Predicted Increases in Fish Methylmercury Muscle Tissue Concentrations
In Goose Bay and Lake Melville

Submitted to:

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1.0 INTRODUCTION

Nalcor Energy (Nalcor) is developing the remaining hydroelectric potential of the lower Churchill River through hydroelectric generating facilities at Muskrat Falls and Gull Island. The Muskrat Falls portion of the project, which is currently under construction, will create a reservoir with a surface area of $101km^2$ and aquatic residence time of approximately 10 days. The existing river within the proposed footprint of the Muskrat Falls reservoir area has a surface area of ~$60km^2$ therefore the area of additional terrestrial flooding will be approximately $41km^2$, representing a 65-70 percent increase in the existing waterbody surface area. Note that of this 41 km^2 total, approximately 11 km^2 consists of gravel bars and riparian soils with no organic soils, although some deciduous shrubs may be present. Thus, the surface area of forested habitat with an intact organic soil horizon is about 30 km^2.

Many fish species have been predicted to be influenced by the Muskrat Falls project in terms of habitat change and methylmercury as part of the assessment process. Much of the baseline data required for the Environmental Assessment and Environmental Effects Monitoring (EEM) programs describe these species, their potential for interaction with the project, as well as the estimation of potential effects (e.g., Nalcor 2009; Amec 2016a).

One of the most well-known issues surrounding the formation of new reservoirs is the increase in methylmercury (MeHg) concentration in aquatic biota, especially fish resident within the reservoir (e.g., Bodaly et al. 1984; Jackson 1986; French 1997; Anderson et al. 1995). While this has been very well studied within reservoirs, the phenomenon of transport and bioaccumulation of methylmercury in downstream fish populations has been seldom studied (e.g., Anderson 2011; Schetagne et al. 2000). With respect to Muskrat Falls reservoir, possible increases in methylmercury concentration in tissues of fish and marine mammals that are consumed by local human populations downstream in Goose Bay and Lake Melville, has been a very contentious issue since the Calder et al. (2016) publication. While the potential for human health risks to residents due to increased exposure to methylmercury in various fish species from Goose Bay and Lake Melville was modeled and included in Nalcor's Human Health Risk Assessment (HHRA) (Dillon 2016), new information has been developed, especially since the Schartup et al. 2015 and Calder et al. 2016 publications. This relates to the spatial and temporal extent of feeding by key aquatic species within the 'exposure zone' (i.e., downstream area with increased methylmercury above baseline) as well as the amount (e.g., concentration change in water or mass (gm) of methylmercury delivered downstream over time).

Bioaccumulation of methylmercury by biota is almost exclusively via diet (e.g., Hall et al. 1997) which is why prey/food sources of species informs exposure to methylmercury. Therefore, life cycles and feeding habitat used by fish species captured and consumed by local residents is key to understanding and predicting any potential future mercury increases. Of importance is understanding how key species might feed within the zone of exposure in Goose Bay and Lake Melville. For example, if key species do not feed within an area of Lake Melville that is affected by methylmercury exported from the reservoir (i.e., within the zone of exposure), methylmercury concentrations will not change. If organisms are partially exposed, it is reasonable to expect that concentrations will only change in proportion to exposure.

Thus, information on species distribution within and downstream of the Muskrat Fall reservoir, their abundance, trophic position within the food web, and baseline MeHg concentrations is of critical importance. This information, based on data collected since 1998, was presented to the Independent Experts Committee (IEC) on two separate occasions; September 7, 2017 and February 15, 2018. The data collected directly from the lower Churchill River since 1998 clearly shows that the habitat use and exposure of fish species to potential increases in MeHg concentrations in water, and hence the food web, have been inconsistently applied to previous HHRA predictions.

1.1 Purpose

The purpose of this document is to provide summary life history and habitat use by key species identified as being important in local diets that are targeted within Goose Bay and Lake Melville. This data is critical to determining the exposure of these species to any predicted increases in water MeHg concentrations exported downstream from the Muskrat Falls reservoir. New reservoir mercury modelling and detailed hydrodynamic modelling that describes the predicted increase and distribution of water MeHg concentrations in Goose Bay and Lake Melville have been used to inform how fish tissue MeHg concentrations may change over time. The magnitude of change is dictated by the time and space a particular species may forage within Goose Bay and different parts of Lake Melville. It should be noted that to date, most concern by residents is related to fish species captured and consumed within the estuarine environment downstream of the Muskrat Falls reservoir in Goose Bay and Lake Melville. As such, the Muskrat Falls reservoir area and the riverine section of the lower Churchill River are not the focus of this summary as these areas do not contribute to potential human exposure. It has also been conservatively assumed that total mercury concentrations in fish muscle tissue analyzed as part of the baseline program consists entirely of methylmercury based on local comparisons of paired total and methylmercury samples (also see Lasorsa and Allen-Gil 1995; Anderson and Depledge 1997; Marrugo et al. 2007).

2.0 BIOACCUMULATION OF MEHG IN FISH

The primary exposure pathway to methylmercury by all aquatic organisms is almost exclusively via diet (e.g., Hall et al. 1997). Following formation of the Muskrat Falls Reservoir it is predicted that a greater net export of MeHg will be delivered by lower Churchill River to Goose Bay and Lake Melville. Given that this is a very dynamic process and a hydraulically complex environment, it is difficult to predict how changes will occur over time in different parts of Lake Melville. For example, deep water beneath the brackish surface layer will be less influenced and the eastern portion of Lake Melville will be less affected than the western portion, simply because of dilution and loss to photodegradation (e.g., Sellers et al. 1996) and other losses. However, areas of dynamic mixing between the freshwater surface layer and the underlying marine layer where light penetration, and thus productivity, is high is where methylmercury will be most accumulated by bacteria, phytoplankton and nanoplankton. This phenomenon will ultimately distribute methylmercury into the base of the aquatic food web across areas of exposure; however, recent hydrodynamic modelling shows that this occurs disproportionately. Relatively greater water concentrations of methylmercury will be available for accumulation in Goose Bay biota than Lake Melville because of a variety of factors including dilution, photo-demethylation (e.g., Sellers 1992), adsorption to particles, settling and progressive uptake by biota. Thus, where an organism spends its time feeding will dictate its magnitude of exposure. This has important implications in terms of predicted increases in fish MeHg.

For a fish to be exposed, it must occupy and feed in the same space as the contaminant for a sustained period. Therefore, life history is an important factor, informing the magnitude of exposure on both a spatial and temporal scale to produce a change in tissue mercury concentrations. For this analysis, the predicted relative increase in MeHg concentration in water is assumed to be the predicted upper maximum relative increase in fish muscle tissue should a fish be fully exposed to that water concentration. That is, the correlation between the increase in MeHg concentration in water and the increase in prey species concentration is assumed at a 1:1 ratio. This is a conservative assumption but acknowledges uncertainty in attempting to rationalize or justify a lower increase ratio relative to water. This also follows the assumption made in the Calder et al. (2016) paper, therefore comparisons to relative increases between the two can be considered. The predicted relative increase in fish tissue MeHg in Goose Bay and Lake Melville also does not take into account the biomass of MeHg that can be produced by Muskrat Falls reservoir nor the biomass of biota within Goose Bay and Lake Melville for uptake; therefore, they are considered conservative overestimates. Biomass effects on accumulation of MeHg is addressed in Azimuth (2018).

2.1 Predicted Methylmercury Increases in Water

Detailed modelling has been utilized to predict MeHg that will be generated by the Muskrat Falls reservoir using RESMERC and empirical data from the Experimental Lakes Area (ELA) (Harris and Hutchinson 2018). Fludex was an experimentally flooded series of boreal forest systems at the Experimental Lakes Area (ELA) of northwestern Ontario, where net MeHg import, generation and export was measured over a five-year period (Hall et al. 2005). RESMERC is a calibrated model that simulates the magnitude and timing of response, including pulse, of MeHg through the Muskrat Falls reservoir system. The pulse is modelled through the reservoir in various steps in the ecosystem; water, sediments, lower trophic levels, to higher trophic levels (Harris and Hutchinson 2018). At Muskrat Falls Reservoir, a portion of the methylmercury generated will be transported downstream to the lower reaches of the river, Goose Bay and Lake Melville. The quantity of MeHg exported from Muskrat Falls reservoir was estimated using both the results of RESMERC and Fludex. The estimates were used as input parameters for extensive hydrodynamic modelling of Goose Bay and Lake Melville which estimated MeHg increases based on reservoir MeHg outflows (Brunton 2018) and various natural processes that affect MeHg concentrations such as freshwater flows, salinity, currents, flushing, winds, ice, transport, photodegradation, and settling (Brunton 2018). Details of the hydrodynamic model are provided in Brunton (2018).

Hydrodynamic model results indicate that MeHg generated from Muskrat Falls reservoir will be transported downriver via the upper freshwater layer that enters the estuary habitat. Therefore, it has been assumed that the general exposure concentration of prey occurs within the epilimnion, occupying the top 20m of the estuary. This is the depth to which the combined surface freshwater layer and the upper saline water mix, just above the deeper marine layer or hypolimnion. This zone is highly productive and exposed to additional nutrients (Schartup et al. 2015). We have assumed that within this productive zone is where MeHg is accumulated within the lower trophic levels (nano and zooplankton). Thus, it is assumed that larger prey will ultimately derive any increased accumulation of MeHg here. The hydrodynamic modelling also shows that as water from Muskrat Falls reservoir travels downriver and throughout Goose Bay and Lake Melville, predicted concentrations decrease. **Figure 2-1** provides the boundary between three distinct areas where concentrations differ; Goose Bay, West Lake Melville, and East Lake Melville. These three areas are identified as different "zones of exposure" for predicting increases in fish MeHg tissue concentrations. **Table 2-1** provides an estimate of the predicted relative increase in MeHg concentrations within the epilimnion relative to baseline (i.e., 0.017 ng/L) for the three zones of exposure based on the hydrodynamic model results. The predicted relative increase in water is the mean of the consecutive three-year sequence with the highest predicted MeHg concentrations within the upper 20m of the water column, using results from both RESMERC and Fludex. More detailed information can be found in the Technical Memorandum by Harris and Hutchinson (2018). The rationale for using a three-year mean is to realistically estimate the level of exposure throughout the life span of those key fish species in Goose Bay and Lake Melville (see Section 2.2).

2.2 Potential Fish Exposure to Methylmercury

Nalcor has collected baseline data since 1998 on the lower Churchill River, Goose Bay, and Lake Melville. Included in this baseline data are the ongoing results of species distribution and abundance, trophic feeding position, and total mercury concentrations in fish and seals. Detailed summaries of the results are provided in **Appendices A and B**.

In total, the baseline sampling program for the Lower Churchill Hydroelectric Development has sampled over 10,140 fish from over 20 different species between 1998-2017. While many species of fish have been identified as being consumed by residents in previous HHRAs (e.g., Calder et al. 2016 and Dillon 2016), many have either not been captured within or downstream of the Muskrat Falls reservoir (see Amec 2017 and **Appendix A**), have only been captured within the marine environment beyond Lake Melville (e.g., Li et al. 2016; Calder et al. 2016), or do not feed in Lake Melville upon their return to tributaries to spawn. For these species, increases in MeHg exposure are not anticipated and therefore have not been included in further estimates of bioaccumulation increases. **Figure 2-2** provides an overview of the relative abundances of many of the species captured.

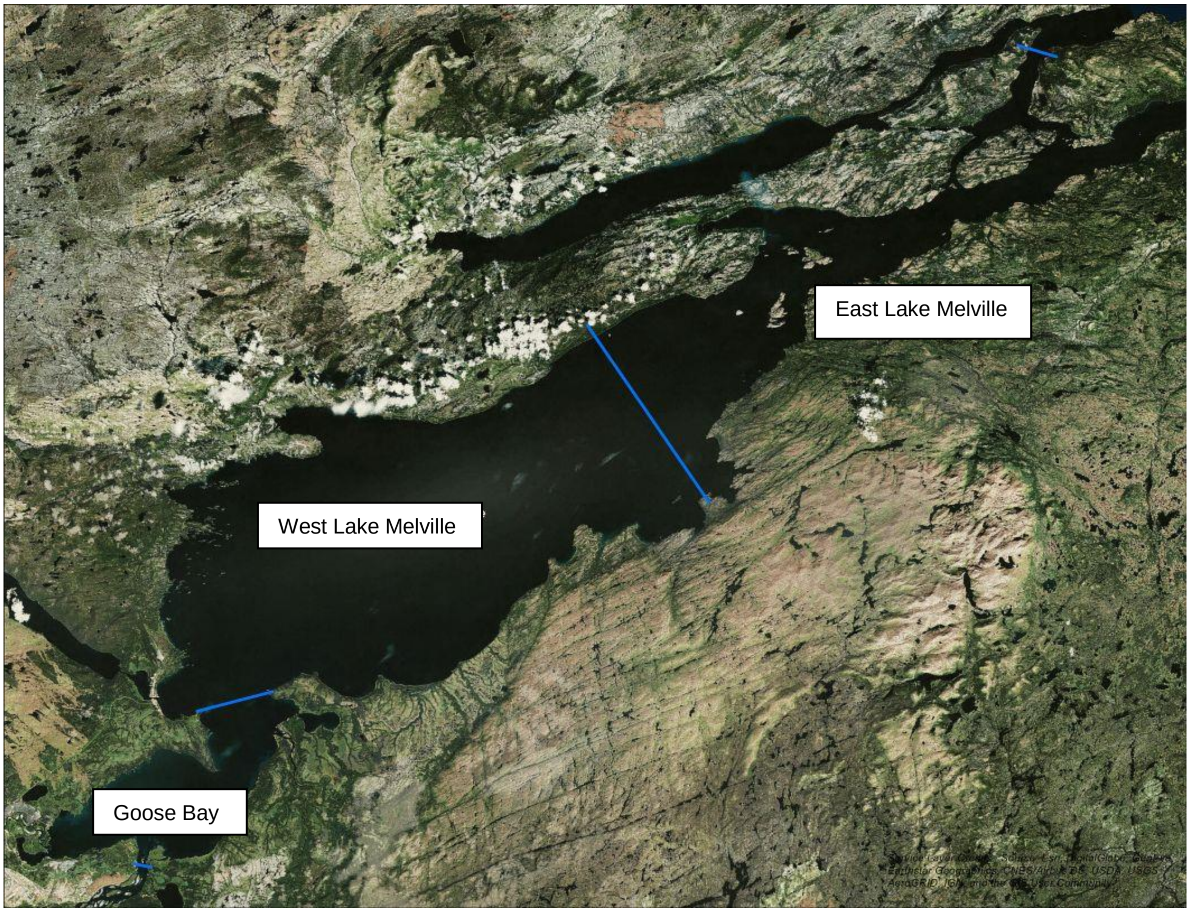

Figure 2-1: General overview of different zones of exposure based on hydrodynamic model (Brunton 2018)

Table 2-1: Hydrodynamic Model Estimates of water MeHg concentration (ng/L) increases (above baseline), Goose Bay, West Lake Melville, East Lake Melville

	Goose Bay	West Lake Melville	East Lake Melville
Baseline MeHg Water Concentration (ng/L)	0.017	0.017	0.017
Peak Additional Concentration (max 3-yr; ng/L)	0.019	0.006	0.005
Total Predicted Concentration (max 3-yr + baseline; ng/L)	0.036	0.023	0.022
Relative MeHg Increase in Water	**2.12x**	**1.35x**	**1.29x**

				Lake Melville		Dietary Pathway		
		Lower Churchill River	Goose Bay	West Basin	East Basin	Freshwater	Estuarine	Marine
Riverine / Estuarine	Longnose sucker	●	●	○	○	X	X	-
	Northern pike	◐	○	-	-	X	-	-
	Lake whitefish	○	○	-	-	X	X	-
	lake chub	◐	◐	◐	-	X	X	-
	Stickleback	●	◐	◐	◐	X	X	-
	Rainbow Smelt	○	◐	●	●	X	X	X
	Brook trout	○	◐	●	●	-	X	X
	Artic char	-	-	-	-	-	-	X
	Lake Trout	-	-	-	-	X	-	-
	Atlantic Cod	-	-	-	-	-	-	X
	Capelin	-	-	-	-	-	-	X
	Atlantic salmon	-	-	-	-	-	-	X
Estuarine / Marine Fish	Sand lance	-	◐	◐	◐	-	X	X
	Tom cod	-	◐	●	◐	-	X	X
	Rock cod	-	○	○	○	-	-	X
	flounder	-	○	○	◐	-	-	X
	Sculpin	-	○	○	○	-	-	X
	Blenny	-	○	○	○	-	-	X
Marine Mammals	Ringed Seals	○	●	●	●	-	X	X

-	Not present or not applicable
○	Present in low or negligible relative aboundance based on catch-per-unit-effort or stomach content analysis
◐	Present or believed to be present in relatively moderate relative aboundance based on catch-per-unit-effort or stor
●	Present or believed to be present in high relative aboundance based on catch-per-unit-effort or stomach content ar
X	Basis of dietary exposure to MeHg based on organism stable C and N isotope signature and on stomach contents

Figure 2-2: Relative abundance summary of key species captured in baseline sampling programs, 1998-2017.

Key species that have been identified in diet surveys include:

- lake trout (*Salvelinus namaycush*) – are not present outside of the river mouth and are very rare within the lower portion of the river (i.e. Muskrat Falls reservoir area)
- Atlantic salmon (*Salmo salar* – both anadromous and land-locked) – the landlocked form is very rare within the lower portion of the river (i.e., Muskrat Falls reservoir area) and anadromous returning salmon from the Labrador Sea cease feeding as they enter freshwater of Lake Melville
- Atlantic cod (*Gadus morhua*) – this species has not been documented within L. Melville
- Capelin (*Mallotus villosus*) – this species has only rarely been observed in Lake Melville since the early 1970s
- Arctic char (*Salvelinus alpinus*) – This species is not found in the lower Churchill River below the Labrador Plateau and only rarely observed in Lake Melville and typically found beyond the Narrows at the eastern end of Lake Melville.

Only three species; brook trout (*Salvelinus fontinalis*), rainbow smelt (*Osmerus mordax*) and ringed seal (*Pusa hispida*) appear to be abundant and widespread in Goose Bay and Lake Melville and perhaps not coincidentally, have also been identified in dietary surveys as preferred food species by local communities (Dillon 2016). These three species are therefore exposed to greater methylmercury concentrations in prey due to the Muskrat Falls reservoir because of their spatial and temporal overlap with the project. For species that do not feed within an area of Goose Bay / Lake Melville that is affected by methylmercury exported from the reservoir (i.e., within the zones of exposure), methylmercury concentrations will not change. Further details on each of these three species is as follows.

2.2.1 Brook Trout (*Salvelinus fontinalis*)

The brook trout is widely distributed throughout Newfoundland and Labrador (Scott and Crossman 1973), at least as far north as the Hebron Fiord (Black et al. 1986), where they have been reported to make extensive use of clear, cool (<20°C) lake habitats (Ryan and Knoechel 1994). Brook trout are known to have both landlocked and anadromous populations throughout Newfoundland and Labrador (Scott and Crossman 1964, 1998). Anadromous populations may spend one or two months feeding at sea in relatively shallow water, close to their natal stream, while others spend their entire life in freshwater (Scott and Crossman 1964; Morrow 1980; Power 1980; Ryan 1980; Scott and Scott 1988).

Brook trout are found throughout the main stem and tributaries of the lower Churchill River between Muskrat Falls and Churchill Falls (Beak 1980; Ryan 1980; AGRA 1999; AMEC 2000, AMEC 2001), being most abundant upriver of Gull Island (above the Muskrat Falls reservoir area) where river and shoreline substrates contain less fine sand and clay substrates (AGRA 1999; AMEC 2000). Brook trout have also been captured below Muskrat Falls within the main stem but at relatively low rates (AMEC 2000; AMEC 2007; AMEC 2009; Amec Foster Wheeler 2015a; Amec Foster Wheeler 2016a).

Based on habitat utilization data, brook trout use stream (i.e. tributary) habitat where spawning and young-of-year occur. Few samples have been collected within the main stem of the lower Churchill River below Muskrat Falls where only 33 have been captured in a combination of fyke nets and gillnets between 1998-2016; however, they are found in relatively higher numbers within the upper habitat of Caroline Brook. Larger numbers have also been sampled within both Goose Bay (191 total) and Lake Melville (535). In both estuarine environments, brook trout have had some of the highest CPUE and biomass of all species sampled (Amec Foster Wheeler 2015a; 2016a). This is most likely the result of the brackish environment of the estuary being a suitable habitat for anadromous brook trout to feed during the summer months. Typically, brook trout will not feed within an estuarine environment beyond several kilometers of its natal stream (Scott and Scott 1988); therefore, most of the brook trout captured in Goose Bay and Lake Melville are likely not far from their home freshwater tributary.

Specimens have been captured from every age-class between one and six (AGRA 1999; AMEC 2000; Amec Foster Wheeler 2015a; 2016a, 2016b). Mean length-at-age data shows they range between 82 mm in length at age one to almost 415 mm at age six. Growth is relatively linear throughout all years.

The diet of brook trout consists of a wide variety of food types including aquatic invertebrates, fish, and terrestrial invertebrates and vertebrates. Stomach content analysis and stable isotope data indicate that brook trout in the estuary feed primarily on marine prey such as sand lance (*Ammodytes americanus*), rainbow smelt, amphipods, and benthic invertebrates (see **Appendix B**). They are one of the top predators within the estuary food chain.

2.2.2 Rainbow Smelt (*Osmerus mordax*)

Rainbow smelt are typically a schooling, pelagic fish, inhabiting mid-water areas of inshore coastal waters (Leim and Scott 1966; Scott and Scott 1988; Scott and Crossman 1998). In Hamilton Inlet and Lake Melville, they are primarily an inshore anadromous species that occur within bays and estuaries, but are rare in the Churchill River freshwater system (Anderson 1985). They are an important species in that they feed on pelagic plankton and are an important food source for most estuarine piscivores such as gadids (e.g., cod species), flatfish (e.g., winter flounder) and salmonids (e.g. brook trout).

Smelt are typically anadromous, moving from estuaries such as Lake Melville and Goose Bay into nearby rivers and streams to spawn in the spring, likely before ice breakup (JWEL 2001). As the hatched larvae grow, they move into areas of higher salinity, such as deeper parts of the estuary or more coastal areas (JWEL 2001). Smelt begin to school at about 19 mm in length, moving into shallow water and returning to deeper channels during the day (Belyanina 1969). They will generally spend the summer feeding on copepods and planktonic larvae and in the fall, juveniles mix with adult schools and move into the upper parts of the estuary (Buckley 1989) where they remain for the winter.

Within Lake Melville, smelt seem to prefer deeper, cooler waters in the summer (JWEL 2001). The JWEL sampling program identified that smelt, which spend the summer in the cooler waters of Lake Melville, move into Goose Bay from August to October (JWEL 2001; AMEC/BAE 2001). There was a slight peak observed in abundance in October in the western portion of Lake Melville and was suggested to be the result of a migration toward the many rivers in the area (JWEL 2001).

Due to physical barriers, this species does not occur above Muskrat Falls in the Churchill River (Ryan 1980) and based on sampling, is very rare upstream of estuarine influences after spawning. Ryan (1980) recorded two specimens (which appeared to be anadromous) downstream of Muskrat Falls and Amec Foster Wheeler captured a lone adult by fyke net just downstream of Muskrat Island in 2016 (Amec Foster Wheeler 2016a). No other known reports occur in the literature for their presence within the freshwater portion of the lower Churchill River (Ryan 1980, Beak 1980, AGRA 1999, AMEC 2000) upstream of the Mud Lake confluence (AMEC 2000). In addition to sampling conducted related to the Project, the main stem between Happy Valley–Goose Bay and Muskrat Falls as well as several tributaries (eg. Birchy Creek and Caroline Brook), were sampled between 2006 and 2008 for the provincial Department of Transportation and Works. Sampling was conducted using fyke nets and tended gillnets through most open water months (i.e. July and October 2006, May and June 2007, April, May, and June 2008, and May 2009) but did not capture rainbow smelt (unpub. data).

Rainbow smelt have been routinely captured during ongoing baseline sampling since 1999 in both Goose Bay and Lake Melville. Sampling by Amec Foster Wheeler has captured approximately 136 and 155 from Goose Bay and Lake Melville, respectively. Baseline work completed by JWEL in 1998 captured a total of 991 rainbow smelt within Goose Bay / Lake Melville which comprised 31 percent of their total catch (JWEL 2001). Rainbow smelt sampled (AGRA 1998) were predominantly between 151-250mm in length with fairly linear growth through all age classes sampled (ages 1-8).

Stomach content analysis and stable isotope data indicate that like brook trout, rainbow smelt are one of the top predators within the estuary food chain and feed primarily on marine prey such as sand lance, other rainbow smelt, and amphipods/decapods (see **Appendix B**).

2.2.3 Ringed Seal (*Phoca hispida*)

The ringed seal is one of the most abundant and widely distributed resident Arctic pinnipeds (Muir et al. 1999). The following general species life history description is from Lowry (2016). As a species, ringed seals are widely distributed in ice-covered waters of the northern hemisphere, and they may presently number about three million animals (Lowry 2016). They prefer annual, landfast ice, but are also found in multi-year ice (Kingsley et al. 1985).

Throughout most of their range they use sea ice exclusively as their breeding, molting, and resting (haul-out) habitat, rarely if ever moving onto land (Frost and Lowry 1981, Reeves 1998). Reported mean age at sexual maturity for female Ringed Seals varies in the literature from 3.5 to 7.1 years (Holst and Stirling 2002, Krafft et al. 2006). Males likely do not participate in breeding before they are 8-10 years old. Ringed seals can be long lived, with ages close to 50 reported (Lydersen and Gjertz 1987). Regional productivity rates are variable; reproductive success depends on many factors including prey availability, the relative stability of the ice, and sufficient snow accumulation prior to the commencement of breeding (Lukin 1980, Smith 1987, Lydersen 1995).

Outside the breeding and molting seasons, Ringed Seal distribution is correlated with food availability (e.g., Simpkins et al. 2003, Freitas et al. 2008). Numerous studies of their diet have been conducted, and although there is considerable regional variation, several patterns emerge. Most Ringed Seal prey are small, and preferred prey tend to be schooling species that form dense aggregations. Fishes are usually in the 5-10 cm length range and crustacean prey in the 2-6 cm range. Typically, a variety of 10-15 prey species are found, with no more than 2-4 dominant prey species for any given area. Fishes are generally more commonly eaten than invertebrates, but diet is determined to some extent by availability of various types of prey during particular seasons as well as by preference, which in part is influenced by energy content of various available prey (Reeves 1998, Wathne et al. 2000). Commonly eaten prey includes cod species redfish, herring, and capelin in marine waters (Lowry et al. 1980, Holst et al. 2001, Labansen et al. 2007). Invertebrate prey species seem to become more important in the open-water season and often dominate the diet of young animals (Lowry et al. 1980, Holst et al. 2001). Large Amphipods, Krill, Mysids, Shrimps, and Cephalopods are all eaten by Ringed Seals and can be very important in some regions at least seasonally (Agafonova et al. 2007).

