



MEMO

TO: Jackie Wells
FROM: Rob Willis
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SUBJECT: Technical Memo – Supplemental Human Health Risk Assessment (HHRA) of 2021 Fish and Seal Mercury Data
OUR FILE: 22-4223

Supplemental Human Health Risk Assessment (HHRA) of 2021 Fish and Seal Mercury Data

1.0 Introduction

As part of ongoing efforts to continually update predictions regarding the potential for methylmercury (MeHg) levels to increase in Muskrat Falls study area aquatic biota, and the potential for increased MeHg exposure among human consumers of locally harvested aquatic country foods, this report presents the outcomes of human health risk assessment (HHRA) of 2021 aquatic EEM program data on MeHg concentrations in harvested fish and seal species.

Previous HHRA work conducted within the Muskrat Falls HHRA Program (i.e., Dillon, 2016a,b; 2018) focused on the assessment and characterization of baseline and predicted future MeHg exposure and risk. The prediction of MeHg exposure and human health risk in relation to the 2021 aquatic EEM data builds upon the modelling framework developed within the comprehensive 2016 final baseline HHRA (i.e., Dillon, 2016b), and also incorporates and/or builds upon the outcomes of the various modelling studies, field programs, EEM data evaluations, and other studies that were conducted by independent technical experts throughout 2017 and 2018, and that are described in Dillon (2018) and various other documents posted to the Muskrat Falls Project websites:

[\(https://muskratfalls.nalcorenergy.com/environment/generation/;](https://muskratfalls.nalcorenergy.com/environment/generation/)
[https://muskratfalls.nalcorenergy.com/environment/generation/methylmercury-monitoring/\)](https://muskratfalls.nalcorenergy.com/environment/generation/methylmercury-monitoring/)

The Muskrat Falls Human Health Program was initiated in 2013 and has been ongoing since that time. Key elements and milestones of the Human Health Program have been described in previous documentation (in particular, Dillon (2018; 2016b)) and in other documents posted to the above websites. This memo does not elaborate on information that is covered in detail within previous HHRA program documents.

It is acknowledged that while all Muskrat Falls study area HHRA studies to date focus on MeHg exposures, and the potential human health risks of such exposures, Muskrat Falls study area fish and seal mercury concentration data are primarily measured and expressed as total mercury (THg) concentrations, rather than MeHg concentrations. It is very common (for reasons relating to practicality and efficiency) to measure THg rather than MeHg in comprehensive mercury environmental monitoring

programs. In the baseline HHRA (Dillon, 2016b), and the Dillon (2018) assessment of potential future MeHg exposures and risks, it was conservatively assumed that the THg present in fish and seal muscle tissue (meat) was comprised of 100% MeHg, and that the THg present in seal liver was comprised of 40% MeHg (based on literature review conducted during the baseline HHRA program and on empirical study area ringed seal tissue THg and MeHg data that were collected in support of the baseline HHRA). These assumptions continue to apply herein. For the sake of simplicity and consistency, this memo mainly refers to MeHg concentrations in fish and seal (even though the mercury concentrations are reported as THg), and MeHg exposures and risks, unless specifically referring directly to the fish and seal aquatic EEM datasets, which report THg.

2.0 Potential MeHg Exposures and Risks Within the Muskrat Falls Study Area – 2021 Aquatic EEM Data

This section addresses potential MeHg exposures that may be incurred by study area community members due to the harvesting and consumption of fish and seal, and the potential health risks that may be anticipated as a result of such exposures. Assessment of potential MeHg exposures and risks, based on the 2021 aquatic EEM program data, is supplemental to the final baseline HHRA (Dillon, 2016b), and the prediction of potential future MeHg exposures and risks that were presented in Dillon (2018). The 2021 potential MeHg exposures and risks were estimated using the same exposure and risk model developed for the final baseline HHRA, which was also applied for the estimation of potential future MeHg exposures and risks.

Because the evaluation presented herein is based on MeHg concentrations in key fish and seal species from the study area in 2021, the predicted peak MeHg increase factors reported in Table 2-3 of Wood (2018a) for Goose Bay and West Lake Melville were not necessary to apply. Nonetheless, these increase factors continue to represent the current best available estimates of potential future increases in MeHg concentrations within the edible tissues of locally harvested fish species and ringed seal. As previously noted in Dillon (2018), the peak MeHg increase factors were derived in a manner that is believed to be highly conservative, such that their application likely substantially overestimates future dietary MeHg exposures and risks within the study area communities. Also, the peak MeHg increase factors are temporary and are expected to occur within 2 to 3 years following reservoir impoundment. The various studies conducted in 2017 and 2018 (all of which are posted at: <https://muskratfalls.nalcorenergy.com/environment/generation/methylmercury-monitoring/>) collectively indicate that MeHg concentrations in study area aquatic biota are anticipated to gradually increase such that they would peak by post-reservoir impoundment years 2 or 3, persist for potentially 1 year, and then gradually decline thereafter back towards baseline levels.

As previously noted in Dillon (2018) and Wood (2018a,b), brook trout, rainbow smelt and ringed seal (meat and liver) are focused on with respect to the assessment of potential MeHg exposure and risk. These species are the most commonly consumed (as reported in HHRA program diet surveys), are among the most abundant harvested species within the study area, and are the only harvested and consumed species likely to be affected by the Project (i.e., these species are most likely to experience increases in MeHg accumulation within their tissues as a result of the Project). The outcomes of Wood (2018b) and the HHRA Program diet surveys demonstrated that other fish species known to occur within the study area are either not harvested/consumed (based on diet survey results), or, if they are harvested and consumed, are unlikely to be influenced by the Project, given their habitat preferences,

distribution, foraging preferences, life history, and prevalence and abundance within study area water bodies. Thus, brook trout, rainbow smelt and ringed seal are the only species that merit consideration at this time.

Of the study area communities considered in the baseline HHRA (Dillon, 2016b), all but Churchill Falls (CF) merit consideration with respect to current MeHg exposures and risks. CF is excluded from the current HHRA as the fish harvested and consumed by CF residents are extremely unlikely to come from the Muskrat Falls reservoir, areas downstream of the reservoir, Goose Bay or Western Lake Melville (given that the distance between CF and these water bodies is >250 km), and CF residents did not report the consumption of ringed seal meat or liver. Thus, for CF community members, current and future MeHg exposures and risks as a result of the Muskrat Falls Project are expected to equal baseline MeHg exposures and risks.

The HHRA of the 2021 aquatic EEM program MeHg data for brook trout, rainbow smelt and ringed seal meat and liver tissues was conducted using the same model that was developed for the baseline HHRA, and that was also utilized in the Dillon (2018) assessment of potential future MeHg exposures and risks. For the HHRA of the 2021 data, MeHg exposure point concentrations (EPCs) were calculated from the 2021 brook trout, rainbow smelt, and ringed seal meat and liver MeHg (reported as THg) concentration datasets. These 2021 data were provided to Dillon by WSP. Statistical data summaries for the 2021 brook trout, rainbow smelt, and ringed seal meat and liver THg datasets are provided in **Attachment A** to this memo.

All EPCs were calculated using the latest version of the U.S. EPA's ProUCL software. EPC calculation was conducted in the same manner as described in Dillon (2016b), and the EPC units are expressed in mg/kg wet weight (ww) of fish (or seal) tissue. EPC calculation output is provided in **Attachment A**. As previously noted, it was conservatively assumed herein, and throughout the HHRA Program to date, that the THg concentrations measured in fish and seal muscle tissue (meat) were comprised of 100% MeHg, and that the THg concentrations in seal liver were comprised of 40% MeHg.

For the calculation of 2021 MeHg exposures and risks, all other sources and rates of MeHg exposure that were evaluated in the baseline HHRA (i.e., other locally harvested country foods that are not influenced by the Muskrat Falls Project, and grocery store foods) remained constant or unchanged from what was assumed for baseline conditions. This was also the approach taken for the estimation of predicted future peak MeHg exposures and risks in Dillon (2018). For these "other" country food items and grocery store food items, it is considered very likely that current and future MeHg exposures would be no different from baseline MeHg exposures.

Table 1 provides a summary of MeHg EPCs for brook trout, rainbow smelt, and ringed seal meat and liver, for the baseline period, for the future predicted peak MeHg condition, and for 2021 (calculated from measured 2021 aquatic EEM program THg data).

