Polychlorinated Dibenzo-p-Dioxin (CDD) and Polychlorinated Dibenzofuran (CDF) Concentrations in Fillet Tissue of Five Species of Lake Superior Fish

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ABSTRACT

Lake Superior has a large, diverse fishery that has subsistence, cultural, and economic importance to the member tribes of the Great Lakes Indian Fish and Wildlife Commission (GLIFWC)[1]. Unfortunately, anthropogenically derived persistent, bioaccumulative, and toxic (PBT) chemicals are retained in the Great Lakes, including Lake Superior, due to the properties of the contaminants and the lakes' physical and thermal properties. PBT chemicals enter the food chain and can reach concentrations in fish tissues that are potentially unsafe when consumed by people or wildlife. Dioxin and furan compounds (CDD/CDFs) are PBT, have been identified as chemicals of concern by many governments and work groups including the Lake Superior Binational Program, and have been found in many Great Lakes fish. Despite these concerns, few analyses have occurred in United States waters of Lake Superior, especially in areas where tribal harvest takes place. This study analyzed various fillet tissues from five species of commonly harvested Lake Superior fish for CDD/CDFs. Toxic equivalency (TEQ) concentrations (pg TEQ/g fish) were calculated using four different methods (estimates using EPA TEFs, WHO TEFs, and inserting zero or ½ detection limit for non-detected congeners). Dioxin-like polychlorinated biphenyls (PCBs) were not measured and thus were not included in TEQ calculations. Moisture adjusted TEQ concentration ranges measured in muscle tissue (i.e. trimmed, skin-off fillet) for the following fish species were: lake sturgeon (*Acipenser fulvescens*) 0.12 – 0.36, lake herring (*Coregonus artedii*) 0.12 – 0.40, lake whitefish (*Coregonus clupeaformis*) 0.42 – 0.58, lake trout-64 cm (*Salvelinus namaycush namaycush*) 1.7 – 3.6, lake trout-70 cm 1.5 – 2.0, siscowet trout (*Salvelinus namaycush siscowet*) 6.2 – 7.0. Congener homolog patterns were dominated by tetra- and penta-chlorinated furans in all fish tissues. Comparing our results to government issued comparison values assuming such governments would make similar conclusions would be presumptive on the part of the authors. However, these comparison values provide a reference point for discussion. For instance, the largest commonly harvested sizes of lake herring, lake whitefish, and lake trout from Lake Superior, regardless of method of TEQ calculation or how the fillet was trimmed were below current fish consumption advisory levels used by jurisdictions around Lake Superior.

[1] GLIFWC member tribes are: in Wisconsin -- the Bad River Band of the Lake Superior Tribe of Chippewa Indians, Lac du Flambeau Band of Lake Superior Chippewa Indians, Lac Courte Oreilles Band of Lake Superior Chippewa Indians, St. Croix Chippewa Indians of Wisconsin, Sokaogon Chippewa Community of the Mole Lake Band, and Red Cliff Band of Lake Superior Chippewa Indians; in Minnesota -- Fond du Lac Chippewa Tribe, and Mille Lacs Band of Chippewa Indians; and in Michigan -- Bay Mills Indian Community, Keweenaw Bay Indian Community, and Lac Vieux Desert Band of Lake Superior Chippewa Indians.

INTRODUCTION

Lake Superior fish represent an important source of food and economy for many individuals living near the lake. The Lake Superior Chippewa have a long cultural history of harvesting Lake Superior fish for subsistence and economic purposes.
The 2003 estimates of Lake Superior regulated commercial harvest by Wisconsin and Michigan Chippewa tribes were 1,400,000 lbs of lake whitefish (*Coregonus clupeaformis)*, 264,000 lbs of lake trout (*Salvelinus namaycush namaycush)*, 72,000 lbs of lake herring (*Coregonus artedii*), and 11,000 lbs of siscowet trout (*Salvelinus namaycush Siscowet)* (Mattes et al. 2004). As a subsistence food, Lake Superior fish represent a good source of the omega-3 polyunsaturated fatty acids eicosapentaenoic acid and docosahexaenoic acid, which have been shown to reduce the risk of heart disease (Kris-Etherton et al. 2002). Unfortunately, Great Lakes fish have also been found to accumulate persistent, bioaccumulative, and toxic (PBT) chemicals. In order for tribal resource managers to evaluate the unique exposure and potential risk to the tribal population, environmental analysis of tribally important fish species for PBT contaminants is necessary.

Characteristics of the Great Lakes, such as large surface area, water depth, long water retention times, slow sedimentation rates and cold water temperatures, have been identified as attributes that cause the Great Lakes to retain PBT chemicals for long periods of time (Swackhamer et al. 1998, Swackhamer et al. 1999, James et al. 2001). Lake Superior, being the largest, coldest, and deepest of the Great Lakes, and having the longest water retention times and slow sedimentation rates, might be expected to have the greatest propensity to retain PBT chemicals. Yet, Lake Superior has typically experienced the least amount of contamination due to limited urbanization and fewer past and present chemical contaminant inputs relative to the other Great Lakes (Lake Superior Binational Program 2000).

Low concentrations of PBT chemicals are typically found in Lake Superior fish compared to other Great Lakes fish (De Vault et al. 1996). However, Lake Superior does have the highest fish tissue concentrations of toxaphene among the Great Lakes (De Vault et al. 1996, Luross et al. 2002). In addition, Lake Superior lake trout have similar polybrominated diphenyl ether (PBDE) concentrations to those found in Lake Huron and Lake Ontario lake trout (Luross et al. 2002). For these reasons, it is important to monitor fish and other Lake Superior biota, for PBT chemicals.

Polychlorinated dibenzo-p-dioxins (CDDs) and polychlorinated dibenzofurans (CDFs) are PBT chemicals. CDD/CDFs have been linked to health problems such as cancer and developmental and reproductive disorders (ATSDR 1998). CDDs/CDFs have been measured in air, surface water, soil, sediments, plants, and animal tissues, even in remote areas, which have led to the conclusion that the atmosphere is the main mode of transport and subsequent deposition of these compounds (Hites and Harless 1991, Tysklind et al. 1993). Prior to regulatory emission controls, the greatest sources of CDD/CDFs to the environment were municipal and medical waste incineration (USEPA 2001). Currently, the greatest remaining source of CDD/CDFs to the atmosphere is from open ("back yard”) burning of garbage (USEPA 2001). Once these chemicals are released into the atmosphere, they may be deposited locally or transported outside the Great Lakes basin. In general, most people are exposed to CDD/CDFs through consumption of food. CDD/CDFs are lipophilic compounds found primarily in the fatty tissue of animals. CDD/CDFs fall on leaves of crops that are eaten by domestic meat and dairy animals and they fall into surface water or become associated with runoff to surface water where they eventually accumulate in fish tissue. CDDs/CDFs have been measured in tissues of Great Lakes biota (Huestis et al. 1997, Weseloh et al. 1994). Typically, top predator fish have greater PBT concentrations than species lower in the food chain. However, in some cases, CDDs/CDFs have not followed this pattern. For instance, lake whitefish from northern Lake Michigan frequently have greater CDD/CDF concentrations than lake trout from northern Lake Michigan, but are considered lower in the food chain relative to lake trout. Concentrations of CDD/CDFs in these lake whitefish frequently exceed the State of Michigan’s sport fish advisory level of 10 pg TEQ/g fish. This has led the State of Michigan to issue a “do not eat” advisory on northern Lake Michigan lake whitefish for pregnant women, women of childbearing age, and children under the age of fifteen.

The quality of fish consumption advice and the associated risk assessments is dependent on having accurate fish contaminant tissue data. This study attempts to provide CDD/CDF data appropriate for evaluating the exposure and risk to tribal members consuming Lake Superior fish.

The objectives of this study were to determine and report CDD/CDF concentrations in fillets from the following tribally harvested Lake Superior fish: lake whitefish, lake herring, lake trout, siscowet trout, and the non-harvested lake sturgeon (*Acipenser fulvescens*) and to provide a scientific foundation for tribal members to make choices that reduce their exposure to CDD/CDFs.

METHODS

Fish Collection and Storage

All fish tissue analyzed was collected and archived (at -20 ^{o}C) as part of a previous GLIFWC Administration for Native Americans (ANA) funded study that focused on other PBT contaminants (i.e. total PCBs, mercury, total DDT, etc.) in Lake Superior fish (GLIFWC 2000). Fish collections occurred between October 1998 and August 1999 with standard commercial gillnets along the central south shore of Lake Superior in tribally harvested fishing waters (lake trout fisheries management units WI-2, MI-2, MI-3, and MI-4, Figure 1). With the exception of lake sturgeon, the length range selected for each species represented the upper length range of fish commonly harvested by tribal commercial fishermen (Figure 2). In commercial fishing parlance, these upper length ranges are referred to as “jumbo” sizes. Lake sturgeon are not commercially harvested from Lake Superior and were an incidental catch caused by storm conditions during a fisheries monitoring program. Two length ranges of lake trout (63.5 - 66.0 cm; 68.5 - 71 cm), which will be referred to as 64 cm and 70 cm lake trout, and one length range of siscowet trout (62.5 - 65 cm), lake whitefish (56 - 61 cm), and lake herring (38 - 43 cm) were targeted for collection. Lake sturgeon ranged between 49 and 99 cm in length and were considered juveniles. Samples were handled in a similar manner to commercially harvested fish and placed on ice within hours of collection. Samples were frozen intact within 24 hours of collection and remained frozen until processing at the analytical laboratory. The date, time, and conditions of collection and storage were documented on chain-of-custody forms.

Processing

Total length, round weight, and aging material (scales, otoliths, or pectoral fins) were collected from each fish prior to freezing. The Great Lakes Indian Fish and Wildlife Commission's Great Lakes Fisheries Section aged the fish to the nearest year, except for the lake sturgeon which were aged by the U.S. Fish and Wildlife Service (Ashland, WI). Each species collected from the same fisheries management unit were assigned to groups based on similar lengths and ages. At the fish processing laboratory (Environmental Health Lab, University of Wisconsin, Superior, Wisconsin) fish samples were thawed and processed into composites according to the pre-assigned groups.

Each group of fish was processed into one or more tissue composites between fall 1999 and spring 2000. Lake herring samples were processed as untrimmed skin-on, fillets (UTSO). Lake sturgeon samples were processed as trimmed, skin-off fillets (i.e., muscle tissue). Each lake trout, siscowet trout, or lake whitefish fillet was segmented into skin, muscle tissue, and dorsal/ventral fatty tissue (fat). The fat was distinguished from muscle tissue by an experienced tribal commercial fisherman (>20 years). The tribal fisherman trained laboratory staff on this technique. Each tissue (skin, muscle, fat) from a fillet was homogenized individually. All lab utensils and glassware were critically cleaned between composites of different tissue types and species. The individual homogenized tissues within each pre-assigned group were formed into a composite based on equal tissue weights. Moisture analyses were conducted on the composites prior to archiving.

CDD/CDF Extraction and Analyses

Samples were shipped frozen to Triangle Laboratories, Inc. (Durham, NC 27713) in 2003 for analysis of CDDs/CDFs. Samples remained frozen until the time of extraction. Moisture and lipid content were determined for all tissues (Triangle Laboratories 1999, Triangle Laboratories 2001). Ten percent of the samples were split into three aliquots and two of the aliquots were used for matrix spikes and matrix spike duplicates (Triangle Laboratories 2002). Internal standards, used to monitor the effect of the laboratory process, were added to all tissue and quality assurance samples. A standard reference material (WMF-01, Wellington Labs, Guelph, Ontario, Canada) was processed and analyzed three times along with the other samples.

Thawed tissues (25 g) were mixed with sodium sulfate (75 g) in a critically cleaned Soxhlet thimble. All tissue and quality assurance samples were spiked with known concentrations of a suite of $^{13}C_{12}$ labeled congeners and one $^{37}Cl_4$ labeled congener, used as internal standards (Table 1, Triangle Laboratories 1999). Tissues were Soxhlet extracted for 16 hours using a 3:1 mixture of methylene chloride to heptane (Triangle Laboratories 1999). Extracts were rotary evaporated to 10 mL, then diluted with methylene chloride to 25 mL (Triangle Laboratories 1999). Matrix spike and matrix spike duplicate extracts were spiked with a second set of non-labeled congeners (surrogate standards) prior to putting the extracts through a silicic acid column and an alumina column (Triangle Laboratories 2003, Triangle Laboratories 2004). Extracts were injected onto a gas chromatograph (HP 5890) equipped with a 60-m capillary column (DB-5), helium carrier gas, and a high resolution mass spectrometer (VG 70 Series, Triangle Laboratories 2002). To confirm peaks detected using the DB-5 column, a second injection was conducted on a 30-m capillary column (DB-225) connected to similar GC-MS equipment (Triangle Laboratories 2002). Samples were analyzed for 7 CDD and 10 CDF congeners according to a modified form of the U.S. Environmental Protection Agency (EPA) CDD/CDF method 8290 (Triangle Laboratories 2002).

