Aquatic Species Habitat Utilization Overview

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

Submitted to:

Independent Expert Committee

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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 fish species have been modeled and included in Nalcor's Human Health Risk Assessment (HHRA) (Dillon 2016). Simultaneous to this, additional assessments of mercury increases 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 fish species identified within the HHRAs. This information will be helpful in ongoing discussions with local communities and further analysis of potential human risk.

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.

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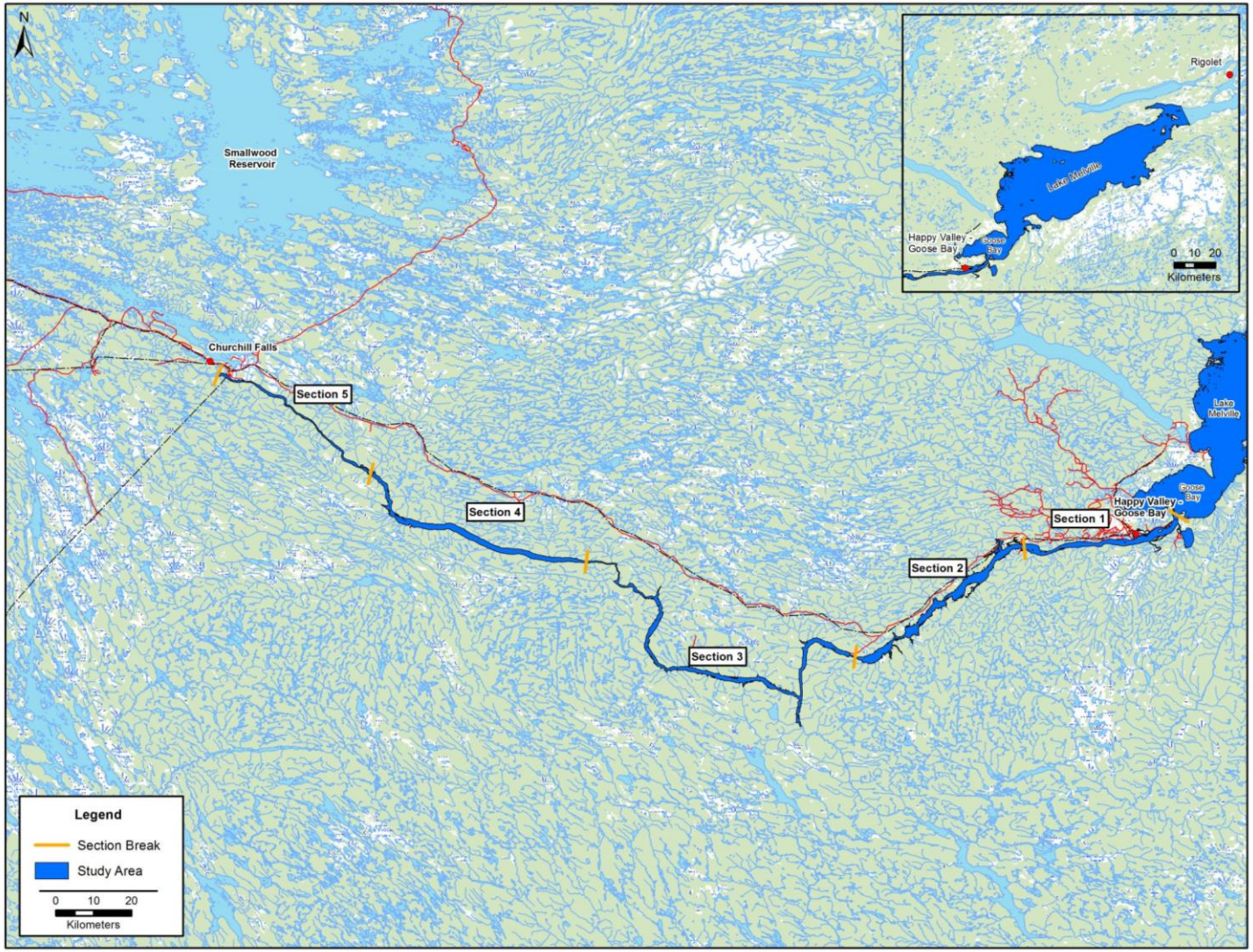

Figure 2-1: Overall baseline study area: mainstem of the lower Churchill River, Goose Bay, and Lake Melville.

