Lower Churchill River Ecosystem

General Species Distribution, Abundance, and Existing Hg Concentrations
Considerations for Modelling Potential Human Consumption/Risks

Jim McCarthy
Feb 15, 2018
Independent Expert Committee

Lower Churchill River Ecosystem

General Species Distribution, Abundance, and Existing Hg Concentrations
Considerations for Modelling Potential Human Consumption/Risks

- Brief Watershed Characteristics
- Species Distributions and Abundance Data
- Baseline Hg Concentrations
- Model Considerations?

- Model Considerations

Lower Churchill River Ecosystem

Model Considerations

Application of a Mechanistic Mercury Model to the Proposed Lower Churchill Reservoirs:

Technical Memorandum in support of the Nalcor response to IR# JRP.166

Prepared for Nalcor

Prepared by.

Reed Harris and David Hutchinson
Reed Harris Environmental Ltd.

Don Beals
Beals and Associates

Environmental Science & Technology

Article

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Future Impacts of Hydroelectric Power Development on Methylmercury Exposures of Canadian Indigenous Communities

Ryan S. D. Calder,[*,†,‡] Amina T. Schartup,[†,‡] Miling Li,[†,‡] Amelia P. Valberg,[†] Prentiss H. Balcom,[‡] and Elsie M. Sunderland[†,‡]

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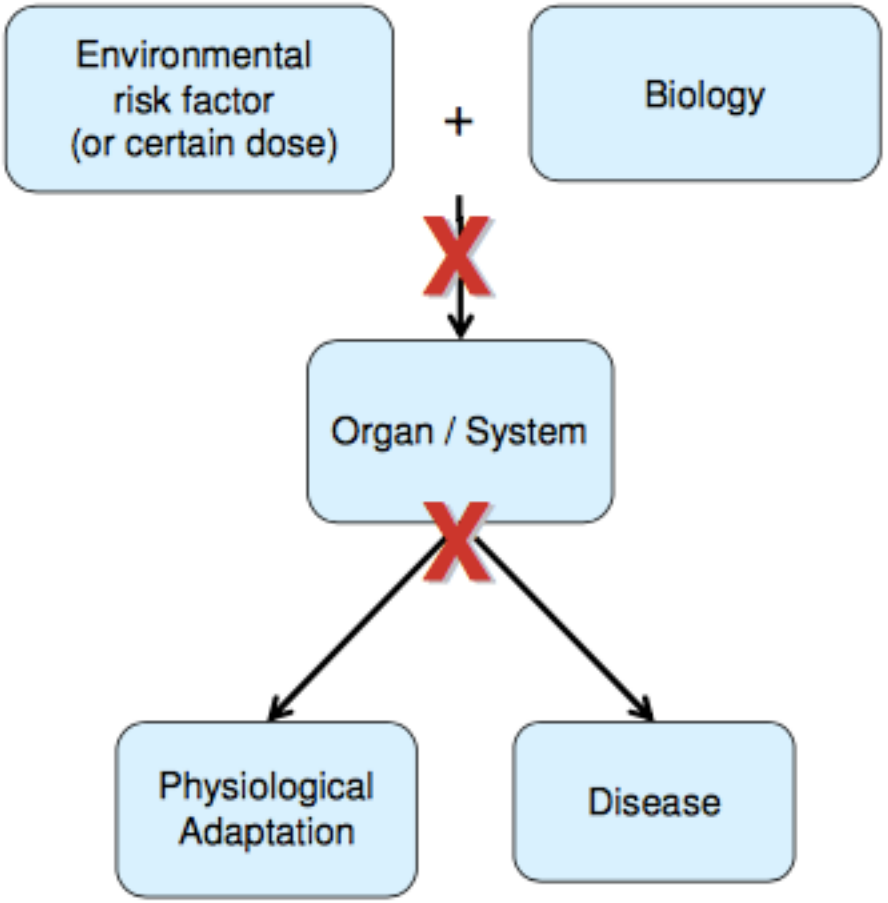
[‡]Harvard John A. Paulson School of Engineering and Applied Sciences, Cambridge Massachusetts 02138, United States