Ringed seal surveys in Goose Bay and Lake Melville have been completed in 2006 and each year between 2013-2016 (SEM 2007; Amec Foster Wheeler 2016a). During aerial surveys each whelping season, the lower reach of the Churchill River is flown for seal presence and in all years, no ringed seals have been recorded within the river itself (SEM 2007; Amec Foster Wheeler 2016a). Very few seals are observed within Goose Bay (Amec Foster Wheeler 2016a). However, it should be noted that harbour seals (*Phoca vitulina*) have been observed within the river during fisheries surveys during open water; the most observed at any location and time has been three (McCarthy, unpubl data). Using the seal density within the observed area (approximately 517km^2), a relative abundance estimate for the entire EEM zone was generated for each survey year. Relative abundances have ranged between 644 and 2,140 animals with the 2015 survey being the lowest to date (Amec Foster Wheeler 2016a). Seal ages in Goose Bay and Lake Melville, typically range between pups and adults up to 32 years of age. Since seal samples from Goose Bay and Lake Melville are harvested by a local hunter for consumption by the local community, samples are generally biased toward younger animals.

Stomach content analysis has only identified rainbow smelt as prey; however, seals are sampled after whelping and foraging may be more restricted. In addition, pups would only be feeding on milk. Stable isotope data indicate ringed seals are the top predator in the estuary (above brook trout and rainbow smelt) and therefore feed on a variety of marine fish species.

2.2.4 Exposure Summary

Table 2-2 provides a summary of the annual percentage of time spent feeding in the identified estuary zones (Goose Bay, West Lake Melville, and East Lake Melville) for brook trout, rainbow smelt, and ringed seal. This table provides estimates of the temporal overlap for each species within Goose Bay, West and

East Lake Melville, which are expected to have differential exposure to MeHg in water exported from the reservoir.

Table 2-2. Summary of estimated percent annual exposure of key species within the identified estuary zones.

Species	Habitat Not Influenced by Muskrat Falls	Goose Bay	West Lake Melville	East Lake Melville
Brook Trout	30%	70%	70%	70%
Rainbow Smelt	0%	20% - 100%	80%	80%
Ringed Seal	34%	0%	66%	

Brook trout remain very near their home stream but would feed within the estuary environment once reaching the age of three. Discussions with local fishers indicate that brook trout have been captured through the ice and therefore, it has been assumed that up to 70% of the year could be spent within the estuary environment with some (30%) overwintering in tributaries and upstream migration for spawning and feeding where no increases in MeHg exposure would occur. While they would not be anticipated to migrate between each of the estuary zones, the estimated annual exposure within each zone would be similar.

Rainbow smelt that live and are captured in Goose Bay / Lake Melville are assumed to spend their entire lives within this environment; that is, they do not migrate to Hamilton Inlet or further offshore. However, based on surveys of the area, it appears that many rainbow smelt congregate within Goose Bay for a couple of months in the fall. It was therefore assumed that rainbow smelt captured and consumed from the Lake Melville zones could have spent up to 20% of their time feeding within Goose Bay each year and this would increase their exposure to higher MeHg water concentrations. Those fish captured and consumed within Goose Bay are assumed to reside 100% within Goose Bay itself and therefore are predicted to have higher overall exposure than those captured within Lake Melville.

Ringed seals have not been observed within the Churchill River and Chaulk et al. (2013) stated that local residents reported that ringed seals are rarely observed in Lake Melville during the summer, compared to early spring. Chaulk et al. (2013) also noted that DFO (B. Sjare) was tracking seals in the area and the data suggested that ringed seals moved in and out of Lake Melville from other areas of coastal Labrador over the course of the ice-free period. While they are relatively abundant in Lake Melville in the winter, they are uncommon in Goose Bay based on surveys completed since 2006. Based on this available information, it is assumed that ringed seals captured and consumed from Lake Melville spend 66% of their time feeding there. An estimated 34% of their annual feeding would occur outside Lake Melville and therefore outside any exposure to increased water MeHg concentrations.

2.3 Predicted Increases in Fish MeHg Concentrations

Based on the predicted increases in MeHg concentrations in water within the three estuary zones (see **Table 2-1**) and the estimated time of exposure for key species (see **Table 2-2**), increases in fish MeHg muscle tissue were predicted (**Table 2-3**) using the product of the cumulative annual exposure to water predicted to have relative increases in MeHg concentration. Ringed seal liver tissue increases are also provided as this has also been identified as an important diet item (Calder et al. 2016; Dillon 2016). Note that the correlation between the increase in MeHg concentration in water and the increase in prey species concentration is assumed at a 1:1 ratio. This is a conservative assumption but acknowledges uncertainty in attempting to rationalize or justify a lower increase ratio relative to water. This also follows the assumption made in the Calder et al. (2016) paper, therefore comparisons to relative increases between the two can be considered. For species that do not feed within an area of Goose Bay / Lake Melville that is affected by methylmercury exported from the reservoir (i.e., within the zones of exposure), methylmercury concentrations will not change.

As stated previously, brook trout would remain near their home stream but would feed within the estuary environment once reaching the age of three. Since they would not migrate between each of the estuary zones, three separate predicted increases are provided; one for each zone where brook trout may be captured for consumption. As expected, brook trout are predicted to increase more in zones closer to Muskrat Falls. The predicted increases in brook trout tissue during the peak of MeHg in water (three-year max) are 78%, 25%, and 20% in Goose Bay, West Lake Melville, and East Lake Melville respectively.

Based on life history for rainbow smelt as described above and the relative increases in MeHg concentrations in water, the predicted increases during the peak of MeHg in water (three-year max) are 112%, 50%, and 46% in Goose Bay, West Lake Melville, and East Lake Melville respectively. These values are the weighted mean of the portion of time spent feeding in Goose Bay and each of the zones in Lake Melville (see Table 2-2). As noted above, we have assumed that the percent increase in water would ultimately be translated into a similar increase in biota concentrations of key species.

Based on the available life history information, it was assumed that ringed seals captured and consumed from Lake Melville spend 66% of their time feeding there with 34% of their time outside Lake Melville. It was also assumed that seals would freely move between the whole area of Lake Melville, therefore their predicted increase in MeHg would be the weighted mean of the two Lake Melville zones (equal exposure of 33% feeding time in each zone). The predicted increases during the peak of MeHg in water (three-year max) is therefore 21% throughout Lake Melville.

As shown, predicted increases are between 20-112% based on species habitat use and MeHg increases in each of the identified zones. It is critical that the role of life history, habitat, migratory habits, distribution and ecology interact with hydrodynamics to play a critical role in exposure of key species (rainbow smelt, brook trout, ringed seal) to increased MeHg concentrations exported from the Muskrat Falls reservoir. These predicted increases will be incorporated into exposure estimates within the Human Health Risk Assessment (HHRA).

Table 2-3: Summary of predicted increases in MeHg muscle tissue concentration in brook trout, rainbow smelt, and ringed seal

Species	Goose Bay			West Lake Melville			East Lake Melville		
	Predicted MeHg Increase	Baseline MeHg	**Predicted MeHg Conc (mg/kg)**	Predicted MeHg Increase	Baseline MeHg	**Predicted MeHg Conc (mg/kg)**	Predicted MeHg Increase	Baseline MeHg	**Predicted MeHg Conc (mg/kg)**
Brook Trout[a]	1.78x	0.07	**0.125**	1.25x	0.04	**0.050**	1.20x	0.03	**0.036**
Rainbow Smelt[b]	2.12x	0.02	**0.043**	1.50x	0.02	**0.030**	1.46x	0.04	**0.058**
Ringed Seal Tissue[a]	1.32x	-	**-**	1.21x	0.13	**0.157**	1.21x	0.13	**0.157**
Ringed Seal Liver[a]	1.32x	-	**-**	1.21x	13.42	**16.24**	1.21x	13.42	**16.24**

[a] mean MeHg tissue concentrations from 2017 samples.
[b] mean MeHg tissue concentrations from 2016 samples.

3.0 CLOSURE

The biological and habitat use data presented within this report has been compiled using baseline data collected by Wood and others since 1998. The methodologies used to collect and generate the data are generally accepted practices described in detail within the EEM and the Fish Habitat Compensation Plan baseline studies, and have been used for studies within the lower Churchill River, as well as other projects throughout Newfoundland and Labrador.

Yours truly,

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Appendix A – Aquatic Species Habitat Overview, Churchill River, Goose Bay and Lake Melville, 1998-2016

Appendix B – Summary of Isotope and Stomach Data, Goose Bay / Lake Melville

Aquatic Species Habitat Utilization Overview

Churchill River, Goose Bay, and Lake Melville
1998-2016

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0	16/03/2017	Draft for review	J McCarthy	M Gosse	D Robbins / P Madden
1	2/02/2018	Draft submission to IEC for review and Calder incorporation	J McCarthy	D Robbins	
2		Draft submission to Nalcor	J McCarthy	M Gosse	JB Dempson
3	12/07/2018	Revised and appended to Tech memo	J McCarthy	D Robbins	P Madden

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1.0 INTRODUCTION

Nalcor Energy (Nalcor) is developing the remaining hydroelectric potential of the lower Churchill River through hydroelectric generating facilities at Muskrat Falls and Gull Island. The Muskrat Falls portion of the project, which is currently under construction, will result in the creation of a reservoir with a surface area of 101km^2. The existing river within the proposed footprint of the Muskrat Falls reservoir area has a surface area of ~60km^2 therefore the area of additional terrestrial flooding will be approximately 41km^2, representing a 65-70 percent increase in the existing waterbody surface area.

Many freshwater, estuarine, and marine fish species are within the project's zone of influence and could therefore be affected either directly or indirectly. Much of the baseline data required for the Environmental Assessment and Environmental Effects Monitoring (EEM) program described these species, their potential for interaction with the project, as well as the estimation of potential effects. Interactions between the project and local residents through downstream methylmercury uptake by various species have been modeled and included in Nalcor's Human Health Risk Assessment (HHRA) (Dillon 2016). Simultaneous to this, additional assessments of mercury increase and potential human effects have been published (see Schartup et al. 2016; Calder et al. 2016).

1.1 Purpose

The purpose of this document is to provide additional species summary information related to the species identified within the HHRAs. This information will be helpful in ongoing discussions with local communities and further analysis of potential human risk. The species habitat use information included by this dataset has been used to modify potential species methylmercury exposure related to project effects, both within and downstream of the reservoir.

2.0 STUDY AREA

Figure 2-1 provides a general overview of the Churchill River watershed and the various study regions (e.g., Smallwood Reservoir, Muskrat Falls Reservoir, lower Churchill River, Goose Bay, Lake Melville) where sampling has occurred.

Nalcor has collected baseline data since 1998 on the lower Churchill River, Goose Bay, and Lake Melville. Included in this baseline data are the ongoing results of total mercury concentrations in fish and seal samples. There has also been additional sampling and analysis prior to 1998 as a result of monitoring/research related to the larger Churchill Falls Hydroelectric Development located upriver that was completed in 1974. Fisheries and Oceans Canada (DFO) have also collected data on the Churchill River (e.g., Ryan 1980, Anderson 2011) and this has also been incorporated into this baseline description, where possible.

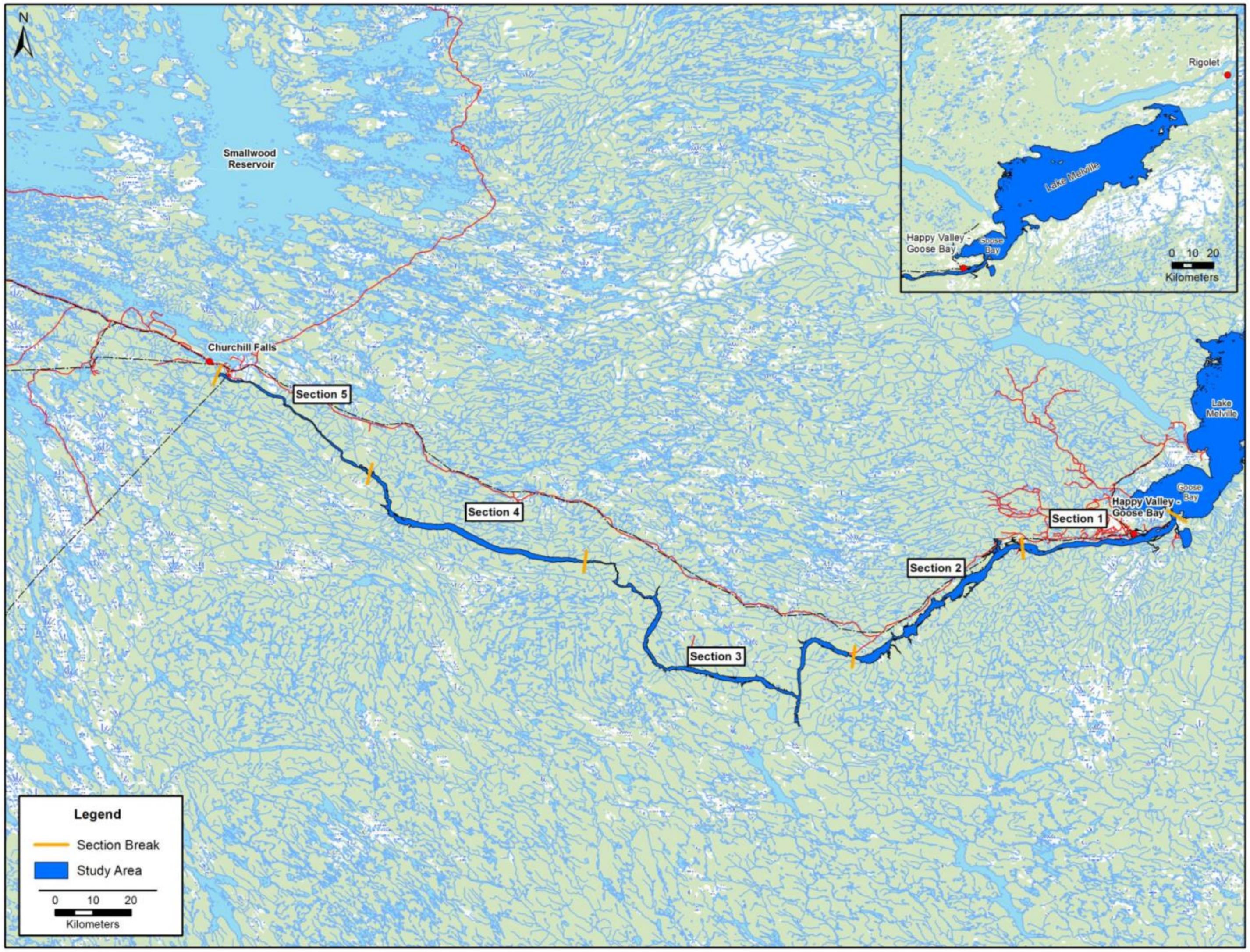

Figure 2-1: Overall baseline study area: mainstem of the lower Churchill River, Goose Bay, and Lake Melville.

Most sampling within the lower Churchill River between the existing Churchill Falls facility and Goose Bay was completed and catalogued by larger river sections with similar habitat conditions. A brief overview of each study section is provided below. Detailed habitat characterization is provided in various reports issued by Nalcor (e.g., AGRA 1999, AMEC 2001, AMEC 2013a). Sampling specifically associated with the Muskrat Falls portion of the Project has been concentrated both within the Muskrat Falls Reservoir Area (Section Two) and downstream of Muskrat Falls. Downstream of Muskrat Falls includes the lower section of the river to English Point at its outflow to Goose Bay Estuary (Section One) as well as Goose Bay Estuary and Lake Melville (Figure 2-1).

The riverine portions of the study area have been sampled much more intensely than the estuarine areas of Goose Bay and Lake Melville; however, these areas have been expanded upon since 2013 and now include fish sample locations just west of Rigolet. The river above the Muskrat Falls Reservoir area (Sections Three, Four and Five) have also been sampled but to a lesser extent.

2.1 Goose Bay and Lake Melville

Lake Melville is a tidal lake/fiord containing brackish waters located at latitude approximately 54° North, along the Labrador coast. Its length is approximately 130km, with a width of 30km near its western end and a maximum depth in excess of 180m. Included within Lake Melville is “The Backway”, an arm of the lake extending for approximately 30km from the eastern boundary with depths again over 180m (Bobbitt and Akenhead 1982).

A large portion of the Labrador Plateau (Ungava Peninsula) drains into Lake Melville, with the largest watershed feeding it being the Churchill River, which flows into Lake Melville via Goose Bay Estuary. Goose Bay is a western extension of Lake Melville, situated at its southwest corner and extending for 25km. Goose Bay is approximately 55m deep and connected to Lake Melville by a 2.5km wide, 6m deep channel known as the Goose Bay Narrows (Bobbitt and Akenhead 1982; AMEC- BAE Newplan 2001).

Freshwater input from several rivers, plus the deep basins of Goose Bay and Lake Melville, form a layered saline system with freshwater tending to flow seaward at the surface and saline coastal waters entering the inlets in deeper layers (Bobbitt and Akenhead 1982; Schartup et al. 2016). The thin surface water layer, typically with salinities of less than 10, mixes very slowly in Lake Melville. The salinity changes to approximately 25 below a very sharp halocline at approximately 25m water depth. The mixing and exchange of water will depend on the density (salinity) of the water at the sill depth. Shallow sills at the Lake Melville Narrows (near Rigolet at the mouth of Lake Melville) and at the mouth of Goose Bay, significantly restrict water movement, resulting in a tidal range within Goose Bay of 0.3 to 0.6m, compared to 1.2 to 1.8m along the coast (Bobbitt and Akenhead 1982).

The water in Goose Bay and Lake Melville is warmer than on the Labrador shelf at comparable depths as the sill depth at the Narrows to Lake Melville prevents the colder shelf water from entering the lake (Bobbitt and Akenhead 1982). Temperatures recorded in the thin surface layer of Lake Melville have been up to 15°C, whereas the surface water on the Labrador shelf is typically only slightly above 5°C. Below the sharp thermocline in Lake Melville, the water is close to -0.5°C, whereas on the shelf there is a core of -1.5°C water between 50 and 100m (Vilks and Mudie 1983). Similar temperature patterns have been observed in Goose Bay, as illustrated by the results of conductivity, temperature, depth (CTD) water profiles (AMEC- BAE Newplan 2001).

Prior to development of the Churchill Falls Generating Facility, the Churchill River contributed 50-80% of the total freshwater inflow to Goose Bay. During winter, most of the water in the Labrador Basin (drainage basin feeding the Churchill River) would freeze and cause a drastic seasonal decrease in fresh water inflow (Coachman 1953 in Bobbitt and Akenhead 1982). Since the Churchill Falls Generating Facility development, there has been a notable change in the freshwater inflow into Goose Bay Estuary. The greatest difference occurs in the winter, December to April, where the flow rates have approximately tripled, whereas during June and July, rates have decreased by about a third (Bobbitt and Akenhead 1982).

Glaciomarine mud, comprising clay, silt and some fine sand, is the dominant sediment deposited in the Goose Bay Basin. At the outlet of the Churchill River into Goose Bay, a large semi-submerged delta comprised of sand, silt and clay has formed from the erosion activities upstream. Sieve analysis has demonstrated that the depositional sequence has the heavier sand remaining close to shore with progressive deposition of finer material further out into the basin, with the very fine clays being carried out into Lake Melville (Amec-BAE 2001).

2.2 River Section One

Section One of the river is approximately 43 km long and includes the freshwater main stem between the mouth of the river (English Point) at Goose Bay Estuary and Muskrat Falls (Figure 2-2). The segment is relatively slow flowing (mean water velocity of 0.5m/s), deep (mean water depth of 9.1m), wide (mean width of 1,561m) and a bottom substrate composition almost entirely of mobile sand and smaller material. The surficial geology of the material is fluvial and/or eolian in nature (Minaskuat 2008). The shoreline in some sections is lined/armoured with larger material such as rubble, cobble and boulder, which has been exposed by shoreline erosion (AMEC 2013a).

Acoustic Doppler Current Profiler (ADCP) testing of the river bottom substrate for bed movement near the Trans Labrador Highway's Black Rock Bridge indicates that the substrate is mobile (AMEC 2009). This would make this river section a challenge for benthic macroinvertebrate and fish species that rely on stable, larger substrate particularly for cover and spawning. This river segment is also very rich in suspended sediments compared to those further upriver and currently experiences considerable variation in Total Suspended solids (TSS) concentrations. Suspended sediment concentrations have been recorded from <2 to 1570mg/L within this area, with a mean of approximately 66mg/L. Highest concentrations are typically measured during late winter and spring when runoff from the watershed typically increases (Minaskuat 2007; Amec Foster Wheeler 2016a). The sandy substrate also results in naturally increased turbidity.

Larger tributaries draining into this section include Caroline Brook and the Traverspine, Peter Jackies and McKenzie Rivers.

Figure 2-2: Typical shoreline and bottom substrate, Section One Churchill River.

2.3 River Section Two (future Muskrat Falls Reservoir Area)

Section Two of the river is approximately 58 km long and includes the main stem between Muskrat Falls and Gull Island (i.e. the proposed Muskrat Falls reservoir location). This segment is also relatively slow flowing compared to other river sections (estimated mean water velocity of 1.3m/s), shallow (estimated mean water depth of 6.0m), wide (mean width estimated at 1,030m), and a bottom substrate composition dominated by sand and finer material (85% sand). While ADCP tests for bottom movement have not been conducted within this river section, similar substrates and slightly higher velocities would indicate that a similar substrate dynamic to that in Section One would be present. Similar to Section One, the surficial geology of the material is primarily fluvial and/or eolian in nature (Minaskuat 2008). Figure 2-3 presents typical shoreline and substrate conditions in this river section. Similar to habitat below Muskrat Falls, this section is also very rich in suspended sediments compared to those further upriver. In particular, suspended sediment concentrations have been recorded from <2 to 1170mg/L within this area, with a mean of approximately 42mg/L. Highest concentrations were measured during late winter and spring when runoff from the watershed typically increases (Minaskuat 2007; Amec Foster Wheeler 2016a). These lower reaches of the river are also primarily comprised of sandy substrate, resulting in naturally increased turbidity.

While the majority of the river segment is shallow, Gull Lake is relatively deep (greater than 50m). Gull Lake is also maintained by the same frazil ice process as that described above for the pool below Muskrat

Falls. In this respect, it too contains limited winter refuge for fish as it is filled with ice and velocities greater than that typically found in a large pool.

The most complex ice processes in the Churchill River generally occur between Gull Island and Goose Bay (Hatch 2007). The portion of the Churchill River downstream of Gull Island to Muskrat Falls typically has enough water velocity to prevent an ice cover from forming, except for border ice, and stationary ice covers at the slow-flowing stretches at Sandy Island Lake and Gull Lake (Hatch 2007). The open fast-flowing water generates large amounts of frazil, slush and pan ice, which are then carried downstream. Below Muskrat Falls, the drifting ice becomes trapped under the edge of a stationary ice cover which forms between Muskrat Falls and Goose Bay typically by the end of November. This causes a massive ice jam, backing up the river flow, raising the upstream water level and decreasing velocity. In some years this permits an ice cover to develop and progress upstream (Hatch 2007). During spring breakup, the ice cover upstream of the jam is rapidly eroded by the fast-flowing water, but the jam takes longer to melt away. On average, the ice is completely broken up by the end of May (Hatch 2007).

Larger tributaries emptying into this main stem section include Edward's Brook, Lower Brook, Upper Brook and Pinus River.

Figure 2-3: Typical shoreline and bottom substrate, Section Two Churchill River.

2.4 River Section Three

Section Three is approximately 119 km long and begins to flow through bed material that is primarily upriver of the heavy marine sand deposits found throughout the lower sections. The surficial geology of the river bed and shoreline material is more colluvial and/or glaciofluvial in nature (Minaskuat 2008). This segment is faster flowing (estimated mean water velocity of 1.9m/s) with similar water depths (estimated mean water depth of 8.2m) to previous sections. The estimated mean width is narrower (293m) as a result of less-erodible shoreline material. The bottom substrate composition in this section is dominated by larger material such as boulders, rubble and cobble. Figure 2-4 presents typical shoreline and substrate conditions in this section of river. As expected with a reduced source of finer material, TSS in this river section is much reduced in relation to that measured further downriver. Sample measurements have ranged between <1 and 39mg/L with a mean of approximately 6 mg/L (Minaskuat 2007; Amec Foster Wheeler 2016a).

Open water persists through the winter between Winokapau Lake and Gull Lake. Ice pans are transported as far as Gull Lake where they become trapped at an ice jam formed at a stationary ice cover (Hatch 2007).

Larger tributaries emptying into this main stem section include Bob's Brook, Minipi River, Beaver Brook, Cache River and Shoal River.

Figure 2-4: Typical shoreline and bottom substrate, Section Three Churchill River.

2.5 River Section Four (Winokapau Lake)

Section Four consists of Winokapau Lake which is approximately 46km long and approximately 1,266m wide. The shoreline of the lake is generally very steep and consisting of bedrock. In terms of littoral habitat, most is located at the inflow (near Elizabeth River), outflow and around a small spur of land on the north side of the lake (named Long Point). The littoral material in these areas generally consist of gravel-sized substrate and larger. The maximum water depth of Winokapau Lake is over 200m and hence the flow through the segment is slow. The thermocline within the lake, when one forms, is near 25m water depth. The estimated mean water velocity is 0.03m/s. The bottom substrate composition in this section is predominantly silt with some sand and clay material. Winokapau Lake bottom sediment contains higher concentrations of trace elements, nutrients and carbon compared to the rest of the river (Minaskuat 2007). Overall, sediment quality is good throughout the river, and only nickel concentrations in portions of Winokapau Lake exceeded Sediment Quality Guidelines for the Protection of Aquatic Life probably effect level (PEL), or other relevant benchmark values (Minaskuat 2007). Figure 2-5 presents typical shoreline and substrate conditions in this section of river. As expected with a reduced source of finer material, TSS in this river section is much reduced in relation to that measured further downriver. Sample measurements range between <5 and 7mg/L (Minaskuat 2007).

Figure 2-5: Typical shoreline substrate, Section Four Churchill River.

Lake Winokapau is normally covered by a stationary ice cover from November through to the end of May. This ice cover typically melts in place (Hatch 2007).

The only large tributary that empties into this main stem section is Fig River.

2.6 River Section Five

Section Five is approximately 70 km long and begins at the inflow of Winokapau Lake and extends upriver to the tailrace of the Churchill Falls Generating Facility. The river flows through a single, straight channel, passing through a narrow valley approximately 300m below the surrounding uplands. Similar to Section Three, the river flows over bed material that is primarily upriver of the heavy marine sand deposits found throughout the lower sections. The surficial geology of the river bed and shoreline material is more colluvial and/or glaciofluvial in nature (Minaskuat 2008). This segment is similar in estimated mean water velocity as Section Two (estimated mean water velocity of 1.1m/s) but has similar estimated mean water depths (8.4m) to that of Section Three (i.e. deeper than Section Two). The estimated mean width is 438m, similar to Section Three, as a result of similar shoreline material. The bottom substrate composition in this section is dominated by material such as rubble and cobble. Figure 2-6 presents typical shoreline and substrate conditions in this section of river. As expected with a reduced source of finer material, TSS in this river section is much reduced in relation to that measured further downriver. Sample measurements range between <5 and 9mg/L (Minaskuat 2007).