Data Summation and Analysis

Data were summarized using PC SAS 6.12 and Microsoft Excel 2000. Four toxic equivalency (TEQ) concentrations were calculated for each tissue sample in order to provide a toxicity-weighted mass of CDDs/CDFs present. TEQs were calculated only for CDD/CDF dioxin-like congeners. Dioxin-like polychlorinated biphenyls (PCBs) were not measured and thus were not included in TEQ calculations. The concentrations varied in the type of toxic equivalency factors (TEFs) used to calculate the TEQ values and how the non-detections were reported. Non-detections were either assigned a value of zero or one-half the limit of detection (LOD), creating two separate data sets. The resulting concentrations in each of those data sets were converted to EPA-TEQs and World Health Organization (WHO)-TEQs using the mammalian EPA-TEFs and the WHO-TEFs for CDDs/CDFs, respectively (Table 1). Thus, for each sample an EPA-TEQ concentration with non-detections set to zero, an EPA-TEQ concentration with non-detections set to one-half the LOD, a WHO-TEQ concentration with non-detections set to zero, and a WHO-TEQ concentration with non-detections set to one-half the LOD were calculated. In some instances the analytical laboratory was able to detect a congener was present, but unable to precisely quantify the concentrations. In those instances, the lab reported an estimated concentration referred to as an estimated maximum potential concentration (EMPC). EMPCs were included in the TEQ calculations.

Adjusting for Moisture Loss

Between 1999 and 2003, many of the tissue samples lost moisture and were no longer similar to the 1999 moisture content measurements. Prior to assessing the CDD/CDF concentrations for human consumption purposes, the tissue concentrations were adjusted to 1999 moisture content levels using the following equation:

$$C_{f2003} * (S_{1999} / S_{2003}) = C_{f1999} \qquad \text{Eq.1}$$

where,

C_{f2003} = fish tissue concentration measured in 2003 (ppt-TEQ),
C_{f1999} = fish tissue concentration estimated for 1999 after moisture adjustment, (i.e., fish tissue that could be consumed) (ppt-TEQ),
S_{2003} = mass of dehydrated solids in 1999, and
S_{1999} = mass of dehydrated solids in 2003.

The mathematical re-hydrations resulted in the sample concentrations decreasing due to the weight of water being added back into the tissue weight.

Correlation to Lipid Content

Lipid is often linearly correlated with PBT concentrations in biota (Mackay 1982). The least squares regression method was used to determine whether this correlation existed between tissues within a species (lake whitefish, lake trout, and siscowet trout) in order to estimate TEQ concentration in tissues that were not directly measured for CDD/CDFs. A linear relationship between lipid content and TEQ muscle tissue concentrations was determined and is discussed in the Results section. For lake trout, the 2003 lipid content versus TEQ relationship was used to estimate the TEQ concentration in the unanalyzed skin samples for the 64 cm lake trout (all management units) and in the skin samples of 70 cm lake trout (all management units except for MI-4, where skin concentrations were directly analyzed). The weights of each tissue type (skin, fat, muscle) were multiplied by the sample specific TEQ concentrations to calculate the weight in nanograms (ng) of each of the 17 congeners. The chemical weights, for each set of three tissues that made up a single fish composite, were summed together, and then divided by the average UTSO weight to estimate a TEQ concentration for the UTSO fillet. The UTSO fillet concentrations were compared to muscle tissue concentration, which allowed an estimate of the percent reduction in TEQ concentrations from trimming away fat and removing skin.

Tissue Homolog Distributions

The analytical laboratory provided up to two estimates of the concentration of each homolog group for the tetra, penta-, hexa-, hepta-, and octa-chlorinated CDDs/CDFs. One estimate included an EMPC while the other estimate did not. The mean percentage for each homolog group was similar between tissue types and species. Because of these similar percentages, a single mean percentage, combining all species and tissues, was calculated for each homolog group for both types of estimates.

RESULTS

Description of Fish Samples

A total of 267 fish comprised of three species and two subspecies were collected from the south shore of Lake Superior between October 1998 and August 1999. Of these 267 fish, 235 were collected from near shore reefs east of the Keweenaw Peninsula within the MI4 lake trout management unit (Figure 1). The 235 fish were made up of lake herring (48), lake trout (94), lake whitefish (47), and siscowet trout (46). On average, the fish ranged between 42 - 73 cm in length, 5.8 - 17 years of age, and 600 - 3000 g in round weight (Table 2). The remaining 32 fish (8 lake sturgeon and 24 lake trout) were collected from one of three fisheries management units (WI2, MI2, MI3) between the Bayfield and Keweenaw Peninsulas. The 24 lake trout ranged between 68 - 71 cm in length, 6 - 15 years of age, and 2,750 - 3,525 g in round weight. The 8 lake sturgeon were 49 - 99 cm in length and 3 - 9 years old. Round weight was not measured on the lake sturgeon.

The lake trout, lake whitefish, and siscowet trout fillets were segmented into skin, muscle, and fat. The range of the average tissue weights were 43.5 - 71.0 g, 62.0 - 105 g, and 374 - 562 g for skin, muscle, and fat, respectively (Table 3). The average UTSO fillets ranged from 479 - 738 g.

Quality Control Samples

The mean (± one standard deviation, SD) recoveries of the labeled congeners were 76 ± 9.4% in blanks and 74 ± 14% in lab controls. The spiked samples (i.e., matrix spikes) had an average recovery for labeled congeners of 85 ± 27% and the non-spiked samples had an average labeled congener recovery of 75 ± 25%. The standard reference material (SRM) labeled congener recovery was 68 ± 13%. The percent recovery for spiked non-labeled congeners from lab controls and samples were 97 ± 9.6% and 96 ± 18%, respectively (Table 4).

For lab control duplicates, labeled congeners had a mean (± one SD) relative percent difference (RPD) of 23 ± 23%, and non-labeled congeners had a mean RPD of 3.9 ± 4.3% (Table 5). Duplicate spiked samples had a mean RPD for labeled congeners of 11 ± 8.1%, and a mean RPD for the non-labeled congeners of 6.8 ± 6.7% (Table 5).

A total of five blank samples were run during the study. Each blank was analyzed for the 17 CDD/CDF congeners and 10 homolog groups. Three out of 75 congener analyses resulted in low but detectable levels of three different congeners. The congeners 1,2,3,6,7,8-HxCDF and 2,3,7,8-TCDD were each detected once at a concentration of 0.04 pg/g. The congener 1,2,3,4,6,7,8,9-OCDD was also detected once at a concentration of 0.69 pg/g. Five out of 40 homolog estimates also resulted in low but detectable levels of four different homolog groups. The tetra- and hepta-CDD homolog groups were each detected once at estimated concentrations of 0.04 pg/g and 0.1 pg/g, respectively. The tetra-CDF homolog group was detectable once at 0.33 pg/g and the hexa-CDF homolog group was detectable twice at 0.05 and 0.11 pg/g.

The standard reference material (SRM) was analyzed three times. The SRM was certified for the CDD congeners 2,3,7,8-TCDD, 1,2,3,7,8-PeCDD, and 1,2,3,6,7,8-HxCDD, and certified for CDF congeners 2,3,7,8-TCDF and 2,3,4,7,8-PeCDF. The SRM results were below the certified reference values (Table 6).

Tissue Concentrations

TEQ concentrations were dependent on the calculation method used. Fish tissue concentrations were slightly higher when WHO TEFs were used in place of EPA TEFs and/or when one-half the LOD was added in place of zero for non-detected congeners. Results are reported for both non-moisture adjusted (2003, Table 7) and moisture adjusted (1999, Table 8) tissues. On average, the tissue samples had more moisture in 1999 than in 2003. Tissues ranged from 13 - 59% moisture in 2003, with most being around 13%. In 1999, the tissues ranged from 54 - 78% moisture (Table 8). In 1999, the muscle tissue samples ranged from 72 - 78% moisture, and the skin and fat samples ranged from 54 - 67% moisture (Table 8). In order to compensate for the loss in moisture (and subsequent loss in tissue mass) between 1999 and 2003, the lost weight of moisture was mathematically added back to the tissue mass (see *Moisture Adjusted TEQ Concentrations* section). Because concentrations are a ratio of chemical mass to tissue mass, mathematically adding moisture to the tissue resulted in a decrease in the TEQ concentrations (Table 8). However, the trends across species and between tissue types did not change. The non-moisture adjusted estimates of TEQ concentration are based on lab-reported data. The moisture adjusted concentrations are more representative of the fish at the time of processing and thus are more appropriate for evaluating the data for human consumption purposes.

Non-Adjusted TEQ Concentrations

Mean TEQ concentration ranges (ppt) in muscle tissue for the following fish species were: lake sturgeon, 0.5 – 1.6; lake whitefish, 1.4 – 2.0; 64-cm lake trout, 2.2 – 4.7, 70-cm lake trout 4.8 – 6.3, siscowet trout 24 – 28 (Table 7). Mean TEQ concentrations (ppt) in UTSO lake herring fillets ranged from 0.4 – 1.3 (Table 7). Regardless of type of TEFs used or tissue type, siscowet trout samples had, on average, the highest TEQ concentrations and lake herring and juvenile lake sturgeon samples had the lowest concentrations (Figure 3).

Moisture Adjusted TEQ Concentrations

Mean TEQ concentration ranges (ppt) in muscle tissue for the following fish species were: lake sturgeon, 0.12 – 0.36; lake whitefish, 0.42 – 0.58; 64-cm lake trout, 1.7 – 3.6, 70-cm lake trout 1.5 – 2.0, siscowet trout, 6.2 – 7.0 (Table 8). Mean TEQ concentrations (ppt) in UTSO lake herring fillets ranged from 0.12 – 0.40 (Table 8). The EPA-TEQ-based concentrations with zero being used in place of non-detections were the lowest estimates of TEQ concentration (Figure 4). The WHO-TEQ-based concentrations with one-half of the LOD being used in place of non-detections were the highest estimates of

TEQ concentration (Figure 5). Muscle tissue with the skin and fat removed had concentrations between 43 and 68 percent less than the UTSO fillets (Table 9).

Correlation to Lipid Content

For those species in which multiple tissue types were analyzed, lipid content of the tissue was highly correlated ($r^2 = 0.53$ to 0.96, $p < 0.0001$) with the TEQ concentrations within a species (Table 10). Lake whitefish and lake trout regressions had similar slopes (1999 moisture corrected range - 23.4-30.3 for lake whitefish, 27.8-32.3 for lake trout), while siscowet regression had slopes 5 to 8 fold higher (1999 moisture corrected range - 175-182) (Table 10). Physiological differences between species may account for the greater slopes seen in the siscowet regressions compared to lake trout and lake whitefish.

Tissue Homolog Distributions

The tetra- and penta-CDF homolog groups made up the majority of the mass of CDD/CDFs present in Lake Superior fish tissue. On average, when including the EMPC values into the total concentration, the homolog groups for the tetra- and penta-CDF congeners made up 93% of the total concentration of CDDs/CDFs (Table 11). When the EMPC values were excluded, the average for these two homolog groups was reduced to 84%, with all of the CDD homolog groups contributing a larger percentage to the homolog estimates (Table 11). The effect on the congener distribution as a result of using the EMPC values is small and likely within the statistical variability associated with CDD/CDF analysis. EMPC values were used in all subsequent calculations for the reason of providing a more conservative estimate of TEQ concentrations in fish tissue.

DISCUSSION

Tissue TEQ Concentrations

Based on Lake Superior sediment cores, CDDs/CDFs began accumulating in Lake Superior around 1909 ± 9 years and reached peak concentration in 1973 ± 4 years (Pearson et al. 1997, Baker and Hites 2000). Since the 1970s, CDD/CDF concentrations in sediments have declined by approximately 50% or more (Pearson et al. 1970, Baker and Hites 2000). This declining trend has been paralleled by similar CDD/CDF reductions in tissues from Great Lakes biota, such as herring gull eggs (Weseloh et al. 1994). Despite these declining trends, CDDs/CDFs are still found at measurable levels in many commercially sold foods (IOM 2004).

The current study found measurable concentrations of CDDs/CDFs in fillet tissues of the "jumbo" sizes of tribal commercially harvested Lake Superior fish (lake herring, lake trout, lake whitefish, siscowet trout). Overall, using WHO – TEFs with one-half the LOD inserted for non-detections resulted in the highest estimates of TEQ concentrations in all species and tissue types. The lowest TEQ concentrations were found in lake herring and lake whitefish. Lake herring UTSO fillets averaged less than 0.5 ppt TEQ.