Table 1: Summary of MeHg EPCs: Baseline, Potential Future Peak Conditions, and 2021; mg/kg ww

Key Species	Baseline MeHg EPC	Future Peak Predicted MeHg EPC (Peak Increase Factor X Baseline EPC)	2021 MeHg EPC
brook trout	0.07; N=340	0.11; N=340	0.074; N=81 [max=0.24]
rainbow smelt	0.12; N=142	0.22; N=142	0.054; N=73 [max=0.12]
ringed seal meat	0.34; N=159	0.43; N=159	0.031; N=30 [max=0.08]
ringed seal liver	9.1; N=145	11.5; N=145	0.30; N=30 [max=0.57]

Notes:

N=sample size (# of samples); max=maximum MeHg concentration.

All EPC units are in mg/kg ww.

All fish and seal mercury data were measured as THg concentrations (which, in the table, are referred to as MeHg concentrations). For HHRA purposes, it was conservatively assumed that THg measured in fish and seal muscle tissue (meat) was comprised of 100% MeHg, and that THg in seal liver was comprised of 40% MeHg.

It is noted that all brook trout and rainbow smelt Hg EPCs for the baseline, future peak predicted, and 2021 conditions are below the Health Canada maximum level for mercury in fish of 0.5 mg THg/kg ww fish (<https://www.canada.ca/en/health-canada/services/food-nutrition/food-safety/chemical-contaminants/maximum-levels-chemical-contaminants-foods.html#a2>). The 2021 maximum measured concentrations of THg in brook trout and rainbow smelt are also below this Health Canada maximum level. During the baseline period, maximum measured concentrations of THg in brook trout and rainbow smelt were also below this Health Canada maximum level of 0.5 mg THg/kg ww (Dillon, 2016b).

2.1 HHRA Outcomes: Evaluation of 2021 MeHg Data

Outcomes of the HHRA of the 2021 MeHg data for brook trout, rainbow smelt, and ringed seal meat and liver showed either no change in MeHg hazard quotients relative to the baseline MeHg hazard quotients (the hazard quotient is the primary indicator of potential human health risk in a HHRA), or decreased MeHg hazard quotients relative to the baseline MeHg hazard quotients. Model-predicted hair MeHg concentrations, and blood MeHg concentrations for the assessed human receptors and study area communities followed the same pattern as the MeHg hazard quotients. **Tables 2 to 5** summarize the changes in these key HHRA outcomes based on the assessment of 2021 brook trout, rainbow smelt and ringed seal meat and liver MeHg data, relative to both baseline and predicted future peak conditions HHRA outcomes.

The HHRA of the 2021 MeHg data does not alter any of the conclusions made within the previous baseline HHRA, and the results presented in **Tables 2 to 5** should be considered in the same context and perspective that was provided in the final baseline HHRA report (i.e., Dillon, 2016b).

Specifically, the HHRA outcomes suggest a low to negligible potential for human health risk resulting from current MeHg exposures, and the calculated MeHg exposures and risks are similar to what would be expected in numerous communities in North America where food consumption patterns comprise the ingestion of both store-bought foods and country food items that are of aquatic origin. HHRA outcomes also do not indicate a need for corrective action or risk management (such as specific consumption advisories) at this time. However, standard precautionary recommendations as per those made in Dillon (2016b) and Dillon (2018) continue to be considered prudent to apply.

For example, despite the conservatism and the high likelihood that the HHRA substantially overestimates MeHg exposures and risks to nursing mothers, breast-feeding infants, females of child-bearing age and the developing fetus, standard universal advice that pregnant women and nursing mothers avoid, restrict or temporarily cease their consumption of certain country and store-bought food items that tend to be elevated in MeHg, is prudent, and should apply within the study area communities. It must be recognized that this well-established precautionary advice applies to pregnant women and nursing mothers anywhere, and is not made for the study area communities because of baseline HHRA, future predicted peak HHRA, or 2021 HHRA outcomes. It must also be recognized that there are numerous and universally well-established benefits (to both the infant and mother) of breast-feeding, and HHRA outcomes indicate no reason whatsoever for there to be concerns regarding breast-feeding in relation to the levels of MeHg exposure within study area communities. In general, breast-feeding should never be stopped due to fears over chemical exposure unless specifically recommended by a physician. The benefits of breast-feeding far outweigh the potential health risks from chemical exposure in the overwhelmingly vast majority of cases. Given the HHRA outcomes, and recognizing the inherent conservatism and tendency for the HHRA approaches to overestimate exposure and risk, there is no cause for concern in relation to potential infant MeHg exposures that may be incurred via breast-feeding. Thus, any new or soon-to-be mothers within the study area communities should continue to be encouraged to breast-feed their infants and young toddlers, if they are able to. Following the standard universal precautionary measures for MeHg will further reduce what is an already low to negligible potential for significant MeHg exposure and risk.

In addition (as noted previously in Dillon, 2016a,b and Dillon, 2018), it may be prudent to recommend to those study area residents that consume ringed seal meat and organs, that only younger ringed seals be harvested for human consumption (as older seals tend to have higher THg and MeHg concentrations in both their muscle and liver tissue). Typically, it is the younger seals that are preferentially harvested, but encouraging this practice would likely reduce the Hg exposures that may be incurred from seal meat and liver consumption.



MEMO

TABLE 2: SUMMARY OF METHYLMERCURY (MeHg) HAZARD QUOTIENTS (HQs) FOR MUSKRAT FALLS STUDY AREA EXPOSURE/CONSUMPTION SCENARIOS (COMMUNITIES) – BASELINE, POTENTIAL FUTURE PEAK CONDITIONS, AND 2021

Human Receptor Type	HQ Type	Baseline Happy Valley-Goose Bay (HVGB)	Potential Future Peak HVGB	2021 HVGB	Baseline Sheshatshiu (SH)	Potential Future Peak SH	2021 SH	Baseline North West River (NWR) and Mud Lake (ML)	Potential Future NWR and ML	2021 NWR and ML
M Toddler	HQ1	1.3	1.39	1.1	1.0	1.1	1.0	1.5	1.7	1.3
	HQ2	NA	NA	NA	NA	NA	NA	NA	NA	NA
	HQ3	0.64	0.69	0.53	0.50	0.53	0.50	0.77	0.82	0.66
M Child	HQ1	1.5	1.6	1.5	1.4	1.5	1.4	1.6	1.7	1.5
	HQ2	NA	NA	NA	NA	NA	NA	NA	NA	NA
	HQ3	0.77	0.8	0.73	0.71	0.73	0.70	0.80	0.83	0.76
M Teen	HQ1	1.2	1.2	0.99	0.95	0.97	0.94	1.2	1.3	1.0
	HQ2	0.25	0.26	0.21	0.20	0.21	0.20	0.25	0.27	0.22
	HQ3	NA	NA	NA	NA	NA	NA	NA	NA	NA
M Adult	HQ1	2.5	2.6	2.1	2.1	2.1	2.1	2.5	2.7	2.2
	HQ2	0.53	0.55	0.45	0.44	0.45	0.44	0.54	0.57	0.46
	HQ3	NA	NA	NA	NA	NA	NA	NA	NA	NA
F Toddler	HQ1	1.4	1.5	1.1	1.1	1.1	1.1	1.6	1.8	1.4
	HQ2	NA	NA	NA	NA	NA	NA	NA	NA	NA
	HQ3	0.68	0.74	0.57	0.54	0.56	0.53	0.82	0.88	0.71
F Child	HQ1	1.6	1.7	1.5	1.5	1.5	1.4	1.7	1.7	1.6
	HQ2	NA	NA	NA	NA	NA	NA	NA	NA	NA
	HQ3	0.79	0.83	0.75	0.73	0.76	0.72	0.83	0.86	0.78
F Teen	HQ1	1.3	1.4	1.1	1.1	1.1	1.1	1.4	1.4	1.2
	HQ2	0.28	0.29	0.24	0.23	0.23	0.23	0.29	0.30	0.25
	HQ3	0.65	0.69	0.56	0.54	0.55	0.53	0.68	0.71	0.58

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Human Receptor Type	HQ Type	Baseline Happy Valley-Goose Bay (HVGB)	Potential Future Peak HVGB	2021 HVGB	Baseline Sheshatshiu (SH)	Potential Future Peak SH	2021 SH	Baseline North West River (NWR) and Mud Lake (ML)	Potential Future NWR and ML	2021 NWR and ML
F Adult	HQ1	3.0	3.1	2.6	2.5	2.5	2.5	3.0	3.2	2.6
	HQ2	0.63	0.66	0.54	0.53	0.54	0.52	0.64	0.68	0.55
	HQ3	1.5	1.6	1.3	1.2	1.3	1.2	1.5	1.6	1.3
Infant with F Teen Mother	HQ1	2.6	2.7	2.2	2.1	2.1	2.1	2.6	2.8	2.3
	HQ3	1.3	1.4	1.1	1.1	1.1	1.0	1.3	1.4	1.1
Infant with F Adult Mother	HQ1	5.8	6.1	5.0	4.9	5.0	4.8	5.9	6.2	5.1
	HQ3	2.9	3.1	2.5	2.4	2.5	2.4	2.9	3.1	2.5

Notes:

M=Male; F=Female.

