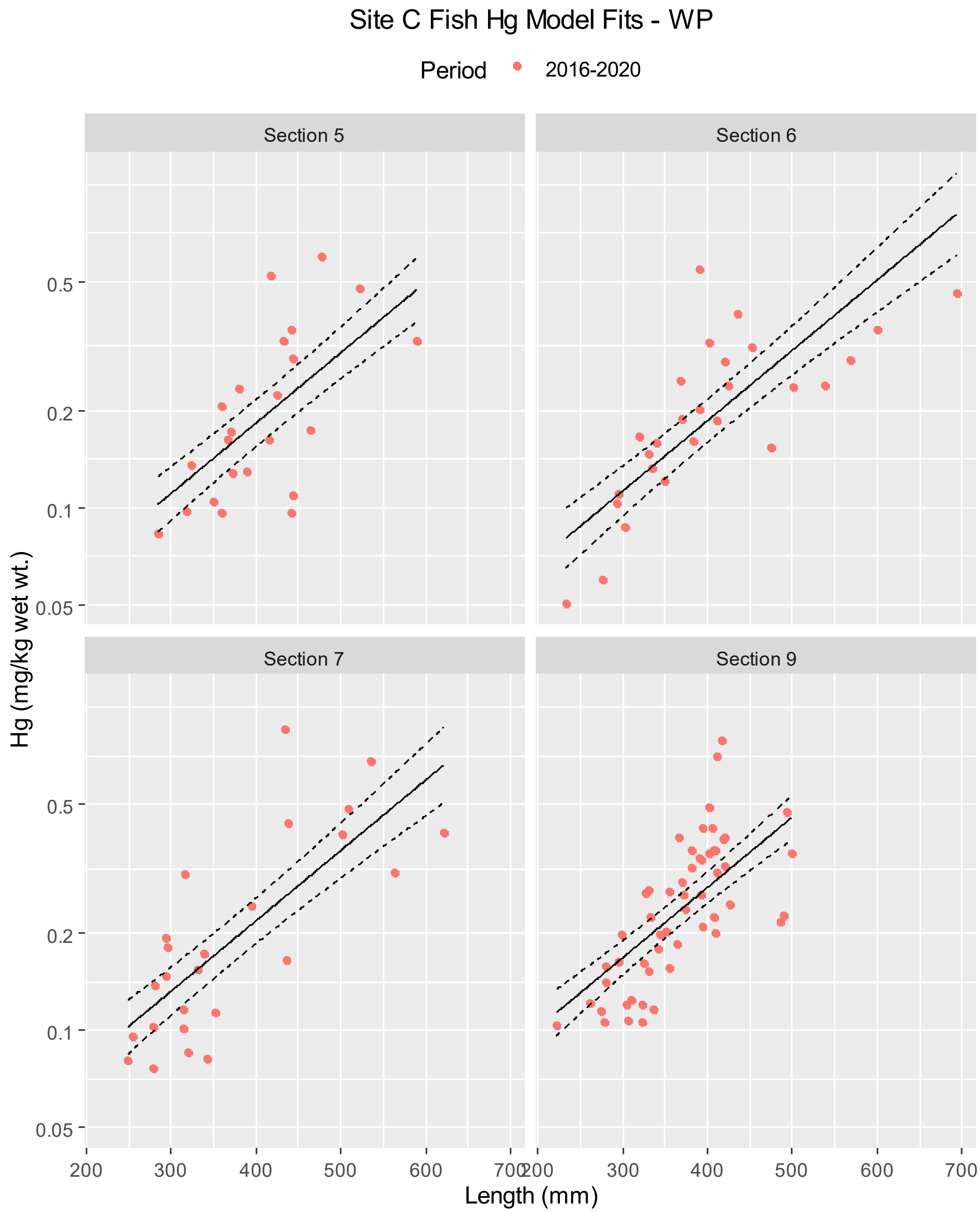
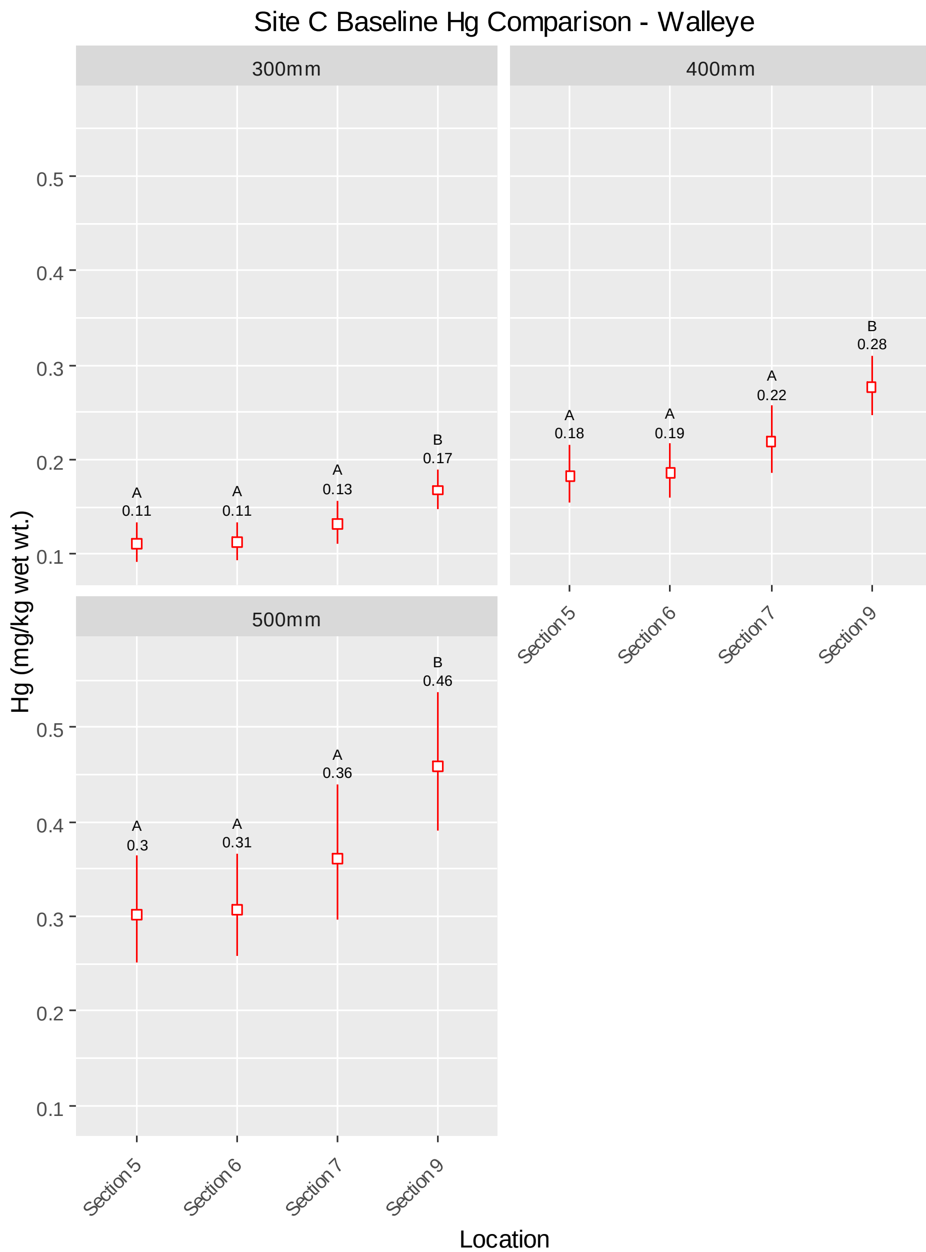


Figure 6-6. Estimated mercury concentrations (and 95% confidence intervals) for select sizes (250 mm, 350 mm, 450 mm) for each location in the spatial assessment of Walleye mercury concentrations for Peace River Sections 5, 6, 7, and 9 across the recent baseline period (2017-2020).



Note: Letters above estimates show which are not statistically different from one another (same letters) or which are statistically different (different letters); combinations (e.g., “AB”) show estimates that are not statistically different from other groups that are different (e.g., “A” and “B”).

7 REDSIDE SHINER

Due to low overall catch numbers (n = 23) of Redside Shiner, coupled with a lack of length-mercury relationship, modelling was not carried out for this target species.

Table 7-1. Morphometric data for Redside Shiner for fish with mercury data (upper panel) and fish with methylmercury data (lower panel).

Section	Year	Length (mm)	Weight (g)	Condition (K)	Hg (ppm ww)	d13C (‰)	d15N (‰)
Section 5	2010	n=11; 99 (85-119)	n=11; 14 (6-26)	n=11; 1.3 (0.977-1.543)	n=11; 0.049 (0.032-0.06)	n=11; -25.5 (-26--24.3)	n=11; 8.1 (7.6-8.6)
Section 5	2017	n=1; 90 (90-90)	n=1; 9 (9-9)	n=1; 1.24 (1.235-1.235)	n=1; 0.048 (0.048-0.048)	n=1; -26.1 (-26.1--26.1)	n=1; 8.6 (8.6-8.6)

Section	Year	Length (mm)	Weight (g)	Condition (K)	MeHg (ppm ww)	d13C (‰)	d15N (‰)
Section 5	2020	n=7; 72 (46-106)	n=7; 5 (0.4-15)	n=7; 0.97 (0.302-1.259)	n=7; 0.049 (0.027-0.091)	n=7; -27.8 (-28.3--27.2)	n=7; 7.4 (6.9-7.9)
Section 7	2020	n=4; 45 (33-53)	n=2; 1 (0.2-1.3)	n=2; 0.8 (0.557-1.04)	n=4; 0.04 (0.024-0.076)	n=4; -27.5 (-28.1--26.8)	n=4; 7.2 (6.6-8.5)

Note that at this time, no Redside Shiner in the dataset have both mercury and methylmercury data.

Table 7-2. Fish formally identified as outliers in length-weight (L-W), length-mercury (L-Hg) and/or mercury-nitrogen isotope (Hg-dN) relationship.

Waterbody	SectionID	Year.Caught	FishID	Sp	FL.mm	Wt.g	Hg.ppm.ww	outlier
Peace River	Section 5	2020	1436	RSC	51	0.4	NA	L-W

Figure 7-1. Length Frequency for Redside Shiner (RSC) by location across all sampling years.

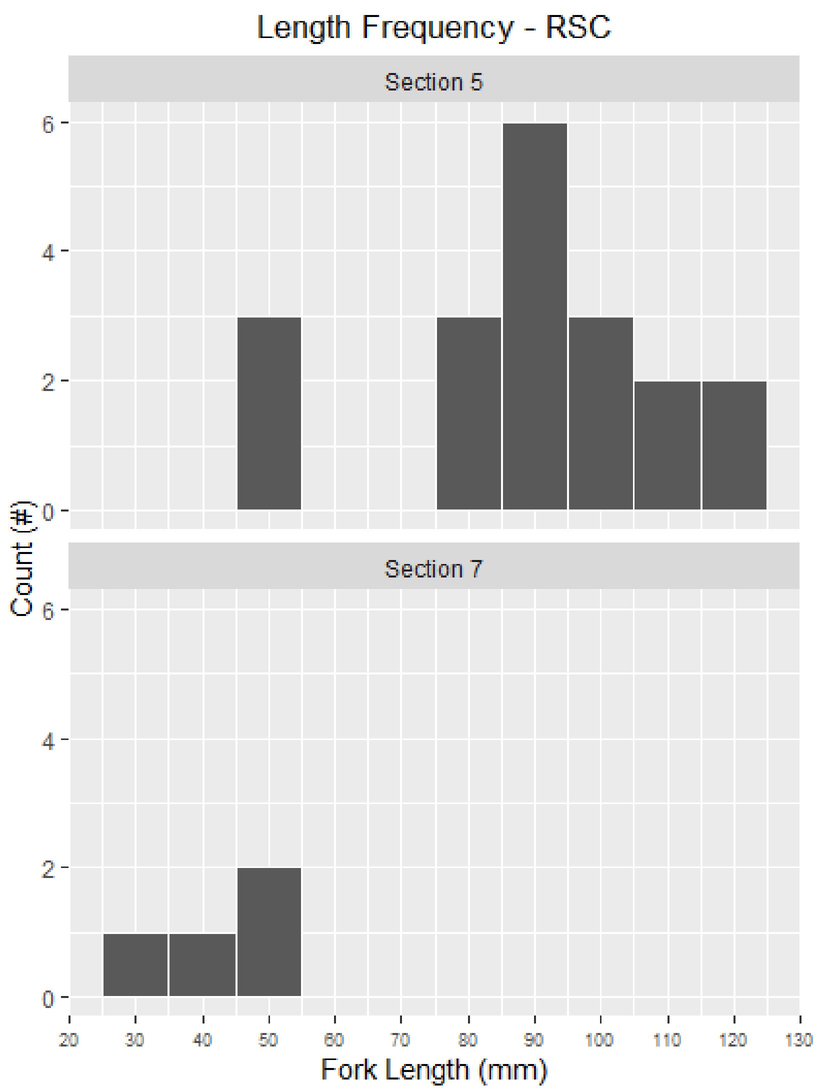
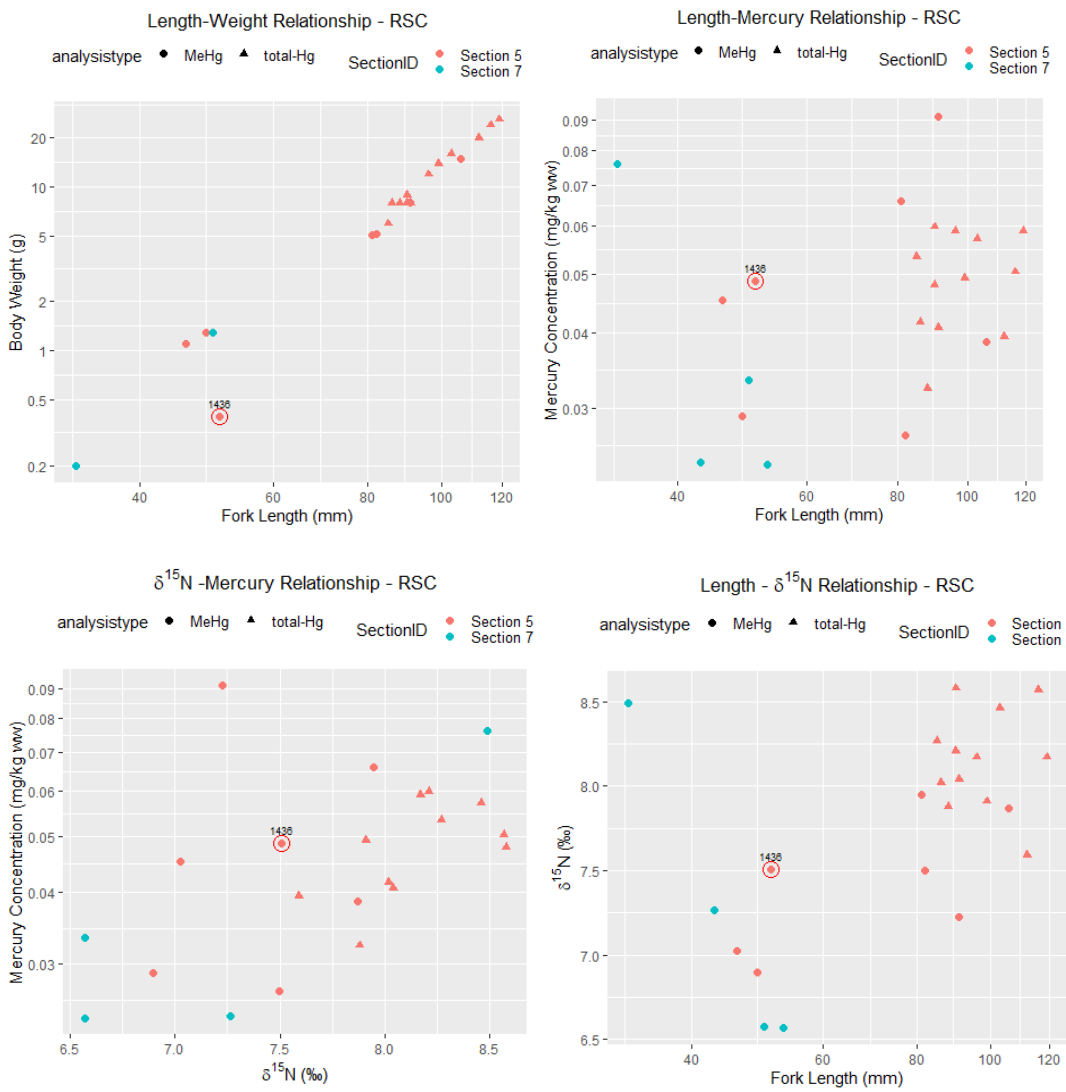


Figure 7-2. Key mercury-related relationships for Redside Shiner (RSC) across all sampling years.



Note: Red circle indicates length-weight outlier. Methylmercury (MeHg) and total mercury (total Hg) are plotted together.

8 NON-TARGET SPECIES

Tissue mercury samples were collected from non-target species on an opportunistic basis over baseline years; the breakdown by species and location for length, weight, condition, age, mercury, δ13C, and δ15N are presented in **Table 8-1**.

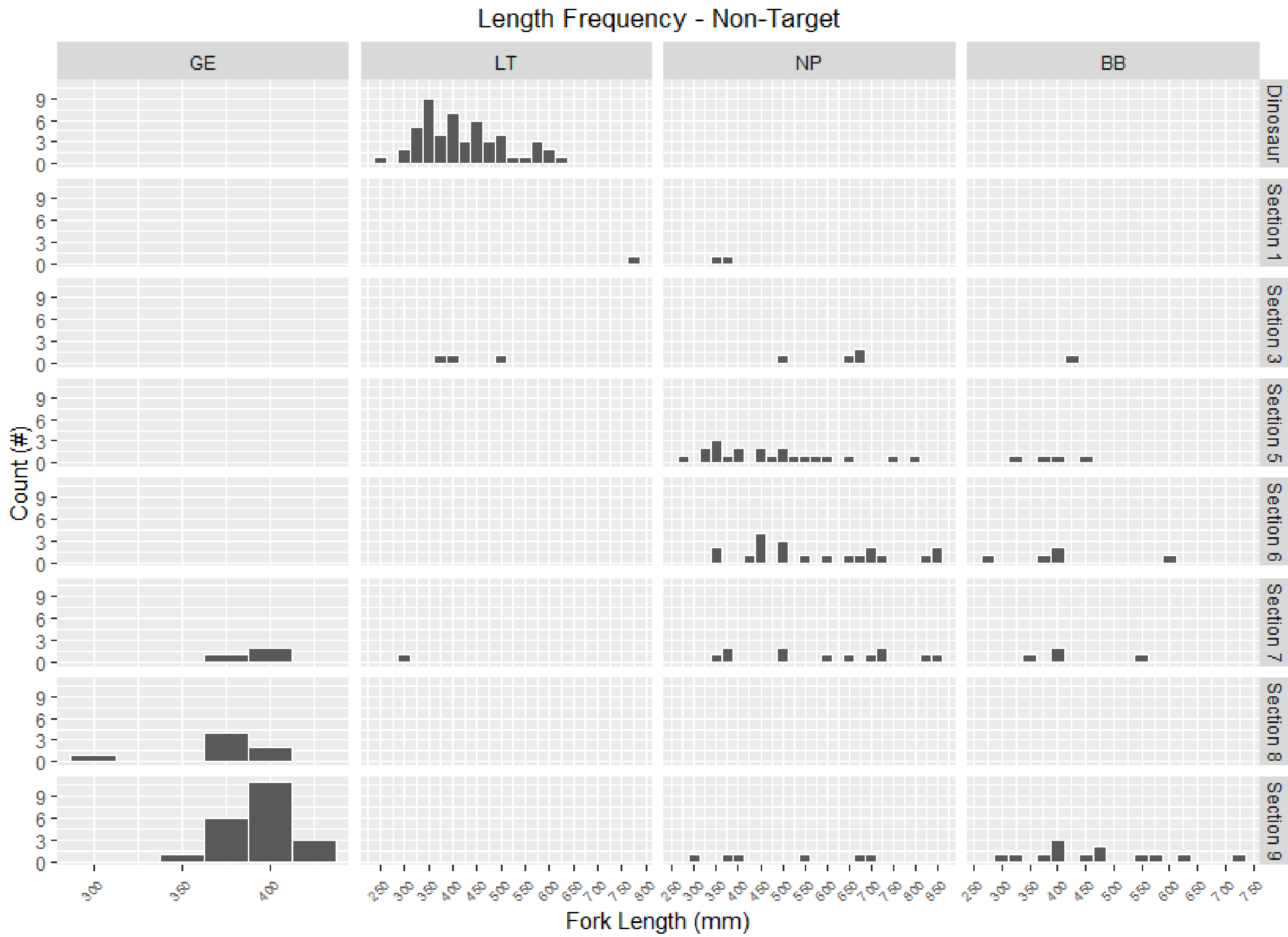
Analysis of the non-target species' datasets was limited to plotting key mercury-related relationships; no formal outlier assessment or characterization of size-mercury relationships were conducted.

Mercury-related relationships were plotted for species with more than 5 data points: Goldeye (GE; n=31), Lake Trout (LT, n=57), Northern Pike (NP, n=65) and Burbot (BB, n=27). Fish length range is provided in **Figure 8-1** and key mercury-related relationships (excluding Age-Length as age data were generally sparce for non-target species) are shown in **Figure 8-2**. With the exception of Goldeye, the non-target species generally had good representation across their size range (**Figure 8-1**). The Lake Trout dataset consists mainly of fish caught in Dinosaur Reservoir; there is a surprisingly weak length-mercury relationship for this species. Northern Pike and Burbot both have positive mercury-related relationships.

Table 8-1. Morphometric data for non-target species by location (all sampling years combined).

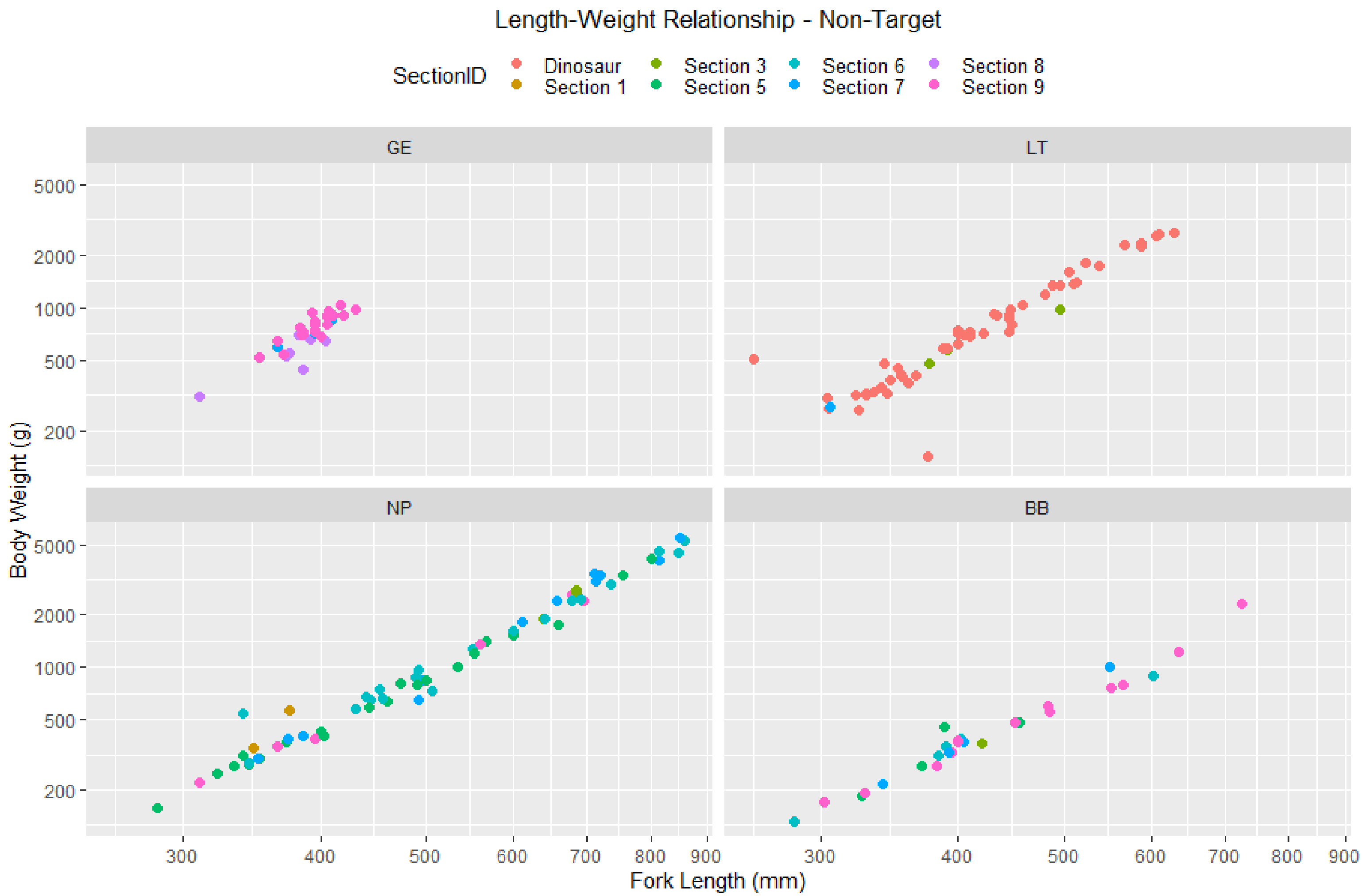
Species	Section ID	Length (mm)	Weight (g)	Condition (K)	Age (yrs)	Hg (ppm ww)	d13C (‰)	d15N (‰)
GE	Section 7	n=3; 391 (366-410)	n=3; 721 (600-854)	n=3; 1.2 (1.14-1.24)	n=3; 12 (11-12)	n=3; 0.159 (0.11-0.221)	n=3; -26.3 (-26.6--25.8)	n=3; 9 (8.7-9.2)
GE	Section 8	n=7; 374 (310-404)	n=7; 549 (314-702)	n=7; 1.03 (0.78-1.26)	n=7; 10 (9-11)	n=7; 0.247 (0.153-0.334)	n=7; -26 (-26.8--25.2)	n=7; 9.8 (9.4-10.1)
GE	Section 9	n=21; 395 (352-430)	n=21; 793 (525-1036)	n=21; 1.27 (1.06-1.55)	n=2; 16 (15-16)	n=21; 0.252 (0.177-0.37)	n=19; -26.1 (-27.3--25.2)	n=19; 8.8 (8.2-9.5)
LT	Dinosaur	n=52; 424 (260-630)	n=51; 922 (141-2676)	n=51; 1.04 (0.27-2.89)	n=45; 7 (4-13)	n=52; 0.092 (0.021-0.137)	n=52; -31.4 (-35.4--25.4)	n=52; 11.9 (9.3-13.1)
LT	Section 1	n=1; 780 (780-780)	n=0; NA (NA)	n=0; NA (NA)	n=0; NA (NA)	n=1; 0.109 (0.109-0.109)	n=1; -34.9 (-34.9--34.9)	n=1; 12.3 (12.3-12.3)
LT	Section 3	n=3; 421 (376-495)	n=3; 680 (485-985)	n=3; 0.89 (0.81-0.95)	n=1; 4 (4-4)	n=3; 0.124 (0.066-0.154)	n=3; -26.9 (-27--26.9)	n=3; 11.2 (11-11.6)
LT	Section 7	n=1; 306 (306-306)	n=1; 272 (272-272)	n=1; 0.95 (0.95-0.95)	n=1; 3 (3-3)	n=1; 0.207 (0.207-0.207)	n=1; -31.8 (-31.8--31.8)	n=1; 14.1 (14.1-14.1)
GR	Section 3	n=3; 353 (337-362)	n=3; 565 (473-646)	n=3; 1.27 (1.22-1.36)	n=0; NA (NA)	n=3; 0.038 (0.026-0.046)	n=3; -27.9 (-28.1--27.6)	n=3; 8 (7.8-8.4)
GR	Section 7	n=1; 336 (336-336)	n=1; 482 (482-482)	n=1; 1.27 (1.27-1.27)	n=1; 3 (3-3)	n=1; 0.018 (0.018-0.018)	n=1; -26.5 (-26.5--26.5)	n=1; 7.4 (7.4-7.4)
NP	Section 1	n=2; 362 (348-375)	n=2; 454 (345-563)	n=2; 0.94 (0.82-1.07)	n=0; NA (NA)	n=2; 0.053 (0.035-0.071)	n=2; -30.8 (-31.5--30.1)	n=2; 7.7 (7.3-8)
NP	Section 3	n=4; 628 (505-684)	n=3; 2435 (1897-2737)	n=3; 0.81 (0.73-0.86)	n=1; 4 (4-4)	n=4; 0.182 (0.106-0.337)	n=4; -26.8 (-28--25.9)	n=4; 9.9 (9.1-10.6)
NP	Section 5	n=21; 475 (284-800)	n=21; 992 (159-4139)	n=21; 0.71 (0.61-0.81)	n=2; 3 (3-3)	n=21; 0.119 (0.04-0.508)	n=20; -27.2 (-28.7--25.1)	n=20; 9 (7.9-10.3)
NP	Section 6	n=20; 575 (340-860)	n=20; 1801 (284-5260)	n=20; 0.78 (0.57-1.4)	n=3; 4 (2-5)	n=20; 0.166 (0.036-0.873)	n=17; -26.7 (-27.3--26)	n=17; 10.1 (9.1-11)
NP	Section 7	n=12; 598 (351-850)	n=12; 2177 (305-5470)	n=12; 0.78 (0.55-0.95)	n=0; NA (NA)	n=12; 0.209 (0.037-0.64)	n=10; -26.7 (-27.6--26.3)	n=10; 10.2 (9-11.4)
NP	Section 9	n=6; 501 (310-696)	n=6; 1217 (221-2595)	n=6; 0.73 (0.64-0.83)	n=3; 4 (1-6)	n=6; 0.106 (0.042-0.244)	n=4; -26.4 (-26.6--26.1)	n=4; 9.7 (8.4-10.6)
BB	Section 3	n=1; 420 (420-420)	n=1; 367 (367-367)	n=1; 0.5 (0.5-0.5)	n=0; NA (NA)	n=1; 0.17 (0.17-0.17)	n=1; -28.1 (-28.1--28.1)	n=1; 10.4 (10.4-10.4)
BB	Section 5	n=4; 384 (326-454)	n=4; 351 (186-485)	n=4; 0.6 (0.52-0.78)	n=0; NA (NA)	n=4; 0.076 (0.039-0.099)	n=2; -27.1 (-27.4--26.9)	n=2; 8.7 (8.1-9.2)
BB	Section 6	n=5; 412 (283-601)	n=5; 415 (131-889)	n=5; 0.55 (0.41-0.6)	n=0; NA (NA)	n=5; 0.094 (0.032-0.117)	n=5; -27 (-27.7--26)	n=5; 10.1 (9.1-11.4)
BB	Section 7	n=4; 422 (341-550)	n=4; 480 (216-1000)	n=4; 0.57 (0.55-0.6)	n=0; NA (NA)	n=4; 0.129 (0.075-0.16)	n=4; -27 (-29.6--24.6)	n=4; 10.2 (8.7-11.2)
BB	Section 9	n=13; 469 (302-725)	n=13; 650 (170-2310)	n=13; 0.53 (0.44-0.62)	n=0; NA (NA)	n=13; 0.157 (0.039-0.255)	n=12; -26.2 (-26.7--25.8)	n=12; 10.3 (8.8-11.2)

Figure 8-1. Length frequency for non-target species by location (across all sampling years; GR not shown due to insufficient number of fish).

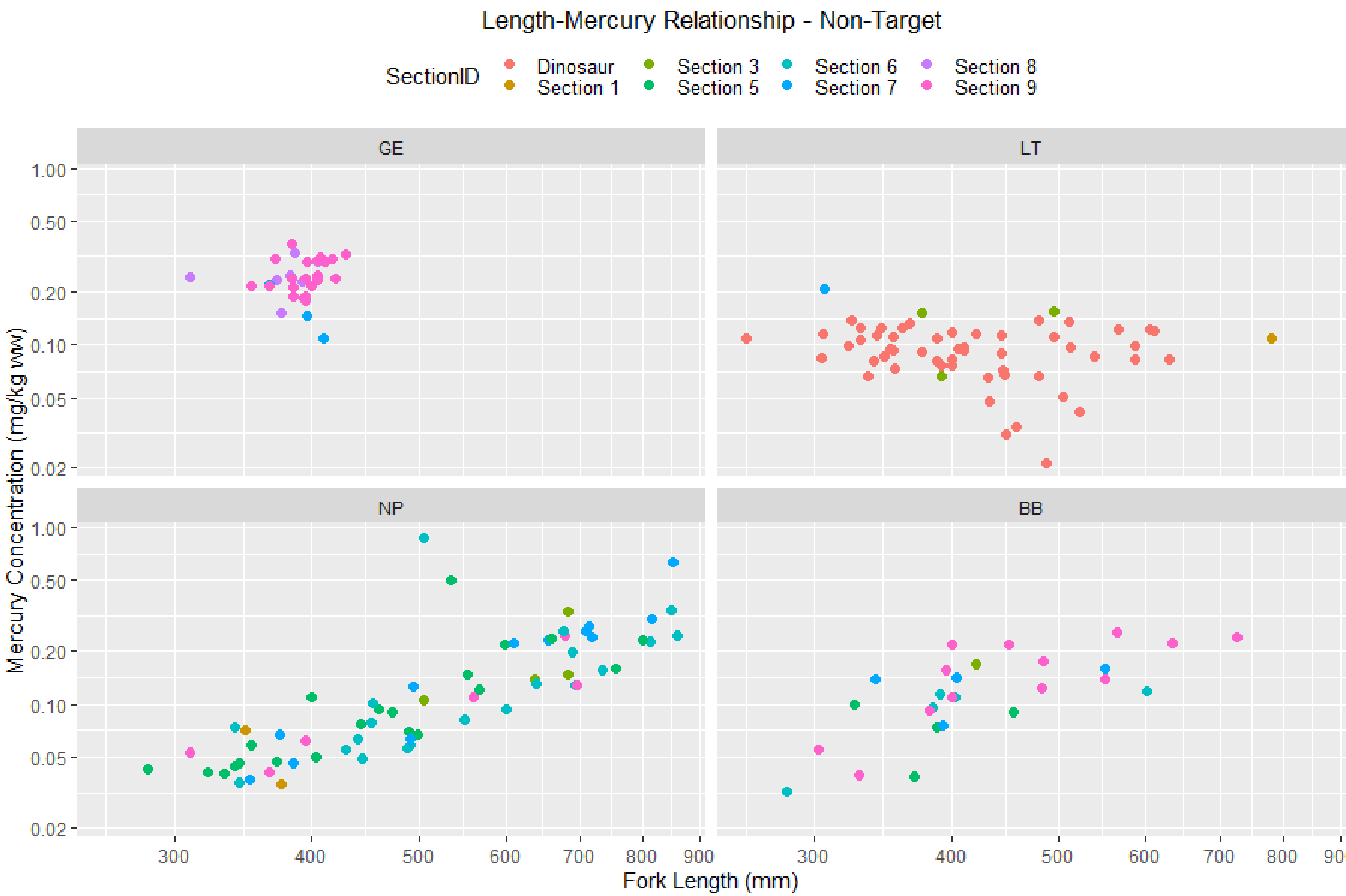


LT = Lake Trout, GR = Arctic Grayling, NP = Northern Pike, BB = Burbot, LW = Lake Whitefish

Figure 8-2. Key mercury-related relationships for non-target species (across all sampling years; GR and LW not shown due to insufficient number of fish).

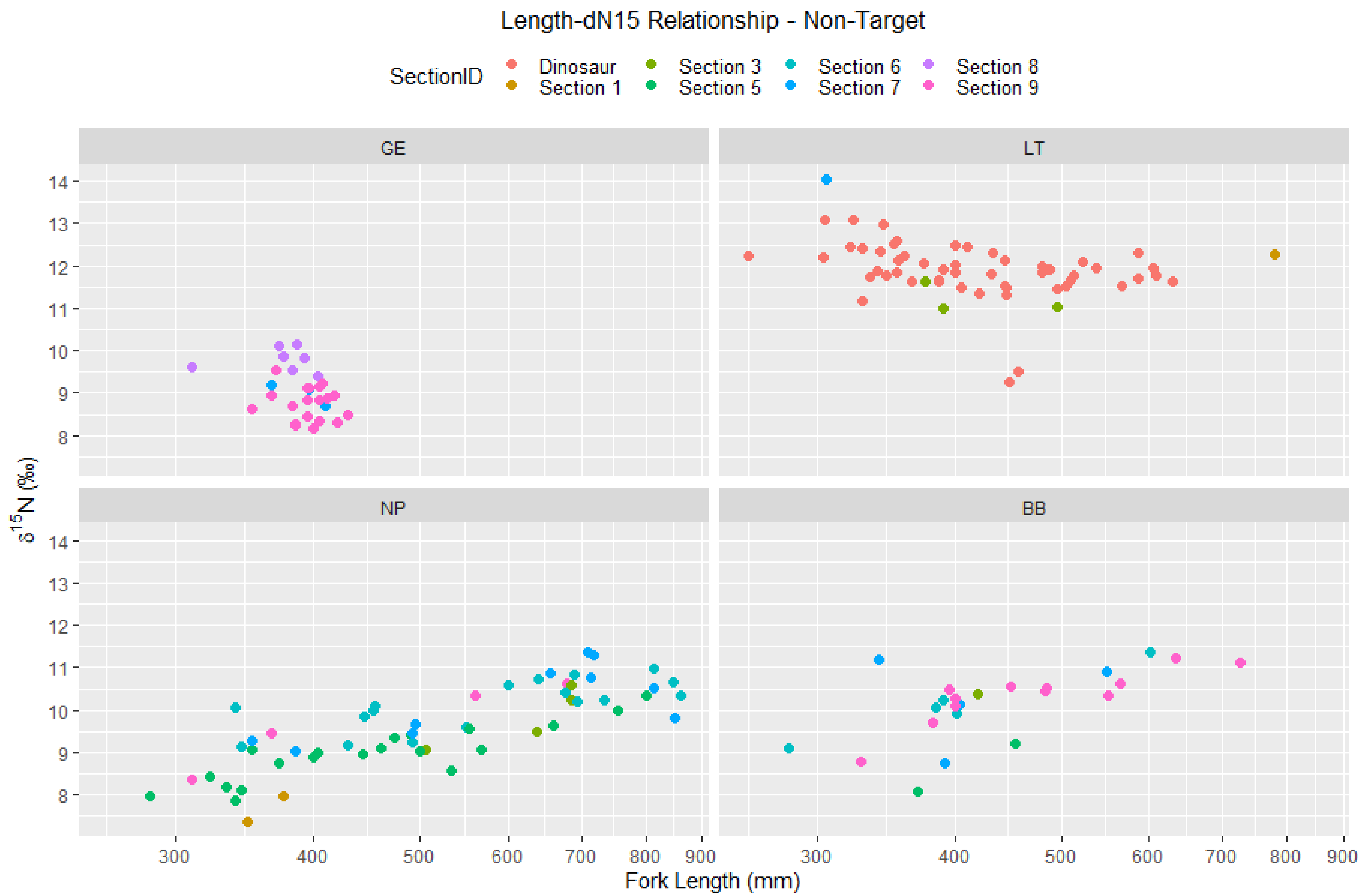


GE = Goldeye, LT = Lake Trout, NP = Northern Pike, BB = Burbot



GE = Goldeye, LT = Lake Trout, NP = Northern Pike, BB = Burbot

GE = Goldeye, LT = Lake Trout, NP = Northern Pike, BB = Burbot



GE = Goldeye, LT = Lake Trout, NP = Northern Pike, BB = Burbot

APPENDICES

APPENDIX A:
DATA QUALITY ASSESSMENT OF BASELINE FISH MERCURY DATASET (2010-2020)

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TABLES

APPENDICES

Appendix A1: SINLAB Interpretation Guide

1 INTRODUCTION

BC Hydro has committed to undertaking a broad range of environmental monitoring programs to collect information integral to understanding, and managing if appropriate, environmental changes related to the construction and operations of BC Hydro's Site C Clean Energy Project (Site C). The Site C Methylmercury Monitoring Plan (MMP; see *text box*) is one of these commitments, and spans the baseline, diversion and operations phases of Site C. Baseline sampling for Site C has been ongoing for a decade, starting initially in 2010 through 2011 ("early" baseline period) to support the environmental assessment process, then continuing more recently in 2017 through 2020 ("recent" baseline period) to characterize conditions prior to impoundment. Collectively, these efforts have resulted in the current fish mercury baseline dataset[1]; data and sources for the MMP dataset are summarized in **Table 1-1**.

MMP Background

The MMP is being developed by BC Hydro to meet the methylmercury-related conditions of the provincial Environmental Assessment Certificate (EAC) and the Federal Decision Statement (FDS). To that end, the MMP is being designed in consultation with Indigenous Groups to characterize mercury concentrations in fish, to understand Project-related mercury changes over time and, working with Health Authorities, to effectively communicate potential health risks associated with consuming fish from the Site C Reservoir and downstream in the Peace River.

While the MMP is technically a new program, we use the term "MMP" to collectively refer to past and future fish mercury monitoring efforts for Site C.

The MMP dataset is comprised of the following key data:

- *Fish morphometrics* (i.e., size and shape) –measured in the field and limited to length and weight.

[1] Additional baseline data were sourced from the Fish and Wildlife Compensation Program (FWCP) Peace Region's Williston-Dinosaur Watershed Fish Mercury Investigation (Azimuth 2019), which included mercury data from fish collected in the Dinosaur reservoir (upstream of Site C, and a possible reference waterbody for the MMP) in 2016 and 2017. However, data quality results for these samples are reported elsewhere (Azimuth 2019) and the data are not stored in the MMP database.

- *Tissue chemistry* – typically focusing on mercury (and moisture), but other metals were occasionally assessed too; analyzed in an analytical laboratory using a tissue sample. Tissue preferentially obtained using non-destructive techniques (Baker et al. 2004).
- *Tissue stable isotopes analysis (SIA)* – typically limited to carbon and nitrogen only; analyzed in an analytical laboratory using a tissue sample. Tissue preferentially obtained using non-destructive techniques (Baker et al. 2004).
- *Fish age* – a combination of methods used including capture history and aging structures (otoliths [destructive], fin rays [non-destructive] and scales [non-destructive]). Where available capture history and aging results are used together to refine age estimates (Golder and Gazey 2018, 2019, 2020).

Recognizing the advantages of developing a single repository for the growing mercury dataset, BC Hydro commissioned Golder Associates Inc. (Golder), in collaboration with Azimuth Consulting Group Inc. (Azimuth), to develop an Access database for the MMP (Golder 2020), to house all Site C generated mercury-related data.

In working through the MMP design process (starting in 2019), a number of MMP study design (now in draft, BC Hydro 2021) questions were raised internally that were difficult to answer without the benefit of statistical analysis of the baseline data collected to-date so Azimuth was commissioned to produce the *Preliminary Analysis of Site C Baseline Fish Mercury Data: Site C Methylmercury Monitoring Plan (MMP)* (Azimuth 2021). In the interest of time, this effort did not include an assessment of the data quality, but it was recognized that a full assessment of the baseline data (as well as the Access Database itself) was of high importance to ensure data quality now and into the future of the MMP (which is expected to be a ~25+ year program). This technical memorandum is a companion document to Azimuth 2021, presenting the QA/QC assessment for the Site C baseline fish mercury dataset.

1.1 Quality Assurance/Quality Control

A Quality Assurance/Quality Control (QA/QC) program helps to ensure that the chemical and biological data collected for the MMP are representative of the material or populations being sampled, are of known quality, have sufficient laboratory precision to be highly repeatable, are properly documented, and are scientifically defensible.

- *Quality Assurance* (QA) are the practices employed (e.g., use of experienced field staff, Standard Operating Procedures [SOPs], field data sheets, and certified laboratories) to collect scientifically defensible data meeting data quality objectives (DQOs).

- *Quality Control* (QC) are the measures taken to verify that the specific DQOs (e.g., limits for bias and precision) are met. QC measures can be based in the field (e.g., field duplicates, equipment blanks, and travel blanks) or laboratory (e.g., lab duplicates, method blanks, certified reference materials [CRMs], and lab standards).

