From: Barnes, Marvin [mailto:Marvin.Barnes@dfo-mpo.gc.ca]
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Subject: Primary Publication - Mercury in Fish Downstream of Smallwood Reservoir

Attached is a copy of a manuscript titled "*Duration and Extent of Elevated Mercury Levels in Downstream Fish Following Reservoir Creation*" . This is a peer reviewed primary paper that has been accepted by a scientific journal and may be considered as "in press". This document may help inform any discussions by the Joint Review Panel or others regarding the Lower Churchill Generation Project.

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Regards,

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Duration and Extent of Elevated Mercury Levels in Downstream Fish Following Reservoir Creation

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Abstract

While mercury accumulation in reservoir fish following impoundment is a well known phenomenon, consequences for downstream populations are less understood. In particular, the effects on downstream estuarine populations have only rarely been studied. This study examined data from a Northern Canadian reservoir system to demonstrate that elevated mercury levels can be seen in fish downstream for a distance of over 300 km and into the estuary for some species. The Smallwood Reservoir in Labrador, Canada, created in the mid 1970's, drains into the Churchill River and hence into Lake Melville, a large estuarine fjord. Mercury levels in most species in the Churchill River were elevated immediately following impoundment and have since declined as have the levels in several estuarine species. Return times for downstream fish were similar to those in the reservoir and depended on trophic position and habitat use. Lake whitefish, longnose suckers and northern pike showed evidence of a shift in trophic position below the Churchill Falls tailrace.

Introduction

Mercury is a ubiquitous contaminant of freshwater biota. It is found in low levels in fish from pristine environments and elevated levels are usually attributed to human disturbance (i.e. impoundment), direct (e.g. industrial wastes) and/or indirect (atmospheric transport and deposition) input. The dominant pathway of mercury uptake in aquatic biota is through food (Hall *et al.*, 1997) and the contaminant is biomagnified up through the food chain. The highest levels of mercury in fish are generally found in the piscivores particularly in lakes with long food chains (Anderson *et al.*, 1995, Cabana *et al.*, 1994). Species specific habitat use (Roux, 2009), water quality (Schetagne & Verdon, 1999a) and catchment characteristics (Sampaio da Silva *et al*. 2009) have also been shown to influence mercury levels in freshwater fish.

Elevated levels of mercury in fish from recently impounded reservoirs have been known since the early 1970's (Smith et al., 1974). Return times (the time required for mercury concentrations in reservoir fish to return to background levels) for fish from boreal forest reservoirs range from 6 to 30 plus years (Anderson et al. 1995, Scruton et al. 1994, Bodaly et al. 2007). Fish from reservoirs in insular Newfoundland can return to background levels after 7 to 12 years (Scruton et al. 1994). While piscivores in the Smallwood Reservoir, Labrador, have been show to take 20 years or longer (Anderson et al. 1995). Theoretical models developed by Messier et al. (1985) predict returns at 20 years for planktivorous lake whitefish and 30 years for piscivorous northern pike. These predicted return times accord well with observations from reservoirs in Northern Quebec (Schetagne & Verdon, 1999b), Northern Manitoba (Bodaly et al. 2007) and Finland (Verta et al. 1986).

Downstream effects of reservoir creation on fish mercury levels have been less studied. Monitoring programs for boreal reservoirs have demonstrated effects as far down stream as 275 km (Schetagne & Verdon, 1999b, Bodaly et al. 2007). The extent and duration appears to vary from system to system and may depend on the hydrological characteristics of the rivers and reservoirs, in particular the extent of dilution from tributaries below the reservoir and the presence of large deep lakes (Schetagne & Verdon, 1999b). Trophic position also influences the magnitude and duration of the elevated mercury levels. Lake whitefish in the Caniapisco River in Northern Quebec were shown to return to background levels within 2-4 years while the levels in lake trout remained high for 4-8 years (Schetagne & Verdon, 1999b). Lake whitefish below the Robert Bourassa Reservoir on the La Grande system were found to have higher mercury levels than those in the reservoir above. This was attributed to a change in trophic position when the downstream whitefish became piscivorous, feeding on cisco and other fish chopped up by passage through the turbines (Brouard et al. 1994).

Less is known about the potential for downstream effects on estuarine fish. The sole study, found that for coastal James Bay elevated mercury levels were limited to fish exposed to the freshwater outflow of the La Grande system (Schetagne & Verdon, 1999b).

Mercury in fish from the Churchill River system in Labrador, Canada, has been studied for over 30 years since the creation of the Smallwood Reservoir in the early 1970’s. Mercury in fish in the reservoir was significantly elevated over background levels and the return times for reservoir fish are similar to other boreal reservoirs (Anderson et al. 1995, Schetagne & Verdon, 1999b, Bodaly et al. 2007). Recently there has been renewed interest in the evolution of mercury in the river as two new hydroelectric developments are proposed for the river. The objective of the study reported here, was to examine the extensive dataset on mercury in fish from the Smallwood Reservoir, the Churchill River and Lake Melville, to determine the extent and duration of downstream effects of the Smallwood Reservoir.