HQ values are rounded to two significant figures. HQ values are unitless.

Bolded values indicate exceedance of target HQ value of 1.0.

HQ1 refers to HQ based on use of the U.S. EPA (2001a,b) and NRC (2000) TRV (See Dillon, 2016b).

HQ2 refers to HQ based on use of the Health Canada (2010c; 2007) TRV for the general adult population (See Dillon, 2016b). This TRV was also applied to M and F teen receptors (>12 to <20 years).

HQ3 refers to HQ based on use of the Health Canada (2010c; 2007) TRV for women of child-bearing age (considered to be both teen and adult life stages) and children <12 years of age (See Dillon, 2016b).

NA=not applicable for a given receptor; due to application of the gender and age-specific TRVs for MeHg from Health Canada.

TABLE 3: SUMMARY OF PREDICTED HAIR MeHg CONCENTRATIONS (mg/kg ww) FOR HUMAN RECEPTORS ASSESSED IN THE HHRA – BASELINE, POTENTIAL FUTURE PEAK CONDITIONS, AND 2021

Receptor	Baseline HVGB	Potential Future HVGB	2021 HVGB	Baseline SH	Potential Future SH	2021 SH	Baseline NWR and ML	Potential Future NWR and ML	2021 NWR and ML
M Toddler	1.4	1.6	1.2	1.1	1.2	1.1	1.7	1.9	1.5
M Child	1.7	1.8	1.6	1.6	1.7	1.6	1.8	1.9	1.7
M Teen	1.3	1.4	1.1	1.1	1.1	1.1	1.3	1.4	1.2
M Adult	2.8	3.0	2.4	2.4	2.4	2.3	2.9	3.0	2.5
F Toddler	1.5	1.7	1.3	1.2	1.3	1.2	1.9	2.0	1.6
F Child	1.8	1.9	1.7	1.7	1.7	1.6	1.9	1.9	1.8
F Teen	1.5	1.6	1.3	1.2	1.2	1.2	1.5	1.6	1.3
F Adult	3.4	3.5	2.9	2.8	2.9	2.8	3.4	3.6	2.9
Pregnant F Teen	1.0	1.1	0.9	0.8	0.8	0.8	1.0	1.1	0.9
Pregnant F Adult	2.3	2.5	2.0	2.0	2.0	1.9	2.4	2.5	2.1

Notes:

F=female; M=male; ww =wet weight.

Bolded values denote an exceedance over the applicable “no action” Health Canada hair guidance value(s) for THg/MeHg (2 mg/kg ww for pregnant F; F 0-49 yrs; M≤18 yrs; and, 5 mg/kg ww for F≥50 yrs; M >18 yrs).

TABLE 4: SUMMARY OF PREDICTED BLOOD MeHg CONCENTRATIONS ($\mu\text{g/L}$) FOR HUMAN RECEPTORS ASSESSED IN THE HHRA – BASELINE, POTENTIAL FUTURE PEAK CONDITIONS, AND 2021

Receptor	Baseline HVGB	Potential Future HVGB	2021 HVGB	Baseline SH	Potential Future SH	2021 SH	Baseline NWR and ML	Potential Future NWR and ML	2021 NWR and ML
M Toddler	5.8	6.3	4.8	4.6	4.8	4.5	7.0	7.5	6.0
M Child	7.0	7.3	6.6	6.5	6.6	6.4	7.3	7.6	6.9
M Teen	5.2	5.5	4.5	4.3	4.4	4.3	5.4	5.7	4.7
M Adult	11.2	11.8	9.7	9.4	9.6	9.4	11.4	12	9.9
F Toddler	6.2	6.7	5.1	4.9	5.1	4.8	7.5	8.0	6.4
F Child	7.2	7.5	6.8	6.6	6.8	6.5	7.5	7.8	7.1
F Teen	5.9	6.3	5.1	4.9	5.0	4.8	6.1	6.5	5.3
F Adult	13.4	14.1	11.5	11.3	11.5	11.2	13.6	14.4	11.8
Pregnant F Teen	4.0	4.3	3.5	3.3	3.4	3.3	4.2	4.4	3.6
Pregnant F Adult	9.4	9.9	8.1	7.9	8.0	7.8	9.5	10	8.2

Notes:

F=female; M=male.

Bolded values denote an exceedance over the applicable “no action” Health Canada blood guidance value(s) for MeHg (8 $\mu\text{g/L}$ for pregnant F; F 0-49 yrs; M \leq 18 yrs; and, 20 $\mu\text{g/L}$ for F \geq 50 yrs; M $>$ 18 yrs).

TABLE 5: SUMMARY OF PREDICTED FETAL BLOOD MeHg CONCENTRATIONS ($\mu\text{g/L}$) – BASELINE, POTENTIAL FUTURE PEAK CONDITIONS, AND 2021

Community	Predicted Fetal Blood Concentration ($\mu\text{g/L}$) Based on Pregnant Female Teen	Predicted Fetal Blood Concentration ($\mu\text{g/L}$) Based on Pregnant Female Adult
Baseline HVGB	6.9	15.9
Potential Future HVGB	7.2	16.8
2021 HVGB	5.9	13.7
Baseline SH	5.6	13.4
Potential Future SH	5.8	13.6
2021 SH	5.6	13.2
Baseline NWR and ML	7.1	16.2
Potential Future NWR and ML	7.5	17
2021 NWR and ML	6.1	13.9

Notes:

Bolded concentrations exceed the Health Canada (Legrand et al., 2010) “no action” blood guidance value of 8 $\mu\text{g/L}$. Health Canada considers that <8 $\mu\text{g/L}$ of MeHg in maternal blood is protective of the developing fetus as well as infants and young and older children (up to adolescence).



MEMO

3.0 References Cited

Dillon. 2018. Technical Memo: Lower Churchill Hydroelectric Generation Project (LCHGP) Supplementary Human Health Risk Assessment (HHRA) – Overview of HHRA Program Status and Supplementary Assessment of Potential Future Human Exposures and Risks Due to Methylmercury. November 20th, 2018.

Dillon. 2016a. Technical Memo: Preliminary Human Exposure and Risk Calculations for Total Mercury (THg) and Methylmercury (MeHg) Associated with the Consumption of Ringed Seal Meat (Muscle Tissue) and Liver. March 14th, 2016.

Dillon. 2016b. Final Baseline Human Health Risk Assessment: Lower Churchill Hydroelectric Generation Project. Submitted by: Dillon Consulting Limited. Submitted to: Nalcor Energy. October, 2016.

Health Canada. 2010c. Federal Contaminated Site Risk Assessment in Canada Part II: Health Canada Toxicological Reference Values (TRVs) and Chemical-Specific Factors. Version 2.0. September, 2010. Prepared by: Contaminated Sites Division, Safe Environments Directorate. Cat.: H128-1/11-638E-PDF.

Health Canada (HC). 2007. Human Health Risk Assessment of Mercury in Fish and Health Benefits of Fish Consumption. Bureau of Chemical Safety, Food Directorate, Health Products and Food Branch, Health Canada. March, 2007. Cat.: H164-54/2007E-PDF.

Legrand, M., Feeley, M., Tikhonov, C., Schoen, D., and Li-Muller, A. 2010. Methylmercury blood guidance values for Canada. *Can. J. Public Health*. 101(1):28-31.

National Research Council (NRC). 2000. Toxicological effects of methylmercury. Committee on the Toxicological Effects of Methylmercury, Board on Environmental Studies, Integrated Risk Information System (IRIS) U.S. Environmental Protection Agency, Chemical Assessment Summary, National Center for Environmental Assessment and Toxicology, Commission on Life Sciences, National Research Council. Washington, DC: National Academy Press.

U.S. EPA. 2001a. Water Quality Criterion for the Protection of Human Health: Methylmercury. Final. Office of Science and Technology, Office of Water, U.S. Environmental Protection Agency. Washington, DC. EPA-823-R-01-001. January, 2001.