The Site C baseline fish mercury data collection to-date has been integrated into other monitoring programs and therefore has not had a dedicated QA/QC program; however, each of the monitoring programs that the mercury data are sourced from have had their own QA/QC program. QA/QC by year/program are summarized in **Table 1-2**.

This technical memorandum presents a centralized QA/QC assessment conducted by Azimuth for the Site C baseline fish mercury dataset. Broadly this assessment supports two MMP-related efforts:

- *MMP Database* - Golder, in collaboration with Azimuth, developed an Access database for the MMP (Golder 2020), to house all MMP-related data. Data are continually added to the database, on a roughly annual basis. Presently, the database includes data up to and including 2020 data.
- *Preliminary Baseline Fish Mercury Analysis* – To support development of the MMP, statistical analyses were conducted by Azimuth (2021) to better understand temporal and spatial trends in the baseline dataset.

While mercury (and other parameters) has been and will be monitored in other environmental media (e.g., water, sediment and invertebrates) as part of the MMP, this QA/QC assessment is limited to fish at this time.

1.2 Document Structure

The remainder of this document is structured as follows:

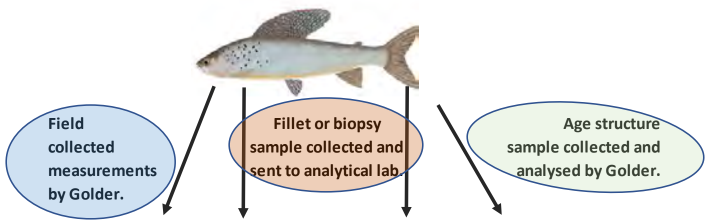
- *MMP Database Quality* (**Section 2**) – assesses the functionality of database structure and verifies that the stored MMP fish-related data matches the original sources.
- *Data Quality* (**Section 3**) – assesses the actual quality of the MMP fish-related data.

Table 1-1. Summary of mercury and supporting data compiled for MMP.

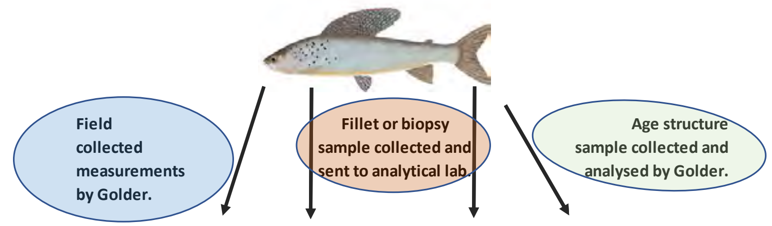
Program	Year Data Collected	Locations (MMP Specific)	Species (MMP Target)[1]	Data Type[2]	Analysis	Lab Report	Data Report
Site C EA	2010	Dinosaur, Section 3 and 5	BT, MW, LSU, RSC	Field	Mainstream	NA	Azimuth 2011
				Hg	ALS	L937092	
				Hg	ALS	L937091	
				SIA	SINLAB	SINLAB 2010 Fish and Benthos RBA 001-126-1	
				Age	Golder[3]	none located	
	2011	Dinosaur, Section 1, 3, 7 and 8	BT, RB, MW, LSU, WP, GE	Field	Mainstream	NA	Mainstream 2013 / Azimuth 2014
				Hg	ALS	L1085007	
				SIA	SINLAB	SINLAB 2011 Fish RBA 222-390	
				Age	Golder[3]	none located	
FWCP	2016	Dinosaur	RB, LSU	Field	Azimuth	NA	Azimuth 2019
				Hg	ALS	L1864020	
				SIA	SINLAB	Si Data Report	
	2017	Dinosaur	BT, RB	Hg	ALS	L1987923	
				SIA	SINLAB	Dinosaur Derby 17AZ 001-212	
				Age	North/South	Azimuth-PeaceR-R.Baker_QAQC	
FAHMFP	2017	Section 1, 3, 5, 6, 7 and 9	BT, RB, MW, LSU, RSC, WP, GE	Field	Golder	NA	Golder & Gazey 2018
				Hg	ALS	L2212785[4]	Azimuth 2020
						L2212694[4]	Azimuth 2020
						L2023871	Azimuth 2020
				SIA	SINLAB	18 Golder 001-452	Azimuth 2020
				Age	Golder	Digital deliverable to BCH[3]	Golder & Gazey 2018
	2018	Section 1, 3, 5, 6, 7 and 9	BT, RB, MW, LSU, WP, GE	Field	Golder	NA	Golder & Gazey 2019
				Hg	ALS	L2212624	Azimuth 2020
						L2212391	Azimuth 2020
				SIA	SINLAB	18 Golder 001-452	Azimuth 2020
				Age	Golder	Digital deliverable to BCH[3]	Golder & Gazey 2019
	2019	Section 1, 3, 5, 6, 7 and 9	BT, MW, LSU, WP, GE	Field	Golder	NA	Golder & Gazey 2020
				Hg	ALS	L2395235	Azimuth 2020
				SIA	SINLAB	19 GOLD 001 - 189	Azimuth 2020
				Age	Golder	Digital deliverable to BCH[3]	Golder & Gazey 2020
	2020	Section 1, 3, 5, 6, 7 and 9	BT, RB, MW, LSU, RSC, WP, GE, LT, NP, BB	Field	Golder	NA	in prep.
					Triton	NA	in prep.
				Hg	ALS	VA20C3662	in prep.
				MeHg	ALS	VA20B7317	in prep.
				SIA	SINLAB	21Gold 001-151	in prep.
						20TRI 001-011	in prep.
				Age	Golder	Digital deliverable to BCH[3]	in prep.

Notes:
[1] Species Codes: BT = Bull Trout, MW = Mountain Whitefish, RB = Rainbow Trout, LSU = Longnose Sucker, RSC = Redside Shiner, WP = Walleye, GE = Goldeye
[2] Analysis Codes: Hg = Mercury, MeHg = Methylmercury, SIA = Carbon and Nitrogen Stable Isotope Analysis.
[3] Raw data are included with annual report as digital attachment.
[4] Collected in 2017 but analysed in 2019.

Table 1-2. Summary of QA/QC workflow for recent (2017-2020) and early (2010-2011) baseline Site C mercury and supporting data.



Year Fish Caught	Step in Process	Length (L) & Weight (W)	Mercury (Hg)	Stable Isotope Analysis (SIA)	Age
Recent Period (2017-2020, FAHMFP)	Field	Qualfied professionals conduct field program. Electronic entry with QA features built in.	Baker et al., 2004 sampling procedures. Field duplicate samples (collected in 2017 and 2020 only).	Baker et al., 2004 sampling procedures. Field duplicate samples (collected in 2020 only).	Age structure collected: Finray (GR, GE, MW, RB), Scales (GE, NP, LT, BT, WE).[1] Otoliths where fish succumbed to sampling only.
	Laboratory	n/a	Lab (ALS) QC: lab duplicates, lab control samples, method blanks and certified reference materials.	Lab (SINLAB) QC: laboratory duplicates, secondary standards and check standards.	Two experienced personnel independently age each structure. Aging methods evaluated annually and adjusted based on lessons learned and lit review.
	Database	Electronic entry completed in the field.	Direct electronic import from lab report(s). Some years have multiple ALS lab reports.	Direct electronic import from lab report.	Direct electronic import (append query from FAHFMP database to MMP database).
	Statistical Analysis	L vs W outlier assessment (Azimuth 2021).	L vs Hg & dN vs Hg outlier assessments (Azimuth 2021).	dN vs Hg outlier assessment (Azimuth 2021).	None, less precise measurement than length



Year Fish Caught	Step in Process	Length (L) & Weight (W)	Mercury (Hg)	Stable Isotope Analysis (SIA)	Age
Early Period (2010-2011, Site C Baseline)	Field	Qualfied professionals conduct field program. Hardcopy datasheet entry in field, transcribed to Excel database, 10% QA check.	Baker et al., 2004 sampling procedures. Field duplicate samples.	Baker et al., 2004 sampling procedures.	Age structure collected: Otolith (MW), Finray (LSU, RB, BT), Scales (RSC).[1]
	Laboratory	n/a	Lab (ALS) QC: lab duplicates, lab control samples, method blanks and certified reference materials.	Lab (SINLAB) QC: laboratory duplicates, secondary standards and check standards.	Two experienced personnel independently aged each structure.
	Database	Electronic transfer from Excel database to Access database.	Direct electronic import from lab report(s). Some years have multiple reports.	Direct electronic import from lab report.	Electronic transfer from 2011 database (Excel) to Access database.
	Statistical Analysis	L vs W outlier assessment (Azimuth 2021).	L vs Hg & dN vs Hg outlier assessments (Azimuth 2021).	dN vs Hg outlier assessment (Azimuth 2021).	None, less precise measurement than length

Notes:

The FWCP data from Dinosaur Reservoir is not included in this table. Readers are directed to Azimuth (2019) for information on field and laboratory QA/QC. These data were merged with the Site C data prior to conducting the statistical analyses.

[1] Species Codes: BT = Bull Trout, MW = Mountain Whitefish, RB = Rainbow Trout, LSU = Longnose Sucker, RSC = Redside Shiner, WP = Walleye, GE = Goldeye

Azimuth 2021 = Preliminary Analysis of Site C Baseline Fish Mercury Data Report

2 DATABASE QUALITY

An Access database for the MMP that centralizes all mercury-related data for Site C, has been developed and maintained by Golder and Associates (Golder). For details on the contents and organization of the baseline Access database, see the metadata summary report (Golder 2020). Here we document the process undertaken by Azimuth, with the assistance of Golder, to ensure through compiling and centralizing various data sources into a database, data quality is maintained. That is, documenting how the information is transcribed from source into the database, and reviewing data systematically to ensure from a structural perspective, it matches the information from the original sources.

Data Transfer to Access Database

Early period fish morphometric data (and other field-collected data) were manually entered into Excel from hardcopy datasheets by an experienced professional. This Excel data had at a minimum 10% of transcribed e-data reviewed independently by a second experienced professional to check for completeness and accuracy. Excel data were bulk transferred to the Access database and spot checked from accuracy (i.e., the correct data type was transferred to the correct Access table/column).

Recent period fish morphometric data (and other field-collected data) were input to the Access database by direct transfer from the electronic FAHMFP database and spot checked for accuracy.

Chemistry and SIA lab data (including select laboratory QC data[2]) was directly transferred from electronic lab reports (copies of reports also stored in the database).

Age data was either input from Excel (early period) or from FAHMFP database (recent period).

Database Assessment

The assessment of the database looked at two main aspects:

[2] Chemistry and SIA laboratory QC data was input to the Access database with the exception of the results for SIA check standards and secondary standards, which was reported in a format not easily electronically transferred. These QC components are tracked manually, outside of the database.

1. That the database design (i.e., collection of tables/fields) allowed for the inclusion of all relevant MMP information.
2. That the data were imported completely and accurately from the sources into the appropriate tables/fields in the database.

Thus, the database assessment did not focus on the quality of the specific data being housed (see **Section 3** for details), but rather on the completeness and accuracy of the data in bulk and the structure of the database itself. Ultimately, the database needs to provide unambiguous linkages across information types: fish-related information (e.g., date, species, catch location, and morphometric data), tissue mercury (and other metals) data, tissue SIA data, and age data in order to function as intended. The following checks/modifications were conducted on the database to assess/improve this functionality:

- *Verification of number of mercury samples by year* – this provided a direct comparison of data with original sources, particularly for the early period data (summarized previously; Azimuth 2014). Note that the year the samples was collected, rather than the sample laboratory reporting date, was used to determine the year for a given sample.

  Accounting for samples was challenging for the 2017 data, where some tissue samples were erroneously discarded by the chemistry laboratory prior to analysis and records related to the incident were incomplete. This effort was also hampered by

  - Inconsistent naming conventions employed by the field team (e.g., fish IDs used as sample labels rather than listed mercury sample IDs).
  - In response to the chemistry lab mistake, samples originally destined for SIA were redirected for mercury analysis, but without updating the sampling records; the redirected samples were analyzed and reported in 2019.
  - Due to the redirect (see above bullet), multiple tissue samples from the same fish were inadvertently analyzed (termed “inadvertent duplicates” to reflect their status accurately).
  - Cases where fish recorded in the database were without an associated tissue mercury result (due to sample throw-away); these fish records were removed from the database.

- *Identification/verification of mercury data measurement units* – this is a common error in fish mercury studies, but is easy to verify. Units are generally mg/kg, but can be reported on a wet weight or dry weight basis. The convention for tissue mercury concentrations is on a wet weight basis, but concentrations reported in dry weight can be converted using moisture content (measured or assumed). Results were verified against the original lab reports.

- *Identification of tissue sample type* – the two options are biopsy and fillet; the former is generally associated with non-lethal sampling and the latter with lethal sampling. This is important to know only as it relates to laboratory analytical methods and tissue chemistry results reporting (i.e., biopsy samples reported on a dry weight basis).
- *Standardization of species names* – this is important to ensure consistency across sampling periods and correctly associate sample results to a particular fish species.
- *Unique identifiers for fish and fish/year* – non-lethal sampling allows for the possibility of catching the same fish in different years (note that any fish caught more than once in the same year would not be sampled again). Unique identifiers for the fish in general and for each capture event for that fish facilitates individual records for each capture (e.g., to accommodate different results for location, morphometric measures, etc.) while allowing easy identification of capture history, and hence evolution of tissue mercury concentrations for that particular fish.
- *Identification of age structures used* – methods for aging fish have been modified over the years at Site C to obtain more accurate estimates of age (see **Section 3.2**). Confidence in the age estimates differs according to the aging structure used and species. A database field was added to document the aging structure type.
- *Identification of Field Quality Control Samples* – there were inconsistencies in the collection of field duplicate samples across years, including the 2017 situation (see first bullet above). Field duplicate samples are submitted "blind" (i.e., the lab does not know which samples are duplicates) to verify the precision of the laboratory. The results are provided alongside the rest of the samples, so additional information (recorded in the field) is needed to pair the duplicate sample to the original sample. Consequently, a table (tble2TissueSample) was added to the database to provide information on sample QC type, explicitly identifying all samples as an original sample (SAMP) or a duplicate (DUP) sample with pairing information. Note that cases where multiple duplicates were found (e.g., as occurred with the inadvertent duplicates from 2017), the duplicates were numbered (e.g., DUP1, DUP2, etc.) and the first in the series used for QC purposes.

3 DATA QUALITY

3.1 Assessment Overview

A summary of the QA/QC workflow for each of the two Site C baseline sampling periods is presented for the field and laboratory, database, and statistical analyses in **Table 1-2**. Database quality was discussed in **Section 2**. Details on QA/QC for the statistical analysis (e.g., outlier assessment, etc.) of the MMP baseline dataset is reported in the companion document *Preliminary Analysis of Site C Baseline Fish Mercury Data: Site C Methylmercury Monitoring Plan (MMP)* (Azimuth 2021). This section focuses on the assessment of the overall quality of the MMP data, with subsections on Quality Assurance (**Section 3.2**) and Quality Control (**Section 3.3**) for the field and laboratory components.

3.2 Quality Assurance

Careful collection, documentation and handling of all samples and data, regardless of media, data type, or frequency is a key component of QA on a field program. Below is an assessment of the QA component of the Site C baseline fish mercury data.

For all data sources, field programs were carried out by experienced field crews that follow standard field procedures, as described in each program's reports (see **Table 1-1** for list of reports).

Field Datasheets

The 2010 and 2011 Site C EA sampling programs (Azimuth 2011, Azimuth 2014) relied on recording field-collected information and data in field data sheets initially, followed by scanning the data sheets and transcribing the data into Excel after returning from the field. In the field, data entry included two or more of the field crew to ensure that all data were logged correctly. At a minimum, 10% of transcribed e-data were reviewed independently by a second experienced professional to check for completeness and accuracy.

As of 2015[3], BC Hydro implemented a system of electronic entry of all FAHMFP field data, which has a number of benefits from a data quality perspective. 1) there is no extra data-handling required as is the case with field hard copy to office electronic copy transcription. 2) the

[3] While the FAHMFP has been collecting data since 2015, mercury data collection under this program began in 2017.

FAHFMP database has built-in QC features. For example, a warning prompt if the fish body condition measure is outside an acceptable range. For further information see the FAHMFP study design document (BC Hydro 2015).

Standard Operating Procedures (SOPs)

Tissue sampling methods (mercury and SIA) for both the early and recent MMP baseline periods were based on Baker et al. (2004). A brief synopsis of these procedures is as follows:

A sample of dorsal muscle tissue is acquired from all fish. Fish captured alive are anesthetized, biopsied, then released alive. Tissue plugs are collected from anaesthetized fish using single-use tissue biopsy sampler. The tissue sample is placed into sterile, individually-labeled vials, kept on ice, and frozen at the end of the field day. Fish that succumb to capture have fillet tissue removed, samples placed into labelled bag, kept on ice, and frozen at the end of the field day. All fish collected (whether biopsied or filleted) also have a small piece of tissue (either a single biopsy plug or fillet) collected for stable carbon and nitrogen isotope analysis (SIA).

For ageing structure collection methods, see annual FAMHFP reports (recent period; Golder & Gazey, 2018, 2019, and 2020) and Azimuth reports (early period; Azimuth 2011 and 2014).

Certified Laboratories

The certified laboratories contracted to analyze field samples for baseline mercury-related data are named in **Table 1-1**.

Shipments of samples to the analytical laboratories were accompanied by chain-of-custody (CoC) forms detailing sample identification, reporting requirements, and sample handling information. CoC forms not only inform the laboratory of sample details, they also help ensure that sample handling instructions are followed, sample hold-times are met, and that all samples are accounted for.

Mercury and Moisture (Chemistry) Analysis

All tissue analyses for mercury and moisture in the MMP dataset have been conducted by ALS Environmental (ALS), a CALA-accredited lab in Burnaby, BC. The BC environmental laboratory QA/QC procedures are detailed in Austin (2020).

Carbon and Nitrogen Stable Isotopes Analysis (SIA)

All SIA analyses were completed by the University of New Brunswick's (UNB) Stable Isotopes in Nature lab (SINLAB). SINLAB was established in 1999 as part of UNB's Canadian Rivers Institute under the direction of Dr. Rick Cunjak. They specialize in SIA in environmental samples to support academic, private and government researchers.

Age Analysis

Golder has conducted all the fish ageing analysis for the FAHFMP data sourced for the MMP. QA/QC procedures for all MMP baseline data sources include independently assessing ageing structures by two or more experienced individuals.

To continually increase the accuracy of ages assigned using aging structures, specifically fin rays, FAMHFP ageing methods are modified relative to previous study years based on lessons learned and literature reviews. Aging methods, including changes, are described in the annual FAHFMP Mon-2, Task 2a reports, the most recent of which is particularly thorough (Golder and Gazey 2020).

Through years of experience with Site C fish age data, Golder has gathered evidence that not all age data are created equal, with some ageing structures and methods of ageing producing higher quality (more accurate) data than others. Age data methods have been modified and updated over the baseline years in an effort to produce high quality data.

Generalizing across species, the hierarchy of the quality of aging methods is: encounter history & years at-large > otoliths > fin rays > scales (Golder and Gazey, 2020). However, rather than assign a qualitative value to the data (i.e., good, moderate, poor), the MMP Database instead provides the method that was used for ageing, thereby leaving the decision of whether or not to include the ages in an analysis up to the user (i.e., does the user consider fin rays, as an example, to be accurate enough for their purposes).

To-date, the MMP has utilized age and weight data as supporting variables, not primary variables like length, in the assessment of size-mercury relationships in fish. For this reason, all age data have been deemed acceptable for the MMP assessments and included in analysis, recognizing that there is known bias in subsets of the data. To ensure full transparency for future MMP data assessments involving fish age, aging data and aging methods have been carefully documented in the MMP database.

3.3 Quality Control

This section provides the results of QC samples for the field and lab, where appropriate, followed by an overall statement of data quality for each of the four main data types.

3.3.1 Fish ID and Morphometrics

Fish identification and morphometric data for the Site C MMP are comprised of species, maturity, body length, and body weight measurements.

Field

As noted in **Section 3.2**, in the recent baseline period (FAHMFP sampling), fish identification and morphometric data were recorded directly into an electronic FAHMFP database in the field. This electronic system included instantaneous QC checks of length and weight by calculating condition (K) and comparing the results for each fish to expected norms.

Lab

There is no laboratory QC component for these data.

Overall

These data meet the data quality needs of the MMP.

3.3.2 Tissue Chemistry

Field

Field Duplicates (FD)

FDs were collected as a QC measure to provide insights into (a) within-fish variability in tissue mercury and (b) the precision of laboratory analyses. FD samples are collected from the same fish and treated independently through the sampling and analysis process; they are submitted "blind" to the lab. Data quality objectives (DQOs) are based on relative percent difference (RPD) between the original and duplicate samples (see calculation below) or the absolute difference (DIFFx) between the original and duplicate samples; the specific DQO values are set at 1.5x higher than those used by ALS for laboratory duplicates (i.e., RPD = 45% and DIFFx = 3x the method detection limit [MDL]). This approach is consistent with the Canadian Council of Ministers of the Environment (CCME) (2016) approach for field QC samples, which acknowledges that DQOs should be set to recognize the higher variability expected when a sample is processed through the whole laboratory analysis process (i.e., not just post-homogenization process as is done in laboratory duplicates).

RPDs are calculated as follows:

$$RPD = \frac{(A - B)}{(\frac{A + B}{2})} x\ 100$$

where: A = original sample result; B = duplicate sample result; both samples need to be measured above the MDL. The calculated RPD is compared to the DQO.

FD samples pass if either the RPD or DIFFx meets their respective DQO.

Field QC results across sampling years are summarized in **Table 3-1**. A total of 50 field duplicate samples were analyzed in the baseline dataset. Field duplicates were explicitly included in the 2010, 2011 and 2020 monitoring events, but were not collected in 2017 through 2019. However, there were some inadvertent FDs in 2017 that stem from a laboratory error[4]. Six (12%) of the 50 FD samples across the baseline dataset did not meet the FD DQO (**Table 3-2**). These results suggest that while the majority of samples met the precision-related DQOs, the absolute results of individual sample results should be interpreted with some caution due to the variability in precision.

Lab

ALS' laboratory QC results are summarized in **Table 3-3**; details on each QC sample type and their respective results are described below.

Laboratory Duplicates (LD)

LD samples provide insights into the precision of laboratory analyses. Duplicate aliquots are taken from the samples and run through part (aliquots taken post digestion) or all (aliquots taken from the sample tissue) the laboratory analytical process. DQOs are based on RPD between the original and duplicate samples or the DIFFx between the original and duplicate samples. The mercury laboratory RPD DQO for precision is 30% and the laboratory DIFFx DQO for mercury is 2 x MDL.

Twenty-six of 27 laboratory duplicates met ALS' DQOs for LC samples (**Table 3-3**). Details regarding the only sample not meeting the DQO are provided in **Table 3-4**. These results show that ALS' analytical process was working as intended, providing good precision in the mercury analyses.

Laboratory Control Samples (LCS)

LC samples provide insights into whether the laboratory systems are working as intended. They are comprised of a mixture of analyte-free water to which known amounts of the method analytes are added. They are essentially an internal version of a certified reference material. The DQO for LCSs for tissue mercury are 30% (i.e., recovery of 70 to 130%).

[4] The laboratory discarded a number of the original tissue samples submitted for mercury analysis. Samples originally destined for stable isotope analysis (SIA) were redirected to ALS for mercury analysis. As some of the original samples were already analyzed, this led to multiple results from the same fish, or an "inadvertent" field duplicate.

Only two of 69 LCS samples failed to meet the DQOs (**Table 3-3**). Details regarding the two samples that failed to meet DQOs are provided in **Table 3-5**. Overall, these results indicate good accuracy and precision in ALS' mercury analyses.

Matrix Blanks (MB)

MB samples are analyzed to assess background interference or contamination that exists in the analytical system that could lead to elevated concentrations or false positive data. These samples are comprised of analyte-free water. The DQO for method blanks is that the results are <MDL (i.e., no detectable concentrations found).

None of the 116 MB samples analyzed over the years contained detectable amounts of mercury (**Table 3-3**), suggesting that the sensitivity of the analytical instruments were set appropriately.

Certified Reference Materials or Reference Materials (CRM or RM)

CRMs (aka RMs) are similar to LCS samples, but the dried tissue media are purchased from external suppliers. CRMs have a known concentration against which the lab must achieve a precision of within 10% either side of the CRM.

All 117 CRM samples met the DQOs (**Table 3-3**). These results confirm the accuracy and precision of ALS' tissue mercury analyses.

Overall

A total of 382 field and lab QC checks related to tissue mercury were conducted across sampling years. Only 9 (2%) of those checks failed to meet their respective DQOs, 6 of which were field duplicates. Four of those 6 cases were in 2011. Given the lab duplicates results (96% met DQOs), the field duplicate results suggest possible incomplete homogenization of some tissues in 2011, warranting some caution in putting too much emphasis on the results of individual fish that year. Overall, the QC results verify that the accuracy and precision of tissue mercury analyses meet the data quality needs of the MMP.

3.3.3 Tissue Stable Isotopes

Field

Field Duplicates (FD)

FD samples are collected from the same fish and treated independently through the sampling and analysis process; they are submitted "blind" to the lab. DQOs are based on relative percent difference (RPD) between the original and duplicate samples (see **Section 3.3.2** for calculation).

FDs provide insights into (a) within-fish variability in tissue and (b) the precision of laboratory analyses. Due to the general high precision and accuracy of SIA, FDs were not included as a QC measure prior to 2020.

Generally, FD DQO values are set at 1.5x higher than those used for laboratory (see **Section 3.3.2** for further discussion). However, SINLAB does not provide laboratory duplicate DQOs (see next sub-section for further discussion), so FD DQOs were not developed in advance for SIA. Rather, FD RPD results for SIA were evaluated based on their magnitude alone, with consideration as to how they provide insights into laboratory precision. RPDs for the FD samples are provided in **Table 3-6**. The RPD results for most samples were less than 5%, with many (24 of 30; 80%) of the results at or below 2%. The highest RPD was still only 9%. These results verify high precision for FDs.

Lab

SINLAB provides an Interpretation Guide (**Appendix A1**) with all laboratory data results, which includes discussion of QC standards and is updated occasionally to reflect updated acceptability values for standards. The types of QC samples that SINLAB uses to ensure their laboratory processes are working properly are described below, along with their results.

Laboratory Duplicates (LD)

LDs provide insights into the precision of laboratory analyses. Duplicate aliquots are taken from the samples and run through part (aliquots taken post digestion) or all (aliquots taken from the sample tissue) the laboratory analytical process. DQOs are based on RPD between the original and duplicate samples. LDs are identified in SINLAB analytical results by an "R" appended to the end of the sample ID. SINLAB does not have a set acceptability range for LDs, based on the following rationale:

> *"Different tissues have different matrices and things such as lipid content, how finely ground, residual shells, to name a few, can make the replicates more variable. As such, a "set" acceptable range* [for LDs] *does not exist. Typically, a duplicate sample with a difference of greater than 0.5 per mil is flagged, and when possible, run again."* (Anne McGeachy, pers. comm. 2021).

To our knowledge, none of the laboratory duplicates were flagged, or re-run by the lab. Calculated RPDs for LDs (**Table 3-7**) were all at or below 4%.

Secondary Standards and Check Standards (Standards)

Secondary standards[5] are SINLAB's internal working standards (i.e., created by SINLAB). They are calibrated against and traceable to International Atomic Energy Agency (IAEA) primary standards (CH6, CH7, N1, and N2) and are subjected to round robin testing for verification as a part of SINLAB's QA/QC protocol. Check standards are commercially available standards and are analyzed in each SINLAB run (batch of samples).

Results for secondary and check standards (**Table 3-7**) were generally within the acceptable range. The only exception was in the 2020 results for Redside Shiner (lab report 20TRI 001-011; submitted by Triton), where the mean results for USGS61 (secondary standard), CH7 (check standard) and nicotinamide (check standard) were outside the acceptable range. The lab provided the following explanation:

> *"If any of our standards, on a given day, have a deviation of greater than 0.2* [per mil] *we will take extra time to review traces and see if the data are acceptable. The Interpretation Guide is just a "guide" to give you an idea of the results we see in the lab. I am not sure when this guide was last updated, given our restricted access to campus during COVID. In 2020, close to 300 USGS61 samples were run: the average value for the year was -34.96 and the standard deviation of 0.12. Although your samples land at the edge of this range, we felt the data were acceptable.*
>
> *There are typically 13 points that make up the regression line used to bring the observed values to the international scale. If one standard is slightly off, it does not usually change the regression line by much. In the case of the Triton data (run in October 2020) the equipment was stable throughout the run and the traces looked good. Only the standards around -30 were slightly off from the expected values and none of your samples were in this range. Again, we felt this was not a difference worth holding up the data and running it a second time. Following your inquiry, I was curious as to what the results for your samples would have looked like if the values in the -30 range were a little tighter. The difference in the slope and intercept are so slight that the resulting delta values for the Triton samples change by less than 0.2 per mil…"* (Anne McGeachy, pers. comm. 2021)

[5] SINLABs secondary standards are analogous to ALS' laboratory control samples.

After our request for more information, SINLAB offered to re-run the samples, but Azimuth and Triton agreed with SINLAB's interpretation that the data were acceptable as-is, and there was no need to re-run the analysis.

Overall

SIA data are used in the MMP to provide ecological context to the tissue mercury results. SIA data can be used to provide high-level insights into why tissue mercury concentrations might be different among species, locations or time periods, or to help understand the results for individual fish (e.g., those with different feeding strategies than their cohorts).

Overall, the field and lab QC checks provide confirmation that SINLAB's laboratory processes are resulting in high quality SIA data that meets the needs of the Site C MMP.

3.3.4 Fish Age

Field

For information on the age data field QC procedure, see each program's reports (see **Table 1-1** for list of reports).

Lab

For information on the age data lab QC procedure, see each program's reports (see **Table 1-1** for list of reports).

Overall

The relative variability of fish age data are typically much higher than either fish length or weight. Golder has introduced methods meant to improve the accuracy and precision of estimates, but not to a level where the results would be similar to fish length from a measurement variability perspective. As discussed in **Section 3.2**, the magnitude of variability, and hence confidence in the aging results, depends on the aging structures used.

Age is used in the MMP to help inform fish growth rates, which can affect tissue mercury concentrations (e.g., faster growing fish tend to "dilute" tissue mercury concentrations relative to slower growing fish). While fish mercury programs are usually limited to the ages of fish sampled in the program, the MMP has the added benefit of the full FAHMFP dataset to make inferences about different growth rates among locations, populations or time periods. In addition, both the MMP and FAHMFP databases include a field identifying the aging structure used, providing a means of understanding the degree of confidence associated with each age estimate.

Overall, the aging data meets the needs of the MMP.

Table 3-1. Summary of field quality control results for the Site C baseline fish mercury dataset, 2010 through 2020.

Event(s): 2010 to 2020

	Pass	Fail	ND
Field Duplicate			
2010	7	1	0
2011	16	4	0
2017	8	1	0
2018	0	0	0
2019	0	0	0
2020	13	0	0
Totals	44	6	0

Table 3-2. Details for field duplicate samples not meeting data quality objectives.

Event(s): 2010 to 2020

Year	Group	Analyte	Units	DL	Samp	Dup	RPD	DIFFx	FD.QC
2011	20	Mercury (Hg)-Total	mg/kg wwt	0.001	0.0188	0.0437	79.7	24.9	Fail
2011	4	Mercury (Hg)-Total	mg/kg wwt	0.001	0.0282	0.0720	87.4	43.8	Fail
2011	18	Mercury (Hg)-Total	mg/kg wwt	0.001	0.0457	0.0063	151.5	39.4	Fail
2011	17	Mercury (Hg)-Total	mg/kg wwt	0.001	0.0331	0.1040	103.4	70.9	Fail
2017	22	Mercury (Hg)-Total	mg/kg wwt	0.001	0.0210	0.0550	89.5	34.0	Fail
2010	8	Mercury (Hg)-Total	mg/kg	0.005	0.3390	0.1650	69.0	34.8	Fail

Table 3-3. Summary of laboratory quality control results for the Site C baseline fish mercury dataset, 2010 through 2020.

Event(s): 2010 to 2020				Event(s): 2010 to 2020			
	Pass	**Fail**	**ND**		**Pass**	**Fail**	**ND**
Lab Duplicate				*Lab Control Sample*			
2010	4	0	0	2010	0	0	0
2011	11	1	0	2011	0	0	0
2017	4	0	0	2017	26	0	0
2018	4	0	0	2018	19	2	0
2019	2	0	0	2019	15	0	0
2020	2	0	0	2020	9	0	0
Totals	27	1	0	Totals	69	2	0
Matrix Blank				*Certified Reference Material*			
2010	22	0	0	2010	29	0	0
2011	23	0	0	2011	17	0	0
2017	26	0	0	2017	26	0	0
2018	21	0	0	2018	21	0	0
2019	15	0	0	2019	15	0	0
2020	9	0	0	2020	9	0	0
Totals	116	0	0	Totals	117	0	0

Table 3-4. Details for laboratory duplicates not meeting data quality objectives.

Event(s): 2010 to 2020

Year	Reference	QC_Lot	Analyte	RPD	DIFFx	LD.QC
2011	L1085007-137	NA	Mercury (Hg)-Total	66.7	58.5	Fail

Table 3-5. Details for laboratory control samples not meeting data quality objectives.

Event(s): 2010 to 2020

Year	ALS_QC_ID	QC_Lot	Analyte	Percent	Limit	LCS.QC
2018	WG2970096-3	1026173	Mercury (Hg)-Total	147.7	70-130	Fail
2018	WG2970099-3	1026174	Mercury (Hg)-Total	163.4	70-130	Fail

Table 3-6. Stable Isotope field duplicate sample quality control results.

Site C 2020 SIA Field Dupicates

Paramete	Fish ID 1294				Fish ID 1295				TL-LKTR-10			Fish ID 1296			
	dw or ww	Original	Duplicate	RPD (%)	dw or ww	Original	Duplicate	RPD (%)	Original	Duplicate	RPD (%)	dw or ww	Original	Duplicate	RPD (%)
d13C		-29.44	-30.74	-4		-31.0518	-30.1223	3					-29.6283	-29.5165	0
d15N	ww	7.39568	7.260208	2	ww	7.605076	7.455435	2	4.11	4.02	2	ww	9.32347	9.469147	-2

Paramete	Fish ID 1297				Fish ID 1298				TL-LKTR-10			Fish ID 1299			
	dw or ww	Original	Duplicate	RPD (%)	dw or ww	Original	Duplicate	RPD (%)	Original	Duplicate	RPD (%)	dw or ww	Original	Duplicate	RPD (%)
d13C		-27.5416	-27.7515	-1		-29.0314	-28.578	2					-29.3957	-29.4986	0
d15N	ww	7.969764	7.907331	1	ww	7.328587	7.34147	0	4.11	4.02	2	ww	8.424633	8.349317	1

Paramete	Fish ID 1300				Fish ID 1301				TL-LKTR-10			Fish ID 1302			
	dw or ww	Original	Duplicate	RPD (%)	dw or ww	Original	Duplicate	RPD (%)	Original	Duplicate	RPD (%)	dw or ww	Original	Duplicate	RPD (%)
d13C		-31.5923	-29.9401	5		-28.9483	-28.8879	0					-30.0124	-29.8609	1
d15N	ww	8.556436	7.789402	9	ww	9.210496	8.787339	5	4.11	4.02	2	ww	9.711942	9.70005	0

Paramete	Fish ID 1303				Fish ID 1304				TL-LKTR-10			Fish ID 1305			
	dw or ww	Original	Duplicate	RPD (%)	dw or ww	Original	Duplicate	RPD (%)	Original	Duplicate	RPD (%)	dw or ww	Original	Duplicate	RPD (%)
d13C		-26.2191	-26.2419	0		-26.133	-26.233	0					-25.9479	-25.8261	0
d15N	ww	11.2916	11.29556	0	ww	10.96457	10.89321	1	4.11	4.02	2	ww	11.05673	11.10925	0

Paramete	Fish ID 1306			
	dw or ww	Original	Duplicate	RPD (%)
d13C		-25.5133	-25.3789	1
d15N	ww	11.08554	11.4361	-3

Note: samples from 2020 only

Table 3-7. Stable Isotope laboratory quality control results, 2010 to 2020.

Lab	Year Caught	Lab ID	# of Samples	Analytes	Laboratory Duplicates		Check Standards (N2, CH7, Nicotinamide	Secondary Standards (USGS61, LBS, MLS)
					# of duplicate samples	RPD Range (%)		
SINLAB	2010	SINLAB 2010 Fish and Benthos RBA 001-126-1	126	C and N SIA	6	RPD = 0 - 3% (+/-)	Met Lab DQO	Met Lab DQO
SINLAB	2011	SINLAB 2011 Fish RBA 222-390	169	C and N SIA	8	RPD = 0 - 2% (+/-)	Met Lab DQO	Met Lab DQO
SINLAB	2017	18 Golder 001-452	58	C and N SIA	5	RPD = 0 - 3% (+/-)	Met Lab DQO	Met Lab DQO
SINLAB	2018	18 Golder 001-452	86	C and N SIA	20	RPD = 0 - 2% (+/-)	Met Lab DQO	Met Lab DQO
SINLAB	2019	19 GOLD 001 - 189	58	C and N SIA	14	RPD = 0 - 4% (+/-)	Met Lab DQO	Met Lab DQO
SINLAB	2020	20 TRI 001-011	11	C and N SIA	1	RPD = 0 -1% (+/-)	CH7 and Nicotinamide mean results outside the acceptable range.	USGS61 mean result outside the acceptable range.
SINLAB	2020	21Gold 001-151	152	C and N SIA	10	RPD = 0 - 2% (+/-)	Met Lab DQO	Met Lab DQO

Notes:
RPD = Relative Percent Difference
DQO = Data Quality Objective

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SINLAB INTERPRETATION GUIDE

For further information please visit our website:
https://www.isotopeecology.com/

Instrumentation

Continuous Flow-Isotope Ratio Mass Spectrometry (CF-IRMS) is used for stable isotope analysis of $\delta^{13}C$, $\delta^{15}N$ and $\delta^{2}H$. The SINLAB currently operates the following mass spectrometer/conflo combinations:

- $Delta^{Plus}$ XP – Conflo III
- Delta V Plus – Conflo IV

(All manufactured by Thermo Finnigan; Bremen, Germany)

Carbon & Nitrogen Methodology

Dried, ground and homogeneous samples are weighed into tin capsules and analyzed for $\delta^{13}C$ and $\delta^{15}N$ by an Elemental Analyzer (EA) coupled to one of the IRMS/Conflo combinations listed above. Samples are introduced into the EA by an autosampler where complete combustion occurs in the presence of oxygen to generate CO_2 and nitrogen oxide (N_xO_x) gases. Combustion occurs in a quartz tube filled with chromium oxide and silvered cobaltous oxide. A second quartz tube filled with fine copper wire is used for the reduction of nitrogen oxides (N_xO_x) to N_2 gas. Gas Chromatography (GC) is used to separate CO2 and N2 peaks with helium as a carrier gas. A water trap of magnesium perchlorate & silica chips is located before the GC column to remove water.

The SINLAB currently utilizes two elemental analyzers for $\delta^{13}C$ and $\delta^{15}N$ analyses.

Elemental Analyzer	Autosampler	Combustion Temperature	Reduction Temperature	GC Length	GC Temperature
CE NC2500 (Carlo Erba; Milan, Italy)	PN150	1050ºC	650ºC	4m	50ºC
Costech 4010 (Costech; California, USA)	Zero Blank	1000ºC	650ºC	3m	40ºC

Stable isotope measurements are reported as isotope delta δ in parts per thousand (‰) relative to the international standard: Vienna Pee Dee Belemnite (VPDB) for carbon, and atmospheric air (AIR) for nitrogen. Isotope values are normalized using secondary standards: USGS61, BLS, and MLS for animal tissues; and CMS, SPS, SPL and EPS for sediments and plant material. All of these standards were calibrated against IAEA standards. See below for standard descriptions.

Hydrogen Methodology

Samples are weighed into silver capsules and loaded into a Costech Zeroblank autosampler. Samples are converted to hydrogen (H_2) gas by pyrolysis using a Thermo-Finnigan High Temperature Conversion Elemental Analyzer (TC/EA). Pyrolysis occurs in a ceramic tube lined with a glassy carbon reactor and filled with glassy carbon chips at a temperature of 1400ºC. Helium is used as the carrier gas and a 1.5m GC column held at 100ºC separates H_2 sample gas and other interfering gases produced

Stable-hydrogen isotope (δ^2H) measurements for keratin tissues are normalized to the international standard VSMOW (Vienna Standard Mean Ocean Water). We determine the non-exchangeable δ^2H of samples using the comparative equilibration approach (Wassenaar and Hobson 2003) with two secondary keratin standards (EC1 and EC2). These standards were previously calibrated to account for the H exchangeability between the H atoms of ambient water vapor and tissues (Wassenaar and Hobson 2000, 2003). This technique requires that samples along with these standards of known H isotope ratios are left to exchange with local atmospheric hydrogen for 72 hours prior to analysis. See below for standard descriptions.

Standards

Secondary Standards **–** These are SINLAB working standards used to bring data to the international scale. They are calibrated against and traceable to IAEA primary standards (CH6, CH7, N1, and N2). These standards are subjected to round robin testing for verification as a part of our QA/QC protocol. Values below- used as check standards within a run

USGS61 = commercially available pure compound (caffeine)
$\delta^2H_{(VSMOW)}$ = 96.9 ‰ +/- 0.9
$\delta^{13}C_{(VPDB)}$ = –35.05‰ +/- 0.04
$\delta^{15}N_{(AIR)}$ = -2.87 ‰ +/- 0.04

BLS = Bovine Liver Standard developed by SINLAB
$\delta^{13}C_{(VPDB)}$ = –18.76 ‰ +/- 0.14
$\delta^{15}N_{(AIR)}$ = 7.17 ‰ +/- 0.17

MLS = Muskellunge muscle standard developed by SINLAB
$\delta^{13}C_{(VPDB)}$ = –22.30 ‰ +/- 0.18
$\delta^{15}N_{(AIR)}$ = 14.00 ‰ +/- 0.11

CMS = Corn Meal Standard developed by SINLAB
$\delta^{13}C_{(VPDB)}$ = –13.25 ‰ +/- 0.11
$\delta^{15}N_{(AIR)}$ = 4.42 ‰ +/- 0.12

EPS = Ephedra Plant Standard developed by SINLAB
$\delta^{13}C_{(VPDB)}$ = -30.96 ‰ +/- 0.09
$\delta^{15}N_{(AIR)}$ = 0.35 ‰ +/- 0.12

SPL = Spirulina standard developed by SINLAB
$\delta^{13}C_{(VPDB)}$ = -24.97 ‰ +/- 0.12
$\delta^{15}N_{(AIR)}$ = 12.94 ‰ +/- 0.09

SPS = Seaweed plant standard developed by SINLAB
$\delta^{13}C_{(VPDB)}$ = -28.40 ‰ +/- 0.10
$\delta^{15}N_{(AIR)}$ = 21.10 ‰ +/- 0.10

EC1 = caribou hoof keratin standard- Environment Canada, Saskatoon, Canada
$\delta^{2}H_{(VSMOW)}$ = –197.00 ‰ +/- 1.8
$\delta^{18}O_{(VSMOW)}$ = 2.40 ‰ +/- 0.6

EC2 = kudu horn keratin standard - Environment Canada, Saskatoon, Canada
$\delta^{2}H_{(VSMOW)}$ = –54.10 ‰ +/- 0.6
$\delta^{18}O_{(VSMOW)}$ = 21.20 ‰ +/- 0.6

KERATIN STANDARD = Keratin powder purchased from Spectrum. B/N SJ1400
$\delta^{2}H_{(VSMOW)}$ = –121.60 ‰ +/- 2.0
$\delta^{18}O_{(VSMOW)}$ = 10.60 ‰ +/- 0.6

THS = Topi horn keratin standard developed by SINLAB, $\delta^{18}O$ unverified
$\delta^{2}H_{(VSMOW)}$ = –40.60 ‰ +/- 2.0
$\delta^{18}O_{(VSMOW)}$ = 20.28 ‰ +/- 0.6 (unverified)

<u>Check Standards</u> – These standards are analyzed in each analytical run as part of SINLAB's QA/QC protocol to assess the analytical accuracy.