Figure 2-6: Typical shoreline and bottom substrate, Section Five Churchill River.

Upstream of Winokapau Lake, the river is mostly ice covered from November to April. Open water patches have been observed in the upper end of the reach closest to the Churchill Falls Generating facility, likely due to residual heat in the generating station discharge (Hatch 2007).

Larger tributaries emptying into this main stem section include Elizabeth and Metchin Rivers.

2.7 Churchill Falls Hydroelectric Development (Smallwood Reservoir)

Upriver of Section Five is the Churchill Falls Hydroelectric Development; approximately 240km upriver from Muskrat Falls. The Churchill Falls Hydroelectric Development includes the Smallwood Reservoir system that was flooded between 1971-73. The total area of the Smallwood reservoir is estimated at 5,000 km^2 and includes approximately 2,450 km^2 of unharvested forest, bog, and taiga (Anderson 2011). Approximately 75% of all flow from the lower Churchill River comes from the Smallwood Reservoir (Anderson 2011). Water levels within the Smallwood Reservoir typically fluctuate by three metres annually with an overall range of approximately nine metres (CFLco, unpublished data).

This area has been studied to a lesser extent in recent years; however, sampling of select fish species was completed in 2017 and will be included in the ongoing database when available.

3.0 SAMPLING METHODS

Within most of the study area, sampling for species presence, relative abundance, and population metrics has primarily been completed using a combination of live-capture fyke nets, gillnets, electrofishing, and night snorkeling. Complete descriptions of the methods are available in the Lower Churchill Hydroelectric Generation Project Aquatic Environmental Effects Monitoring (EEM) Program; Muskrat Falls (AMEC 2013a). In addition to methods carried forward during the baseline EEM program, beach seining and otter trawls were completed in 1998 within Goose Bay Estuary and Lake Melville (JWEL 2001). In addition, it is noted that radio telemetry tracking of several species within the lower Churchill River was also completed (JWEL 2000) and relevant movement information has been provided within species overviews.

3.1 Fyke Nets

In the anticipation of a long-term monitoring program associated with the project, a shift in primary sampling method was necessary. During the 2013 sampling program, fyke nets, a live capture sampling method, became the predominant technique employed throughout the riverine habitats included in the Lower Churchill Project's aquatic monitoring programs. Prior to the 2013 program, experimental gillnets were the primary sampling technique (see Section 3.2).

Fyke nets are a form of passive sampling, which is generally non-destructive, meaning the majority of fish captured can be live released following processing. Processing includes the collection of lengths, weights and identification to species. Fyke nets used for this program are the double-bag type that have been manufactured specifically for the program so that are all similar dimensions and sampling gear remains consistent from year to year.

As a means of reducing sampling bias, fyke nets are set in random locations; chosen through GIS. Typically, each is set in relatively shallow water habitats (less than two metres water depth) and secured to shore; however, they have been deployed at variable depths. The lead lines and traps are deployed perpendicular to the shoreline. Depending on the strength of the flow and current, they may be set in the lee of small islands or points within the larger main stem. The lead lines and the traps sit on the bottom and range in height between 0.5-1.5m therefore they sample moving fish both along the bottom and within the water column. Fyke nets are generally set (e.g., a net-night) for at least a 16-hour duration, which will encompass the dusk to dawn period, when fish movement is generally more prevalent. Sampling during these times has been consistent throughout the sampling program since 1999 when this gear type was first included.

3.2 Gillnets

As outlined in the EEM Program (AMEC 2013a), fyke nets have become the primary sample technique to monitor fish within the riverine habitats throughout the Lower Churchill River. Since 2013, gillnets have only been included as a means of augmenting fish collection for mercury analysis. Gillnets remain the primary sampling technique employed in Goose Bay and Lake Melville due to the need for mercury samples and the physical habitat limitations of each sampling area.

Scientific gillnets comprise a series of six separate panels each of different gillnet mesh size ranging from 13mm (0.5 inch) to 127mm (5 inch). As a means of reducing bycatch of non-target species outlined in the EEM Program, the two smaller panels (13mm and 25mm) were removed from gillnet sets prior to deployment since 2015. Similar to fyke nets, gillnets are typically set (e.g., a net-night) for at least 16 hours to cover the dawn and dusk periods. Data collected included those similar to fyke nets, and included the collection of mercury samples and various samples related to fish health monitoring. Gillnets have been used to collect data since 1998 related to the Lower Churchill Hydroelectric Development but have also been used in the Churchill River system since the Smallwood Reservoir was created in 1974.

3.3 Electrofishing

Electrofishing is a standard sampling method that provides data on fish habitat utilization, species presence/absence and standing stocks. The primary limitation with electrofishing is the habitat types where it is most suitable; smaller and shallower streams and deltas where barrier nets can be established and wading with the electrofishing unit is possible. As a result, this method is best suited to tributary deltas and streams.

Standard quantitative electrofishing stations are completed in the lower Churchill River at select sites as outlined in previous surveys. In addition to quantitative stations, index sites (standard 300 second sweeps) are also completed to provide greater overall sample coverage for fish species utilization and presence. Stations are completed during late summer (August-September) as per existing sampling so that values are comparable between sample years. In order to maintain consistency within datasets from year to year, population and biomass estimates are also normalized to one habitat unit (100m^2).

3.4 Snorkel Surveys

Electrofishing and other passive sampling methods (e.g., fyke nets) generate very useful data in terms of the overall utilization of fish life-cycle stages within various habitat types but they do not provide data on whether each species life-cycle stage is utilizing specific habitat features such as a particular substrate size, velocity or water depth. This may be particularly useful in determining specific habitat use as well as the number of fish observed within that habitat. Snorkel surveys are a useful method to determine species presence and habitat use within specific nearshore habitat types. The method employed has been developed for larger river systems (Hagen et al. 2004) and has been used in other monitoring programs in the province such as Granite Canal (AMEC 2008) and Northeast River (AMEC 2012).

Snorkel surveys are most accurately completed during night (sun down) as fish are startled less by divers and are less likely to move to cover (Hagen et al. 2004). Experienced biologist(s) snorkel slowly along established habitat transects and enumerate the fish species life-cycle stages observed as well as the habitat they are using. Each snorkel location is 350m in total length and is divided into 25m transects.

3.5 Beach Seine

A beach seine is used to sample nearshore habitats and is particularly useful for sampling over slightly cobbled substrates. Beach seining was completed in Goose Bay and Lake Melville by JWEL (2001). Typically, the seine was deployed from a boat, and covered an area of 73.2m^2. Two seines were completed in each identified sampling location. Beach seining has not been completed in subsequent sampling programs.

3.6 Otter Trawl

The otter trawl is a boat-deployed trap that is 5m in diameter and effective over a wide variety of substrates, ranging from clay to small boulders in 3-100m water depth (JWEL 2001). Otter trawls were used in Goose Bay and Lake Melville. Each tow was completed along consistent habitat types, maintaining a particular depth interval. Once the trawl was deployed, the boat maintained a speed of 2 knots and each transect was a total of five minutes duration. Each trawl was capable of sampling an area of 927m^2 during a five-minute tow (JWEL 2001).

4.0 SAMPLING EFFORT

As stated previously, sampling efforts by Nalcor have been ongoing since 1998 and both sample coverage and effort has been extensive. To assist in putting the fish relative abundance numbers in perspective, the overall effort within each habitat is provided in Table 4-1 below.

Table 4-1: Summary of sampling effort by location and dominant gear types, 1998-2016.

Gear Type	Muskrat Falls Reservoir Area	Churchill River below Muskrat Falls Reservoir Area	Goose Bay Estuary	Lake Melville
Fyke Net (net-nights)	453	651	6	14
Gillnet (net-nights)	54	93	29 + 36[1]	21 + 36[1]
Electrofishing (stations)	57	11	na	na
Snorkel Survey (transects)	342	56	na	na
Beach Seine (stations)	na	na	12[1]	24[1]
Otter Trawl (5 min hauls)	na	na	21[1]	21[1]

[1] Sample effort completed in 1998 by JWEL (see JWEL 2001). Provided as separate effort to assist in species overviews within the text.

5.0 SPECIES OVERVIEW

In total, the baseline sampling program for the Lower Churchill Hydroelectric Development, which includes Muskrat Falls, has sampled over 15,600 fish from approximately 29 different species between 1998-2016. By study location;

- 2,285 fish from 15 species have been captured upriver of the Muskrat Falls Reservoir Area (efforts were concentrated in 1998, 1999, 2000, 2006, and 2010 only);
- 3,323 fish from 15 species have been captured in the future Muskrat Falls Reservoir Area;
- 3,212 fish from 13 species have been captured in the lower Churchill River below Muskrat Falls;
- 4,122 fish from 23 species have been captured in Goose Bay Estuary; and
- 2,690 fish from 19 species have been captured in Lake Melville.

Tables 5-1 to 5-3 and Figures 5-1 to 5-3 present relative abundance estimates for each fish species captured within Section Two (what will become the Muskrat Falls reservoir area) and Section One (below Muskrat Falls) of the lower Churchill River as well as Goose Bay, and Lake Melville, respectively (most upstream to downstream). Table 5-4 and Figure 5-4 provide supplemental fyke net results from Goose Bay and Lake Melville completed in 2016. Outer Lake Melville is a sample area near in the eastern portion of the lake near Valley Bight (see Figure 5-5). Estimates of Catch-Per-Unit-Effort (CPUE) for other sections of the river are available in baseline reports (e.g., AGRA 1999, AMEC 2000, 2007). It should be noted that most sampling has occurred during ice-free conditions between June and October and therefore species distribution during the spring ice break up and winter are likely underrepresented. For brevity, the most utilized and effective sampling method for each sample area has been presented below. Summaries of all methods are provided in the 2016 Baseline Report (Amec Foster Wheeler 2016a).

Table 5-1: Summary of mean fyke net CPUE in the mainstem below Muskrat Falls (Section One), 2006 through 2016, Fall sampling

Species	2006-2014		2015		2016	
	Relative abundance CPUE[1]	Biomass CPUE[2]	Relative abundance CPUE[1]	Biomass CPUE[2]	Relative abundance CPUE[1]	Biomass CPUE[2]
Brook Trout	0.08	9.73	0.05	20.37	0.03	5.88
Burbot	0.03	13.84	0.03	40.00	0.03	28.41
Lake Chub	0.72	4.74	1.15	8.10	0.57	6.39
Lake Whitefish	0.02	1.89	0.02	0.03	0.02	0.18
Longnose Dace	0.14	0.32	0.05	0.12	0.05	0.21
Longnose Sucker	0.85	102.76	1.43	60.72	0.48	33.08
Northern Pike	0.09	4.03	0.05	1.76	0.30	28.77
Rainbow smelt	0.00	0.00	0.00	0.00	0.02	0.32
Round Whitefish	0.00	0.00	0.10	10.48	0.00	0.00
Sculpin	0.07	0.18	0.22	0.65	0.13	0.27
Stickleback[3]	3.07	5.87	7.90	16.80	6.18	18.01
White Sucker	0.59	105.14	0.58	68.11	0.48	65.26
Total	5.65	248.48	11.58	227.14	8.30	186.76

1 Relative abundance CPUE expressed as fish/net-night

2 Biomass CPUE expressed as grams/net-night

3 Threespine Stickleback

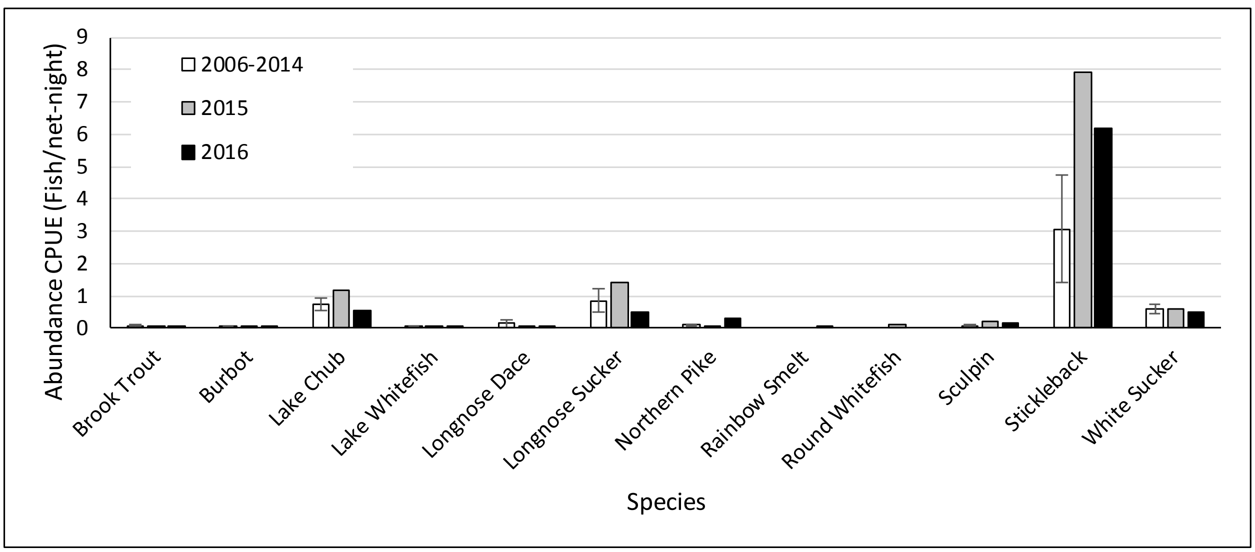

Figure 5-1: Fyke net relative abundance CPUE (fish/net-night) in the mainstem below Muskrat Falls (Section One), 2006 – 2016, Fall sampling (bars present the standard error of the mean CPUE from 2006-2014)

Table 5-2: Summary of mean gillnet CPUE in the Goose Bay, 1999 through 2016

Species	1999-2014		2015		2016	
	Mean Relative abundance CPUE[1]	Mean Biomass CPUE[2]	Mean Relative abundance CPUE[1]	Mean Biomass CPUE[2]	Mean Relative abundance CPUE[1]	Mean Biomass CPUE[2]
Atlantic herring	0.08	23.50	0.00	0.00	0.00	0.00
Brook trout	13.68	3388.07	3.00	487.60	1.33	362.67
Lake chub	5.47	95.29	5.50	86.40	0.00	0.00
Lake whitefish	0.58	197.12	0.00	0.00	0.67	366.57
Longnose sucker	44.38	3812.07	36.00	2325.95	3.67	593.33
Northern pike	0.05	0.90	0.00	0.00	0.00	0.00
Rainbow smelt	7.18	308.04	0.00	0.00	0.00	0.00
Rock cod	0.28	235.96	0.00	0.00	0.00	0.00
Round whitefish	0.13	13.81	0.00	0.00	0.00	0.00
Tomcod	3.28	197.92	1.50	21.10	0.00	0.00
White sucker	9.81	1559.80	15.50	2707.45	3.33	702.57
Winter flounder	0.05	7.28	0.00	0.00	0.00	0.00
Total	84.97	9839.75	61.50	5628.50	9.00	2025.13

1 Relative abundance CPUE expressed as fish/net-night

2 Biomass CPUE expressed as grams/net-night

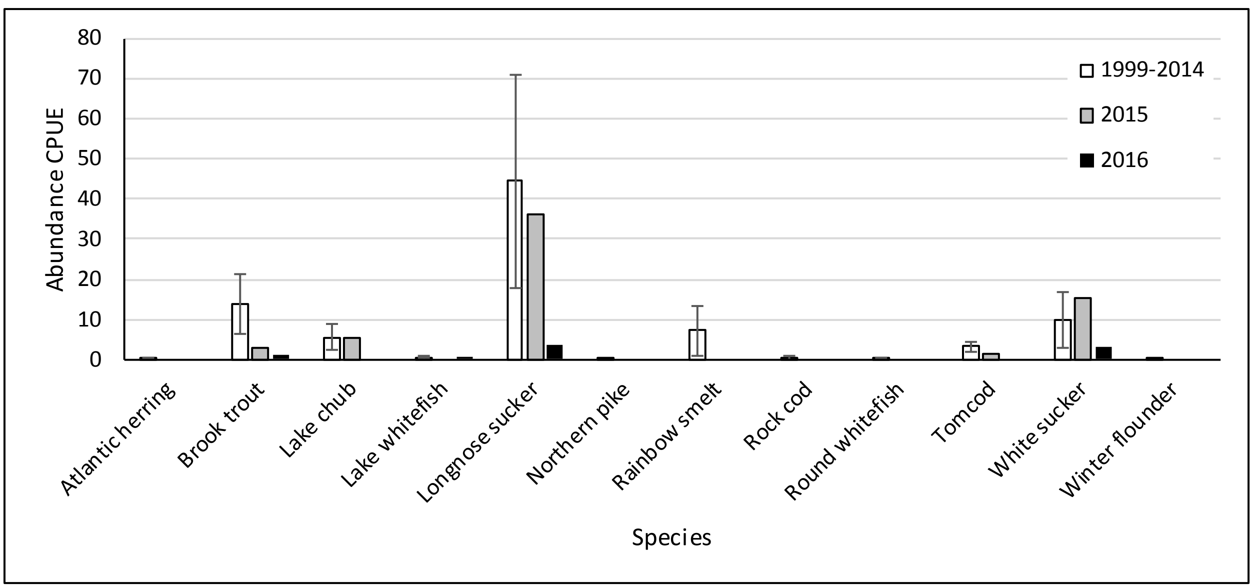

Figure 5-2: Mean gillnet relative abundance CPUE in Goose Bay, 1999 through 2016 (Error bars represent the standard error of the annual mean relative abundance CPUE from 1999-2014).

Table 5-3: Summary of mean gillnet CPUE in the Lake Melville, 2011 through 2016

Species	2011-2014		2015		2016	
	Relative abundance CPUE	Biomass CPUE	Relative abundance CPUE	Biomass CPUE	Relative abundance CPUE	Biomass CPUE
Atlantic salmon	0.00	0.00	0.25	487.50	0.00	0.00
Brook trout	16.90	4573.51	30.25	7,928.30	9.75	2487.78
Lake chub	4.52	76.20	3.00	50.38	0.00	0.00
Lake whitefish	0.58	73.66	0.50	51.18	0.00	0.00
Longhorn sculpin	0.07	0.63	0.00	0.00	0.00	0.00
Longnose sucker	15.83	1264.52	11.50	1,215.70	1.25	190.70
Rainbow smelt	5.35	225.37	4.25	114.70	0.00	0.00
Round whitefish	0.23	21.82	0.00	0.00	0.00	0.00
Tomcod	6.32	424.15	10.25	393.83	0.25	15.33
White sucker	9.43	1201.35	4.50	1,024.70	1.50	514.20
Winter flounder	1.58	87.58	0.00	0.00	0.00	0.00
Total	60.82	0.00	64.50	11,266.28	12.75	3,208.01

1 Relative abundance CPUE expressed as fish/net-night

2 Biomass CPUE expressed as grams/net-night

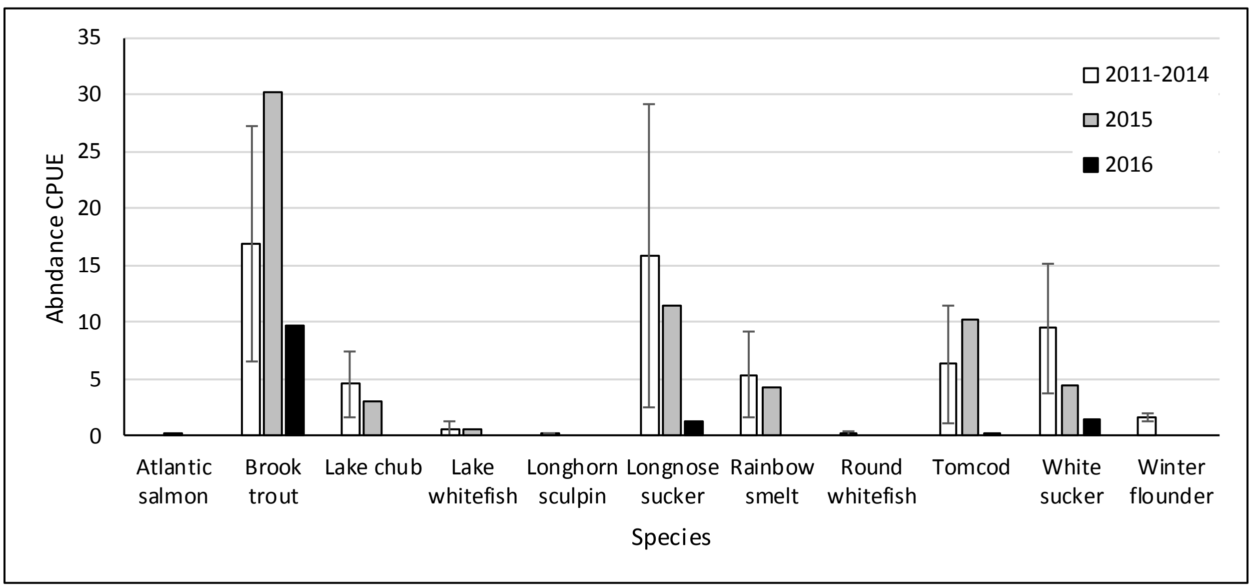

Figure 5-3: Gillnet relative abundance CPUE (fish/net-night) in Lake Melville, 2011 through 2016 (Error bars represent the standard error of the annual mean relative abundance CPUE from 2011-2014).

Table 5-4: Summary of mean fyke net CPUE in estuarine sampling areas, 2016

Species	Goose Bay		Lake Melville		Outer Lake Melville	
	Relative abundance CPUE	Biomass CPUE	Relative abundance CPUE	Biomass CPUE	Relative abundance CPUE	Biomass CPUE
Blenny	0.00	0.00	0.38	2.91	0.00	0.00
Brook trout	0.00	0.00	0.00	0.00	4.50	2344.60
Lake chub	2.33	21.90	5.63	58.93	0.00	0.00
Longnose sucker	2.50	107.08	2.00	245.96	0.50	61.35
Rainbow Smelt	0.17	1.83	2.00	25.80	17.00	194.00
Sculpin	0.00	0.00	0.13	0.86	0.00	0.00
Stickleback	2.67	5.70	6.25	15.61	0.00	0.00
Tomcod	10.50	46.20	29.13	500.34	0.00	0.00
White Sucker	0.33	47.63	2.25	529.64	0.00	0.00
Winter flounder	0.00	0.00	1.75	46.94	2.50	149.05
Total	18.50	230.35	49.50	1,426.99	24.50	2,749.00

1 Relative abundance CPUE expressed as fish/net-night

2 Biomass CPUE expressed as grams/net-night

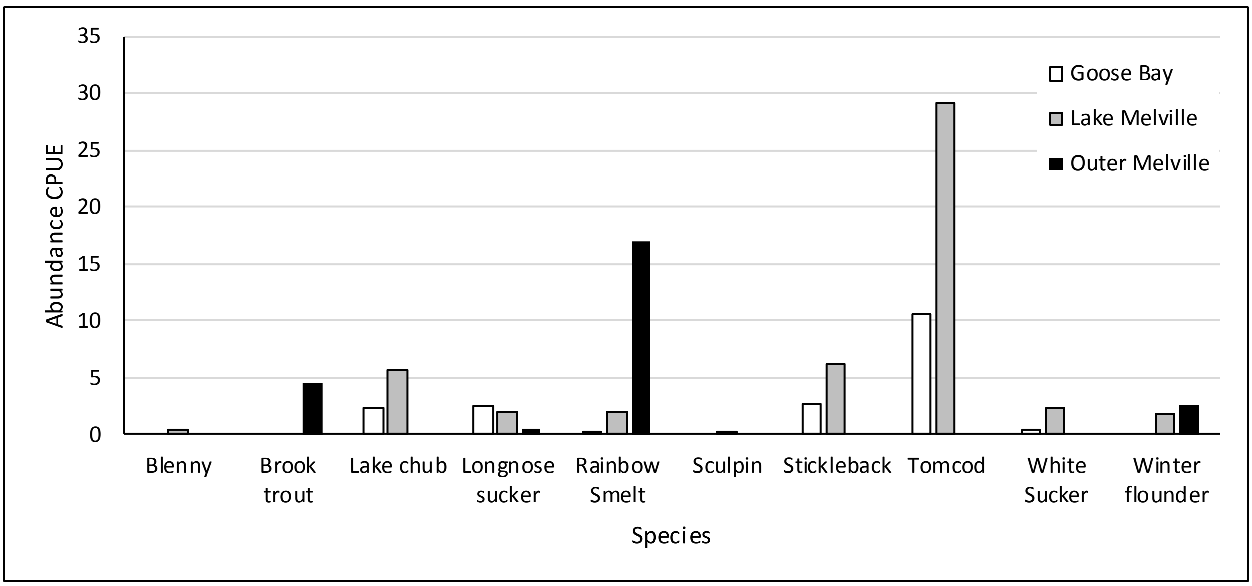

Figure 5-4: Mean fyke net Relative abundance CPUE (fish/net-night) in estuarine sampling areas, 2016

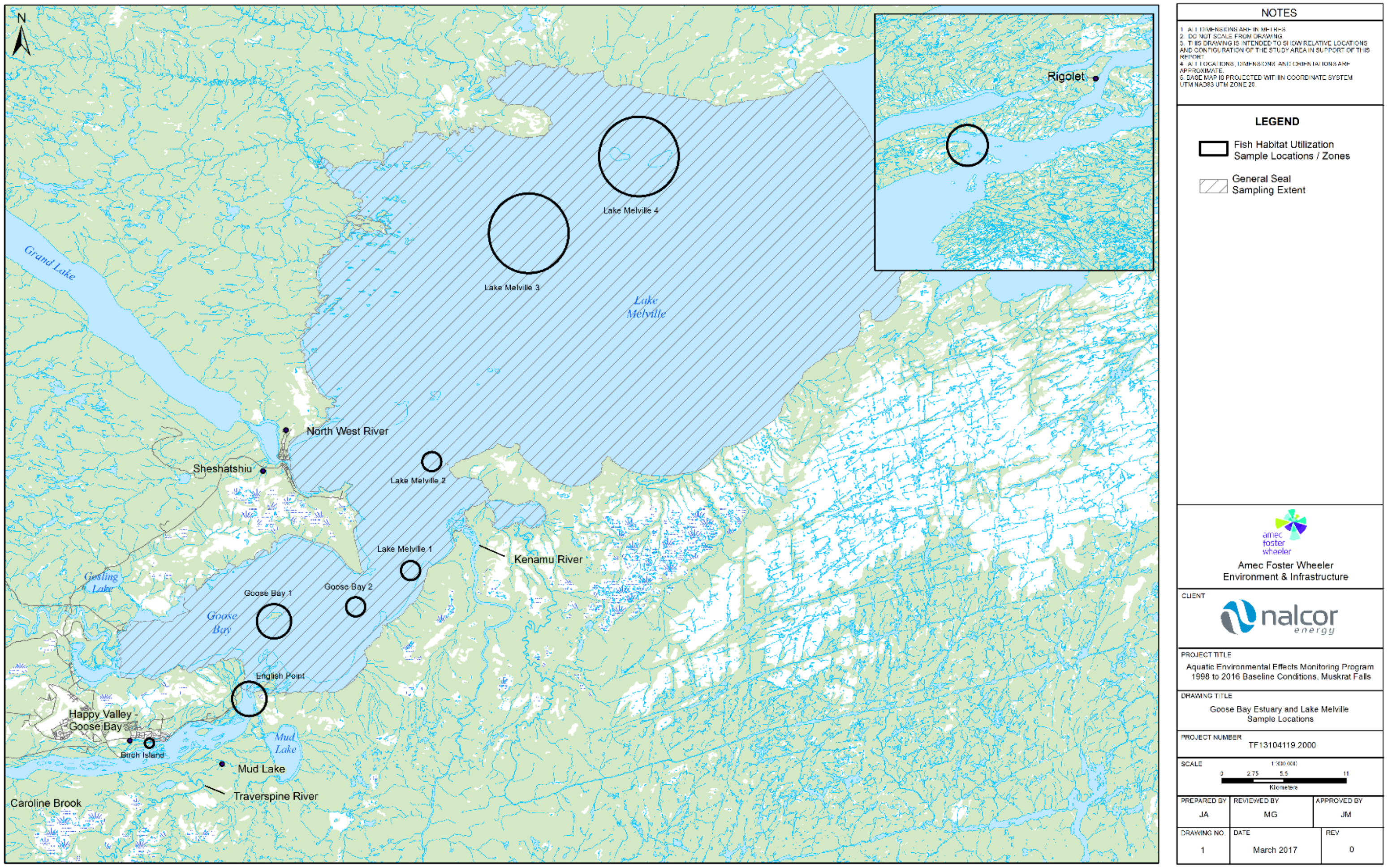

Figure 5-5: Overall EEM study area: Goose Bay estuary and Lake Melville (reproduced from AMEC 2013b).