U.S. EPA. 2001b. Methylmercury (MeHg). CASRN 22967-92-6. Integrated Risk Information System, United States Environmental Protection Agency.

https://cfpub.epa.gov/ncea/iris2/chemicalLanding.cfm?substance_nmbr=73.

Wood. 2018a. Predicted Increases in Fish Methylmercury Muscle Tissue Concentrations in Goose Bay and Lake Melville. Submitted to: Nalcor Energy. Submitted by: Jim McCarthy, Wood Environment and Infrastructure Solutions. July, 2018.

Wood. 2018b. Aquatic Species Habitat Utilization Overview: Churchill River, Goose Bay, and Lake Melville. 1998-2016. Submitted to: Nalcor Energy. Submitted by: Jim McCarthy, Wood Environment & Infrastructure Solutions. July, 2018.

Attachment A: 2021 Brook Trout, Rainbow Smelt and Ringed Seal (Meat and Liver) Data Summaries and Statistical Output

year	section	area	species	length	st_length	thg
2021	0	GB	BK	200	250	0.01
2021	0	GB	BK	244	250	0.01
2021	0	GB	BK	232	250	0.03
2021	0	GB	BK	238	250	0.03
2021	0	GB	BK	240	250	0.02
2021	0	GB	BK	260	250	0.03
2021	0	GB	BK	302	250	0.03
2021	0	GB	BK	263	250	0.02
2021	0	GB	BK	205	250	0.03
2021	0	GB	BK	233	250	0.07
2021	0	GB	BK	228	250	0.04
2021	0	GB	BK	251	250	0.05
2021	0	GB	BK	285	250	0.08
2021	0	LM	BK	280	250	0.11
2021	0	LM	BK	288	250	0.06
2021	0	LM	BK	258	250	0.07
2021	0	LM	BK	245	250	0.09
2021	0	LM	BK	251	250	0.09
2021	0	LM	BK	252	250	0.05
2021	0	LM	BK	266	250	0.09
2021	0	LM	BK	240	250	0.07
2021	0	LM	BK	195	250	0.06
2021	0	LM	BK	242	250	0.08
2021	0	LM	BK	215	250	0.05
2021	0	LM	BK	344	250	0.08
2021	0	LM	BK	314	250	0.11
2021	0	LM	BK	285	250	0.05
2021	0	LM	BK	263	250	0.1
2021	0	LM	BK	305	250	0.09
2021	0	LM	BK	232	250	0.06
2021	0	LM	BK	201	250	0.05
2021	0	LM	BK	240	250	0.05
2021	0	LM	BK	234	250	0.1
2021	0	LM	BK	264	250	0.09
2021	0	LM	BK	258	250	0.08
2021	0	LM	BK	260	250	0.07
2021	0	LM	BK	225	250	0.07
2021	0	LM	BK	222	250	0.04
2021	0	LM	BK	221	250	0.07
2021	0	LM	BK	279	250	0.07
2021	0	LM	BK	242	250	0.06
2021	0	LM	BK	459	250	0.24
2021	0	LM	BK	405	250	0.17
2021	0	OM	BK	324	250	0.03
2021	0	OM	BK	325	250	0.06
2021	0	OM	BK	362	250	0.06
2021	0	OM	BK	218	250	0.06
2021	0	OM	BK	228	250	0.06
2021	0	OM	BK	223	250	0.05
2021	0	OM	BK	165	250	0.03
2021	0	OM	BK	380	250	0.04
2021	1	BM	BK	267	250	0.08
2021	1	BM	BK	260	250	0.06
2021	1	BM	BK	286	250	0.08
2021	1	BM	BK	256	250	0.08
2021	1	BM	BK	278	250	0.19
2021	1	BM	BK	268	250	0.09
2021	1	BM	BK	259	250	0.07
2021	1	BM	BK	266	250	0.08
2021	1	BM	BK	208	250	0.06
2021	1	BM	BK	196	250	0.06
2021	1	BM	BK	177	250	0.06
2021	1	BM	BK	234	250	0.03
2021	1	BM	BK	223	250	0.11
2021	1	BM	BK	261	250	0.08
2021	1	BM	BK	238	250	0.07
2021	1	BM	BK	163	250	0.02
2021	1	BM	BK	260	250	0.05
2021	1	BM	BK	316	250	0.15
2021	1	BM	BK	203	250	0.03
2021	1	BM	BK	208	250	0.02
2021	1	BM	BK	211	250	0.06
2021	1	BM	BK	220	250	0.06

2021 BROOK TROUT THg DATA

Fish species codes **Area codes** **Section codes - refers to the initial river section codes used in early baseline reports**

AM - Above Muskrat Falls in area of reservoir
 AS - atlantic salmon 0 - Goose Bay and Lake Melville (downstream of the river)
 BM - Below Muskrat Falls
 BK - brook trout 1 - River between Goose Bay and Muskrat Falls
 but upriver of Goose Bay
 LF - lake whitefish GB - Goose Bay 2 - River between Muskrat Falls and Grizzle Rapids (the reservoir area)
 LS - longnose sucker LM - west Lake Melville 3 - River between Grizzle Rapids and outflow of Winokapau Lake
 NP - northern pike OM - outer Lake Melville 4 - Winokapau Lake
 RS - rainbow smelt SL - above reservoir 5 - River between Winokapau Lake and Churchill Falls tailrace
 TC - tomcod
 WS - white sucker

0.572869655 **Correlation Coefficient (length vs THg)**

THg Summary Statistics (Excel)
 N 81
 min 0.01 (<RDL)
 max 0.24
 arithmean 0.065308642
 median 0.06

THg ProUCL 5.2 Statistics

General Statistics on Uncensored Full Data
 Date/Time of Computation ProUCL 5.2 4/10/2023 4:05:40 PM
 User Selected Options
 From File Worksheet.xls
 Full Precision ON
 From File: Worksheet.xls

General Statistics for Uncensored Dataset

Variable	NumObs	# Missing	Minimum	Maximum	Mean	Geo-Mean	SD	SEM	MAD/0.67	Skewness	CV
C0	81	0	0.01	0.24	0.065309	0.055899	0.03752	0.004169	0.029652	1.968772	0.574496

Percentiles for Uncensored Dataset

Variable	NumObs	# Missing	10%ile	20%ile	25%ile(Q1)	50%ile(Q2)	75%ile(Q3)	80%ile	90%ile	95%ile	99%ile
C0	81	0	0.03	0.04	0.05	0.06	0.08	0.08	0.1	0.11	0.2

Goodness-of-Fit Test Statistics for Uncensored Full Data Sets without Non-Detects

User Selected Options
 Date/Time of Computation ProUCL 5.2 4/10/2023 4:08:02 PM
 From File Worksheet.xls
 Full Precision ON
 Confidence Coefficient 0.95

C0

Raw Statistics
 Number of Valid Observations 81
 Number of Distinct Observations 15
 Minimum 0.01
 Maximum 0.24
 Mean of Raw Data 0.0653086
 Standard Deviation of Raw Data 0.0375195
 Khat 3.3712077
 Theta hat 0.0193725
 Kstar 3.2545786
 Theta star 0.0200667
 Mean of Log Transformed Data -2.884216
 Standard Deviation of Log Transformed Data 0.5933793

Normal GOF Test Results

Correlation Coefficient R 0.912417
 Approximate Shapiro Wilk Test Statistic 0.8492399
 Approximate Shapiro Wilk P Value 2.02E-11
 Lilliefors Test Statistic 0.1625045
 Lilliefors Critical (0.0500000) Value 0.0985442

2021	1	BM	BK	217	250	0.06
2021	1	BM	BK	250	250	0.07
2021	1	BM	BK	255	250	0.06
2021	1	BM	BK	212	250	0.05
2021	1	BM	BK	162	250	0.05
2021	1	BM	BK	216	250	0.01
2021	1	BM	BK	183	250	0.05
2021	1	BM	BK	190	250	0.04

Data not Normal at (0.0500000) Significance Level

Gamma GOF Test Results

Correlation Coefficient R	0.9630977
A-D Test Statistic	1.3877676
A-D Critical (0.0500000) Value	0.7578991
K-S Test Statistic	0.1415991
K-S Critical(0.0500000) Value	0.09983

Data not Gamma Distributed at (0.0500000) Significance Level

Lognormal GOF Test Results

Correlation Coefficient R	0.963885
Approximate Shapiro Wilk Test Statistic	0.930734
Approximate Shapiro Wilk P Value	2.44E-04
Lilliefors Test Statistic	0.178551
Lilliefors Critical (0.0500000) Value	0.098544