ACETANILIDE = commercially available pure compound
Batch 2880 (Feb 2010 – Apr 2011) - $\delta^{13}C_{(VPDB)}$ = –27.87 ‰ +/- 0.12
$\delta^{15}N_{(AIR)}$ = –2.05 ‰ +/- 0.13

Batch 149699 (Apr 2011-Aug 2012) - $\delta^{13}C_{(VPDB)}$ = –31.59 ‰ +/- 0.12
$\delta^{15}N_{(AIR)}$ = –2.32 ‰ +/- 0.23

Costech (Aug 2012 – July 2020) - $\delta^{13}C_{(VPDB)}$ = –33.81 ‰ +/- 0.14
$\delta^{15}N_{(AIR)}$ = –0.92 ‰ +/- 0.23

Batch 317490 (July 2020 – Present) - $\delta^{13}C_{(VPDB)}$ = –26.54 ‰ +/- 0.06
$\delta^{15}N_{(AIR)}$ = –5.09 ‰ +/- 0.37

NICOTINAMIDE = commercially available pure compound
Batch 237264 (Mar 2018 – Present) - $\delta^{13}C_{(VPDB)}$ = –32.50 ‰ +/-0.1
$\delta^{15}N_{(AIR)}$ = –2.00 ‰ +/- 0.1

BENZOIC ACID = commercially available pure compound, δ^{18}O unverified
HEKAtech (Feb 2010 – Present) $\delta^{2}H_{(VSMOW)}$ = -76‰ +/- 2.0 (unverified)
$\delta^{18}O_{(VSMOW)}$ = 25.7‰ +/- 0.6 (unverified)

N2 = ammonium sulfate – Primary standard certified by IAEA.
$\delta^{15}N_{(AIR)}$ = 20.3 ‰ +/- 0.14

CH7 = polyethylene foil – Primary standard certified by IAEA.
$\delta^{13}C_{(VPDB)}$ = –32.2 ‰ +/- 0.1
$\delta^{2}H_{(VSMOW)}$ = 100.3 ‰ +/- 2.0

PROTEIN = casein – Certified by Elemental Microanalysis Ltd.
$\delta^{13}C_{(VPDB)}$ = –26.98 ‰ +/- 0.13
$\delta^{15}N_{(AIR)}$ = 5.94 ‰ +/- 0.08

***HIGH ORGANIC SEDIMENT*=** Certified by Elemental Microanalysis Ltd.
$\delta^{13}C_{(VPDB)}$ = –26.27 ‰ +/- 0.15
$\delta^{15}N_{(AIR)}$ = 4.42 ‰ +/- 0.2

***SORGHUM FLOUR*=** Certified by Elemental Microanalysis Ltd.
$\delta^{13}C_{(VPDB)}$ = –13.68 ‰ +/- 0.19
$\delta^{15}N_{(AIR)}$ = 1.58 ‰ +/- 0.15

PEACH LEAF = NIST 1547 peach leaves - not certified
$\delta^{13}C_{(VPDB)}$ = –26.17 ‰ +/- 0.08
$\delta^{15}N_{(AIR)}$ = 1.94 ‰ +/- 0.12

ATS = Atlantic salmon standard developed by SINLAB
$\delta^{2}H_{(VSMOW)}$ = –113.8 ‰ +/- 2.0
$\delta^{18}O_{(VSMOW)}$ = 17.50 ‰ +/- 0.6 (unverified)

LAT = Lake trout standard developed by SINLAB, δ^{18}O unverified
$\delta^{2}H_{(VSMOW)}$ = –165.60 ‰ +/- 2.0
$\delta^{18}O_{(VSMOW)}$ = 4.70 ‰ +/- 0.6 (unverified)

Column Headings

CLIENT ID = ID code assigned to sample by the client.

SINLAB ID = ID code assigned to the client's samples; starting with the year, each client is given a two or three letter identifier and samples numbered sequentially; ex, 15ABC 001.

Date = date sample was analyzed.

Position = position in the analytical run for that particular day; samples are weighed into 96-well ELISA trays, a typical animal tissue run will consist of approximately 73 samples, 22 standards, and 1 blank.

Weight = weight of the tissue analyzed; animal tissues are weighed at 1.000 ± 0.100 milligrams and plant tissues are weighed at 3.100 ± 0.100 milligrams for C and N isotope analysis. Keratin tissues are weighed at 0.200 ± 0.020mg for H isotope analysis.

CO2 ampl = the relative amount of CO_2 gas measured by the mass spectrometer in volts (V), a function of the weight of tissue used and the total amount of carbon (%C) it contains.

N2 ampl = the relative amount of N_2 gas measured by the mass spectrometer in volts (V), a function of the weight of tissue used and the total amount of nitrogen (%N) it contains.

H2 ampl = the relative amount of H_2 gas measured by the mass spectrometer in volts (V), a function of the weight of tissue used and the total amount of hydrogen (%H) it contains.

δ^{13}C = the relative isotope ratio difference between the sample and the international standard (VPDB) according to the formula:

$\delta^{13}C = [(R_{sample}/R_{standard})-1]*1000$ where R is the isotopic ratio of the heavy to light ($^{13}C/^{12}C$)

δ^{15}N = the relative isotope ratio difference between the sample and the international standard (AIR) according to the formula:

$\delta^{15}N = [(R_{sample}/R_{standard})-1]*1000$ where R is the isotopic ratio of the heavy to light ($^{15}N/^{14}N$)

δ^{2}H = the relative isotope ratio difference between the sample and the international standard (VSMOW) according to the formula:

$\delta^{2}H = [(R_{sample}/R_{standard})-1]*1000$ where R is the isotopic ratio of the heavy to light ($^{2}H/^{1}H$)

%C = percent of carbon in the sample by weight; calculated with NICOTINIMIDE for animals and ACETANILIDE for plants

%N = percent of nitrogen in the sample by weight; calculated with NICOTINIMIDE for animals and ACETANILIDE for plants

C/N = ratio of carbon to nitrogen in the sample; simple division of %C by %N.

%H= percent of hydrogen in the sample by weight; calculated with BENZOIC ACID

%O= percent of oxygen in the sample by weight; calculated with BENZOIC ACID

Comment Codes

NR = no repeat; not enough sample tissue to allow another analysis

No drop = equipment malfunction wherein autosampler fails to turn; often leads to a "double-up" with the following sample

Double-up = two samples drop together

LR = lipid-rich. Samples may contain high lipid content according to the C/N ratio (Logan et al. 2008)

Whole bug = individual analyzed without grinding

1/4, 1/8, 1/16, 1/32 = indicates the size of a filter paper sample that was cut into a "pie-slice" for analysis

Scraped from paper = filtered material was scraped from the top of filter rather than analyzed as a "pie slice"

LE = Lipid extracted, a common technique to remove lipids from tissues such as liver, eggs, and muscle of some fishes. Lipids have different δ^{13}C than proteins and carbohydrates.

AT = Acid treated, a common technique to remove carbonates (that have different δ^{13}C values than organic tissues) from organisms such as crustaceans.

Colours

Gray shading = repeated sample as part of regular QA/QC routine (four of every 73 samples)
Red text = highlights low amplitude peaks or a poor repeat

Please address any questions about this document to:

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APPENDIX B:
CHARACTERIZATION OF LENGTH-MERCURY RELATIONSHIPS

Table of Contents

1 INTRODUCTION

The Site C Methyl Mercury Monitoring Plan (MMP) is designed based on the assumption that catch is similar across the fish size distribution for a given species at each location/year combination. However, there are often discrepancies in size distributions that would affect the analysis if they were based on mean mercury concentrations for each location/event combination. Modelling length-mercury relationships facilitates removing potential bias related to catching larger or smaller fish relative to other locations/year sampled. While length-mercury relationships are characterized across the full size range of fish sampled (within a given species), numerical presentation of results is simplified by focusing on one or more key sizes (sometimes referred to as "standardized" sizes[1]).

As described in Section 2 of the main report, the baseline fish mercury dataset is comprised of fish mercury results for a number of species caught in various locations over a number of sampling events from 2010 to 2020. The following sections present details on the methods and results of statistical analyses conducted to characterize baseline fish mercury concentrations.

1.1 Length-Mercury Relationship Modelling

Three main model types were used to determine patterns in the data that needed to be taken into consideration for characterizing baseline conditions. There were:

1. **Temporal trends** – this focused on looking at data for specific locations over time to determine if tissue mercury concentrations were different across sampling years. The presence or absence of temporal trends will inform options for treating baseline data (e.g., appropriateness of pooling across all or certain years).
2. **Spatial trends** – this focused on looking at data for a specific time period (i.e., during which no temporal patterns were identified) to determine if tissue mercury

[1] Historically, fish mercury data were often simplified to means per species-location-year of interest. The major limitation of that approach is that tissue mercury concentrations are often positively correlated to fish size, so random differences in the size of fish caught can impart a bias in the mean. This potential bias was overcome by using the length-mercury relationship to estimate mercury concentrations for a specific sized fish. The "standardized" size (i.e., a single size per species) was used to allow comparisons both within and among studies. The main limitation of using a single size to represent tissue concentrations for a species is that information about other size classes is lost. Consequently, we try to use more than one size class (up to four or five) to provide a more complete understanding of fish mercury concentrations.

concentrations differed among sampling locations. The presence or absence of spatial patterns will inform options for pooling across locations.

3. **Baseline sampling periods** – this focused on testing for differences between the early and recent baseline sampling periods to characterize past and current conditions in terms of fish mercury concentrations, with the latter being used to inform fish consumption guidance.

Note that due to data limitations for Dinosaur Reservoir there was insufficient data to include that location in either the temporal or spatial trend assessments. Consequently, data from that location were also excluded from the baseline period assessment.

The general process for the statistical analysis for each of the main model types followed the following steps:

- **Variables** – the following primary variables were included in the various model fits:
  - *Mercury* (Hg; FishHg in model fits) – measured total mercury concentrations in fish muscle tissue (mg/kg dw); assumed to all be present as methylmercury (Bloom 1992).
  - *Length* – fish length (generally fork length) was used to help account for the known influence of fish size on tissue mercury concentrations. Length was "centered" (LC) on the standardized size for each species, which allows direct interpretation of the regression coefficients from the output. Note that the quadratic model fits also include length squared (LC2; LC2 in model fits).
  - *Site* (see above) - this was included to account for variability related to site-specific factors.
  - *Year* – based on the sampling year (Year.Caught in model fits).
  - *Period* – refers to the early (2010/2011) or recent (2017-2020) baseline time periods.
- **Transformations** – Length-mercury data were plotted using various transformations to determine which was most suitable.
- **Model Fitting** – A set of nine models were used to fit the data used to assess temporal (**Table 1-1**), spatial (**Table 1-2)** or period (**Table 1-3**) trends in the dataset; these models ranged from simple year/location/period-specific intercepts through linear forms (with and without length-year/location/period interaction terms) to quadratic polynomials (with/without various interaction terms). From a size-mercury relationship characterization perspective, this array of models covers the spectrum from no relationship with size (fit0) through general size-dependent relationships to more complex models capable of characterizing more site-specific relationships. In our

experience, no single model form adequately characterizes fish mercury relationships across all species and conditions. Each of the model forms included have been used in to describe fish length-mercury relationships. While the linear fits are more commonly used, the quadratic models were included as they can better characterize size-mercury relationships in some situations. For example, a quadratic fit best characterized the length-mercury relationship for Lake Trout in Williston Reservoir (Azimuth 2019b), where the relationship changed in response to reduced growth rates in larger fish. Quadratic fits provide more flexibility to fit different slopes and intercepts, which we anticipate will be useful when mercury concentrations in the environment are dynamic (e.g., in a newly created reservoir) and affect smaller fish more rapidly than larger fish.

- **Model Over-fitting** – One drawback of polynomial models is that they can over-fit data. Over-fitting occurs when a model is sufficiently parameterized to allow it to respond too closely to the underlying data, essentially describing random error rather than the underlying length-mercury relationship. For length-mercury relationships, the general expectation is that mercury concentrations increase with fish size, often more sharply when fish growth slows down later in life. Consequently, key signs of model over-fitting in these relationships is when the curve shape shows a decrease in slope of the relationship, or even a reversal (negative slope) of the relationship, across the size range. A good example of model over-fitting comes from the analysis of temporal trends in mercury concentrations in Bull Trout, where fit7 (**Table 1-1, Figure 1-1**) is clearly over-fitting the data (e.g., model fit reasonably characterizes the 2017 data, but predicts decreasing mercury concentrations in larger fish) relative to fit5 (**Table 1-1**, **Figure 1-1**). Cases of model over-fitting are noted in the results, but details for each fit are not included in the results.
- **Model Selection** – A variant of Akaike's Information Criterion (AIC), corrected for bias in small sample sizes (AICc), was used to compare models (Burnham and Anderson 2002). Models with the lowest AICc values were considered first, by examining model coefficients, plotting the fit along with the data and viewing model diagnostics (e.g., residuals, Q-Q plot, Cook's distance, and residual distribution). In cases where models over-fitted the data (see previous bullet), the next best model, generally more parsimonious, was selected.
- **Outlier Identification** – Formal assessment of outliers was conducted for selected models. This involved identifying data that were clear outliers (studentized residuals > 4) or had high leverage (Cook's distance > 0.5) values. For simplicity, these are collectively referred to as "outliers" hereafter, but any instances are documented along with the

driver for their categorization. The models were run with and without the outliers, but only results with outliers removed are reported.

- **Mercury Concentration Estimates and Confidence Limits** – Selected models were used to estimate mercury concentrations, and associated confidence intervals, for one or more selected fish sizes for each year/location/period modelled. Given that the models could have not only different intercepts, but also different slopes (linear models) or polynomial curve shapes (quadratic models) for the various locations (e.g., lakes or reaches), up to three standard sizes were selected for each species to facilitate comparisons among locations (Sections) and among years.

Table 1-1. Models fit to fish length and tissue mercury concentrations to assess temporal trends in the Site C baseline data.

Fit	Model[1]	Comments
fit0	FishHg ~ Year.Caught	simple means by Year.Caught
fit1	FishHg ~ LC	linear - all Year.Caughts same
fit2	FishHg ~ LC + LC2	quadratic - all Year.Caughts same
fit3	FishHg ~ Year.Caught + LC	linear - Year.Caught-specific intercepts
fit4	FishHg ~ Year.Caught + LC + LC2	quadratic - Year.Caught-specific intercepts
fit5	FishHg ~ Year.Caught + LC + Year.Caught:LC	linear - Year.Caught-specific intercepts/slopes
fit6	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC	quadratic - Year.Caught-specific intercepts/slopes (length)
fit7	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC2	quadratic - Year.Caught-specific intercepts/quadratics (length^2)
fit8	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC + Year.Caught:LC2	quadratic - Year.Caught-specific intercepts/slopes/quadratics

[1] LC=length centered on standard length (varies by species); LC2=LC^2

Table 1-2. Models fit to fish length and tissue mercury concentrations to assess spatial trends in the Site C baseline data.

Fit	Model[1]	Comments
fit0	FishHg ~ Location	simple means by location
fit1	FishHg ~ LC	linear - all locations same
fit2	FishHg ~ LC + LC2	quadratic - all locations same
fit3	FishHg ~ Location + LC	linear - location-specific intercepts
fit4	FishHg ~ Location + LC + LC2	quadratic - location-specific intercepts
fit5	FishHg ~ Location + LC + Location:LC	linear - location-specific intercepts/slopes
fit6	FishHg ~ Location + LC + LC2 + Location:LC	quadratic - location-specific intercepts/slopes (length)
fit7	FishHg ~ Location + LC + LC2 + Location:LC2	quadratic - location-specific intercepts/quadratics (length^2)
fit8	FishHg ~ Location + LC + LC2 + Location:LC + Location:LC2	quadratic - location-specific intercepts/slopes/quadratics

[1] LC=length centered on standard length (varies by species); LC2=LC^2

Table 1-3. Models fit to fish length and tissue mercury concentrations to characterize the early and recent baseline periods in the Site C baseline data.

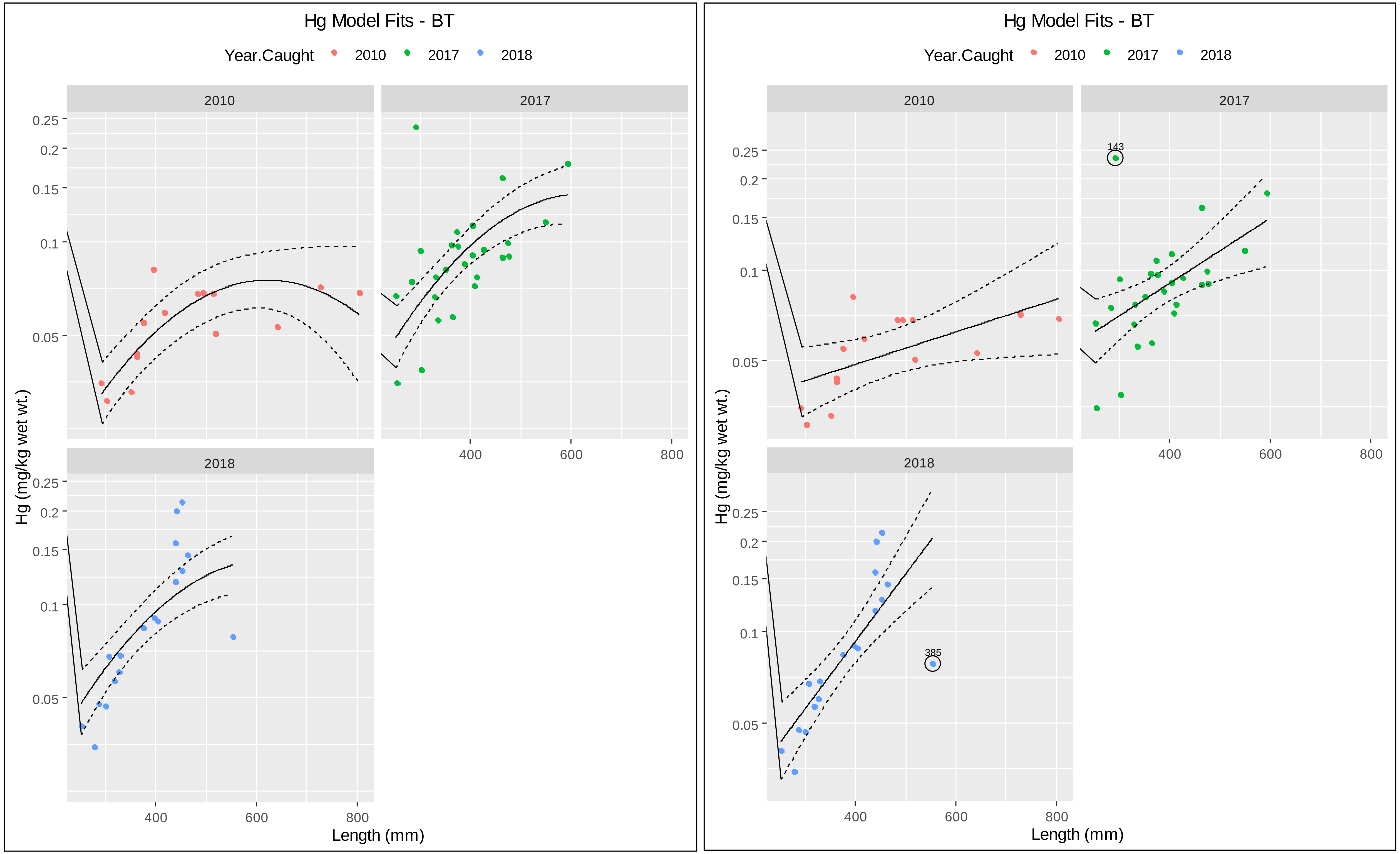
Fit	Model[1]	Comments
fit0	FishHg ~ Period	simple means by period
fit1	FishHg ~ LC	linear - all periods same
fit2	FishHg ~ LC + LC2	quadratic - all periods same
fit3	FishHg ~ Period + LC	linear - period-specific intercepts
fit4	FishHg ~ Period + LC + LC2	quadratic - period-specific intercepts
fit5	FishHg ~ Period + LC + Period:LC	linear - period-specific intercepts/slopes
fit6	FishHg ~ Period + LC + LC2 + Period:LC	quadratic - period-specific intercepts/slopes (length)
fit7	FishHg ~ Period + LC + LC2 + Period:LC2	quadratic - period-specific intercepts/quadratics (length^2)
fit8	FishHg ~ Period + LC + LC2 + Period:LC + Period:LC2	quadratic - period-specific intercepts/slopes/quadratics

[1] LC=length centered on standard length (varies by species); $LC2=LC^2$

Figure 1-1 Example of model over-fitting (panel a) and parsimonious model-fitting (panel b) from the analysis of temporal trends in mercury concentrations in Bull Trout.

a) model over-fit to data

b) model appropriately fit to data



2 BULL TROUT

Temporal Assessment

The temporal assessment was conducted to determine whether there were any changes in the length-mercury relationship for Bull Trout across sampling years. To control for spatial trends, the analysis was limited to **Section 3**, which had three years (2010, 2017 and 2018) with 15 or more samples (see Bull Trout section of main report for catch details by location/year).

Key information on the modelling and associated results were as follows:

- *Transformations* – Total mercury concentrations in fish tissue were log-transformed.
- *Initial Model Selection* – The suite of temporal models (**Table 1-1**) was initially run with all the data. Fits 7, 8, 4 and 6, all quadratic model forms, had the lowest AICc values (**Table 2-1**), but all over-fit the data (see **Section 1.1** for details on over-fitting). The model selected for the analysis was fit5, which had the following structure (linear model with year-specific intercepts and slopes):

  *Log Hg ~ Year + Length + Year*Length*

- *Outliers/High Leverage Data* – Formal outlier assessment of the initial fit5 run (with all data) identified two points (**Figure 2-3**) as outliers and/or having high leverage (**Table 2-2**); these were removed ("trimmed") from the dataset.
- *Final Model Selection* – Given the potential for outliers or high-leverage data to influence the model fits, the model selection process was repeated with the trimmed dataset. This time, fit6 (over-fit the data) had the lowest AICc (**Table 2-6**), followed by fit5, which was used to characterize the length-mercury relationship.
- *Fitted length-mercury Relationships* – Final model results are shown in **Figure 2-4** and summarized in **Table 2-4**. The model fits generally show strong positive relationships between length and mercury concentrations. Model residuals were visually examined and indicated that the fit was good. The model had an adjusted R2 of 0.76 and showed statistically significant differences in Bull Trout mercury concentrations among years.
- *Predicted Mercury Concentrations for Standard Sized Fish by Year* – Using the length-mercury model shown above, and where the underlying data supported making a prediction (e.g., predictions were not made for 700-mm Bull Trout in 2017 or 2018), tissue mercury concentrations were estimated for three standard fish sizes: 400 mm, 550 mm and 700 mm. The predictions (and their 95% confidence limits) were used to compare fish tissue mercury concentrations among years (**Figure 2-5**); statistical

differences among year-size combinations determined using the selected model were annotated on the plot. The results show that Bull Trout mercury concentrations were generally lower in 2010 than in 2017 and 2018.

Spatial Assessment

The spatial assessment was conducted to determine whether there are differences in the length-mercury relationship for Bull Trout among Peace River sampling locations. Given the temporal changes identified previously, the spatial assessment was limited to the recent time period only. Five sampling locations (Sections 1, 3, 5, 6, and 7) had 14 or more samples across the recent sampling period (2017 to 2020), with a total of 148 samples (see Bull Trout section of main report for catch details by location/year).

Key information on the spatial modelling and associated results were as follows:

- *Transformations* – Mercury concentrations were log-transformed.
- *Initial Model Selection* – The suite of spatial models (**Table 1-2**) was initially run with all the data. Fit4, a quadratic model form, had the lowest AICc values (**Table 2-5**), but over-fit the data (see **Section 1.1** for details on over-fitting). The model selected for the analysis (fit1) had the following structure (linear model with no location-specific differences):

  Log Hg ~ Length

- *Outliers/High Leverage Data* – No outliers or high leverage points were identified.
- *Final Model Selection* – As no outliers or high-leverage points were identified, fit1 using all data was used to characterize the length-mercury relationship.
- *Fitted length-mercury Relationships* – Final model results are shown in **Figure 2-6** and summarized in **Table 2-6**. The model fits generally show strong positive relationships between length and mercury concentrations. Model residuals were visually examined and indicated that the fit was good. The model had an adjusted R2 of 0.59 and showed no statistically significant differences in Bull Trout mercury concentrations among locations.
- *Predicted Mercury Concentrations for Standard Sized Fish by Year* – Using the length-mercury model shown above, tissue mercury concentrations were estimated for three standard fish sizes: 400 mm, 550 mm and 700 mm. Given that location did not improve model fit (i.e., mercury concentrations did not differ significantly among Sections), the single set of predictions (and their 95% confidence limits) is valid for all modelled locations for the recent period (2017 – 2020) (**Figure 2-7**).

Baseline Period Assessment

This analysis was conducted to characterize potential differences between the early and recent baseline monitoring periods for Peace River locations (i.e., excluding Dinosaur Reservoir), with the recent period results used to support the development of fish consumption advice based on current conditions. The analysis included 169 samples, with 21 from the early baseline period and 148 from the recent period (see Bull Trout section of main report for catch details by location/year).

Key information on the modelling and associated results were as follows:

- *Transformations* – Mercury concentrations were log-transformed.
- *Initial Model Selection* – The suite of baseline period models (**Table 1-3**) was initially run with all the data. Fit5 had the lowest AICc value (**Table 2-7**) and was the initial model selection; it has the following structure (linear model with year-specific intercepts and slopes):

  *Log Hg ~ Period + Length + Period*Length*

- *Outliers/High Leverage Data* – Formal outlier assessment of the initial fit5 run (with all data) identified one point (**Figure 2-8**) as having high leverage (**Table 2-8**); this was removed ("trimmed") from the dataset.
- *Final Model Selection* – Given the potential for outliers or high-leverage data to influence the model fits, the model selection process was repeated with the trimmed dataset. Fit5 once again had the lowest AICc (**Table 2-9**), so was used to characterize the length-mercury relationship.
- *Fitted length-mercury Relationships* – Final model results are shown in **Figure 2-9** and summarized in **Table 2-10.** The model fits generally show strong positive relationships between length and mercury concentrations. Model residuals were visually examined and indicated that the fit was good. The model had an adjusted R2 of 0.62 and showed statistically significant differences in Bull Trout mercury concentrations among periods.
- *Predicted Mercury Concentrations for Standard Sized Fish by Period* – Using the length-mercury model shown above, and where the underlying data supported making a prediction, tissue mercury concentrations were estimated for three standard fish sizes: 400 mm, 550 mm and 700 mm. The predictions (and their 95% confidence limits) were used to compare fish tissue mercury concentrations between the two baseline sampling periods (**Figure 2-10**); statistical differences between periods for each standard size were determined using the selected model and were annotated on the plot. The results show

that Bull Trout mercury concentrations, when adjusted for fish size, increased more than two-fold between the early and the recent baseline period.

Table 2-1. Comparison of initial model fit results for the temporal assessment of length-mercury relationship by year for Bull Trout.

Fit	Model[1]	Df	AICc	Delta
fit7	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC2	8	37.1	0.0
fit8	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC + Year.Caught:LC2	10	41.8	4.7
fit4	FishHg ~ Year.Caught + LC + LC2	6	44.4	7.4
fit6	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC	8	45.3	8.2
fit5	FishHg ~ Year.Caught + LC + Year.Caught:LC	7	47.1	10.0
fit3	FishHg ~ Year.Caught + LC	5	54.0	16.9
fit2	FishHg ~ LC + LC2	4	69.2	32.1
fit0	FishHg ~ Year.Caught	4	74.5	37.4
fit1	FishHg ~ LC	3	78.5	41.4

[1] LC=length centered on standard size; $LC2=LC^2$

Table 2-2. Outlier and/or high leverage data points excluded from the temporal assessment of Bull Trout fish mercury concentrations.

Waterbody	Year.Caught	FishID	SectionID	Sp	FL.mm	Wt.g	Hg.ppm.ww	StudRes	CooksD	OutType[1]
Peace River	2017	143	Section 3	BT	290	205	0.23540	4.527	0.235	Outlier
Peace River	2018	385	Section 3	BT	554	1977	0.07854	3.975	0.967	High Leverage

[1] Outlier types: 'Outlier' = studentized residual > 4; 'High Leverage' = Cook's distance > 0.5.

Table 2-3. Comparison of final model fit results for the temporal assessment of length-mercury relationship by year for Bull Trout.

Fit	Model[1]	Df	AICc	Delta
fit6	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC	8	5.1	0.0
fit5	FishHg ~ Year.Caught + LC + Year.Caught:LC	7	6.8	1.7
fit7	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC2	8	9.0	4.0
fit8	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC + Year.Caught:LC2	10	9.6	4.5
fit4	FishHg ~ Year.Caught + LC + LC2	6	16.1	11.0
fit3	FishHg ~ Year.Caught + LC	5	37.7	32.6
fit2	FishHg ~ LC + LC2	4	53.3	48.3
fit0	FishHg ~ Year.Caught	4	68.3	63.3
fit1	FishHg ~ LC	3	68.7	63.7

[1] LC=length centered on standard size; $LC2=LC^2$

Table 2-4. Final model results for the temporal assessment of Bull Trout fish mercury concentrations.

Predictor	Estimate	95% CI[1]	p-value
(Intercept)	-2.960	-3.083, -2.837	<0.001
Year.Caught			
2010	—	—	
2017	0.6769	0.5058, 0.8480	<0.001
2018	1.074	0.8591, 1.288	<0.001
LC	0.0012	0.0004, 0.0021	0.004
Year.Caught * LC			
2017 * LC	0.0019	0.0005, 0.0033	0.008
2018 * LC	0.0060	0.0042, 0.0079	<0.001

[1] CI = Confidence Interval

Model: FishHg ~ Year.Caught + LC + Year.Caught:LC

Overall Results: $F(5,51)=32$; Adjusted $R^2 = 0.760$; N = 57.0

Table 2-5. Comparison of final model fit results for the spatial assessment of length-mercury relationship by Peace River sampling location for Bull Trout (2017 – 2020).

Fit	Model[1]	Df	AICc	Delta
fit4	FishHg ~ Location + LC + LC2	8	112.9	0.0
fit1	FishHg ~ LC	3	113.0	0.2
fit2	FishHg ~ LC + LC2	4	113.7	0.8
fit3	FishHg ~ Location + LC	7	114.0	1.1
fit7	FishHg ~ Location + LC + LC2 + Location:LC2	12	114.8	2.0
fit5	FishHg ~ Location + LC + Location:LC	11	118.5	5.6
fit8	FishHg ~ Location + LC + LC2 + Location:LC + Location:LC2	16	120.0	7.2
fit6	FishHg ~ Location + LC + LC2 + Location:LC	12	120.1	7.3
fit0	FishHg ~ Location	6	240.3	127.4

[1] LC=length centered on standard size; $LC2=LC^2$

Note: as there were no outliers, there are no initial fit results.

Table 2-6. Final model results for the spatial assessment of Bull Trout fish mercury concentrations (2017 – 2020).

Predictor	Estimate	95% CI[1]	p-value
(Intercept)	-1.917	-2.002, -1.832	<0.001
LC	0.0032	0.0027, 0.0036	<0.001

[1] CI = Confidence Interval

Model: FishHg ~ LC

Overall Results: $F(1,146)=212$; Adjusted $R^2 = 0.592$; N = 148

Table 2-7. Comparison of initial model fit results for the baseline period assessment of length-mercury relationship by year for Bull Trout.

Fit	Model[1]	Df	AICc	Delta
fit5	FishHg ~ Period + LC + Period:LC	5	135.2	0.0
fit6	FishHg ~ Period + LC + LC2 + Period:LC	6	135.6	0.4
fit4	FishHg ~ Period + LC + LC2	5	136.2	1.0
fit3	FishHg ~ Period + LC	4	136.8	1.6
fit8	FishHg ~ Period + LC + LC2 + Period:LC + Period:LC2	7	137.7	2.6
fit7	FishHg ~ Period + LC + LC2 + Period:LC2	6	138.4	3.2
fit1	FishHg ~ LC	3	187.1	51.9
fit2	FishHg ~ LC + LC2	4	188.1	52.9
fit0	FishHg ~ Period	3	275.0	139.8

[1] LC=length centered on standard size; LC2=LC^2

Table 2-8. Outlier and high leverage data points excluded from the baseline period assessment of Bull Trout fish mercury concentrations.

Waterbody	Year.Caught	FishID	SectionID	Sp	FL.mm	Wt.g	Hg.ppm.ww	StudRes	CooksD	OutType[1]
Peace River	2011	1246	Section 3	BT	754	4120	0.3280702	3.752	0.923	High Leverage

[1] Outlier types: 'Outlier' = studentized residual > 4; 'High Leverage' = Cook's distance > 0.5.

Table 2-9. Comparison of final model fit results for the baseline period assessment of length-mercury relationship by year for Bull Trout.

Fit	Model[1]	Df	AICc	Delta
fit6	FishHg ~ Period + LC + LC2 + Period:LC	6	121.1	0.0
fit5	FishHg ~ Period + LC + Period:LC	5	121.6	0.5
fit8	FishHg ~ Period + LC + LC2 + Period:LC + Period:LC2	7	121.8	0.7
fit4	FishHg ~ Period + LC + LC2	5	128.3	7.2
fit7	FishHg ~ Period + LC + LC2 + Period:LC2	6	130.4	9.3
fit3	FishHg ~ Period + LC	4	130.4	9.3
fit1	FishHg ~ LC	3	186.1	65.0
fit2	FishHg ~ LC + LC2	4	186.8	65.7
fit0	FishHg ~ Period	3	263.5	142.4

[1] LC=length centered on standard size; LC2=LC^2

Table 2-10. Final model results for the baseline period assessment of Bull Trout fish mercury concentrations.

Predictor	Estimate	95% CI[1]	p-value
(Intercept)	-2.804	-2.984, -2.624	<0.001
Period			
2010-2011	—	—	
2017-2020	0.8872	0.6890, 1.085	<0.001
LC	0.0012	0.0001, 0.0023	0.038
Period * LC			
2017-2020 * LC	0.0020	0.0008, 0.0032	0.001

[1] CI = Confidence Interval

Model: FishHg ~ Period + LC + Period:LC

Overall Results: F(3,164)=90; Adjusted R^2 = 0.621; N = 168

Figure 2-1. Length frequency and age frequency for Bull Trout (BT) by location across all years (2010–2020).

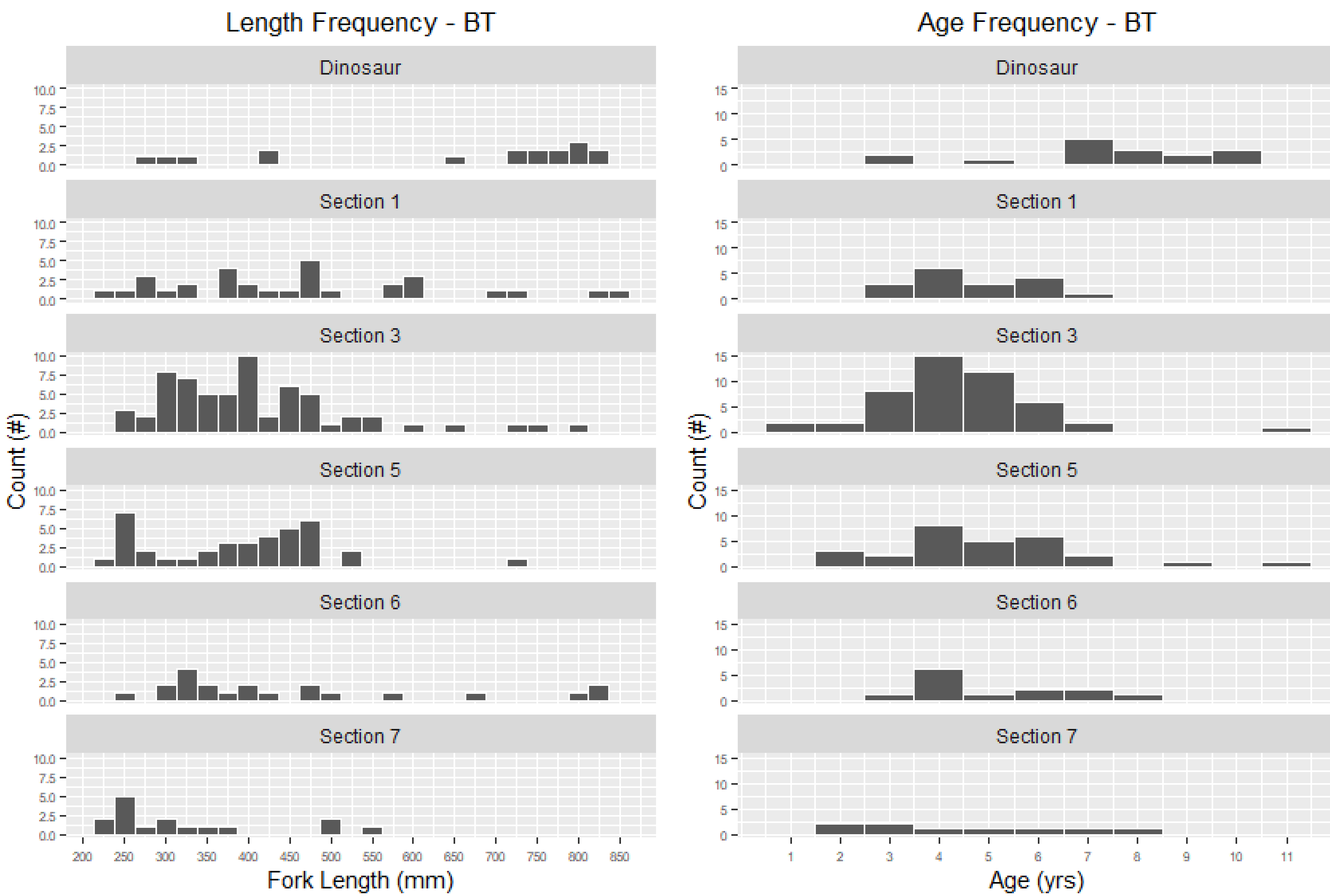


Figure 2-2. Key mercury relationships for Bull Trout (BT) across all years (2010–2020).

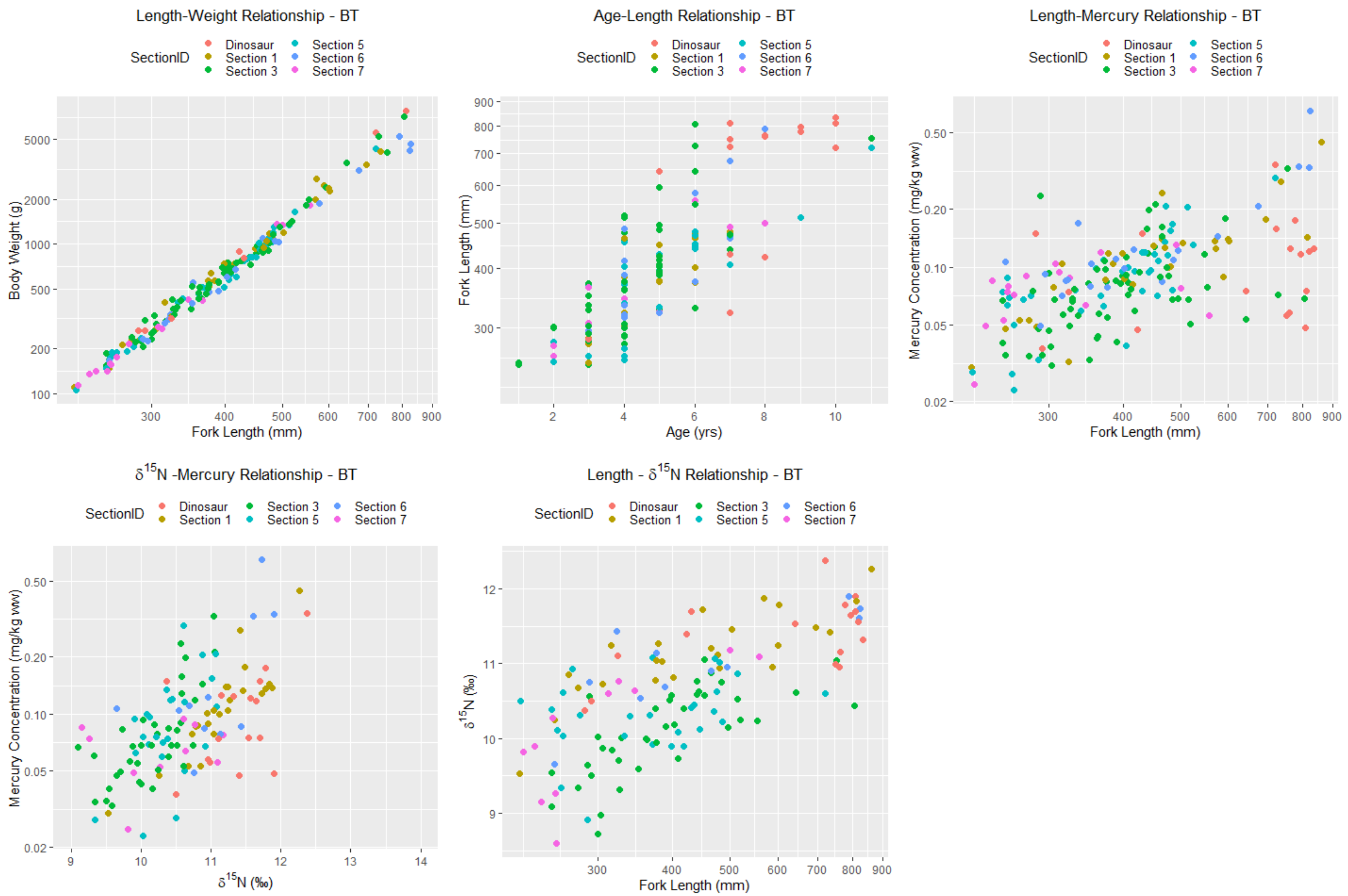
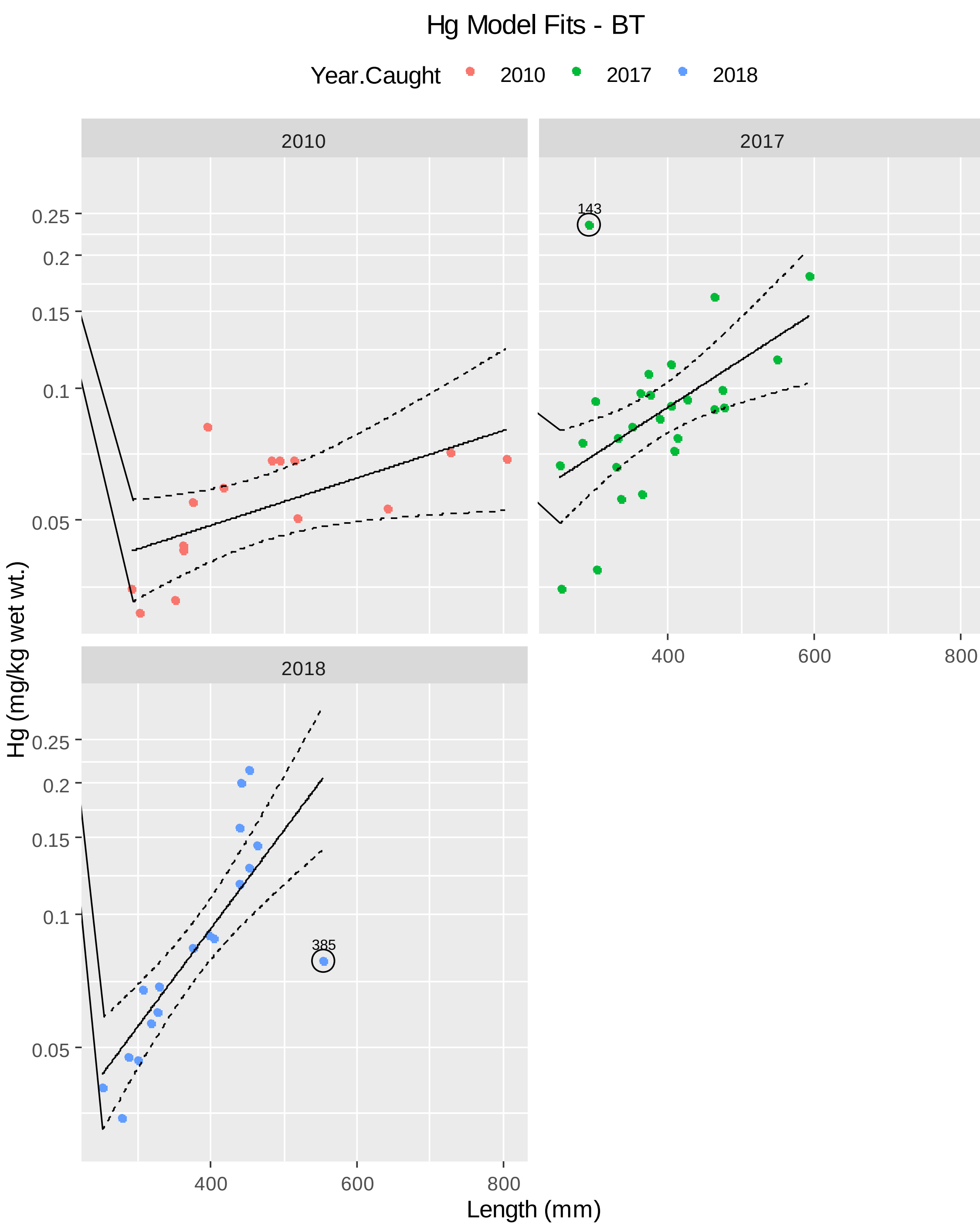
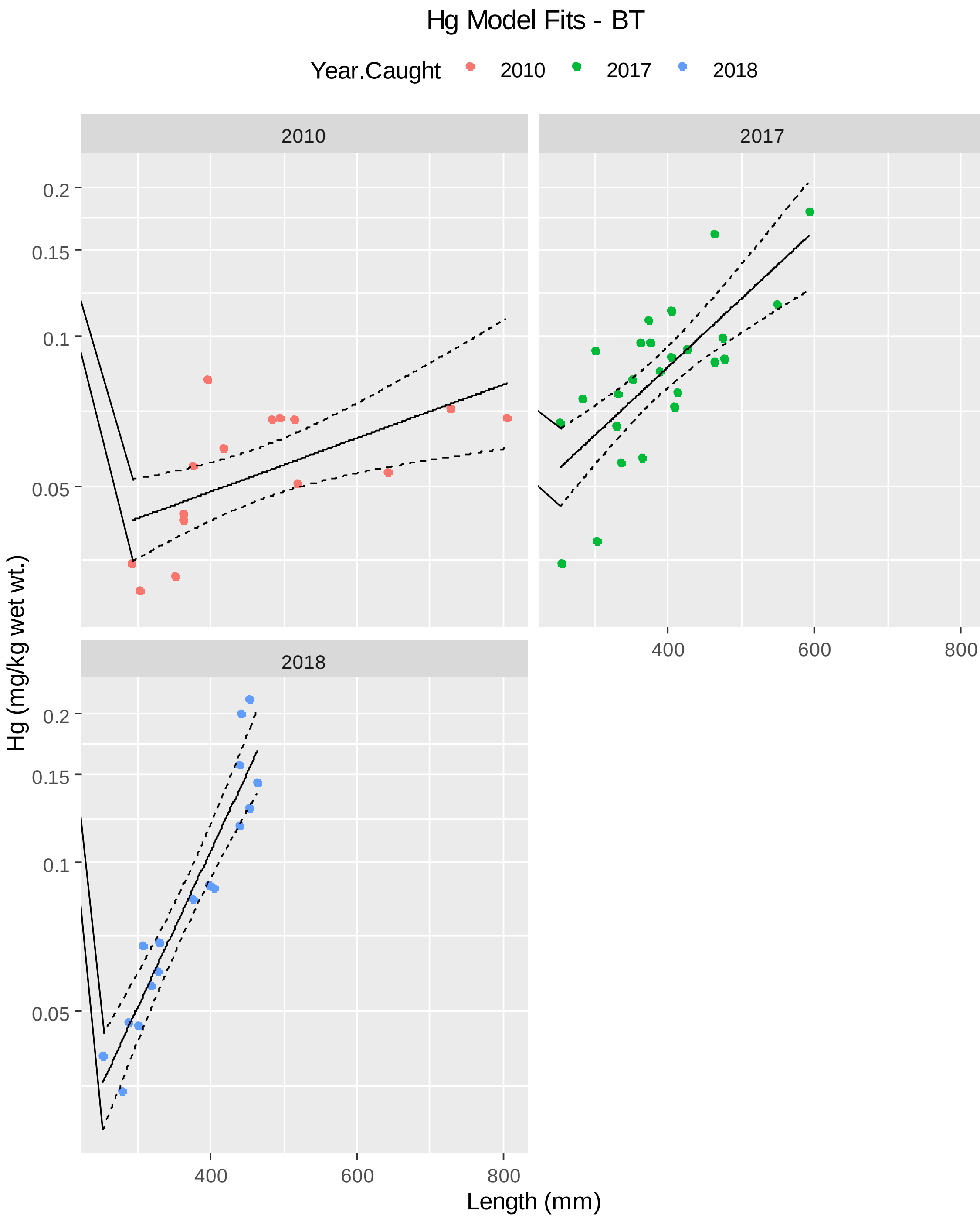


Figure 2-3. Initial model fit results and identified outliers for the temporal assessment of Bull Trout mercury concentrations for Section 3 (2010, 2017 and 2018 [see note]).