Model ≠ Real World

Environmental Illness

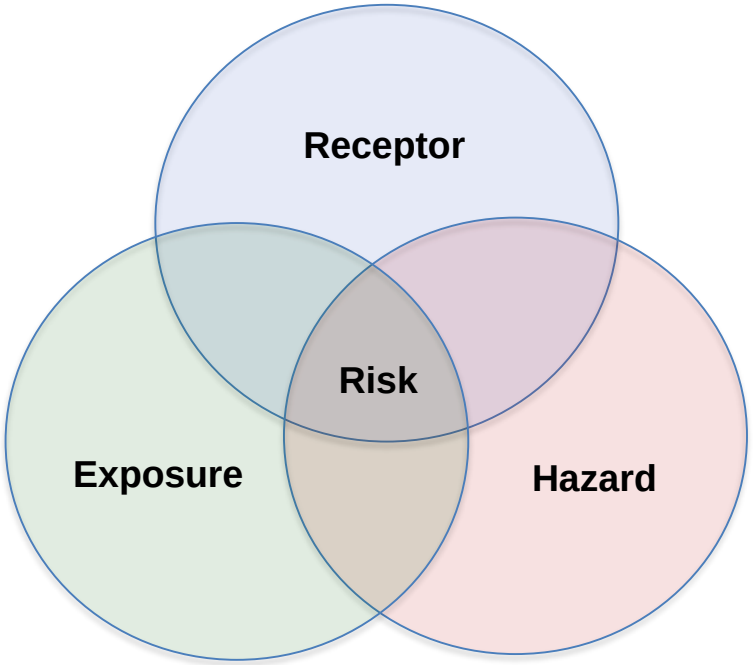
- Defining the extent and impact of exposure is the key to understanding environmental illnesses
- No harm without exposure
- Exposure does not always mean harm



OLLSON
Environmental Health Management

Risk Assessment 101

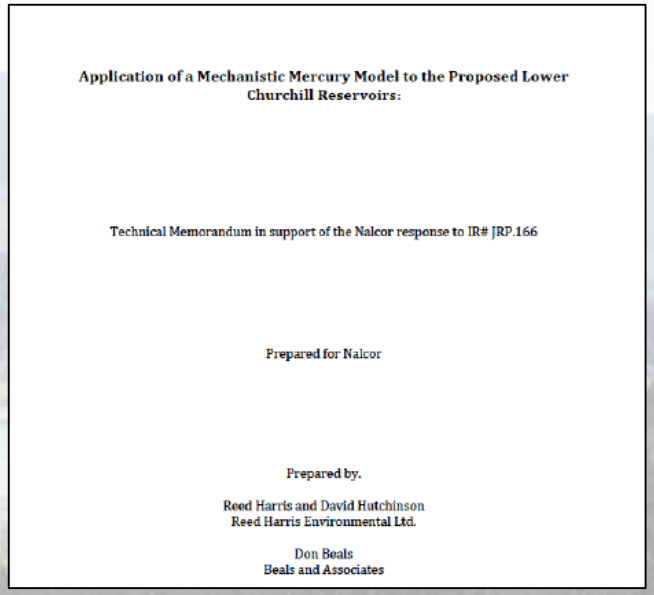
- Risk Assessment (RA) is a tool that can be used for estimating the potential for adverse effects that could arise from the presence of contamination in the environment.



Lower Churchill River Ecosystem

Resmerc Model Food Web Considerations/Input

- Simulates magnitude and timing of response, including pulse of MeHg pulse through the system
- Pulse works through various steps in ecosystem
  - water/sediments/lower trophic levels/higher trophic levels
- To what extent can fish MeHg "catch up" to increases at base of ecosystem, before exposure starts to decline
- Calibrate model to existing conditions, then predict effects of flooding
- Requires food web data
  - **Who eats whom (stomach contents, isotopes)**
  - **Habitat Info (who lives/moves where)**
  - **Baseline Hg values to validate the model (sediment, inverts, fish, plankton)**
  - **Growth rates**
- Limitations:
  - Can't represent complexity of true food webs, but try to capture key features affecting the magnitude and timing of response
  - Is MeHg in lower trophic levels linked to MeHg in water or sediments?
  - How will food web change after flooding?
  - **Assume some energetic models**
  - **Not all data collection is directly applicable to the model**