Calder et al. (2016) recently identified top methylmercury (MeHg) exposure sources/pathways for local resource users downstream of the Muskrat Falls Project that included fish species as well as other animals. These fish species have been described in greater detail below based on Nalcor data collected since 1998. While other species have been captured in the lower Churchill River system (e.g., burbot), the species described below have been based on community fish captures listed in Table S5 (supplemental information in Calder et al. 2016), methylmercury concentrations in aquatic species harvested in the Lake Melville Region (Tables S6a and S6b in Calder et al. 2016), and Biological Accumulation Factor calculations (Tables S7a and S7b in Calder et al. 2016). The same species are input parameters to a revised mercury model being generated by Reed Harris and Associates for use in a re-analysis of the existing Nalcor HHRA.

5.1 Northern Pike (*Esox lucius*)

The northern pike has a circumpolar distribution in the northern hemisphere above 40° North latitude (Toner and Lawler 1969; Scott and Crossman 1998). Its native North American range includes Alaska, most of Canada south of the Arctic Circle, the drainages of the Missouri and Ohio Rivers, and the Great Lakes (Inskip 1982). Pike occur throughout the Churchill River system (Anderson 1985) in relatively low abundance however they occur most in the slower habitat downriver of Gull Island Rapids (i.e. Sections One and Two), with Section One having the greatest relative abundance (Ryan 1980; AGRA 1999; AMEC 2000; AMEC 2009; Amec Foster Wheeler 2016a). Specimens have also been captured at the mouths of tributaries where slower flowing delta-like habitat occurs (eg. Lower Brook, Elizabeth River, Caroline Brook and McKenzie River) (Scruton 1984; AGRA 1999; Amec Foster Wheeler 2016a; 2016b). Many of the pike captured within the mouth of McKenzie River were yearlings and one-year old juveniles (Amec Foster Wheeler 2016a). Beak (1980) also gill netted specimens on Minipi Lake and Dominion Lake and speculated that the species probably occurs on most lakes and ponds in plateau headwater systems of the lower Churchill tributaries. One northern pike has been captured in the Goose Bay estuary (live released) since 1998 and none within Lake Melville (Amec Foster Wheeler 2016a). JWEL did not capture any northern pike in Goose Bay or Lake Melville (JWEL 2001).

Northern pike are not adapted to strong currents and occur most frequently in lakes (Inskip 1982) where they inhabit backwaters and pools (Christenson and Smith 1965; Crossman 1978). In Canada, pike generally inhabit clear, slow, heavily vegetated habitat or weedy bays of lakes (McPhail and Lindsey 1970; Becker 1983; Scott and Crossman 1998) throughout all stages of their life cycle (Ford et al. 1995; Inskip 1982). They have been found over a wide range of water turbidity, although they are much more common in clear and only slightly turbid water (Becker 1983). Based on habitat utilization data and the habitat-types characterized for the lower Churchill River, highest overall utilization for northern pike tends to be within the slower water velocities of the main stem followed by littoral zone habitat of Winokapau Lake. A breakdown of habitat utilization by life-cycle stage shows that highest spawning and young-of-year utilization is within slower water velocity main stem habitat and littoral habitat of Winokapau Lake. Juvenile use is highest throughout the main stem of the lower Churchill River while adults utilize slower velocity tributary habitat and littoral zone habitat of Winokapau Lake. Northern pike were not captured in any deep-water sets within Winokapau Lake (AMEC 2001).

Northern pike have been aged up to eleven years old in the lower Churchill River. Mean length-at-age data shows they range between 104 mm in length at age one to over 930 mm at age eleven. Growth is shown as being relatively linear, although there tends to be a slight reduction in growth after age six. Growth rates determined from baseline sampling are in concurrence with historic rates provided for the lower Churchill River in Anderson (1985).

Northern pike are early spring spawners, with males and females moving into flooded vegetated areas immediately after spring thaw. They generally spawn during daylight hours in shallow, heavily vegetated floodplains of rivers, marshes, and lakes (Clark 1950; Franklin and Smith 1963; McCarraher and Thomas 1972; Scott and Crossman 1998; Bradbury et al. 1999). Adhesive eggs are attached to vegetation where they incubate for only twelve to fourteen days. The newly hatched young (6 to 8 mm in length) remain attached to the vegetation and feed on the yolk sac. After 6 to 10 days, the yolk is absorbed and the free swimming young feed heavily on zooplankton and immature aquatic insects. Within seven to ten days the juveniles begin to feed on small fish and by the time pike reach 50 mm in length, fish have become the primary diet. Baseline aquatic vegetation surveys have identified areas where suitable northern pike spawning habitat occurs. The largest of these include Birchy Creek near Goose Bay, Caroline Brook, the mouth of McKenzie River, the lower sections of Lower Brook and areas near the Metchin River.

The overall sex ratio of specimens within the lower Churchill River favored males (69%). The diet of northern pike sampled consists entirely of fish.

Northern pike were not captured, tagged or recorded below Muskrat Falls (i.e. Section One) during the 1998 migration study (JWEL 2000). Most pike were tagged and tracked in Sections Two and Four (Winokapau Lake), with most activity recorded in Section Two. During the duration of the study, the majority of the tagged northern pike remained sedentary. Primary areas included the confluence with Upper Brook and the lower end of Gull Lake. The main exceptions to this were migrations undertaken during spawning season. Migrations were generally short in nature, the longest recorded was 46.3km, and were concentrated to the mouths or lower reaches of tributaries in Sections Two (i.e. Upper Brook) and Four (i.e. Elizabeth River and small stream west of Long Point). During spawning season, pike were noted in areas consisting of slow habitat; sandy substrate with ample amounts of aquatic vegetation.

During sampling associated with the Smallwood Reservoir, highest levels in 1977-78 were recorded downstream of the reservoir with a peak total mercury level of 1.53 mg/kg for a 600mm standard length northern pike (~4x background) with significant elevated levels downstream to Gull Lake. Concentrations of mercury in northern pike within the lower reaches of the Churchill River were not significantly different from those of other Labrador lakes (Anderson 2011). Mercury concentrations from ongoing baseline data collection associated with the project are provided in **Table** 5-5.

Table 5-5: Summary of total mercury concentrations in northern pike within the baseline study area, 1999-2016

Year	Total Mercury (mg/kg)		
	Sample Size	**Mean (SE)**	**Range**
Muskrat Falls reservoir area			
1999	4	0.34 (0.10)	0.15-0.61
2010	0	-	-
2012	16	0.33 (0.03)	0.19-0.68
2013	10	0.15 (0.04)	<0.05-0.41
2014	5	0.21 (0.04)	0.10-0.30
2015	3	0.26 (0.07)	0.14-0.38
2016	23	0.18 (0.03)	<0.02-0.49
Mainstem and Tributaries Below Muskrat Falls			
1999	3	0.13 (0.03)	0.08-0.17
2010	11	0.03 (0.01)	0.01-0.08
2011	5	0.09 (0.02)	0.05-0.15
2012	7	0.08 (0.01)	0.06-0.13
2013	29	0.06 (0.01)	<0.05-0.18
2014	10	0.09 (0.01)	<0.05-0.16
2015	5	0.07 (0.01)	<0.05-0.12
2016	15	0.05 (0.01)	<0.02-0.19
Goose Bay			
2013	1	0.05	-
Lake Melville – none captured			
Eastern Lake Melville – none captured			

Note: Values below detection limits have been incorporated as the detection limit (i.e. 0.02-0.05mg/kg) to produce a conservative estimate of mean concentrations.

5.2 Arctic Charr (*Salvelinus alpinus*)

The Arctic charr has the most northerly distribution of all anadromous and freshwater salmonids. Beak (1980) reported landlocked populations of Arctic charr in both Minipi and Dominion Lakes, where they are believed to be relict from the last glaciation. While they may be present in other larger water bodies on the Churchill plateau, based on all sampling conducted, Arctic charr are not present in the main stem of the Churchill River (Scruton 1984) and have not been collected during any known sampling program in the lower Churchill River, Goose Bay, or Lake Melville (Amec Foster Wheeler 2016a). The Environmental Assessment of the project references the Innu Traditional Knowledge Committee report that indicates that Arctic char have been caught occasionally at North west point (Nalcor 2009).

Although noted in Calder et al. (2016) as being one of the top 20 food sources exposed to MeHg increases downstream of Muskrat Falls, no Arctic charr have been captured during any sampling in Goose Bay or Lake Melville (Amec Foster Wheeler 2016a; JWEL 2001). Samples included in the Calder et al. (2016) analysis were collected 20 miles East of Rigolet (see Table S5 in supplemental information) and would therefore represent a sea-run sample of unconfirmed origin.

Arctic charr were not sampled as part of any post-Smallwood mercury sampling program.

5.3 Atlantic Salmon (*Salmo salar*)

Atlantic salmon are distributed throughout the northern portion of the Atlantic Ocean from Portugal to Norway in the east, throughout southern Iceland and Greenland, and from Hudson Bay to the Connecticut River in the west (Scott and Crossman 1998). In Canada, the anadromous form is distributed throughout eastern Quebec, the Maritimes and Newfoundland and Labrador (Scott and Crossman 1973; Scott and Scott 1988; Black et al. 1986; COSEWIC 2010). Throughout Newfoundland and Labrador, Atlantic salmon occur in both anadromous and landlocked populations (Smith 1988).

Anadromous salmon typically can spend up to one-three years at sea before returning to their home river to spawn in the fall. Upstream migration may occur from July to August in Labrador (see Grant and Lee 2004) with spawning occurring approximately early October – November. During their upstream migration, adult salmon cease feeding (Grant and Lee 2004). Some individuals, usually females, can spawn more than one year. In Labrador, young salmon will typically remain within the freshwater environment for 3-6 years until they reach a length of 12-20 cm (Grant and Lee 2004) before smolting and heading to sea. Adult migration and growth typically occurs in the marine environment. Recent work completed on adult Atlantic salmon in Lake Melville indicates that isotopic signatures of elements within sampled fish (including MeHg) is derived from the marine environment (Li et al. 2016) indicating that adults do not feed extensively within Lake Melville.

During the smolting process, salmon parr move downstream and undergo physiological adaptations for life in a saline environment. Some Atlantic salmon parr in Newfoundland have been shown to use estuaries as rearing habitat as well as during the smolting process (Cunjak et al. 1989; 1990; Cunjak 1992); however, extensive sampling of both the main stem of the lower Churchill River, Goose Bay, and Lake Melville does not indicate any use of these habitats by salmon parr. For example, no juvenile Atlantic salmon have been captured in the main stem, Goose Bay or Lake Melville during any sampling program since 1998 (Amec Foster Wheeler 2015a; 2016a; JWEL 2001) and juveniles have only been captured in low numbers within sampled tributaries (Caroline Brook and McKenzie River) below Muskrat Falls. However, sampling in generally completed in June, August and September and downstream migrations in July might not be adequately documented.

Past reports from both the commercial and recreational fisheries indicate a relatively small salmon migration into the Lake Melville area (Anderson 1985). Two rivers in the region are scheduled Atlantic salmon rivers; Tom Luscombe and Double Mer; however, a large local subsistence fishery for Atlantic salmon and brook trout is conducted on several other larger rivers including Kenamu River. The apparent general under-utilization of rivers in the Lake Melville area by salmon is probably related to lack of good spawning areas, low winter discharges and high turbidity which reduces the quality of parr-rearing habitat and the impact of past fisheries (Anderson 1985). Since 1998, only two adult Atlantic salmon (1998 and 2012) have been captured within the main stem of the lower Churchill River below Muskrat Falls during baseline data collection and one other during the radio telemetry program in 1998 (JWEL 2000). While salmon are using the tributaries directly flowing into the lower Churchill River (both Caroline Brook and McKenzie River have confirmed salmon juveniles), they do not appear to be present in large numbers. Anadromous Atlantic salmon are not found above Muskrat Falls as it is a barrier to upstream migration (Bruce et al. 1975, Ryan 1980, Anderson 1985, AGRA 1999, Nalcor 2009).

5.3.1 Ouananiche

Landlocked Atlantic salmon, commonly called ouananiche, are the dominant species in some Newfoundland lakes where they may exist in either normal or dwarf forms (Smith 1988). Ouananiche are found throughout the main stem of the Churchill River between Muskrat Falls and Churchill Falls (Beak 1980; Ryan 1980; AGRA 1999; Amec Foster Wheeler 2016a), being most abundant in Section Three and Four (Gull Island through Winokapau Lake) (AGRA 1999; AMEC 2000). Sampling since 1998 using gillnets, fyke nets, angling, and snorkeling, has only produced six ouananiche in Section Two of the main stem (i.e., the Muskrat Falls Reservoir area). In Winokapau Lake, most ouananiche have been sampled in the littoral and near-surface habitat of the profundal zone. Although typically a riverine species, ouananiche have only rarely been captured in tributary habitat upstream of Muskrat Falls.

Based on habitat utilization data and the habitat-types characterized for the lower Churchill River, highest overall utilization for ouananiche is intermediate velocity main stem habitat. A breakdown of habitat utilization by life-cycle stage shows that highest spawning and young-of-year utilization is within fast and intermediate velocity main stem habitat types. Juvenile and adult utilization is highest in intermediate velocity main stem habitat. The species has not been captured in any deep-water sampling within Winokapau Lake (AMEC 2001; 2007). While ouananiche have been captured in low abundance within any tributary or stream habitat sampled, the literature does suggest that the habitat types present would be suitable.

Ouananiche may typically live for up to ten years in Newfoundland (Leggett 1965). Specimens have been captured within the upper portions of the Churchill River, above the Muskrat Falls reservoir area, ranging in age from three to eight (AGRA 1999; AMEC 2000). Mean length-at-age data shows they range between 245 mm in length at age three to almost 450 mm at age eight. Growth is shown as being relatively slow between ages three and four with an increase in rate after age four. This may be a reflection of prey selection as many larger, older ouananiche sampled were feeding on a larger proportion of fish and terrestrial mammals. Growth rates determined from baseline sampling are in concurrence with historic rates for the lower Churchill River provided in Anderson (1985).

Ouananiche typically mature at 2-3 years of age (Leggett 1965; Lee 1971; Leggett and Power 1969). Spawning typically occurs in October or November, depending on water temperature, with females ascending tributaries to prepare redds (nests). Lake-spawning has also been observed along shorelines (Leggett 1965) as well as near areas of moving water, usually above outlet streams and near the mouths of inlet streams (Leggett 1965; Harvey and Warner 1970; Einarsson et al. 1990). Typical egg production at spawning is 1,500 eggs per kg of female (Scott and Crossman 1973) but this can be variable.

In the Churchill River watershed ouananiche reach maturity as early as age four (AMEC 2000), however the age-class where 50% of ouananiche mature is six years old. All ouananiche sampled greater than age six were maturing therefore alternate year spawning was not evident (AGRA 1999; AMEC 2000; Amec Foster Wheeler 2015a, 2016a).

Scruton et al. (1995) have shown that ouananiche will overwinter in deep warmer waters of reservoir systems as well as fast-flowing ice-free waters of inlets, outlets and canals.

The diet of ouananiche consists of a wide variety of food types including aquatic invertebrates, fish, and terrestrial vertebrates. Aquatic invertebrates were the most frequent food type consumed within those sampled from the Churchill River. Ouananiche greater than 350 mm in length have a relatively large proportion of their diet consisting of terrestrial mammals (meadow voles, mice and shrews).

The majority of ouananiche movement activity recorded by telemetry was located within Section Five, close to the Churchill Falls Generation facility tailrace (JWEL 2001). It should also be noted, however, that all ouananiche tagged were captured within Section Five. Approximately sixty percent of those tagged underwent long distance migrations (>10km). The longest migration measured was 80km. Most of the long-distance movements occurred in the fall, which coincides with the spawning season of ouananiche. The upper reaches of Section Five (near the Churchill Falls Generating facility) as well as the Unknown River were identified as spawning locations for those fish tagged. The identified areas where ouananiche were recorded spawning are classified as intermediate velocity main stem habitat.

Atlantic salmon (anadromous or ouananiche) were not a target of sampling associated with the formation of the Smallwood Reservoir. Mercury concentrations from ongoing baseline data collection associated with the project are provided in **Table** 5-6.

5.4 Brook trout (*Salvelinus fontinalis*)

The brook trout is widely distributed throughout Newfoundland and Labrador (Scott and Crossman 1973), at least as far north as the Hebron Fiord (Black et al. 1986), where they have been reported to make extensive use of clear, cool (<20°C) lake habitats (Ryan and Knoechel 1994). Brook trout are known to have both landlocked and anadromous populations throughout Newfoundland and Labrador (Scott and Crossman 1964, 1998). Anadromous populations may spend one or two months feeding at sea in relatively shallow water, close to their natal stream, while others spend their entire life in freshwater (Scott and Crossman 1964; Morrow 1980; Power 1980; Ryan 1980; Scott and Scott 1988).

Brook trout are found throughout the main stem and tributaries of the lower Churchill River between Muskrat Falls and Churchill Falls (Beak 1980; Ryan 1980; AGRA 1999; AMEC 2000, AMEC 2001), being most abundant in Section Three and Five (Gull Island to Winokapau Lake and upriver of Winokapau Lake) (AGRA 1999; AMEC 2000). Brook trout have also been captured below Muskrat Falls within the main stem but at relatively low rates (AMEC 2000; AMEC 2007; AMEC 2009; Amec Foster Wheeler 2015a; Amec Foster Wheeler 2016a).

Table 5-6: Summary of total mercury concentrations for Atlantic salmon within the baseline study area, 1999-2016

Year	Total Mercury (mg/kg)		
	Sample Size	Mean (SE)	Range
Muskrat Falls reservoir area – ouananiche			
1999	1	0.12	-
2010	0	-	-
2012	0	-	-
2013	0	-	-
2014	1	0.06	-
2015	2	0.19 (0.10)	0.09-0.29
2016	0	-	-
Mainstem and Tributaries Below Muskrat Falls – no sample sizes sufficient for analysis			
2012	1	0.11	-
Goose Bay – none captured			
Lake Melville – Atlantic salmon			
2011	0	-	-
2013	0	-	-
2014	0	-	-
2015	24	0.09 (0.01)	<0.05-0.16
2016	15	0.04 (<0.01)	0.03-0.08
Eastern Lake Melville – none captured			

Note: Values below detection limits have been incorporated as the detection limit (i.e. 0.02-0.05mg/kg) to produce a conservative estimate of mean concentrations.

Based on habitat utilization data and the habitat-types characterized for the lower Churchill River, highest overall utilization for brook trout is stream (i.e. tributary) habitat followed by areas of intermediate water velocity within the main stem of the lower Churchill River. Use of lake Melville by juvenile and adult brook trout is amongst the highest utilization (Amec Foster Wheeler 2016a). A breakdown of habitat utilization by life-cycle stage shows that highest spawning utilization is within stream and slower velocity tributary habitat types. Young-of-year utilization is also greatest in stream/tributary habitat. Juvenile and adult utilization is highest in stream, tributary, and the slower/intermediate water velocity within the main stem of the lower Churchill River. Brook trout were not captured in any deep-water sampling within Winokapau Lake (AMEC 2001).

Few samples have been collected within the main stem of the lower Churchill River below Muskrat Falls (33 in a combination of fyke nets and gillnets between 1998-2016); however, they are found in relatively higher numbers within the upper habitat of Caroline Brook. Larger numbers have also been sampled within both Goose Bay (191 total) and Lake Melville (535). In both estuarine environments, brook trout have had some of the highest CPUE and biomass of all species sampled (Amec Foster Wheeler 2015a; 2016a). This is most likely the result of the brackish environment of the estuary being a suitable habitat for anadromous brook trout to feed during the summer months. Typically, brook trout will not feed within an estuarine environment beyond several kilometers of its natal stream (Scott and Scott 1988); therefore, most of the brook trout captured are likely from the larger nearby tributaries such as Mud Lake and Kenamu River.

Specimens have been captured from every age-class between one and six (AGRA 1999; AMEC 2000; Amec Foster Wheeler 2015a; 2016a, 2016b). Mean length-at-age data shows they range between 82 mm in length at age one to almost 415 mm at age six. Growth is relatively linear throughout all years. Growth rates determined from baseline sampling are in concurrence with historic rates for the lower Churchill River provided in Anderson (1985).

In the Churchill River watershed, brook trout reach maturity as early as age two (AMEC 2000), however the age-class where 50% of brook trout mature is four years old. All brook trout sampled greater than age four were maturing therefore alternate year spawning is not evident (AGRA 1999; AMEC 2000).

In general, movements of tagged brook trout were relatively short distances, with approximately ten percent exceeding 10km in distance (JWEL 2000). The longest migration recorded was 93.5km. Most migrations were undertaken in late summer to early fall, which coincides with the brook trout spawning season. All movements during this time were to areas of fast and intermediate habitat types, with the majority being focused in Section Three (above the Muskrat Falls Reservoir area).

The diet of brook trout consists of a wide variety of food types including aquatic invertebrates, fish, and terrestrial invertebrates and vertebrates. Aquatic invertebrates were the most frequent food type consumed; however, fish was a large component of brook trout in the 151-250 mm size range (AGRA 1999; AMEC 2000; Amec Foster Wheeler 2015a; 2015b).

Previous sampling in 1977-78 after the Smallwood Reservoir was created showed total mercury concentrations in brook trout from Goose Bay and Lake Melville (standard fish length of 300mm) peaked at 0.15 mg/kg which was similar to other freshwater brook trout samples but approximately four-times greater than sea-run samples from other coastal Labrador locations. By 2005, levels had declined significantly (Anderson 2011). Mercury concentrations from ongoing baseline data collection associated with the project are provided in **Table** 5-7.

5.5 Lake Trout (*Salvelinus namaycush*)

Lake trout are widely distributed in northern North America and are found throughout southern Labrador, except for the southeastern corner (Scott and Crossman 1973; Black et al. 1986). In the south, lake trout prefer cool (<10°C), deep lakes, but in the north where temperatures are lower, they may inhabit shallow lakes and large rivers (McPhail and Lindsey 1970; Ryan 1980). Lake trout occur throughout the Churchill River watershed, but are more prevalent in the upper reaches (Anderson 1985; AGRA 1999; AMEC 2000, 2001). Beak (1980) reported the species as present in the main stem only above Gull Island Rapids (i.e., the upper extent of the Muskrat Falls reservoir area). Sampling since 1998 confirms this as only one lake trout has been captured in Gull Lake within Section Two (the Muskrat Falls Reservoir area) and only one below Muskrat Falls. The only lake trout captured below Muskrat Falls was in 2006 (AMEC 2007) but its condition was poor and seemed as though it had come over the falls in a weakened condition.

Table 5-7: Summary of total mercury concentrations in brook trout within the baseline study area, 1999-2016

Year	Total Mercury (mg/kg)		
	Sample Size	Mean (SE)	Range
Muskrat Falls reservoir area			
1999	26	0.07 (0.01)	0.03-0.16
2010	0	-	-
2012	1	0.11	
2013	7	0.06 (0.01)	<0.05-0.15
2014	2	0.05 (<0.01)	-[1]
2015	2	0.12 (0.04)	0.08-0.16
2016	0	-	-
Mainstem and Tributaries Below Muskrat Falls			
1999	0	-	-
2010	0	-	-
2011	12	0.08 (0.01)	0.04-0.17
2012	18	0.08 (<0.01)	<0.05-0.12
2013	30	0.05 (<0.01)	<0.05-0.09
2014	8	0.06 (<0.01)	<0.05-0.08
2015	13	0.12 (0.03)	<0.05-0.37
2016	35	0.03 (<0.01)	<0.02-0.0.06
Goose Bay			
1999	9	0.06 (0.01)	0.04-0.14
2011	48	0.08 (<0.01)	0.03-0.17
2013	26	0.07 (0.02)	<0.05-0.44
2014	30	0.05 (<0.01)	<0.05-0.10
2015	6	0.05 (<0.01)	<0.05-0.07
2016	6	0.08 (0.01)	0.04-0.13
Lake Melville			
2011	0	-	-
2013	30	0.06 (<0.01)	<0.05-0.10
2014	30	0.05 (<0.01)	<0.05-0.08
2015	31	0.07 (0.01)	<0.05-0.32
2016	30	0.06 (<0.01)	<0.02-0.11
Eastern Lake Melville			
2016	32	0.04 (<0.01)	<0.02-0.11

Note: Values below detection limits have been incorporated as the detection limit (i.e. 0.02-0.05mg/kg) to produce a conservative estimate of mean concentrations.
[1] All fish were below detection limits

Lake trout are primarily located within Winokapau Lake (Section Four) and Section Five of the lower Churchill River (Beak 1980; Ryan 1980; AGRA 1999; AMEC 2000, AMEC 2001; Amec Foster Wheeler 2016a); being most abundant in Winokapau Lake (AGRA 1999; AMEC 2000). Based on habitat utilization data and the habitat-types characterized for the lower Churchill River, highest overall utilization by lake trout is lacustrine habitat of Winokapau Lake (both littoral and profundal) and faster water velocity habitat within the main stem of the lower Churchill River. A breakdown of habitat utilization by life-cycle stage shows that highest spawning utilization is within tributary habitat and Young-of-year utilization is greatest within littoral zone habitat of Winokapau Lake. Juvenile utilization is also highest in littoral zone habitat of Winokapau Lake with adults utilizing profundal habitat within Winokapau Lake and faster water velocity habitat within the main stem of the lower Churchill River.