Lake whitefish muscle tissue averaged less than 0.6 ppt TEQ and UTSO fillets averaged less than 1.8 ppt TEQ (Table 8). Lake trout muscle tissue averaged less than 4 ppt TEQ and UTSO fillets less than 5 ppt TEQ. Among the species in this study, siscowet trout had the highest average concentrations, averaging up to 7 ppt TEQ in muscle tissue and 21 ppt TEQ in UTSO fillets.

The Michigan Department of Environmental Quality (MI DEQ) has created a database of fish tissue CDD/CDF concentrations from both Lake Superior and other Great Lakes. MI DEQ calculates TEQ concentrations using EPA – TEFs and zero inserted for non-detections. Concentrations are measured in both whole fish and UTSO fillets. For purposes of comparison, UTSO fillet data from the current study was also converted to EPA - TEQ concentrations with zero inserted for non-detections. Both datasets include measurements of the same CDD/CDF congeners (Table 1) and were measured at the same laboratory (Triangle Laboratories, Inc., now Eno River Laboratories, Inc.), making concentration comparisons appropriate. Both fish length and concentration comparisons are shown in Table 12.

Lake Herring

The average EPA - TEQ concentration measured in lake herring (mean length, 42 ± 0.5 cm) from the current study was 0.12 ± 0.3 ppt. MI DEQ measured a TEQ concentration of 1.8 ppt in one 64.6 cm lake herring from Lake Superior (Table 12). MI DEQ lake herring TEQ concentrations from other Great Lakes were not available.

Lake Trout

Lake trout muscle tissue concentrations from this study averaged 1.7 ± 0.9 ppt (64 cm lake trout) and 1.5 ± 0.4 ppt (70 cm lake trout) EPA-TEQ with zero used in place of non-detections. These same groups of lake trout averaged 64.4 ± 0.2 cm and 69.7 ± 0.4 cm in length respectively. The Chippewa Ottawa Resource Authority through their Inter-Tribal Fisheries and Assessment Program (1998) reported two lake trout (58 cm in length) muscle tissue concentrations of 0.64 and 1.31 ppt EPA-TEQ with zero used in place of non-detections which compare favorably to this study's results (Table 12). UTSO fillet data using EPA - TEQ with zero inserted for non-detections from the current study averaged 3.0 ± 0.9 ppt for 64 cm lake trout and 2.9 ± 0.7 ppt for 70 cm lake trout (Table 12). Lake trout fillet data from Lake Superior was not available from MI DEQ. However, MI DEQ measured UTSO fillet concentrations from Lake Michigan and Lake Huron lake trout. The Lake Michigan lake trout had an average length of 59.4 ± 3.2 cm and an average concentration of 5.4 ± 1.8 ppt EPA - TEQ (Table 12). These data were collected between 1996-1997. The Lake Huron lake trout had an average length of 61.3 ± 7.7 cm and an average concentration of 12.1 ± 5.2 ppt EPA - TEQ (Table 12). These data were collected between 1991-1996. The mean EPA - TEQ lake trout concentrations from Lake Superior measured in the current study are lower than average MI DEQ EPA - TEQ concentrations from Lakes Michigan or Huron even though the fish measured in the current study were, on average, longer and most likely older. Within a water body, longer and older fish are generally thought to have greater contaminant concentrations than shorter and younger fish.

Lake Whitefish

The average EPA - TEQ concentration measured in lake whitefish from the current study was 1.3 ± 0.1 ppt EPA - TEQ. These fish averaged 57.3 ± 0.3 cm in length. MI DEQ measured a similar mean lake whitefish concentration of 2.5 ± 1.4 ppt EPA - TEQ in 2000 (Table 12). These fish averaged 54.7 ± 5.3 cm in length. In contrast, Lake Michigan, Lake Huron, and Lake Erie lake whitefish UTSO fillets averaged 12.4 ± 6.2, 11.4 ± 9.5, and 7.7 ± 2.7 ppt EPA - TEQ respectively (Table12). The mean lake whitefish length from each of these datasets was 55.3 ± 7.2, 55.3 ± 5.3, and 54.6 ± 6.6 cm respectively.

Siscowet Trout

MI DEQ siscowet trout concentrations from Lake Superior averaged 8.2 ± 5.5 ppt EPA - TEQ and were on average 54.6 ± 6.6 cm in length. This compares to siscowet trout concentrations from the current study that averaged 19 ± 5.1 ppt EPA - TEQ and were on average 64.0 ± 0.2 cm in length. Although the mean concentrations are different between the datasets, the ranges overlap (Table 12). This suggests that differences between MI DEQ data and this dataset are likely due to differences in length and/or age.

The general conclusion to draw from these comparisons is that data collected from the current study agrees well with other TEQ data collected from Lake Superior fish and that Lake Superior fish have, on average, lower CDD/CDF concentrations than fish from other Great Lakes (we did not compare to Lake Ontario). This agrees with other data collected from the Great Lakes that shows Lake Superior fish generally (other than toxaphene, alpha-hexachlorocyclohexane (alpha-HCH), and PBDEs) have the lowest concentrations of PBT contaminants (De Vault et al. 1996).

TEQ concentration was strongly correlated with the lipid in the samples. Within each species, lipid content was predictive ($r^2 = 0.53$ to 0.96, $p < 0.001$, Table 10) of the TEQ concentration between samples. This strong lipophilic nature of CDDs/CDFs resulted in estimates of 43 to 68 percent reductions in TEQ concentrations when the skin and fat tissues were removed from fillets. An additional 50 percent reduction in CDDs/CDFs has been shown to occur during cooking (Zabik and Zabik 1995).

Human Health

Determining TEQ concentrations in fish tissue is relatively straight forward compared to the task of determining the risk CDDs/CDFs pose to human health. CDDs/CDFs are detected at some level in almost all, if not all food, in the national food supply. The 2001 U.S. Food and Drug Administration's (FDA) Total Diet Survey reported the range of average WHO - TEQ concentrations in various commercially sold food including meat, dairy products, fruits, and vegetables. Concentrations varied from below detection to as high as 0.46 and 0.24 ppt-TEQ in meat and dairy products, respectively (IOM 2004, Table 13). The fish samples in the U.S. FDA's Total Diet Survey ranged from 0.005 to 0.33 ppt-TEQ (depending how non-detected congeners were treated in TEQ calculations) and included tuna, shrimp, salmon, fish sticks, and fast-food fish sandwiches. The Total Diet Survey did not appear to include a wide range of fresh and marine fish that are sold in the U.S., and also did not include fish from the Great Lakes. This may explain the rather narrow range of fish tissue TEQ concentrations. Lake Superior fish muscle tissues generally had lower TEQ concentrations than other Great Lakes fish, but were greater than most TEQ concentrations in other commercially sold food. However, it is important to realize that, for most populations, the amount of dairy, meat, and other foods being consumed is greater than the amount of fish. Therefore, total CDD/CDF exposure from other foods can be greater than exposure from fish consumption (IOM 2004).

People are currently being exposed to CDD/CDFs in their daily diets. The U.S. FDA, a lead federal agency on protecting and monitoring the national food supply, currently does not issue a single, uniform CDD/CDF guidance value, but instead, seems to evaluate situations on a case by case basis. For example, in 1997, in response to an incident where commercially raised chickens became contaminated with CDDs/CDFs, the U.S. FDA established a "level of concern" of 1 ppt-2,3,7,8-TCDD in edible tissues of meat, poultry, fish, eggs, and other food products from animals exposed to CDD/CDF contaminated feed (FSIS 1997). Food exceeding 1 ppt was deemed adulterated and was to be destroyed. This is in stark contrast to a U.S. FDA opinion issued in 1985 which stated unlimited fish consumption was acceptable below 25 ppt-TEQ, restricted consumption between 25 to 50 ppt-TEQ, and no consumption above 50 ppt-TEQ (DRBC 2002).

Other federal and state agencies have estimated their own fish consumption guidance levels that are not regulatory in nature and are more applicable to sport fish consumption scenarios. The U.S. EPA suggests fish tissue concentrations of CDDs/CDFs greater than 1.2 ppt-TEQ should not be consumed by anyone (U.S. EPA 2000). The State of Maine uses a CDD/CDF fish tissue concentration of 1.5 ppt-TEQ to set fish consumption advisories. The States of Michigan and Wisconsin use a value of 10 ppt-TEQ and the Province of Ontario uses 10.1 ppt-TEQ to set fish consumption advisories (Table 14). Comparing the results from this study to any of these comparison values and drawing conclusions about how a state, federal, or provincial agency would evaluate the concentrations in this study would be highly subjective on the part of the authors. However, they provide a reference point upon which to make some generalizations about the data. For instance, the largest commonly harvested sizes of lake herring, lake whitefish, and lake trout from Lake Superior, regardless of method of TEQ calculation or how the fillet was trimmed, were all below current fish consumption advisory levels used by jurisdictions around Lake Superior (Table 14). Because PBTs such as CDD/CDFs tend to accumulate to greater concentrations in larger fish, smaller fish from Lake Superior are likely to contain lower CDD/CDF concentrations than those reported here. Sport fish consumption advice for Lake Superior fish (except for siscowet) is generally triggered by other contaminants such as mercury, PCBs, and toxaphene, and not CDD/CDFs.

The responsibility of unbiased and protective fish consumption advice ultimately resides with federal, state, and tribal governments providing such advice to their citizens, residents, or members, respectively. The data provided in this report was collected for that purpose. Most, if not all, fish consumption advisories are a combination of risk assessment and risk management. Risk assessments for fish consumption advisories typically consist of a fish tissue chemical comparison value and a specific method for comparing the fish tissue concentrations to the comparison value. For example, some agencies may compare average concentrations to a comparison value, while others may use the 95% upper bound confidence limit, while others still may consider finding one fish above a comparison value requires fish consumption restrictions. Thus, risk assessments can vary between jurisdictions. In addition, risk management decisions not only include the risk assessment results but also may consider other social and economic factors such as cultural subsistence use of a resource. Although opinions differ about the appropriate fish tissue comparison value for CDDs/CDFs and about the methods of comparing fish tissue concentrations to that value, the body of science that has developed since the 1980s explaining CDD/CDF toxicity is pointing towards lower, not higher, acceptable CDD/CDF concentrations in food.

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TABLES

Table 1. Labeled and non-labeled CDD/CDF congeners and associated Environmental Protection Agency (EPA) and World Health Organization (WHO) toxic equivalency factors (TEFs).

Abbreviated Name	Full Name	EPA	WHO
NON-LABELED CONGENERS			
2,3,7,8-TCDD	2,3,7,8-Tetrachlorodibenzo-p-dioxin	1	1
1,2,3,7,8-PeCDD	1,2,3,7,8-Pentachlorodibenzo-p-dioxin	0.5	1
1,2,3,4,7,8-HxCDD	1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	0.1	0.1
1,2,3,6,7,8-HxCDD	1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	0.1	0.1
1,2,3,7,8,9-HxCDD	1,2,3,7,8,9- Hexachlorodibenzo-p-dioxin	0.1	0.1
1,2,3,4,6,7,8-HpCDD	1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	0.01	0.01
1,2,3,4,6,7,8,9-OCDD	1,2,3,4,6,7,8,9-Octachlorodibenzo-p-dioxin	0.001	0.0001
2,3,7,8-TCDF	2,3,7,8-Tetrachlorodibenzofuran	0.1	0.1
1,2,3,7,8-PeCDF	1,2,3,7,8-Pentachlorodibenzofuran	0.5	0.5
2,3,4,7,8-PeCDF	2,3,4,7,8-Pentachlorodibenzofuran	0.1	0.1
1,2,3,4,7,8-HxCDF	1,2,3,4,7,8-Hexachlorodibenzofuran	0.05	0.05
1,2,3,6,7,8-HxCDF	1,2,3,6,7,8-Hexachlorodibenzofuran	0.1	0.1
1,2,3,7,8,9-HxCDF	1,2,3,7,8,9-Hexachlorodibenzofuran	0.1	0.1
2,3,4,6,7,8-HxCDF	2,3,4,6,7,8-Hexachlorodibenzofuran	0.1	0.1
1,2,3,4,6,7,8-HpCDF	1,2,3,4,6,7,8-Heptachlorodibenzofuran	0.01	0.01
1,2,3,4,7,8,9-HpCDF	1,2,3,4,7,8,9-Heptachlorodibenzofuran	0.01	0.01
1,2,3,4,6,7,8,9-OCDF	1,2,3,4,6,7,8,9-Octachlorodibenzofuran	0.001	0.0001
LABELED CONGENERS			
$^{37}Cl_4$-2,3,7,8-TCDD[a]	$^{37}Cl_4$-2,3,7,8-Tetrachlorodibenzo-p-dioxin	NA	NA
$^{13}C_{12}$-2,3,7,8-TCDD[b]	$^{13}C_{12}$-2,3,7,8-Tetrachlorodibenzo-p-dioxin	NA	NA
$^{13}C_{12}$-1,2,3,7,8-PeCDD[b]	$^{13}C_{12}$-1,2,3,7,8-Pentachlorodibenzo-p-dioxin	NA	NA
$^{13}C_{12}$-1,2,3,4,7,8-HxCDD[a]	$^{13}C_{12}$-1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	NA	NA
$^{13}C_{12}$-1,2,3,6,7,8-HxCDD[b]	$^{13}C_{12}$-1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	NA	NA
$^{13}C_{12}$-1,2,3,4,6,7,8-HpCDD[b]	$^{13}C_{12}$-1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	NA	NA
$^{13}C_{12}$-1,2,3,4,6,7,8,9-OCDD[b]	$^{13}C_{12}$-1,2,3,4,6,7,8,9-Octachlorodibenzo-p-dioxin	NA	NA
$^{13}C_{12}$-2,3,7,8-TCDF[b]	$^{13}C_{12}$-2,3,7,8-Tetrachlorodibenzofuran	NA	NA
$^{13}C_{12}$-1,2,3,7,8-PeCDF[b]	$^{13}C_{12}$-1,2,3,7,8-Pentachlorodibenzofuran	NA	NA
$^{13}C_{12}$-2,3,4,7,8-PeCDF[a]	$^{13}C_{12}$-2,3,4,7,8-Pentachlorodibenzofuran	NA	NA
$^{13}C_{12}$-1,2,3,4,7,8-HxCDF[a]	$^{13}C_{12}$-1,2,3,4,7,8-Hexachlorodibenzofuran	NA	NA
$^{13}C_{12}$-1,2,3,6,7,8-HxCDF[b]	$^{13}C_{12}$-1,2,3,6,7,8-Hexachlorodibenzofuran	NA	NA
$^{13}C_{12}$-1,2,3,7,8,9-HxCDF[a]	$^{13}C_{12}$-1,2,3,7,8,9-Hexachlorodibenzofuran	NA	NA
$^{13}C_{12}$-2,3,4,6,7,8-HxCDF[a]	$^{13}C_{12}$-2,3,4,6,7,8-Hexachlorodibenzofuran	NA	NA
$^{13}C_{12}$-1,2,3,4,6,7,8-HpCDF[b]	$^{13}C_{12}$-1,2,3,4,6,7,8-Heptachlorodibenzofuran	NA	NA
$^{13}C_{12}$-1,2,3,4,7,8,9-HpCDF[a]	$^{13}C_{12}$-1,2,3,4,7,8,9-Heptachlorodibenzofuran	NA	NA