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Lower Churchill River Ecosystem

Model Considerations

Brook trout feb 7/18

Current food web settings in RESMERC simulations of Muskrat Falls Reservoir

Biomasses:
Biomass of top predator (e.g. could be ~~northern pike or lake trout~~): 1 kg/ha — too high for riverine — 200 grams/ha
Biomass of yellow perch 10 kg/ha — sculpin in riverine (10 g/ha)
Biomass of lake whitefish: 10 kg/ha — rainbow smelt + sandlance in estuary (~~200g/ha~~) — fish good for estuary
Biomass of low trophic level fish (e.g. dace): 10 kg/ha — Benthic inverts in riverine (220g/ha)

brook trout

·1gm invert/m2 : 200g/ha

The reservoir model has a maximum of 4 fish species. The downstream model can include as many fish species and food web compartments as desired. We can also set up different food webs at different locations in the same simulation in the downstream model (not in the reservoir model).

Riverine
bt ~ 0.2 kg/ha
sculpin ~ 10 g/ha
inverts ~ 0.2 kg/ha

Estuary
bt ~ kg/ha 2 kg/ha Lake Melville ~ 0.5 kg/ha Goose Bay
rainbow smelt ~ 0.1 kg/ha " ~ 0 Goose Bay
sandlance ~ 0.01 kg/ha " ~ 0
zooplankton ~ 0.43 mg/m³ in riverine
phytoplankton ~ 588 mg/m³ in riverine

- Model Inputs
  - Representative species & parameters
  - Representative food web

Current food web settings in RESMERC simulations of Muskrat Falls Reservoir

Maximum ages:
~~Northern pike: 20 years~~ Brook trout ~ 7yrs
~~Yellow perch: 8 years~~ Rainbow smelt ~ 5yrs
~~Lake whitefish: 15 years~~ Sandlance ~ 5yrs
~~Low trophic fish (e.g. dace): 3 years~~ Sculpin ~ 7yrs
Phytoplankton biomass: ~~0.2 mg/L dry weight~~
Zooplankton biomass: ~~0.1 mg/L dry weight~~
Benthic organism biomass ~~25 kg/ha wet weight~~
— see other page.

Each year fish hatch on a given date (Spawndate). In the example at the right, norther pike hatch on day 122. Day 1 = January 1.

Fish that hatch each year are followed separately in the model through time.

Fish don't spawn until they reach a certain size ("LowerSpawnWt), 500 g in the example on the right. When spawning occurs, fish lose weight and mercury. The MeHg concentration in eggs is assigned a value that is the ratio of MeHg in egg vs the fish ("SpawnHgfrac"), 0.01 in this case.

Inputs for: New Muskrat Falls (718)

Fish Level 1

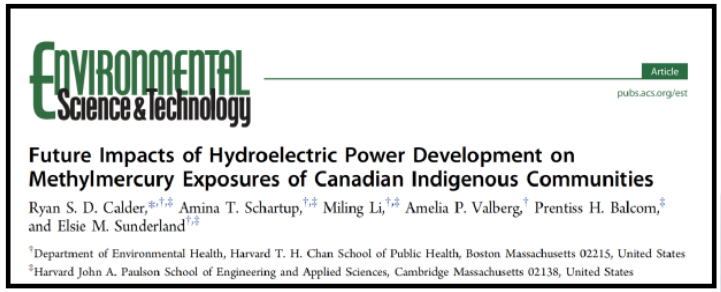
Input Name	Units	Input value
DietFish		1
LowRat	dimensionless	0.15
HighRat	dimensionless	0.4
LowFishing	cm	0
PercentProd	dimensionless	0
SpawnDate	day	122
LowerSpawnWt	grams	500
SpawnWtLossFrac	dimensionless	0.05
SpawnHgFrac	dimensionless	0.01

Variable Description

Spawning date. fish spawn on this date. The number entered represents the number of days into a simulation when fish spawn. For example, if your simulation starts on January st, and you want the Fishatoro to spawn on May st, you would enter a value of 2.