Although lake trout were noted in Calder et al. (2016) as being one of the top 20 food sources exposed to MeHg increases downstream of Muskrat Falls, no lake trout have been captured during any sampling in Goose Bay or Lake Melville since 1999 (Amec Foster Wheeler 2016a; JWEL 2001). The 13 lake trout samples included in the Calder et al. (2016) analysis were noted as being collected from the Churchill River; however, the location was not provided and was unlikely to be located downstream of Muskrat Falls or within the area of the Muskrat Falls Reservoir (see Table S5 in supplemental information).

Specimens captured within the lower Churchill River, upstream of the Muskrat Falls Reservoir area, ranged in age from five to nine (AGRA 1999; AMEC 2000). Mean length-at-age data shows they range between 272 mm in length at age five to almost 565 mm at age nine. Growth has been shown as being relatively linear throughout years five to eight with an increase in growth apparent at age nine. Growth rates determined from baseline sampling have been in concurrence with historic rates for the lower Churchill River provided in Anderson (1985).

Lake trout usually spawn in shallow inshore areas of lakes, rarely in streams (Machniak 1975; Martin and Olver 1980; Ford et al. 1995). In most areas of Canada, spawning occurs in late summer-early fall (Scott and Crossman 1973; Ford et al. 1995), mainly in September or October in Labrador (Grant and Lee 2004).

Sexual maturity is thought to occur at a relatively old age. When Parsons (1975) sampled the Ossokmanuan Reservoir (part of the Smallwood Reservoir system) they found no sexually mature lake trout under nine years of age, and Ryan (1980) concluded that in the lower Churchill River, they reach maturity at seven years of age. This estimation was confirmed through sampling for the Project, which recorded lake trout maturing at seven years of age. The results also indicate that individuals may not spawn each year as many older fish between seven and nine years of age were not showing signs of maturing for that year (AGRA 1999; AMEC 2000).

The diet of lake trout consists of aquatic invertebrates, fish and terrestrial mammals. Fish was the most frequent food type identified (AGRA 1999; AMEC 2000).

Lake trout were not included in the original scope of work for the telemetry/movement study; however, five were captured and tagged (JWEL 2000). Lake trout activity was generally concentrated within Winokapau Lake and its outflow. Tracking indicates that lake trout used the entirety of Winokapau Lake, with limited movement upstream or downstream. There was a small concentration of activity near the east end of the lake during the late fall as well as downriver from the confluence of Cache River.

Lake trout were sampled in 1978 in Smallwood Reservoir and Winokapau Lake after the formation of the Smallwood Reservoir. Peak total mercury concentration for a standard 600mm fish length reached 1.72 mg/kg (~3x background). Samples from 1999 showed no significant difference from background (Anderson 2011). No lake trout were captured for total mercury analysis during baseline data collection to date.

5.6 Lake Whitefish (*Coregonus clupeaformis*)

Lake whitefish are widely distributed throughout North America from the Atlantic coastal watersheds westward across Canada and the northern United States, to British Columbia, the Yukon Territory, and Alaska (Scott and Crossman 1998). They are distributed throughout southern Labrador (Bruce 1974; Parsons 1975; Beak Consultants Ltd. 1979; Black et al. 1986; Scott and Crossman 1998; LGL Limited 1999). There are two forms of lake whitefish within the lower Churchill River; normal and a dwarf form. The discrimination between both forms is primarily size-at-maturity and length-at-age as per the identification key of Doyon (1998). Besides size-at-maturity and length-at-age, the primary difference between the two forms is the dwarf form tends to be more zooplankivorous and pelagic in nature while the normal form are more benthic feeders (Bruce 1984). Although they are generally found in lakes, they are relatively abundant in the main stem of the Churchill River, as well as the adjoining lakes and ponds within its watershed (Anderson 1985).

They are distributed throughout, from the upper reaches near the existing Churchill Falls Generating facility downstream to the estuary; however, they are most abundant in the upriver segments (Sections Four and Five). Below Muskrat Falls, lake whitefish has been the most abundant salmonid captured; a total of 121 fish between 1998-2016. Lake whitefish have been considerably lower in abundance from Goose Bay (19 total captured by Amec Foster Wheeler) and Lake Melville (10 total captured) in the same time period. While JWEL (2001) does not provide total numbers, they indicate that lake whitefish were captured in Goose Bay during the 2000 summer sampling season; none were captured in October indicating that they may have already ascended rivers to spawn (JWEL 2001). None were captured by JWEL in Lake Melville (JWEL 2001).

While primarily a lacustrine species, based on habitat utilization data and the habitat-types characterized for the lower Churchill River, highest overall utilization for both forms of lake whitefish tends to be faster water velocity habitat within the main stem of the Churchill River, followed by lacustrine habitat types (profundal and littoral). A breakdown of habitat utilization by life-cycle stage shows that highest spawning utilization for both forms is within tributaries. Young-of-year habitat use for both forms appears to be highest within faster velocity main stem habitat as well as profundal habitat of Winokapau Lake. Juvenile utilization is also highest in faster velocity main stem habitat and littoral habitat within Winokapau Lake; with the dwarf form using faster main stem habitat and the normal form using lacustrine. This is most likely associated with their differing feeding preferences. Adults tend to utilize the faster water velocity habitat within the main stem (normal and dwarf) as well as the lacustrine habitat within Winokapau Lake. Within Winokapau Lake, the adult normal form utilizes both littoral and profundal habitats while the dwarf form more heavily utilizes the open-water profundal habitat type. Neither adult form was found to utilize any tributary or stream habitat outside spawning activities.

Specimens have been captured within the Churchill River from every age-class between one and eighteen with additional adults aged as old as twenty-eight (AMEC 2000; Amec Foster Wheeler 2016a). Mean length-at-age data shows they range between 120 mm in length at age one to almost 420 mm at age eighteen. Growth is shown as being relatively linear; however older fish show slightly slower growth. Growth rates determined from baseline sampling do not appear to concur with historic rates for the lower Churchill River provided in Anderson (1985) but more closely resemble those generated for the upper Churchill River watershed/reservoirs (Ryan 1980).

In Labrador, spawning migrations are reported from early September to mid-October (Scruton et al. 1997). In the Churchill River watershed lake whitefish reach maturity over a range of 3-9 years old (Anderson 1985). Sampling conducted for the Project indicates that the age-class where 50% of the lake whitefish were maturing was three years old; however mature individuals were identified at age two. In the extreme northern limits of their range, individuals have been known to only spawn once every two or three years (Scott and Crossman 1998); this may occur within the lower Churchill River as a portion of adults assessed for maturity greater than seven years old were not maturing (AGRA 1999; AMEC 2000; Amec Foster Wheeler 2016a).

Scott and Crossman (1973) note that more northerly populations tend to produce fewer eggs. Egg counts can vary greatly depending on a fish's size, with specimens from the Ossokmanuan Reservoir yielding anywhere from 967 to 20,963 eggs per fish (Bruce and Parsons 1976). The overall sex ratio of specimens sampled was in favor of males (58%).

The diet of lake whitefish consists of a majority of aquatic invertebrates and algae/detritus (AMEC 2001; Amec Foster Wheeler 2015a; 2016a).

Lake whitefish were not captured within Section One (below Muskrat Falls), or Section Three during the telemetry study (JWEL 2000). Movement patterns varied by river section of capture; fish from Sections Two and Four generally stayed within close vicinity to their tagging locations; i.e. Gull Lake and Winokapau Lake. However, fish tagged in Section Five were noted to make migrations downstream of varying distances. Forty-eight percent of the whitefish tagged within the tailrace of the Churchill Falls Generating facility moved downstream in the late fall (mid-September to mid-October), shortly after the typical spawning season. The median migration distance was 5.7km, with a maximum of 240km (one individual traveled from the tailrace region to Gull Lake). In addition, tagged fish from Winokapau Lake remained there for the duration of the study and while there was no identifiable cluster of spawning activity, it can be assumed that spawning did occur within the lake. The identified potential spawning habitats are predominantly found within fast and intermediate velocity habitat types.

Standard length (300mm) lake whitefish were sampled for total mercury in 1977-78 after formation of the Smallwood Reservoir. Total mercury concentrations in the lower Churchill River downstream to

Winokapau Lake peaked at 0.76 mg/kg (~5x background) but by 1987, values were no longer elevated compared to background (Anderson 2011). Mercury concentrations from ongoing baseline data collection associated with the project are provided in **Table** 5-8.

Table 5-8: Summary of total mercury concentrations in lake whitefish within the baseline study area, 1999-2016

Year	Total Mercury (mg/kg)		
	Sample Size	Mean (SE)	Range
Muskrat Falls reservoir area			
1999	26	0.13 (0.02)	0.05-0.36
2010	11	0.09 (0.01)	0.04-0.16
2012	11	0.14 (0.03)	0.04-0.43
2013	4	0.07 (0.02)	<0.05-0.14
2014	6	0.06 (0.01)	<0.05-0.10
2015	1	0.19	-
2016	12	0.06 (0.01)	<0.02-0.18
Mainstem and Tributaries Below Muskrat Falls			
1999	16	0.10 (0.02)	<0.02-0.23
2010	7	0.03 (0.01)	<0.01-0.05
2011	17	0.08 (0.01	0.04-0.23
2012	5	0.10 (0.02)	0.04-0.15
2013	0	-	-
2014	3	0.05 (<0.01)	-[1]
2015	2	0.09 (0.03)	0.06-0.12
2016	2	0.08 (0.03)	<0.05-0.10
Goose Bay			
1999	7	0.13 (0.02)	0.03-0.21
2011	1	0.10	-
2013	4	0.007 (0.01)	<0.05-0.09
2014	1	0.05	-
2015	0	-	-
2016	2	0.11 (0.02)	0.09-0.13
Lake Melville			
2011	0	-	-
2013	0	-	-
2014	7	0.05 (<0.01)	<0.05-0.06
2015	2	0.06 (0.01)	<0.05-0.07
2016	0	-	-
Eastern Lake Melville – none captured			

Note: Values below detection limits have been incorporated as the detection limit (i.e. 0.05mg/kg) to produce a conservative estimate of mean concentrations.

5.7 Round Whitefish (*Prosopium cylindraceum*)

Round whitefish are widely distributed in lakes and ponds as well as brackish waters throughout North America and into northern Asia (McPhail and Lindsey 1970; Becker 1983; Scott and Crossman 1998). In Canada, they range from northern New Brunswick, Labrador, and Ungava west through parts of Quebec, Ontario, and the Great Lakes and north westward from northern Manitoba through the Northwest Territories and northern British Columbia (Scott and Crossman 1998). Round whitefish have been reported in the Churchill River system (Beak Consultants Ltd 1979; Ryan 1980; AGRA 1999) but appear to be limited in distribution based on sampling; however, they have been captured in the system both above and below Muskrat Falls (Sections One, Two, Three, Four and Five), being most abundant in Winokapau Lake (AGRA 1999; AMEC 2000; Amec Foster Wheeler 2016a). In 2000, they were only captured in sampling conducted in the pelagic (open-water) habitat of Winokapau Lake and they have been captured very infrequently in tributary habitat; primarily juveniles. Below Muskrat Falls, a total of 44 have been captured between 1998-2016 within the main stem of the river. Juveniles have been captured in McKenzie River during electrofishing and fyke netting and both juveniles and adults have been observed during snorkeling surveys (Amec Foster Wheeler 2016a). Adults have been observed making upriver spawning migrations during fall snorkel surveys in 2015 (Amec Foster Wheeler 2016a) and juveniles were identified in 2012, 2014, 2015, and 2016. Very few round whitefish have been captured since 1998 in Goose Bay (two by Amec Foster Wheeler and three by JWEL) or Lake Melville (three by Amec Foster Wheeler).

While primarily a lacustrine species, based on habitat utilization data and the habitat-types characterized for the lower Churchill River, highest overall utilization for round whitefish tends to be within all riverine main stem habitats. A breakdown of habitat utilization by life-cycle stage shows that highest spawning utilization is within streams and littoral habitat of Winokapau Lake. Young-of-year habitat use appears to be highest within slower water velocity main stem habitat. Juvenile and adult utilization is highest in slower and intermediate water velocity main stem habitat. Neither juvenile nor adult life-cycle stages were captured in any deep-water samples within Winokapau Lake (AMEC 2001).

Round whitefish can live for up to 14 years and can reach sizes of 2 kg; however, the average size is much smaller. Ryan (1980) indicates that the growth rates for round whitefish in the Churchill River are at an intermediate level when compared to results from other regions of North America. Specimens have been captured within the Churchill River from every age-class between one and ten (AGRA 1999; AMEC 2000; Amec Foster Wheeler 2016a). Mean length-at-age data shows they range between 84 mm in length at age one to almost 340 mm at age ten. Growth is shown as being relatively linear up to age four or five with a reduction in growth in older fish. Growth rates determined from baseline sampling are in concurrence with historic rates for the lower Churchill River provided in Anderson (1985).

According to Scott and Crossman (1973), round whitefish are fall spawners (October to December) which utilize gravelly shallows of lakes, river mouths and sometimes rivers as spawning substrate. Spawning can take place in the inshore areas of lakes, at river mouths, or occasionally in rivers (McPhail and Lindsey 1970; Scott and Crossman 1998; Bradbury et al. 1999). In the Churchill River watershed round whitefish reach maturity as early as age one (AMEC 2000), however the age-class where 50% of round whitefish were maturing is four years old. As with lake whitefish, all those sampled greater than age four were maturing therefore alternate year spawning was not evident (AGRA 1999; AMEC 2000).

Typical mean egg production at spawning is 12,000 eggs per kg of female (Scott and Crossman 1998). The eggs remain in the spawning substrate until hatching occurs the following April or May. The overall sex ratio of specimens within the lower Churchill River was fairly even between males and females (AGRA 1999; AMEC 2000; Amec Foster Wheeler 2016a).

The diet of round whitefish consists of a majority of aquatic invertebrates and algae/detritus with evidence of limited feeding on other fish.

Round whitefish were not sampled as part of any post-Smallwood mercury sampling program nor are they included in the baseline as a regular target for mercury body burden.

5.8 Rainbow Smelt (*Osmerus mordax*)

Rainbow smelt are typically a schooling, pelagic fish, inhabiting mid-water areas of inshore coastal waters (Leim and Scott 1966; Scott and Scott 1988; Scott and Crossman 1998). In Hamilton Inlet and Lake Melville, they are primarily an inshore anadromous species that occur within bays and estuaries, but are rare in the Churchill River freshwater system (Anderson 1985). They are an important species in that they feed on pelagic plankton and are an important food source for most estuarine piscivores such as gadids (e.g., cod species), flatfish (e.g., winter flounder) and salmonids (e.g. brook trout).

Smelt are typically anadromous, moving from estuaries such as Lake Melville and Goose Bay into nearby rivers and streams to spawn in the spring, likely before ice breakup (JWEL 2001). As the hatched larvae grow, they move into areas of higher salinity, such as deeper parts of the estuary or more coastal areas (JWEL 2001). Smelt begin to school at about 19 mm in length, moving into shallow water and returning to deeper channels during the day (Belyanina 1969). They will generally spend the summer feeding on copepods and planktonic larvae and in the fall, juveniles mix with adult schools and move into the upper parts of the estuary (Buckley 1989) where they remain for the winter.

Within Lake Melville, smelt seem to prefer deeper, cooler waters in the summer (JWEL 2001). The JWEL sampling program identified that smelt, which spend the summer in the cooler waters of Lake Melville, move into Goose Bay from August to October (JWEL 2001; AMEC/BAE 2001); the relative abundances of smelt in Goose Bay estuary nearly quadrupled from July to August and nearly doubled from August to October (JWEL 2001). There was a slight peak observed in abundance in October in the western portion of Lake Melville and was suggested to be the result of a migration toward the many rivers in the area (JWEL 2001).

Due to physical barriers, this species does not occur above Muskrat Falls in the Churchill River (Ryan 1980) and based on sampling, is very rare upstream of estuarine influences after spawning. Ryan (1980) recorded two specimens (which appeared to be anadromous) downstream of Muskrat Falls and Amec Foster Wheeler captured a lone adult by fyke net just downstream of Muskrat Island in 2016 (Amec Foster Wheeler 2016a). No other known reports occur in the literature for their presence within the freshwater portion of the lower Churchill River (Ryan 1980, Beak 1980, AGRA 1999, AMEC 2000) upstream of the Mud

Lake confluence (AMEC 2000). In addition to sampling conducted related to the Project, the main stem between Happy Valley–Goose Bay and Muskrat Falls as well as several tributaries (eg. Birchy Creek and Caroline Brook), were sampled between 2006 and 2008 for the provincial Department of Transportation and Works. Sampling was conducted using fyke nets and tended gillnets through most open water months (i.e. July and October 2006, May and June 2007, April, May, and June 2008, and May 2009) but did not capture rainbow smelt (unpub. data).

Rainbow smelt have been routinely captured during ongoing baseline sampling since 1999 in both Goose Bay and Lake Melville. Sampling by Amec Foster Wheeler has captured approximately 136 and 155 from Goose Bay and Lake Melville, respectively. Baseline work completed by JWEL in 1998 captured a total of 991 rainbow smelt within Goose Bay / Lake Melville which comprised 31 percent of their total catch (JWEL 2001). Rainbow smelt sampled (AGRA 1998) were predominantly between 151-250mm in length with fairly linear growth through all age classes sampled (ages 1-8). The overall sex ratio favored males (63%). Of the 51 rainbow smelt examined for maturity, 36 were maturing for the 2000 spawning season (early spring spawners). The length-class when at least fifty percent were maturing was 151-200mm. The smallest fish which was maturing was 163mm. The age when at least fifty percent were maturing was three.

Previous sampling after the Smallwood Reservoir was created showed rainbow smelt peaked in total mercury (standard fish length of 200mm) at 0.32 mg/kg in 1978, declined in 1999 and by 2008, concentrations were significantly lower at approximately 0.1 mg/kg (Anderson 2011). Mercury concentrations from ongoing baseline data associated with the project are provided in **Table** 5-9.

5.9 Threespine Stickleback (*Gasterosteus aculeatus*)

Threespine stickleback have an almost circumpolar distribution and are widely distributed in the northern hemisphere (Scott and Scott 1988; Scott and Crossman 1998). In Newfoundland and Labrador, it is a euryhaline species and exists as both a freshwater resident and anadromous marine-dwelling form (Scott and Scott 1988; Scott and Crossman 1998). Spawning generally occurs in the summer months, but timing can range from April to September depending in local conditions (Scott and Crossman 1998). Freshwater resident populations spawn in both lakes and rivers, with anadromous populations spawning in brackish or fresh waters (Leim and Scott 1966; Coad and Power 1973; Morrow 1980; Wootton 1984). River-spawning populations undergo a spring migration from lakes or larger rivers into smaller, slower tributaries and backwaters (Scott and Scott 1988; Scott and Crossman 1998). The males build nests over sandy/muddy substrates in areas of low flow and are usually found in the vicinity of submergent vegetation (Hagen 1967; Virgl and McPhail 1994). Lake spawning populations utilize two distinct habitat types; either open-water (Griswold and Smith 1972; Larson 1976; Lewis 1978; Wootton 1984) or in association with aquatic vegetation (McPhail and Lindsey 1970; Larson 1976; Morrow 1980; Sandlund et al. 1987).

Table 5-9: Summary of mean total mercury concentrations, rainbow smelt, baseline study area, 1999-2016

Year	Total Mercury (mg/kg)		
	Sample Size	Mean (SE)	Range
Muskrat Falls reservoir area – none captured			
Mainstem and Tributaries Below Muskrat Falls			
2016	1	0.02	-
Goose Bay			
1999	29	0.18 (0.01)	0.08-0.31
2011	61	0.09 (0.01)	0.03-0.22
2013	21	0.08 (0.01)	<0.05-0.15
2014	2	0.10 (0.04)	0.06-0.13
2015	0	-	-
2016	1	0.02	-
Lake Melville			
2011	0	-	-
2013	21	0.07 (0.01)	<0.05-0.14
2014	26	0.07 (<0.01)	<0.05-0.11
2015	12	0.05 (<0.01)	<0.05-0.06
2016	6	0.02 (<0.01)	<0.02-0.02
Eastern Lake Melville			
2016	16	0.03 (<0.01)	<0.02-0.05

Note: Values below detection limits have been incorporated as the detection limit (i.e. 0.02-0.05mg/kg) to produce a conservative estimate of mean concentrations.

Males construct a nest of small twigs, algae or plant debris typically over a sandy or mud bottom (McPhail and Lindsey 1970; Griswold and Smith 1972; Scott and Crossman 1973; Ryan 1980; Scott and Scott 1988). Females deposit adhesive eggs in clusters in the nest (Morrow 1980). The male subsequently guards and fans the nest (Leim and Scott 1966; McPhail and Lindsey 1970; Scott and Crossman 1973; Scott and Scott 1988), protecting the young for up to 2 weeks after hatching or until they are able to fend for themselves (Wootton 1976; Scott and Scott 1988). Newfoundland populations normally mature in their second or third year (Ryan 1984) and generally do not live past three years (Ryan 1984; Fitzpatrick 1988).

Its presence has been noted through the Churchill River system (Anderson 1985, Scott and Crossman 1973); being found at the mouth of the Elizabeth River (Beak 1980) and Upper Brook (AGRA 1999), and also found in stomach contents of ouananiche, lake trout, burbot, brook trout and northern pike caught in the main stem (Ryan 1980). Since 1998, threespine stickleback have been the most abundant species captured, accounting for almost half of the total catch in the mainstem below Muskrat Falls (Amec Foster Wheeler 2015a; 2016a). They were commonly collected throughout the sampling program in Goose Bay and Lake Melville in the nearshore areas by JWEL (2001) using beach seines. Collections within the estuarine environment comprised mainly juveniles (JWEL 2001).

5.10 Longnose Sucker (*Catostomus catostomus*)

The longnose sucker can be found throughout North America; from Alaska to western Labrador, and from the northern United States to the southern portion of the Northwest Territories (Scott and Crossman 1973). Longnose suckers are primarily bottom dwellers (McPhail and Lindsey 1970; Morrow 1980) and inhabit lakes, rivers and reservoirs. They have also been reported in brackish waters near the vicinity of river mouths (Walters 1955). Longnose suckers are one of the most abundant species within the lower Churchill River. Except for the pelagic and profundal habitat within Winokapau Lake, they are distributed throughout the main stem downriver to the estuary (Ryan 1980; Anderson 1985; AGRA 1999; AMEC 2000, 2001, 2007, 2009; Amec Foster Wheeler 2015a; Amec Foster Wheeler 2016a) as well as adjoining lakes and tributaries (Ryan 1980; Anderson 1985; AGRA 1999). Beak (1980) also reported this species as most abundant in the upper stretches of the lower Churchill watershed tributary systems, where gradients are gentler and where lakes and ponds are more common along main stems. They are the second-most abundant fish species captured below Muskrat Falls (565 fish total between 1998-2016). They are also very abundant within the brackish water of Goose Bay (941 total captured) and Lake Melville (292 captured).

Spawning generally occurs in the spring (mid April or May); however, Ryan (1980) observed spawning in June in the Labrador region. Longnose suckers are broadcast spawners, with adhesive eggs being repeatedly broadcast over a clean substrate comprised of cobble or rubble. As many as 17,000 to 60,000 eggs per female are released during a spawning period of five days (Scott and Crossman 1998). Eggs will typically incubate for two weeks before hatching, although this is temperature dependent.

Based on habitat utilization data and the habitat-types characterized for the lower Churchill River, highest overall utilization tends to be within intermediate water velocity habitat of the lower Churchill River main stem. A breakdown of habitat utilization by life-cycle stage shows that highest spawning utilization is within slower stream and tributary habitat. Young-of-year habitat use also appears to be highest within stream habitat as well as within intermediate water velocity habitat of the lower Churchill River main stem. This would suggest that once hatched, young longnose sucker have greater survival in faster-velocity habitat within the lower Churchill River. Juvenile utilization is highest in streams and slower habitat within the tributaries as well as intermediate water velocity habitat of the lower Churchill River main stem; that is they tend to utilize slightly slower habitat types than those most-utilized by young-of-year. Adults utilize the littoral zone habitat within Winokapau Lake the highest as well as intermediate and faster water velocity habitat of the lower Churchill River main stem.

Specimens have been captured within the Churchill River from every age-class between one and thirteen (AGRA 1999; AMEC 2000; Amec Foster Wheeler 2016a). Mean length-at-age data shows they range between 65mm in length at age one to almost 400mm at age thirteen. Growth is shown as being relatively linear at a rate near the lower limits exhibited by the species as a whole (Ryan 1980). Growth rates determined from baseline sampling are in concurrence with historic rates for the lower Churchill River provided in Anderson (1985).

The diet of longnose suckers consists entirely of invertebrates, mullocs, and algae/detritus (AGRA 1999; AMEC 2000; Amec Foster Wheeler 2016a). The overall sex ratio of specimens sampled was highly in favour of males (77%). Most sampling has not been conducted at a time period to accurately assess the age of sexual maturity; however, literature data from Anderson (1985) indicates that sexual maturity within the Churchill River system occurs at six to seven years of age.

The vast majority of longnose sucker where tagged and tracked within Sections Four and Five of the lower Churchill River (JWEL 2000). There were considerable migrations shown, with one individual migrating upwards of 204km. The median migration measured however was 13.8km. Of the longnose suckers that were tagged, fifty percent migrated during late May to June, presumably to spawning areas, and returned to original locations during August to early September. There was a concentration of activity surrounding Long Point in Winokapau Lake, suggesting this is a possible spawning area for those fish tagged. The upper section of Winokapau Lake, near Fig and Elizabeth Rivers, also had a substantial amount of movement during spawning season. The identified potential spawning habitats are located within main stem fast and intermediate habitats.

Sampling for total mercury in 1977-78 showed significantly elevated levels as far downstream as Winokapau Lake with a peak of 1.43 mg/kg (~11x background) directly below the tailrace for a standard 400mm length fish. Levels were not significantly different from background by 1996 (Anderson 2011). Mercury concentrations from ongoing baseline data collection associated with the project are provided in **Table** 5-10.

5.11 Rock Cod/Greenland Cod (*Gadus ogac*)

Rock cod is a coastal species, tolerant of low salinities and moderate temperatures and exhibits little preference for any particular bottom substrate type (Backus 1957). They typically do not undertake the extensive seasonal migrations of the Atlantic cod (*Gadus morhua*), but there have been reports of rock cod moving from nearshore to offshore in James Bay during summer (see Morin and Dodson 1986 in JWEL 2001).

Rock cod spawn during February and March in brackish waters (Scott and Scott 1988). They are opportunistic feeders and a large portion of their diet within Lake Melville is comprised of sculpin and flounder, along with small quantities of crab, shrimp, and whelk (see Smith et al. 1981 in JWEL 2001). Diet information collected by JWEL (JWEL 2001) showed rock cod eating, in order of frequency in stomachs, rainbow smelt, mysids, tomcod, and benthic invertebrates.