Study Site

The Churchill is the largest river in Labrador, Canada (Fig. 1) with a watershed of ~120,000 km^2. It originates in western Labrador and flows eastward to the Labrador Sea.

The upper watershed covering much of the Labrador plateau was impounded to create the Smallwood Reservoir in the early 1970's. The Churchill River itself flows over 300 km from the reservoir to the estuary, Lake Melville.

The Smallwood Reservoir (Fig. 1) was flooded between 1971 and 1973. It covers 5695 km^2 of which 2450 km^2 was flooded forest, bog and taiga. The total volume of the reservoir is 2.83 x 10^{10} m^3 divided into 3 main basins connected over shallower sills. The water management regime includes a spring drawdown of 3 – 7 m depending on the basin.

The Churchill River runs eastward from Churchill Falls through two large lakes, Winokapau and Gull, and thence to the estuary. The average annual flow at Muskrat Falls on the lower Churchill is 1840 m^3/s 75% of which comes from the Smallwood Reservoir. The upper river flows rapidly through a narrow valley which widens out below Muskrat Falls where the river becomes braided and shallow. Lake Winokapau is 45 km long by 1.5 wide with a maximum depth of 206 m. Gull Lake is 10 km by 2.5 with a maximum depth of 55m. Fish passage from the lower Churchill is impeded by Muskrat Falls

The estuary of the Churchill River is a large fjord (130 x 30 km) with two basins. The river flows into the inner estuary, Goose Bay, which in turn connects to Lake Melville. Goose Bay has a maximum depth of 55m while that of Lake Melville is 180 m. Seventy five percent of the freshwater inflow to the estuary comes from the Churchill River. Lake Melville connects to the Labrador Shelf through Groswater Bay.

Materials and Methods

Fish populations from the Churchill River system have been sampled for mercury at intervals since 1977 (Tab. 1). Similar sampling protocols were followed throughout. Because mercury varies with the size of fish, sample protocols were designed to collect a certain number of fish representing the range of sizes in the population (Schetagne & Verdon, 1999a). Fishing was done with experimental gangs of gill nets with mesh of different sizes that could be tied up as size categories were completed. Samples of underrepresented size categories were completed by angling where necessary. Once caught, fish were sized, weighed and sampled for aging structures (scale, otholith or opercular bone). A section of the left dorsal fillet of each fish was removed and immediately frozen pending mercury analysis. The samples were analyzed for total mercury by cold vapour atomic absorption spectroscopy (Uthe et al., 1970, Envir. Can, 1979) or isotope dilution ICPMS (Veinott & Miller-Banoub, 2004) (Tab. 1).

Seven sample sites, representative of the Churchill River system from the Smallwood Reservoir to the Lake Melville estuary (Fig.1, Tab. 1) were selected for this study. The number of stations sampled varied over time so not all sites were sampled at each time. Fish from all stations in the Smallwood Reservoir were pooled for the purposes of this analysis (Tab. 1). Numbers and species of fish caught at each site also varied. Two planktivores/insectivores/omnivores (lake whitefish and brook trout), two benthivores (white and longnose suckers) and two piscivores (lake trout and northern pike), common species in the Churchill River system were retained for analysis in this study based on the adequacy of sample sizes over space and time. The size ranges of rainbow smelt and tomcod were not great enough to produce significant relationships between fish length and mercury. Average mercury levels were used for comparisons in these species.

Data on mercury levels in fish from 95 headwater lakes scattered throughout Labrador (Scruton 1984) was used to determine baseline levels for comparison with the Churchill River system.

Mercury levels in fish vary with size. As a result any comparisons must be made on a size weighted basis. One such approach is to use the length – Hg relationship to calculate the mercury level in a fish of average size (standard length) for a population (Brouard et al. 1990). Mercury was calculated for standard length fish using the relationship between fork length and mercury levels. Only sites and times where the relationship was significant were retained for further analysis. All data were log transformed to remove heteroscedasticity. Mercury levels and 95% confidence intervals for standard length fish were calculated from the length – Hg regressions and back transformed for comparison with the baseline data. Mercury levels were considered significantly elevated ($P < 0.05$) if the confidence intervals did not overlap those of the baseline levels for standard length fish.

Results

Insectivores

Lake whitefish (*Coregonus clupeaformis* Mitch.) is an abundant planktivore/benthivore found throughout the Churchill River system and into the upper estuary. They ranged in size from 85 to 610 mm with a median size of 390 mm (Tab.2). Mercury levels in lake whitefish were significantly elevated after impoundment of the reservoir as far downstream as Lake Winokapau (Fig. 2a). Highest levels were seen in fish found immediately below the reservoir (peak = 0.76 mg/kg, 5X elevated, Tab.3). Mercury in these fish was significantly higher than those from the reservoir itself. By 1987, mercury levels in whitefish throughout the system were no longer elevated compared to lake whitefish from Labrador headwater lakes.