[a] Chemical added for use as a surrogate standard.

[b] Chemical added for use as an internal standard.

NA: not applicable.

Table 2. Mean (± standard deviation) age (yr), length (cm) and weight (g) of the composites of lake herring, lake sturgeon, 64-cm lake trout, 70-cm lake trout, lake whitefish, and siscowet trout.

Species	Number of		Composite Mean ± SD		
	Fish	Composites	Age (years)	Length (cm)	Weight (g)
Lake Herring	48	4	9.4 ± 0.4	41.7 ± 0.5	600 ± 27
Lake Sturgeon	8	3	5.8 ± 2.8	73.1 ± 23.0	Na
Lake Trout 64-cm	46	4	8.6 ± 1.9	64.4 ± 0.2	2300 ± 76
Lake Trout 70-cm	72	7	10 ± 1.5	69.7 ± 0.4	3000 ± 105
Lake Whitefish	47	4	9.3 ± 1.3	57.3 ± 0.3	1650 ± 105
Siscowet Trout	46	4	17 ± 2.0	63.5 ± 0.2	2250 ± 145

Table 3. The mean (± standard deviation) tissue weight (g) of trimmed dorsal/ventral fatty tissue (fat), skin, muscle, and untrimmed, skin-on fillets (UTSO) for 64 cm lake trout, 70 cm lake trout, lake whitefish, and siscowet trout.

Species	Length (cm)	Fat (g)	Skin (g)	Muscle (g)	UTSO (g)
Lake Trout 64-cm	64.4 ± 0.2	62.0 ± 17.9	43.5 ± 1.3	374 ± 20	479 ± 34
Lake Trout 70-cm	69.7 ± 0.4	105 ± 18.7	71.0 ± 5.7	562 ± 34	738 ± 43
Lake Whitefish	57.3 ± 0.3	87.5 ± 1.3	56.2 ± 1.8	455 ± 15	599 ± 16
Siscowet Trout	63.5 ± 0.2	104 ± 12.0	57.8 ± 2.1	377 ± 19	539 ± 32

Table 4. Percent recovery of carbon ($^{13}C_{12}$ or $^{37}C_4$) - labeled congeners and non-labeled congeners (spikes) in blanks, lab control samples, and fish tissue samples.

SAMPLE TYPE	CHEMICAL SET	NUMBER OF ANALYSES	PERCENT RECOVERY MEAN ± SD
Blanks	C-labeled	80	76 ± 9.4%
Lab Control Samples	C-labeled	160	74 ± 14 %
Lab Control Samples	Non-labeled	170	97 ± 9.6 %
Matrix Spikes	C-labeled	192	85 ± 27 %
Matrix Spikes	Non-labeled	204	96 ± 18 %
Fish Tissue Samples	C-labeled	912	75 ± 25 %
SRM	C-labeled	48	68 ± 13 %

Table 5. Relative percent difference for lab control samples and duplicates (LCS/LCSD) and matrix spike samples and duplicates (MS/MSD).

Sample Type	Chemical Set	Number of Pairs of QC Samples	Number of Analyses	RPD Mean ± SD
LCS/LCSD	C-labeled	5	80	23 ± 23 %
LCS/LCSD	Non-labeled	5	85	3.9 ± 4.3 %
MS/MSD	C-labeled	6	96	11 ± 8.1 %
MS/MSD	Non-labeled	6	102	6.8 ± 6.7 %

Table 6. Three standard reference material (WMF-01, Wellington Labs, Guelph, Ontario, Canada) analyses and the associated reference value for each congener.

Chemical[a]	**Reference Value**	**SRM1**	**SRM2**	**SRM3**
2,3,7,8-TCDD	13.1 ± 4.4	1.5	1.7	1.4
1,2,3,7,8-PeCDD	2.72 ± 1.3	0.49	0.48	0.8
1,2,3,7,8,9-HxCDD	0.22 ± 0.3	ND	ND	ND
1,2,3,6,7,8-HxCDD	0.88 ± 0.4	0.19	ND	ND
1,2,3,4,7,8-HxCDD	0.27 ± 0.4	ND	ND	ND
1,2,3,4,6,7,8-HpCDD	0.59 ± 0.7	ND	ND	ND
1,2,3,4,6,7,8,9-OCDD	3.91 ± 6.2	0.56	ND	0.92
2,3,7,8-TCDF	13.1 ± 4.9	1.5	ND	2.2
2,3,4,7,8-PeCDF	7.15 ± 2.2	0.99	0.95	ND
2,3,4,6,7,8-HxCDF	0.68 ± 1.2	ND	8.1	ND
1,2,3,7,8-PeCDF	1.53± 1.4	ND	2.3	1.8
1,2,3,7,8,9-HxCDF	0.25 ± 0.4	12	28	25
1,2,3,6,7,8-HxCDF	0.51± 0.7	ND	4.4	ND
1,2,3,4,7,8-HxCDF	0.86 ± 1.0	5.1	45	33
1,2,3,4,7,8,9-HpCDF	0.3 ± 0.5	ND	ND	ND
1,2,3,4,6,7,8-HpCDF	1.01 ± 1.9	ND	ND	ND
1,2,3,4,6,7,8,9-OCDF	1.38 ± 2.1	ND	ND	ND

[a] Names in bold represent certified reference values.
ND: non-detections.

Table 7. Mean (± one standard deviation) lipid content (%) and tissue toxic equivalency (TEQ) concentrations (pg TEQ_{df}[a]/g fish) by species and tissue type for four methods of calculating total CDD and CDF TEQ concentrations. Reported TEQ concentrations are NOT adjusted for tissue moisture loss between 1999 and 2003.

Species	**Tissue Type**[c]	**% Lipid 1999**	**% Lipid 2003**	**EPA Mammalian TEFs ND = zero pg TEQ_{df}/ g**	**EPA Mammalian TEFs ND = ½ LOD pg TEQ_{df}/ g**	**WHO Mammalian TEFs ND = zero pg TEQ_{df}/ g**	**WHO Mammalian TEFs ND = ½ LOD pg TEQ_{df}/ g**
Lake Herring	UTSO	5 ± 0.5	4 ± 1	0.4 ± 0.1	1.2 ± 0.30	0.5 ± 0.1	1.3 ± 0.3
Lake Sturgeon	Muscle	7 ± 2	6 ± 2	0.5 ± 0.3	1.5 ± 0.4	0.6 ± 0.3	1.6 ± 0.4
Lake Whitefish	Fat	27 ± 3	24 ± 5	10 ± 2.0	11 ± 2.1	13 ± 2.5	13 ± 2.6
Lake Whitefish	Skin	18 ± 3	15 ± 4	6.3 ± 0.9	6.7 ± 0.9	7.8 ± 1.1	8.2 ± 1.1
Lake Whitefish	Muscle	5 ± 1	4 ± 0.5	1.4 ± 0.1	1.6 ± 0.2	1.8 ± 0.2	2.0 ± 0.2
Lake Trout (64 cm)	Fat	32 ± 5	22 ± 7	10 ± 5.2	10 ± 5.2	12 ± 5.8	12 ± 5.9
Lake Trout (64 cm)	Skin	15 ± 1	Na	Na	Na	Na	Na
Lake Trout (64 cm)	Muscle	8 ± 1	6 ± 1	2.2 ± 0.4	4.2 ± 0.6	2.6 ± 0.5	4.7 ± 0.7
Lake Trout (70 cm)	Fat	31 ± 3	30 ± 3	16 ± 3.7	17 ± 3.7	19 ± 3.9	20 ± 4.1
Lake Trout (70 cm)[b]	Skin	16 ± 2	17 ± 12	10 ± 3.2	12 ± 4.1	12 ± 3.4	14 ± 4.3
Lake Trout (70 cm)	Muscle	8 ± 1	7 ± 1	4.8 ± 1.2	5.4 ± 1.2	5.7 ± 1.3	6.3 ± 1.3
Siscowet Trout	Fat	33 ± 2	47 ± 13	160 ± 65	170 ± 65	170 ± 64	170 ± 64
Siscowet Trout	Skin	14 ± 1	14 ± 1	23 ± 6.5	23 ± 6.4	25 ± 6.5	25 ± 6.5
Siscowet Trout	Muscle	17 ± 1	17 ± 2	24 ± 6.4	25 ± 6.3	27 ± 4.7	28 ± 4.7

[a] TEQ_{df} = Toxic equivalency calculated using only dioxin/furan congeners.

[b] TEQ concentrations and lipid percentages are only for the 4 lake trout composite samples taken from Lake Superior fisheries management unit MI-4.

[c] Tissue Type – UTSO = untrimmed skin-on fillet, Muscle = trimmed, skin-off fillet, Fat = dorsal/ventral fatty tissue.

Table 8. Mean (± one standard deviation) moisture content (%) and rehydrated tissue toxic equivalency (TEQ) concentrations (pg TEQ_{df}[a]/g fish) by species and tissue type for four methods of calculating total dioxin (CDD) and furan (CDF) TEQ concentrations. Reported TEQ concentrations are adjusted for tissue moisture loss between 1999 and 2003.