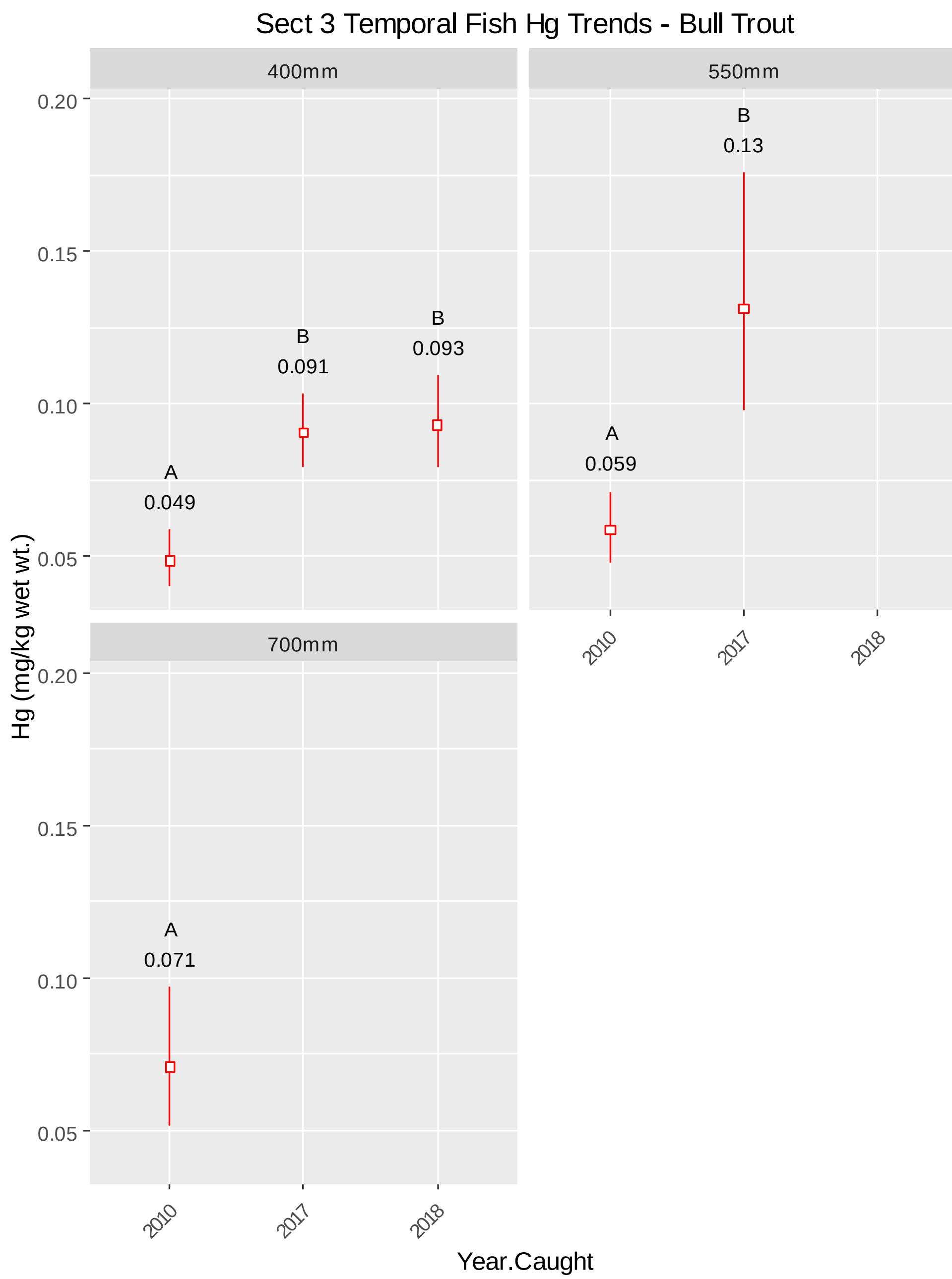
Note: Only years with 15 or more samples were included.

Figure 2-4. Final model fit results for the temporal assessment of Bull Trout mercury concentrations for Section 3.



Note: Only years with 15 or more samples were included.

Figure 2-5. Estimated mercury concentrations (and 95% confidence intervals) for select sizes (400 mm, 550 mm, 700 mm) for each year in the temporal assessment of Bull Trout mercury concentrations for Section 3.



Note: Letters above estimates show which are not statistically different from one another (same letters) or which are statistically different (different letters); combinations (e.g., “AB”) show estimates that are not statistically different from other groups that are different (e.g., “A” and “B”). Only years with more than 15 samples were included.

Figure 2-6. Final model fit results for the spatial assessment of Bull Trout fish mercury concentrations across Peace River locations for the recent baseline period (2017 – 2020).

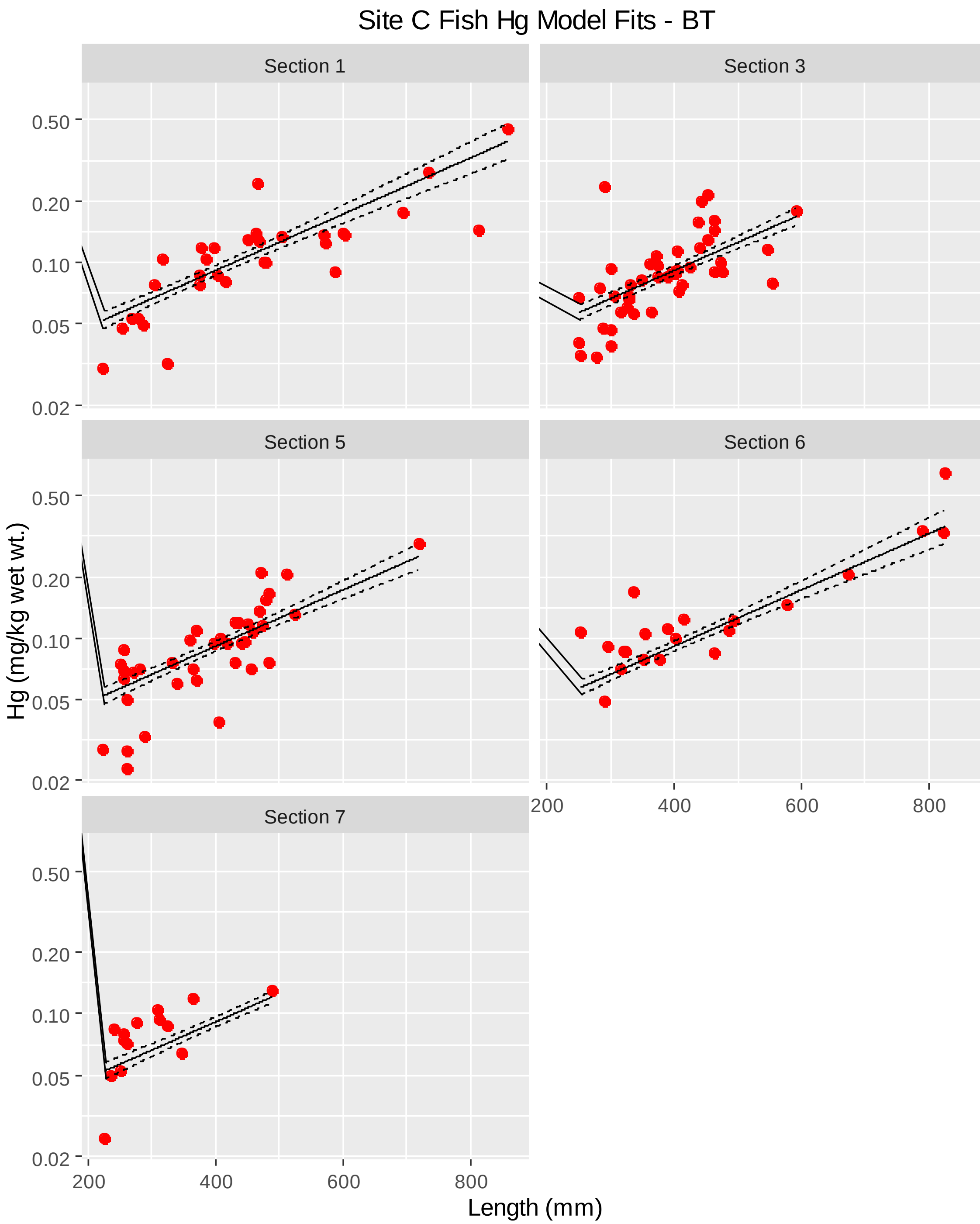
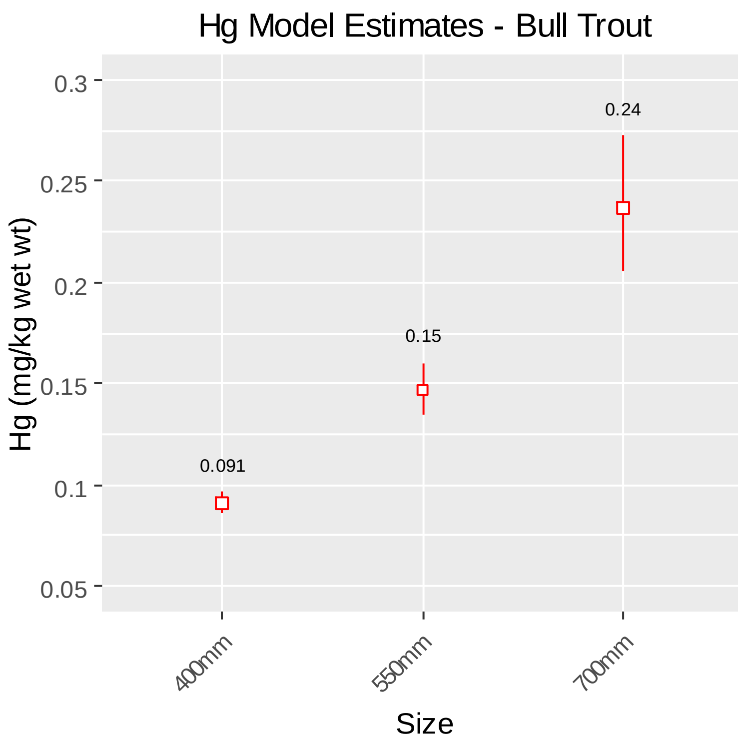


Figure 2-7. Estimated mercury concentrations (and 95% confidence intervals) for Bull Trout for select sizes (400 mm, 550 mm, 700 mm) across Peace River locations in the spatial assessment using recent baseline data (2017 – 2020).



Note: The location (Section) parameter did not improve the length-mercury model, indicating no statistically significant differences in BT mercury concentrations across river sections.

Figure 2-8. Initial model fit results and identified outliers for the baseline period assessment of Bull Trout fish mercury concentrations across Peace River locations.

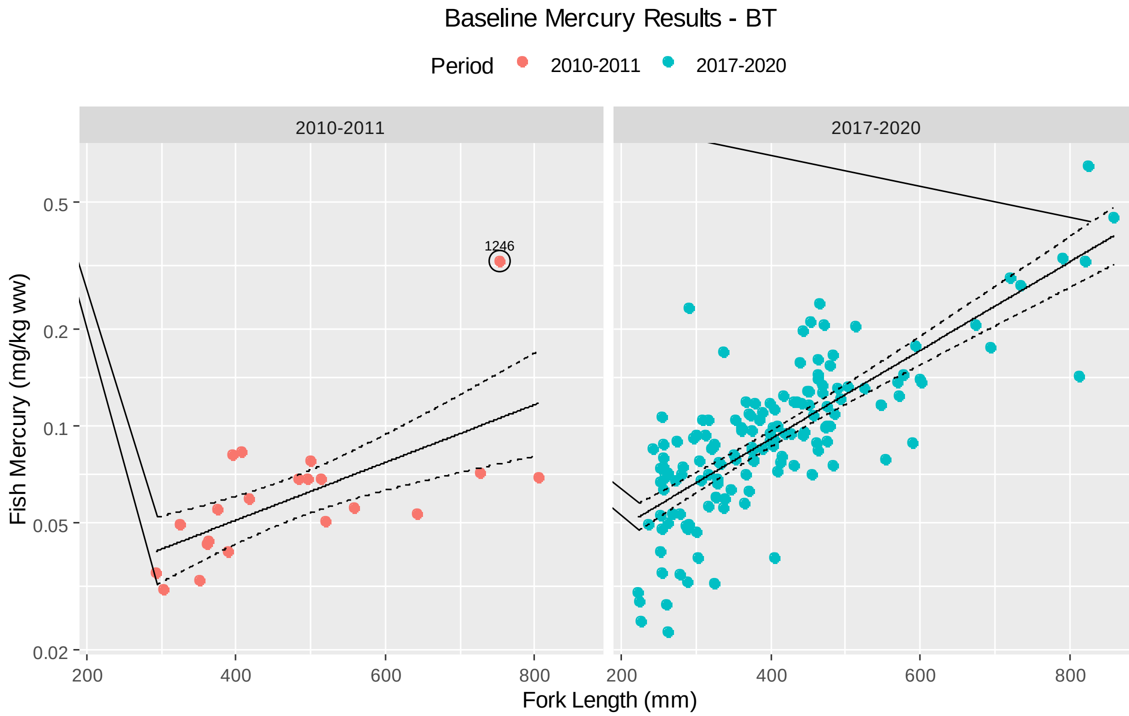


Figure 2-9. Final model fit results for the baseline period assessment of Bull Trout fish mercury concentrations across Peace River locations.

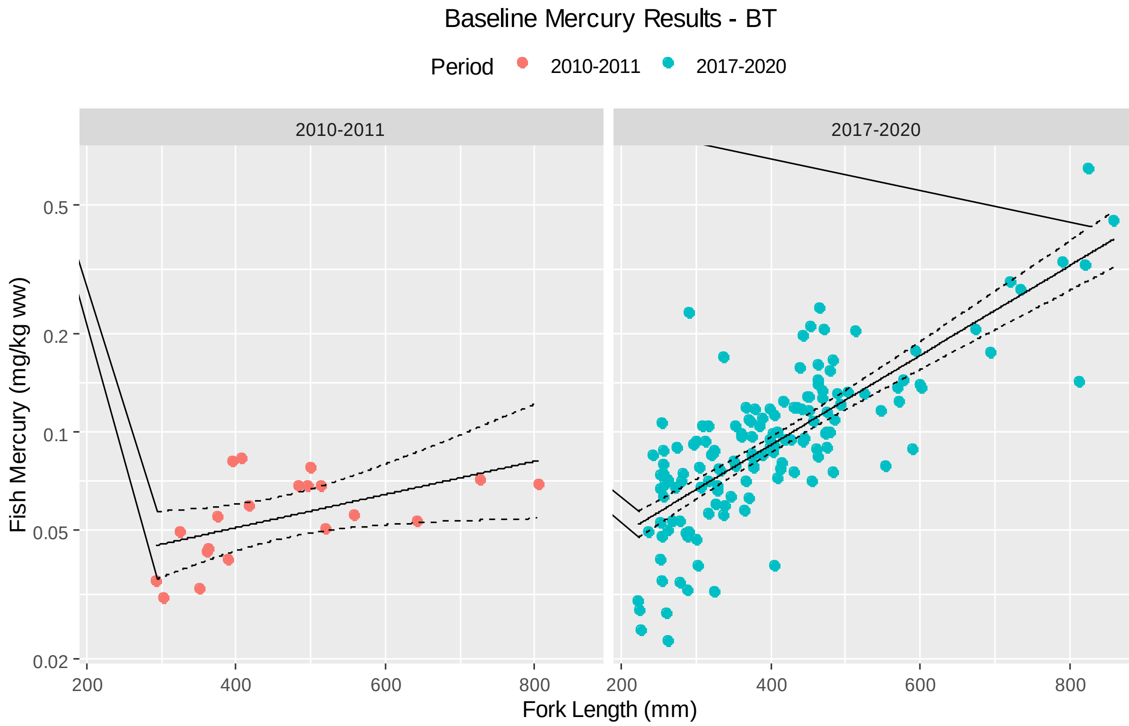
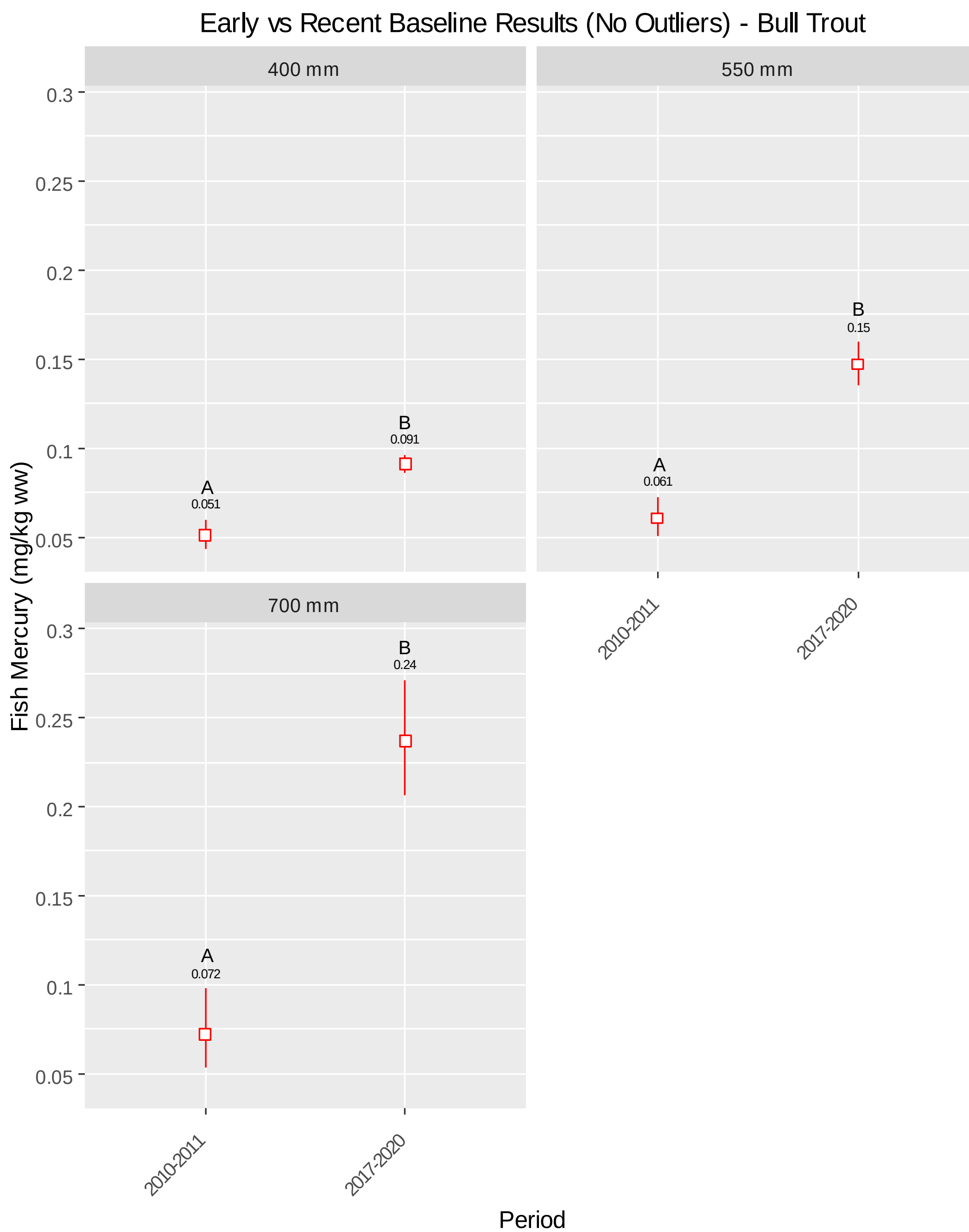


Figure 2-10. Estimated mercury concentrations (and 95% confidence intervals) for select sizes (400 mm, 550 mm, 700 mm) for each period in the baseline period assessment of Bull Trout fish mercury concentrations across Peace River locations.



Note: Letters above estimates show which are not statistically different from one another (same letters) or which are statistically different (different letters); combinations (e.g., “AB”) show estimates that are not statistically different from other groups that are different (e.g., “A” and “B”).

3 MOUNTAIN WHITEFISH

Temporal Assessment

The temporal assessment was conducted to determine whether there were any changes in the length-mercury relationship for Mountain Whitefish across sampling years. To control for potential spatial trends the analysis was limited to Section 3, which had six years (2010, 2011, 2017, 2018, 2019, and 2020) with 11 or more samples, with a total of 87 samples across all years (see Mountain Whitefish section of main report for catch details by location/year).

Key information on the modelling and associated results were as follows:

- *Transformations* – Mercury concentrations were log-transformed.
- *Initial Model Selection* – The suite of temporal models (**Table 1-1**) was initially run with all the data. Fit5 had the lowest AICc value (**Table 3-2**), was selected for use, and has the following structure (linear model with year-specific intercepts and slopes):

  *Log Hg ~ Year + Length + Year*Length*

- *Outliers/High Leverage Data* – Formal outlier assessment of the initial fit5 run (with all data) identified one point (**Figure 3-3**) as an outlier (**Table 3-3**); this was removed ("trimmed") from the dataset.
- *Final Model Selection* – Given the potential for outliers or high-leverage data to influence the model fits, the model selection process was repeated with the trimmed dataset. Fit5 still had the lowest AICc (**Table 3-4**), and so was used to characterize the length-mercury relationship.
- *Fitted length-mercury Relationships* – Final model results are shown in **Figure 3-4** and summarized in **Table 3-5**. The model fits generally show strong positive relationships between length and mercury concentrations. Model residuals were visually examined and confirmed a reasonable fit. The model had an adjusted R2 of 0.78 and showed statistically significant differences in Mountain Whitefish mercury concentrations among years.
- *Predicted Mercury Concentrations for Standard Sized Fish by Year* – Using the length-mercury model shown above, and where the underlying data supported making a prediction, tissue mercury concentrations were estimated for three standard fish sizes: 200 mm, 350 mm and 500 mm. The predictions (and their 95% confidence limits) were used to compare fish tissue mercury concentrations among years (**Figure 3-5**); statistical differences among year-size combinations determined using the selected model were

annotated on the plot. The results show that Mountain Whitefish mercury concentrations were generally lower in 2010/2011 than in 2017 through 2020.

Spatial Assessment

The spatial assessment was conducted to determine whether there are differences in the length-mercury relationship for Mountain Whitefish among sampling locations. Given the temporal changes identified previously, the spatial assessment was limited to the recent time period only. Six sampling locations (Sections 1, 3, 5, 6, 7, and 9) had 34 or more samples across the recent sampling period (2017 to 2020), with a total of 307 samples; (see Mountain Whitefish section of main report for catch details by location/year). However, 27 of these fish were smaller than 200 mm, which had quite low mercury concentrations, so the dataset was trimmed to remove these very small fish, resulting in 280 samples. This adjustment allowed the models to more accurately characterize mercury concentrations in MW between 200 and 300 mm.

Key information on the spatial modelling and associated results were as follows:

- *Transformations* – Mercury concentrations were log-transformed.
- *Initial Model Selection* – The suite of spatial models (**Table 1-2**) was initially run with all the data. Fits 6 and 4, both quadratic model forms, had the lowest AICc values (Table 3-6), but over-fit the data (see **Section 1.1** for details on over-fitting). The model selected for the analysis was fit3, which had the following structure (linear model with no location-specific differences):

  Log Hg ~ Location + Length

- *Outliers/High Leverage Data* – Formal outlier assessment of the initial fit3 run (with all data) identified one point (**Figure 3-6**) as an outlier (**Table 3-7**); this was removed ("trimmed") from the dataset.
- *Final Model Selection* – Given the potential for outliers or high-leverage data to influence the model fits, the model selection process was repeated with the trimmed dataset. Fits 6 and 4 still had the lowest AICc values (**Table 3-8**), but as both still over-fit the data, fit3 was used to characterize the length-mercury relationship.
- *Fitted length-mercury Relationships* – Final model results are shown in **Figure 3-7** and summarized in **Table 3-9**. The model fits generally show strong positive relationships between length and mercury concentrations. Model residuals were visually examined and indicated that the fit was good. The model had an adjusted R2 of 0.66 and showed statistically significant differences in Mountain Whitefish mercury concentrations among locations.

- *Predicted Mercury Concentrations for Standard Sized Fish by Year* – Using the length-mercury model shown above, and where the underlying data supported making a prediction, tissue mercury concentrations were estimated for three standard fish sizes: 200 mm, 350 mm and 500 mm. The predictions (and their 95% confidence limits) were used to compare fish tissue mercury concentrations among locations for the recent period (2017 – 2020) (**Figure 3-8**). The results suggest that Mountain Whitefish mercury concentrations generally increase downstream.

Baseline Period Assessment

This analysis was conducted to characterize potential differences between the early and recent baseline monitoring periods, with the latter information being used to support the development of fish consumption advice based on current conditions. The analysis included 356 samples, with 49 from the early baseline period and 307 from the recent period (see Mountain Whitefish section of main report for catch details by location/year).

Key information on the modelling and associated results were as follows:

- *Transformations* – Mercury concentrations were log-transformed.
- *Initial Model Selection* – The suite of baseline period models (**Table 1-3**) was initially run with all the data. Fit3 had the lowest AICc value (**Table 3-10**) and was the initial model selection; it has the following structure (linear model with period-specific intercepts):

$$Log\ Hg \sim Period + Length$$

- *Outliers/High Leverage Data* – Formal outlier assessment of the initial fit3 run (with all data) identified one point (**Figure 3-9**) as an outlier (**Table 3-11**); this was removed (“trimmed”) from the dataset.
- *Final Model Selection* – Given the potential for outliers or high-leverage data to influence the model fits, the model selection process was repeated with the trimmed dataset. Fit3 once again had the lowest AICc (**Table 3-12**), so was used to characterize the length-mercury relationship.
- *Fitted length-mercury Relationships* – Final model results are shown in **Figure 3-10** and summarized in . The model fits generally show strong positive relationships between length and mercury concentrations. Model residuals were visually examined and indicated that the fit was good. The model had an adjusted R2 of 0.68 and showed statistically significant differences in Mountain Whitefish mercury concentrations among periods.

- *Predicted Mercury Concentrations for Standard Sized Fish by Period* – Using the length-mercury model shown above, and where the underlying data supported making a prediction, tissue mercury concentrations were estimated for three standard fish sizes: 400 mm, 550 mm and 700 mm. The predictions (and their 95% confidence limits) were used to compare fish tissue mercury concentrations between the two baseline sampling periods (**Figure 3-11**); statistical differences between periods for each standardized size were determined using the selected model and were annotated on the plot. The results show that Mountain Whitefish mercury concentrations nearly doubled between the early period (2010-2011) and the recent baseline period (2017 – 2020)

Table 3-1. Potential mercury-related outliers and assessment outcome for Mountain Whitefish.

Waterbody	Year.Caught	FishID	SectionID	Sp	FL.mm	Wt.g	Hg.ppm.ww	Relationship	Outcome
Dinosaur Reservoir	2010	1102	Dinosaur	MW	304	670	0.03311	L-W	retained
Dinosaur Reservoir	2010	1107	Dinosaur	MW	234	70	0.01848	L-W	retained

Table 3-2. Comparison of initial model fit results for the temporal assessment of length-mercury relationship by year for Mountain Whitefish.

Fit	Model[1]	Df	AICc	Delta
fit5	FishHg ~ Year.Caught + LC + Year.Caught:LC	13	83.2	0.0
fit6	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC	14	85.9	2.7
fit3	FishHg ~ Year.Caught + LC	8	91.5	8.2
fit4	FishHg ~ Year.Caught + LC + LC2	9	93.9	10.7
fit8	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC + Year.Caught:LC2	19	97.6	14.4
fit7	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC2	14	101.2	18.0
fit1	FishHg ~ LC	3	110.0	26.8
fit2	FishHg ~ LC + LC2	4	112.2	29.0
fit0	FishHg ~ Year.Caught	7	160.5	77.3

[1] LC=length centered on standard size; LC2=LC^2

Table 3-3. Outlier and high leverage data points excluded from the temporal assessment of Mountain Whitefish mercury concentrations.

Waterbody	Year.Caught	FishID	SectionID	Sp	FL.mm	Wt.g	Hg.ppm.ww	rstud	cooks	OutType[1]
Peace River	2018	426	Section 3	MW	415	772	0.015554	4.443	0.432	Outlier

[1] Outlier types: 'Outlier' = studentized residual > 4; 'High Leverage' = Cook's distance > 0.5.

Table 3-4. Comparison of final model fit results for the temporal assessment of length-mercury relationship by year for Mountain Whitefish.

Fit	Model[1]	Df	AICc	Delta
fit5	FishHg ~ Year.Caught + LC + Year.Caught:LC	13	63.3	0.0
fit6	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC	14	65.9	2.5
fit3	FishHg ~ Year.Caught + LC	8	77.8	14.5
fit8	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC + Year.Caught:LC2	19	78.7	15.4
fit4	FishHg ~ Year.Caught + LC + LC2	9	80.1	16.7
fit7	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC2	14	87.1	23.7
fit1	FishHg ~ LC	3	101.1	37.8
fit2	FishHg ~ LC + LC2	4	103.3	40.0
fit0	FishHg ~ Year.Caught	7	157.7	94.3

[1] LC=length centered on standard size; LC2=LC^2

Table 3-5. Model results for the temporal assessment of Mountain Whitefish mercury concentrations.

Predictor	Estimate	95% CI[1]	p-value
(Intercept)	-3.650	-3.813, -3.487	<0.001
Year.Caught			
2010	—	—	
2011	0.0426	-0.2018, 0.2871	0.7
2017	0.5546	0.3244, 0.7848	<0.001
2018	0.5490	0.2959, 0.8021	<0.001
2019	0.4846	0.2623, 0.7069	<0.001
2020	0.5599	0.2977, 0.8221	<0.001
LC	0.0049	0.0031, 0.0068	<0.001
Year.Caught * LC			
2011 * LC	-0.0032	-0.0071, 0.0008	0.11
2017 * LC	0.0065	0.0027, 0.0103	0.001
2018 * LC	0.0035	-0.0005, 0.0075	0.084
2019 * LC	0.0015	-0.0008, 0.0038	0.2
2020 * LC	-0.0045	-0.0088, -0.0001	0.043

[1] CI = Confidence Interval

Model: FishHg ~ Year.Caught + LC + Year.Caught:LC

Overall Results: F(11,74)=23; Adjusted R^2 = 0.776; N = 86.0

Table 3-6. Comparison of initial model fit results for the spatial assessment of length-mercury relationship by Peace River sampling location for Mountain Whitefish (2017 – 2020).

Fit	Model[1]	Df	AICc	Delta
fit6	FishHg ~ Location + LC + LC2 + Location:LC	14	255.1	0.0
fit4	FishHg ~ Location + LC + LC2	9	255.7	0.6
fit3	FishHg ~ Location + LC	8	258.5	3.4
fit5	FishHg ~ Location + LC + Location:LC	13	258.7	3.6
fit7	FishHg ~ Location + LC + LC2 + Location:LC2	14	262.1	7.0
fit8	FishHg ~ Location + LC + LC2 + Location:LC + Location:LC2	19	262.3	7.2
fit2	FishHg ~ LC + LC2	4	279.6	24.5
fit1	FishHg ~ LC	3	281.4	26.3
fit0	FishHg ~ Location	7	524.5	269.4

[1] LC=length centered on standard size; LC2=LC^2

Table 3-7. Outlier and high leverage data points excluded from the temporal assessment of Mountain Whitefish mercury concentrations.

Waterbody	Year.Caught	FishID	SectionID	Sp	FL.mm	Wt.g	Hg.ppm.ww	rstud	cooks	OutType[1]
Peace River	2018	426	Section 3	MW	415	772	0.015554	4.017	0.048	Outlier

[1] Outlier types: 'Outlier' = studentized residual > 4; 'High Leverage' = Cook's distance > 0.5.

Table 3-8. Comparison of final model fit results for the spatial assessment of length-mercury relationship by Peace River sampling location for Mountain Whitefish (2017 – 2020).

Fit	Model[1]	Df	AICc	Delta
fit6	FishHg ~ Location + LC + LC2 + Location:LC	14	237.4	0.0
fit4	FishHg ~ Location + LC + LC2	9	239.4	2.0
fit5	FishHg ~ Location + LC + Location:LC	13	241.8	4.3
fit3	FishHg ~ Location + LC	8	242.5	5.1
fit8	FishHg ~ Location + LC + LC2 + Location:LC + Location:LC2	19	244.4	7.0
fit7	FishHg ~ Location + LC + LC2 + Location:LC2	14	245.5	8.0
fit2	FishHg ~ LC + LC2	4	261.8	24.4
fit1	FishHg ~ LC	3	264.0	26.5
fit0	FishHg ~ Location	7	521.0	283.6

[1] LC=length centered on standard size; LC2=LC^2

Table 3-9. Model results for the spatial assessment of Mountain Whitefish mercury concentrations (2017 – 2020).

Predictor	Estimate	95% CI[1]	p-value
(Intercept)	-3.103	-3.219, -2.988	<0.001
Location			
Section 1	—	—	
Section 3	0.0029	-0.1479, 0.1538	>0.9
Section 5	0.1889	0.0335, 0.3444	0.017
Section 6	0.2012	0.0448, 0.3575	0.012
Section 7	0.4047	0.2328, 0.5765	<0.001
Section 9	0.1755	0.0240, 0.3270	0.023
LC	0.0083	0.0067, 0.0099	<0.001
Location * LC			
Section 3 * LC	-0.0013	-0.0034, 0.0008	0.2
Section 5 * LC	-0.0031	-0.0052, -0.0010	0.004
Section 6 * LC	-0.0024	-0.0045, -0.0004	0.020
Section 7 * LC	-0.0008	-0.0032, 0.0017	0.5
Section 9 * LC	-0.0013	-0.0034, 0.0009	0.2

[1] CI = Confidence Interval

Model: FishHg ~ Location + LC + Location:LC

Overall Results: $F(11,267)=48$; Adjusted $R^2 = 0.664$; N = 279

Table 3-10. Comparison of initial model fit results for the baseline period assessment of length-mercury relationship by year for Mountain Whitefish.

Fit	Model[1]	Df	AICc	Delta
fit3	FishHg ~ Period + LC	4	337.9	0.0
fit5	FishHg ~ Period + LC + Period:LC	5	339.2	1.2
fit4	FishHg ~ Period + LC + LC2	5	339.8	1.9
fit6	FishHg ~ Period + LC + LC2 + Period:LC	6	340.9	3.0
fit7	FishHg ~ Period + LC + LC2 + Period:LC2	6	341.8	3.9
fit8	FishHg ~ Period + LC + LC2 + Period:LC + Period:LC2	7	342.7	4.8
fit1	FishHg ~ LC	3	403.7	65.7
fit2	FishHg ~ LC + LC2	4	404.4	66.4
fit0	FishHg ~ Period	3	713.0	375.0

[1] LC=length centered on standard size; LC2=LC^2

Table 3-11. Outlier and high leverage data points excluded from the baseline period assessment of Mountain Whitefish mercury concentrations.

Waterbody	Year.Caught	FishID	SectionID	Sp	FL.mm	Wt.g	Hg.ppm.ww	StudRes	CooksD	OutType[1]
Peace River	2018	426	Section 3	MW	415	772	0.015554	4.262	0.038	Outlier

[1] Outlier types: 'Outlier' = studentized residual > 4; 'High Leverage' = Cook's distance > 0.5.

Table 3-12. Comparison of final model fit results for the baseline period assessment of length-mercury relationship by year for Mountain Whitefish.

Fit	Model[1]	Df	AICc	Delta
fit3	FishHg ~ Period + LC	4	320.2	0.0
fit5	FishHg ~ Period + LC + Period:LC	5	321.2	1.0
fit4	FishHg ~ Period + LC + LC2	5	321.9	1.8
fit6	FishHg ~ Period + LC + LC2 + Period:LC	6	322.8	2.7
fit7	FishHg ~ Period + LC + LC2 + Period:LC2	6	324.0	3.8
fit8	FishHg ~ Period + LC + LC2 + Period:LC + Period:LC2	7	324.6	4.4
fit1	FishHg ~ LC	3	390.4	70.2
fit2	FishHg ~ LC + LC2	4	390.9	70.7
fit0	FishHg ~ Period	3	709.5	389.3

[1] LC=length centered on standard size; LC2=LC^2

Table 3-13. Model results for the baseline period assessment of Mountain Whitefish mercury concentrations.

Predictor	Estimate	95% CI[1]	p-value
(Intercept)	-3.476	-3.582, -3.370	<0.001
Period			
2010-2011	—	—	
2017-2020	0.5185	0.4041, 0.6329	<0.001
LC	0.0062	0.0058, 0.0067	<0.001

[1] CI = Confidence Interval

Model: FishHg ~ Period + LC

Overall Results: $F(2,352)=379$; Adjusted $R^2 = 0.683$; $N = 355$

Figure 3-1. Length Frequency and age frequency for Mountain Whitefish (MW) by location across all years (2010 – 2020)

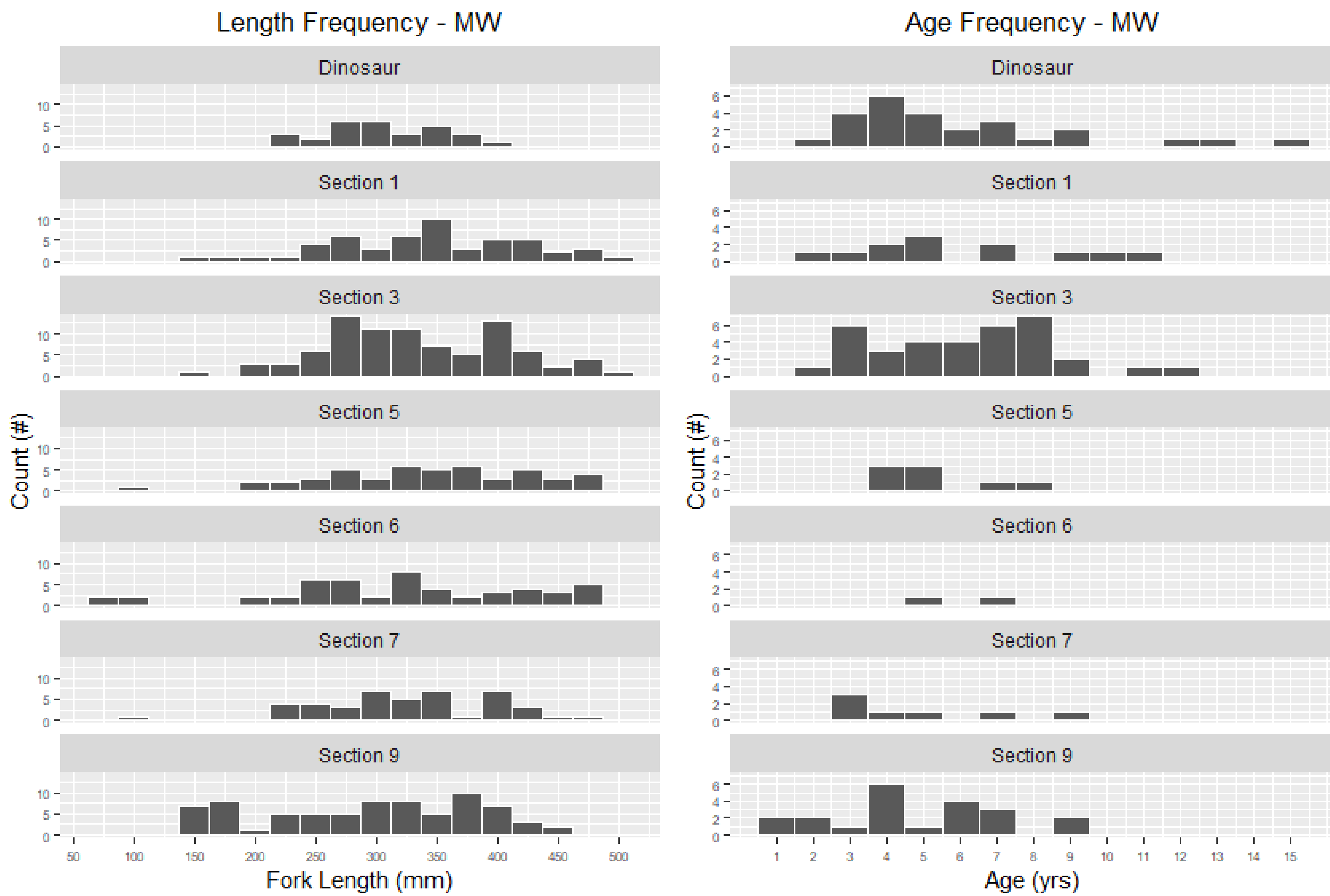


Figure 3-2. Key mercury-related relationships for Mountain Whitefish (MW) across all years (2010 – 2020). Red circles indicate length-weight outliers.