Brook trout (*Salvelinus fontinalis* Mitch.) is common in lakes and rivers throughout Labrador. Small brook trout are primarily insectivores however they will take other prey if available (Scott and Crossman, 1998). Land locked populations are found in the Smallwood Reservoir and the Churchill River to Muskrat Falls and anadromous populations (sea trout) in the estuary. Brook trout may grow to over 600 mm with a median size in the Churchill system of 290 mm (tab. 2). Mercury levels in brook trout were significantly elevated in the reservoir and downstream as far as the reaches of the Lower Churchill following reservoir creation (Fig. 2b). Brook trout immediately below the reservoir had the highest mercury levels in 1978 (peak = 0.32, 3X elevated, Tab. 3) but this was not significantly different from those in the reservoir. Mercury in brook trout from the reservoir and just below it at Churchill Falls continued to be significantly higher in 1987. Too few samples were taken from the reservoir in the following years to be used for this analysis however, by 1992, levels in brook trout at Gull Lake were not significantly different from those found in natural Labrador lakes. Mercury in anadromous brook trout (sea trout) is considered with other estuarine fish below.

Benthivores

White sucker (*Catastomus commersoni*, Lacépède) is a common benthivore throughout the Churchill River system into the upper estuary. They range in size up to 575 mm with a median of 395 mm (Tab. 2). Mercury was elevated in white suckers downstream as far as the lower reaches of the Churchill River (peak = 0.45, 5X elevated, Tab. 3) following reservoir creation and has remained significantly higher than mercury in white suckers from headwater lakes since that time (Fig. 3a).

Longnose sucker (*Catastomus catastomus*, Forster) is another common benthivore throughout the Churchill River system. They range in size up to 565 mm with a median of 340 mm (Tab. 2). Mercury was significantly elevated in longnose suckers as far downstream as Lake Winokapau in 1977-78 and Gull Lake in 1987 with the highest levels being found below the reservoir (Fig. 3b). The peak of this downstream effect was seen immediately below the reservoir at Churchill Falls in 1977-78 (peak = 1.43, 11X elevated, Tab. 3) and at Lake Winokapau in 1987. Although levels remained elevated in 1992 and 1996 they were similar throughout the upper Churchill system. By 1996 mercury levels in most longnose sucker did not differ significantly from those in other Labrador lakes.

Piscivores

Lake trout (*Salvelinus namaycush*, Walbaum) are pelagic piscivores found mostly in the deepwater habitats of the Churchill system. They were occasionally taken at Churchill Falls and in Gull Lake however only the Smallwood Reservoir and Lake Winokapau produced samples sizes sufficient for this analysis. They ranged in size up to 990 mm with a median of 575mm (Tab. 2). Mercury levels were significantly elevated for trout from both sites through 1996 (peak = 1.72 mg/kg, 3X elevated Fig. 4a, Tab. 3). Levels were not significantly different from background in 1999.

Northern pike (*Esox lucius*, Linnaeus) is a piscivore that prefers littoral habitats. They were caught in the Smallwood Reservoir and as far down stream as the lower reaches of the Churchill River. The maximum length was 940 mm and the median was 630 (Tab. 2). Mercury levels in northern pike were significantly elevated in the reservoir until 1996 when levels were not significantly different from background (Fig. 4b). Highest levels in 1977-78 were seen downstream of the Reservoir (peak = 1.53 mg/kg, 4X elevated, Tab. 3) with significantly elevated levels seen as far downstream as Gull Lake. Levels in the lower reaches of the Churchill River were not significantly different from those of northern pike from other Labrador Lakes.

Estuarine Fish

Sampling frequency and intensity were much lower for Goose Bay and Lake Melville. However, sufficient sample sizes exist to allow comparisons of three species commonly found in the estuary. Rainbow smelt (*Osmerus mordax* Mitch.) and tomcod (*Microgadus tomcod* Walbaum) are small (< 250 mm maximum length, 200 mm median length, Tab. 2) pelagic fish that feed on invertebrates and fish in brackish water, entering freshwater to spawn. Sea run brook trout (sea trout, *Salvalinus fontinalis* Mitch.) spend several months feeding on invertebrates and fish in the estuary before returning to freshwater to spawn. They range in size up to 600 mm with a median of 325 (Tab. 2). Mercury levels in smelt from Goose Bay were highest in 1978 (peak = 0.32 mg/kg, Tab. 3), declined in 1999 and were significantly lower in 2008 (Fig. 5). Mercury in tomcod declined significantly from 1978 to 1999 (Peak = 0.17, Tab. 3, Fig. 5). Background levels of mercury levels in sea trout from other sites in coastal Labrador (Bruce et al. 1977) were significantly lower than those found in freshwater lakes of Labrador (Figs. 2 and 5). However in 1978, mercury in sea trout from Lake Melville and Goose Bay was similar to that of freshwater brook trout and significantly higher than that of sea trout from other sites along the Labrador coast (peak = 0.15, 4X elevated, Tab. 3). By 2005, the mercury levels of sea trout in Lake Melville had declined significantly.