Species	**Tissue Type**[b]	**Percent Moisture 1999**	**Percent Moisture 2003**	**EPA Mammalian TEFs ND = zero pg TEQ_{df}/ g**	**EPA Mammalian TEFs ND = ½ LOD pg TEQ_{df}/ g**	**WHO Mammalian TEFs ND = zero pg TEQ_{df}/ g**	**WHO Mammalian TEFs ND = ½ LOD pg TEQ_{df}/ g**
Lake Herring	UTSO	74 ± 2.5	13 ± 0	0.12 ± 0.03	0.36 ± 0.09	0.16 ± 0.03	0.40 ± 0.09
Lake Sturgeon	Muscle	80	13 ± 0	0.12 ± 0.06	0.34 ± 0.10	0.14 ± 0.08	0.36 ± 0.09
Lake Whitefish	Fat	54 ± 8.4	13 ± 0	5.5 ± 1.1	5.7 ± 1.1	6.9 ± 1.3	7.1 ± 1.4
Lake Whitefish	Skin	58 ± 5.5	13 ± 0	3.1 ± 0.5	3.2 ± 0.5	3.8 ± 0.6	4.0 ± 0.5
Lake Whitefish	Muscle	74 ± 2.4	13 ± 0	0.42 ± 0.04	0.47 ± 0.05	0.53 ± 0.05	0.58 ± 0.05
Lake Whitefish	UTSO	Na	Na	1.3 ± 0.1	1.4 ± 0.1	1.6 ± 0.1	1.7 ± 0.2
Lake Trout (64 cm)	Fat	55 ± 1.6	48 ± 7.3	8.7 ± 4.4	8.9 ± 4.4	10 ± 5.0	11 ± 5.0
Lake Trout (64 cm)	Skin	58 ± 0.6	Na	4.8 ± 0.3	5.4 ± 0.3	5.6 ± 0.4	6.3 ± 0.3
Lake Trout (64 cm)	Muscle	72 ± 2.7	59 ± 20	1.7 ± 0.9	3.3 ± 1.4	2.1 ± 1.1	3.6 ± 1.6
Lake Trout (64 cm)	UTSO	Na	Na	3.0 ± 0.9	4.3 ± 1.1	3.6 ± 1.0	4.9 ± 1.2
Lake Trout (70 cm)	Fat	55 ± 1.6	18 ± 11	9.0 ± 3.2	9.7 ± 3.1	11 ± 2.8	11 ± 2.7
Lake Trout (70 cm)	Skin	58 ± 0.6	13 ± 0	5.0 ± 1.2	5.8 ± 1.5	6.0 ± 1.4	6.7 ± 1.6
Lake Trout (70 cm)	Muscle	72 ± 2.7	13 ± 0	1.5 ± 0.4	1.7 ± 0.4	1.8 ± 0.4	2.0 ± 0.4
Lake Trout (70 cm)	UTSO	Na	Na	2.9 ± 0.7	3.2 ± 0.6	3.6 ± 0.7	3.7 ± 0.6
Siscowet Trout	Fat	67 ± 9.6	24 ± 14	71 ± 25	71 ± 25	75 ± 24	75 ± 24
Siscowet Trout	Skin	63 ± 5.2	13 ± 0	9.8 ± 2.8	10 ± 2.8	11 ± 2.8	11 ± 2.8
Siscowet Trout	Muscle	78 ± 2.0	13 ± 0	6.2 ± 1.6	6.4 ± 1.6	6.8 ± 1.2	7.0 ± 1.2
Siscowet Trout	UTSO	Na	Na	19 ± 5.1	19 ±5.1	20 ± 5.1	21 ± 5.1

[a] TEQ_{df}= Toxic equivalency calculated using only dioxin/furan congeners.

[b] Tissue Type – UTSO = untrimmed skin-on fillet, Muscle = trimmed, skin-off fillet, Fat = dorsal/ventral fatty tissue.

Table 9. Percentage reduction in total toxic equivalency (TEQ) concentration due to removal of the skin and fat tissue from the fillets of three fish species.

Species	**UTSO**[a]	**Muscle**	**% Reduction**
Lake Whitefish	1.3	0.42	68
Lake Trout	3.0	1.7	43
Lake Trout	2.9	1.5	48
Siscowet Trout	19	6.2	67

[a] UTSO = Untrimmed skin-on fillet.

Table 10. Slope, y-intercept, and the correlation coefficient (r^2) for linear regressions of lipid content (1999[a] and 2003[b]) versus toxic equivalency (TEQ) concentrations in three species of fish. All regressions were significant at $\alpha = 0.05$ ($p < 0.0001$).

Species	Year	TEQ_{df}[c] Calculation	Slope	y-intercept	r^2
Lake Whitefish	1999	EPA – Zero	21.9	-0.618	0.87
		EPA - ½ LOD	22.7	-0.590	0.86
		WHO - Zero	27.5	-0.775	0.86
		WHO - ½ LOD	28.3	-0.747	0.86
Lake Whitefish	2003	EPA – Zero	23.4	-0.310	0.96
		EPA - ½ LOD	24.4	-0.284	0.96
		WHO - Zero	29.4	-0.393	0.96
		WHO - ½ LOD	30.3	-0.367	0.96
Lake Trout	1999	EPA – Zero	27.0	0.053	0.56
		EPA - ½ LOD	26.2	0.844	0.53
		WHO - Zero	32.6	-0.057	0.63
		WHO - ½ LOD	31.8	0.734	0.60
Lake Trout	2003	EPA – Zero	27.8	0.496	0.56
		EPA - ½ LOD	27.1	1.260	0.53
		WHO - Zero	33.0	0.580	0.61
		WHO - ½ LOD	32.3	1.342	0.58
Siscowet Trout	1999	EPA – Zero	350	-46.0	0.81
		EPA - ½ LOD	351	-45.9	0.81
		WHO - Zero	366	-47.6	0.81
		WHO - ½ LOD	367	-47.5	0.82
Siscowet Trout	2003	EPA – Zero	175	-16.6	0.77
		EPA - ½ LOD	175	-16.4	0.77
		WHO - Zero	182	-16.6	0.78
		WHO - ½ LOD	182	-16.4	0.78

[a] 1999 TEQ concentrations are adjusted for moisture loss.
[b] 2003 TEQ concentrations are not adjusted for moisture loss.
[c] TEQ_{df} = Toxic equivalency calculated using only dioxin/furan congeners.

Table 11. Mean (± one standard deviation) percent of each homolog group with and without estimated maximum potential concentration (EMPC) values.

Homolog Group	**N**	**Percent of Total with EMPC**	**Percent of Total without EMPC**
Total TCDD	57	0.2 ± 0.1	0.9 ± 1.0
Total PeCDD	57	0.4 ± 0.2	2.9 ± 2.1
Total HxCDD	57	0.3 ± 0.3	1.8 ±1.7
Total HpCDD	57	0.04 ± 0.06	0.3 ± 0.4
Total TCDF	57	55 ± 4.7	51 ± 18
Total PeCDF	57	38 ± 4.1	33 ± 16
Total HxCDF	57	5.5 ± 3.0	3.2 ± 3.3
Total HpCDF	57	0.4 ± 0.2	5.8 ± 6.8
1,2,3,4,6,7,8,9-OCDD	57	0.07 ± 0.2	0.4 ± 0.4
1,2,3,4,6,7,8,9-OCDF	57	0.007 ± 0.05	0.05 ± 0.2

Table 12. A comparison of Great Lakes Indian Fish & Wildlife Commission (GLIFWC) 1998-99 dioxin/furan (CDD/CDF) toxic equivalency (TEQ) concentrations measured in Lake Superior fish to TEQ data collected by other agencies (Michigan Department of Environmental Quality, MI DEQ and Chippewa Ottawa Resource Authority, CORA) in Lake Superior and other Great Lakes. TEQ concentrations were calculated using Environmental Protection Agency (EPA) Toxic equivalency factors (TEFs) and zero inserted for non-detected CDD/CDF congeners. GLIFWC samples were composites and MI DEQ and CORA samples were individual fish.

Agency	**Date**	**Lake**	**Species**	**Sample Type**	**No. Analyses/No. Fish[c]**	**Length Mean (cm)**	**Length Range (cm)**	**Mean TEQ (pg TEQ_{df}[d]/g fish)**	**TEQ Range (pg TEQ_{df}/g fish)**
GLIFWC	‘98-99	Superior	L. Herring	UTSO[a]	4/48	41.7 ± 0.5	38.4-46.7	0.12 ± 0.03	0.07 - 0.15
MI DEQ	‘00	Superior	L. Herring	UTSO	1/1	64.6	-	1.8	-
GLIFWC	‘98-99	Superior	L. Trout	Muscle[b]	4/46	64.4 ± 0.2	63.2-65.8	1.7 ± 0.9	1.0 - 3.0
GLIFWC	‘98-99	Superior	L. Trout	Muscle[b]	7/72	69.7 ± 0.4	68.3-71.4	1.5 ± 0.4	1.0 - 2.1
CORA	‘98	Superior	L. Trout	Muscle[b]	2/2	58	-	1.0 ± 0.5	0.64 - 1.3
GLIFWC	‘98-99	Superior	L. Trout	UTSO	4/46	64.4 ± 0.2	63.2-65.8	3.0 ± 0.9	2.0 - 4.1
GLIFWC	‘98-99	Superior	L. Trout	UTSO	7/72	69.7 ± 0.4	68.3-71.4	2.9 ± 0.7	2.3 - 4.0
MI DEQ	’96-97	Michigan	L. Trout	UTSO	20/20	59.4 ± 3.2	53.6-64.7	5.4 ± 1.8	2.6 - 8.7
MI DEQ	’91-96	Huron	L. Trout	UTSO	38/38	61.3 ± 7.7	50.5-79.0	12 ± 5.2	4.0 - 28
GLIFWC	‘98-99	Superior	Siscowet	UTSO	4/46	63.5 ± 0.2	62.2-65.3	19 ± 5.1	13 - 25
MI DEQ	’95-03	Superior	Siscowet	UTSO	30/30	54.6 ± 6.6	46.5-71.5	8.2 ± 5.5	1.5 - 27
GLIFWC	‘98-99	Superior	L. Whitefish	UTSO	4/47	57.3 ± 0.3	55.9-61.0	1.3 ± 0.1	1.2 - 1.5
MI DEQ	‘00	Superior	L. Whitefish	UTSO	15/15	54.7 ± 5.3	45.4-62.3	2.5 ± 1.4	0.77 - 5.3
MI DEQ	’96-99	Michigan	L. Whitefish	UTSO	40/40	55.3 ± 7.2	43.0-71.0	12 ± 6.2	3.6 - 28
MI DEQ	’96-99	Huron	L. Whitefish	UTSO	29/29	55.3 ± 5.3	47.0-63.6	11 ± 9.5	0.75 - 47
MI DEQ	‘97	Erie	L. Whitefish	UTSO	8/8	54.6 ± 6.6	45.0-67.0	7.7 ± 2.7	4.5 - 13

[a] UTSO = Untrimmed Skin-On Fillet.
[b] Muscle = Trimmed, skin-off fillet.
[c] No. Analyses/No. Fish = No. Analyses denotes the number of laboratory analyses the data represent. No. Fish denotes the number of fish represented in those analyses. When the two numbers are equal, individual fish were analyzed, when the numbers are not equal, composites were analyzed.
[d] TEQ_{df} = Toxic equivalency calculated using only dioxin/furan congeners.

Table 13. Range of mean TEQ concentrations based on dioxins(CDDs) and furans for foods analyzed in the U.S. Food and Drug Administration (FDA) Total Diet Study[a].

Food Category	**Example Foods[b]**	**Range of Means WHO-TEQ (ppt)**	
		ND[c] = 0	ND[c] = ½ LOD[d]
Dairy	cheese, milk, ice cream, yogurt, cream, pudding, infant formula	<0.00005 - 0.2426	0.0035 - 0.2534
Meat	beef, bologna, ham, liver, cheeseburger, lamb, pork, salami	0.0004 - 0.4592	0.0073 - 0.4595
Poultry	chicken, turkey	0.0005 – 0.0556	0.0062 – 0.0580
Fish	fish sticks, salmon, fish sandwich, shrimp, clam chowder soup, canned tuna,	0.0026 – 0.3254	0.0054 – 0.3257
Eggs	eggs, egg muffin sandwich	0.0107 – 0.0498	0.0313 – 0.0498
Fruits/Vegetables	apple, apricot, asparagus, avocado, fruit and vegetable baby foods, banana, beets, broccoli, cabbage, cherries carrots, corn, green beans, mushrooms, okra, orange peach, pear, potato, raisin, spinach, tomato,watermelon	0.0001 - 0.0904	0.0006 - 0.1188
Fats/Oils	Butter, margarine, olive oil mayonnaise, salad dressing	0.0019 – 0.2200	0.0095- 0.2202
Other	Cake, Cereal, Cola, Cookies, muffins, pancakes, rice, peanut butter, taco	0.0001 – 0.0472	0.0019 – 0.0619

[a] Base on Appendix B, Table B-2 from IOM 2004.
[b] Example list is not comprehensive, see citation in “a” above.
[c] ND = non-detections.
[d] LOD = limit of detection.

Table 14. Current toxic equivalency (TEQ) sport fish consumption trigger levels used by federal agencies, states, and provinces bordering Lake Superior. Consumption advice resulting when fish tissue concentrations exceed the trigger level is also given.

Jurisdiction	**TEQ Concentration Trigger Level (ppt)**	**Advice (when fish concentration is > trigger level)**
US EPA	1.2	Do Not Eat for everyone
US FDA	No single uniform trigger level regulating sale of fish	
Michigan	10	If >10% to 50% of samples exceed trigger level sensitive populations[a] "do not eat", general population[b] "restrict consumption". If >50% exceed the trigger level then "do not eat" for everyone.
Wisconsin	10	May issue "do not eat" advice to all populations – best professional judgement
Ontario	10.1[c]	Sensitive populations "do not eat", general population 1 meal/week

[a] Sensitive populations – pregnant women, women of childbearing age, children under age 15.
[b] General populations – Women older than 15 not planning on becoming pregnant or beyond childbearing age and men above age 15.
[c] - Advice will be changing in 2005 (Hayton, personal communication).