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 10ppt, mixes very slowly in Lake Melville. The salinity changes to approximately 25ppt 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). 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 (Bobbit 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 (AGRA 1998).

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. In particular, 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.

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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, 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.

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 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 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 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, 2000; AMEC 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).

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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	
	Abundance CPUE[1]	Biomass CPUE[2]	Abundance CPUE[1]	Biomass CPUE[2]	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 Abundance CPUE expressed as fish/net-night

2 Biomass CPUE expressed as grams/net-night

3 Threespine Stickleback

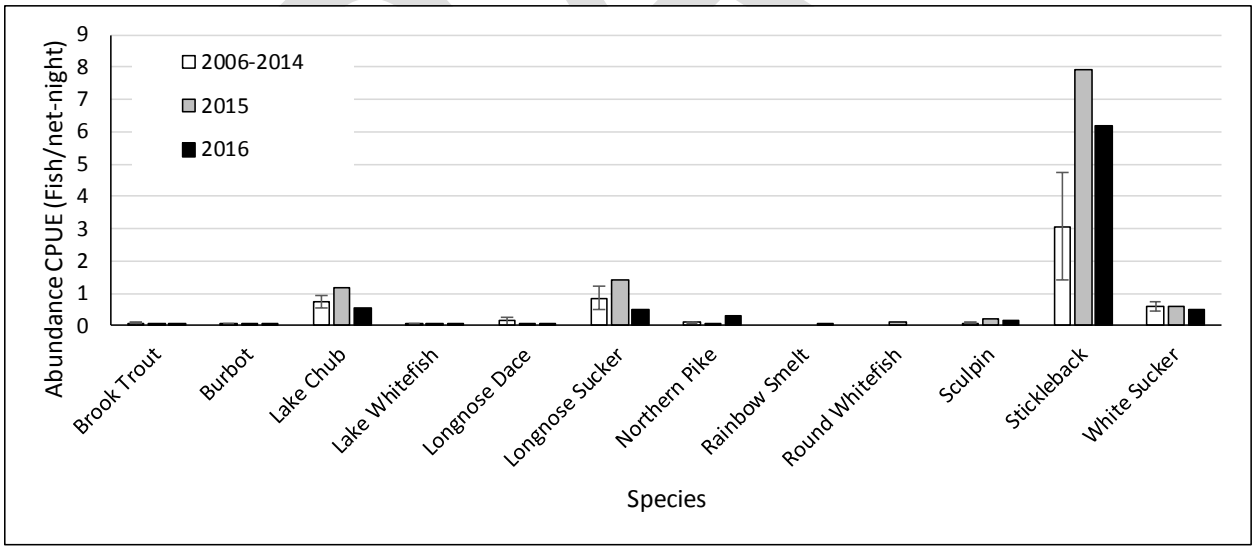

Figure 5-1: Fyke net abundance CPUE (fish/net-night) in the mainstem below Muskrat Falls (Section One), 2006 – 2016, Fall sampling (bars present the standard error of the mean CPUE from 2006-2014)

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

Species	1999-2014		2015		2016	
	Mean Abundance CPUE[1]	Mean Biomass CPUE[2]	Mean Abundance CPUE[1]	Mean Biomass CPUE[2]	Mean 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 Abundance CPUE expressed as fish/net-night