Discussion

Fish downstream of the Smallwood Reservoir showed significantly elevated levels of mercury following the creation of the reservoir (Tab. 3). While these effects were limited to the upper reaches of the river into Lake Winokapau for lake whitefish and lake trout, they extended to Gull Lake for longnose sucker and northern pike and to the lower Churchill (below Gull Lake) for brook trout and white sucker. This is not consistent with the dilution effect of a large downstream lake (Winokapau) proposed by Schetagne & Verdon, (1999) but rather suggest that habitat use and prey preferences may also play a role in determining the downstream extent of mercury contamination.

Mercury levels in lake whitefish, longnose sucker and northern pike immediately below the reservoir were amplified over those of reservoir fish. This may be the result of a change in trophic position by downstream fish. Stable isotope studies have demonstrated that among lake differences in mercury levels for a given species can be attributed to differences in diet and trophic position (Cabana & Rasmussen 1994). Similarly, lake whitefish have been shown to become piscivorous below dams (Brouard *et al*. 1994) feeding on pieces of fish chopped up by passage through the turbines. This may also be the case for longnose sucker who have been shown to become more reliant on bathypelagic production in the presence of conspecific white suckers (Roux, 2009). They may be feeding on the pieces of fish deposited to the benthos below the dam. Suckers are also common prey of northern pike in this system (Roux, 2009) suggesting that the amplification signal is passed up to higher trophic levels. A similar effect was not seen for brook trout or white sucker which tend to utilize more littoral habitat or for lake trout though the latter were not commonly caught at the Churchill Falls tailrace.

As with reservoir fish the duration of elevated mercury is dependant upon trophic position. Return times for insectivores, lake whitefish and brook trout were less than 20 years while piscivores, northern pike and lake trout had return times between 20 and 30 years as did the benthivorous longnose sucker. Mercury levels in white sucker remained elevated after 35 years. Although data for northern pike are somewhat limited after 1996, it appears that littoral species had longer return times than pelagic or bathy pelagic species at similar trophic levels. This is consistent with the hypothesis that mercury cycling in the littoral zone plays a significant role in determining mercury levels in reservoirs and downstream following flooding.

Estuarine species were also affected by the impoundment of the Smallwood Reservoir (Tab. 3, Fig. 5). Mercury was elevated in three species common to upper Lake Melville in 1978 and has declined since then. Because data on estuarine species has limited spatial and temporal resolution it is not possible to estimate duration and extent although it appears that the duration is greater than 20 years for rainbow smelt and less than 28 years for sea trout. Mercury levels were quite similar in all three species despite the size discrepancy. All three generally feed on crustaceans and small fish during the estuarine phase of their life history (Scott & Crossman, 1999) and stable isotope measurement of smelt and sea trout from Lake Melville (Anderson unpub.) put both species at similar trophic levels. This suggests that the effects of an upstream reservoir on estuarine fish are through the lower foodweb of the estuary. Estuarine effects will also be influenced by the hydrodynamics of the estuary. Most (85%) of the freshwater flowing into upper Lake Melville comes from the Churchill River.

In summary, downstream effects of reservoir creation are seen in elevated mercury levels of riverine and estuarine fish. The extent and duration appear to depend on the trophic position and habitat preferences of the individual species. Return times are similar to those for fish from boreal forest reservoirs, < 20 years for lower trophic levels and 20 – 30 years for piscivores. Elevated mercury levels are seen farther downstream for littoral species. Estuarine fish over 300 km down stream of the reservoir also had elevated mercury levels however, further work is required to elucidate the spatial and temporal extent of estuarine effects.

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Table Legends

Table 1. Sampling sites and dates used for this study. Site locations (SR = Smallwood Reservoir, CF = Churchill Falls Tailrace, W = Lake Winokapau, G = Gull Lake, LC = Lower Churchill River, GB = Goose Bay, LM = Lake Melville) are shown in Figure 1. Samples from stations in the Smallwood Reservoir were combined and included as one site for this study. Fish tissue samples were analysed by cold vapour atomic absorbtion (CVAA, Uthe et al. 1970) or by isotope dilution ICPMS (Veinott & Miller-Banoub 2004)

Table 2. Characteristics of the species used in this study for fish sampled by Bruce et al (1979) from the Churchill River system. Standard length for each species was selected as close to the median length of each population and to allow comparisons with other species feeding in a similar trophic position.

Table 3. Duration and extent of mercury elevation in fish from the Churchill River system following creation of the Smallwood Reservoir in 1971.

Table 1. Sampling sites and dates used for this study. Site locations (SR = Smallwood Reservoir, CF = Churchill Falls Tailrace, W = Lake Winokapau, G = Gull Lake, LC = Lower Churchill River, GB = Goose Bay, LM = Lake Melville) are shown in Figure 1. Samples from stations in the Smallwood Reservoir were combined and included as one site for this study. Fish tissue samples were analyzed by cold vapour atomic absorbtion (CVAA, Uthe et al. 1970) or by isotope dilution ICPMS (Veinott & Miller-Banoub, 2004). Comparison between the two methods gave similar results (Veinott & Miller-Banoub, 2004).