FIGURES

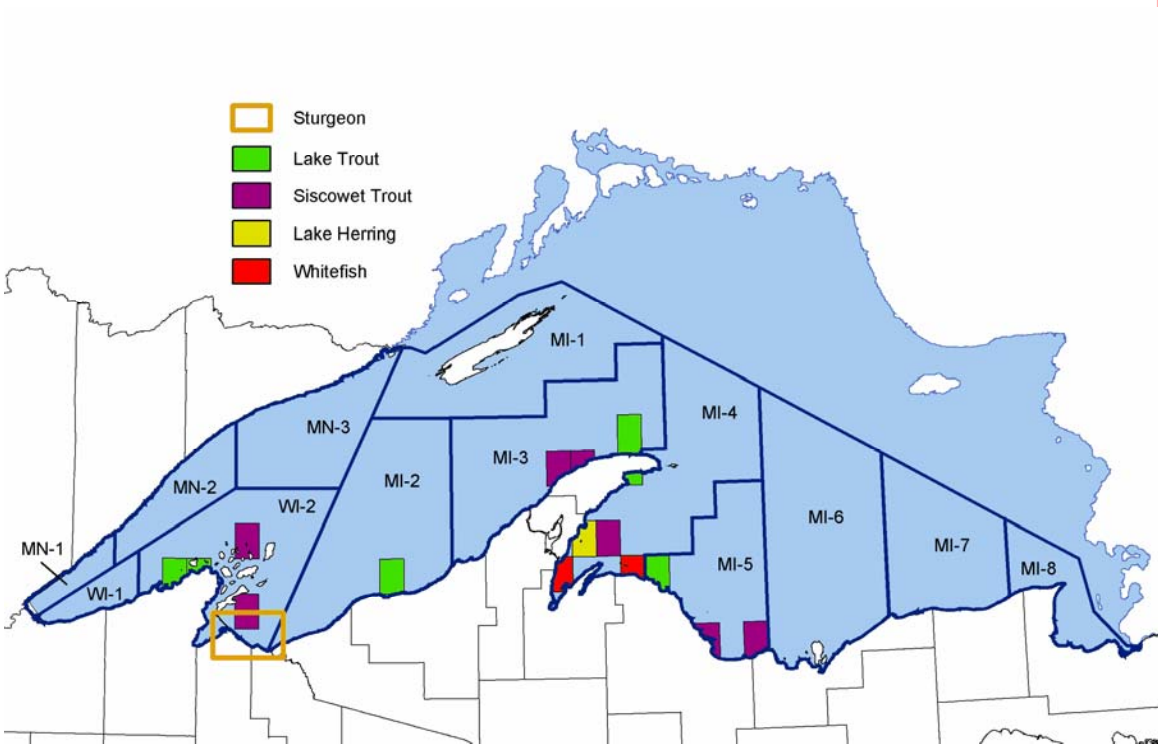

Figure 1. Map of Lake Superior management units in U.S. waters and areas of collection of fish for contaminant analysis. The various colors represent species specific collection locations.

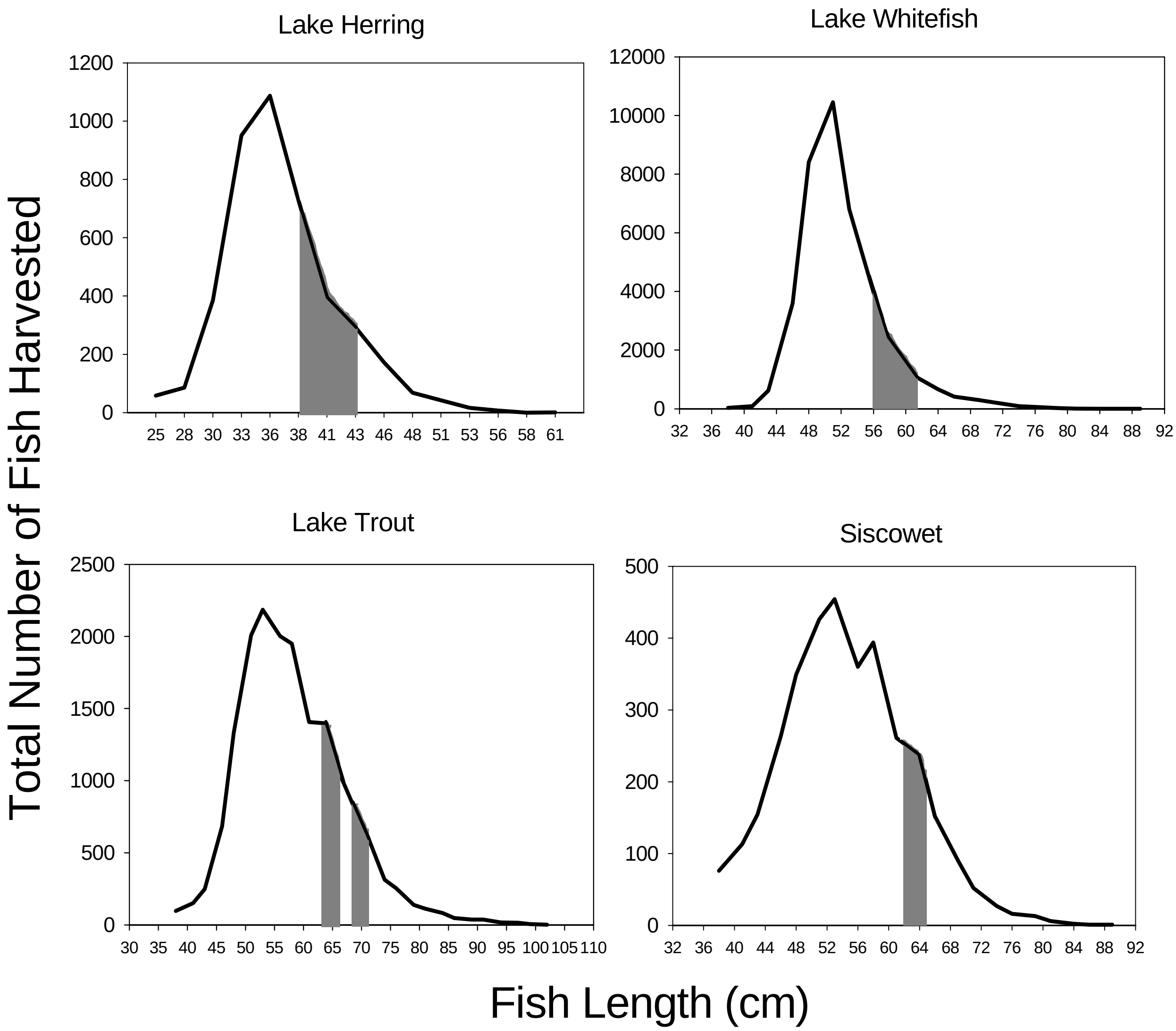

Figure 2. Harvest monitoring catch distributions for lake herring (*Coregonus artedii*), lake whitefish (*Coregonus clupeaformis*), lake trout (*Salvelinus namaycush namaycush*), and siscowet trout (*Salvelinus namaycush siscowet*) from the Inter-tribal gill net fishery in Michigan waters of Lake Superior 1986 – 1998. Shaded areas indicate size ranges from which fish species were collected for PBT contaminant analysis from a previous GLIFWC Administration for Native Americans (ANA) funded study (October 1998 – August 1999).

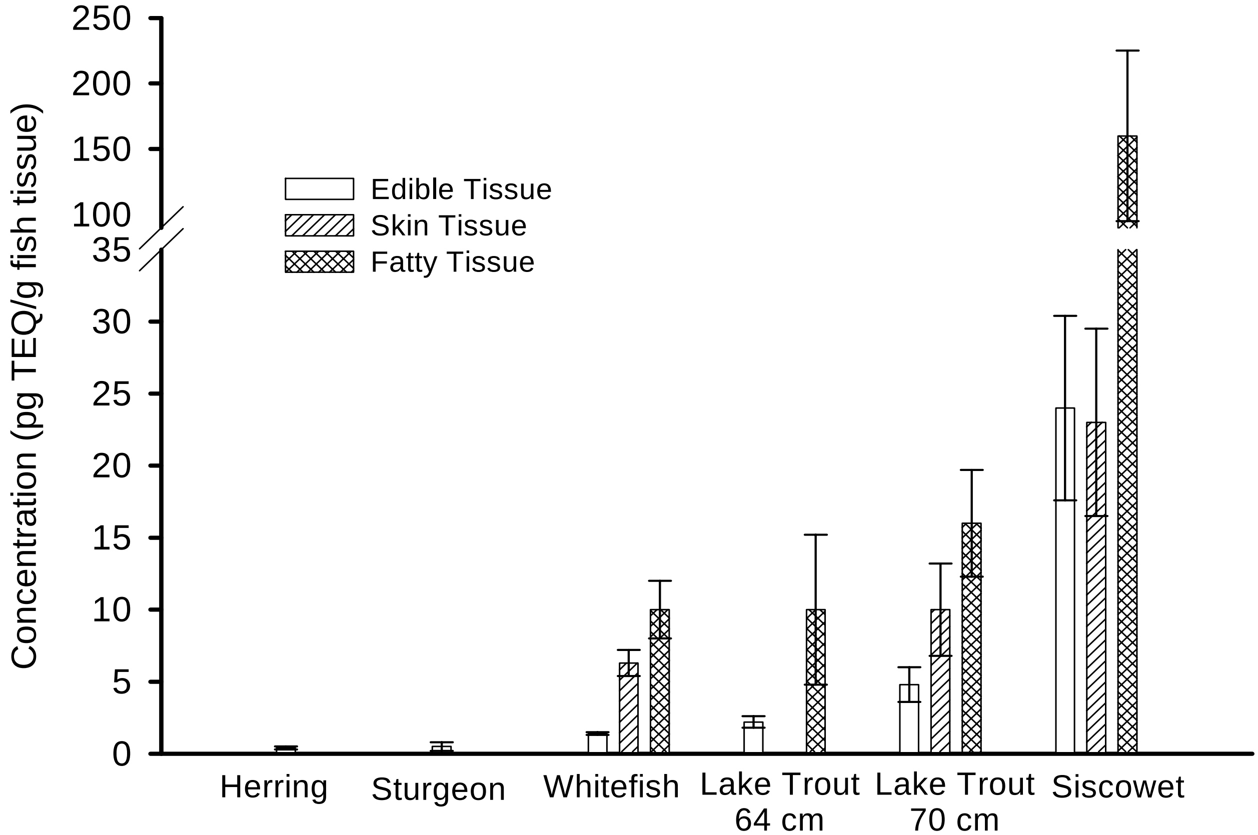

Figure 3. Mean (± one standard deviation) tissue concentrations (pg Toxic equivalency (TEQ)/g fish) <u>not adjusted for moisture loss</u> by species, length where applicable, and tissue type calculated using Environmental Protection Agency (EPA) toxic equivalency factors (TEFs) and zero inserted for non-detections.