Table 5-10: Summary of total mercury concentrations in longnose sucker within the baseline study area, 1999-2016

Year	Total Mercury (mg/kg)		
	Sample Size	Mean (SE)	Range
Muskrat Falls reservoir area			
1999	0	-	-
2010	30	0.15 (0.01)	<0.05-0.38
2012	31	0.11 (0.01)	<0.05-0.40
2013	8	0.07 (0.01)	<0.05-0.10
2014	3	0.08 (0.02)	<0.05-0.10
2015	1	0.05	-
2016	4	0.05 (0.02)	<0.02-0.09
Mainstem and Tributaries Below Muskrat Falls			
1999	0	-	-
2010	21	0.03 (<0.01)	0.01-0.09
2011	30	0.11 (0.02)	0.01-0.33
2012	31	0.07 (0.01)	0.03-0.22
2013	30	0.10 (0.01)	<005-0.28
2014	9	0.08 (0.01)	<0.05-0.16
2015	27	0.12 (0.02)	<0.05-0.36
2016	37	0.05 (0.01)	<0.02-0.25
Goose Bay			
1999	0	-	-
2011	31	0.03 (<0.01)	0.02-0.11
2013	30	0.05 (<0.01)	<0.05-0.08
2014	30	0.05 (<0.01)	<0.05-0.06
2015	30	0.05 (<0.01)	-
2016	29	0.02 (<0.01)	<0.02-0.09
Lake Melville			
2011	15	0.07 (0.01)	0.03-0.21
2013	26	0.05 (<0.01)	<0.05-0.08
2014	27	0.05 (<0.01)	<0.05-0.05
2015	30	0.05 (<0.01)	<0.05-0.09
2016	21	0.02 (<0.01)	<0.02-0.06
Eastern Lake Melville			
2016	1	0.02	-

Note: Values below detection limits have been incorporated as the detection limit (i.e. 0.05mg/kg) to produce a conservative estimate of mean concentrations.

In a report on the commercial viability of a Greenland cod fishery in the Lake Melville area, Smith et al. (1981 as noted in JWEL 2001) noted that relative abundances were greatest near Northwest River and to a lesser extent Goose Bay, during a fall and winter survey. During July, rock cod were one of the most abundant fish in collections by JWEL (2001) in Lake Melville, but catches were substantially less in August. In Goose Bay, the relative abundance of rock cod was similar in July and August, but nearly doubled in October (JWEL 2001). The relative abundance of rock cod in Goose Bay and Lake Melville coincided well with when rainbow smelt were most abundant (JWEL 2001). There was also good correlation between the depth at which rock cod and smelt were most common. In Goose Bay, both species were most abundant near the bottom during July, August and October, suggesting a predator-prey relationship (JWEL 2001). Given these indications of movement and feeding, it may be suggested that rock cod will remain in Goose Bay throughout the fall and early winter feeding on rainbow smelt and in late winter, will spawn in the estuary. A single rock cod was captured by Amec Foster Wheeler in 2013 in Goose Bay (AMEC 2013a).

Rock cod were not sampled as part of any post-Smallwood mercury sampling program.

5.12 Atlantic Cod (*Gadus morhua*)

Atlantic cod inhabit cool-temperate to subarctic waters from inshore regions to the edge of the continental shelf (Scott and Scott 1988). Atlantic cod occur throughout the Canadian Atlantic area and in each of the different regions there are one or more identifiable cod stocks, each with its own set of characteristics (Scott and Scott 1988). There are at least 12-14 recognized stocks, of which the most important is the southern Labrador-east Newfoundland stock. Others include the northern Labrador stock.

Although noted in the Calder et al. (2016) paper as being one of the top 20 food sources exposed to MeHg increases downstream of Muskrat Falls, no Atlantic cod have been captured during any sampling in Goose Bay or Lake Melville (Amec Foster Wheeler 2016a; JWEL 2001). Samples included in the Calder et al. (2016) analysis were collected from St. Lewis Bay (see Table S5 in supplemental information) located on the coast of Labrador approximately 300km south of Rigolet and the outlet of Lake Melville into Hamilton Inlet.

Atlantic cod were not sampled as part of any post-Smallwood mercury sampling program.

5.13 Longhorn Sculpin (*Myoxocephalus Octodecemspinosus*)

The longhorn sculpin is a year-round resident of coastal waters, moving into deeper waters in winter and returning to shallower water in spring (Scott and Scott 1988). Longhorn sculpin have not been sampled in Goose Bay and Lake Melville since 1999 (AMEC 2000 JWEL 2001; Amec Foster Wheeler 2016a).

They typically feed on other fish and consume a variety of crabs, shrimp, molluscs, squid, sea squirts, and small fishes such as herring, mackerel, smelt, and sand lance.

Longhorn sculpin were not sampled as part of any post-Smallwood mercury sampling program.

5.14 Capelin (*Mallotus villosus*)

The capelin is a marine fish of cold, deep waters, found in the Atlantic Ocean on the offshore banks and in coastal areas, occasionally spending winter and early spring months in deep bays off the east coast of Newfoundland (Scott and Scott 1982). They are pelagic planktonic feeders, primarily feeding on copepods, amphipods, euphasiids and shrimp (JWEL 2001). The largest concentrations in Canadian waters are typically located off Newfoundland and the Labrador coast. An intensive migration inshore by coastal populations takes place prior to spawning activities on beaches. Beach spawning in south-central Labrador occurs during late June to late July. Where capelin are present within the marine ecosystem, they play an important role as a key food source for larger fish, birds and mammals. In the absence of capelin, as is apparently the case in the relatively warm and fresh Goose Bay/Lake Melville ecosystem, rainbow smelt and possibly sand lance to some extent, fill this niche (JWEL 2001).

There are very few reports of the occurrence of capelin in Lake Melville, but JWEL (2001) noted that this may reflect the lack of fisheries research in the area. If capelin exist in Lake Melville, their occurrence may be restricted by the availability of suitable habitat. Backus (1957) reports that capelin are not known to occur in Lake Melville in the summer, and that no spawning beaches are known in the area. In speculating their absence, Backus (1957) suggested that the water in Lake Melville may be too warm in the summer for capelin to spawn and that spawning may occur in Hamilton Inlet. Further evidence of the absence or low relative abundance of capelin in the area, comes from a study of Rock cod in Lake Melville in 1979, which reported no capelin in any of the stomachs examined (Smith et al. 1979 as in JWEL 2001). The number of rock cod stomachs examined was not provided. Additionally, only two capelin were collected in Lake Melville during July 1998 surveys by JWEL (JWEL 2001) and none collected since then by Amec Foster Wheeler (2016a). Capelin have not been identified in any number within Goose Bay or Lake Melville since the early 1970s (M. Clement, pers. Comm.).

Capelin were not sampled as part of any post-Smallwood mercury sampling program.

5.15 Ringed Seal (*Phoca hispida*)

The ringed seal is one of the most abundant and widely distributed resident Arctic pinnipeds (Muir et al. 1999). The following general species life history description is from Lowry (2016). As a species, ringed seals are widely distributed in ice-covered waters of the northern hemisphere, and they may presently number about three million animals (Lowry 2016). They prefer annual, landfast ice, but are also found in multi-year ice (Kingsley et al. 1985).

Throughout most of their range they use sea ice exclusively as their breeding, molting, and resting (haul-out) habitat, rarely if ever moving onto land (Frost and Lowry 1981, Reeves 1998). Their ability to create and maintain breathing holes in ice using well-developed claws on their fore-flippers allows them to thrive in areas where even other ice-associated seals cannot reside (Lowry 2016). Although Ringed Seals are quite small they deal with the thermal challenges posed by the arctic winter by having a very thick blubber layer, and by building lairs (small caves) in the snow on top of sea ice during the winter. The lairs are particularly important for neonatal survival (Lydersen and Smith 1989). Ringed Seals also use natural cracks along pressure ridges and leads in the sea ice for surfacing and breathing.

Reported mean age at sexual maturity for female Ringed Seals varies in the literature from 3.5 to 7.1 years (Holst and Stirling 2002, Krafft et al. 2006). Males likely do not participate in breeding before they are 8-10 years old. Ringed seals can be long lived, with ages close to 50 reported (Lydersen and Gjertz 1987). Regional productivity rates are variable; reproductive success depends on many factors including prey availability, the relative stability of the ice, and sufficient snow accumulation prior to the commencement of breeding (Lukin 1980, Smith 1987, Lydersen 1995).

A single pup is born in late February-early March for the Ladoga, Saimaa, and Baltic subspecies (Sipilä and Hyvärinen 1998) and March-May for the others (Frost and Lowry 1981). Most births occur in subnivean lairs excavated in snow that accumulates near ice ridges or shorelines. Lairs provide thermal protection against cold air temperatures and high wind chill and afford at least some protection from predators (Smith 1976, Smith and Stirling 1975, Gjertz and Lydersen 1986). For Arctic Ringed Seals, lactation lasts an average of 39 days and pups are weaned at approximately 20 kg (Lydersen and Kovacs 1999). Females become receptive for mating towards the end of the lactation period, similar to other phocid seals.

Ringed Seals molt from mid-May to mid-July and during that period they spend quite a bit of time hauled out (Reeves 1998). Feeding intensity is at a minimum during molting (Ryg et al. 1990).

Although they may dive to more than 500 m (Born et al. 2004), in many areas where they feed, the water is not that deep and dives are correspondingly shallower (Gjertz et al. 2000).

Outside the breeding and molting seasons, Ringed Seal distribution is correlated with food availability (e.g., Simpkins et al. 2003, Freitas et al. 2008). Numerous studies of their diet have been conducted, and although there is considerable regional variation, several patterns emerge. Most Ringed Seal prey are small, and preferred prey tend to be schooling species that form dense aggregations. Fishes are usually in the 5-10 cm length range and crustacean prey in the 2-6 cm range. Typically, a variety of 10-15 prey species are found, with no more than 2-4 dominant prey species for any given area. Fishes are generally more commonly eaten than invertebrates, but diet is determined to some extent by availability of various types of prey during particular seasons as well as by preference, which in part is influenced by energy content of various available prey (Reeves 1998, Wathne et al. 2000). Commonly eaten prey includes cod species redfish, herring, and capelin in marine waters (Lowry et al. 1980, Holst et al. 2001, Labansen et al. 2007). Invertebrate prey species seem to become more important in the open-water season and often dominate the diet of young animals (Lowry et al. 1980, Holst et al. 2001). Large Amphipods, Krill, Mysids, Shrimps, and Cephalopods are all eaten by Ringed Seals and can be very important in some regions at least seasonally (Agafonova et al. 2007).

Ringed seal surveys in Goose Bay and Lake Melville have been completed in 2006 and each year between 2013-2016 (SEM 2007; Amec Foster Wheeler 2016a). Using the seal density within the observed area (approximately 517km^2), a relative abundance estimate for the entire EEM zone was generated for each survey year (**Table** 5-11). Relative abundances have ranged between 644 and 2,140 animals with the 2015 survey being the lowest to date (Amec Foster Wheeler 2016a). Seal ages in Goose Bay and Lake Melville, based on 2016 samples, typically range between pups and adults up to eleven years of age. Since seal samples from Goose Bay and Lake Melville are harvested by a local hunter for consumption by the local community, samples are generally biased toward younger animals. Stomach content analysis has only identified rainbow smelt as prey; however, seals are sampled after whelping and foraging may be more restricted. In addition, pups would only be feeding on milk. Mercury concentrations from ongoing baseline data collection associated with the project are provided in **Table** 5-12.

Table 5-11: Summary of seal relative abundance estimates in Goose Bay and Lake Melville, 2006 through 2016

Sample Year	Total Observed	Relative abundance Estimate	95% Confidence Interval
2006	474	1,888	1,746-2,029
2013	535	2,140	2,081-2,199
2014	196	880	858-901
2015	161	644	621-666
2016	393	1,572	1,523-1,620

Note: Relative abundance estimates and confidence intervals are number of individuals within the entire EEM zone

Table 5-12: Summary of total mercury concentrations (muscle and liver) in ringed seal within the baseline study area, 1999-2016. Only captured in Lake Melville.

Life-stage	Year	Total Mercury (mg/kg)		
		Sample Size	Mean (SE)	Range
Muscle				
Pup	2011	9	0.14 (0.03)	<0.05-0.35
	2012	24	0.04 (0.01)	0.01-0.16
	2013	27	0.09 (0.01)	0.07-0.13
	2014	24	0.13 (0.02)	<0.05-0.30
	2015	24	0.09 (0.01)	0.06-0.15
	2016	25	0.07 (<0.01)	<0.05-0.11
Non Pup	2011	5	0.24 (0.05)	0.09-0.39
	2012	6	1.24 (1.01)	0.16-6.30
	2013	3	0.16 (0.03)	0.11-0.20
	2014	4	0.81 (0.34)	0.19-1.43
	2015	3	0.52 (0.18)	0.27-0.87
	2016	5	0.45 (0.20)	0.17-1.25
Liver				
Pup	2012	24	0.32 (0.07)	0.04-1.70
	2013	27	0.33 (0.04)	<0.05-0.9
	2014	24	0.54 (0.10)	0.09-1.81
	2015	24	0.25 (0.02)	0.13-0.44
	2016	25	0.30 (0.05)	0.09-1.23
Non Pup	2012	6	39.66 (16.65)	0.98-110.00
	2013	3	17.67 (7.61)	2.50-26.40
	2014	4	12.91 (2.88)	7.76-18.20
	2015	3	10.86 (0.95)	9.07-12.30
	2016	5	36.19 (12.62)	6.76-78.30

Note: Values below detection limits have been incorporated as the detection limit (i.e. 0.05mg/kg) to produce a conservative estimate of mean concentrations.

Calder et al. (2016) classified Ringed seals as spending up to 25% of their time in riverine habitat; however, during aerial surveys each season, the lower reach of the Churchill River is flown for seal presence and in all years, no ringed seals have been recorded within the river itself (SEM 2007; Amec Foster Wheeler 2016a). Very few seals are observed within Goose Bay (Amec Foster Wheeler 2016a). However, it should be noted that harbour seals (*Phoca vitulina*) have been observed within the river during fisheries surveys during open water; the most observed at any location and time has been three (McCarthy, unpubl data).

6.0 LIFE HISTORY SUMMARY

The bioaccumulation factors (BAFs) calculated by Calder et al. (2016) were the quotient of the methylmercury concentration within each fish species divided by the methylmercury concentration within the water. They were adjusted prior to final incorporation into the risk estimate model based on an estimate of the fraction of lifespan each species spent feeding in each environment (i.e., marine, estuary, freshwater) (see Supplemental Table S7a and S7b in Calder et al. 2016). However, based on the data presented in this report, modifications to the Calder et al. (2016) final BAFs are recommended to better represent actual habitat use.

In total, the baseline sampling program for the Lower Churchill Hydroelectric Development, which includes Muskrat Falls, has sampled over 10,140 fish from 19 different species between 1998-2016. Many fish species that are relied upon by local residents of the Lake Melville area such as lake trout, Arctic charr, Atlantic salmon (both anadromous and landlocked), and Atlantic cod have either not been captured, or captured in extremely low relative abundance both within and downstream of the Muskrat Falls reservoir area. This includes Goose Bay and Lake Melville. These species would not therefore be considered within the zone of influence of the project. These data of species relative abundance and distribution should be considered in the context of any mercury modelling exercises and especially in determining or completing any Human Health Risk Assessments.

7.0 CLOSURE

The biological and habitat suitability data presented within this report has been compiled using baseline data collected by Amec Foster Wheeler and others since 1998. The methodologies used to collect and generate the data are generally accepted practices described in detail within the EEM and the Fish Habitat Compensation Plan baseline studies, and have been used for studies within the lower Churchill River, as well as other projects throughout Newfoundland and Labrador (AMEC 2013b).

Yours truly,

Wood Environment & Infrastructure Solutions

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Memo

To: Peter Madden, Nalcor

From: Jim McCarthy

cc: Reed Harris, Randy Baker

Date: May 10, 2018

Re. Summary of Isotope and Stomach Data, Goose Bay / Lake Melville Estuary

1. Introduction

As part of the ongoing baseline data collection for the Environmental Effects Monitoring (EEM) Program for the Muskrat Falls portion of the lower Churchill Project, fish have been collected for numerous analyses. Presented below is a brief summary of ongoing stable isotope and stomach content data that provides estimates of downstream habitat use and feeding behaviour to support recent modelling of mercury bioaccumulation and exposure risk due to consumption. The data has been separated by location of capture below Muskrat Falls (e.g., riverine below Muskrat Falls, Goose Bay, inner Lake Melville, and outer Lake Melville). Inner Lake Melville includes all sample locations in the western portion of the lake while outer Lake Melville are those fish sampled near Valley Bight at the eastern end of Lake Melville (Figures 1-1 and 1-2). Additional food web analysis is ongoing as part of PhD research.

Fin clips have been collected from subsets of fish and analyzed for stable isotope ($\delta^{13}C$ and $\delta^{15}N$) ratios by the Stable Isotope in Nature Laboratory (SINLab) at UNB. The ratio of stable isotopes of nitrogen can be used to estimate trophic position because the $\delta^{15}N$ of a consumer is typically enriched by 3-4$^{o/oo}$ relative to its diet (DeNiro and Epstein 1981, Post 2002, Jardine et al 2003, Borga et al. 2011). When comparing among ecosystems (eg. Freshwater to estuary), the $\delta^{15}N$ and $\delta^{13}C$ of an organism alone provides little information about its absolute trophic position or ultimate source of carbon. This is because there is considerable variation among ecosystems in the $\delta^{15}N$ and $\delta^{13}C$ or the base of the food web from which organisms draw their nitrogen and carbon (Post 2002). Without suitable estimates of food web base $\delta^{15}N$ and $\delta^{13}C$, there is no way of knowing if variation reflects changes in food web structure and carbon flow, or just variation in the base nitrogen or carbon values. The simplest model for estimating the trophic position of a secondary consumer is: trophic position = $\lambda + (\delta^{15}N_{secondary\ consumer} - \delta^{15}N_{base})/\Delta_n$, where λ is the trophic position of the organism used to estimate $\delta^{15}N_{base}$ (Post 2002, Borga et al. 2011).

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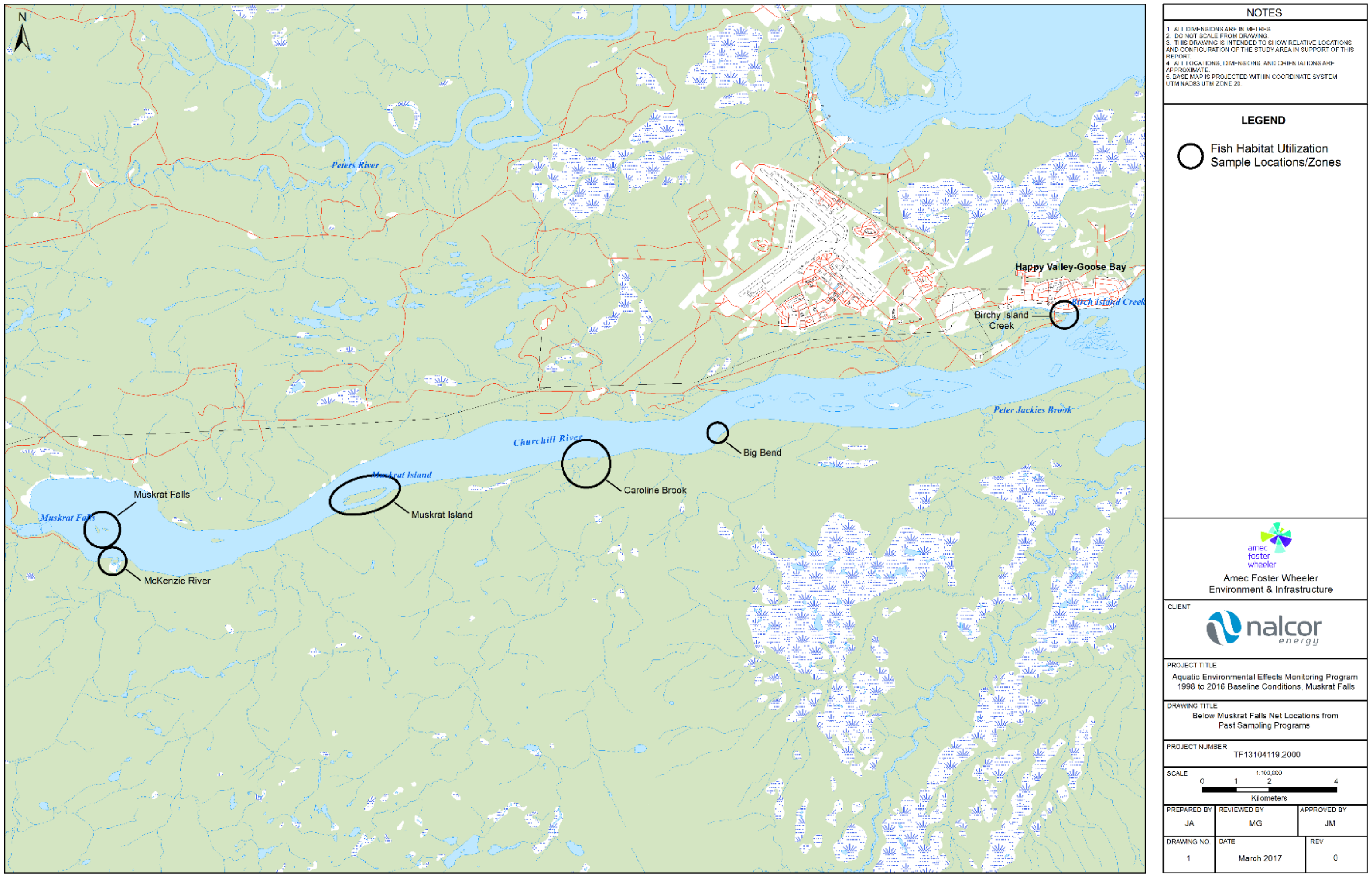

Figure 1-1: Overall EEM study area: mainstem of the lower Churchill River (AMEC 2013b).

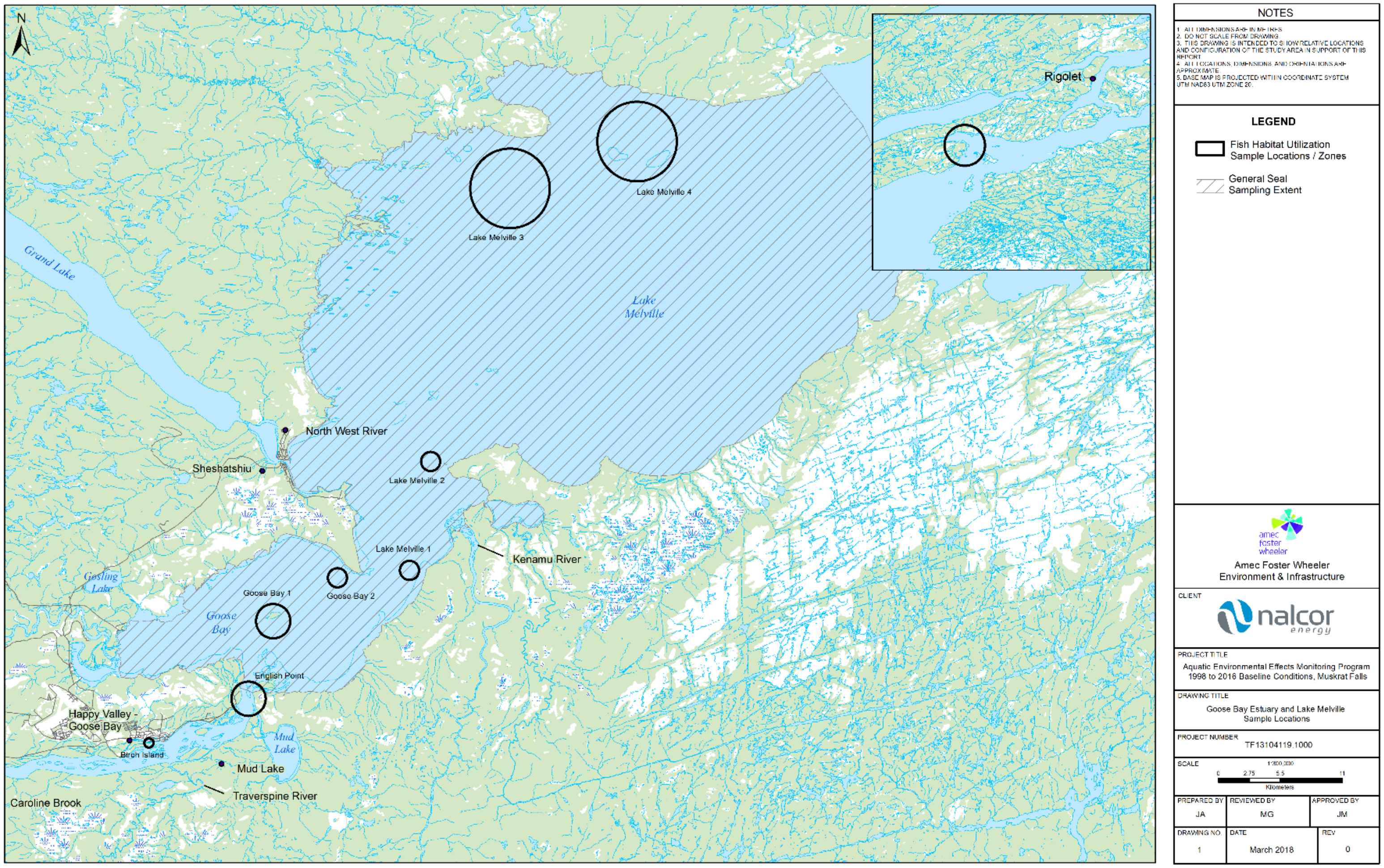

Figure 1-2: Overall EEM study area: Goose Bay estuary and Lake Melville (AMEC 2013b).

Using isotope data from base organisms from the main stem of the Churchill River and estuary (e.g., molluscs, phytoplankton and zooplankton), the trophic position of each fish species was estimated.

In addition to stable isotopes, prey selection by key species has been ongoing via stomach content analysis which can augment isotope data. Stomach content analysis of a subset of samples (focusing on salmonids, northern pike, rainbow smelt and tomcod) was completed from 2017 to augment the trophic results determined by stable isotope ratios. The data presented has been characterized as the percent of all non-empty stomachs analyzed that contained that prey type and does not estimate the quantity within each stomach. Since one fish could have been feeding on multiple prey types, a single stomach sample can be included in multiple categories. Because the number of benthic macroinvertebrate families is high, individual families were consolidated into a larger benthic macroinvertebrate category for ease of presentation.