Year	Study sites*	Number of stations in SR	Analysis Hg	Reference
1977-78	SR, CF, W, G, LC, GB, LM	16	CVAA	Bruce et al. 1979
1987	SR, CF, W, G, GB	3	CVAA	Anderson et al, 1995
1992	SR, W, G	2	CVAA	Anderson et al, 1995
1996	SR, W, G	3	CVAA	This study
1999	SR, W, G, LC, GB	3	CVAA	Nalcor Energy, 1999
2004-05	SR, W, G, LC, GB	3	ICPMS	This study, Roux, 2009
2008	LM		CVAA	This study
1982	reference lakes (n=92)		CVAA	Scruton, 1984

Table 2. Characteristics of the species used in this study for fish sampled by Bruce et al (1979) from the Churchill River system. Standard length for each species was selected as close to the median length of each population and to allow comparisons with other species feeding in a similar trophic position.

Species	Size range (mm)	Median size (mm)	Standard length (mm)	Distribution	Trophic position
Lake whitefish	85-610	390	300	reservoir to estuary	planktivore
Brook trout	85-605	290	300	reservoir and river	Planktivore/omnivore
White sucker	170-575	395	400	reservoir to estuary	benthivore
Longnose sucker	300-565	340	400	reservoir to estuary	benthivore
Lake trout	175-990	575	600	reservoir to Gull Lake	piscivore
Northern Pike	300-940	630	600	reservoir and river	piscivore
Rainbow smelt	150-220	200	200	estuary	Crustaceans, small fish
Tomcod	175-235	200	200	estuary	Crustaceans, small fish
Sea trout	160-600	325	300	estuary	Crustaceans, small fish

Table 3. Magnitude, duration and extent of mercury elevation in fish from the Churchill River system following creation of the Smallwood Reservoir in 1971. Peak Hg is the maximum mercury level calculated for a standard length fish. Magnification (Mag.) is the increase relative to background levels for Labrador lakes. Standard lengths used for each species are found in Table 1.

Trophic position	Habitat	Species	Peak Hg (mg/kg)	Mag.	Duration (years)	Extent (km)	Highest below dam
Planktivore/insectivore /omnivore	pelagic	Lake whitefish	0.76	5X	< 16	150	yes
	littoral	Brook trout	0.32	3X	< 21	320	no
benthivore	benthic	White sucker	0.45	5X	> 35	320	no*
	Benthic (bathypelagic)	Longnose sucker	1.43	11X	< 28	250	yes
piscivore	pelagic	Lake trout	1.72	3X	< 28	150	no*
	littoral	Northern Pike	1.53	4X	< 25	250	yes
Planktovore/piscivore	estuarine	Rainbow smelt	0.32	$\geq$3X	> 20	-	-
		Tomcod	0.17	?	?	-	-
		Sea trout	0.15	4X	< 28	-	-

*N = 3, levels similar to those for fish of equivalent size in Smallwood Reservoir

Figure Legends

Figure 1. Map of the Churchill River system in Labrador, Canada showing field sites used in this study.

Figure 2. Mercury levels in standard length planktivore/insectivores Lake Whitefish (a) and Brook Trout (b) in the Churchill River system. Sample year is indicated above each plot. Mercury (mg/kg) is shown on the x axis and sample site progressing downstream from the Smallwood Reservoir is shown on the y-axis. Error bars represent the 95% confidence interval. Grey bars indicate that mercury levels are significantly ($P < 0.05$) higher than those for fish from Labrador Lakes. Black bars indicate that mercury levels are significantly higher ($P < 0.05$) than those for fish in the Smallwood Reservoir.

Figure 3. Mercury levels in standard length benthivores White sucker (a) and Longnose sucker (b) in the Churchill River system. Sample year is indicated above each plot. Mercury (mg/kg) is shown on the x axis and sample site progressing downstream from the Smallwood Reservoir is shown on the y-axis. Error bars represent the 95% confidence interval. Grey bars indicate that mercury levels are significantly ($P < 0.05$) higher than those for fish from Labrador Lakes. Black bars indicate that mercury levels are significantly higher ($P < 0.05$) than those for fish in the Smallwood Reservoir.

Figure 4. Mercury levels in standard length piscivores Lake trout (a) and Northern pike (b) in the Churchill River system. Sample year is indicated above each plot. Mercury (mg/kg) is shown on the x axis and sample site progressing downstream from the Smallwood Reservoir is shown on the y-axis. Error bars represent the 95% confidence interval. Grey bars indicate that mercury levels are significantly ($P < 0.05$) higher than those for fish from Labrador Lakes. Black bars indicate that mercury levels are significantly higher ($P < 0.05$) than those for fish in the Smallwood Reservoir.

Figure 5. Mercury in standard length fish for the Lake Melville Estuary. Sea trout sampled at other sites on the Labrador coast (LC) are included as an indication of background levels. Note that values for smelt in 2008, tomcod in 1999 and sea trout in 2005 are the mean and its associated confidence interval. While fish taken at these times had a median size similar to the standard length there was an insufficient range in sizes to permit a significant size – mercury relationship.