Data not Lognormal at (0.0500000) Significance Level

Non-parametric GOF Test Results

Data do not follow a discernible distribution at (0.0500000) Level of Significance

UCL Statistics for Uncensored Full Data Sets

User Selected Options

Date/Time of Computation	ProUCL 5.2 4/10/2023 4:09:23 PM
From File	WorkSheet.xls
Full Precision	ON
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

CO

General Statistics

Total Number of Observations	81	Number of Distinct Observations	15
		Number of Missing Observations	0
Minimum	0.01	Mean	0.065309
Maximum	0.24	Median	0.06
SD	0.03752	Std. Error of Mean	0.004169
Coefficient of Variation	0.574496	Skewness	1.968772

Normal GOF Test

Shapiro Wilk Test Statistic	0.84924	Shapiro Wilk GOF Test	
1% Shapiro Wilk P Value	2.02E-11	Data Not Normal at 1% Significance Level	
Lilliefors Test Statistic	0.162505	Lilliefors GOF Test	
1% Lilliefors Critical Value	0.113959	Data Not Normal at 1% Significance Level	

Assuming Normal Distribution

95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	0.072246	95% Adjusted-CLT UCL (Chen-1995)	0.07314
		95% Modified-t UCL (Johnson-1978)	0.072398

Gamma GOF Test

A-D Test Statistic	1.387768	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0.757899	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.141599	Kolmogorov-Smirnov Gamma GOF Test	
5% K-S Critical Value	0.09983	Data Not Gamma Distributed at 5% Significance Level	

Gamma Statistics

k hat (MLE)	3.371208	k star (bias corrected MLE)	3.254579
Theta hat (MLE)	0.019373	Theta star (bias corrected MLE)	0.020067
nu hat (MLE)	546.1357	nu star (bias corrected)	527.2417
MLE Mean (bias corrected)	0.065309	MLE Sd (bias corrected)	0.036201
Adjusted Level of Significance	0.047037	Approximate Chi Square Value (0.05)	474.9897
		Adjusted Chi Square Value	474.0989

Assuming Gamma Distribution

95% Approximate Gamma UCL	0.072493	95% Adjusted Gamma UCL	0.072629
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Lognormal GOF Test

Shapiro Wilk Test Statistic	0.930734	Shapiro Wilk Lognormal GOF Test	
10% Shapiro Wilk P Value	2.44E-04	Data Not Lognormal at 10% Significance Level	

Lilliefors Test Statistic	0.178551	Lilliefors Lognormal GOF Test	
10% Lilliefors Critical Value	0.090176	Data Not Lognormal at 10% Significance Level	
Data Not Lognormal at 10% Significance Level			

Lognormal Statistics			
Minimum of Logged Data	-4.60517	Mean of logged Data	-2.88422
Maximum of Logged Data	-1.42712	SD of logged Data	0.593379

Assuming Lognormal Distribution			
95% H-UCL	0.075621	90% Chebyshev (MVUE) UCL	0.080628
95% Chebyshev (MVUE) UCL	0.087032	97.5% Chebyshev (MVUE) UCL	0.09592
99% Chebyshev (MVUE) UCL	0.11338		

Nonparametric Distribution Free UCL Statistics
 Data do not follow a Discernible Distribution

Nonparametric Distribution Free UCLs			
95% CLT UCL	0.072166	95% BCA Bootstrap UCL	0.072716
95% Standard Bootstrap UCL	0.072064	95% Bootstrap-t UCL	0.073348
95% Hall's Bootstrap UCL	0.073858	95% Percentile Bootstrap UCL	0.072469
90% Chebyshev(Mean, Sd) UCL	0.077815	95% Chebyshev(Mean, Sd) UCL	0.08348
97.5% Chebyshev(Mean, Sd) UCL	0.091343	99% Chebyshev(Mean, Sd) UCL	0.106788

Selected UCL is arithmetic mean of non-parametric UCL estimates, where alpha=0.05:
 0.0743

Suggested UCL to Use			
95% Student's-t UCL	0.072246	(rejected as data distribution is non-parametric and student's-t ucl assumes normality)	

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. Recommendations are based upon data size, data distribution, and skewness using results from simulation studies. However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

year	section	area	species	length	st_length	thg
2021	0	GB	RS	184	150	0.07
2021	0	GB	RS	140	150	0.07
2021	0	GB	RS	117	150	0.04
2021	0	GB	RS	186	150	0.1
2021	0	GB	RS	137	150	0.06
2021	0	LM	RS	143	150	0.06
2021	0	LM	RS	137	150	0.05
2021	0	LM	RS	165	150	0.11
2021	0	LM	RS	142	150	0.06
2021	0	LM	RS	143	150	0.08
2021	0	LM	RS	152	150	0.08
2021	0	LM	RS	121	150	0.03
2021	0	LM	RS	132	150	0.04
2021	0	LM	RS	146	150	0.06
2021	0	LM	RS	142	150	0.05
2021	0	LM	RS	137	150	0.06
2021	0	LM	RS	127	150	0.05
2021	0	LM	RS	139	150	0.05
2021	0	LM	RS	134	150	0.08
2021	0	LM	RS	123	150	0.04
2021	0	LM	RS	130	150	0.06
2021	0	LM	RS	113	150	0.03
2021	0	LM	RS	128	150	0.04
2021	0	LM	RS	110	150	0.03
2021	0	LM	RS	108	150	0.04
2021	0	LM	RS	112	150	0.05
2021	0	LM	RS	110	150	0.04
2021	0	LM	RS	110	150	0.05
2021	0	LM	RS	173	150	0.08
2021	0	LM	RS	116	150	0.03
2021	0	LM	RS	113	150	0.07
2021	0	LM	RS	122	150	0.1
2021	0	LM	RS	117	150	0.03
2021	0	LM	RS	105	150	0.04
2021	0	LM	RS	109	150	0.03
2021	0	OM	RS	192	150	0.07
2021	0	OM	RS	142	150	0.04
2021	0	OM	RS	148	150	0.05
2021	0	OM	RS	134	150	0.04
2021	0	OM	RS	122	150	0.03
2021	0	OM	RS	151	150	0.04
2021	0	OM	RS	153	150	0.04
2021	0	OM	RS	114	150	0.03
2021	0	OM	RS	116	150	0.03
2021	0	OM	RS	116	150	0.02
2021	0	OM	RS	120	150	0.04
2021	0	OM	RS	125	150	0.07
2021	0	OM	RS	130	150	0.04
2021	0	OM	RS	127	150	0.04
2021	0	OM	RS	113	150	0.02
2021	0	OM	RS	110	150	0.06
2021	0	OM	RS	110	150	0.04
2021	0	OM	RS	150	150	0.03
2021	0	OM	RS	161	150	0.06
2021	0	OM	RS	155	150	0.04
2021	0	OM	RS	153	150	0.06
2021	0	OM	RS	145	150	0.05
2021	0	OM	RS	141	150	0.06
2021	0	OM	RS	121	150	0.04
2021	0	OM	RS	122	150	0.05
2021	0	OM	RS	122	150	0.02
2021	0	OM	RS	113	150	0.02
2021	0	OM	RS	117	150	0.04
2021	0	OM	RS	112	150	0.03
2021	1	BM	RS	123	150	0.01
2021	1	BM	RS	84	150	0.03
2021	1	BM	RS	154	150	0.12
2021	1	BM	RS	147	150	0.06
2021	1	BM	RS	138	150	0.07
2021	1	BM	RS	131	150	0.01
2021	1	BM	RS	129	150	0.01
2021	1	BM	RS	102	150	0.01
2021	1	BM	RS	89	150	0.03

2021 RAINBOW SMELT THg DATA

Fish species codes	Area codes	Section codes - refers to the initial river section codes used in early baseline reports
AM - atlantic salmon	AM - Above Muskrat Falls in area of reservoir	0 - Goose Bay and Lake Melville (downstream of the river)
BK - brook trout	BM - Below Muskrat Falls	
LF - lake whitefish	but upriver of Goose Bay	1 - River between Goose Bay and Muskrat Falls
LS - longnose sucker	GB - Goose Bay	2 - River between Muskrat Falls and Grizzle Rapids (the reservoir area)
NP - northern pike	LM - west Lake Melville	3 - River between Grizzle Rapids and outflow of Winokapau Lake
RS - rainbow smelt	OM - outer Lake Melville	4 - Winokapau Lake
TC - tomcod	SL - above reservoir	5 - River between Winokapau Lake and Churchill Falls tailrace
WS - white sucker		