2 Biomass CPUE expressed as grams/net-night

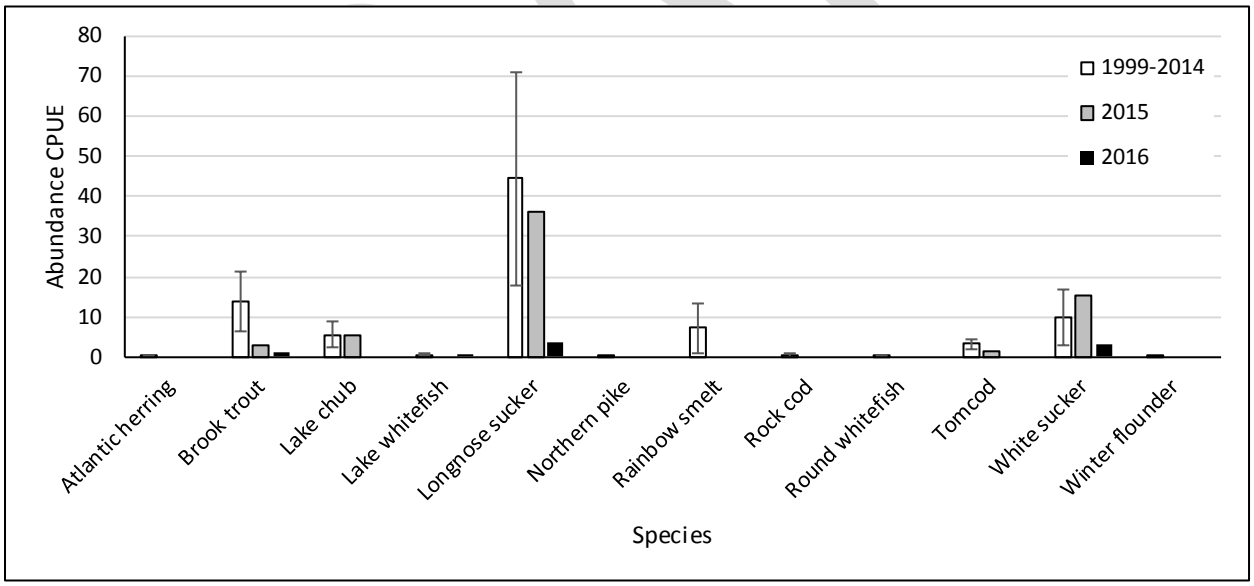

Figure 5-2: Mean gillnet abundance CPUE in Goose Bay, 1999 through 2016 (Error bars represent the standard error of the annual mean abundance CPUE from 1999-2014).

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

Species	2011-2014		2015		2016	
	Abundance CPUE	Biomass CPUE	Abundance CPUE	Biomass CPUE	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 Abundance CPUE expressed as fish/net-night

2 Biomass CPUE expressed as grams/net-night

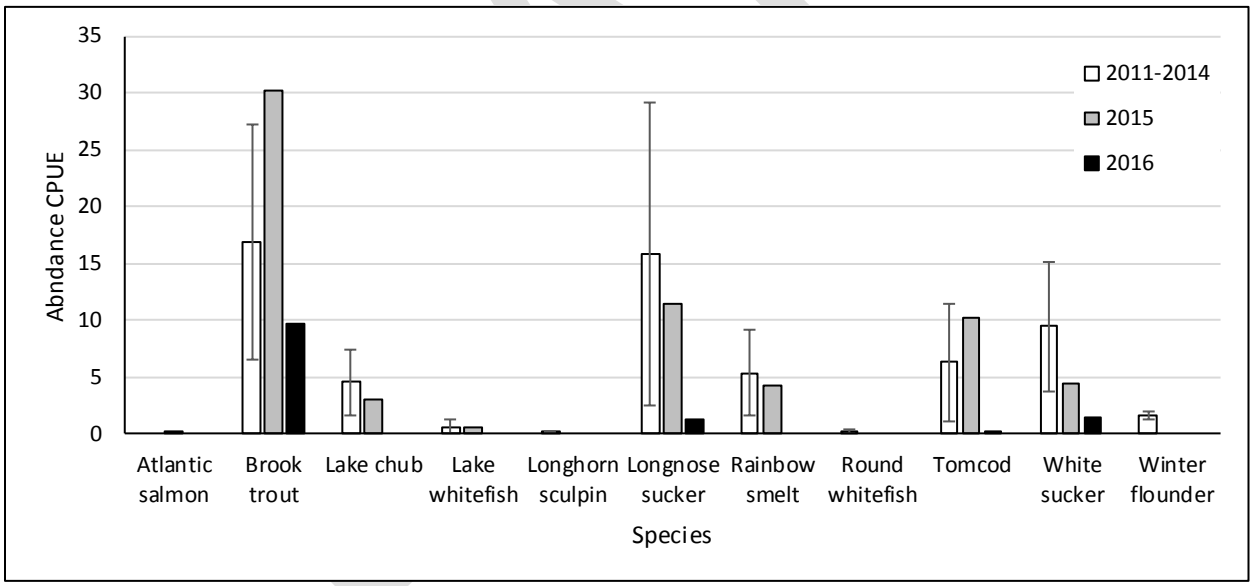

Figure 5-3: Gillnet abundance CPUE (fish/net-night) in Lake Melville, 2011 through 2016 (Error bars represent the standard error of the annual mean abundance CPUE from 2011-2014).