Figure 1. Map of the Churchill River system in Labrador, Canada showing field sites used in this study

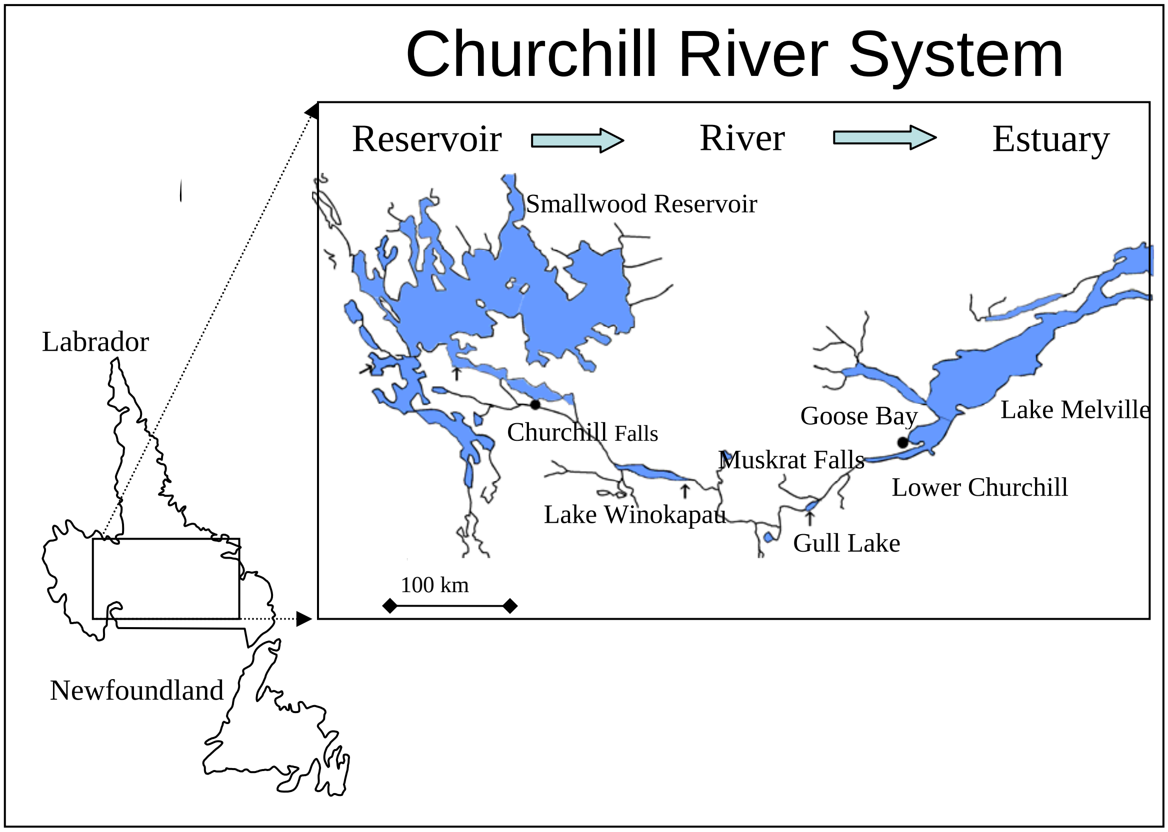
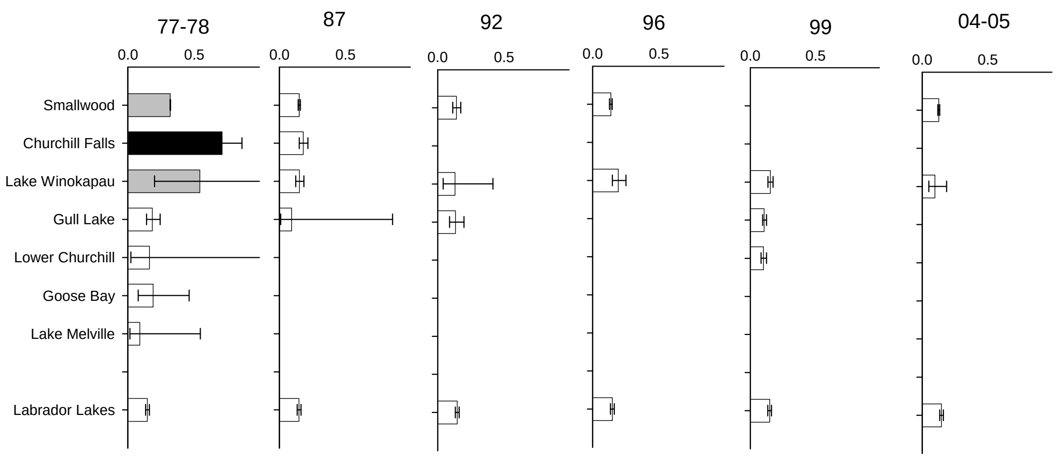


Figure 2. Mercury levels in standard length planktivore/insectivores Lake Whitefish (a) and Brook Trout (b) in the Churchill River system. Sample year is indicated above each plot. Mercury (mg/kg) is shown on the x axis and sample site progressing downstream from the Smallwood Reservoir is shown on the y-axis. Error bars represent the 95% confidence interval. Grey bars indicate that mercury levels are significantly (P < 0.05) higher than those for fish from Labrador Lakes. Black bars indicate that mercury levels are significantly higher (P < 0.05) than those for fish in the Smallwood Reservoir.