2. General Isotope Trends

To illustrate the general trends in isotope data, Figure 2-1 shows a generalized plot of isotope signatures for fish sampled in the estuarine (Goose Bay and Lake Melville) and freshwater environments of the lower Churchill River and its tributaries below Muskrat Falls in 2017. The graph shows the division of isotope signatures between the two habitats, as shown by variations in the $\delta^{13}C$ values. It also shows that there are fish that have been sampled in the freshwater environment that display isotope signatures similar to estuarine environments; however, the species and numbers are limited. Note that the identification of 'estuarine' and 'freshwater' are not indicative of the life history of the species, rather it identifies the location in which the specimen was captured (i.e. estuarine samples have been collected from Goose Bay and Lake Melville, while freshwater samples are from the mainstem and associated tributaries below Muskrat Falls). For example, species such as brook trout that are captured in the freshwater of the lower Churchill River below Muskrat Falls show an estuarine isotope signature because they are returning from feeding in the estuary and do not spend considerable time in the main stem prior to migrating up tributaries to spawn.

Freshwater

Figure 2-2 presents the isotope signatures for all species sampled within the mainstem of the Churchill River and tributaries below Muskrat Falls during 2017. Brook trout and Atlantic salmon have the highest $\delta^{15}N$ values and therefore make up the highest trophic levels sampled in 2017.

A general $\delta^{13}C$ ratio greater than -23 can indicate estuarine/marine habitat use (B. Graham, pers. comm. 2011). Several species captured in freshwater in 2017 (i.e. brook trout, northern pike and white sucker) showed $\delta^{13}C$ ranges that could potentially include a marine signature (Figure 2-3). Since netting in Goose Bay and Lake Melville began, brook trout and white sucker have been captured in relatively high abundances in these habitats (see Amec Foster Wheeler 2016). There have been very few northern pike captured within the estuary, however isolated captures of juveniles around Rabbit Island in Goose Bay have occurred. Pike could be preying on fish with estuarine influence (i.e., prey may be feeding near/within the estuary environment).

Goose Bay and Lake Melville

Samples collected from Goose Bay and Lake Melville also show within species variability. Figure 2-4 presents isotope ranges for each fish captured in Goose Bay and Lake Melville during 2017. Brook trout, rainbow smelt and tomcod occupied the highest trophic levels in 2017, similar to

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past sampling programs. Unlike the freshwater habitats, very few fish captured in the estuary environment showed potential freshwater signatures.

Since isotope analysis of ringed seal muscle samples began, they have consistently been shown to occupy the highest trophic level within Goose Bay and Lake Melville (Figure 2-6), indicating that they are likely relying on fish as a primary food source.

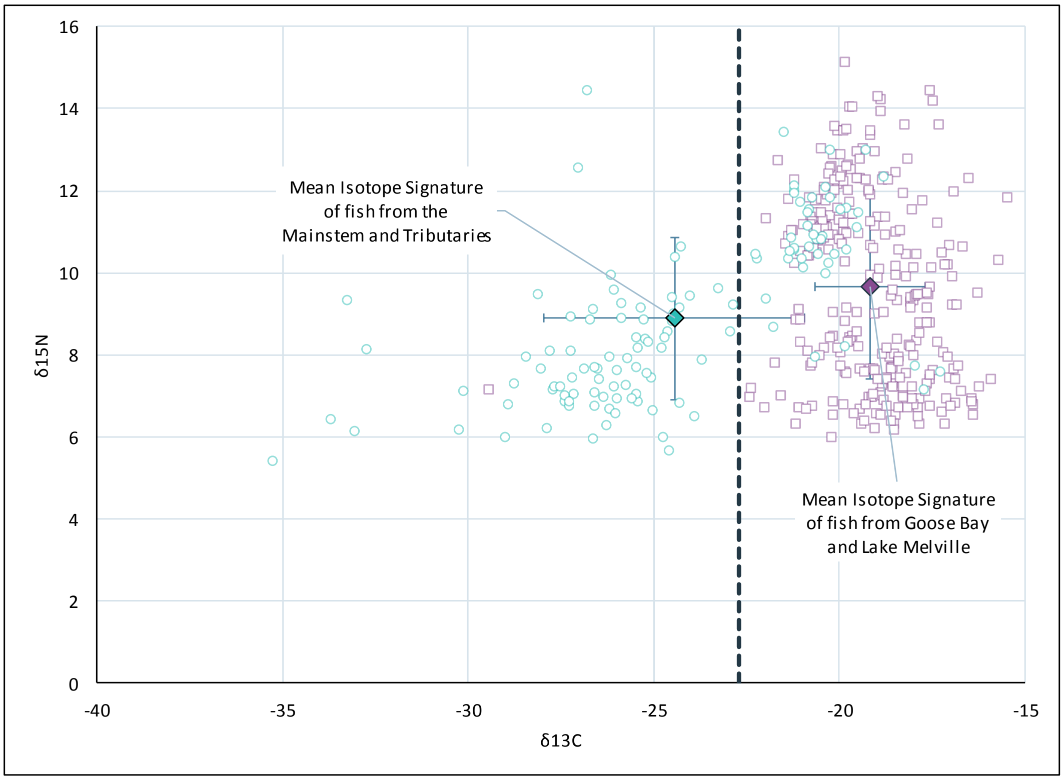

Figure 2-1: Isotope signatures from fish captured within the mainstem and tributaries below Muskrat Falls, Goose Bay and Lake Melville, 2017

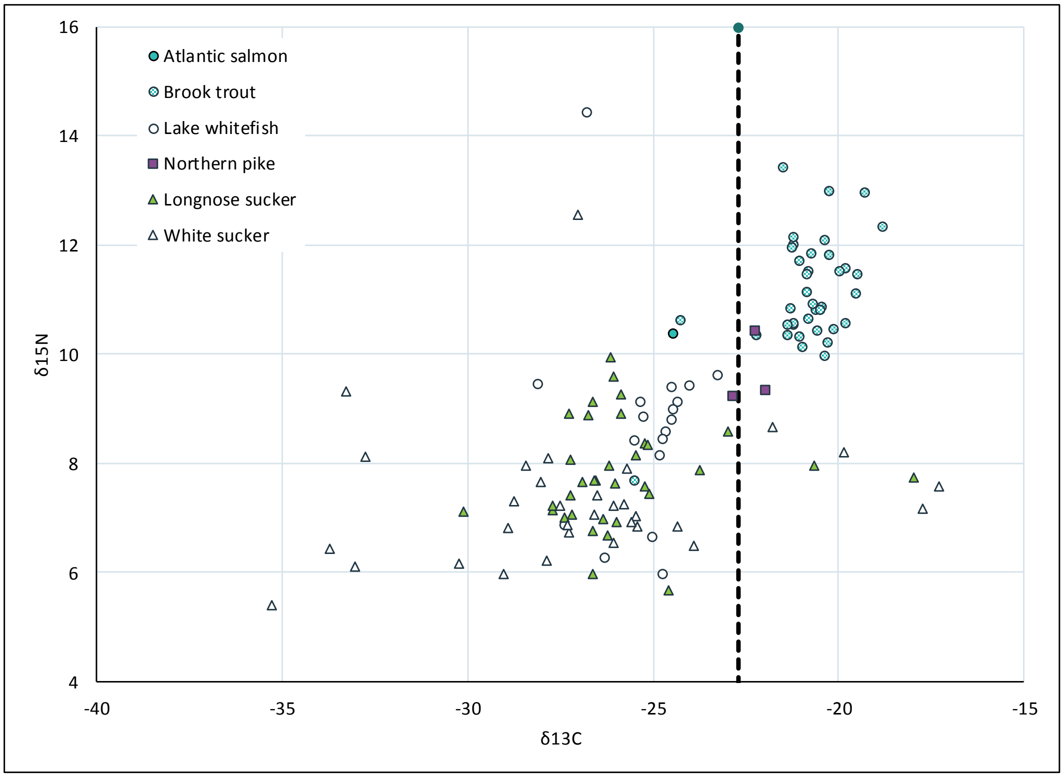

Figure 2-2: Isotope signatures of fish captured the mainstem and tributaries below Muskrat Falls, 2017

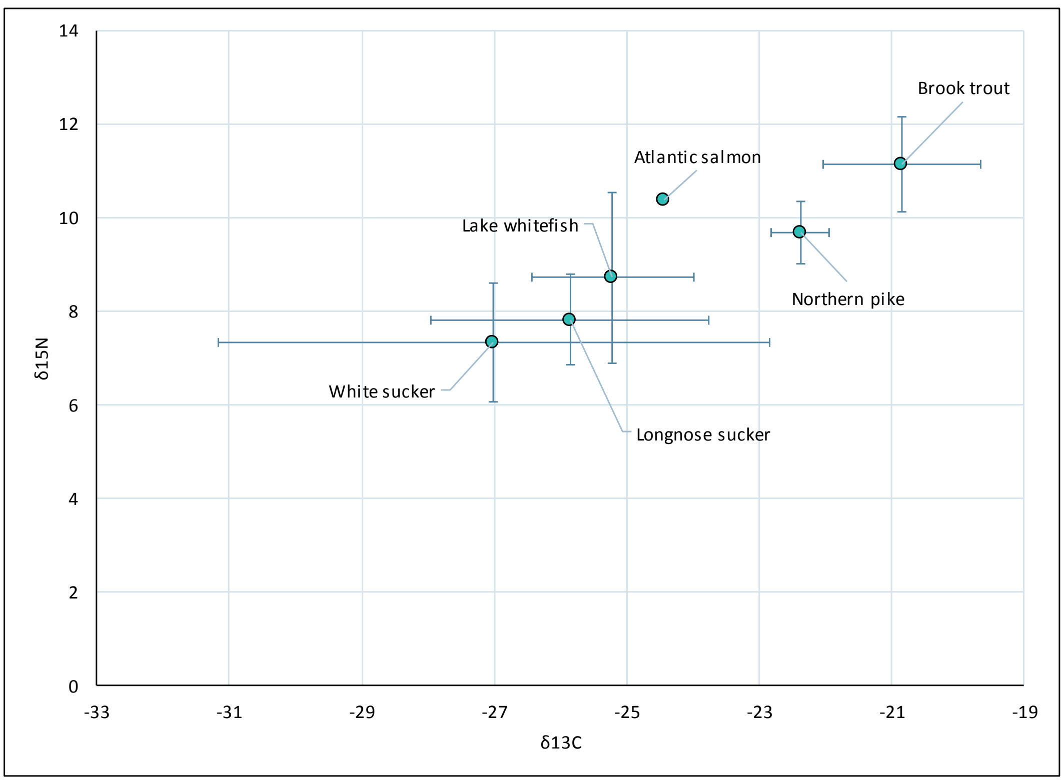

Figure 2-3: Variability in carbon (habitat usage) and nitrogen (trophic level) signatures in fish captured in the mainstem and tributaries below Muskrat Falls, 2017

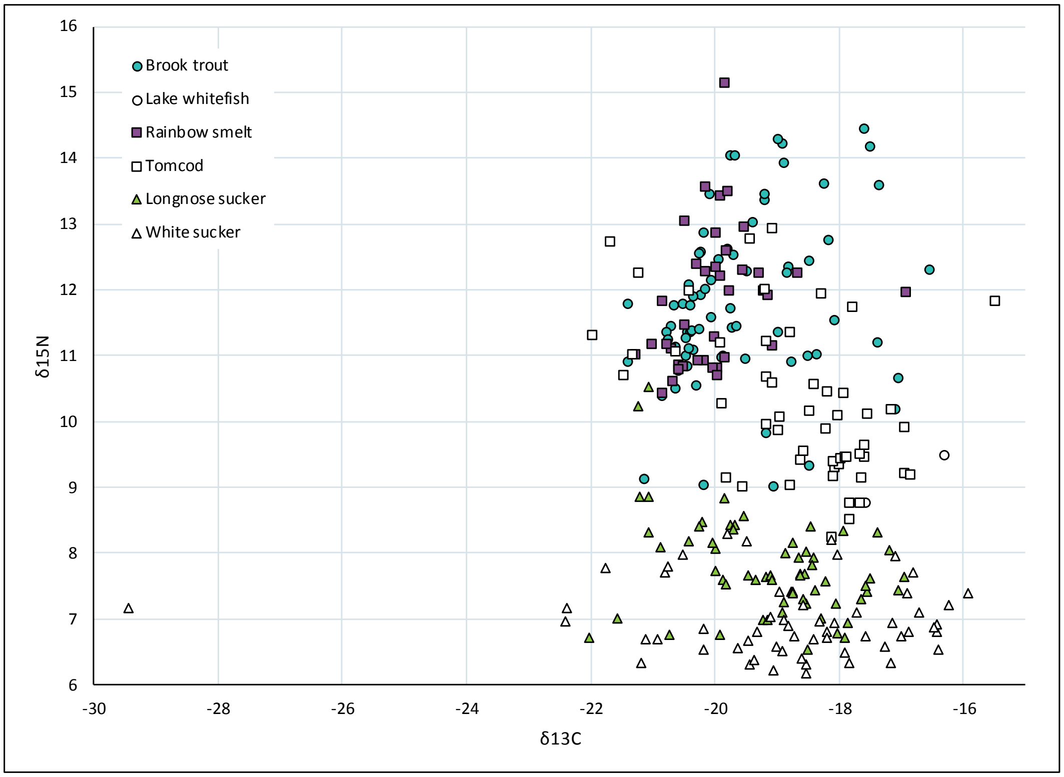

Figure 2-4: Isotope signatures of fish captured in Goose Bay and Lake Melville, 2017

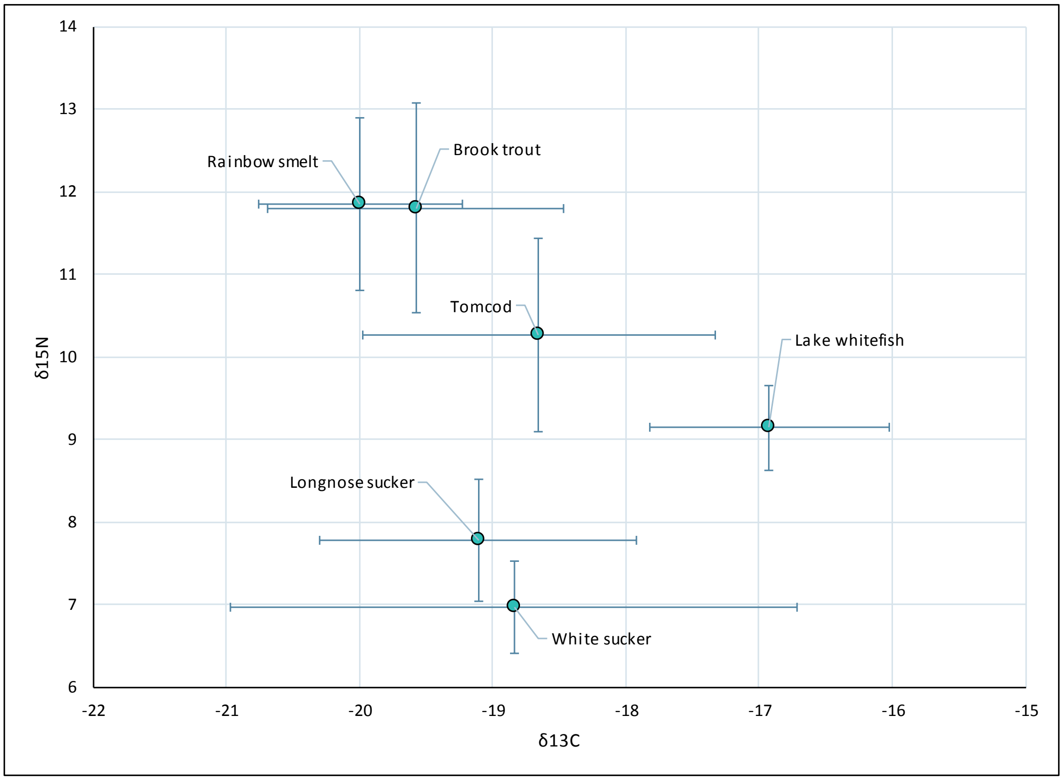

Figure 2-5: Variability in carbon (habitat usage) and nitrogen (trophic level) signatures in fish captured Goose Bay and Lake Melville, 2017

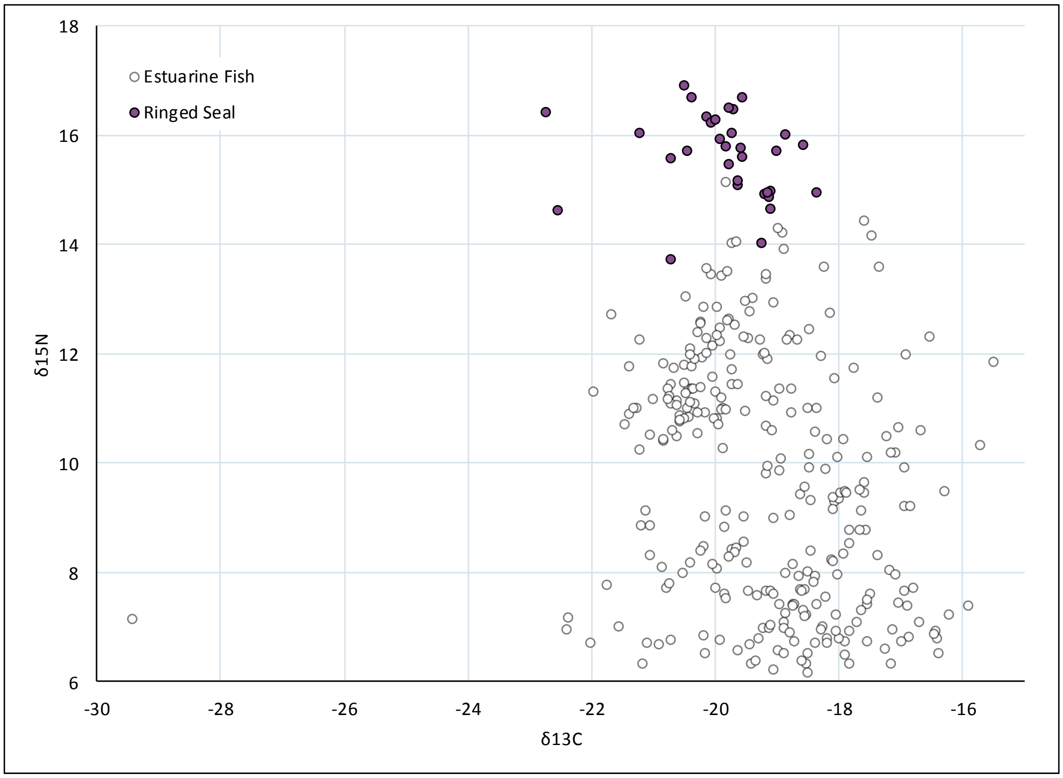

Figure 2-6: *Ringed seal isotope signatures, 2017*

3. Food Chain / Species Trophic Position

Table 1-1 provides a summary of mean stable isotope data collected from key fish species included in the EEM program since 2011 separated in the above noted locations. This data was used to estimate trophic position and food chain length for each species. Table 1-2 provides a general summary of stomach contents within each species to assist in feeding habitat characterization (e.g., freshwater or saline) and interpretation of isotope values.

As shown in Table 1-1, most piscivorous fish species are at the highest trophic positions, generally between values of 4-5. These species include Atlantic herring, Atlantic salmon, brook trout, rainbow smelt, and tom cod which all primarily feed in the estuarine environment as adults (Atlantic salmon off the Labrador coast). Species such as lake whitefish show a slightly lower trophic position as they typically rely on benthic invertebrates and larger amphipods/zooplankton and do not consume other fish species. It is noteworthy that northern pike also appear to be at a general trophic range of 2-5-3.5 likely due to their major prey being suckers (a fish also at a lower trophic range of ~1.5-2.5). Ringed seals have the greatest trophic values as they likely feed on a variety of fish and are one of the top predators monitored in Lake Melville.

It should be noted that some of the variability within the trophic ranges of fish could be due to variations in sample sizes between years and varying size classes of fish sampled (e.g., the data were not separated by age-class or size) for this exercise.

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Table 3-1: Summary of mean annual stable isotope data and trophic level estimates, Churchill River, Labrador.

Species	Location	Year	Sample Size (n)	Mean Carbon δC^{13} ($^{o/oo}$)	Mean Nitrogen δN^{15} ($^{o/oo}$)	Estimated Trophic Level & Food Chain Length[1]
Atlantic herring	Goose Bay	2011	1	-18.4	13.2	4.7
Atlantic salmon	Inner Lake Melville	2010	6	-19.8	10.7	4.0
Atlantic salmon	Inner Lake Melville	2013	2	-18.7	11.9	4.3
Atlantic salmon	Inner Lake Melville	2015	22	-21.0	11.9	4.3
Brook trout	Goose Bay	2011	43	-21.3	10.9	4.0
Brook trout	Goose Bay	2013	26	-19.7	10.7	4.0
Brook trout	Goose Bay	2014	30	-18.9	12.8	4.6
Brook trout	Goose Bay	2015	6	-19.1	10.9	4.0
Brook trout	Goose Bay	2016	6	-19.5	11.1	4.1
Brook trout	Goose Bay	2017	11	-18.5	11.0	4.1
Brook trout	Inner Lake Melville	2013	35	-18.5	10.7	4.0
Brook trout	Inner Lake Melville	2014	30	-19.7	11.9	4.3
Brook trout	Inner Lake Melville	2015	29	-18.9	12.6	4.5
Brook trout	Inner Lake Melville	2016	30	-19.6	11.8	4.3
Brook trout	Inner Lake Melville	2017	32	-19.7	12.2	4.4
Brook trout	Outer Lake Melville	2017	29	-19.8	11.7	4.3
Brook trout	Below Muskrat Falls	2010	2	-26.4	14.3	5.5
Brook trout	Below Muskrat Falls	2011	12	-23.0	11.1	4.6
Brook trout	Below Muskrat Falls	2012	18	-22.3	11.9	4.8
Brook trout	Below Muskrat Falls	2013	30	-22.4	10.2	4.3
Brook trout	Below Muskrat Falls	2014	8	-24.3	9.06	4.0
Brook trout	Below Muskrat Falls	2015	11	-23.9	10.4	4.4
Brook trout	Below Muskrat Falls	2016	35	-22.4	10.6	4.4
Brook trout	Below Muskrat Falls	2017	40	-20.9	11.1	4.6
Lake Whitefish	Goose Bay	2011	1	-19.1	10.2	3.8
Lake Whitefish	Goose Bay	2013	4	-20.7	9.1	3.5
Lake Whitefish	Goose Bay	2014	1	-18.4	11.2	4.1
Lake Whitefish	Goose Bay	2016	2	-21.1	9.5	3.6
Lake Whitefish	Inner Lake Melville	2014	7	-19.1	9.2	3.5
Lake Whitefish	Inner Lake Melville	2015	2	-20.2	9.3	3.6
Lake whitefish	Goose Bay	2017	2	-16.9	9.1	3.5
Lake whitefish	Below Muskrat Falls	2010	6	-24.3	8.6	2.9
Lake whitefish	Below Muskrat Falls	2011	14	-24.4	9.8	3.3
Lake whitefish	Below Muskrat Falls	2012	5	-22.8	9.6	3.2
Lake whitefish	Below Muskrat Falls	2014	3	-24.8	9.2	3.1
Lake whitefish	Below Muskrat Falls	2015	2	-23.2	9.2	3.1
Lake whitefish	Below Muskrat Falls	2016	2	-21.6	10.8	3.6
Lake whitefish	Below Muskrat Falls	2017	19	-25.2	8.7	3.0
Rainbow Smelt	Goose Bay	2011	30	-20.9	12.6	4.5
Rainbow Smelt	Goose Bay	2013	21	-20.4	12.7	4.6
Rainbow Smelt	Goose Bay	2014	2	-18.2	14.2	5.0
Rainbow Smelt	Goose Bay	2016	1	-19.9	9.3	3.6
Rainbow Smelt	Inner Lake Melville	2013	21	-20.3	12.7	4.6
Rainbow Smelt	Inner Lake Melville	2014	25	-19.6	13.3	4.7
Rainbow Smelt	Inner Lake Melville	2015	12	-20.1	12.7	4.6
Rainbow Smelt	Inner Lake Melville	2016	6	-20.2	11.3	4.1
Rainbow Smelt	Outer Lake Melville	2016	16	-18.3	10.6	3.9
Rainbow Smelt	Inner Lake Melville	2017	16	-20.4	11.6	4.2
Rainbow Smelt	Outer Lake Melville	2017	22	-19.7	12.1	4.4
Rainbow Smelt	Below Muskrat Falls	2016	1	-21.6	10.7	3.8
Tom cod	Goose Bay	2011	6	-20.5	12.6	4.1
Tom cod	Goose Bay	2013	8	-20.7	11.0	4.0

Species	Location	Year	Sample Size (n)	Mean Carbon δC^{13} ($^{o/oo}$)	Mean Nitrogen δN^{15} ($^{o/oo}$)	Estimated Trophic Level & Food Chain Length[1]
Tom cod	Goose Bay	2014	1	-19.0	10.7	4.0
Tom cod	Goose Bay	2016	6	-20.9	10.9	4.4
Tom cod	Inner Lake Melville	2011	7	-20.4	13.1	4.7
Tom cod	Inner Lake Melville	2013	12	-17.4	10.3	3.8
Tom cod	Inner Lake Melville	2014	30	-18.7	11.5	4.2
Tom cod	Inner Lake Melville	2015	8	-17.9	11.5	4.2
Tom cod	Inner Lake Melville	2016	30	-18.0	10.6	3.8
Tom cod	Goose Bay	2017	3	-19.1	12.1	4.5
Tom cod	Inner Lake Melville	2017	39	-18.6	10.1	3.8
Tom cod	Outer Lake Melville	2017	11	-18.8	10.5	3.9
Winter flounder	Inner Lake Melville	2011	10	-19.6	13.5	4.8
Longnose sucker	Goose Bay	2011	29	-18.8	7.5	1.6
Longnose sucker	Goose Bay	2013	27	-17.8	8.0	1.7
Longnose sucker	Goose Bay	2014	29	-18.4	8.5	1.9
Longnose sucker	Goose Bay	2015	29	-17.4	8.0	1.7
Longnose sucker	Goose Bay	2016	29	-18.6	7.4	1.5
Longnose sucker	Inner Lake Melville	2011	15	-17.7	8.6	1.9
Longnose sucker	Inner Lake Melville	2013	26	-18.5	8.2	1.8
Longnose sucker	Inner Lake Melville	2014	26	-19.1	8.6	1.9
Longnose sucker	Inner Lake Melville	2015	30	-18.3	7.8	1.7
Longnose sucker	Inner Lake Melville	2016	21	-18.9	7.2	1.5
Longnose sucker	Outer Lake Melville	2016	1	-18.4	8.1	1.6
Longnose sucker	Inner Lake Melville	2017	32	-18.9	7.7	1.7
Longnose sucker	Outer Lake Melville	2017	32	-19.3	7.8	1.7
Longnose sucker	Below Muskrat Falls	2011	26	-26.4	8.0	2.8
Longnose sucker	Below Muskrat Falls	2012	29	-26.4	7.3	2.6
Longnose sucker	Below Muskrat Falls	2013	29	-23.4	8.9	3.0
Longnose sucker	Below Muskrat Falls	2014	9	-25.9	9.2	3.1
Longnose sucker	Below Muskrat Falls	2015	27	-26.4	7.8	2.7
Longnose sucker	Below Muskrat Falls	2016	31	-26.6	7.7	2.7
Longnose sucker	Below Muskrat Falls	2017	36	-25.7	7.8	2.7
Northern Pike	Goose Bay	2013	1	-21.0	7.7	2.7
Northern Pike	Below Muskrat Falls	2010	7	-25.5	8.1	2.8
Northern Pike	Below Muskrat Falls	2011	5	-28.2	9.0	3.1
Northern Pike	Below Muskrat Falls	2012	7	-24.6	8.9	3.0
Northern Pike	Below Muskrat Falls	2013	28	-24.6	9.3	3.1
Northern Pike	Below Muskrat Falls	2014	10	-24.5	10.1	3.4
Northern Pike	Below Muskrat Falls	2015	5	-25.9	8.8	3.0
Northern Pike	Below Muskrat Falls	2016	15	-25.8	9.2	3.1
Northern Pike	Below Muskrat Falls	2017	3	-22.4	9.7	3.3
Ringed Seal	Inner Lake Melville	2011	14	-19.5	15.5	5.4
Ringed Seal	Inner Lake Melville	2012	30	-19.1	16.2	5.6
Ringed Seal	Inner Lake Melville	2013	29	-19.2	16.1	5.6
Ringed Seal	Inner Lake Melville	2014	28	-19.5	16.0	5.5
Ringed Seal	Inner Lake Melville	2015	27	-19.6	15.9	5.5
Ringed Seal	Inner Lake Melville	2016	29	-20.1	16.0	5.5
Ringed Seal	Inner Lake Melville	2017	30	-19.9	15.6	5.4

[1] Based on each trophic level accounting for approximately 3.4$^{o/oo}$ although it is recognized that this can be variable.