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

Species	Goose Bay		Lake Melville		Outer Lake Melville	
	Abundance CPUE	Biomass CPUE	Abundance CPUE	Biomass CPUE	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 Abundance CPUE expressed as fish/net-night

2 Biomass CPUE expressed as grams/net-night

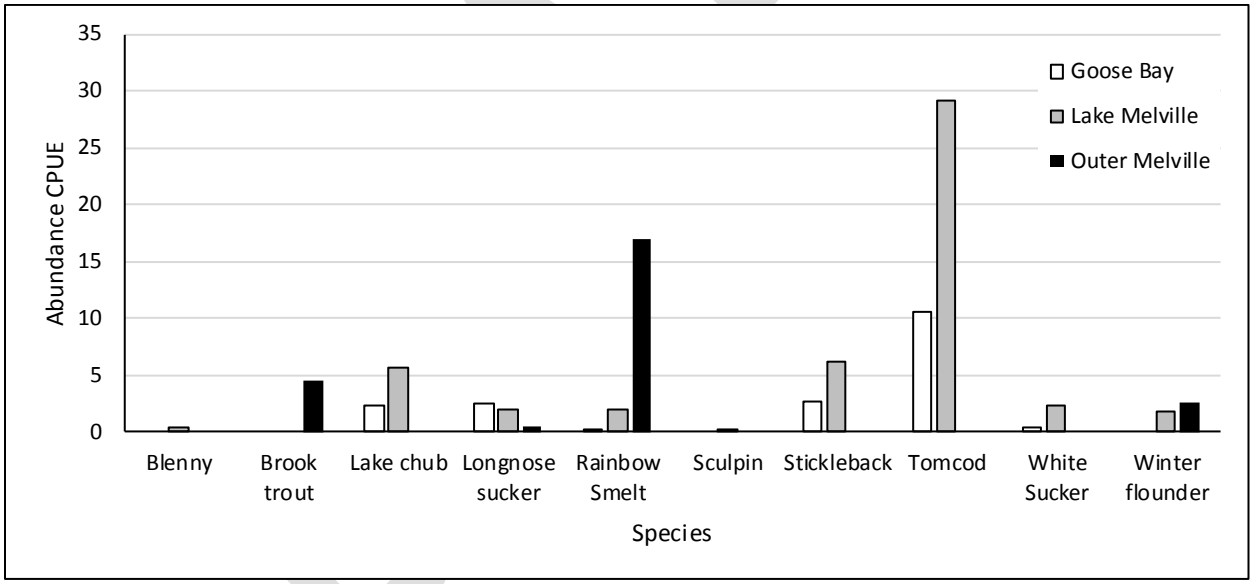

Figure 5-4: Mean fyke net Abundance CPUE (fish/net-night) in estuarine sampling areas, 2016