-a- Lake Whitefish



-b- Brook Trout

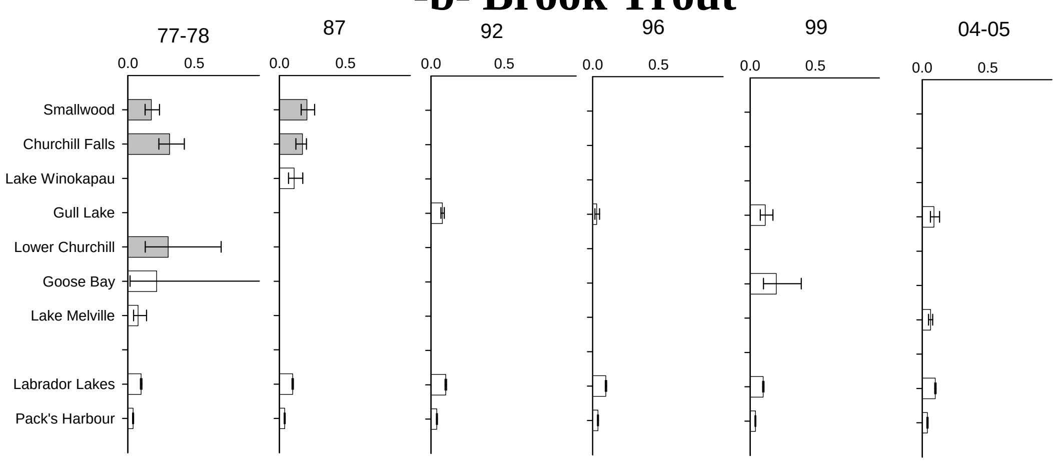


Figure 3. Mercury levels in standard length benthivores White sucker (a) and Longnose sucker (b) in the Churchill River system. Sample year is indicated above each plot. Mercury (mg/kg) is shown on the x axis and sample site progressing downstream from the Smallwood Reservoir is shown on the y-axis. Error bars represent the 95% confidence interval. Grey bars indicate that mercury levels are significantly ($P < 0.05$) higher than those for fish from Labrador Lakes. Black bars indicate that mercury levels are significantly higher ($P < 0.05$) than those for fish in the Smallwood Reservoir.

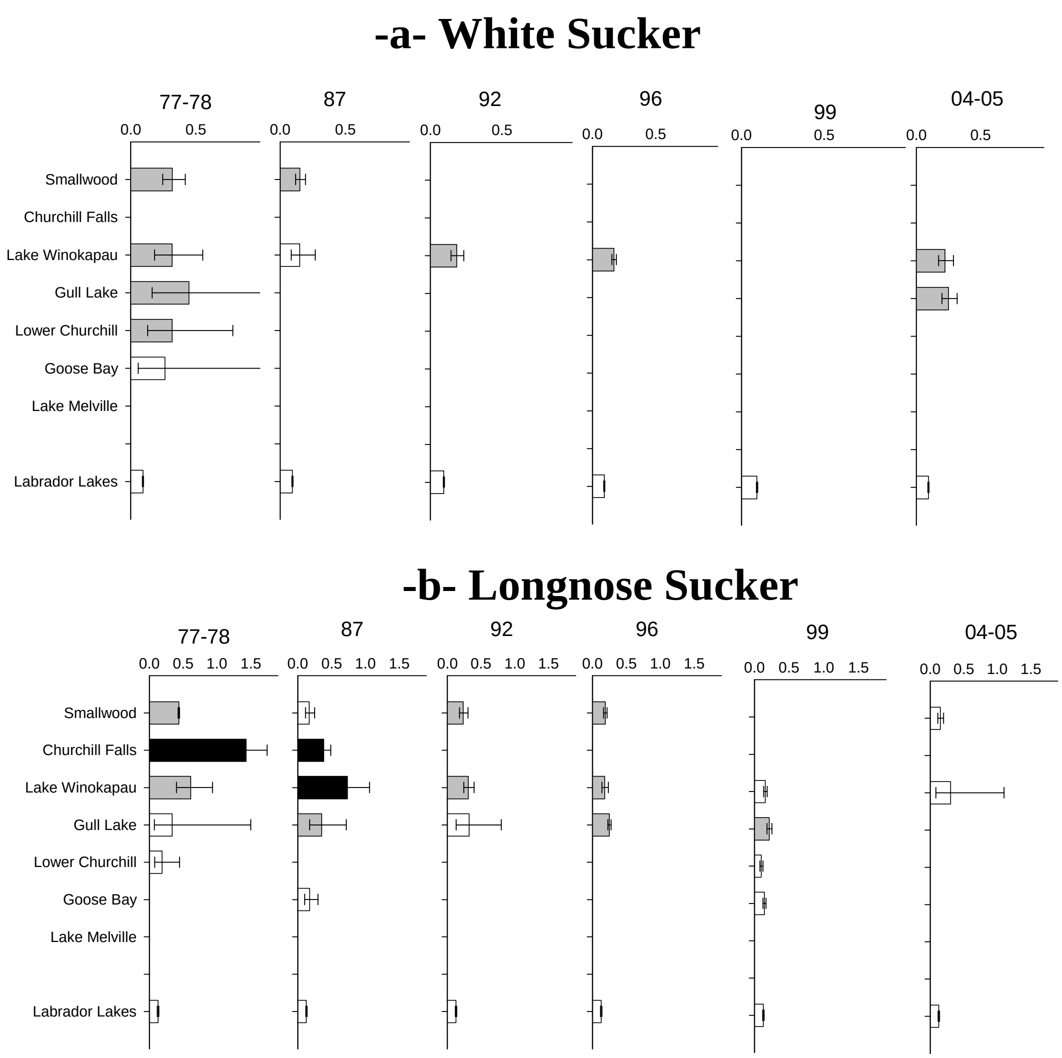
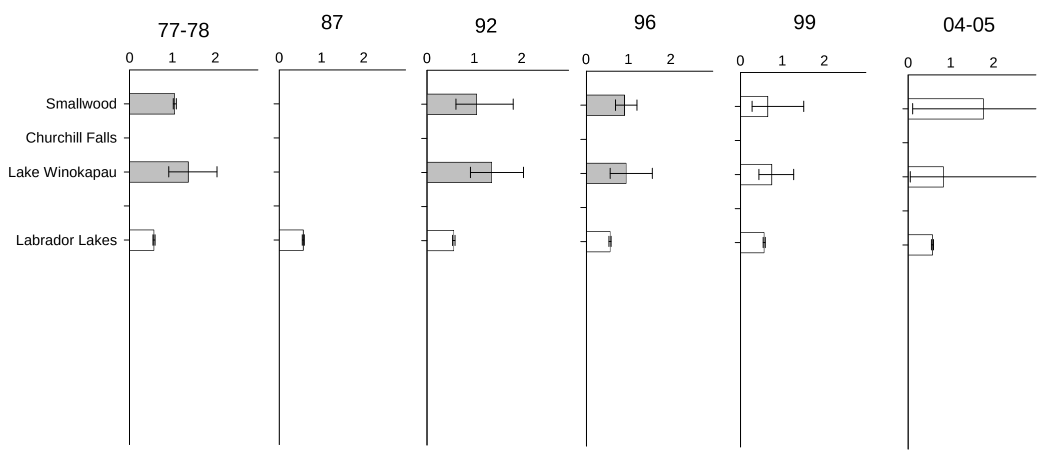