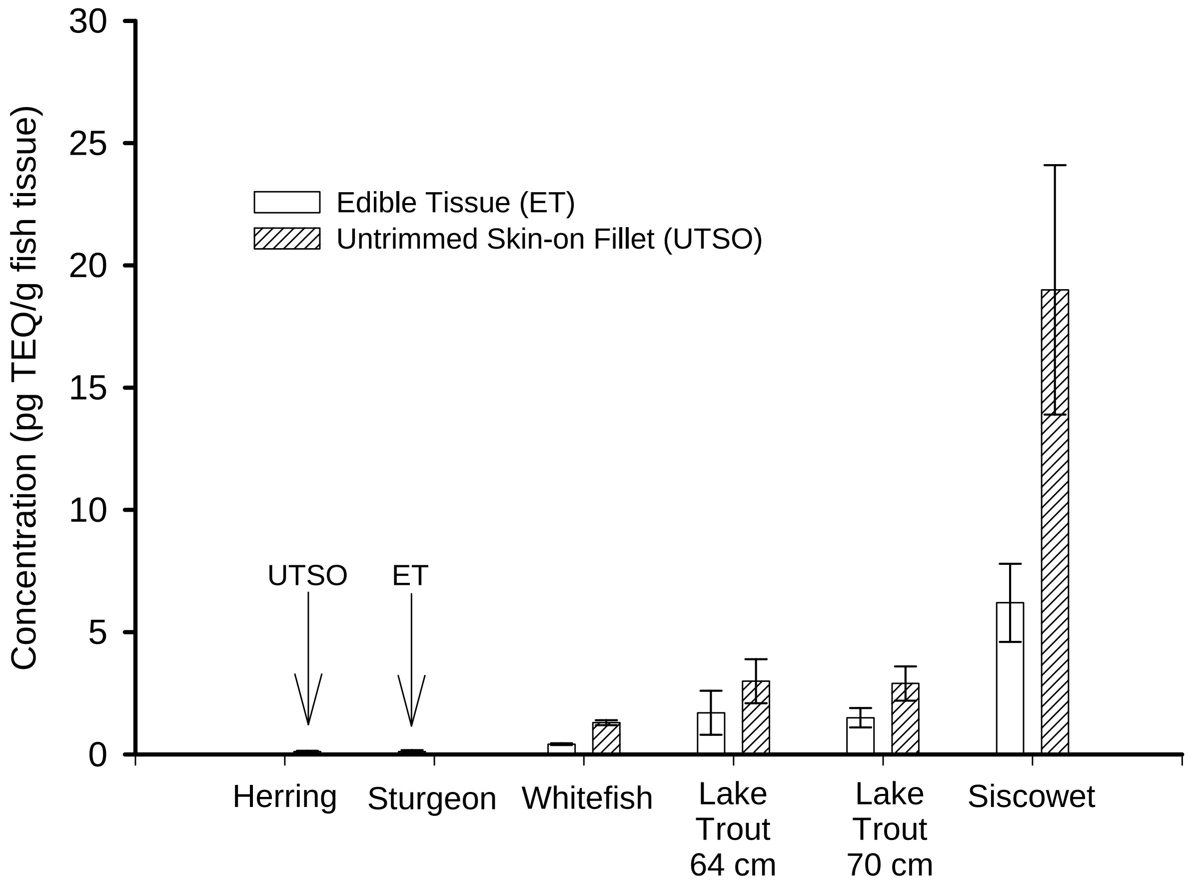

Figure 4. Mean (± one standard deviation) of the <u>rehydrated</u> tissue toxic equivalency (TEQ) concentrations (pg TEQ_{df}/g fish) by species, length where applicable, and tissue type calculated using Environmental Protection Agency (EPA) toxic equivalency factors (TEFs) and zero inserted for non-detections.

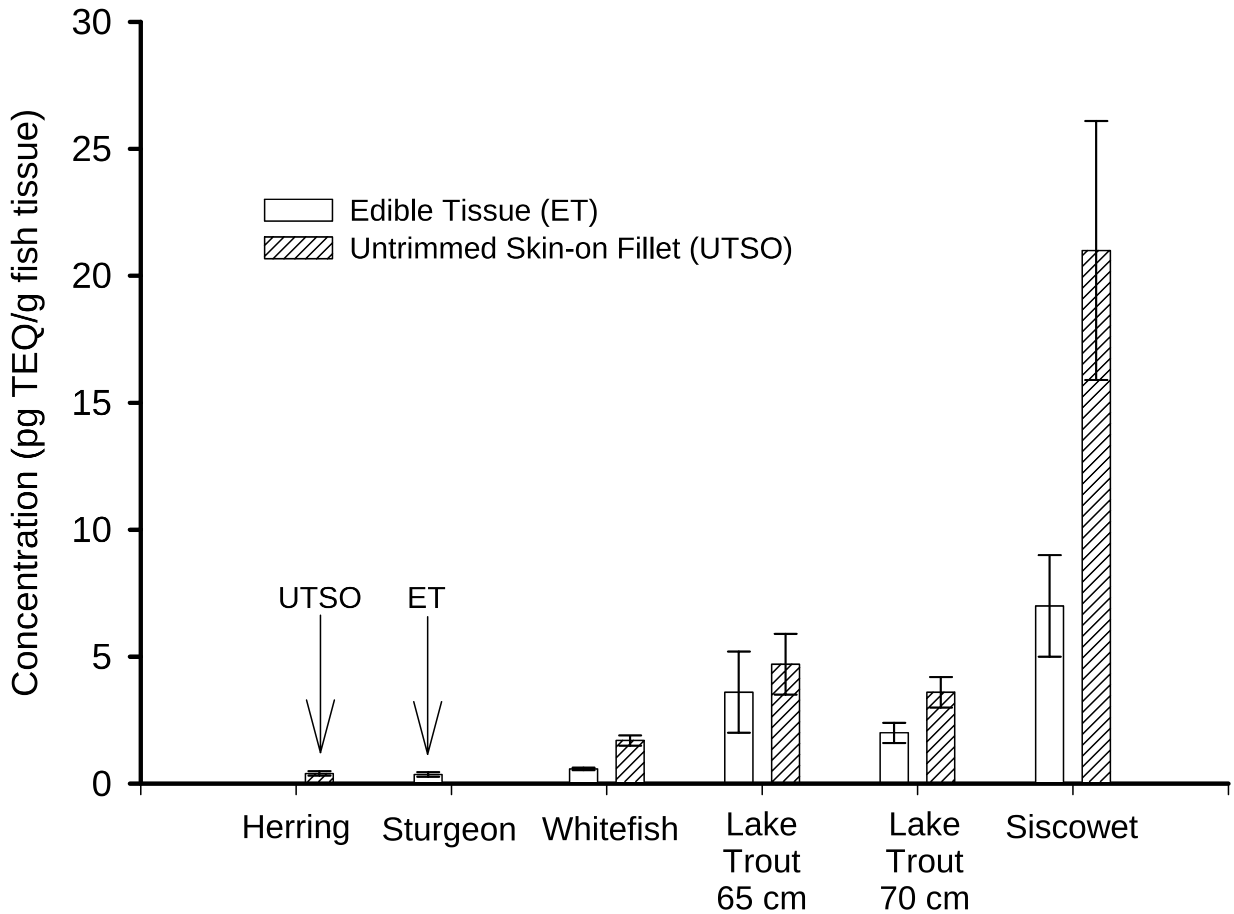

Figure 5. Mean (± one standard deviation) of the rehydrated tissue concentrations (pg TEQ_{df}/g fish) by species, length where applicable, and tissue type calculated using World Health Organization (WHO) toxic equivalency factors (TEFs) and ½ the limit of detection inserted for non-detections.

APPENDICES

APPENDIX 1

Lake Superior Fish Fillet Data and Dioxin/Furan (CDD/CDF) Toxic Equivalency (TEQ) Concentrations Calculated Using Environmental Protection Agency (EPA) Toxic Equivalency Factors (TEFs) and Zero Inserted for Non-Detected Congeners

Appendix 1

Fish Species	Tissue Type	Comp. No.	Mgmt Unit	Mean Tissue Weight (g)	Lipid Content 1999 decimal	Age Years	Mean Round Weight (g)	Mean Length inches	Moisture Content 2003 decimal	Lipid Content 2003 decimal	Total TEQ Measured pg/g	Total TEQ Hydrated 1999 pg/g
Lake Herring	UTSO	1	MI4	.	0.0448	9.2	579	16.1	0.131	0.031	0.249	0.0744
Lake Herring	UTSO	2	MI4	.	0.0502	9.1	638	16.5	0.129	0.031	0.435	0.130
Lake Herring	UTSO	3	MI4	.	0.0550	9.6	633	16.5	0.129	0.040	0.440	0.131
Lake Herring	UTSO	4	MI4	.	0.0552	9.8	604	16.5	0.129	0.046	0.488	0.146
Lake Whitefish	Fat	1	MI4	36	0.259	7.7	1496	22.6	0.130	0.29	12.7	6.82
Lake Whitefish	Skin	1	MI4	44	0.135	7.7	1496	22.6	0.129	0.091	5.60	2.72
Lake Whitefish	Muscle (edible portion)	1	MI4	350	0.0428	7.7	1496	22.6	0.131	0.034	1.59	0.474
Lake Whitefish	UTSO	1	MI4	430	.	7.7	1496	22.6	.	.	.	1.24
Lake Whitefish	Fat	2	MI4	66	0.237	8.9	1659	22.4	0.134	0.23	9.09	4.90
Lake Whitefish	Skin	2	MI4	45	0.190	8.9	1659	22.4	0.130	0.18	6.01	2.92
Lake Whitefish	Muscle (edible portion)	2	MI4	397	0.0444	8.9	1659	22.4	0.134	0.034	1.42	0.426
Lake Whitefish	UTSO	2	MI4	508	.	8.9	1659	22.4	.	.	.	1.23
Lake Whitefish	Fat	3	MI4	69	0.269	9.8	1729	22.6	0.132	0.26	10.7	5.78
Lake Whitefish	Skin	3	MI4	43	0.189	9.8	1729	22.6	0.131	0.17	7.70	3.75
Lake Whitefish	Muscle (edible portion)	3	MI4	379	0.0586	9.8	1729	22.6	0.129	0.034	1.37	0.408
Lake Whitefish	UTSO	3	MI4	491	.	9.8	1729	22.6	.	.	.	1.46
Lake Whitefish	Fat	4	MI4	77	0.303	10.8	1704	22.7	0.131	0.17	8.08	4.34
Lake Whitefish	Skin	4	MI4	42	0.186	10.8	1704	22.7	0.131	0.14	5.90	2.87
Lake Whitefish	Muscle (edible portion)	4	MI4	368	0.0565	10.8	1704	22.7	0.129	0.043	1.28	0.381
Lake Whitefish	UTSO	4	MI4	487	.	10.8	1704	22.7	.	.	.	1.22
Lake Trout	Fat	1	MI2	119	0.339	10.5	3094	27.3	0.134	0.32	16.7	8.68
Lake Trout	Skin	1	MI2	82	0.195	10.5	3094	27.3	.	.	.	5.92
Lake Trout	Muscle (edible portion)	1	MI2	517	0.0960	10.5	3094	27.3	0.132	0.081	6.80	2.13
Lake Trout	UTSO	1	MI2	718	.	10.5	3094	27.3	.	.	.	3.65
Lake Trout	Fat	1	MI3	118	0.273	9.9	3163	27.4	0.132	0.25	10.8	5.60
Lake Trout	Skin	1	MI3	75	0.167	9.9	3163	27.4	.	.	.	5.14
Lake Trout	Muscle (edible portion)	1	MI3	623	0.0734	9.9	3163	27.4	0.134	0.066	4.65	1.46
Lake Trout	UTSO	1	MI3	816	.	9.9	3163	27.4	.	.	.	2.40
Lake Trout	Fat	1	MI4	116	0.342	8.0	3033	27.5	0.133	0.33	12.7	6.56
Lake Trout	Skin	1	MI4	70	0.160	8.0	3033	27.5	0.131	0.34	6.80	3.29
Lake Trout	Muscle (edible portion)	1	MI4	578	0.0869	8.0	3033	27.5	0.133	0.080	4.08	1.28
Lake Trout	UTSO	1	MI4	764	.	8.0	3033	27.5	.	.	.	2.26
Lake Trout	Fat	2	MI4	92	0.331	9.5	2967	27.3	0.129	0.32	19.0	9.77
Lake Trout	Skin	2	MI4	67	0.140	9.5	2967	27.3	0.134	0.066	12.4	6.03
Lake Trout	Muscle (edible portion)	2	MI4	546	0.0701	9.5	2967	27.3	0.134	0.061	3.05	0.956
Lake Trout	UTSO	2	MI4	705	.	9.5	2967	27.3	.	.	.	2.59
Lake Trout	Fat	3	MI4	114	0.326	10.6	2854	27.4	0.135	0.30	13.3	6.92
Lake Trout	Skin	3	MI4	66	0.154	10.6	2854	27.4	0.133	0.14	8.23	3.99
Lake Trout	Muscle (edible portion)	3	MI4	538	0.0866	10.6	2854	27.4	0.134	0.072	5.00	1.57
Lake Trout	UTSO	3	MI4	718	.	10.6	2854	27.4	.	.	.	2.64
Lake Trout	Fat	4	MI4	106	0.259	12.8	2917	27.7	0.435	0.28	18.9	15.0
Lake Trout	Skin	4	MI4	70	0.138	12.8	2917	27.7	0.133	0.13	13.4	6.49
Lake Trout	Muscle (edible portion)	4	MI4	575	0.0746	12.8	2917	27.7	0.133	0.066	5.21	1.63
Lake Trout	UTSO	4	MI4	751	.	12.8	2917	27.7	.	.	.	3.97
Lake Trout	Fat	1	MI4	88	0.376	6.5	2421	25.3	0.503	0.15	2.59	2.34
Lake Trout	Skin	1	MI4	59	0.167	6.5	2421	25.3	.	.	.	5.14