Lower Churchill River Ecosystem

Model Considerations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- Probabilistic
  - Models MeHg flux from sediment to water
  - Water then direct to food web based on BAFs

- Assumes several parameters:
  - Soil Organic Carbon content (%) based on satellite imagery
  - "Steady State" biological MeHg concentrations with peak MeHg fluxes from the reservoir
  - **Fish species list from the "Lake Melville region" (Table S5)**
  - **BAFs calculated and used based on fraction of their lifespan spent in each environment (Tables S7a & S7b)**

Lower Churchill River Ecosystem

Model Considerations

Fish species from the Lake Melville region

- Exposure of each species depends on interaction with the Muskrat Falls Reservoir or any output downstream

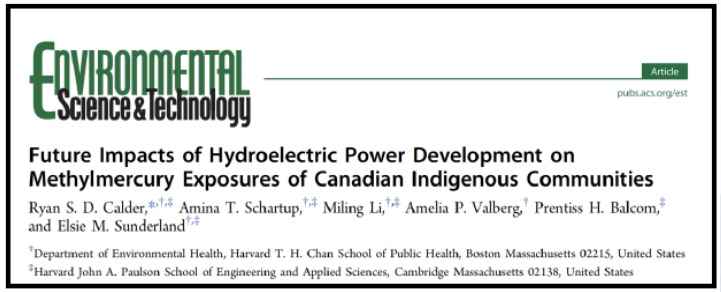
Table S5. Community-based monitoring of fish species from the Lake Melville region between 2014-2015. Analytical methods for total Hg and MeHg analysis are provided in Li et al. (26)

Sample	Location	Date	*n*	Sampled By
Smelt	Churchill River	September 2014	7	Inuit residents of North West River and Rigolet
Brook Trout	Lake Melville		20	Inuit residents of North West River and Rigolet
Lake Trout	Churchill River	June-July 2014	13	Field Research Coordinator
Stickleback	Churchill River and Lake Melville	July-Sept 2014	30	Field Research Coordinator
Salmon	Lake Melville (Rigolet area)	July 2014	3	Rigolet fishers
Long Nose Sucker	Lake Melville (between NWR/Rigolet	July-Aug 2014	20	Inuit fishers, North West River and Rigolet
Whitefish	Lake Melville (between NWR/Rigolet	July-Aug 2014	20	Inuit fishers, North West River and Rigolet
Flatfish	Lake Melville (between NWR/Rigolet	July-Aug 2014	20	Inuit fishers, North West River and Rigolet
Pike	Churchill River	July-Aug 2014 August 2015	13	Inuit fishers (HVGB)
Arctic Char	20 miles East of Rigolet	August 2015	10	Inuit fisher (Rigolet)
Atlantic Cod	St. Lewis Bay	September 2014	5	Labrador fisher
Mussels	Rigolet and NWR areas	June 2015	10	Inuit hunter
Misc. river fish	Churchill River above Muskrat Falls	August 2015	10	Inuit fishers

Lower Churchill River Ecosystem

Model Considerations

BAFs calculated and used based on fraction of a species lifespan spent in each environment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Bioaccumulation Factor (BAF):

- MeHg in biota / MeHg in water
  - Exposure of each species calculated from fraction of lifespan spent in each environment
    - River (Churchill River only based on BAF),
    - Estuary (Goose Bay & Lake Melville),
    - Marine (Groswater Bay and beyond)
  - Predominant habitat/foraging regions were estimated using $\delta^{13}C$, $\delta^{15}N$, $\delta^{199}Hg$ and $\delta^{201}Hg$, and literature (eg., Li et al. 2016 and Bradbury et al. 1999)

Lower Churchill River Ecosystem

Model Considerations

BAFs calculated and used based on fraction of a species lifespan spent in each environment

Arctic char:

- Spend 9/52 weeks in marine (Grant and Lee 2014)
  - Isotope C/N would still have remnant freshwater signal (Jardine et al. 2003)

- None captured in Churchill River, Goose Bay or Lake Melville
  - Traditional Knowledge says they may be in Lake Melville in low abundance
  - Would not reside or spawn in lower Churchill River but may be in other freshwater tributaries of Lake Melville

Table S7a. Bioaccumulation factors (BAFs) between aquatic MeHg concentrations and measured concentrations in biota and the estimated fraction of lifespan for each species spent in the freshwater environment (River), Lake Melville (Estuary) and outer marine regions (Marine).