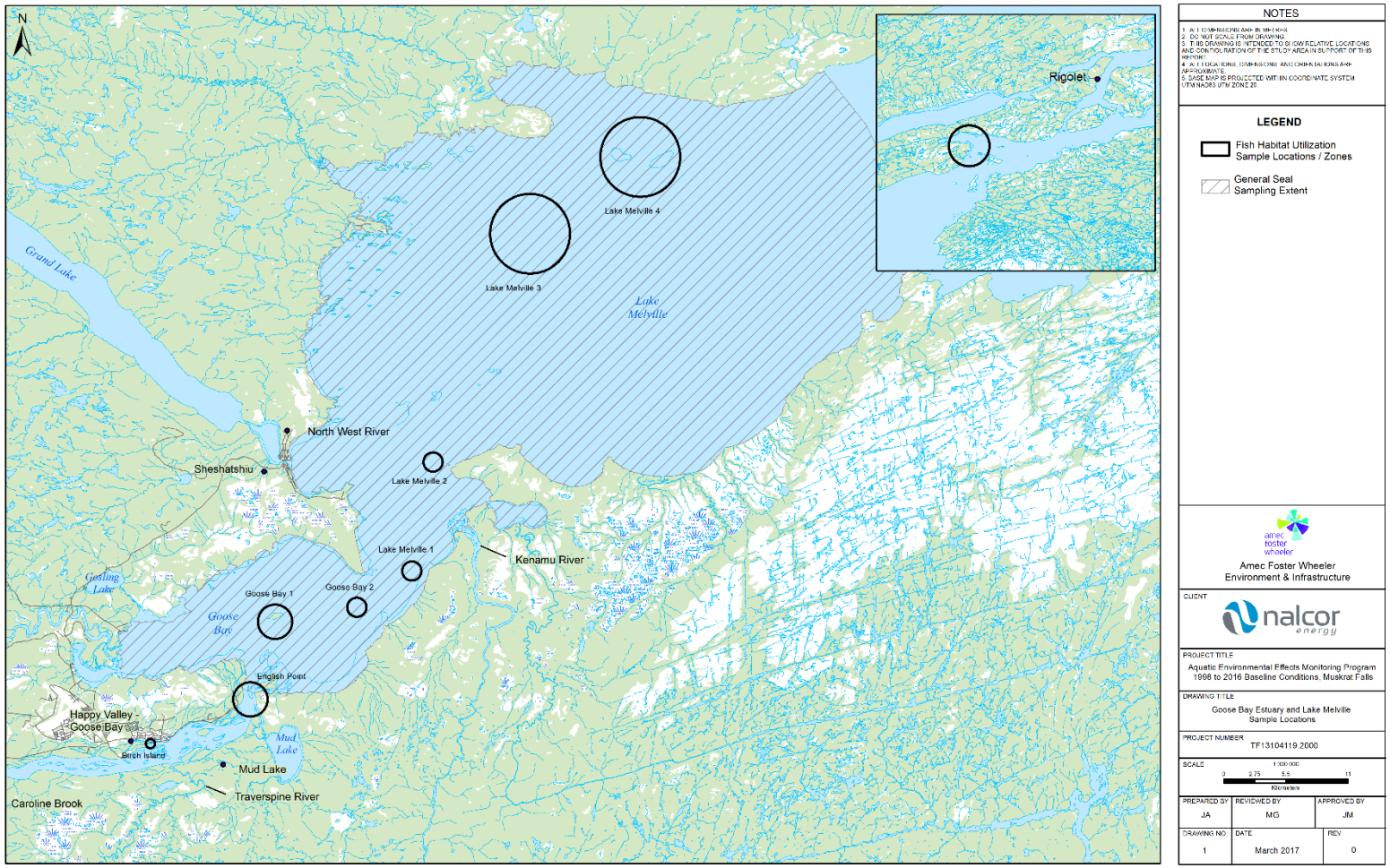

Figure 5-5: Overall EEM study area: Goose Bay estuary and Lake Melville (reproduced from AMEC 2013b).

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 detail below based on Nalcor data collected since 1998. 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 utilized by Nalcor (e.g., Reed Harris).

5.1 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 1998; 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

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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** 5-5.

Table 5-5: 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.

5.2 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).

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 1982); 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** 5-6.

5.3 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 1988). Lake trout occur throughout the Churchill River watershed, but are more prevalent in the upper reaches (Anderson 1985; AGRA 1999; 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 5-6: 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

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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 (Bradbury et al. 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.

5.4 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).

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).

5.5 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 Bradbury et al. 2004) with spawning occurring approximately early October – November. During their upstream migration, adult salmon cease feeding (Bradbury et al. 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 (Bradbury et al. 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, Innu Nation 2007, Nalcor 2009).

5.5.1 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; 2006). 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).

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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** 5-7.

5.6 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; 2000; AMEC 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).

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Table 5-7: 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.

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.

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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** 5-8.

5.7 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).

Table 5-8: 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.

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** 5-9.

5.8 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).

Table 5-9: 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.

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).

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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.

5.9 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 abundance (Ryan 1980; AGRA 1999; AMEC 2000; AMEC 2009b; 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** 5-10.

Table 5-10: 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.

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5.10 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 2016; 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.

5.11 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.

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 abundances were greatest near North West 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 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

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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.

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 2016; 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).

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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 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 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), an abundance estimate for the entire EEM zone was generated for each survey year (**Table** 5-11). 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.

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

Sample Year	Total Observed	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: 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

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all years, no ringed seals have been recorded within the river itself (SEM 2007; Amec Foster Wheeler 2016a). In fact, 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 SUMMARY

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 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 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,

Amec Foster Wheeler Environment & Infrastructure
A Division of Amec Foster Wheeler Americas Limited

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