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Table 3-2: Summary of prey diversity below Muskrat Falls, 2017

Species	Vegetation	Invertebrates	Fish	Plankton
Freshwater				
Brook trout		Odonata, Ephemerelidae, Daphniidae, Plecoptera, Tipulidae, Chironimidae, Coleoptera, Hydroptilidae, Leptophlebidae, Diptera	Rainbow smelt, Lake Chub, Sculpin	
Lake whitefish	Filamentous algae	Daphniidae, Leptoceridae, Chironimidae, Cyelopidae, Chydoridae, Podocopida		
Longnose sucker	Filamentous algae	Chironimid, Hydrachnidia, Bivalves		
Northern pike			3-spine stickleback, Longnose sucker, White sucker	
Rainbow smelt				
Atlantic salmon		Pteronacidae	Unidentified fish	
Goose Bay				
Brook trout		Tricoptera, Chironimidae, Odonata, Formicidae, Hymenoptera	Sculpin, Tomcod, Rainbow smelt, Longnose sucker	
Lake whitefish		Chironimidae, Diptera, Hymenoptera	Sculpin, Unidentified fish	
Longnose sucker				
Northern pike				
Rainbow smelt				Decopod
Tomcod			Lake chub, Sand lance	
Lake Melville				
Brook trout		Diptera, Chironimidae, Hydroptilidae, Ichnumonidae, Cicadellidae, Staphylinidae, Hymenoptera, Bivalve	Tomcod, Sand lance, 3-spine stickleback, Winter flounder, Rainbow smelt, Unidentified fish	Amphipod, Decopod
Lake whitefish				
Longnose sucker				
Northern pike				
Rainbow smelt			Sand lance, Rainbow smelt, Unidentified fish	Decapod, Amphipod
Tomcod		Chironimidae	Sand lance, Sculpin, Rainbow smelt, Lake chub	Amphipod, Decapod, Isopod

Brook trout were collected in all four habitat areas (below Muskrat Falls, Goose Bay, inner Lake Melville, and outer Lake Melville). Below Muskrat Falls, Brook trout displayed generally greater range in tropic level ($\delta^{15}N$), indicating variation in diet (Figure 2-3). In the estuary environments, brook trout showed one of the greatest ranges in $\delta^{15}N$ signatures (Figure 2-5) and suggests they may be opportunistic feeders and are likely preying on various fish and planktonic species.

Stomach content analysis summary is provided in Figure 3-1. As shown, the influence of benthic macroinvertebrates is greatest in those fish captured within or near (i.e. Goose Bay) the lower Churchill River. Similar to other years, most 2017 brook trout in freshwater were captured in September within tributaries of the lower Churchill River such as Caroline Brook and McKenzie River. The presence of marine prey such as sandlance and rainbow smelt in a percentage of the non-empty stomachs indicates a return from the estuary environment. The presence of benthic invertebrates as prey in samples from inner Lake Melville was much lower, possibly indicating lower influence of freshwater. A general increase in prey diversity can also be seen from samples collected from outer Lake Melville (e.g., Valley Bight area). Brook trout from the more eastern portion of the lake preyed on amphipods and decapods which were not identified in freshwater, Goose Bay or inner Lake Melville samples. Sandlance appeared to be a prevalent prey item within Lake Melville while tomcod seemed to play a greater role as prey in Goose Bay but less so further into Lake Melville.

The brook trout stomach content results support the isotope values recorded in both the freshwater and estuary environment. Brook trout captured and sampled in the freshwater environment are feeding on benthic macroinvertebrates and fish with some of the fish being estuary origin. The estuary samples indicate higher numbers of brook trout preying on fish along with zooplankton in outer Lake Melville. This places them near the higher $\delta^{15}N$ values and would explain the high range of $\delta^{15}N$ values measured as they feed at various trophic levels. A similar trophic level and chain length among freshwater and estuary samples indicates the general movement of brook trout into the estuary from freshwater environments to feed (see Table 1-1).

Tomcod were sampled in all estuary environments (i.e., Goose Bay, inner Lake Melville and outer Lake Melville) but not in freshwater. Similar to brook trout and rainbow smelt, tomcod showed one of the greatest ranges in $\delta^{15}N$ signatures (Figure 2-5) and suggest that they may be opportunistic feeders and are likely preying on various fish and planktonic species.

With respect to stomach content analysis, a high proportion of stomachs from Goose Bay were empty in contrast to those from Lake Melville (Figure 3-2). In Goose Bay, fish was the only prey item identified (sandlance and lake chub). In Lake Melville, there seemed to be little freshwater influence in terms of prey items and greater presence of amphipods, isopods and decapods and generally lower predation on fish species in outer Lake Melville. This is also evident in the $\delta^{15}N$ isotope signatures which tended to be lower than those of brook trout and rainbow smelt (see Figure 2-5).

Rainbow smelt were also sampled in all estuary environments, similar to tomcod. Also similar to tomcod and brook trout, they showed some of the largest range in $\delta^{15}N$ signatures (Figure 2-5) and may suggest that they are opportunistic feeders and are likely preying on various fish and planktonic species.

However, those rainbow smelt sampled for stomach contents in Goose Bay appeared to rely heavily on decapods (Figure 3-3). Within inner Lake Melville, fish was the most prevalent prey item with fish and zooplankton (amphipods and decapods) preyed upon in outer Lake Melville.

This trend is similar in some ways to tomcod and likely reflects general prey availability for these species within Lake Melville.

Rainbow smelt showed a similar $\delta^{15}N$ isotope signature range to that of brook trout which indicates that the relative proportions of prey items may be similar among these species diet. They both appear to be the two fish species (of those sampled) highest on the estuary food web (see Figure 1-7).

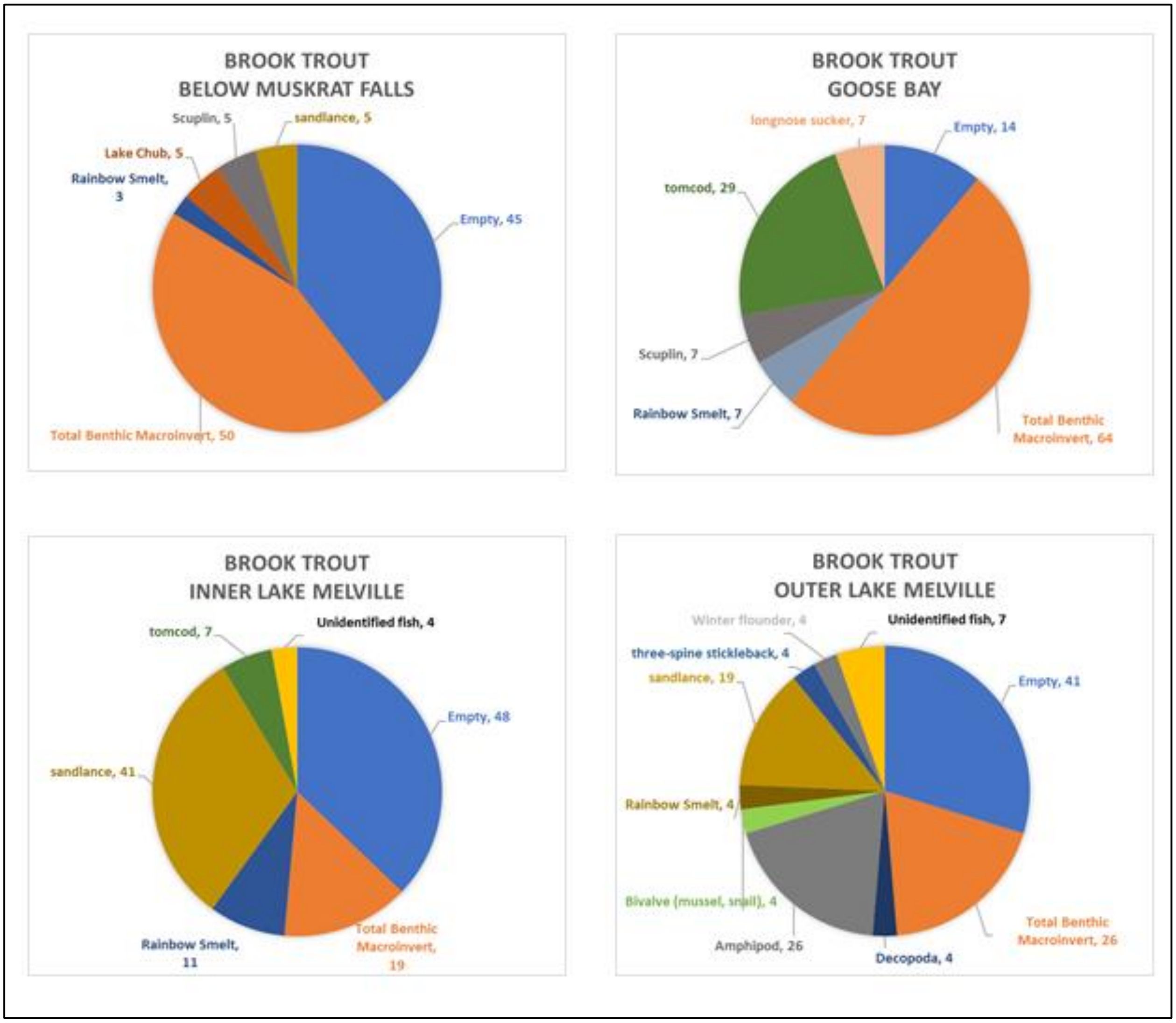

Figure 3-1: Brook trout stomach content analysis. Numbers presented are the percentage of stomachs which contained that prey item.

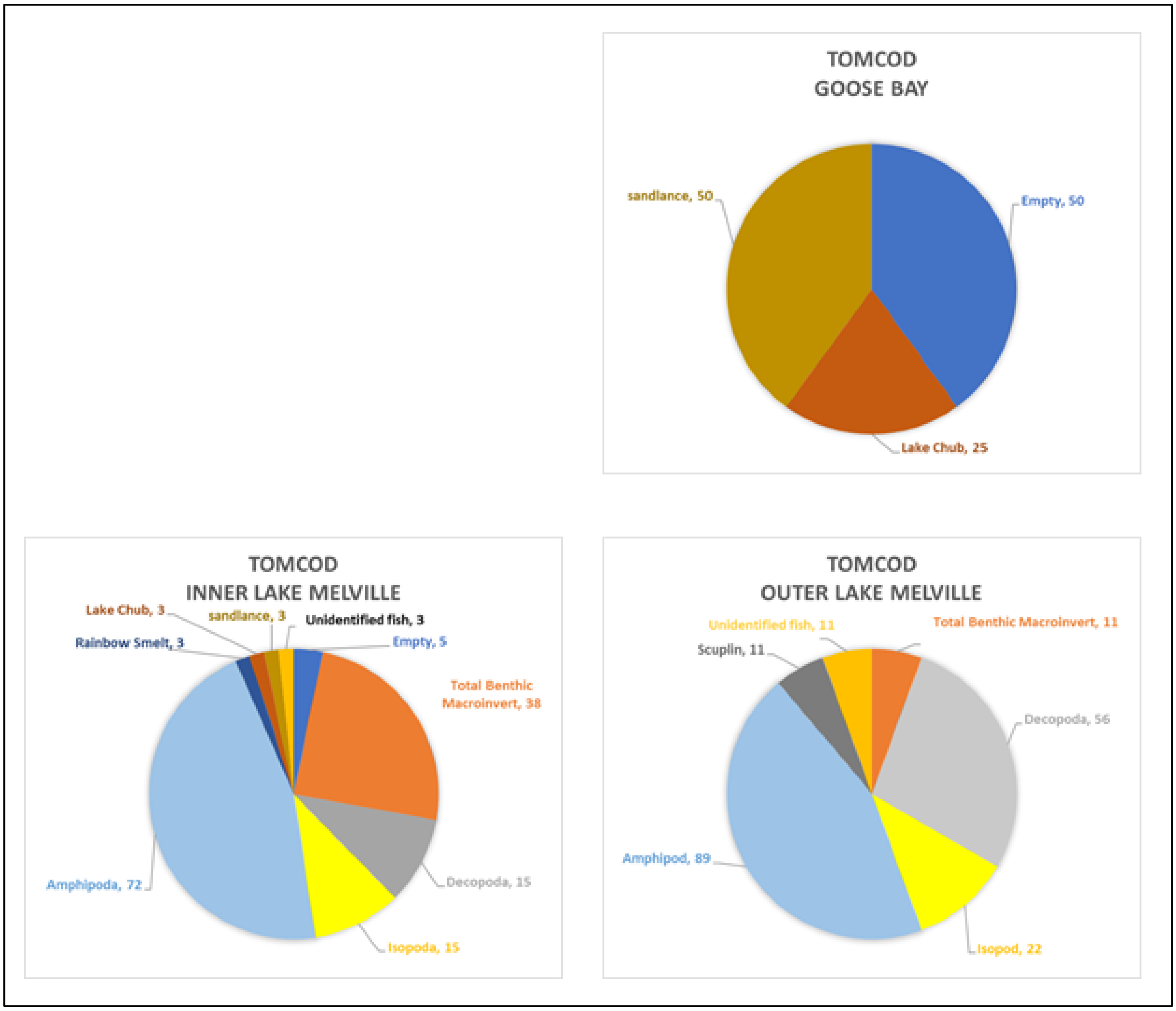

Figure 3-2: Tomcod stomach content analysis. Numbers presented are the percentage of stomachs which contained that prey item.

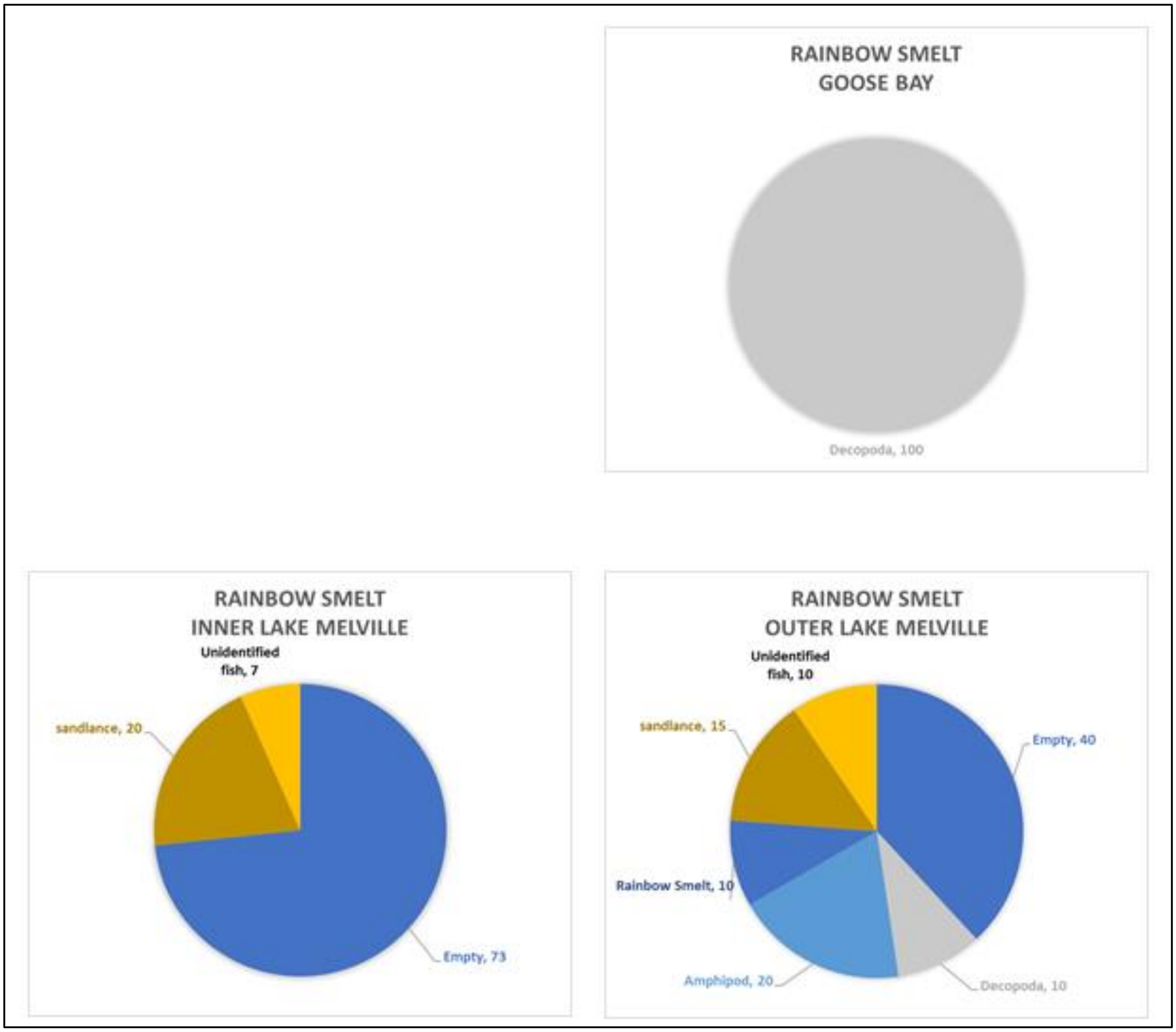

Figure 3-3: Rainbow smelt stomach content analysis. Numbers presented are the percentage of stomachs which contained that prey item.

Lake whitefish were sampled in and near the freshwater environment (Figure 3-4). Similar to brook trout, lake whitefish displayed generally greater range in tropic level ($\delta^{15}N$), indicating variation in diet (Figure 2-3).

As shown via stomach content analysis, there was a large benthic macroinvertebrate prey influence with some fish predation identified within the freshwater environment. The higher benthic invertebrate prey is also reflected in the $\delta^{15}N$ isotope signature range (see Figures 2-3 and 2-5) which places this species, as expected, lower than brook trout, rainbow smelt, tomcod, and northern pike. The species food chain length is also relatively shorter that these other species with the exception of northern pike (see Table 1-1).

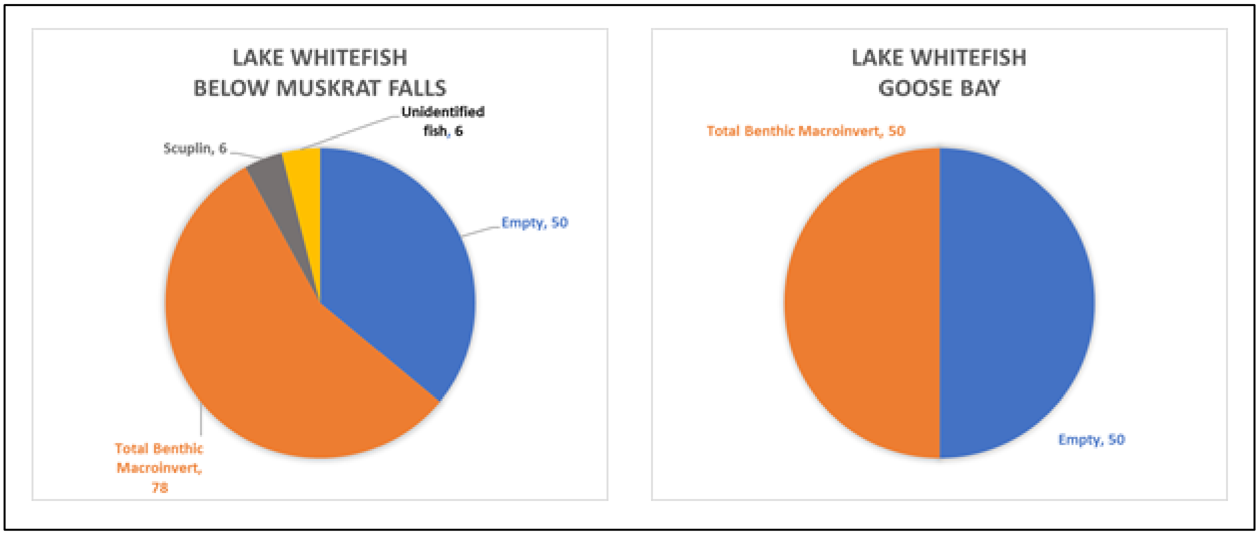

Figure 3-4: Lake whitefish stomach content analysis. Numbers presented are the percentage of stomachs which contained that prey item.

Northern pike were only sampled from the freshwater environment in 2017 (Figure 3-5). Based on isotope signatures, northern pike displayed the lowest variability of $\delta^{15}N$ isotope signature (Figure 2-3), indicating that northern pike are likely relying on other fish as a food primary source and may be keying in on specific species based on abundance or capture success.

Based on stomach content analysis, northern pike appear to be heavily reliant upon fish as a food source within the mainstem and tributaries such as white sucker, longnose sucker, and stickleback. This information tends to confirm that pike are feeding on lower trophic level fish as shown in their $\delta^{15}N$ isotope signature range as shown in Figure 2-3. While they are feeding on other fish, these prey species have relatively short food chain lengths which is reflected in the pike's lower food chain length as well (see Table 1-1).

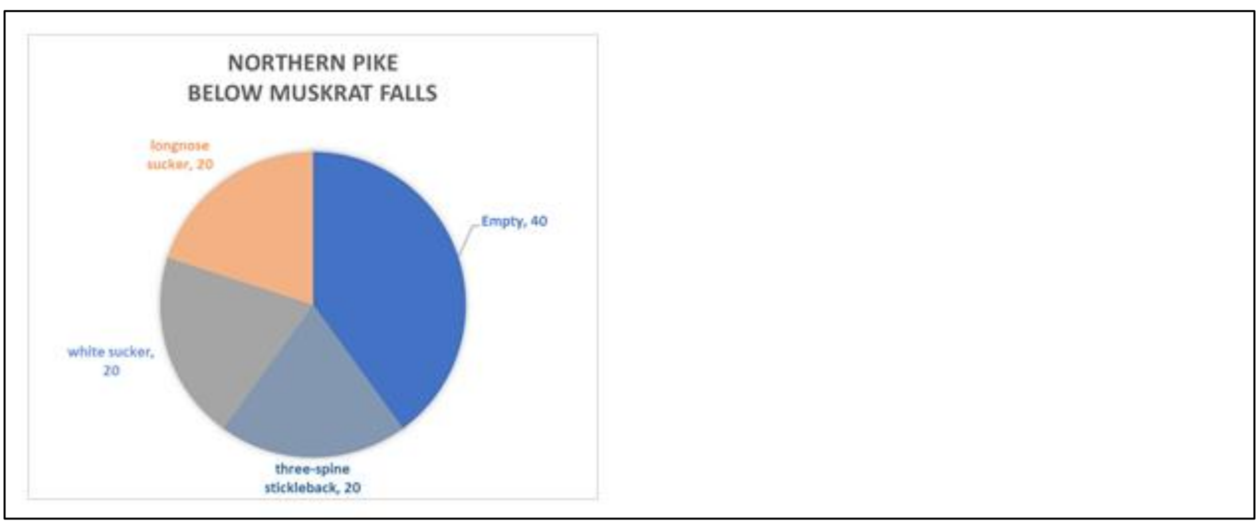

Figure 3-5: Northern pike stomach content analysis. Numbers presented are the percentage of stomachs which contained that prey item.

Longnose sucker showed the greatest range in $\delta^{13}C$ signatures, indicating that they may be feeding on a wide range of terrestrial, benthic, and pelagic carbon sources that have settled to the substrate (Figure 2-5).

Stomach content analysis from Goose Bay (the only location where stomach content analyssi has been completed) confirms that they appear to feed on benthic organisms such as filamentous algae, benthic macroinvertebrates, and bivalves (mussels and snails) (Figure 3-6). Their overall low trophic level and food chain length in all estuarine habitats seems to indicate that they feed at a similar trophic level throughout (see Table 1-1). It is notable however that the estimated trophic level of longnose sucker sampled within the freshwater environment appear to have a slightly higher trophic level and food chain length, possibly related to greater benthic macroinvertebrate diversity in the tributaries (e.g., predacious benthic inverts such as Odonata), bivalve availability, or pelagic contributions to the bottom substrate such as settling zooplankton.

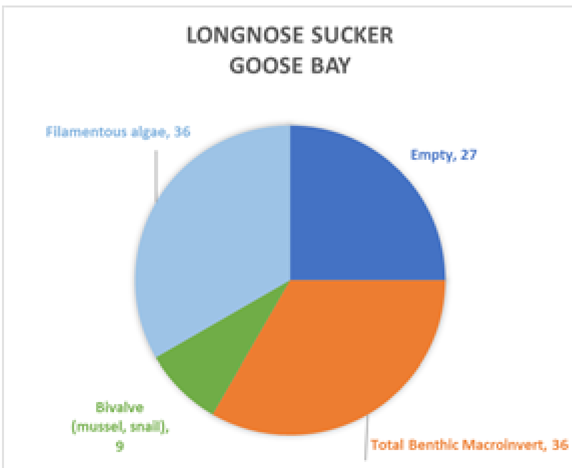

Figure 3-6: Longnose sucker stomach content analysis. Numbers presented are the percentage of stomachs which contained that prey item.

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4. Recommendation on Habitat Utilization and Food web influence

The data on stable isotopes and stomach content analysis suggests that many of the fish species that utilize Lake Melville for feeding are preying on other lower trophic fish and zooplankton that are more marine origin. This would suggest that species spend greater time in the lower more-saline layer of Lake Melville to feed. This information should be considered in terms of the pathway for any predicted increase in methylmercury exposure.

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