Species	log BAF	River	Estuary	Marine	References
Arctic char		0.5	0.5	0	Dunbar (46),
Muscle	6.6				Bradbury et al. (47)[a,b]
Liver	6.6				
Roe	5.6				
Atlantic cod	7.7	0	0–0.50	0–0.50	Li et al. (26)[c,d]
Atlantic salmon		0	0–0.50	0–0.50	Li et al. (26)[c,d]
Muscle	7.3				
Liver	7.4				
Roe	6.4				
Brook trout		0.5	0.5	0	Backus (48), Pilgrim
Muscle	6.8				et al. (49)[a,e]
Liver	6.7				
Roe	6.5				
Capelin		0	0.25	0.75	Li et al. (26)[c]
Muscle	6.0				
Roe	5.1				
Clams	5.8	0	1	0	Harvest location[f]
Black duck		0.5	0.5	0	Longcore et al. (50)[g]
Muscle	6.8				
Eggs	6.2				
Eider		0	0.5–1	0.5–1	BirdLife International
Muscle	6.9				(51)[d,g]
Flatfish	6.6	0	1	0	Armstrong and Starr (52)[a]
Green sea urchin	6.4	0	1	0	Harvest location[f]
Guillemot		0	0.5–1	0.5–1	Butler et al. (53)[d]
Muscle	7.4				
Eggs	7.2				
Gull		0	0.5–1	0.5–1	Baird et al. (54)[g]
Muscle	7.3				
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[a] Stable Hg isotopes suggest mixed habitat (26).
[b] Time spent in open ocean is short (several weeks per year) (46, 47).
[c] Habitat is predominantly offshore and fish migrate into the estuary to feed and/or spawn.
[d] Habitats modeled probabilistically (see Table 2). Reported BAF is expected value.
[e] Habitat is predominantly freshwater. Radiotelemetry monitoring in the Churchill River revealed short (90% < 10 km) seasonal displacements (55).
[f] Sessile and low-motility species are based on predominant fishing location.
[g] Increased MeHg following flooding is scaled by time spent in region (0.5) for migratory species.

Lower Churchill River Ecosystem

Model Considerations

BAFs calculated and used based on fraction of a species lifespan spent in each environment

Atlantic cod:

- Li et al. (2016) identifies them as marine species based on isotopes
- None captured in Churchill River, Goose Bay or Lake Melville
- Ryan et al. (2016) baseline samples collected in St. Lewis Bay
- Traditional Knowledge….

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Lower Churchill River Ecosystem

Model Considerations

BAFs calculated and used based on fraction of a species lifespan spent in each environment

Atlantic salmon:

- Li et al. (2016) identifies adults as marine species based on isotopes
- Juveniles will migrate to marine environment and spend at least a year at sea before returning
- Will cease feeding as they enter the estuary
- Very few captured in the Churchill River

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Lower Churchill River Ecosystem

Model Considerations

BAFs calculated and used based on fraction of a species lifespan spent in each environment

Brook trout:

- Up to 8/52 weeks in estuary (near natal stream) as adults (Bradbury et al. 1999)
- Very few captured in Churchill River
  - Brook trout in Lake Melville are not produced in Churchill River main stem
  - Natal streams would be near estuary sites

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Model Considerations

BAFs calculated and used based on fraction of a species lifespan spent in each environment

Capelin:

- Li et al. (2016) identifies them as marine species based on isotopes
- Two captured in Churchill River, Goose Bay or Lake Melville
- Ryan et al. (2016) did not collect baseline samples collected
- Traditional Knowledge….Chaulk et al. (2013) noted whales near Rigolet chasing capelin

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Lower Churchill River Ecosystem

Model Considerations

BAFs calculated and used based on fraction of a species lifespan spent in each environment

Lake Trout:

- None captured in Muskrat Falls reservoir area or downstream
- They would be in freshwater but not any affected by the reservoir

Table S7b. Bioaccumulation factors (BAFs = MeHg biota/aqueous MeHg) and the estimated fraction of lifespan for each species spent in the freshwater environment (river), Lake Melville (estuary) and outer marine regions (marine).