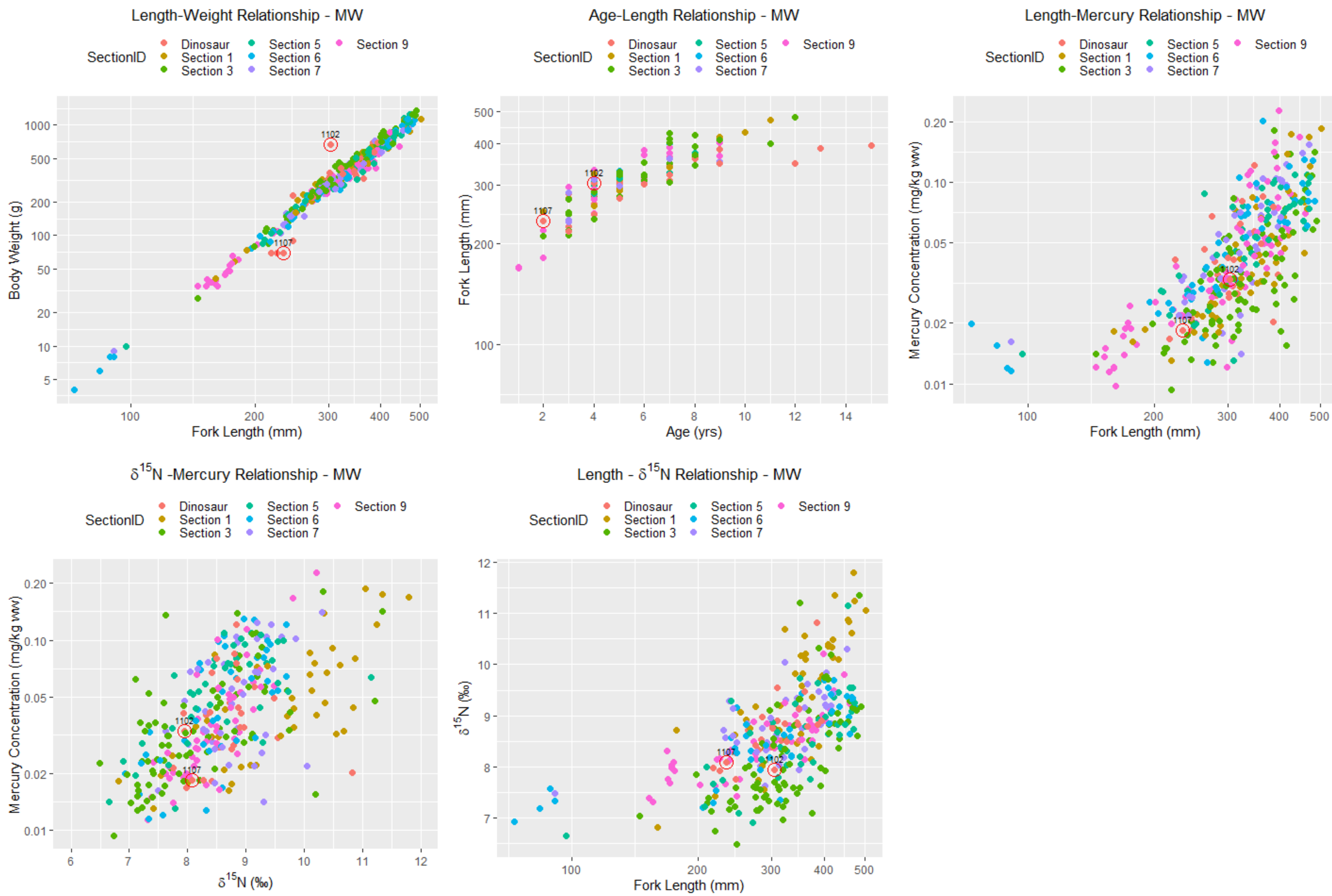


Figure 3-3. Initial model fit results and identified outliers for the temporal assessment of Mountain Whitefish mercury concentrations for Section 3 (2010 – 2020)

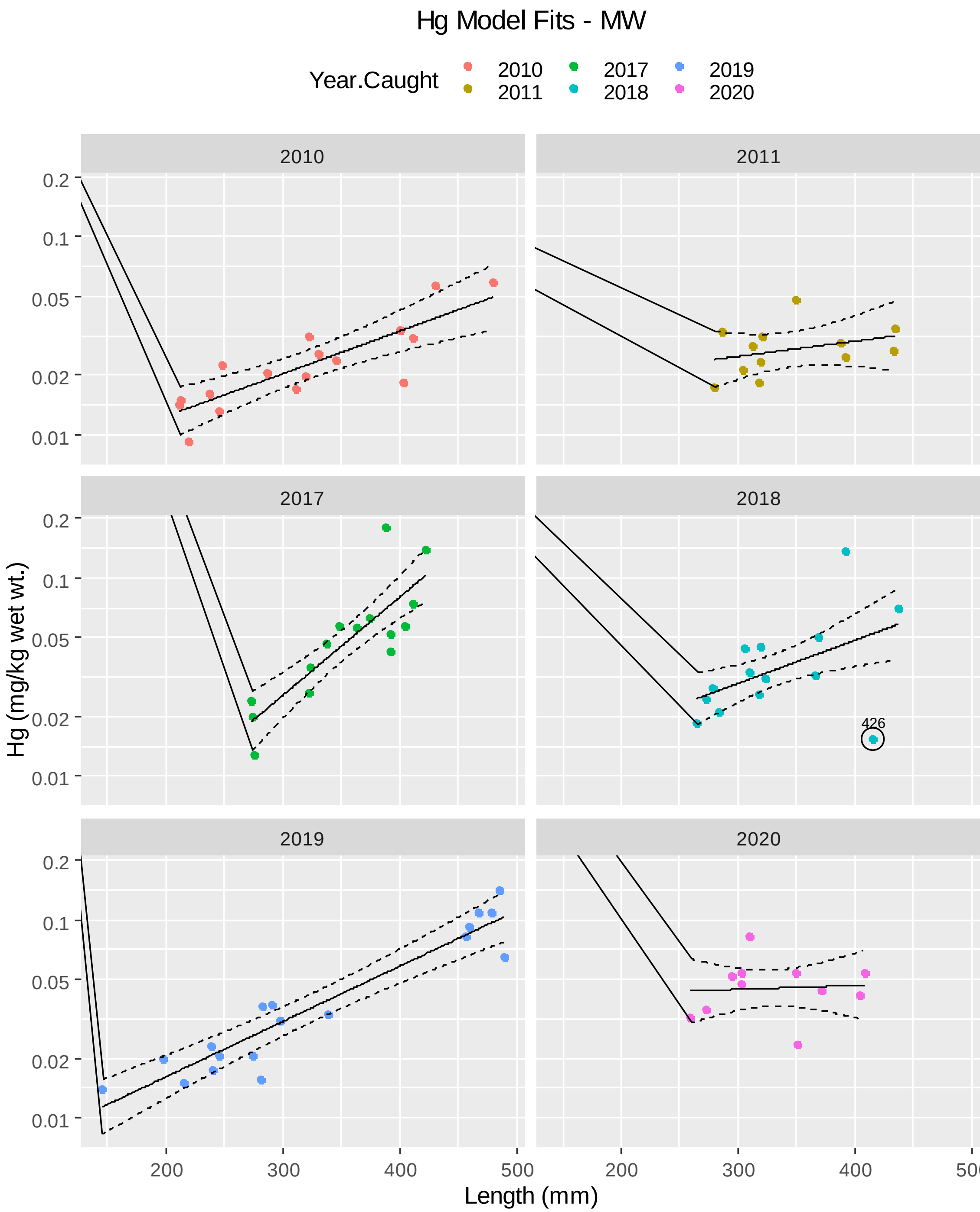


Figure 3-4. Final model fit results for the temporal assessment of Mountain Whitefish mercury concentrations for Section 3.

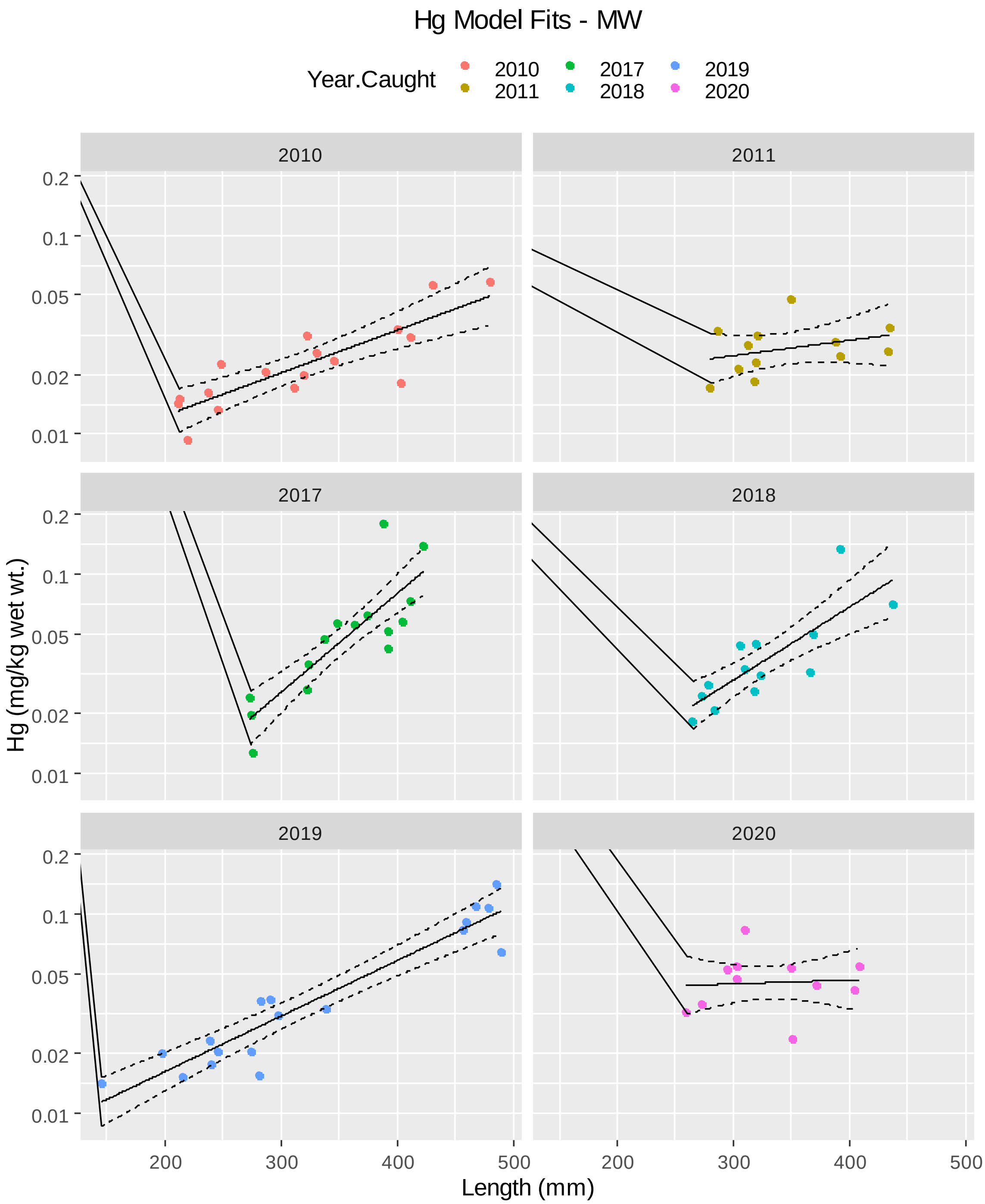
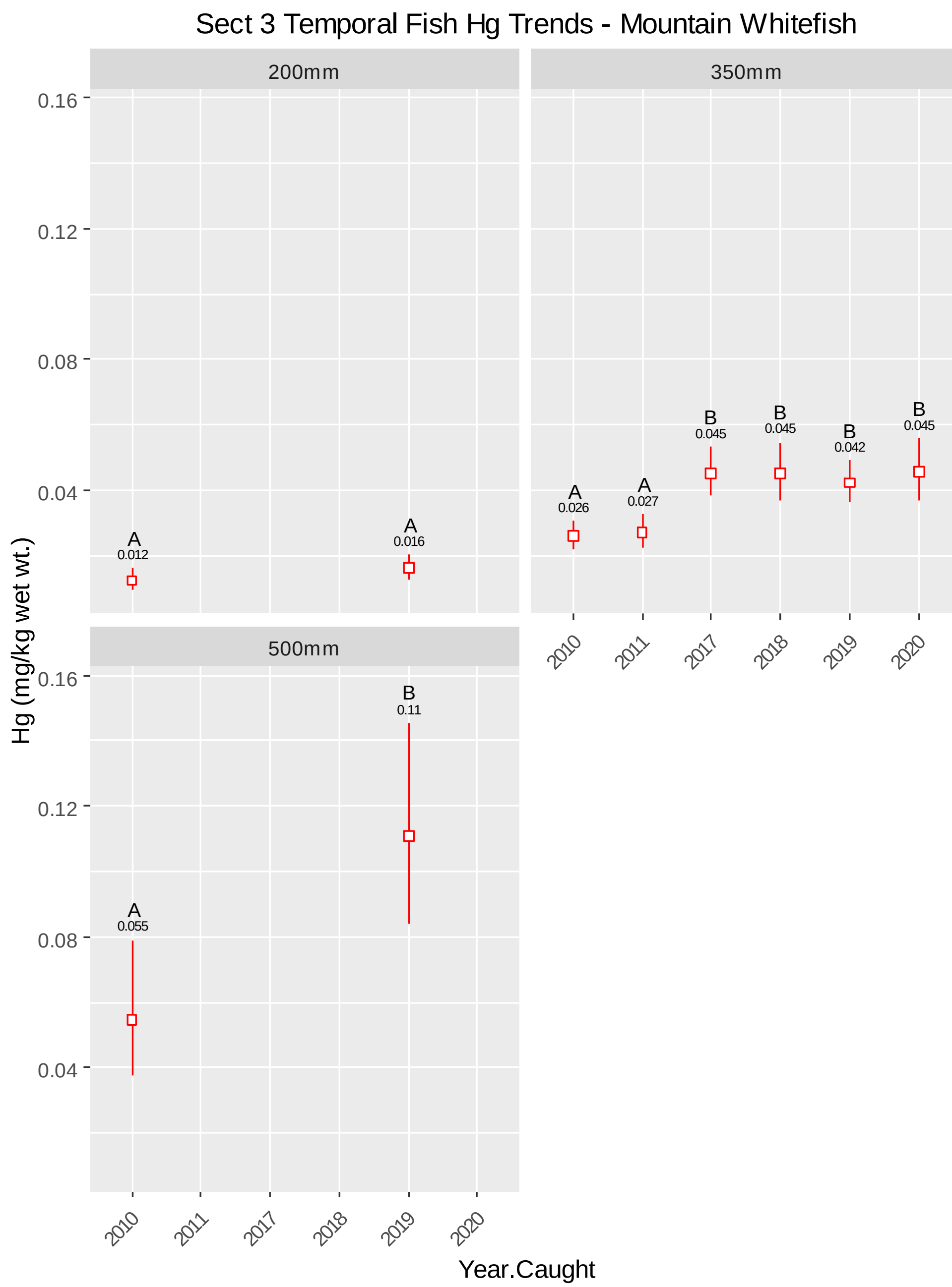


Figure 3-5. Estimated mercury concentrations (and 95% confidence intervals) for select sizes (200 mm, 350 mm, 500 mm) for each year in the temporal assessment of Mountain Whitefish mercury concentrations for Section 3.



Note: Letters above estimates show which are not statistically different from one another (same letters) or which are statistically different (different letters); combinations (e.g., "AB") show estimates that are not statistically different from other groups that are different (e.g., "A" and "B").

Figure 3-6. Initial model fit results and identified outliers for the spatial assessment of Mountain Whitefish mercury concentrations across Peace River locations for the recent baseline period (2017 – 2020).

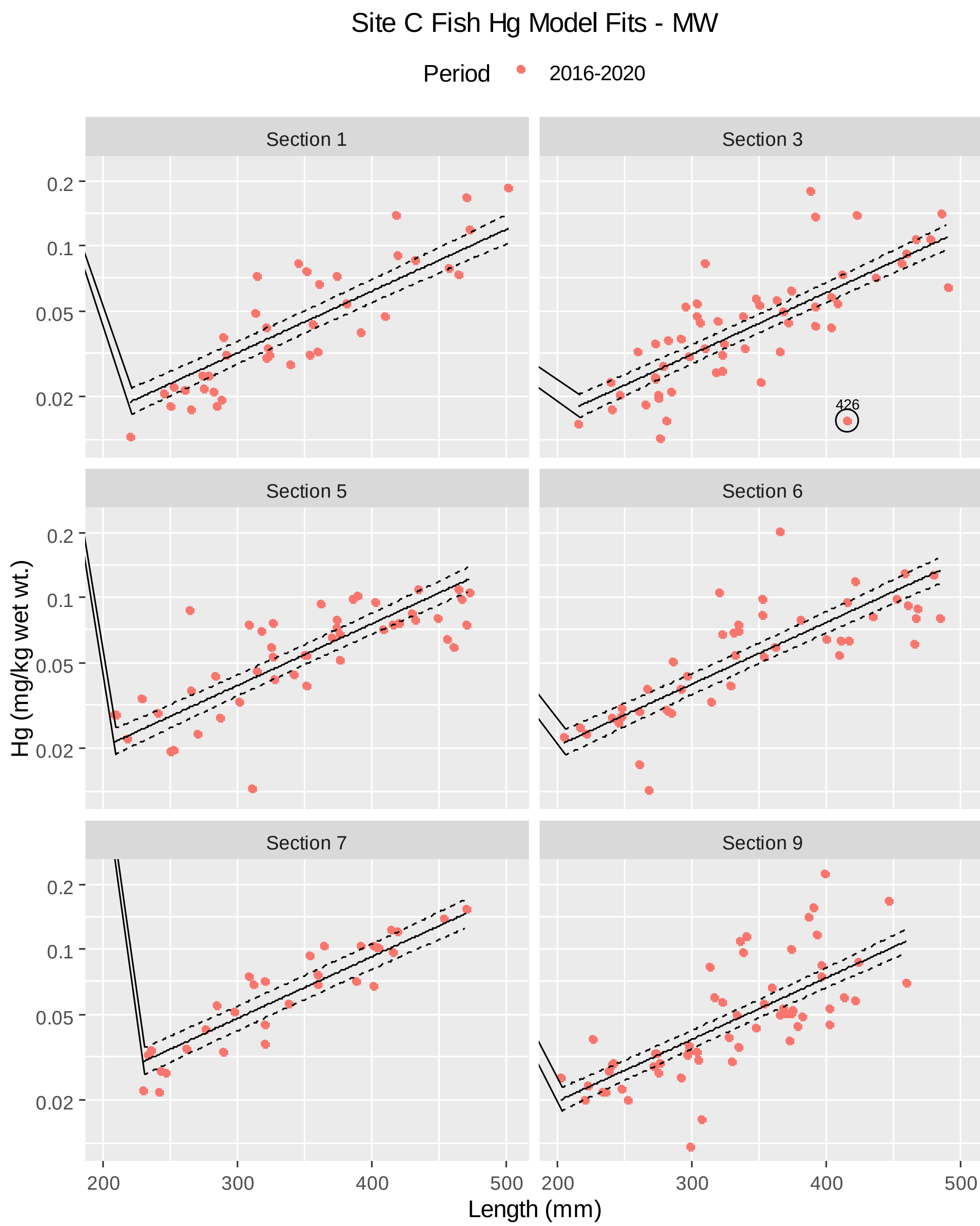


Figure 3-7. Final model fit results for the spatial assessment of Mountain Whitefish mercury concentrations across Peace River locations for the recent baseline period (2017 – 2020).

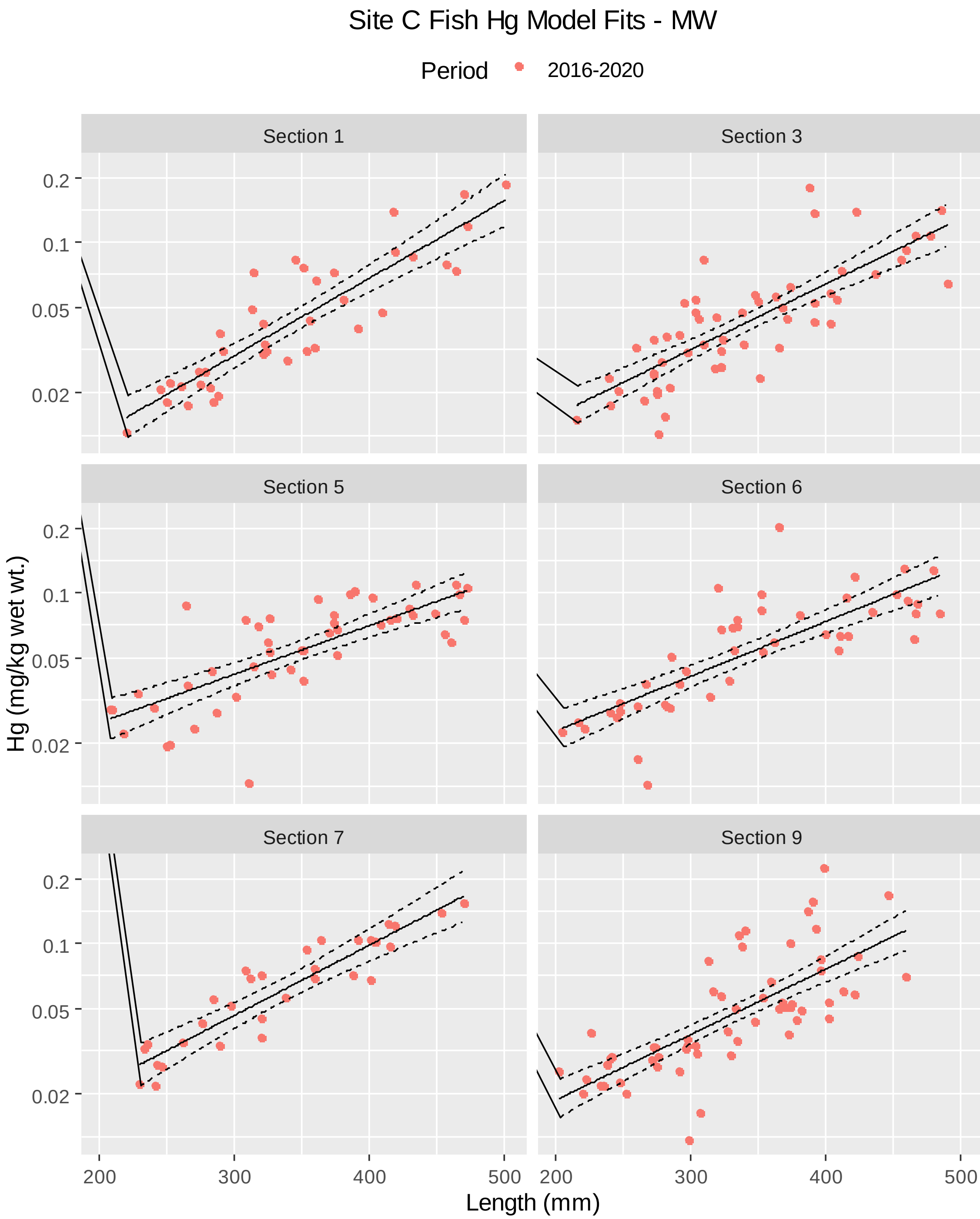
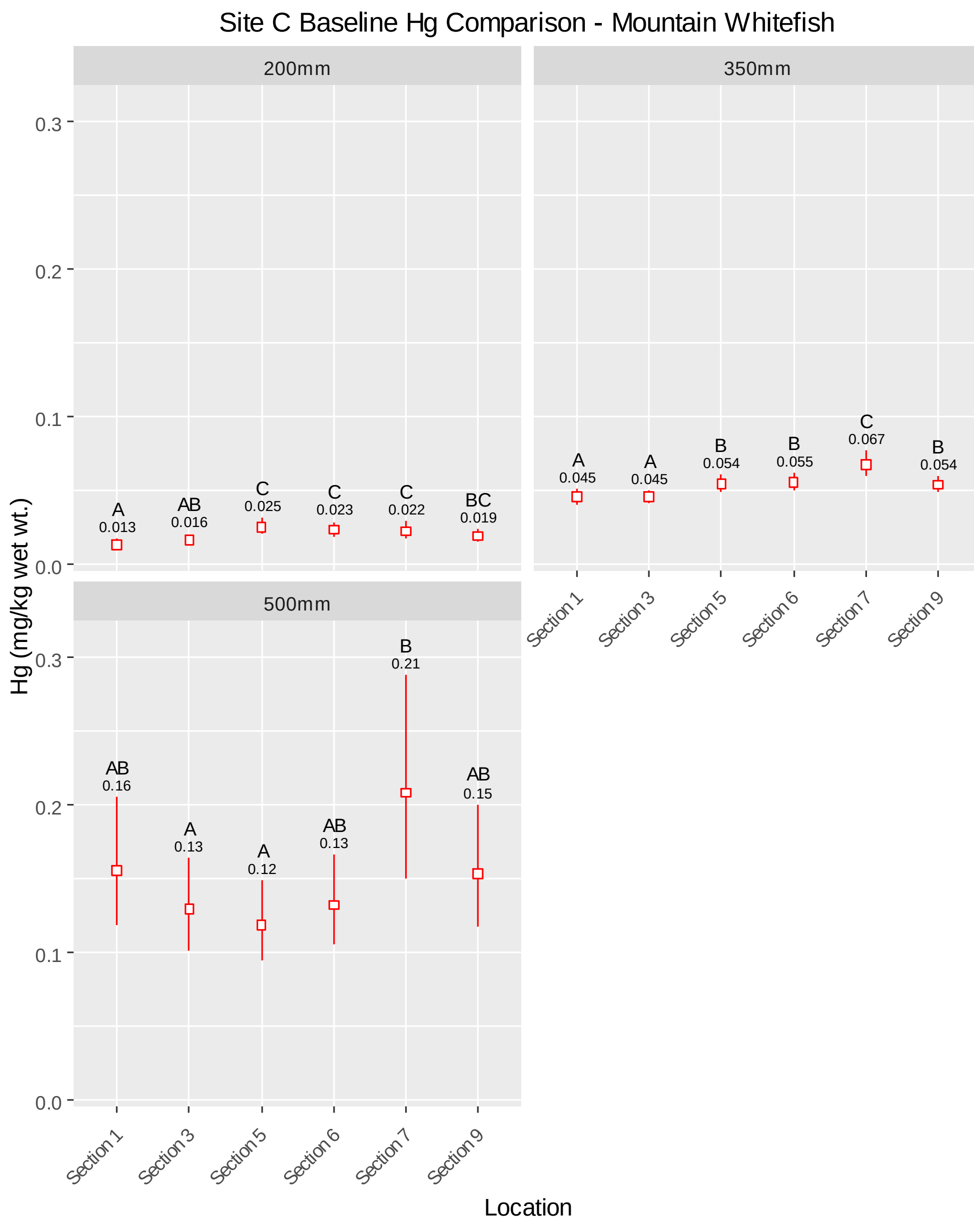


Figure 3-8. Estimated mercury concentrations (and 95% confidence intervals) for select sizes (200 mm, 350 mm, 500 mm) across Peace River sites in the spatial assessment of Mountain Whitefish mercury concentrations across the recent baseline period (2017 – 2020)



Note: Letters above estimates show which are not statistically different from one another (same letters) or which are statistically different (different letters); combinations (e.g., "AB") show estimates that are not statistically different from other groups that are different (e.g., "A" and "B").

Figure 3-9. Initial model fit results and identified outliers for the baseline period assessment of Mountain Whitefish mercury concentrations across Peace River locations.

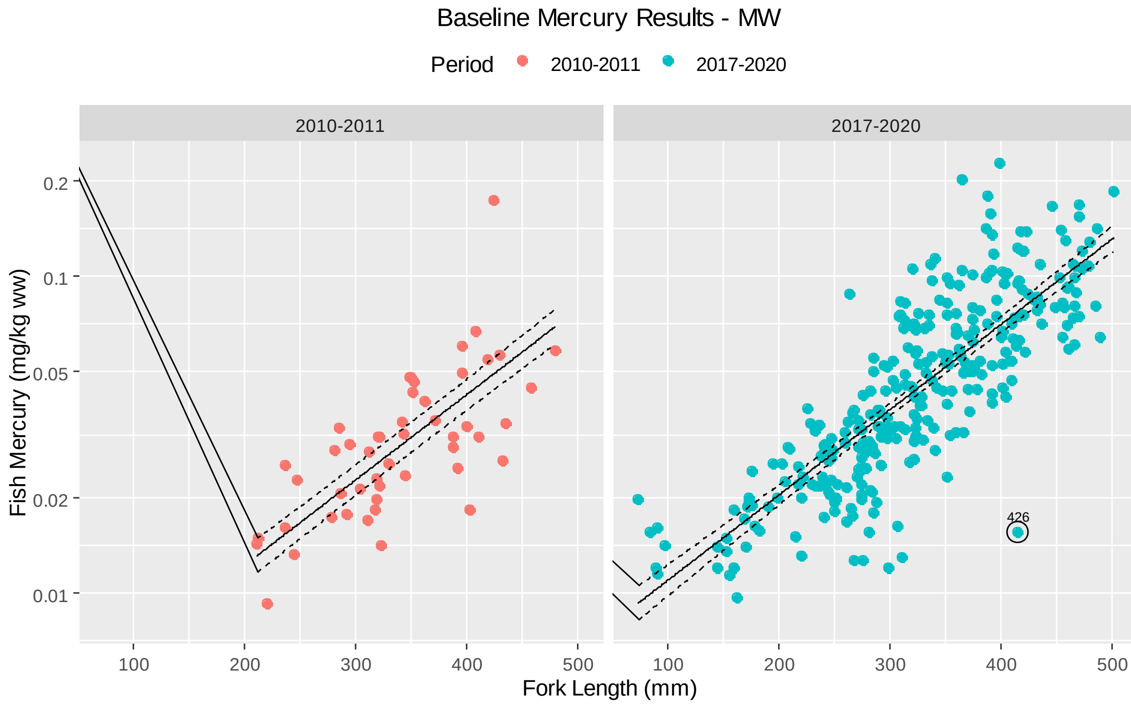


Figure 3-10. Final model fit results for the baseline period assessment of Mountain Whitefish mercury concentrations across Peace River locations.

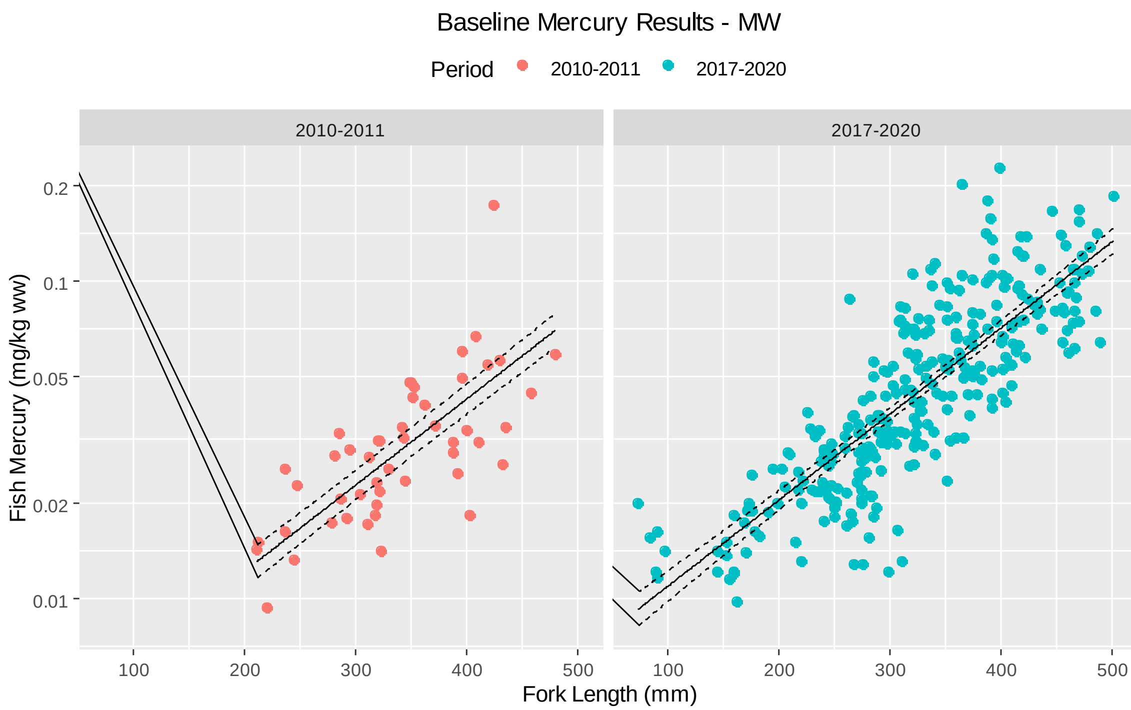
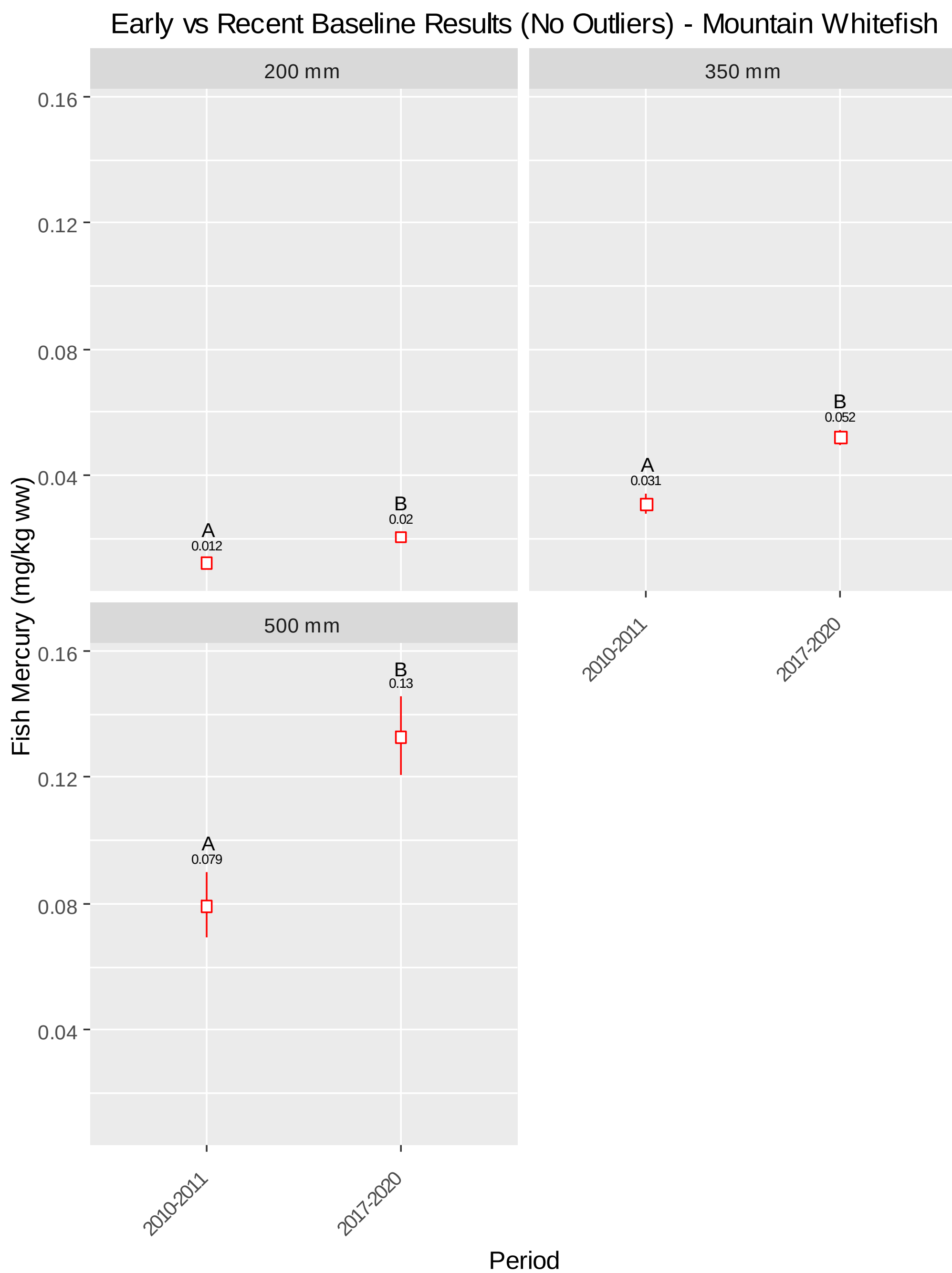


Figure 3-11. Estimated mercury concentrations (and 95% confidence intervals) for select sizes (200 mm, 350 mm, 500 mm) for each year in the baseline period assessment of Mountain Whitefish mercury concentrations across Peace River locations.



Note: Letters above estimates show which are not statistically different from one another (same letters) or which are statistically different (different letters); combinations (e.g., “AB”) show estimates that are not statistically different from other groups that are different (e.g., “A” and “B”).

4 RAINBOW TROUT

Temporal Assessment

The temporal assessment was conducted to determine whether there were any changes in the length-mercury relationship for Rainbow Trout across sampling years. To control for potential spatial trends the analysis was limited to Section 1, which had three years (2010, 2017, and 2018) with 5 or more samples, with a total of 26 samples across all years (see Rainbow Trout section of main report for catch details by location/year). While Dinosaur Reservoir and Section 3 also had three years of data each, Section 1 was the only location that was in the Peace River and had data spanning the early and recent baseline sampling periods.

Key information on the modelling and associated results were as follows:

- *Transformations* – Mercury concentrations were log-transformed.
- *Initial Model Selection* – The suite of temporal models (**Table 1-1**) was initially run with all the data. Fit1 had the lowest AICc value (**Table 4-2**), was selected for use, and has the following structure (linear model with year-specific intercepts and slopes):

  Log Hg ~ Length

- *Outliers/High Leverage Data* – No outliers or high leverage points were identified.
- *Final Model Selection* – As no outliers or high-leverage points were identified, fit1 using all data was used to characterize the length-mercury relationship.
- *Fitted length-mercury Relationships* – Final model results are shown in **Figure 4-3** and summarized in **Table 4-3**. The model fits generally show positive relationships between length and mercury concentrations. Model residuals were visually examined and confirmed a reasonable fit. The model had an adjusted R2 of 0.35 and showed no statistically significant differences in Rainbow Trout mercury concentrations among years.
- *Predicted Mercury Concentrations for Standard Sized Fish by Year* – Using the length-mercury model shown above, and where the underlying data supported making a prediction, tissue mercury concentrations were estimated for three standard fish sizes: 200 mm, 350 mm and 500 mm. The predictions (and their 95% confidence limits) were made for fish size only as year caught was not in the final model (**Figure 4-4**). The results show that Rainbow Trout mercury concentrations have a positive relationship with length, but that concentrations were generally similar across years.

Spatial Assessment

The spatial assessment was conducted to determine whether there are differences in the length-mercury relationship for Rainbow Trout among sampling locations. While no temporal changes were identified in the previous analysis, the spatial assessment was limited to the recent time period only. Two sampling locations (Sections 1 and 3) had 16 or more samples across the recent sampling period (2017 to 2020), with a total of 53 samples; (see Rainbow Trout section of main report for catch details by location/year).

Key information on the spatial modelling and associated results were as follows:

- *Transformations* – Mercury concentrations were log-transformed.
- *Initial Model Selection* – The suite of spatial models (**Table 1-2**) was initially run with all the data. Fit1 had the lowest AICc value (**Table 4-4**), was selected for use, and has the following structure (linear model with year-specific intercepts and slopes):

  Log Hg ~ Length

- *Outliers/High Leverage Data* – No outliers or high leverage points were identified.
- *Final Model Selection* – As no outliers or high-leverage points were identified, fit1 using all data was used to characterize the length-mercury relationship.
- *Fitted length-mercury Relationships* – Final model results are shown in **Figure 4-5** and summarized in **Table 4-5**. The model fits generally show strong positive relationships between length and mercury concentrations. Model residuals were visually examined and indicated that the fit was good. The model had an adjusted R2 of 0.40 and showed statistically significant differences in Rainbow Trout mercury concentrations among locations.
- *Predicted Mercury Concentrations for Standard Sized Fish by Year* – Using the length-mercury model shown above, and where the underlying data supported making a prediction, tissue mercury concentrations were estimated for three standard fish sizes: 200 mm, 350 mm and 500 mm. The predictions (and their 95% confidence limits) were only made for the three standard fish sizes as there were no differences predicted in fish tissue mercury concentrations among locations for the recent period (2017 – 2020) (**Figure 4-6**).

Baseline Period Assessment

This analysis was conducted to characterize potential differences between the early and recent baseline monitoring periods, with the latter information being used to support the development of fish consumption advice based on current conditions. The analysis included 70 samples, with 10 from the early baseline period and 60 from the recent period (see Rainbow Trout section of main report for catch details by location/year).

Key information on the modelling and associated results were as follows:

- *Transformations* – Mercury concentrations were log-transformed.
- *Initial Model Selection* – The suite of baseline period models (**Table 1-3**) was initially run with all the data. Fit1 had the lowest AICc value (**Table 4-6**), was selected for use, and has the following structure (linear model with year-specific intercepts and slopes):

  Log Hg ~ Length

- *Outliers/High Leverage Data* – No outliers or high leverage points were identified.
- *Final Model Selection* – As no outliers or high-leverage points were identified, fit1 using all data was used to characterize the length-mercury relationship.
- *Fitted length-mercury Relationships* – Final model results are shown in **Figure 4-7** and summarized in **Table 4-7**. The model fits generally show strong positive relationships between length and mercury concentrations. Model residuals were visually examined and indicated that the fit was good. The model had an adjusted R2 of 0.38 and showed statistically significant differences in Rainbow Trout mercury concentrations among periods.
- *Predicted Mercury Concentrations for Standard Sized Fish by Period* – Using the length-mercury model shown above, and where the underlying data supported making a prediction, tissue mercury concentrations were estimated for three standard fish sizes: 400 mm, 550 mm and 700 mm. As baseline sampling period did not prove to be a meaningful model parameter (i.e., no statistically significant differences were observed between periods), predictions (and their 95% confidence limits) were only made for the three standard fish sizes (**Figure 4-8**). Thus, the results show that Rainbow Trout mercury concentrations were similar between the early period (2010-2011) and the recent baseline period (2017 – 2020).

Table 4-1. Fish formally identified as outliers in length-weight (L-W), length-mercury (L-Hg) and/or mercury-nitrogen isotope (Hg-dN) relationships.

Waterbody	Year.Caught	FishID	SectionID	Sp	FL.mm	Wt.g	Hg.ppm.ww	Relationship	Outcome
Peace River	2018	581	Section 1	RB	264	224	0.3476000	NA,L-Hg,Hg-dN	excluded
Peace River	2017	140	Section 3	RB	370	528	0.0042900	NA,L-Hg,NA	excluded
Dinosaur Reservoir	2016	RNBW-TW-02	Dinosaur	RB	326	180	0.0233200	L-W,NA,NA	retained
Dinosaur Reservoir	2016	RNBW-TW-05	Dinosaur	RB	234	50	0.0311588	L-W,NA,NA	retained

Table 4-2. Comparison of final model fit results for the temporal assessment of length-mercury relationship by year for Rainbow Trout.