Figure 4. Mercury levels in standard length piscivores Lake trout (a) and Northern pike (b) in the Churchill River system. Sample year is indicated above each plot. Mercury (mg/kg) is shown on the x axis and sample site progressing downstream from the Smallwood Reservoir is shown on the y-axis. Error bars represent the 95% confidence interval. Grey bars indicate that mercury levels are significantly ($P < 0.05$) higher than those for fish from Labrador Lakes. Black bars indicate that mercury levels are significantly higher ($P < 0.05$) than those for fish in the Smallwood Reservoir.

-a- Lake Trout



-b- Northern Pike

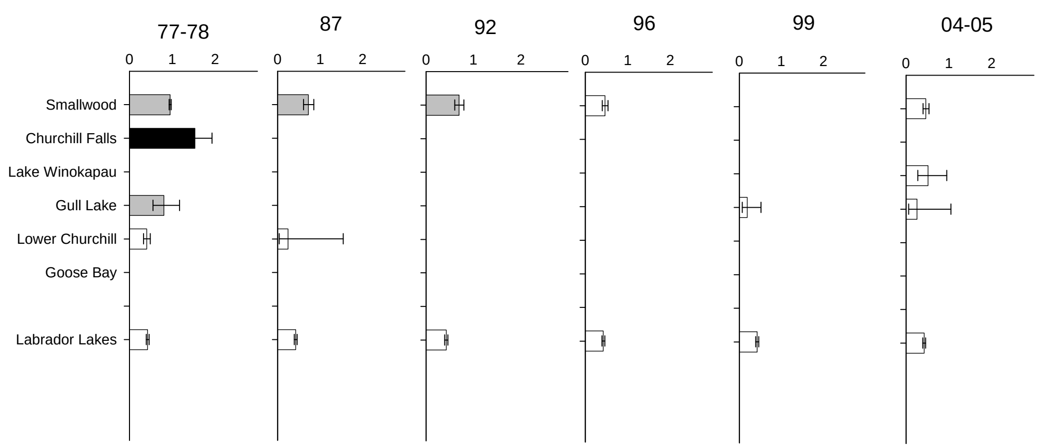


Figure 5. Mercury in standard length fish for the Lake Melville Estuary. Sea trout sampled at other sites on the Labrador coast (LC) are included as an indication of background levels. Note that values for smelt in 2008, tomcod in 1999 and sea trout in 2005 are the mean and its associated confidence interval. While fish taken at these times had a median size similar to the standard length there was an insufficient range in sizes to permit a significant size – mercury relationship.