Correlation Coefficient (length vs THg)
0.585053171

THg Summary Statistics (Excel)

N	73
min	0.01
max	0.12
arithmean	0.048082192
median	0.04

ProUCL 5.2 Statistics

Date/Time of Computation	General Statistics on Uncensored Full Data
User Selected Options	ProUCL 5.2 4/10/2023 5:58:34 PM
From File	WorkSheet.xls
Full Precision	ON
From File: WorkSheet.xls	

General Statistics for Uncensored Dataset

Variable	NumObs	# Missing	Minimum	Maximum	Mean	Geo-Mean	SD	SEM	MAD/0.67:	Skewness	CV
CO	73	0	0.01	0.12	0.048082	0.042534	0.02277	0.002665	0.014826	0.853082	0.473573

Percentiles for Uncensored Dataset

Variable	NumObs	# Missing	10%ile	20%ile	25%ile(Q1)	50%ile(Q2)	75%ile(Q3)	80%ile	90%ile	95%ile	99%ile
CO	73	0	0.022	0.03	0.03	0.04	0.06	0.06	0.078	0.088	0.1128

Goodness-of-Fit Test Statistics for Uncensored Full Data Sets without Non-Detects

User Selected Options	
Date/Time of Computation	ProUCL 5.2 4/10/2023 6:00:03 PM
From File	WorkSheet.xls
Full Precision	ON
Confidence Coefficient	0.95

CO

Raw Statistics

Number of Valid Observations	73
Number of Distinct Observations	11
Minimum	0.01
Maximum	0.12
Mean of Raw Data	0.048082
Standard Deviation of Raw Data	0.02277
Khat	4.2375
Theta hat	0.011347
Kstar	4.072489
Theta star	0.011807
Mean of Log Transformed Data	-3.15745
Standard Deviation of Log Transformed Data	0.531983

Normal GOF Test Results

Correlation Coefficient R	0.967335
Approximate Shapiro Wilk Test Statistic	0.930687
Approximate Shapiro Wilk P Value	6.02E-04
Lilliefors Test Statistic	0.17293

Lilliefors Critical (0.0500000) Value	0.103694
Data not Normal at (0.0500000) Significance Level	
Gamma GOF Test Results	
Correlation Coefficient R	0.987398
A-D Test Statistic	1.08158
A-D Critical (0.0500000) Value	0.755474
K-S Test Statistic	0.132092
K-S Critical(0.0500000) Value	0.104819
Data not Gamma Distributed at (0.0500000) Significance Level	
Lognormal GOF Test Results	
Correlation Coefficient R	0.962155
Approximate Shapiro Wilk Test Statistic	0.918664
Approximate Shapiro Wilk P Value	7.71E-05
Lilliefors Test Statistic	0.166369
Lilliefors Critical (0.0500000) Value	0.103694
Data not Lognormal at (0.0500000) Significance Level	
Non-parametric GOF Test Results	
Data do not follow a discernible distribution at (0.0500000) Level of Significance	

UCL Statistics for Uncensored Full Data Sets

User Selected Options

Date/Time of Computation	ProUCL 5.2 4/10/2023 6:01:39 PM
From File	WorkSheet.xls
Full Precision	ON
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

CO

General Statistics

Total Number of Observations	73	Number of Distinct Observations	11
		Number of Missing Observations	0
Minimum	0.01	Mean	0.048082
Maximum	0.12	Median	0.04
SD	0.02277	Std. Error of Mean	0.002665
Coefficient of Variation	0.473573	Skewness	0.853082

Normal GOF Test

Shapiro Wilk Test Statistic	0.930687	Shapiro Wilk GOF Test
1% Shapiro Wilk P Value	6.02E-04	Data Not Normal at 1% Significance Level
Lilliefors Test Statistic	0.17293	Lilliefors GOF Test
1% Lilliefors Critical Value	0.119915	Data Not Normal at 1% Significance Level
Data Not Normal at 1% Significance Level		

Assuming Normal Distribution

95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	0.052523	95% Adjusted-CLT UCL (Chen-1995)	0.05275
		95% Modified-t UCL (Johnson-1978)	0.052567

Gamma GOF Test

A-D Test Statistic	1.08158	Anderson-Darling Gamma GOF Test
5% A-D Critical Value	0.755474	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.132092	Kolmogorov-Smirnov Gamma GOF Test
5% K-S Critical Value	0.104819	Data Not Gamma Distributed at 5% Significance Level
Data Not Gamma Distributed at 5% Significance Level		

Gamma Statistics

k hat (MLE)	4.2375	k star (bias corrected MLE)	4.072489
Theta hat (MLE)	0.011347	Theta star (bias corrected MLE)	0.011807
nu hat (MLE)	618.675	nu star (bias corrected)	594.5833
MLE Mean (bias corrected)	0.048082	MLE Sd (bias corrected)	0.023826
		Approximate Chi Square Value (0.05)	539.0213
Adjusted Level of Significance	0.046712	Adjusted Chi Square Value	537.9643

Assuming Gamma Distribution

95% Approximate Gamma UCL	0.053039	95% Adjusted Gamma UCL	0.053143
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Lognormal GOF Test

Shapiro Wilk Test Statistic	0.918664	Shapiro Wilk Lognormal GOF Test
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10% Shapiro Wilk P Value 7.71E-05 Data Not Lognormal at 10% Significance Level
 Lilliefors Test Statistic 0.166369 Lilliefors Lognormal GOF Test
 10% Lilliefors Critical Value 0.094889 Data Not Lognormal at 10% Significance Level
 Data Not Lognormal at 10% Significance Level

Lognormal Statistics
 Minimum of Logged Data -4.60517 Mean of logged Data -3.15745
 Maximum of Logged Data -2.12026 SD of logged Data 0.531983

Assuming Lognormal Distribution
 95% H-UCL 0.055104 90% Chebyshev (MVUE) UCL 0.058574
 95% Chebyshev (MVUE) UCL 0.062959 97.5% Chebyshev (MVUE) UCL 0.069047
 99% Chebyshev (MVUE) UCL 0.081004

Nonparametric Distribution Free UCL Statistics
 Data do not follow a Discernible Distribution

Nonparametric Distribution Free UCLs
 95% CLT UCL 0.052466 95% BCA Bootstrap UCL 0.052603 Selected UCL is arithmetic mean of non-parametric UCL estimates where alpha=0.05:
 95% Standard Bootstrap UCL 0.052478 95% Bootstrap-t UCL 0.053005 0.053686
 95% Hall's Bootstrap UCL 0.05295 95% Percentile Bootstrap UCL 0.052603
 90% Chebyshev(Mean, Sd) UCL 0.056077 95% Chebyshev(Mean, Sd) UCL 0.059699
 97.5% Chebyshev(Mean, Sd) UCL 0.064726 99% Chebyshev(Mean, Sd) UCL 0.074599

Suggested UCL to Use
 95% Student's-t UCL 0.052523 (rejected as data distribution is non-parametric and use of student's-t ucl assumes normality)