Fit	Model[1]	Df	AICc	Delta
fit1	FishHg ~ LC	3	22.6	0.0
fit2	FishHg ~ LC + LC2	4	25.2	2.6
fit3	FishHg ~ Year.Caught + LC	5	25.9	3.3
fit4	FishHg ~ Year.Caught + LC + LC2	6	29.4	6.8
fit0	FishHg ~ Year.Caught	4	33.0	10.5
fit5	FishHg ~ Year.Caught + LC + Year.Caught:LC	7	33.2	10.6
fit6	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC	8	37.6	15.0
fit7	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC2	8	37.6	15.0
fit8	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC + Year.Caught:LC2	10	46.9	24.3

[1] LC=length centered on standard size; LC2=LC^2

Table 4-3. Final model results for the temporal assessment of Rainbow Trout mercury concentrations.

Predictor	Estimate	95% CI[1]	p-value
(Intercept)	-3.568	-3.724, -3.412	<0.001
LC	0.0041	0.0017, 0.0065	0.002

[1] CI = Confidence Interval

Model: FishHg ~ LC

Overall Results: $F(1,23)=12$; Adjusted $R^2 = 0.348$; N = 25.0

Table 4-4. Comparison of final model fit results for the spatial assessment of length-mercury relationship by location for Rainbow Trout.

Fit	Model[1]	Df	AICc	Delta
fit1	FishHg ~ LC	3	34.7	0.0
fit3	FishHg ~ Location + LC	4	36.9	2.3
fit2	FishHg ~ LC + LC2	4	37.0	2.3
fit5	FishHg ~ Location + LC + Location:LC	5	38.3	3.7
fit4	FishHg ~ Location + LC + LC2	5	39.3	4.7
fit6	FishHg ~ Location + LC + LC2 + Location:LC	6	40.6	6.0
fit7	FishHg ~ Location + LC + LC2 + Location:LC2	6	41.7	7.1
fit8	FishHg ~ Location + LC + LC2 + Location:LC + Location:LC2	7	42.0	7.3
fit0	FishHg ~ Location	3	61.1	26.4

[1] LC=length centered on standard size; LC2=LC^2

Table 4-5. Final model results for the spatial assessment of Rainbow Trout fish mercury concentrations.

Predictor	Estimate	95% CI[1]	p-value
(Intercept)	-3.617	-3.707, -3.527	<0.001
LC	0.0041	0.0027, 0.0055	<0.001

[1] CI = Confidence Interval

Model: FishHg ~ LC

Overall Results: $F(1,51)=34$; Adjusted $R^2 = 0.397$; N = 53.0

Table 4-6. Comparison of final model fit results for the baseline period assessment of length-mercury relationship by sampling period for Rainbow Trout.

Fit	Model[1]	Df	AICc	Delta
fit1	FishHg ~ LC	3	53.1	0.0
fit3	FishHg ~ Period + LC	4	53.2	0.1
fit2	FishHg ~ LC + LC2	4	55.0	2.0
fit4	FishHg ~ Period + LC + LC2	5	55.3	2.2
fit5	FishHg ~ Period + LC + Period:LC	5	55.4	2.3
fit7	FishHg ~ Period + LC + LC2 + Period:LC2	6	57.3	4.3
fit6	FishHg ~ Period + LC + LC2 + Period:LC	6	57.5	4.4
fit8	FishHg ~ Period + LC + LC2 + Period:LC + Period:LC2	7	59.8	6.7
fit0	FishHg ~ Period	3	83.3	30.3

[1] LC=length centered on standard size; LC2=LC^2

Table 4-7. Final model results for the baseline period assessment of Rainbow Trout fish mercury concentrations.

Predictor	Estimate	95% CI[1]	p-value
(Intercept)	-3.384	-3.477, -3.291	<0.001
LC	0.0041	0.0028, 0.0054	<0.001

[1] CI = Confidence Interval

Model: FishHg ~ LC

Overall Results: $F(1,68)=41$; Adjusted $R^2 = 0.376$; N = 70.0

Figure 4-1. Length Frequency and age frequency for Rainbow Trout (RB) by location across all years (2010 – 2020).

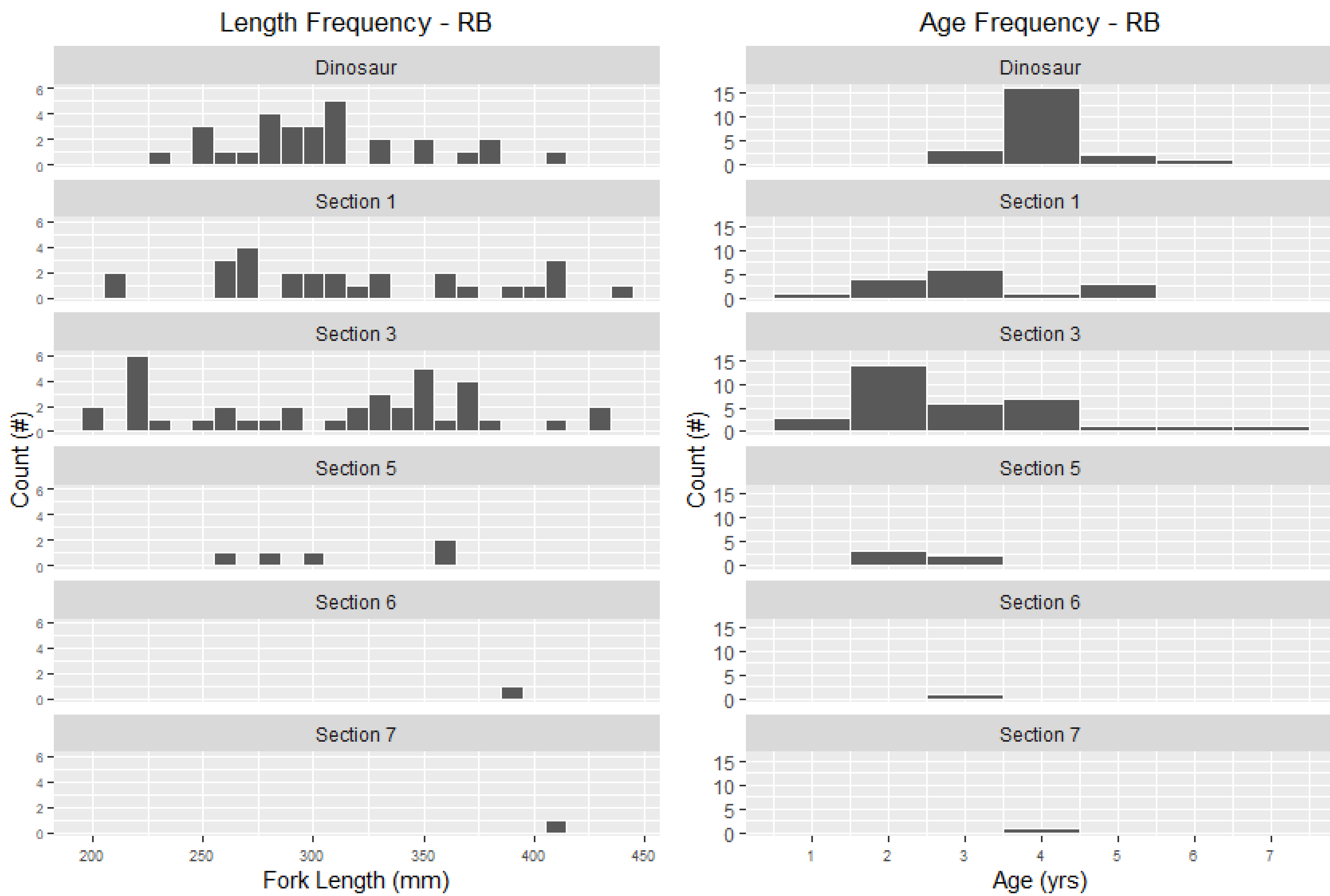


Figure 4-2. Key mercury-related relationships for Rainbow Trout (RB) across all years (2010 – 2020). Red circles indicate length-weight outliers, green circles indicate length-mercury outliers, and blue circles indicate δ15N-mercury outliers.

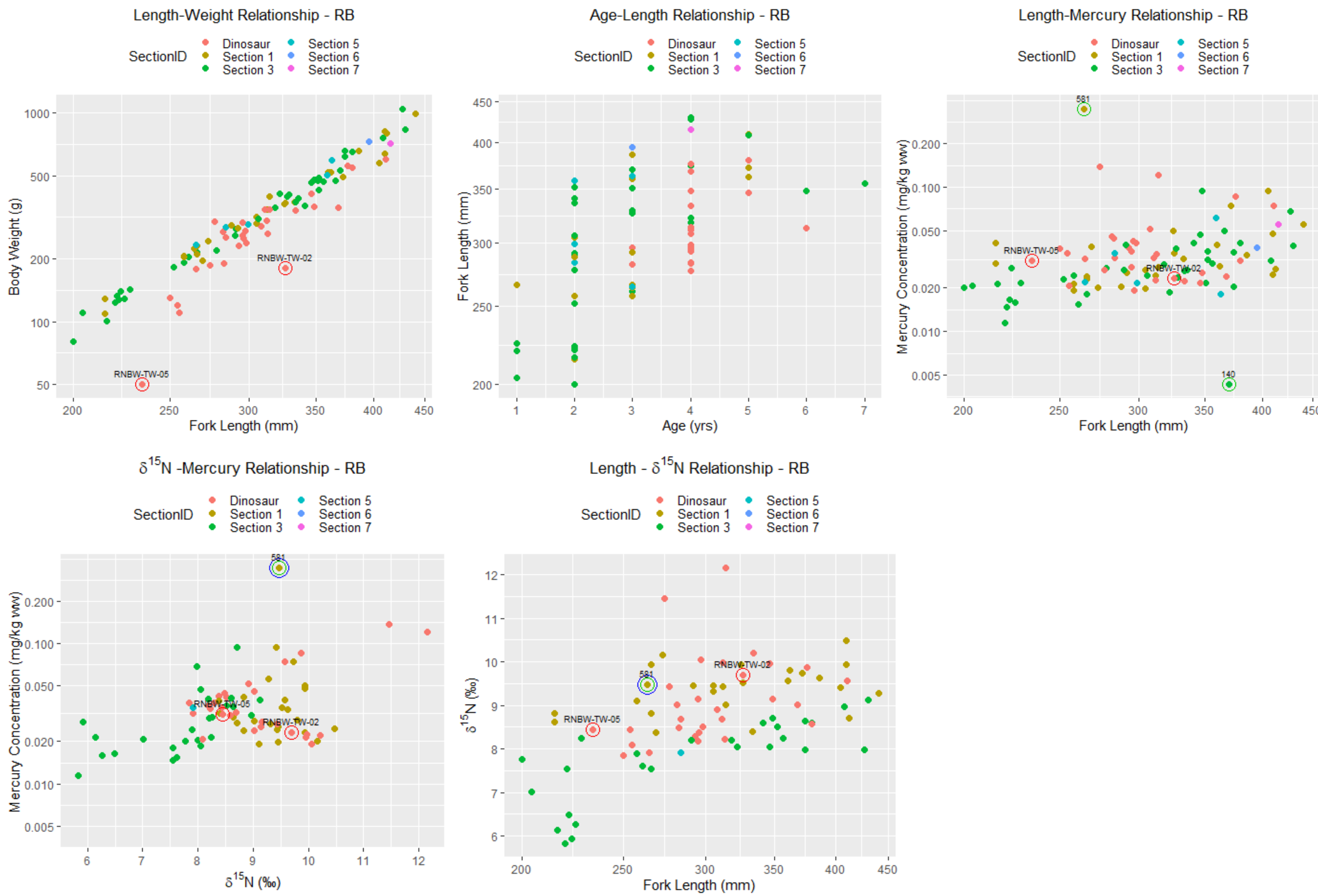
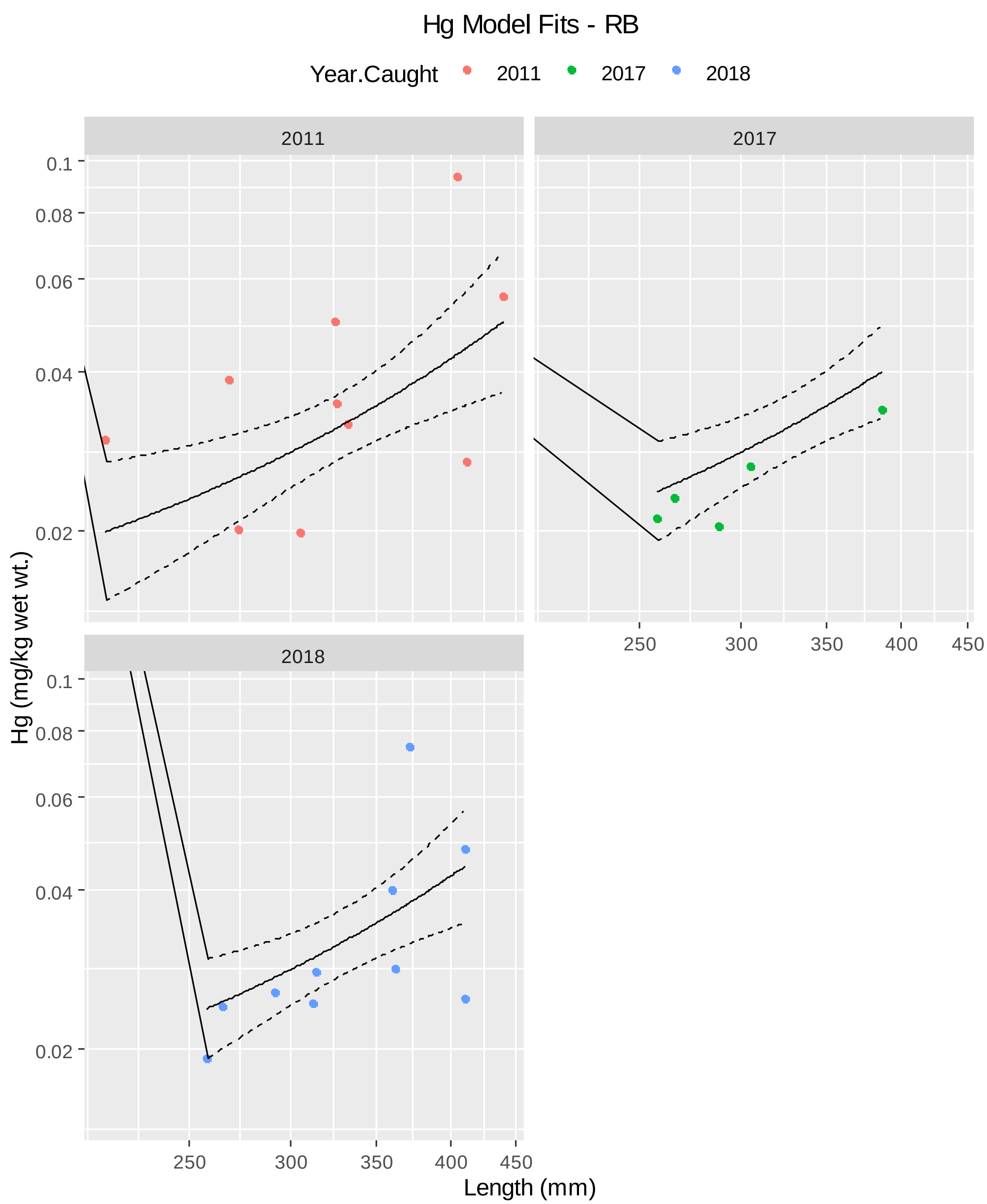
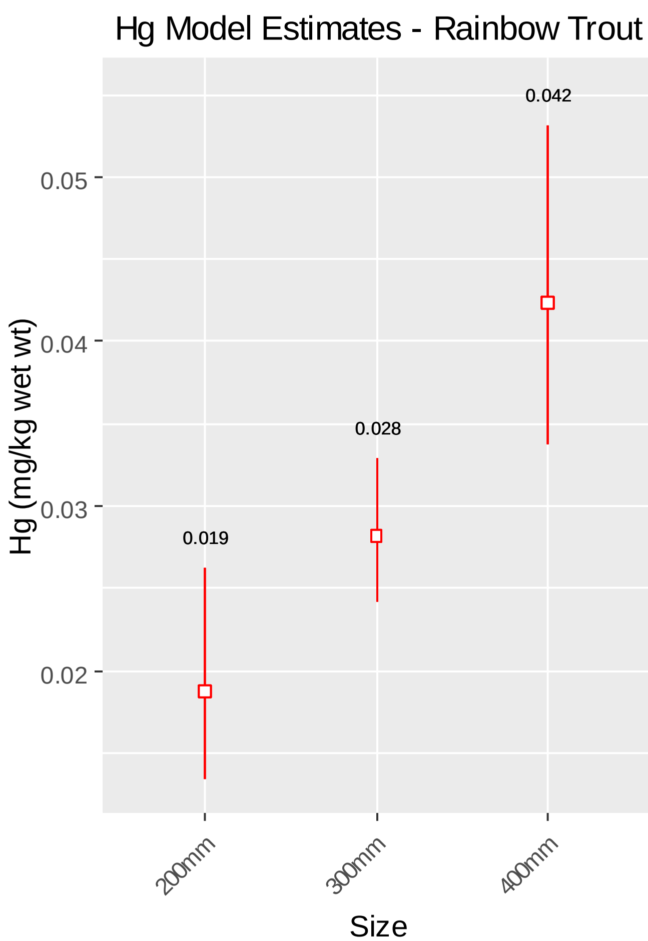


Figure 4-3. Final model fit results for the temporal assessment of Rainbow Trout mercury concentrations for Section 1 (2010, 2017, and 2018 [see note]).



Note: The best model fit (fit1) for Rainbow Trout is dependent on length only and is not improved by considering each year separately. Therefore, the linear model remains consistent across years (i.e., with the same slope and intercept across years). Only years with 5 or more samples were included

Figure 4-4. Estimated mercury concentrations (and 95% confidence intervals) for select sizes (200 mm, 300 mm, 400 mm) for each year in the temporal assessment of Rainbow Trout mercury concentrations for Section 1.



Note: The year parameter did not improve the length-mercury model, indicating no statistically significant differences in Rainbow Trout mercury concentrations across years.

Figure 4-5. Final model fit results for the spatial assessment of Rainbow Trout mercury concentrations for Sections 1 and 3 across the recent baseline period (2017 – 2020).

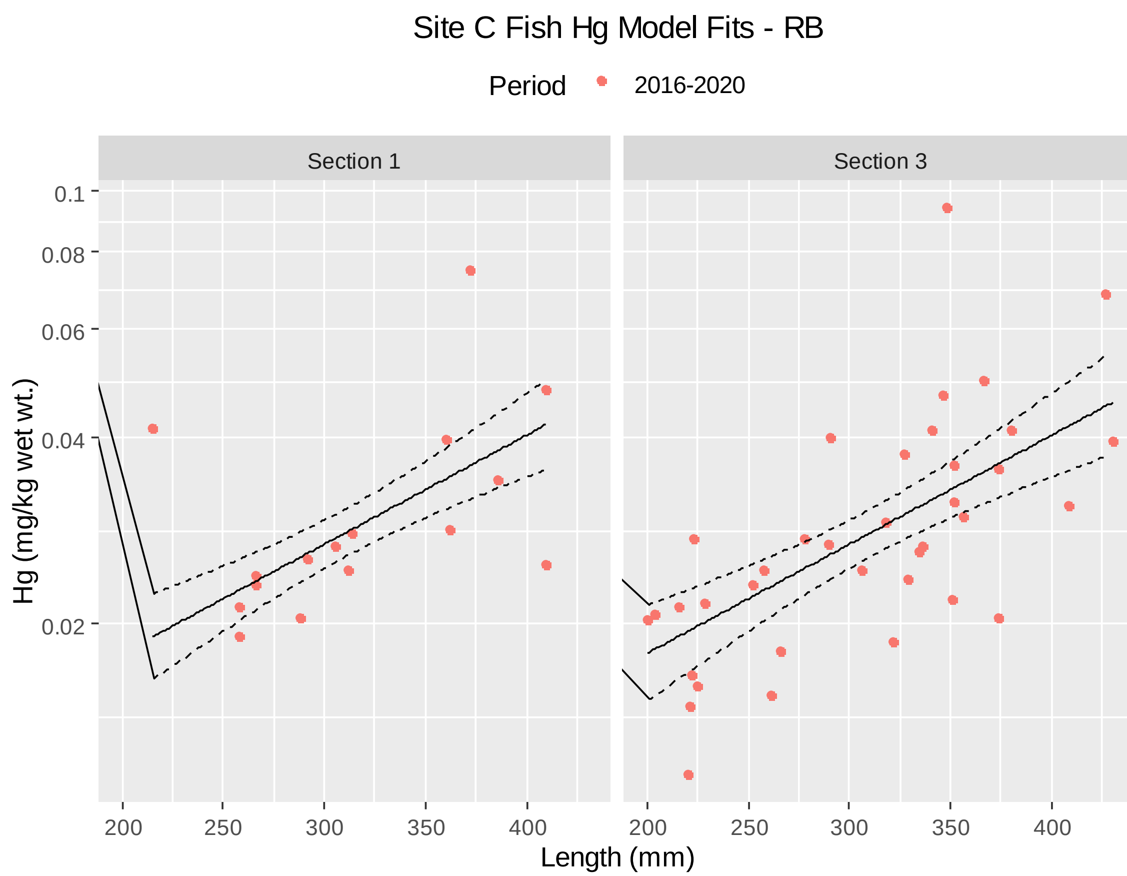
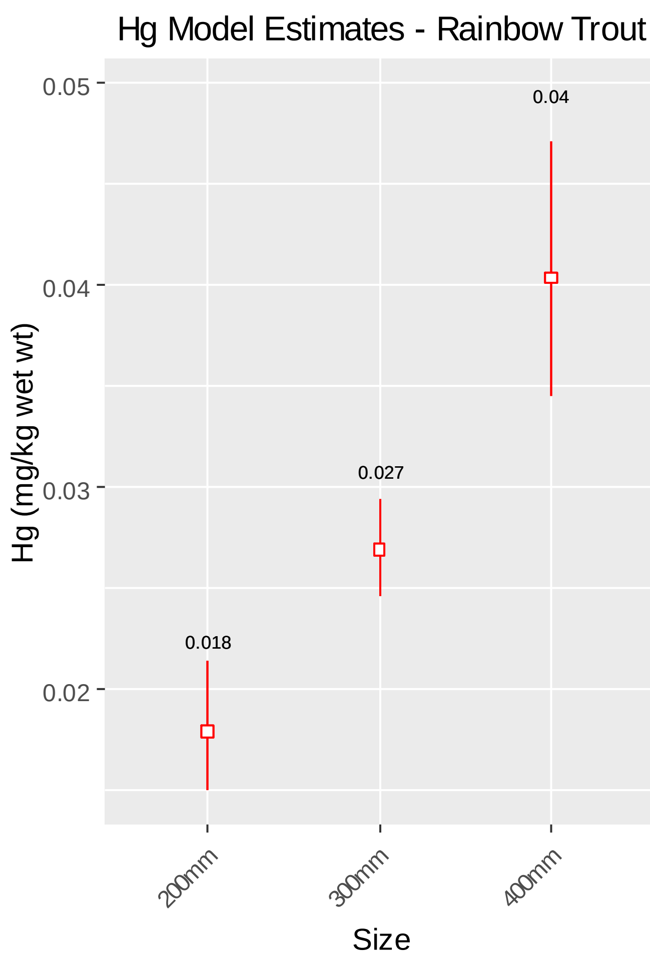


Figure 4-6. Estimated mercury concentrations (and 95% confidence intervals) for select sizes (200 mm, 300 mm, 400 mm) for Sites 1 and 3 in the spatial assessment of Rainbow Trout mercury concentrations using recent baseline data (2017 – 2020).



Note: The location (Section) parameter did not improve the length-mercury model, indicating no statistically significant differences in RB mercury concentrations across river sections.

Figure 4-7. Final model fit results for the baseline period assessment of Rainbow Trout mercury concentrations across Peace River locations.

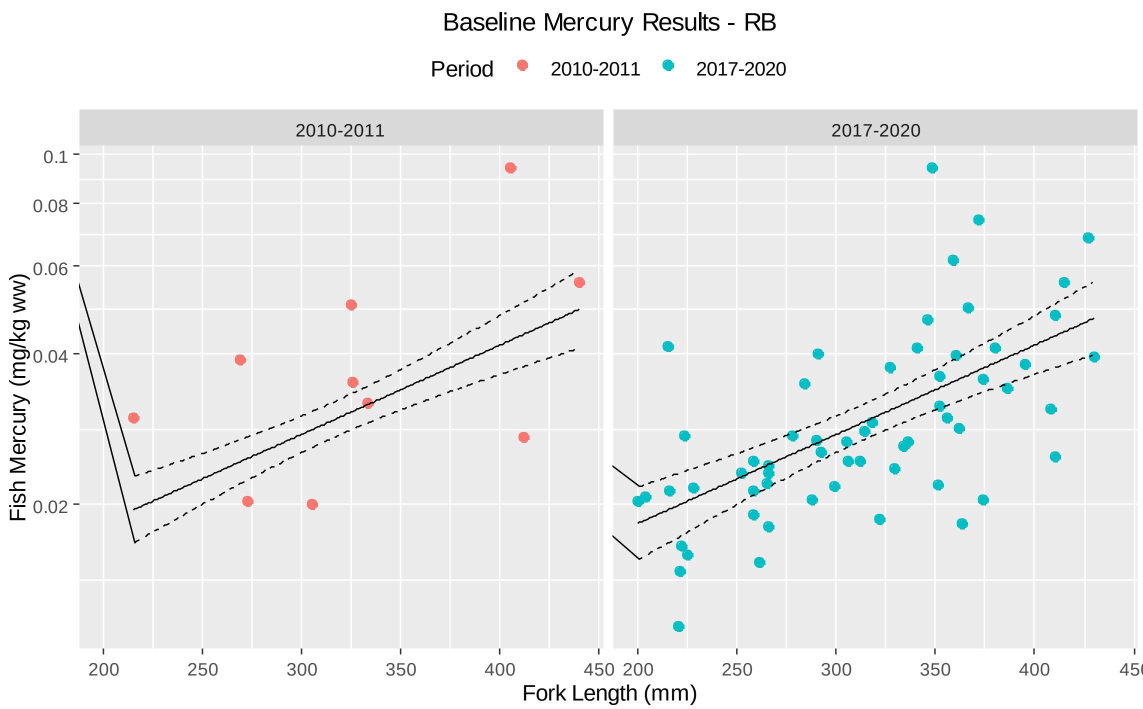
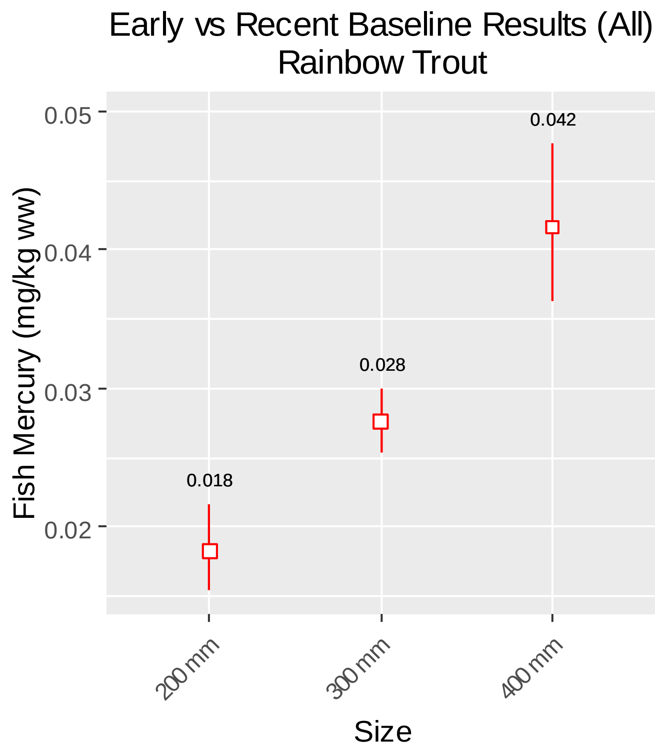


Figure 4-8. Estimated mercury concentrations (and 95% confidence intervals) for select sizes (200 mm, 300 mm, 400 mm) for each period in the baseline period assessment of Rainbow Trout mercury concentrations across Peace River locations.



Note: The period parameter did not improve the length-mercury model, indicating no statistically significant differences in RB mercury concentrations between baseline sampling periods.

5 LONGNOSE SUCKER

Temporal Assessment

The temporal assessment was conducted to determine whether there were any changes in the length-mercury relationship for Longnose Sucker across sampling years. To control for potential spatial trends the analysis was limited to Section 3, which had four years (2010, 2011, 2017, and 2018) with 10 or more samples, with a total of 70 samples across all years (see Longnose Sucker section of main report for catch details by location/year).

Key information on the modelling and associated results were as follows:

- *Transformations* – Mercury concentrations were log-transformed.
- *Initial Model Selection* – The suite of temporal models (**Table 1-1**) was initially run with all the data. Fits 4, 6, 7, 2 and 8 (all quadratic model forms) had the lowest AICc values, respectively, but all over-fit the data. Fit3 had the next lowest AICc value (**Table 5-2**), was selected for use, and has the following structure (linear model with year-specific intercepts and slopes):

  Log Hg ~ Year + Length

- *Outliers/High Leverage Data* – Formal outlier assessment of the initial fit3 run (with all data) did not identify any outliers or high leverage points in the dataset.
- *Final Model Selection* – As no outliers or high-leverage points were identified, fit3 using all data was used to characterize the length-mercury relationship.
- *Fitted length-mercury Relationships* – Final model results are shown in **Figure 5-3** and summarized in **Table 5-3**. The model fits generally show strong positive relationships between length and mercury concentrations. Model residuals were visually examined and confirmed a reasonable fit. The model had an adjusted R2 of 0.45 and showed statistically significant differences in Longnose Sucker mercury concentrations among years.

Predicted Mercury Concentrations for Standard Sized Fish by Year – Using the length-mercury model shown above, and where the underlying data supported making a prediction, tissue mercury concentrations were estimated for three standard fish sizes: 200 mm, 350 mm and 500 mm. The predictions (and their 95% confidence limits) were used to compare fish tissue mercury concentrations among years (**Figure 5-4**); statistical differences among year-size combinations determined using the selected model were annotated on the plot. The results show that

Longnose Sucker mercury concentrations were generally lower in 2010/2011 than in 2017 through 2020.

Spatial Assessment

The spatial assessment was conducted to determine whether there are differences in the length-mercury relationship for Longnose Sucker among sampling locations. Given the temporal changes identified previously, the spatial assessment was limited to the recent time period only. Six sampling locations (Sections 1, 3, 5, 6, 7, and 9) had 10 or more samples across the recent sampling period (2017 to 2020), with a total of 262 samples; (see Longnose Sucker section of main report for catch details by location/year**)**.

Key information on the spatial modelling and associated results were as follows:

- *Transformations* – Mercury concentrations were log-transformed.
- *Initial Model Selection* – The suite of spatial models (**Table 1-2**) was initially run with all the data. Fits 7 and 8, both quadratic model forms, had the lowest AICc values (**Table 5-4**), but over-fit the data (see **Section 1.1** for details on over-fitting). The next lowest AICc value was for fit4, which had the following model structure (quadratic model with location-specific differences in intercept):

  Log Hg ~ Location + Length + Length2

- *Outliers/High Leverage Data* – Formal outlier assessment of the initial fit4 run (with all data) identified no points as outliers or as having high leverage.
- *Final Model Selection* – Given the lack of outliers/high leverage data points, fit4 was retained to characterize the length-mercury relationship.
- *Fitted length-mercury Relationships* – Final model results are shown in **Figure 5-5** and summarized in **Table 5-5**. The model fits generally show strong positive relationships between length and mercury concentrations. Model residuals were visually examined and indicated that the fit was good. The model had an adjusted R2 of 0.52 and showed statistically significant differences in Longnose Sucker mercury concentrations among locations.
- *Predicted Mercury Concentrations for Standard Sized Fish by Year* – Using the length-mercury model shown above, and where the underlying data supported making a prediction, tissue mercury concentrations were estimated for three standard fish sizes: 200 mm, 350 mm and 500 mm. The predictions (and their 95% confidence limits) were used to compare fish tissue mercury concentrations among locations for the recent

period (2017 – 2020) (**Figure 5-6**). The results suggest that Longnose Sucker mercury concentrations are generally higher in Sections 7 and 9 relative to the upstream sections.

Baseline Period Assessment

This analysis was conducted to characterize potential differences between the early and recent baseline monitoring periods, with the latter information being used to support the development of fish consumption advice based on current conditions. The analysis included 303 samples, with 41 from the early baseline period and 262 from the recent period (see Longnose Sucker section of main report for catch details by location/year).

Key information on the modelling and associated results were as follows:

- *Transformations* – Mercury concentrations were log-transformed.
- *Initial Model Selection* – The suite of baseline period models (**Table 1-3**) was initially run with all the data. Fits 7 and 6 had the lowest AICc values, but over-fit the data (see **Section 1.1** for details on over-fitting). The next lowest AICc value was for fit4, which had the following model structure (quadratic model with period-specific differences in intercept):

  Log Hg ~ Period + Length + Length2

- *Outliers/High Leverage Data* – Formal outlier assessment of the initial fit4 run (with all data) identified no outlier or high leverage points in the dataset.
- *Final Model Selection* – Given that no outliers or high-leverage data were identified, fit4 was retained to characterize the length-mercury relationship.
- *Fitted length-mercury Relationships* – Final model results are shown in **Figure 5-7** and summarized in **Table 5-7**. The model fits generally show strong positive relationships between length and mercury concentrations. Model residuals were visually examined and indicated that the fit was good. The model had an adjusted R2 of 0.48 and showed statistically significant differences in Longnose Sucker mercury concentrations among periods.
- *Predicted Mercury Concentrations for Standard Sized Fish by Period* – Using the length-mercury model shown above, and where the underlying data supported making a prediction, tissue mercury concentrations were estimated for three standard fish sizes: 400 mm, 550 mm and 700 mm. The predictions (and their 95% confidence limits) were used to compare fish tissue mercury concentrations between the two baseline sampling periods (**Figure 5-8**); statistical differences between periods for each standardized size were determined using the selected model and were annotated on the plot. The results show that Longnose Sucker mercury concentrations nearly doubled between the early period (2010-2011) and the recent baseline period (2017 – 2020).

Table 5-1. Potential general mercury-related outliers and assessment outcomes for Longnose Sucker.

Waterbody	Year.Caught	FishID	SectionID	Sp	FL.mm	Wt.g	Hg.ppm.ww	Relationship	Outcome
Dinosaur Reservoir	2016	LNSC-TW-05	Dinosaur	LSU	370	400	0.06823188	L-W	retained

Table 5-2. Comparison of final model fit results for the temporal assessment of length-mercury relationship by year for Longnose Sucker.

Fit	Model[1]	Df	AICc	Delta
fit4	FishHg ~ Year.Caught + LC + LC2	5	107.5	0.0
fit6	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC	6	109.2	1.7
fit7	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC2	6	109.8	2.3
fit2	FishHg ~ LC + LC2	4	111.4	3.9
fit8	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC + Year.Caught:LC2	7	111.5	4.0
fit3	FishHg ~ Year.Caught + LC	4	124.9	17.4
fit5	FishHg ~ Year.Caught + LC + Year.Caught:LC	5	126.3	18.8
fit1	FishHg ~ LC	3	136.1	28.6
fit0	FishHg ~ Year.Caught	3	155.1	47.6

[1] LC=length centered on standard size; LC2=LC^2

Table 5-3. Final model results for the temporal assessment of Longnose Sucker mercury concentrations.

Predictor	Estimate	95% CI[1]	p-value
(Intercept)	-3.627	-3.994, -3.259	<0.001
Year.Caught			
2010	—	—	
2011	-0.0394	-0.5465, 0.4676	0.9
2017	0.6645	0.2260, 1.103	0.004
2018	0.5113	0.0949, 0.9277	0.017
LC	0.0074	0.0051, 0.0098	<0.001

[1] CI = Confidence Interval

Model: FishHg ~ Year.Caught + LC

Overall Results: $F(4,65)=13$; Adjusted $R^2 = 0.446$; N = 70.0

Table 5-4. Comparison of final model fit results for the spatial assessment of length-mercury relationship by year for Longnose Sucker.

Fit	Model[1]	Df	AICc	Delta
fit7	FishHg ~ Location + LC + LC2 + Location:LC2	14	408.3	0.0
fit8	FishHg ~ Location + LC + LC2 + Location:LC + Location:LC2	19	410.0	1.7
fit4	FishHg ~ Location + LC + LC2	9	428.4	20.1
fit6	FishHg ~ Location + LC + LC2 + Location:LC	14	431.0	22.7
fit3	FishHg ~ Location + LC	8	432.0	23.7
fit2	FishHg ~ LC + LC2	4	433.7	25.3
fit5	FishHg ~ Location + LC + Location:LC	13	437.4	29.1
fit1	FishHg ~ LC	3	440.2	31.9
fit0	FishHg ~ Location	7	611.8	203.5

[1] LC=length centered on standard size; LC2=LC^2

Table 5-5. Final model results for the spatial assessment of Longnose Sucker mercury concentrations.

Predictor	Estimate	95% CI[1]	p-value
(Intercept)	-3.063	-3.403, -2.723	<0.001
Location			
Section 1	—	—	
Section 3	0.0388	-0.3254, 0.4030	0.8
Section 5	0.0210	-0.3517, 0.3936	>0.9
Section 6	-0.0037	-0.3825, 0.3751	>0.9
Section 7	0.2669	-0.1105, 0.6442	0.2
Section 9	0.2997	-0.0597, 0.6591	0.10
LC	0.0066	0.0058, 0.0074	<0.001
LC2	0.0000	0.0000, 0.0000	0.018

[1] CI = Confidence Interval

Model: FishHg ~ Location + LC + LC2

Overall Results: $F(7,254)=39$; Adjusted $R^2 = 0.519$; $N = 262$

Table 5-6. Comparison of final model fit results for the baseline sampling period assessment of length-mercury relationship by year for Longnose Sucker.

Fit	Model[1]	Df	AICc	Delta
fit7	FishHg ~ Period + LC + LC2 + Period:LC2	6	501.3	0.0
fit6	FishHg ~ Period + LC + LC2 + Period:LC	6	502.6	1.4
fit4	FishHg ~ Period + LC + LC2	5	502.7	1.4
fit8	FishHg ~ Period + LC + LC2 + Period:LC + Period:LC2	7	503.3	2.1
fit5	FishHg ~ Period + LC + Period:LC	5	509.9	8.6
fit3	FishHg ~ Period + LC	4	511.4	10.1
fit2	FishHg ~ LC + LC2	4	536.5	35.2
fit1	FishHg ~ LC	3	550.7	49.4
fit0	FishHg ~ Period	3	689.9	188.6

[1] LC=length centered on standard size; LC2=LC^2

Table 5-7. Final model results for the spatial assessment of Longnose Sucker mercury concentrations.

Predictor	Estimate	95% CI[1]	p-value
(Intercept)	-3.536	-3.712, -3.361	<0.001
Period			
2010-2011	—	—	
2017-2020	0.5834	0.3960, 0.7708	<0.001
LC	0.0066	0.0058, 0.0074	<0.001
LC2	0.0000	0.0000, 0.0000	0.001

[1] CI = Confidence Interval

Model: FishHg ~ Period + LC + LC2

Overall Results: $F(3,299)=92$; Adjusted $R^2 = 0.481$; N = 303

Figure 5-1. Length Frequency and age frequency for Longnose Sucker (LSU) by location across all years (2010 – 2020).

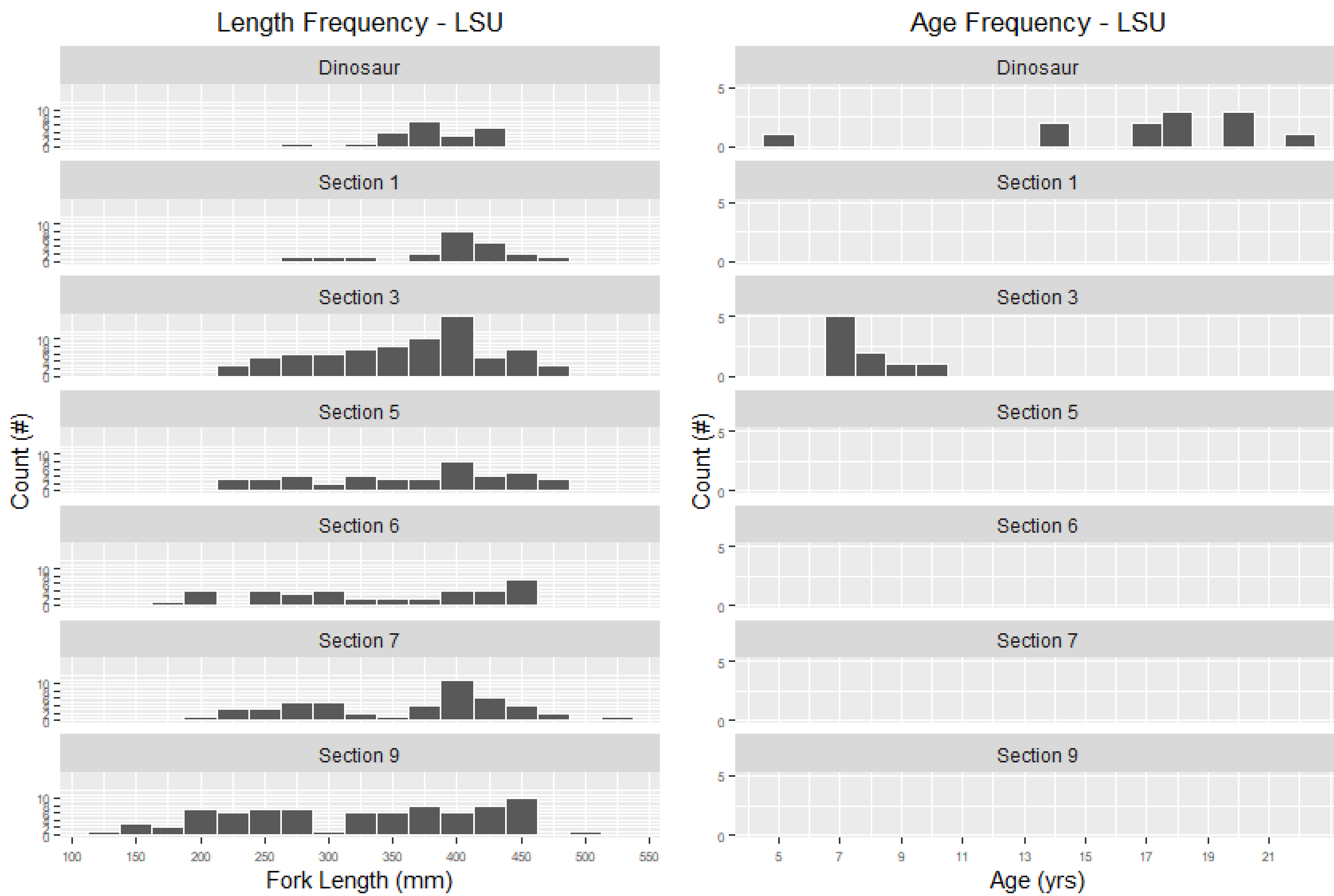


Figure 5-2. Key mercury-related relationships for Longnose Sucker (LSU) across all years (2010 – 2020). Red circles indicate length-weight outliers.