Species	log BAF	River	Estuary	Marine	Reference
Lake trout	6.8	1	0	0	Black et al. (56)
Loon		0.5	0.5	0	McIntyre et al. (57)[a]
Eggs	7.7				
Mussels	5.3	0	1	0	Harvest location[b]
Ouananiche	6.9	1	0	0	Bradbury et al. (47)
Periwinkles	6.4	0	1	0	Harvest location[b]
Porpoise		0	0.25	0.75	Read and Westgate (58)[c]
Muscle	8.1				
Liver	8.4				
Rainbow smelt	6.8	0	1	0	FishBase (59)[d]
Rock cod		0	0–0.50	0–0.50	Ferguson et al. (60)[e,f]
Muscle	7.7				
Liver	7.5				
Sandpiper	6.6	0.5	0.5	0	Gratto-Trevor et al. (61)[a]
Scallops	6.1	0	1	0	Harvest location[b]
Sculpin		0	0.25	0.75	Li et al. (26)[c]
Muscle	7.7				
Liver	7.2				
Seal		0–0.25	0.5–0.75	0.25	Sikumiut Environmental Management Ltd. (62)[f,g]
Muscle	7.1				
Liver	7.1				
Kidney	7.3				
Tern		0	0.5–1	0.5–1	Hatch et al. (63)[a,f]
Muscle	7.3				
Eggs	7.5				

[a] Increased MeHg following flooding is scaled by time spent in region (0.5) for migratory species.
[b] Sessile and low-motility species are based on predominant fishing location.
[c] Habitat is predominantly offshore and fish migrate into the estuary to feed and/or spawn. Habitat fraction is modeled probabilistically (see Table S2). Reported BAF is expected mean.
[d] Hg isotope signature in adults indicates mixed habitat (26).
[e] Same $\delta^{13}C$ and $\delta^{15}N$ stable isotope signature as Atlantic cod.
[f] Habitat fraction modeled probabilistically (see Table S2). Reported BAF is expected mean.
[g] Pups are found in sea ice in estuarine environment.

Lower Churchill River Ecosystem

Model Considerations

BAFs calculated and used based on fraction of a species lifespan spent in each environment

Ouananiche:

- Very few captured in Muskrat Falls reservoir area
- They would be in freshwater but not any affected by the reservoir

Table S7b. Bioaccumulation factors (BAFs = MeHg biota/aqueous MeHg) and the estimated fraction of lifespan for each species spent in the freshwater environment (river), Lake Melville (estuary) and outer marine regions (marine).

Species	log BAF	River	Estuary	Marine	Reference
Lake trout	6.8	1	0	0	Black et al. (56)
Loon		0.5	0.5	0	McIntyre et al. (57)[a]
Eggs	7.7				
Mussels	5.3	0	1	0	Harvest location[b]
Ouananiche	6.9	1	0	0	Bradbury et al. (47)
Periwinkles	6.4	0	1	0	Harvest location[b]
Porpoise		0	0.25	0.75	Read and Westgate (58)[c]
Muscle	8.1				
Liver	8.4				
Rainbow smelt	6.8	0	1	0	FishBase (59)[d]
Rock cod		0	0–0.50	0–0.50	Ferguson et al. (60)[e,f]
Muscle	7.7				
Liver	7.5				
Sandpiper	6.6	0.5	0.5	0	Gratto-Trevor et al. (61)[a]
Scallops	6.1	0	1	0	Harvest location[b]
Sculpin		0	0.25	0.75	Li et al. (26)[c]
Muscle	7.7				
Liver	7.2				
Seal		0–0.25	0.5–0.75	0.25	Sikumiut Environmental Management Ltd. (62)[f,g]
Muscle	7.1				
Liver	7.1				
Kidney	7.3				
Tern		0	0.5–1	0.5–1	Hatch et al. (63)[a,f]
Muscle	7.3				
Eggs	7.5				

[a] Increased MeHg following flooding is scaled by time spent in region (0.5) for migratory species.
[b] Sessile and low-motility species are based on predominant fishing location.
[c] Habitat is predominantly offshore and fish migrate into the estuary to feed and/or spawn. Habitat fraction is modeled probabilistically (see Table S2). Reported BAF is expected mean.
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[f] Habitat fraction modeled probabilistically (see Table S2). Reported BAF is expected mean.
[g] Pups are found in sea ice in estuarine environment.