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. Recommendations are based upon data size, data distribution, and skewness using results from simulation studies. However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Sample Year	species	sample area	Weight (kg)	Length (cm)	Mercury (muscle)	Mercury (liver)	Age	Age Estimate	life_stage
2021	Ringed Seal	LM	22.7	72	0.01	0.19		0	Pup
2021	Ringed Seal	LM	31.8	83	0.01	0.1		0	Pup
2021	Ringed Seal	LM	22.7	70	0.03	0.3		0	Pup
2021	Ringed Seal	LM	18.1	74	0.02	0.13		0	Pup
2021	Ringed Seal	LM	18.1	70	0.03	0.32		0	Pup
2021	Ringed Seal	LM	18.1	70	0.01	0.13		0	Pup
2021	Ringed Seal	LM	22.7	80	0.03	0.32		0	Pup
2021	Ringed Seal	LM	13.6	50	0.03	0.38		0	Pup
2021	Ringed Seal	LM	27.2	80	0.01	0.11		0	Pup
2021	Ringed Seal	LM	29.5	85	0.01	0.12		0	Pup
2021	Ringed Seal	LM	31.8	80	0.01	0.34		0	Pup
2021	Ringed Seal	LM	24.9	80	0.01	0.27		0	Pup
2021	Ringed Seal	LM	22.7	80	0.02	0.44		0	Pup
2021	Ringed Seal	LM	27.2	82	0.01	0.21		0	Pup
2021	Ringed Seal	LM	24.9	70	0.04	0.32		0	Pup
2021	Ringed Seal	LM	27.2	72	0.02	0.24		0	Pup
2021	Ringed Seal	LM	18.1	60	0.01	0.12		0	Pup
2021	Ringed Seal	LM	22.7	70	0.01	0.07		0	Pup
2021	Ringed Seal	LM	22.7	68	0.02	0.24		0	Pup
2021	Ringed Seal	LM	22.7	68	0.02	0.33		0	Pup
2021	Ringed Seal	LM	13.6	60	0.02	0.49		0	Pup
2021	Ringed Seal	LM	22.7	66	0.08	0.3		0	Pup
2021	Ringed Seal	LM	31.8	82	0.01	0.17		0	Pup
2021	Ringed Seal	LM	31.8	80	0.02	0.28		0	Pup
2021	Ringed Seal	LM	18.1	56	0.02	0.15		0	Pup
2021	Ringed Seal	LM	22.7	66	0.01	0.44		0	Pup
2021	Ringed Seal	LM	22.7	64	0.02	0.24		0	Pup
2021	Ringed Seal	LM	31.8	78	0.02	0.57		0	Pup
2021	Ringed Seal	LM	22.7	64	0.02	0.31		0	Pup
2021	Ringed Seal	LM	22.7	68	0.03	0.26		0	Pup

2021 RINGED SEAL MUSCLE THg DATA

Summary Stats - Muscle THg

N	30
min	0.01
max	0.08
arithmean	0.020333
median	0.02
#nd	4
freq nd (%)	13.33%
geomean	0.017381

General Statistics on Uncensored Full Data

Date/Time of Computation	ProUCL 5.16/1/2022 9:25:10 AM
User Selected Options	
From File	WorkSheet.xls
Full Precision	ON

From File: WorkSheet.xls

General Statistics for Uncensored Dataset

Variable	NumObs	# Missing	Minimum	Maximum	Mean	Geo-Mean	SD	SEM	MAD/0.67	Skewness	CV
CO	30	0	0.01	0.08	0.020333	0.0173808	0.014016	0.002559	0.014826	2.835535	0.689291

Percentiles for Uncensored Dataset

Variable	NumObs	# Missing	10%ile	20%ile	25%ile(Q1)	50%ile(Q2)	75%ile(Q3)	80%ile	90%ile	95%ile	99%ile
CO	30	0	0.01	0.01	0.01	0.02	0.02	0.03	0.03	0.0355	0.0684

Goodness-of-Fit Test Statistics for Uncensored Full Data Sets without Non-Detects

User Selected Options	
Date/Time of Computation	ProUCL 5.16/1/2022 9:26:24 AM
From File	WorkSheet.xls
Full Precision	ON
Confidence Coefficient	0.95

CO

Raw Statistics

Number of Valid Observations	30
Number of Distinct Observations	5
Minimum	0.01
Maximum	0.08
Mean of Raw Data	0.0203333
Standard Deviation of Raw Data	0.0140156
Khat	3.3442808
Theta hat	0.00608
Kstar	3.032075
Theta star	0.0067061
Mean of Log Transformed Data	-4.05239
Standard Deviation of Log Transformed Data	0.5381522

Normal GOF Test Results

Correlation Coefficient R	0.8081749
Shapiro Wilk Test Statistic	0.676109
Shapiro Wilk Critical (0.0500000) Value	0.927
Approximate Shapiro Wilk P Value	9.23E-08
Lilliefors Test Statistic	0.2761538
Lilliefors Critical (0.0500000) Value	0.159
Data not Normal at (0.0500000) Significance Level	

Gamma GOF Test Results

Correlation Coefficient R	0.8991093
A-D Test Statistic	1.9803852
A-D Critical (0.0500000) Value	0.7514413
K-S Test Statistic	0.2336292
K-S Critical(0.0500000) Value	0.1609882
Data not Gamma Distributed at (0.0500000) Significance Level	

UCL Statistics for Uncensored Full Data Sets

User Selected Options	
Date/Time of Computation	ProUCL 5.16/1/2022 9:32:43 AM
From File	WorkSheet.xls
Full Precision	ON
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

CO

General Statistics

Total Number of Observations	30	Number of Distinct Observations	5
Minimum	0.01	Mean	0.020333
Maximum	0.08	Median	0.02
SD	0.014016	Std. Error of Mean	0.002559
Coefficient of Variation	0.689291	Skewness	2.835535

Normal GOF Test

Shapiro Wilk Test Statistic	0.676109	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.927	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.276154	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.159	Data Not Normal at 5% Significance Level	

Assuming Normal Distribution

95% Normal UCL	95% UCLs (Adjusted for Skewness)		
95% Student's-t UCL	0.024681	95% Adjusted-CLT UCL (Chen-1995)	0.025958
		95% Modified-t UCL (Johnson-1978)	0.024902

Gamma GOF Test

A-D Test Statistic	1.980385	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0.751441	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.233629	Kolmogorov-Smirnov Gamma GOF Test	
5% K-S Critical Value	0.160988	Data Not Gamma Distributed at 5% Significance Level	

Gamma Statistics

k hat (MLE)	3.344281	k star (bias corrected MLE)	3.032075
Theta hat (MLE)	0.00608	Theta star (bias corrected MLE)	0.006706

Lognormal GOF Test Results

Correlation Coefficient R	0.9137404
Shapiro Wilk Test Statistic	0.8320407
Shapiro Wilk Critical (0.0500000) Value	0.927
Approximate Shapiro Wilk P Value	1.66E-04
Lilliefors Test Statistic	0.2478327
Lilliefors Critical (0.0500000) Value	0.159
Data not Lognormal at (0.0500000) Significance Level	

Non-parametric GOF Test Results

Data do not follow a discernible distribution at (0.0500000) Level of Significance

nu hat (MLE)	200.6569	nu star (bias corrected)	181.9245
MLE Mean (bias corrected)	0.020333	MLE Sd (bias corrected)	0.011677
		Approximate Chi Square Value (0.05)	151.7267
Adjusted Level of Significance	0.041	Adjusted Chi Square Value	150.1388

Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	0.02438	95% Adjusted Gamma UCL (use when n<50)	0.024638

Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.832041	Shapiro Wilk Lognormal GOF Test	
5% Shapiro Wilk Critical Value	0.927	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.247833	Lilliefors Lognormal GOF Test	
5% Lilliefors Critical Value	0.159	Data Not Lognormal at 5% Significance Level	
Data Not Lognormal at 5% Significance Level			

Lognormal Statistics			
Minimum of Logged Data	-4.60517	Mean of logged Data	-4.05239
Maximum of Logged Data	-2.52573	SD of logged Data	0.538152

Assuming Lognormal Distribution			
95% H-UCL	0.024493	90% Chebyshev (MVUE) UCL	0.026166
95% Chebyshev (MVUE) UCL	0.028969	97.5% Chebyshev (MVUE) UCL	0.032858
99% Chebyshev (MVUE) UCL	0.040498		

Nonparametric Distribution Free UCL Statistics
Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs			
95% CLT UCL	0.024542	95% Jackknife UCL	0.024681
95% Standard Bootstrap UCL	0.024366	95% Bootstrap-t UCL	0.027112
95% Hall's Bootstrap UCL	0.043735	95% Percentile Bootstrap UCL	0.025
95% BCA Bootstrap UCL	0.025333		
90% Chebyshev(Mean, Sd) UCL	0.02801	95% Chebyshev(Mean, Sd) UCL	0.031487
97.5% Chebyshev(Mean, Sd) UCL	0.036314	99% Chebyshev(Mean, Sd) UCL	0.045794