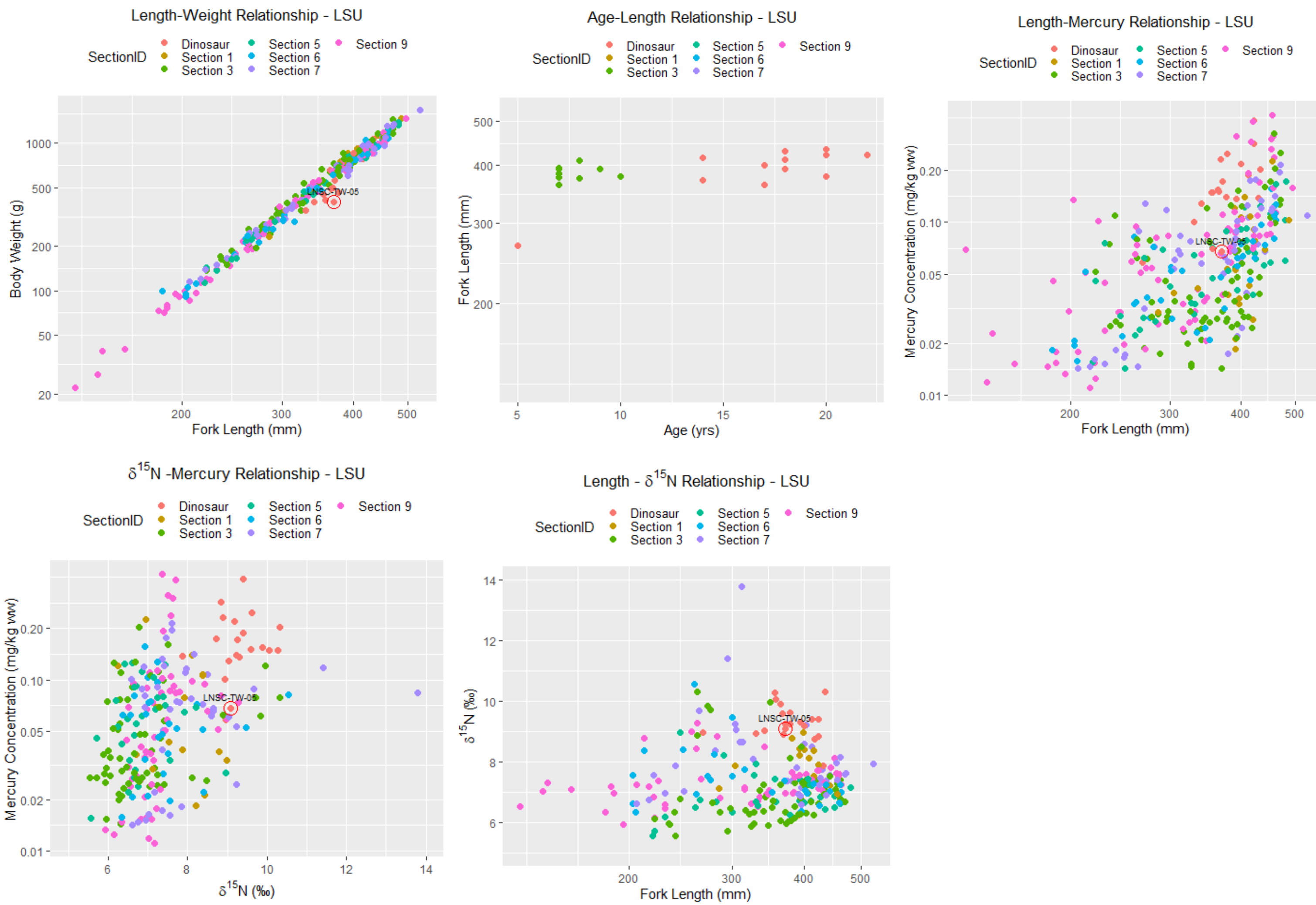
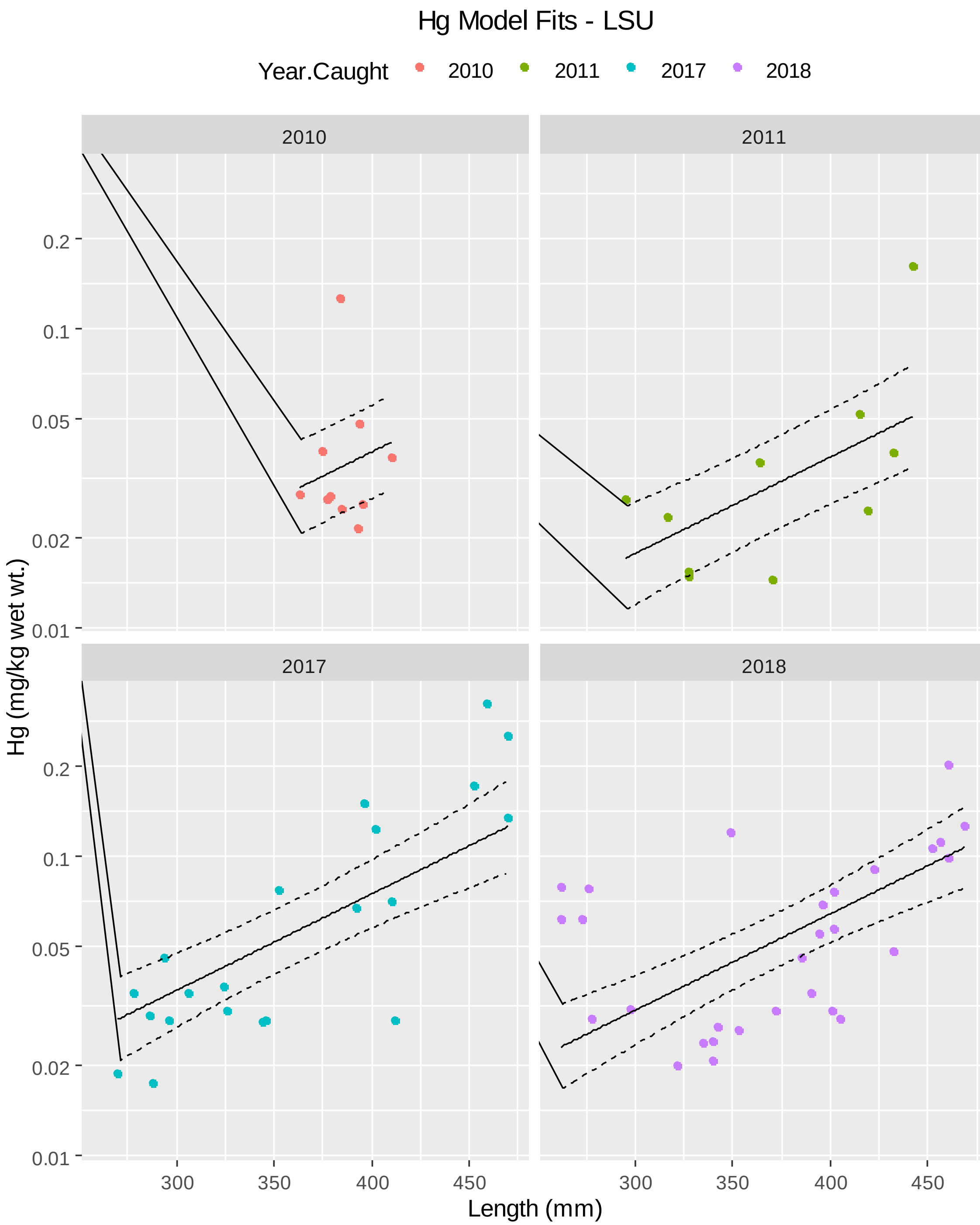
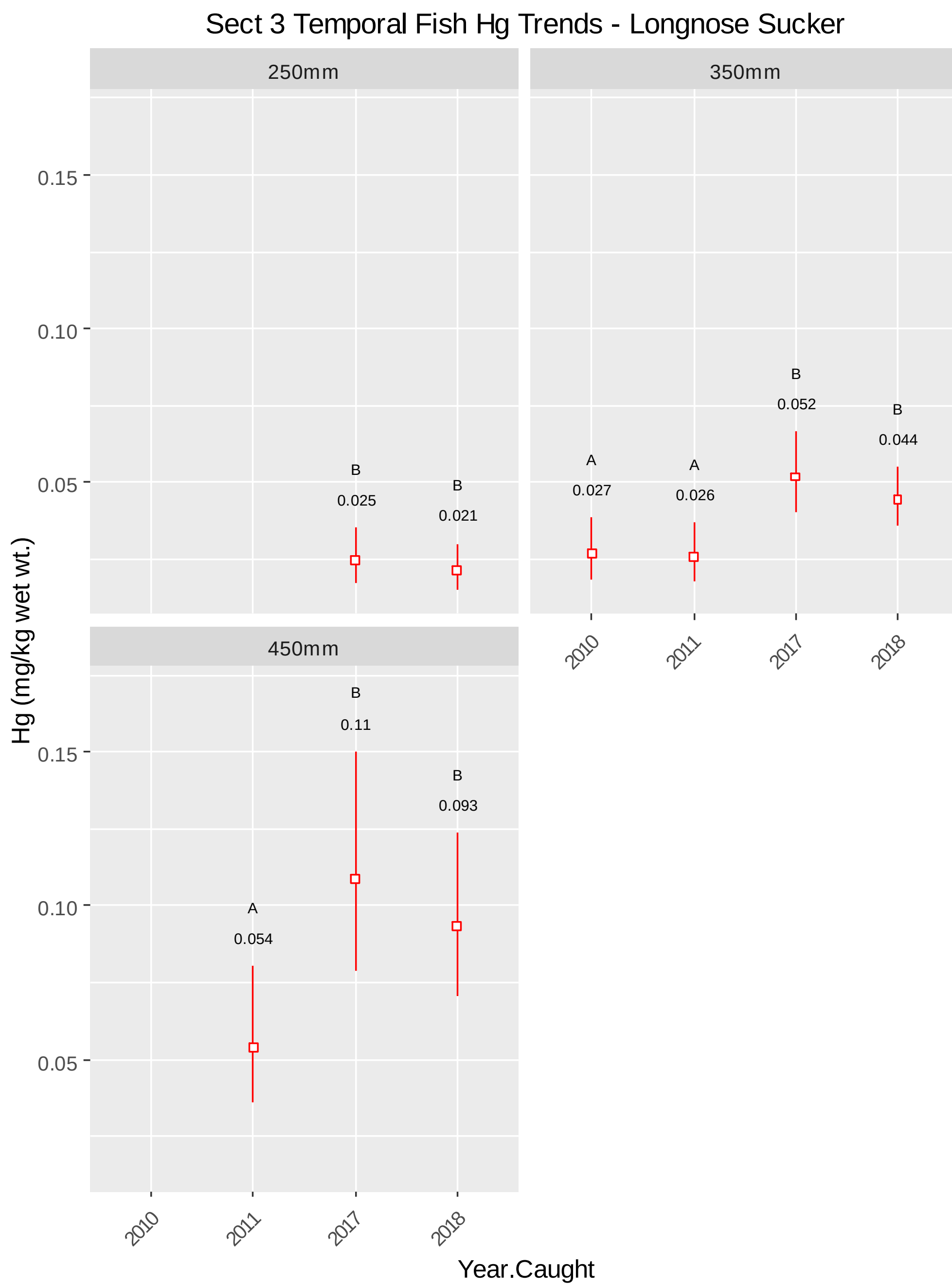


Figure 5-3. Final model fit results for the temporal assessment of Longnose Sucker mercury concentrations for Section 3 (2010, 2011, 2017, and 2018 [see note]).



Note: Only years with 10 or more samples were included.

Figure 5-4. Estimated mercury concentrations (and 95% confidence intervals) for select sizes (250 mm, 350 mm, 450 mm) for each year in the temporal assessment of Longnose Sucker mercury concentrations for Section 3.



Note: Letters above estimates show which are not statistically different from one another (same letters) or which are statistically different (different letters); combinations (e.g., “AB”) show estimates that are not statistically different from other groups that are different (e.g., “A” and “B”).

Figure 5-5. Final model fit results for the spatial assessment of Longnose Sucker mercury concentrations across Peace River locations for the recent baseline period (2017 – 2020).

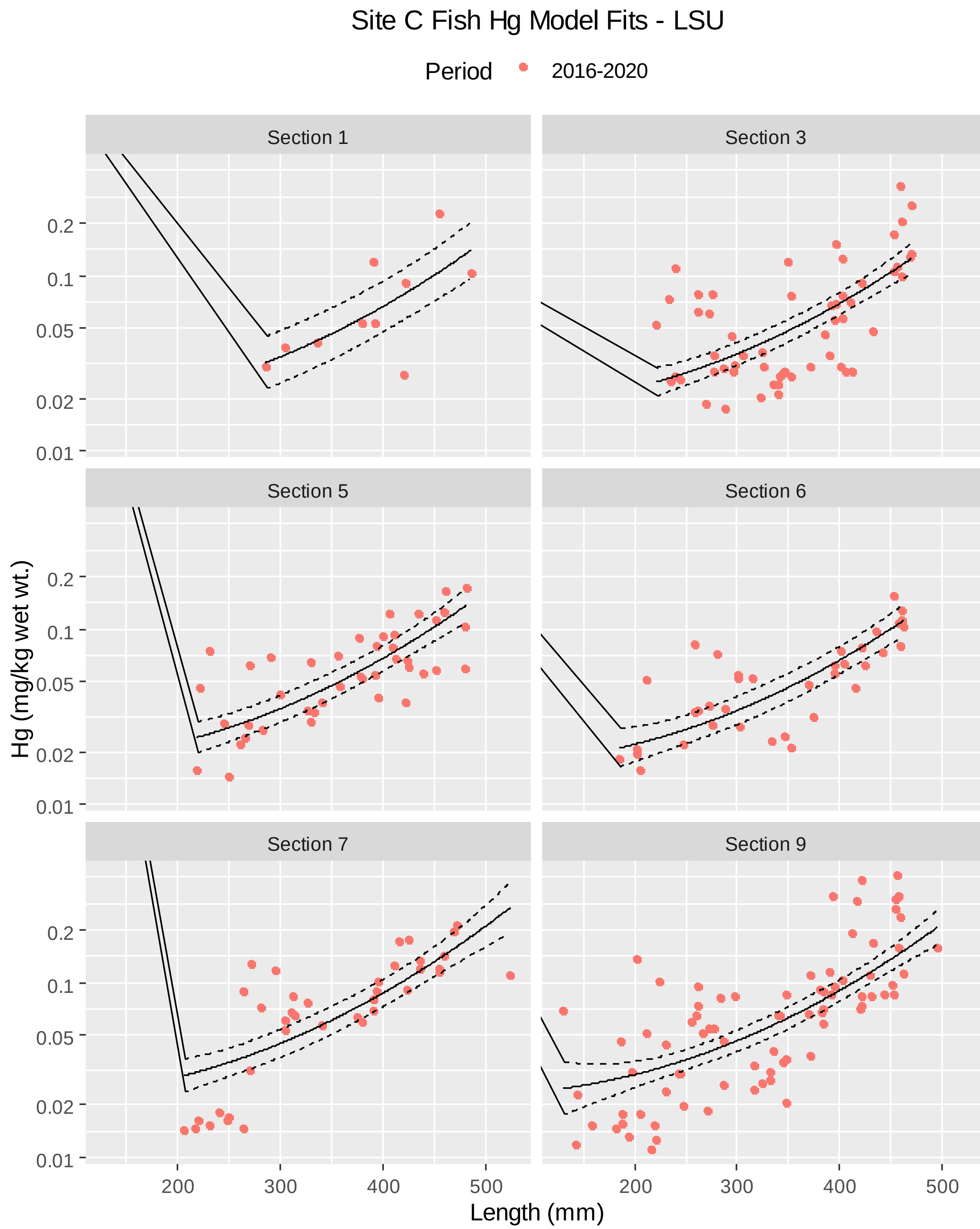


Figure 5-6. Estimated mercury concentrations (and 95% confidence intervals) for Longnose Sucker for select sizes (250 mm, 350 mm, 450 mm) across Peace River locations in the spatial assessment using recent baseline data (2017 – 2020).

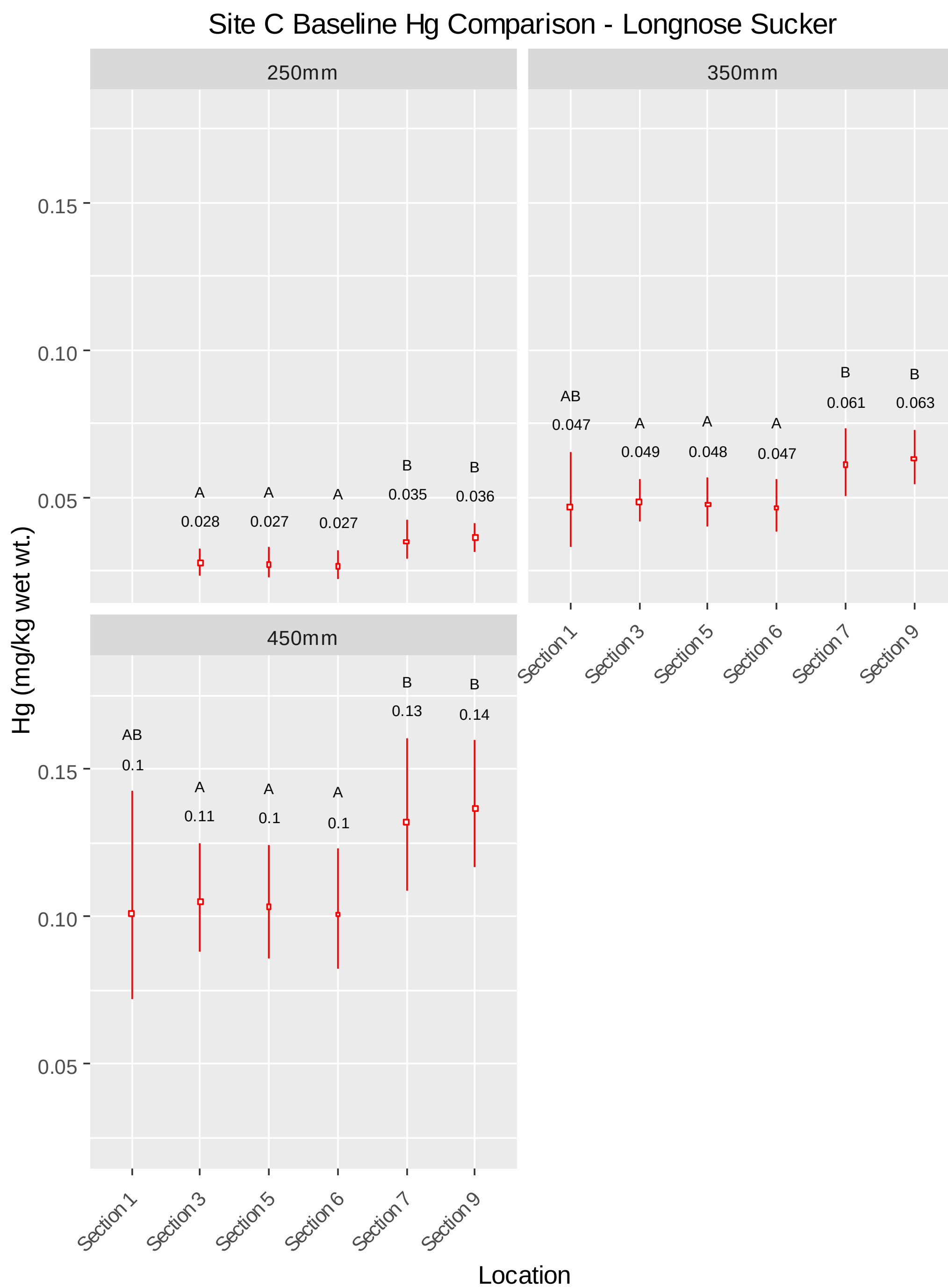


Figure 5-7. Final model fit results for the baseline sampling period assessment of Longnose Sucker mercury concentrations across Peace River locations.

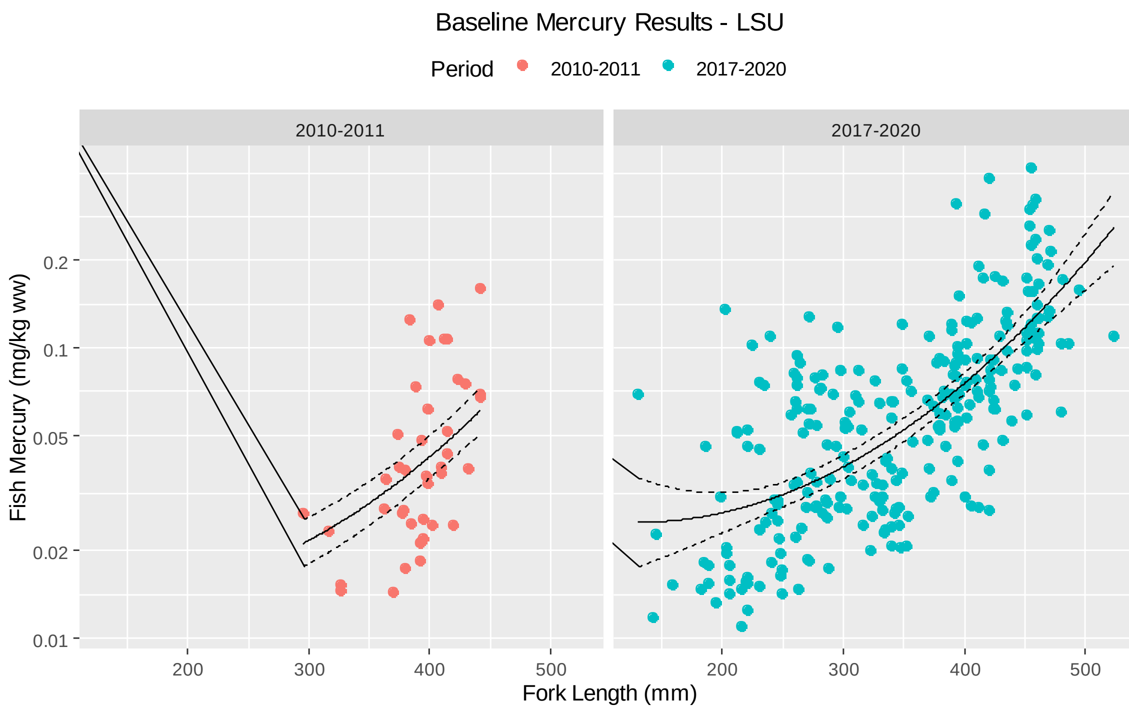
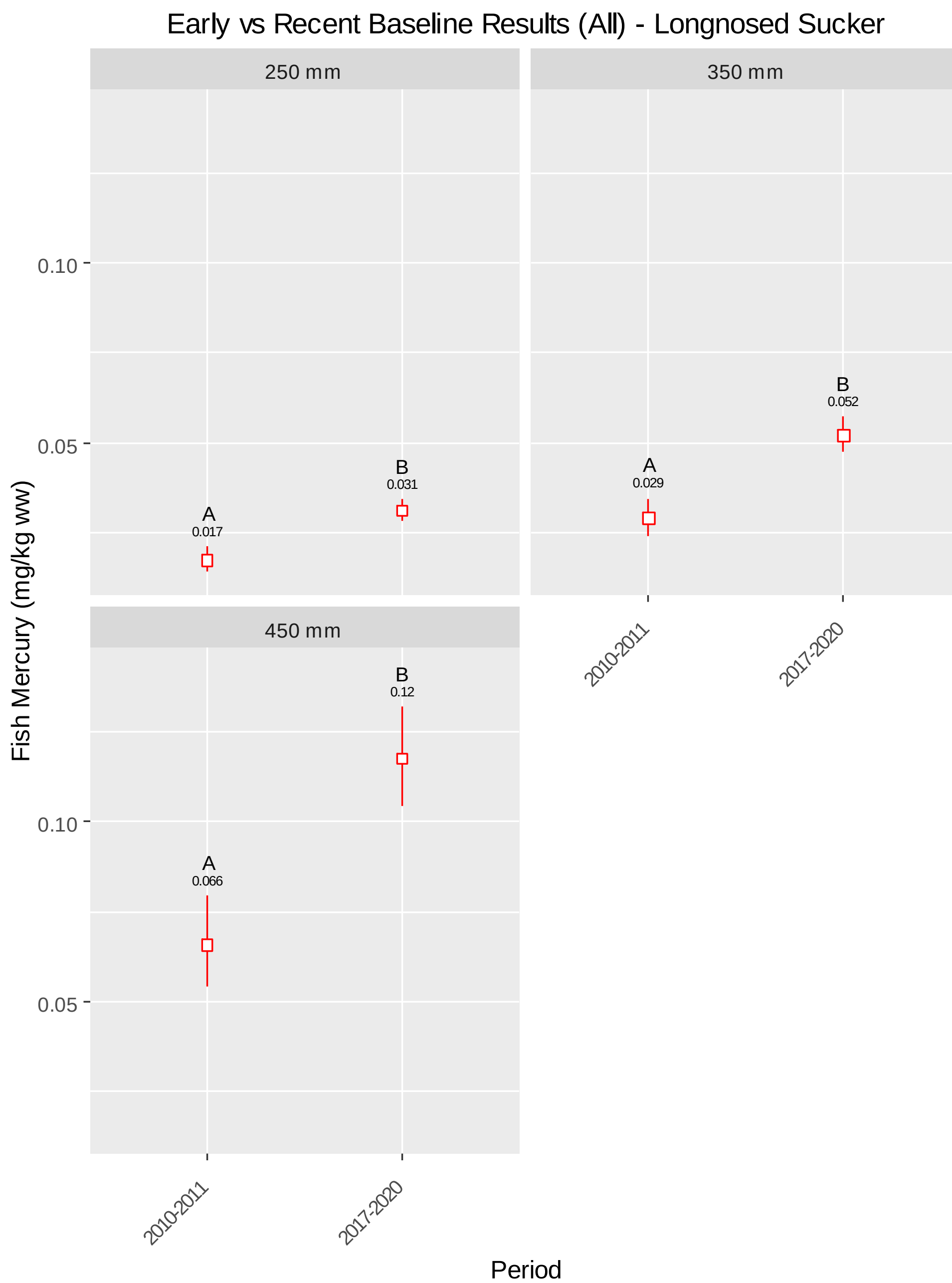


Figure 5-8. Estimated mercury concentrations (and 95% confidence intervals) for Longnose Sucker for select sizes (250 mm, 350 mm, 450 mm) across periods in the baseline sampling period assessment across Peace River locations.



Note: Letters above estimates show which are not statistically different from one another (same letters) or which are statistically different (different letters); combinations (e.g., “AB”) show estimates that are not statistically different from other groups that are different (e.g., “A” and “B”).

6 WALLEYE

Temporal Assessment

The temporal assessment was conducted to determine whether there were any changes in the length-mercury relationship for Walleye across sampling years. To control for potential spatial trends the analysis was limited to Section 7, which had five years (2011, 2017, 2018, 2019, and 2020) with 5 or more samples, with a total of 40 samples across all years (see Walleye section of main report for catch details by location/year).

Key information on the modelling and associated results were as follows:

- Transformations – Mercury concentrations were log-transformed.
- *Initial Model Selection* – The suite of temporal models (**Table 1-1**) was initially run with all the data. Fit3 had the lowest AICc value (**Table 6-2**), was selected for use, and has the following structure (linear model with year-specific intercepts):

  Log Hg ~ Year + Length

- *Outliers/High Leverage Data* – Formal outlier assessment of the initial fit3 run (with all data) did not identify any outliers or high leverage points in the dataset.
- *Final Model Selection* – As no outliers or high-leverage points were identified, fit3 using all data was used to characterize the length-mercury relationship.
- *Fitted length-mercury Relationships* – Final model results are shown in **Figure 6-3** and summarized in **Table 6-3**. The model fits generally show strong positive relationships between length and mercury concentrations. Model residuals were visually examined and confirmed a reasonable fit. The model had an adjusted R^2 of 0.73 and showed statistically significant differences in Walleye mercury concentrations among years. However, as seen in **Figure 6-5**, while the fits were generally good across years, there was little overlap in fish length across sampling years.
- *Predicted Mercury Concentrations for Standard Sized Fish by Year* – Given the lack of overlap across the size range among years, the length-mercury model shown above was not used to estimate tissue mercury concentrations for standard fish sizes. Thus, while the overall model identified statistically different concentrations among years, predictions for specific years were not made due to size range limitations across years.

Spatial Assessment

The spatial assessment was conducted to determine whether there are differences in the length-mercury relationship for Walleye among sampling locations. Given the temporal changes identified previously, the spatial assessment was limited to the recent time period only. Four sampling locations (Sections 5, 6, 7, and 9) had 23 or more samples across the recent sampling period (2017 to 2020), with a total of 54 samples; (see Walleye section of main report for catch details by location/year).

Key information on the spatial modelling and associated results were as follows:

- *Transformations* – Mercury concentrations were log-transformed.
- Initial Model Selection – The suite of spatial models (**Table 1-2**) was initially run with all the data. Fits 4, 6, 7 and 8, all quadratic model forms, had the lowest AICc values (**Table 6-4**), but over-fit the data (see **Section 1.1** for details on over-fitting). The next lowest AICc value was for fit3, which had the following model structure (linear model with location-specific differences in intercept):

  Log Hg ~ Location + Length

- *Outliers/High Leverage Data* – Formal outlier assessment of the initial fit3 run (with all data) identified no points as outliers or as having high leverage.
- *Final Model Selection* – Given the lack of outliers/high leverage data points, fit3 was retained to characterize the length-mercury relationship.
- *Fitted length-mercury Relationships* – Final model results are shown in **Figure 6-5** and summarized in **Table 6-5**. The model fits generally show strong positive relationships between length and mercury concentrations. Model residuals were visually examined and indicated that the fit was good. The model had an adjusted R^2 of 0.53 and showed statistically significant differences in Walleye mercury concentrations among locations.
- *Predicted Mercury Concentrations for Standard Sized Fish by Year* – Using the length-mercury model shown above, and where the underlying data supported making a prediction, tissue mercury concentrations were estimated for three standard fish sizes: 300 mm, 400 mm and 500 mm. The predictions (and their 95% confidence limits) were used to compare fish tissue mercury concentrations among locations for the recent period (2017 – 2020) (**Figure 6-6**). The results suggest that Walleye mercury concentrations are generally higher in Sections 7 and 9, relative to the upstream sections.

Baseline Period Assessment

There were only 6 Walleye tissue samples for the early baseline period and fish sizes generally had limited range and little overlap across years. Consequently, no assessment of differences in tissue mercury concentrations between baseline sampling periods was conducted. However, it is noteworthy that the temporal assessment for Walleye did result in statistically significant differences in mercury concentrations among years, with 2011 generally being different than the recent baseline sampling period (**Figure 6-4**).

Table 6-1. Fish formally identified as outliers in length-weight (L-W), length-mercury (L-Hg) and/or mercury-nitrogen isotope (Hg-dN) relationship.

Waterbody	Year.Caught	FishID	SectionID	Sp	FL.mm	Wt.g	Hg.ppm.ww	Relationship	Outcome
Peace River	2018	571	Section 6	WP	454	1155	0.0385	L-Hg	retained

Table 6-2. Comparison of final model fit results for the temporal assessment of length-mercury relationship by year for Walleye.

Fit	Model[1]	Df	AICc	Delta
fit3	FishHg ~ Year.Caught + LC	7	48.5	0.0
fit4	FishHg ~ Year.Caught + LC + LC2	8	50.0	1.5
fit5	FishHg ~ Year.Caught + LC + Year.Caught:LC	11	59.6	11.1
fit7	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC2	12	59.7	11.1
fit6	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC	12	59.7	11.2
fit1	FishHg ~ LC	3	63.5	15.0
fit0	FishHg ~ Year.Caught	6	64.7	16.2
fit2	FishHg ~ LC + LC2	4	65.7	17.2
fit8	FishHg ~ Year.Caught + LC + LC2 + Year.Caught:LC + Year.Caught:LC2	16	79.2	30.7

[1] LC=length centered on standard size; LC2=LC^2

Table 6-3. Final model results for the temporal assessment of Walley mercury concentrations.

Predictor	Estimate	95% CI[1]	p-value
(Intercept)	-2.360	-2.684, -2.036	<0.001
Year.Caught			
2011	—	—	
2017	0.8746	0.4650, 1.284	<0.001
2018	0.4552	-0.0484, 0.959	0.075
2019	1.094	0.5925, 1.596	<0.001
2020	0.8712	0.4459, 1.296	<0.001
LC	0.0042	0.0024, 0.0061	<0.001

[1] CI = Confidence Interval

Model: FishHg ~ Year.Caught + LC

Overall Results: $F(5,34)=18$; Adjusted $R^2 = 0.727$; N = 40.0

Table 6-4. Comparison of final model fit results for the spatial assessment of length-mercury relationship by year for Walleye.

Fit	Model[1]	Df	AICc	Delta
fit4	FishHg ~ Location + LC + LC2	7	123.9	0.0
fit6	FishHg ~ Location + LC + LC2 + Location:LC	10	129.8	5.9
fit7	FishHg ~ Location + LC + LC2 + Location:LC2	10	130.5	6.5
fit8	FishHg ~ Location + LC + LC2 + Location:LC + Location:LC2	13	136.3	12.3
fit3	FishHg ~ Location + LC	6	140.4	16.5
fit2	FishHg ~ LC + LC2	4	142.4	18.5
fit5	FishHg ~ Location + LC + Location:LC	9	144.2	20.3
fit1	FishHg ~ LC	3	157.9	34.0
fit0	FishHg ~ Location	5	231.2	107.3

[1] LC=length centered on standard size; LC2=LC^2

Table 6-5. Final model results for the spatial assessment of Walleye mercury concentrations.

Predictor	Estimate	95% CI[1]	p-value
(Intercept)	-1.698	-1.865, -1.531	<0.001
Location			
Section 5	—	—	
Section 6	0.0163	-0.2111, 0.2438	0.9
Section 7	0.1783	-0.0554, 0.4121	0.13
Section 9	0.4157	0.2130, 0.6185	<0.001
LC	0.0050	0.0041, 0.0059	<0.001

[1] CI = Confidence Interval

Model: FishHg ~ Location + LC

Overall Results: $F(4,124)=35$; Adjusted $R^2 = 0.530$; N = 129

Figure 6-1. Length Frequency and age frequency for Walleye (WP) by location across all years (2010 – 2020).

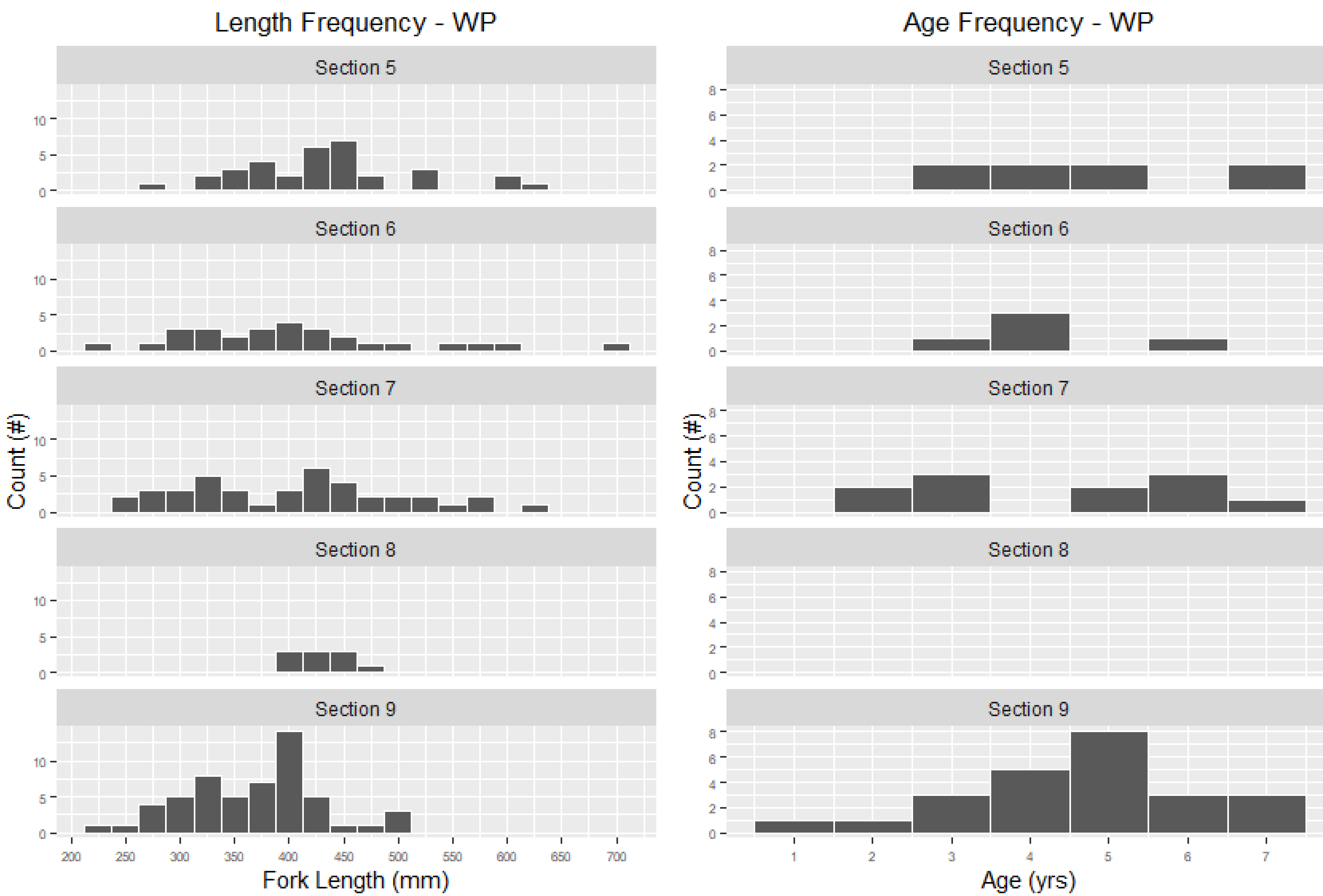


Figure 6-2. Key mercury-related relationships for Walleye (WP) across all years (2010 – 2020). Green circle indicates length-mercury outliers (not carried through as no SIA data).

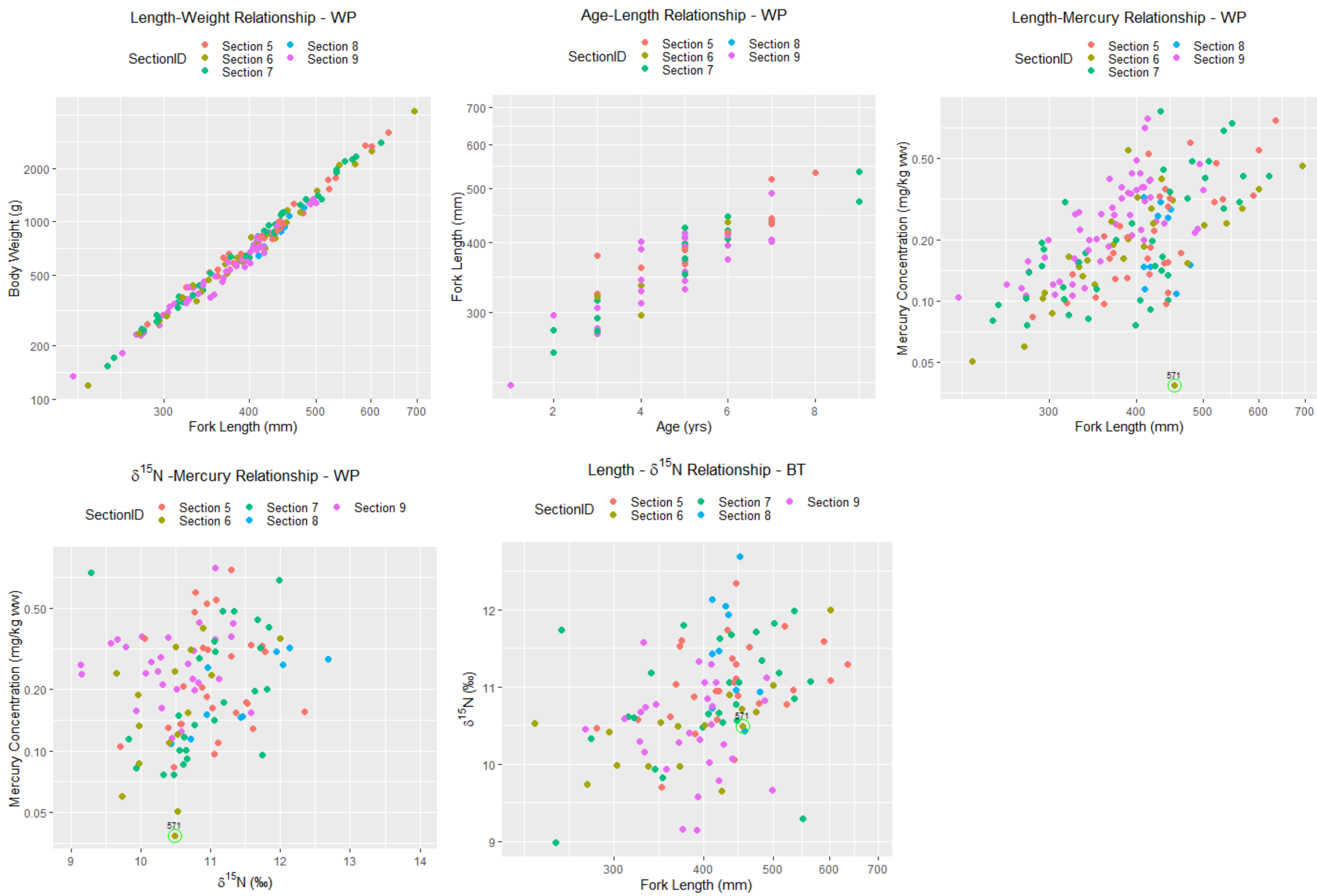
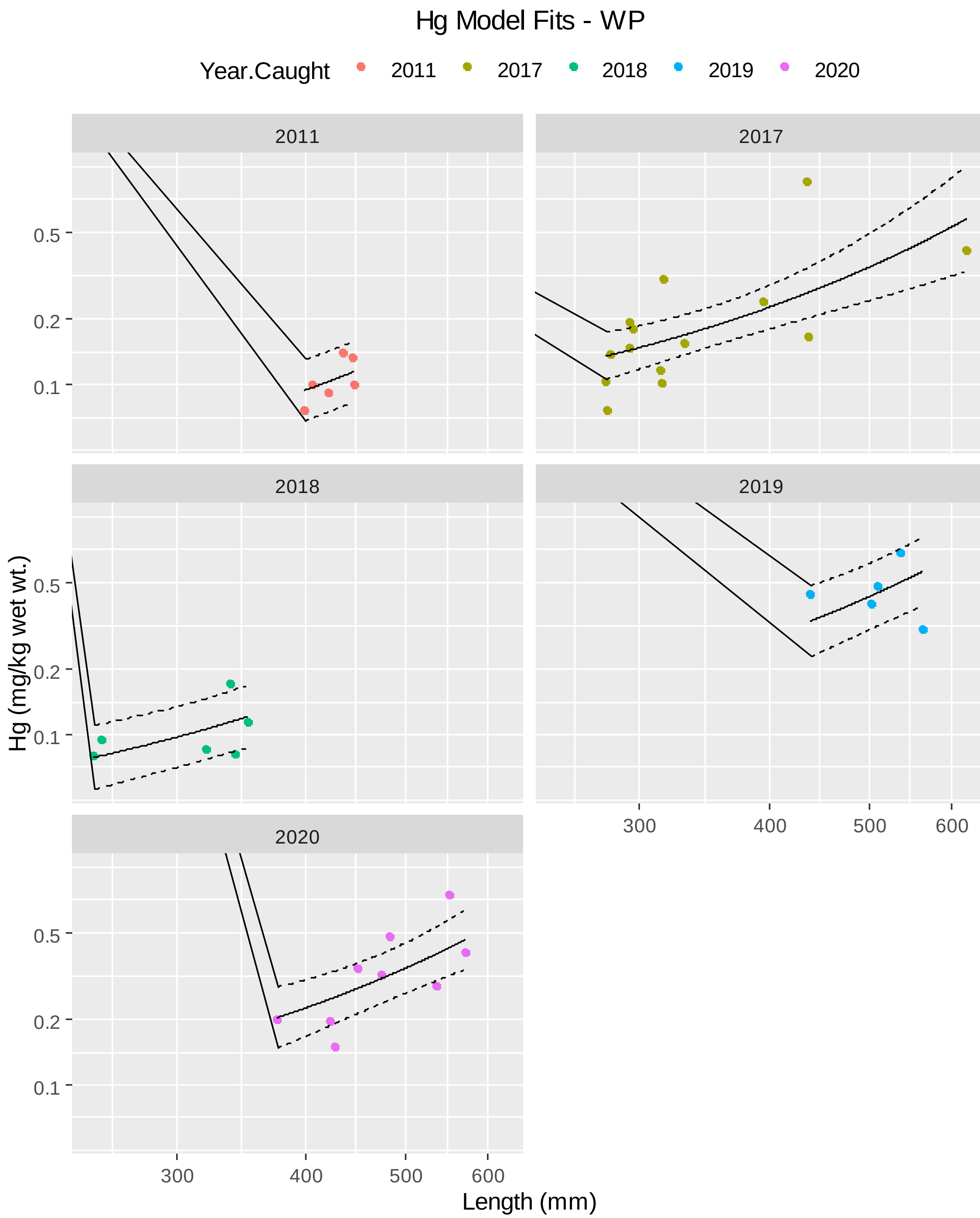


Figure 6-3. Final model fit results for the temporal assessment of Walleye mercury concentrations for Section 7 (2011, 2017 – 2020 [see note]).