Lower Churchill River Ecosystem

Model Considerations

BAFs calculated and used based on fraction of a species lifespan spent in each environment

Seal:

- No Ringed seal observed in Churchill River (that includes Sikumiut Environmental Management Ltd (2008))
- Chaulk et al. (2013) states that elders reported that Ringed Seals are rarely observed in Lake Melville during the summer, compared to early spring.
- Chaulk et al. (2013) also noted that B. Sjare tracking data suggested that Ringed Seals move in and out of Lake Melville from other areas of coastal Labrador over the course of the ice-free period

Table S7b. Bioaccumulation factors (BAFs = MeHg biota/aqueous MeHg) and the estimated fraction of lifespan for each species spent in the freshwater environment (river), Lake Melville (estuary) and outer marine regions (marine).

Species	log BAF	River	Estuary	Marine	Reference
Lake trout	6.8	1	0	0	Black et al. (56)
Loon		0.5	0.5	0	McIntyre et al. (57)[a]
Eggs	7.7				
Mussels	5.3	0	1	0	Harvest location[b]
Ouananiche	6.9	1	0	0	Bradbury et al. (47)
Periwinkles	6.4	0	1	0	Harvest location[b]
Porpoise		0	0.25	0.75	Read and Westgate (58)[c]
Muscle	8.1				
Liver	8.4				
Rainbow smelt	6.8	0	1	0	FishBase (59)[d]
Rock cod		0	0–0.50	0–0.50	Ferguson et al. (60)[e,f]
Muscle	7.7				
Liver	7.5				
Sandpiper	6.6	0.5	0.5	0	Gratto-Trevor et al. (61)[a]
Scallops	6.1	0	1	0	Harvest location[b]
Sculpin		0	0.25	0.75	Li et al. (26)[c]
Muscle	7.7				
Liver	7.2				
Seal		0–0.25	0.5–0.75	0.25	Sikumiut Environmental Management Ltd. (62)[f,g]
Muscle	7.1				
Liver	7.1				
Kidney	7.3				
Tern		0	0.5–1	0.5–1	Hatch et al. (63)[a,f]
Muscle	7.3				
Eggs	7.5				

[a] Increased MeHg following flooding is scaled by time spent in region (0.5) for migratory species.
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[f] Habitat fraction modeled probabilistically (see Table S2). Reported BAF is expected mean.
[g] Pups are found in sea ice in estuarine environment.