Suggested UCL to Use
95% Chebyshev (Mean, Sd) UCL 0.031487

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. Recommendations are based upon data size, data distribution, and skewness. These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006). However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Sample Year	species	sample area	Weight (kg)	Length (cm)	Mercury (muscle)	Mercury (liver)	Age	Age Estimate	life_stage
2021	Ringed Seal	LM	22.7	72	0.01	0.19			0 Pup
2021	Ringed Seal	LM	31.8	83	0.01	0.1			0 Pup
2021	Ringed Seal	LM	22.7	70	0.03	0.3			0 Pup
2021	Ringed Seal	LM	18.1	74	0.02	0.13			0 Pup
2021	Ringed Seal	LM	18.1	70	0.03	0.32			0 Pup
2021	Ringed Seal	LM	18.1	70	0.01	0.13			0 Pup
2021	Ringed Seal	LM	22.7	80	0.03	0.32			0 Pup
2021	Ringed Seal	LM	13.6	50	0.03	0.38			0 Pup
2021	Ringed Seal	LM	27.2	80	0.01	0.11			0 Pup
2021	Ringed Seal	LM	29.5	85	0.01	0.12			0 Pup
2021	Ringed Seal	LM	31.8	80	0.01	0.34			0 Pup
2021	Ringed Seal	LM	24.9	80	0.01	0.27			0 Pup
2021	Ringed Seal	LM	22.7	80	0.02	0.44			0 Pup
2021	Ringed Seal	LM	27.2	82	0.01	0.21			0 Pup
2021	Ringed Seal	LM	24.9	70	0.04	0.32			0 Pup
2021	Ringed Seal	LM	27.2	72	0.02	0.24			0 Pup
2021	Ringed Seal	LM	18.1	60	0.01	0.12			0 Pup
2021	Ringed Seal	LM	22.7	70	0.01	0.07			0 Pup
2021	Ringed Seal	LM	22.7	68	0.02	0.24			0 Pup
2021	Ringed Seal	LM	22.7	68	0.02	0.33			0 Pup
2021	Ringed Seal	LM	13.6	60	0.02	0.49			0 Pup
2021	Ringed Seal	LM	22.7	66	0.08	0.3			0 Pup
2021	Ringed Seal	LM	31.8	82	0.01	0.17			0 Pup
2021	Ringed Seal	LM	31.8	80	0.02	0.28			0 Pup
2021	Ringed Seal	LM	18.1	56	0.02	0.15			0 Pup
2021	Ringed Seal	LM	22.7	66	0.01	0.44			0 Pup
2021	Ringed Seal	LM	22.7	64	0.02	0.24			0 Pup
2021	Ringed Seal	LM	31.8	78	0.02	0.57			0 Pup
2021	Ringed Seal	LM	22.7	64	0.02	0.31			0 Pup
2021	Ringed Seal	LM	22.7	68	0.03	0.26			0 Pup

2021 RINGED SEAL LIVER THg DATA

Summary Stats - Liver THg

N	30
min	0.07
max	0.57
arithmean	0.263
median	0.265
#nd	0
freq nd (%)	0
geomean	0.233313

General Statistics on Uncensored Full Data

Date/Time of Computation	ProUCL 5.16/1/2022 9:52:20 AM
User Selected Options	
From File	WorkSheet.xls
Full Precision	ON

From File: WorkSheet.xls

General Statistics for Uncensored Dataset

Variable	NumObs	# Missing	Minimum	Maximum	Mean	Geo-Mean	SD	SEM	MAD/0.67	Skewness	CV
CO	30	0	0.07	0.57	0.263	0.2333134	0.123488	0.022546	0.111194	0.517371	0.469537

Percentiles for Uncensored Dataset

Variable	NumObs	# Missing	10%ile	20%ile	25%ile(Q1)	50%ile(Q2)	75%ile(Q3)	80%ile	90%ile	95%ile	99%ile
CO	30	0	0.119	0.13	0.155	0.265	0.32	0.332	0.44	0.4675	0.5468

Goodness-of-Fit Test Statistics for Uncensored Full Data Sets without Non-Detects

User Selected Options	
Date/Time of Computation	ProUCL 5.16/1/2022 9:53:40 AM
From File	WorkSheet.xls
Full Precision	ON
Confidence Coefficient	0.95

UCL Statistics for Uncensored Full Data Sets

User Selected Options	
Date/Time of Computation	ProUCL 5.16/1/2022 9:55:31 AM
From File	WorkSheet.xls
Full Precision	ON
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

CO

Raw Statistics

Number of Valid Observations	30
Number of Distinct Observations	22
Minimum	0.07
Maximum	0.57
Mean of Raw Data	0.263
Standard Deviation of Raw Data	0.1234881
Khat	4.3343062
Theta hat	0.0606787
Kstar	3.9230978
Theta star	0.0670389
Mean of Log Transformed Data	-1.455373
Standard Deviation of Log Transformed Data	0.5212069

Normal GOF Test Results

Correlation Coefficient R	0.9806081
Shapiro Wilk Test Statistic	0.9565732
Shapiro Wilk Critical (0.0500000) Value	0.927
Approximate Shapiro Wilk P Value	0.2912315
Lilliefors Test Statistic	0.0997976
Lilliefors Critical (0.0500000) Value	0.159
Data appear Normal at (0.0500000) Significance Level	

Gamma GOF Test Results

Correlation Coefficient R	0.9879207
A-D Test Statistic	0.422455
A-D Critical (0.0500000) Value	0.7485071
K-S Test Statistic	0.1231217
K-S Critical(0.0500000) Value	0.1605563
Data appear Gamma Distributed at (0.0500000) Significance Level	

Lognormal GOF Test Results

CO

General Statistics

Total Number of Observations	30	Number of Distinct Observations	22
		Number of Missing Observations	0
Minimum	0.07	Mean	0.263
Maximum	0.57	Median	0.265
SD	0.123488	Std. Error of Mean	0.022546
Coefficient of Variation	0.469537	Skewness	0.517371

Normal GOF Test

Shapiro Wilk Test Statistic	0.956573	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.927	Data appear Normal at 5% Significance Level	
Lilliefors Test Statistic	0.099798	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.159	Data appear Normal at 5% Significance Level	

Assuming Normal Distribution

95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	0.301308	95% Adjusted-CLT UCL (Chen-1995)	0.30236
		95% Modified-t UCL (Johnson-1978)	0.301663

Gamma GOF Test

A-D Test Statistic	0.422455	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0.748507	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.123122	Kolmogorov-Smirnov Gamma GOF Test	
5% K-S Critical Value	0.160556	Detected data appear Gamma Distributed at 5% Significance Level	

Gamma Statistics

k hat (MLE)	4.334306	k star (bias corrected MLE)	3.923098
Theta hat (MLE)	0.060679	Theta star (bias corrected MLE)	0.067039
nu hat (MLE)	260.0584	nu star (bias corrected)	235.3859

Correlation Coefficient R 0.9797696
 Shapiro Wilk Test Statistic 0.9544895
 Shapiro Wilk Critical (0.0500000) Value 0.927
 Approximate Shapiro Wilk P Value 0.2586807
 Lilliefors Test Statistic 0.1549508
 Lilliefors Critical (0.0500000) Value 0.159
 Data appear Lognormal at (0.0500000) Significance Level

MLE Mean (bias corrected)	0.263	MLE Sd (bias corrected)	0.132783
		Approximate Chi Square Value (0.05)	200.8697
Adjusted Level of Significance	0.041	Adjusted Chi Square Value	199.0346
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50)	0.308192	95% Adjusted Gamma UCL (use when n<50)	0.311034
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.95449	Shapiro Wilk Lognormal GOF Test	
5% Shapiro Wilk Critical Value	0.927	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.154951	Lilliefors Lognormal GOF Test	
5% Lilliefors Critical Value	0.159	Data appear Lognormal at 5% Significance Level	
Data appear Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	-2.65926	Mean of logged Data	-1.45537
Maximum of Logged Data	-0.56212	SD of logged Data	0.521207
Assuming Lognormal Distribution			
95% H-UCL	0.323363	90% Chebyshev (MVUE) UCL	0.345424
95% Chebyshev (MVUE) UCL	0.381444	97.5% Chebyshev (MVUE) UCL	0.431438
99% Chebyshev (MVUE) UCL	0.529643		
Nonparametric Distribution Free UCL Statistics			
Data appear to follow a Discernible Distribution at 5% Significance Level			
Nonparametric Distribution Free UCLs			
95% CLT UCL	0.300084	95% Jackknife UCL	0.301308
95% Standard Bootstrap UCL	0.300155	95% Bootstrap-t UCL	0.303089
95% Hall's Bootstrap UCL	0.302651	95% Percentile Bootstrap UCL	0.299
95% BCA Bootstrap UCL	0.301333		
90% Chebyshev(Mean, Sd) UCL	0.330637	95% Chebyshev(Mean, Sd) UCL	0.361275
97.5% Chebyshev(Mean, Sd) UCL	0.403798	99% Chebyshev(Mean, Sd) UCL	0.487327
Suggested UCL to Use			
95% Student's-t UCL	0.301308		

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. Recommendations are based upon data size, data distribution, and skewness. These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006). However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.