Note: Only years with 5 or more samples were included.

Figure 6-4. Final model fit results for the temporal assessment of Walleye mercury concentrations, showing fits among years for Section7.

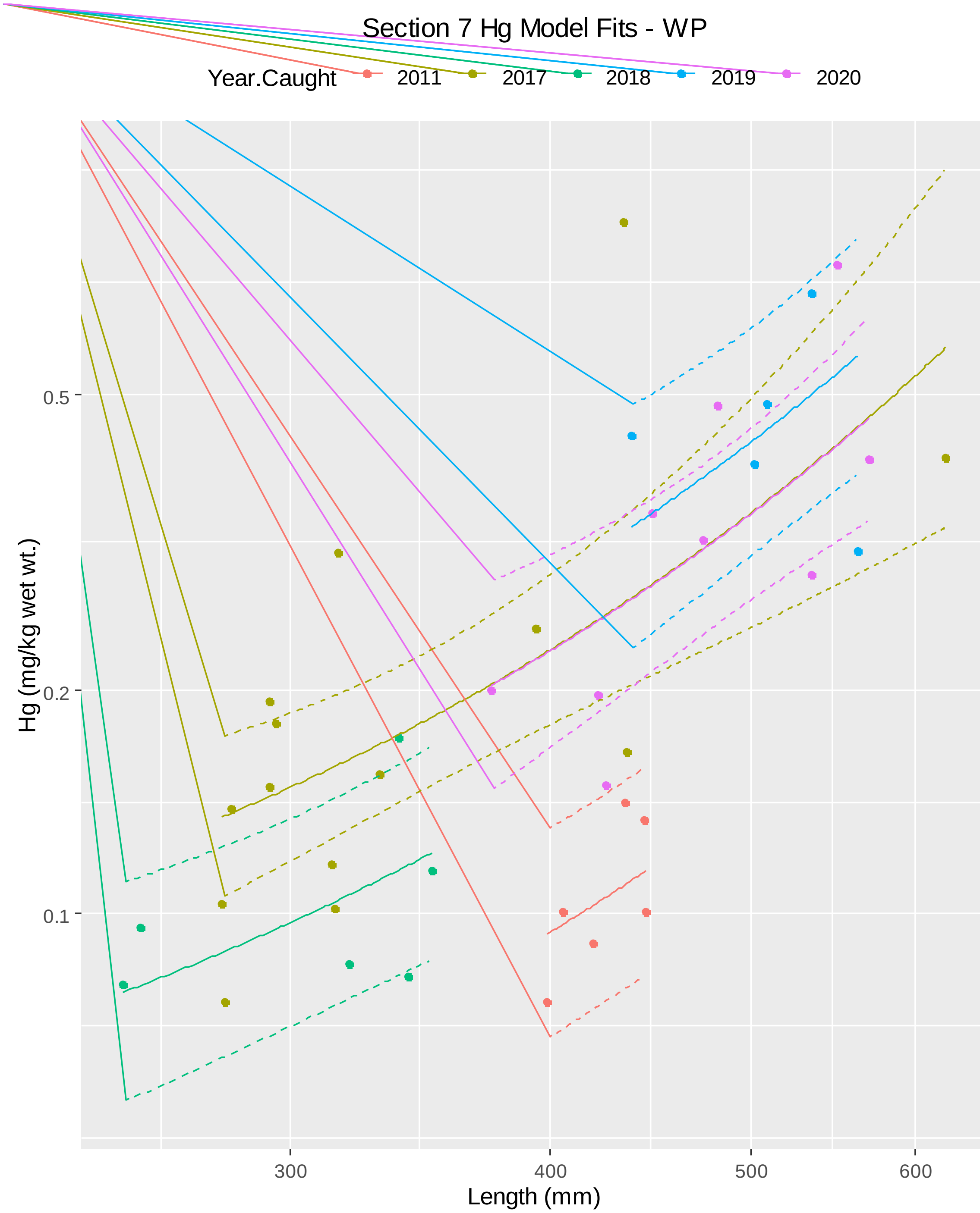


Figure 6-5. Final model fit results for the spatial assessment of Walleye mercury concentrations for Peace River Sections 5, 6, 7, and 9.

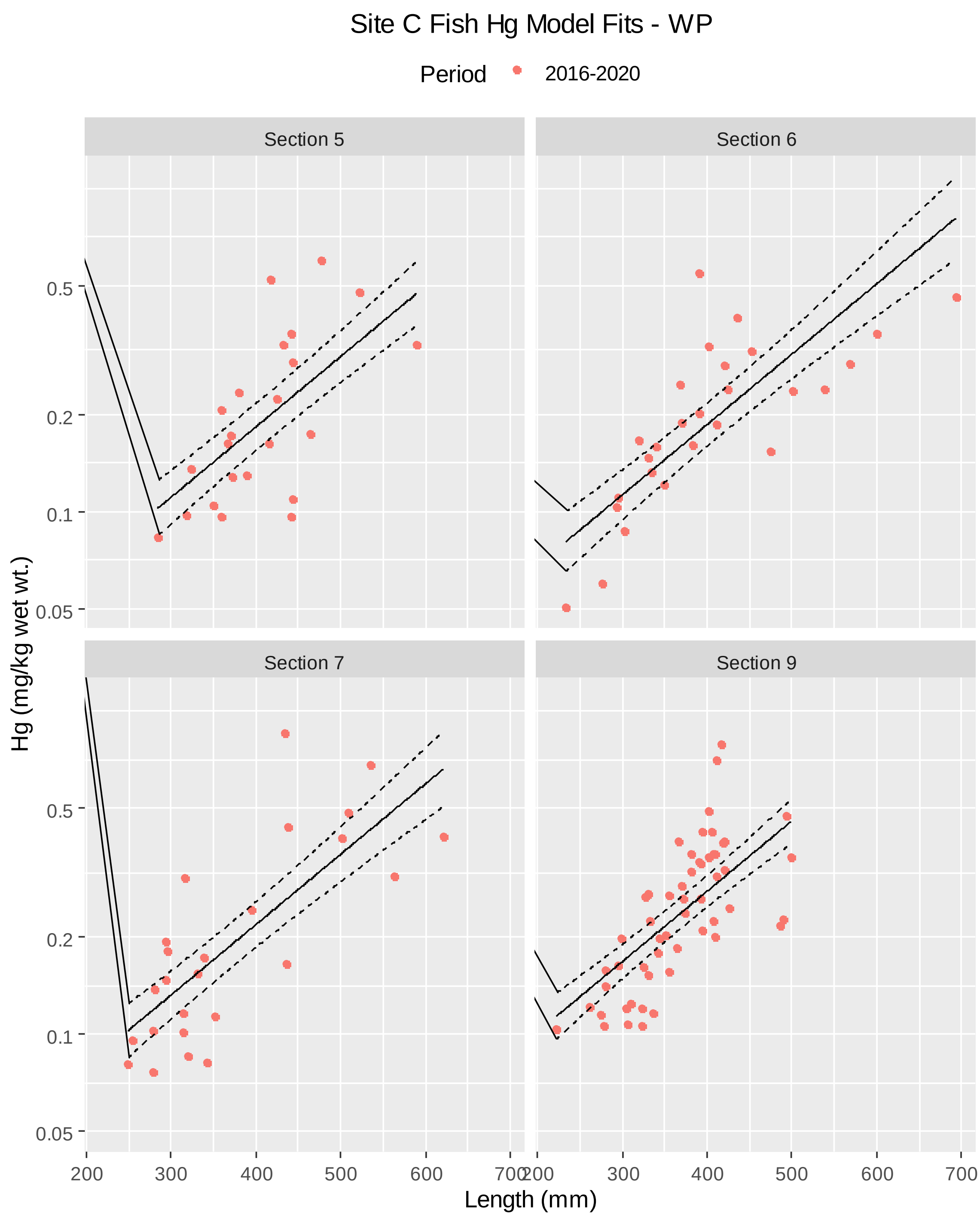
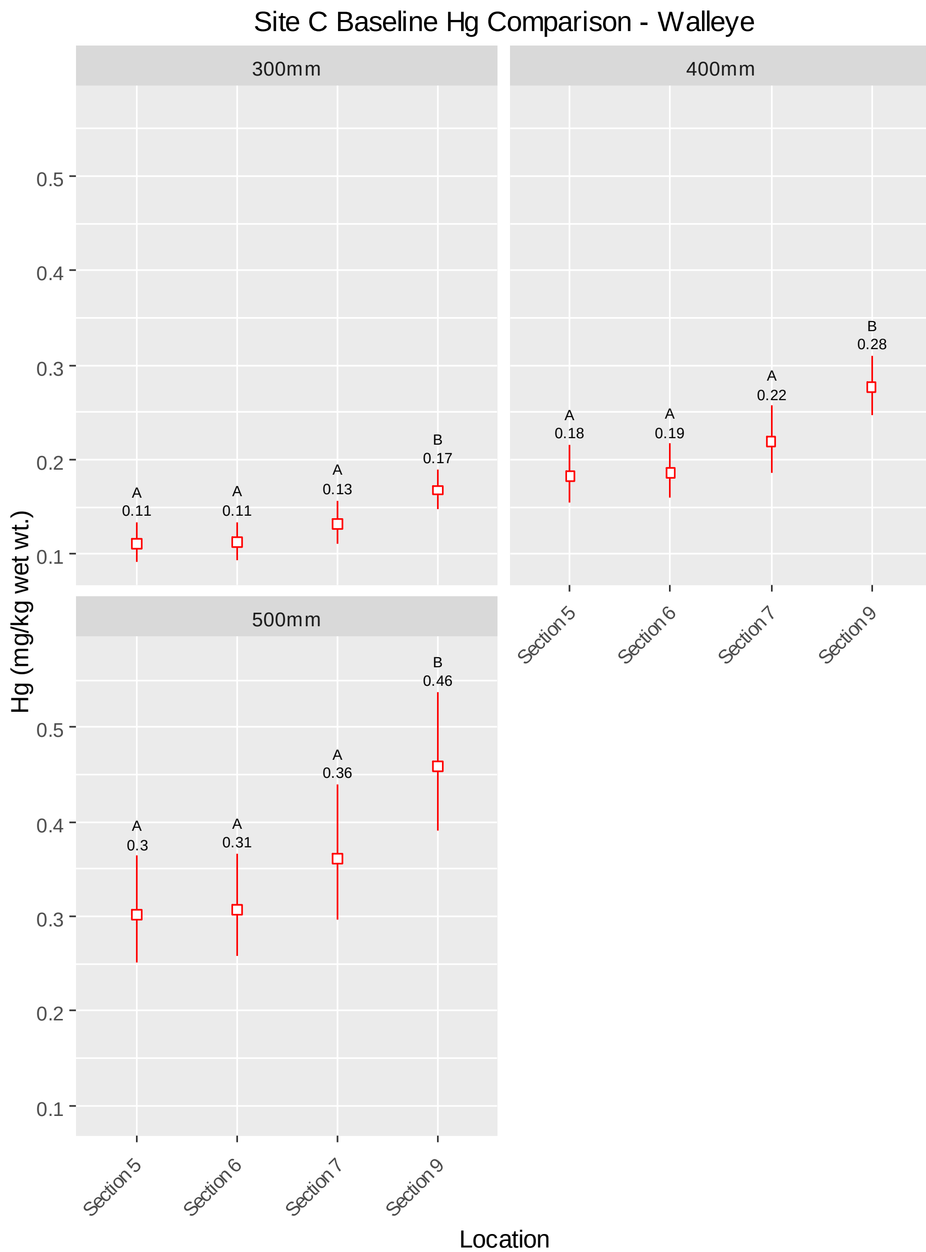


Figure 6-6. Estimated mercury concentrations (and 95% confidence intervals) for select sizes (250 mm, 350 mm, 450 mm) for each location in the spatial assessment of Walleye mercury concentrations for Peace River Sections 5, 6, 7, and 9 across the recent baseline period (2017-2020).



Note: Letters above estimates show which are not statistically different from one another (same letters) or which are statistically different (different letters); combinations (e.g., “AB”) show estimates that are not statistically different from other groups that are different (e.g., “A” and “B”).

7 REDSIDE SHINER

Due to low overall catch numbers (n = 23) of Redside Shiner, coupled with a lack of length-mercury relationship, modelling was not carried out for this target species.

Table 7-1. Morphometric data for Redside Shiner for fish with mercury data (upper panel) and fish with methylmercury data (lower panel).

Section	Year	Length (mm)	Weight (g)	Condition (K)	Hg (ppm ww)	d13C (‰)	d15N (‰)
Section 5	2010	n=11; 99 (85-119)	n=11; 14 (6-26)	n=11; 1.3 (0.977-1.543)	n=11; 0.049 (0.032-0.06)	n=11; -25.5 (-26--24.3)	n=11; 8.1 (7.6-8.6)
Section 5	2017	n=1; 90 (90-90)	n=1; 9 (9-9)	n=1; 1.24 (1.235-1.235)	n=1; 0.048 (0.048-0.048)	n=1; -26.1 (-26.1--26.1)	n=1; 8.6 (8.6-8.6)

Section	Year	Length (mm)	Weight (g)	Condition (K)	MeHg (ppm ww)	d13C (‰)	d15N (‰)
Section 5	2020	n=7; 72 (46-106)	n=7; 5 (0.4-15)	n=7; 0.97 (0.302-1.259)	n=7; 0.049 (0.027-0.091)	n=7; -27.8 (-28.3--27.2)	n=7; 7.4 (6.9-7.9)
Section 7	2020	n=4; 45 (33-53)	n=2; 1 (0.2-1.3)	n=2; 0.8 (0.557-1.04)	n=4; 0.04 (0.024-0.076)	n=4; -27.5 (-28.1--26.8)	n=4; 7.2 (6.6-8.5)

Note that at this time, no Redside Shiner in the dataset have both mercury and methylmercury data.

Table 7-2. Fish formally identified as outliers in length-weight (L-W), length-mercury (L-Hg) and/or mercury-nitrogen isotope (Hg-dN) relationship.

Waterbody	SectionID	Year.Caught	FishID	Sp	FL.mm	Wt.g	Hg.ppm.ww	outlier
Peace River	Section 5	2020	1436	RSC	51	0.4	NA	L-W

Figure 7-1. Length Frequency for Redside Shiner (RSC) by location across all sampling years.

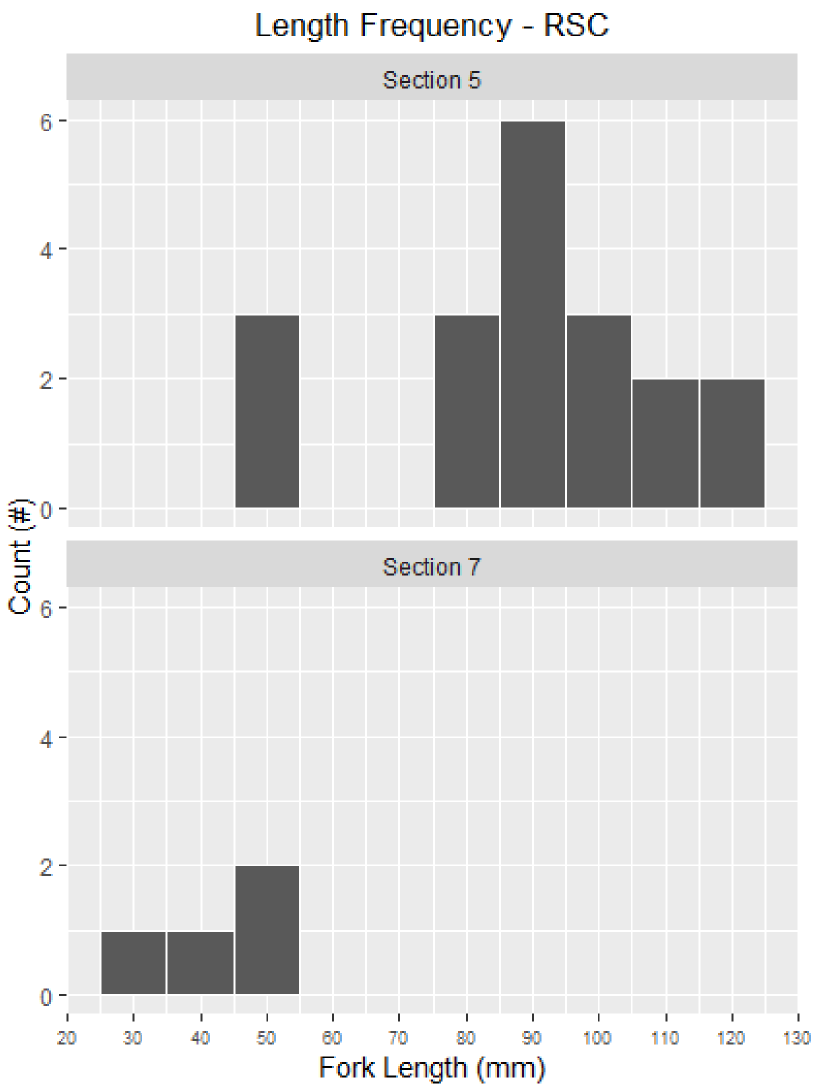
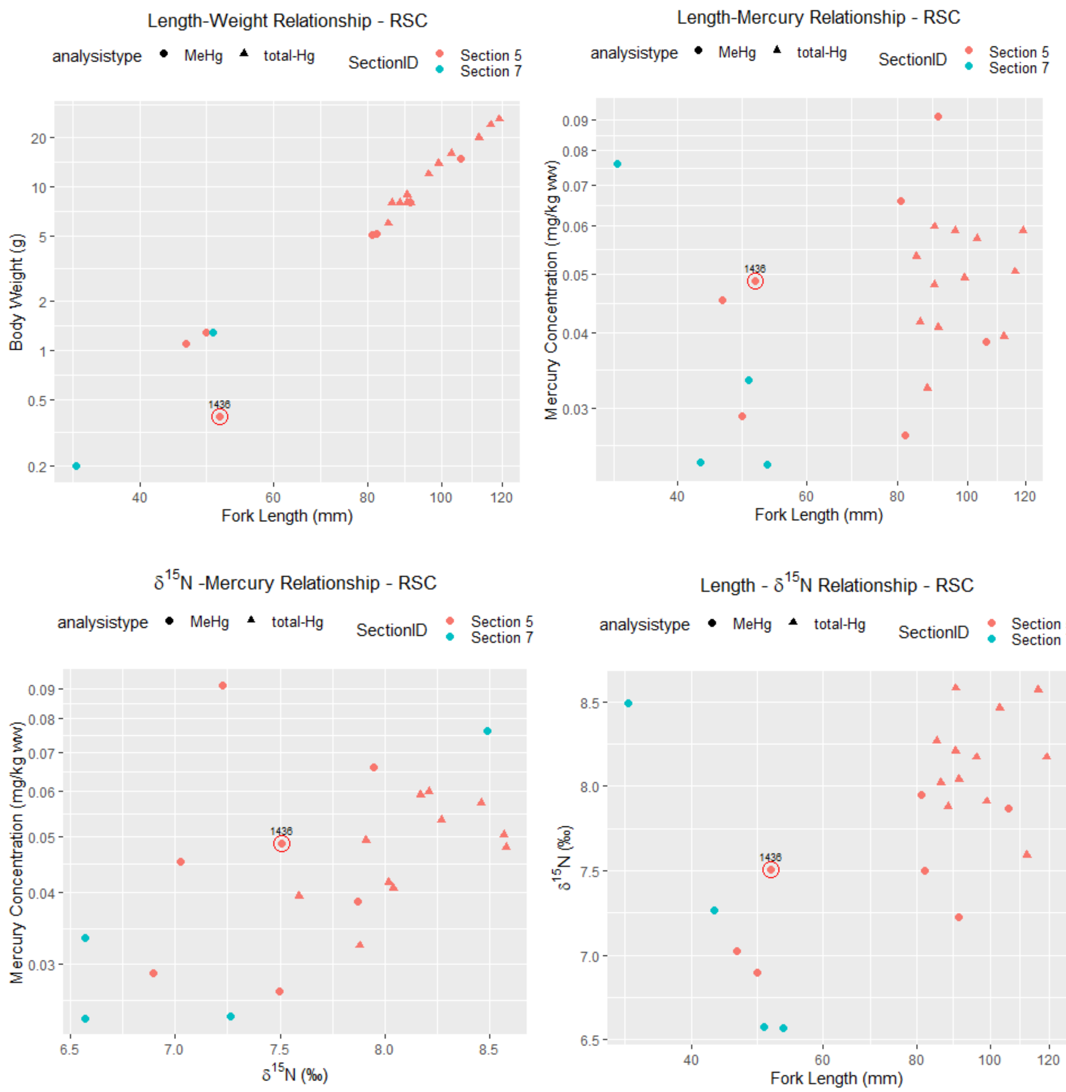


Figure 7-2. Key mercury-related relationships for Redside Shiner (RSC) across all sampling years.



Note: Red circle indicates length-weight outlier. Methylmercury (MeHg) and total mercury (total Hg) are plotted together.

8 NON-TARGET SPECIES

Tissue mercury samples were collected from non-target species on an opportunistic basis over baseline years; the breakdown by species and location for length, weight, condition, age, mercury, δ13C, and δ15N are presented in **Table 8-1**.

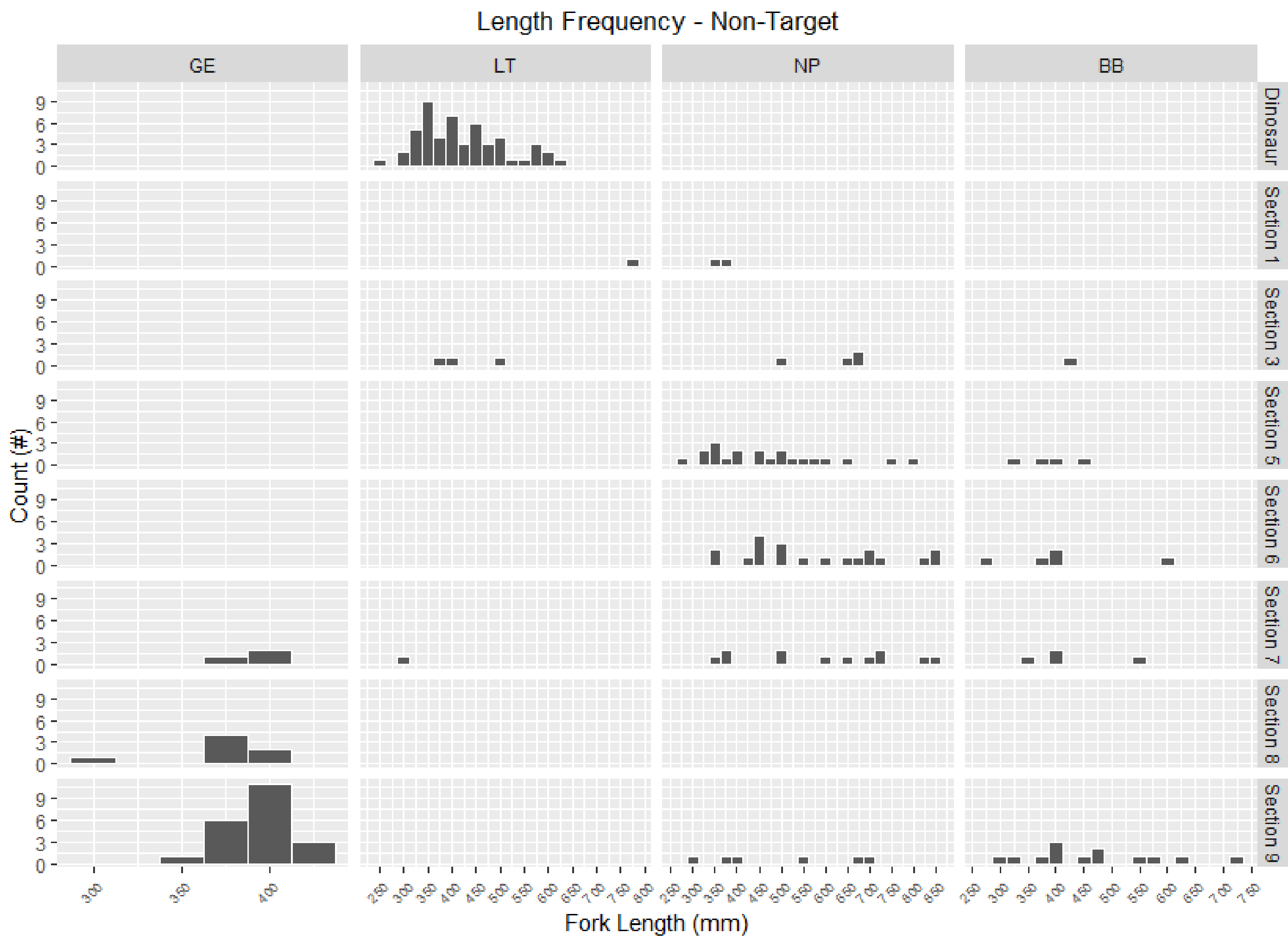
Analysis of the non-target species' datasets was limited to plotting key mercury-related relationships; no formal outlier assessment or characterization of size-mercury relationships were conducted.

Mercury-related relationships were plotted for species with more than 5 data points: Goldeye (GE; n=31), Lake Trout (LT, n=57), Northern Pike (NP, n=65) and Burbot (BB, n=27). Fish length range is provided in **Figure 8-1** and key mercury-related relationships (excluding Age-Length as age data were generally sparce for non-target species) are shown in **Figure 8-2**. With the exception of Goldeye, the non-target species generally had good representation across their size range (**Figure 8-1**). The Lake Trout dataset consists mainly of fish caught in Dinosaur Reservoir; there is a surprisingly weak length-mercury relationship for this species. Northern Pike and Burbot both have positive mercury-related relationships.

Table 8-1. Morphometric data for non-target species by location (all sampling years combined).

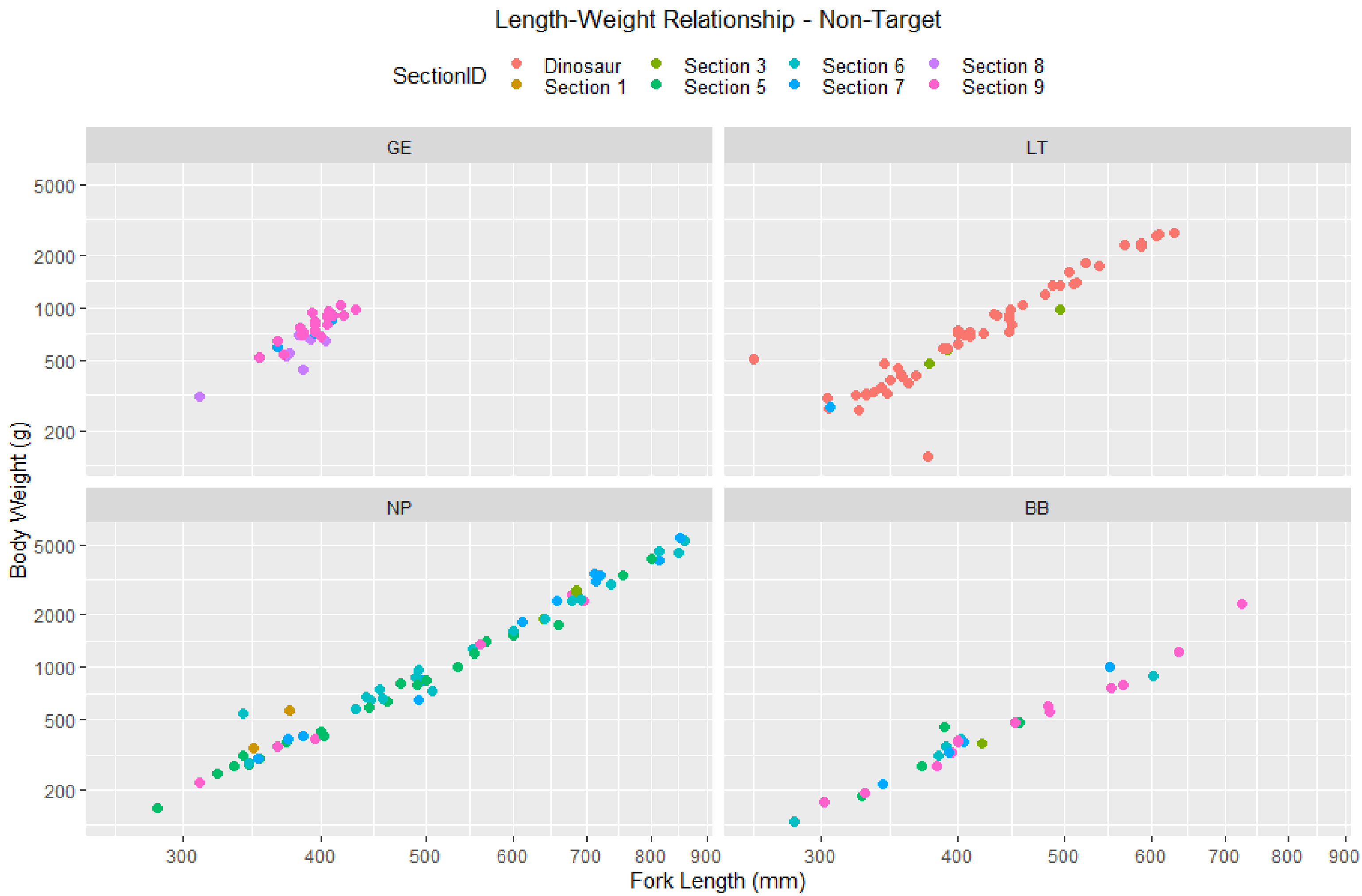
Species	Section ID	Length (mm)	Weight (g)	Condition (K)	Age (yrs)	Hg (ppm ww)	d13C (‰)	d15N (‰)
GE	Section 7	n=3; 391 (366-410)	n=3; 721 (600-854)	n=3; 1.2 (1.14-1.24)	n=3; 12 (11-12)	n=3; 0.159 (0.11-0.221)	n=3; -26.3 (-26.6--25.8)	n=3; 9 (8.7-9.2)
GE	Section 8	n=7; 374 (310-404)	n=7; 549 (314-702)	n=7; 1.03 (0.78-1.26)	n=7; 10 (9-11)	n=7; 0.247 (0.153-0.334)	n=7; -26 (-26.8--25.2)	n=7; 9.8 (9.4-10.1)
GE	Section 9	n=21; 395 (352-430)	n=21; 793 (525-1036)	n=21; 1.27 (1.06-1.55)	n=2; 16 (15-16)	n=21; 0.252 (0.177-0.37)	n=19; -26.1 (-27.3--25.2)	n=19; 8.8 (8.2-9.5)
LT	Dinosaur	n=52; 424 (260-630)	n=51; 922 (141-2676)	n=51; 1.04 (0.27-2.89)	n=45; 7 (4-13)	n=52; 0.092 (0.021-0.137)	n=52; -31.4 (-35.4--25.4)	n=52; 11.9 (9.3-13.1)
LT	Section 1	n=1; 780 (780-780)	n=0; NA (NA)	n=0; NA (NA)	n=0; NA (NA)	n=1; 0.109 (0.109-0.109)	n=1; -34.9 (-34.9--34.9)	n=1; 12.3 (12.3-12.3)
LT	Section 3	n=3; 421 (376-495)	n=3; 680 (485-985)	n=3; 0.89 (0.81-0.95)	n=1; 4 (4-4)	n=3; 0.124 (0.066-0.154)	n=3; -26.9 (-27--26.9)	n=3; 11.2 (11-11.6)
LT	Section 7	n=1; 306 (306-306)	n=1; 272 (272-272)	n=1; 0.95 (0.95-0.95)	n=1; 3 (3-3)	n=1; 0.207 (0.207-0.207)	n=1; -31.8 (-31.8--31.8)	n=1; 14.1 (14.1-14.1)
GR	Section 3	n=3; 353 (337-362)	n=3; 565 (473-646)	n=3; 1.27 (1.22-1.36)	n=0; NA (NA)	n=3; 0.038 (0.026-0.046)	n=3; -27.9 (-28.1--27.6)	n=3; 8 (7.8-8.4)
GR	Section 7	n=1; 336 (336-336)	n=1; 482 (482-482)	n=1; 1.27 (1.27-1.27)	n=1; 3 (3-3)	n=1; 0.018 (0.018-0.018)	n=1; -26.5 (-26.5--26.5)	n=1; 7.4 (7.4-7.4)
NP	Section 1	n=2; 362 (348-375)	n=2; 454 (345-563)	n=2; 0.94 (0.82-1.07)	n=0; NA (NA)	n=2; 0.053 (0.035-0.071)	n=2; -30.8 (-31.5--30.1)	n=2; 7.7 (7.3-8)
NP	Section 3	n=4; 628 (505-684)	n=3; 2435 (1897-2737)	n=3; 0.81 (0.73-0.86)	n=1; 4 (4-4)	n=4; 0.182 (0.106-0.337)	n=4; -26.8 (-28--25.9)	n=4; 9.9 (9.1-10.6)
NP	Section 5	n=21; 475 (284-800)	n=21; 992 (159-4139)	n=21; 0.71 (0.61-0.81)	n=2; 3 (3-3)	n=21; 0.119 (0.04-0.508)	n=20; -27.2 (-28.7--25.1)	n=20; 9 (7.9-10.3)
NP	Section 6	n=20; 575 (340-860)	n=20; 1801 (284-5260)	n=20; 0.78 (0.57-1.4)	n=3; 4 (2-5)	n=20; 0.166 (0.036-0.873)	n=17; -26.7 (-27.3--26)	n=17; 10.1 (9.1-11)
NP	Section 7	n=12; 598 (351-850)	n=12; 2177 (305-5470)	n=12; 0.78 (0.55-0.95)	n=0; NA (NA)	n=12; 0.209 (0.037-0.64)	n=10; -26.7 (-27.6--26.3)	n=10; 10.2 (9-11.4)
NP	Section 9	n=6; 501 (310-696)	n=6; 1217 (221-2595)	n=6; 0.73 (0.64-0.83)	n=3; 4 (1-6)	n=6; 0.106 (0.042-0.244)	n=4; -26.4 (-26.6--26.1)	n=4; 9.7 (8.4-10.6)
BB	Section 3	n=1; 420 (420-420)	n=1; 367 (367-367)	n=1; 0.5 (0.5-0.5)	n=0; NA (NA)	n=1; 0.17 (0.17-0.17)	n=1; -28.1 (-28.1--28.1)	n=1; 10.4 (10.4-10.4)
BB	Section 5	n=4; 384 (326-454)	n=4; 351 (186-485)	n=4; 0.6 (0.52-0.78)	n=0; NA (NA)	n=4; 0.076 (0.039-0.099)	n=2; -27.1 (-27.4--26.9)	n=2; 8.7 (8.1-9.2)
BB	Section 6	n=5; 412 (283-601)	n=5; 415 (131-889)	n=5; 0.55 (0.41-0.6)	n=0; NA (NA)	n=5; 0.094 (0.032-0.117)	n=5; -27 (-27.7--26)	n=5; 10.1 (9.1-11.4)
BB	Section 7	n=4; 422 (341-550)	n=4; 480 (216-1000)	n=4; 0.57 (0.55-0.6)	n=0; NA (NA)	n=4; 0.129 (0.075-0.16)	n=4; -27 (-29.6--24.6)	n=4; 10.2 (8.7-11.2)
BB	Section 9	n=13; 469 (302-725)	n=13; 650 (170-2310)	n=13; 0.53 (0.44-0.62)	n=0; NA (NA)	n=13; 0.157 (0.039-0.255)	n=12; -26.2 (-26.7--25.8)	n=12; 10.3 (8.8-11.2)

Figure 8-1. Length frequency for non-target species by location (across all sampling years; GR not shown due to insufficient number of fish).

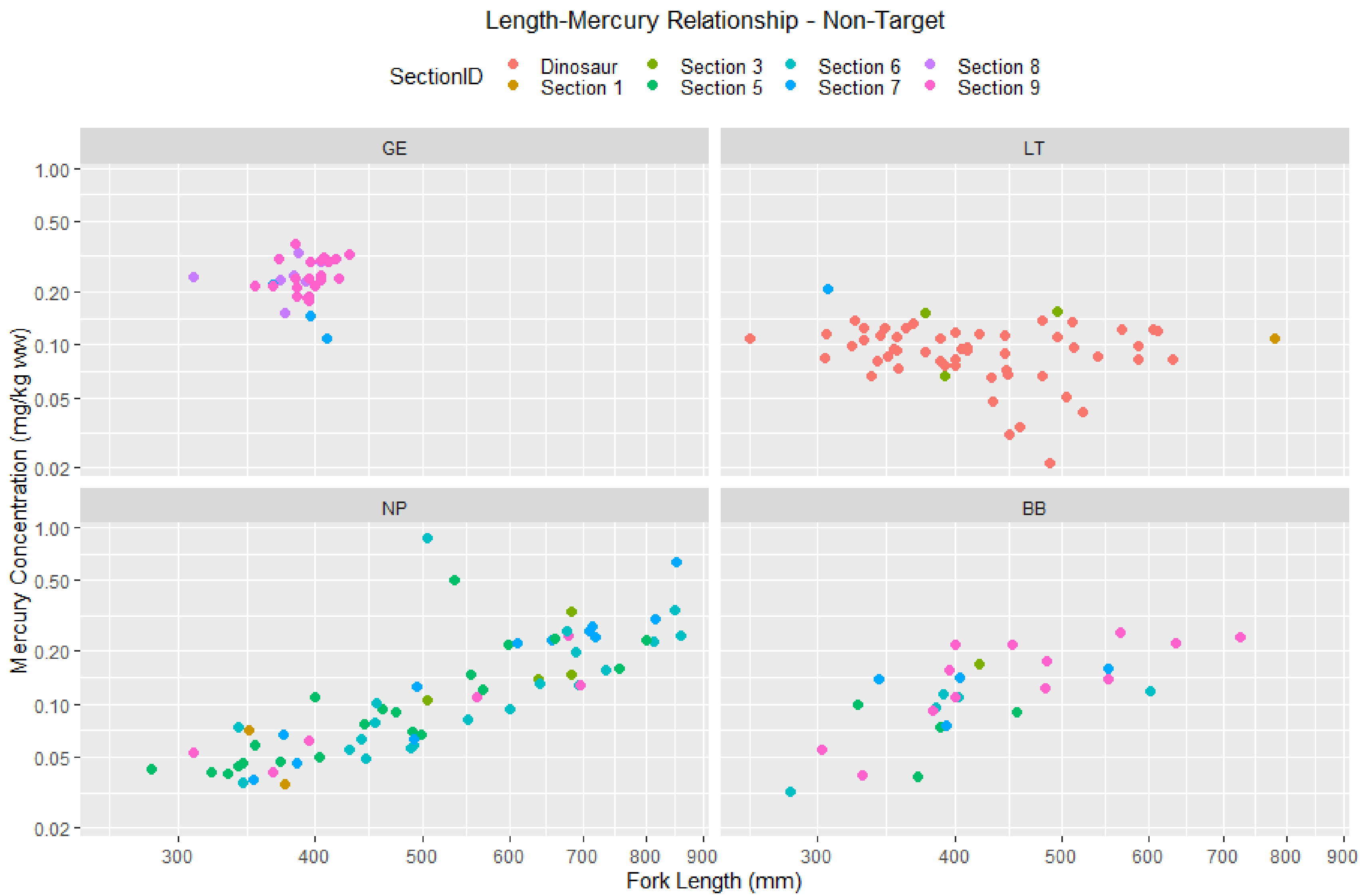


LT = Lake Trout, GR = Arctic Grayling, NP = Northern Pike, BB = Burbot, LW = Lake Whitefish

Figure 8-2. Key mercury-related relationships for non-target species (across all sampling years; GR and LW not shown due to insufficient number of fish).

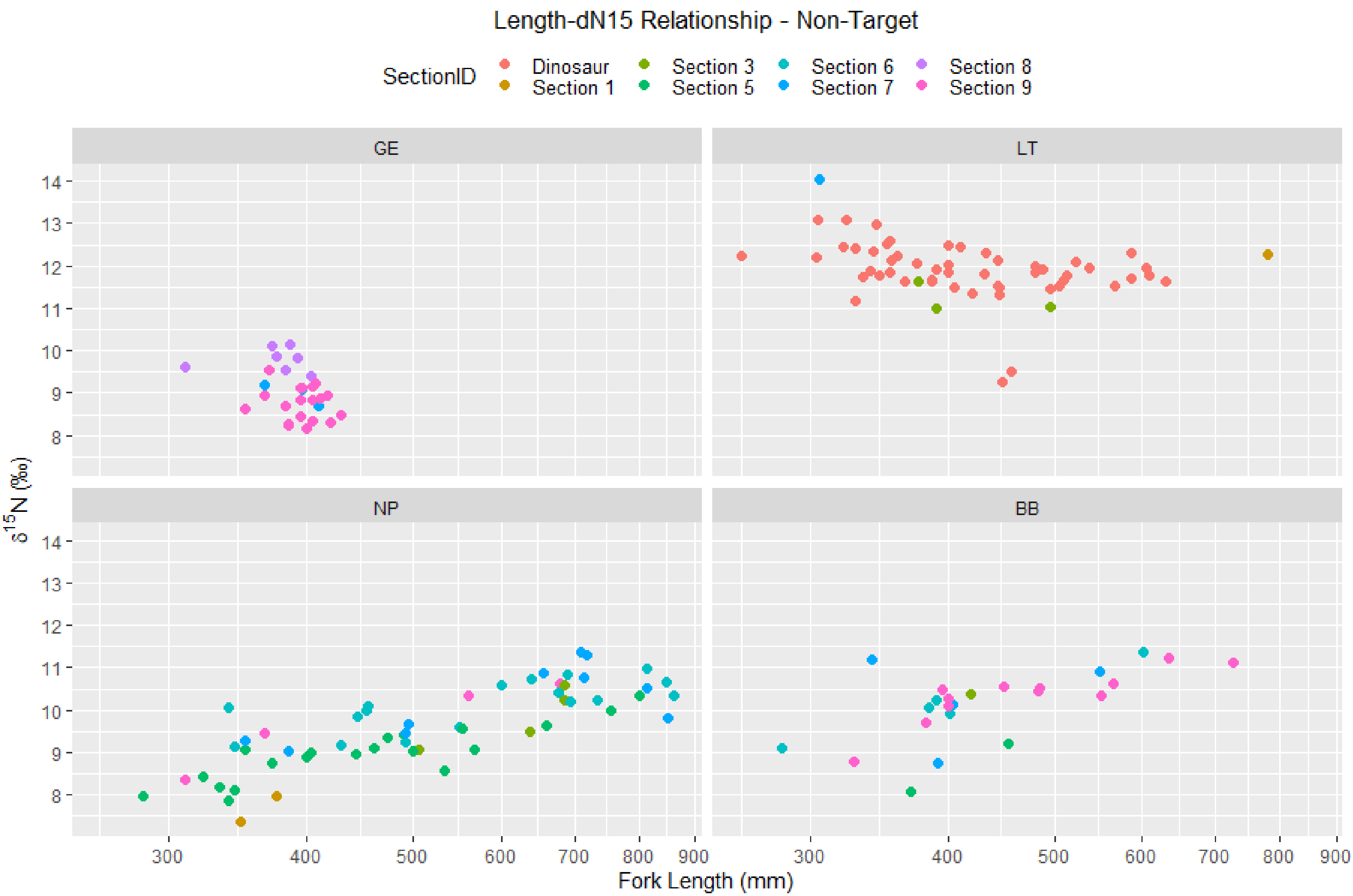


GE = Goldeye, LT = Lake Trout, NP = Northern Pike, BB = Burbot



GE = Goldeye, LT = Lake Trout, NP = Northern Pike, BB = Burbot

GE = Goldeye, LT = Lake Trout, NP = Northern Pike, BB = Burbot



GE = Goldeye, LT = Lake Trout, NP = Northern Pike, BB = Burbot