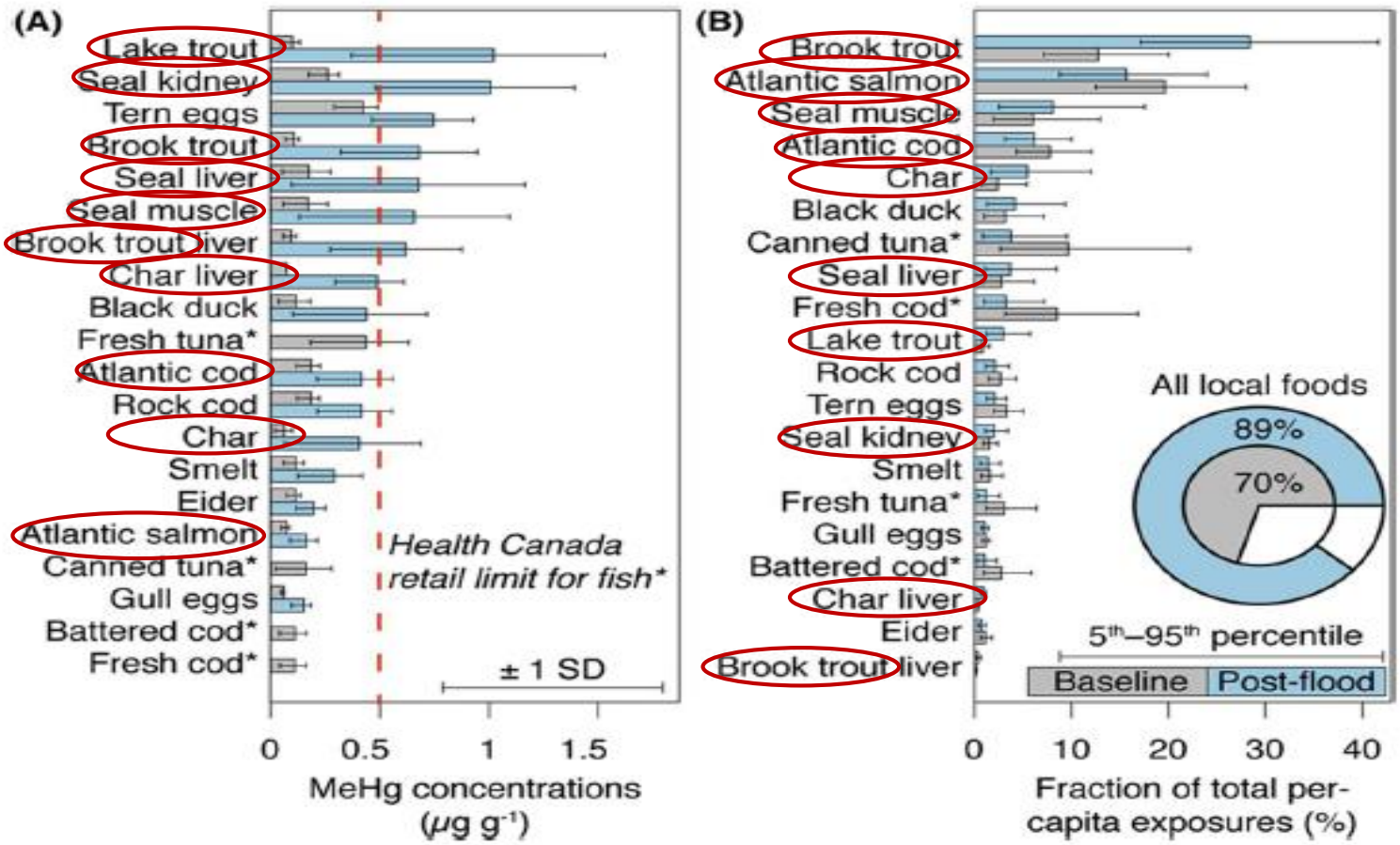
Lower Churchill River Ecosystem

Model Considerations

BAFs calculated and used based on fraction of a species lifespan spent in each environment

Species	Freshwater		Estuary	Marine
	Non-Churchill	Churchill River		
Arctic Char	0.8	0.0	0.0-0.1	0.0-0.1
Atlantic cod	0.0	0.0	0.0-0.1	0.9-1.0
Atlantic salmon	0.4	0.0	0.0	0.6
Brook trout	0.8	0.0	0.2	0.0
Capelin	0.0	0.0	0.0-0.1	0.9-1.0
Lake Trout	1.0	0.0	0.0	0.0
Ouananiche	1.0	0.0	0.0	0.0
Seal	0.0	0.0	0.4-0.75	0.25-0.6

Calder 2016 – Country Food MeHg Predictions



MeHg concentrations in locally caught species increase 1.3 to 10-fold depending on time spent foraging in different environments

OLLSON
Environmental Health Management

Lower Churchill River Ecosystem

Model Considerations

Summary

1. **Species Distributions (and food webs) should be revised based on available data**
   a) **Some identified species are not within the zone of exposure**

2. **Habitat use (for BAF calculations) should be reviewed and revised based on available data**
   a) **Many of the top species are not as exposed as suggested**
   b) **Also exposed to other water sources than Churchill River (BAF)**

3. Baseline Hg concentrations should be reviewed and revised based on available data

4. Organic Carbon estimates should be reviewed based on available data
   a) Reservoir measurements

5. "Steady State" vs Pulse?