Appendix 1

Fish Species	Tissue Type	Comp. No.	Mgmt Unit	Mean Tissue Weight (g)	Lipid Content 1999 decimal	Age Years	Mean Round Weight (g)	Mean Length inches	Moisture Content 2003 decimal	Lipid Content 2003 decimal	Total TEQ Measured pg/g	Total TEQ Hydrated 1999 pg/g
Lake Trout	Muscle (edible portion)	1	MI4	476	0.0941	6.5	2421	25.3	0.703	0.076	1.67	1.53
Lake Trout	UTSO	1	MI4	623	.	6.5	2421	25.3	.	.	.	1.98
Lake Trout	Fat	2	MI4	89	0.353	8.1	2238	25.3	0.502	0.28	13.7	12.4
Lake Trout	Skin	2	MI4	56	0.155	8.1	2238	25.3	.	.	.	4.81
Lake Trout	Muscle (edible portion)	2	MI4	443	0.0841	8.1	2238	25.3	0.324	0.076	2.57	1.04
Lake Trout	UTSO	2	MI4	588	.	8.1	2238	25.3	.	.	.	3.11
Lake Trout	Fat	3	MI4	87	0.266	9.0	2305	25.4	0.376	0.29	13.3	9.59
Lake Trout	Skin	3	MI4	54	0.142	9.0	2305	25.4	.	.	.	4.44
Lake Trout	Muscle (edible portion)	3	MI4	447	0.0765	9.0	2305	25.4	0.785	0.048	2.34	2.96
Lake Trout	UTSO	3	MI4	588	.	9.0	2305	25.4	.	.	.	4.08
Lake Trout	Fat	4	MI4	86	0.280	11.0	2288	25.4	0.545	0.19	10.2	10.3
Lake Trout	Skin	4	MI4	56	0.150	11.0	2288	25.4	.	.	.	4.67
Lake Trout	Muscle (edible portion)	4	MI4	455	0.0746	11.0	2288	25.4	0.557	0.056	2.04	1.25
Lake Trout	UTSO	4	MI4	597	.	11.0	2288	25.4	.	.	.	2.88
Lake Trout	Fat	1	WI2	68	0.316	11.4	3022	27.5	0.133	0.28	20.3	10.5
Lake Trout	Skin	1	WI2	67	0.139	11.4	3022	27.5	.	.	.	4.36
Lake Trout	Muscle (edible portion)	1	WI2	556	0.0739	11.4	3022	27.5	0.133	0.054	4.56	1.43
Lake Trout	UTSO	1	WI2	691	.	11.4	3022	27.5	.	.	.	2.61
Siscowet Trout	Fat	1	MI4	91	0.301	16.5	2223	25.1	0.423	0.31	78.5	45.2
Siscowet Trout	Skin	1	MI4	56	0.146	16.5	2223	25.1	0.131	0.14	16.1	6.91
Siscowet Trout	Muscle (edible portion)	1	MI4	356	0.174	16.5	2223	25.1	0.133	0.18	21.8	5.55
Siscowet Trout	UTSO	1	MI4	503	.	16.5	2223	25.1	.	.	.	12.9
Siscowet Trout	Fat	2	MI4	108	0.317	14.6	2098	25.0	0.287	0.48	217	101
Siscowet Trout	Skin	2	MI4	56	0.125	14.6	2098	25.0	0.134	0.13	30.8	13.3
Siscowet Trout	Muscle (edible portion)	2	MI4	369	0.165	14.6	2098	25.0	0.133	0.15	20.0	5.09
Siscowet Trout	UTSO	2	MI4	533	.	14.6	2098	25.0	.	.	.	25.4
Siscowet Trout	Fat	3	MI4	99	0.353	17.6	2280	24.9	0.132	0.48	211	80.6
Siscowet Trout	Skin	3	MI4	60	0.140	17.6	2280	24.9	0.132	0.14	19.4	8.31
Siscowet Trout	Muscle (edible portion)	3	MI4	379	0.164	17.6	2280	24.9	0.129	0.16	21.8	5.53
Siscowet Trout	UTSO	3	MI4	538	.	17.6	2280	24.9	.	.	.	19.7
Siscowet Trout	Fat	4	MI4	119	0.340	19.4	2448	25.0	0.131	0.62	150	57.1
Siscowet Trout	Skin	4	MI4	59	0.150	19.4	2448	25.0	0.132	0.15	24.9	10.7
Siscowet Trout	Muscle (edible portion)	4	MI4	402	0.194	19.4	2448	25.0	0.131	0.20	33.8	8.60
Siscowet Trout	UTSO	4	MI4	580	.	19.4	2448	25.0	.	.	.	18.8
Lake Sturgeon	Muscle (edible portion)	1	MI2	.	0.0593	3.5	.	22.1	0.130	0.041	0.284	0.065
Lake Sturgeon	Muscle (edible portion)	2	MI2	.	0.0550	5.0	.	25.1	0.129	0.064	0.485	0.111
Lake Sturgeon	Muscle (edible portion)	3	MI2	.	0.100	9.0	.	39.1	0.131	0.088	0.831	0.191

APPENDIX 2

Lake Superior Fish Fillet Data and Dioxin/Furan (CDD/CDF) Toxic Equivalency (TEQ) Concentrations Calculated Using Environmental Protection Agency (EPA) Toxic Equivalency Factors (TEFs) and ½ Detection Limit Inserted for Non-Detected Congeners

Appendix 2

Fish Species	Tissue Type	Comp. No.	Mgmt Unit	Mean Tissue Weight (g)	Lipid Content 1999 decimal	Age Years	Mean Round Weight (g)	Mean Length inches	Moisture Content 2003 decimal	Lipid Content 2003 decimal	Total TEQ Measured pg/g	Total TEQ Hydrated 1999 pg/g
Lake Herring	UTSO	1	MI4	.	0.0448	9.2	579	16.1	0.131	0.031	0.814	0.243
Lake Herring	UTSO	2	MI4	.	0.0502	9.1	638	16.5	0.129	0.031	1.51	0.451
Lake Herring	UTSO	3	MI4	.	0.0550	9.6	633	16.5	0.129	0.040	1.37	0.409
Lake Herring	UTSO	4	MI4	.	0.0552	9.8	604	16.5	0.129	0.046	1.18	0.352
Lake Whitefish	Fat	1	MI4	36	0.259	7.7	1496	22.6	0.130	0.29	13.2	7.06
Lake Whitefish	Skin	1	MI4	44	0.135	7.7	1496	22.6	0.129	0.091	5.99	2.91
Lake Whitefish	Muscle (edible portion)	1	MI4	350	0.0428	7.7	1496	22.6	0.131	0.034	1.80	0.537
Lake Whitefish	UTSO	1	MI4	430	.	7.7	1496	22.6	.	.	.	1.33
Lake Whitefish	Fat	2	MI4	66	0.237	8.9	1659	22.4	0.134	0.23	9.59	5.17
Lake Whitefish	Skin	2	MI4	45	0.190	8.9	1659	22.4	0.130	0.18	6.39	3.11
Lake Whitefish	Muscle (edible portion)	2	MI4	397	0.0444	8.9	1659	22.4	0.134	0.034	1.59	0.475
Lake Whitefish	UTSO	2	MI4	508	.	8.9	1659	22.4	.	.	.	1.32
Lake Whitefish	Fat	3	MI4	69	0.269	9.8	1729	22.6	0.132	0.26	11.4	6.16
Lake Whitefish	Skin	3	MI4	43	0.189	9.8	1729	22.6	0.131	0.17	8.01	3.90
Lake Whitefish	Muscle (edible portion)	3	MI4	379	0.0586	9.8	1729	22.6	0.129	0.034	1.56	0.465
Lake Whitefish	UTSO	3	MI4	491	.	9.8	1729	22.6	.	.	.	1.57
Lake Whitefish	Fat	4	MI4	77	0.303	10.8	1704	22.7	0.131	0.17	8.27	4.44
Lake Whitefish	Skin	4	MI4	42	0.186	10.8	1704	22.7	0.131	0.14	6.29	3.06
Lake Whitefish	Muscle (edible portion)	4	MI4	368	0.0565	10.8	1704	22.7	0.129	0.043	1.42	0.423
Lake Whitefish	UTSO	4	MI4	487	.	10.8	1704	22.7	.	.	.	1.29
Lake Trout	Fat	1	MI2	119	0.339	10.5	3094	27.3	0.134	0.32	17.9	9.27
Lake Trout	Skin	1	MI2	82	0.195	10.5	3094	27.3	.	.	.	6.54
Lake Trout	Muscle (edible portion)	1	MI2	517	0.0960	10.5	3094	27.3	0.132	0.081	7.17	2.25
Lake Trout	UTSO	1	MI2	718	.	10.5	3094	27.3	.	.	.	3.90
Lake Trout	Fat	1	MI3	118	0.273	9.9	3163	27.4	0.132	0.25	12.0	6.22
Lake Trout	Skin	1	MI3	75	0.167	9.9	3163	27.4	.	.	.	5.78
Lake Trout	Muscle (edible portion)	1	MI3	623	0.0734	9.9	3163	27.4	0.134	0.066	5.85	1.84
Lake Trout	UTSO	1	MI3	816	.	9.9	3163	27.4	.	.	.	2.83
Lake Trout	Fat	1	MI4	116	0.342	8.0	3033	27.5	0.133	0.33	14.1	7.31
Lake Trout	Skin	1	MI4	70	0.160	8.0	3033	27.5	0.131	0.34	8.15	3.94
Lake Trout	Muscle (edible portion)	1	MI4	578	0.0869	8.0	3033	27.5	0.133	0.080	4.43	1.39
Lake Trout	UTSO	1	MI4	764	.	8.0	3033	27.5	.	.	.	2.52
Lake Trout	Fat	2	MI4	92	0.331	9.5	2967	27.3	0.129	0.32	21.1	10.9
Lake Trout	Skin	2	MI4	67	0.140	9.5	2967	27.3	0.134	0.066	15.3	7.42
Lake Trout	Muscle (edible portion)	2	MI4	546	0.0701	9.5	2967	27.3	0.134	0.061	3.26	1.02
Lake Trout	UTSO	2	MI4	705	.	9.5	2967	27.3	.	.	.	2.91
Lake Trout	Fat	3	MI4	114	0.326	10.6	2854	27.4	0.135	0.30	14.5	7.52
Lake Trout	Skin	3	MI4	66	0.154	10.6	2854	27.4	0.133	0.14	8.75	4.24
Lake Trout	Muscle (edible portion)	3	MI4	538	0.0866	10.6	2854	27.4	0.134	0.072	5.65	1.77
Lake Trout	UTSO	3	MI4	718	.	10.6	2854	27.4	.	.	.	2.91
Lake Trout	Fat	4	MI4	106	0.259	12.8	2917	27.7	0.435	0.28	19.1	15.2
Lake Trout	Skin	4	MI4	70	0.138	12.8	2917	27.7	0.133	0.13	15.8	7.65
Lake Trout	Muscle (edible portion)	4	MI4	575	0.0746	12.8	2917	27.7	0.133	0.066	5.84	1.83
Lake Trout	UTSO	4	MI4	751	.	12.8	2917	27.7	.	.	.	4.26

Appendix 2

Fish Species	Tissue Type	Comp. No.	Mgmt Unit	Mean Tissue Weight (g)	Lipid Content 1999 decimal	Age Years	Mean Round Weight (g)	Mean Length inches	Moisture Content 2003 decimal	Lipid Content 2003 decimal	Total TEQ Measured pg/g	Total TEQ Hydrated 1999 pg/g
Lake Trout	Fat	1	MI4	88	0.376	6.5	2421	25.3	0.503	0.15	2.87	2.59
Lake Trout	Skin	1	MI4	59	0.167	6.5	2421	25.3	.	.	.	5.78
Lake Trout	Muscle (edible portion)	1	MI4	476	0.0941	6.5	2421	25.3	0.703	0.076	3.77	3.45
Lake Trout	UTSO	1	MI4	623	.	6.5	2421	25.3	.	.	.	3.55
Lake Trout	Fat	2	MI4	89	0.35	8.1	2238	25.3	0.502	0.28	14.0	12.6
Lake Trout	Skin	2	MI4	56	0.16	8.1	2238	25.3	.	.	.	5.46
Lake Trout	Muscle (edible portion)	2	MI4	443	0.084	8.1	2238	25.3	0.324	0.076	5.07	2.04
Lake Trout	UTSO	2	MI4	588	.	8.1	2238	25.3	.	.	.	3.97
Lake Trout	Fat	3	MI4	87	0.27	9.0	2305	25.4	0.376	0.29	13.8	9.94
Lake Trout	Skin	3	MI4	54	0.14	9.0	2305	25.4	.	.	.	5.11
Lake Trout	Muscle (edible portion)	3	MI4	447	0.077	9.0	2305	25.4	0.785	0.048	4.09	5.17
Lake Trout	UTSO	3	MI4	588	.	9.0	2305	25.4	.	.	.	5.87
Lake Trout	Fat	4	MI4	86	0.28	11.0	2288	25.4	0.545	0.19	10.5	10.6
Lake Trout	Skin	4	MI4	56	0.15	11.0	2288	25.4	.	.	.	5.32
Lake Trout	Muscle (edible portion)	4	MI4	455	0.075	11.0	2288	25.4	0.557	0.056	3.84	2.36
Lake Trout	UTSO	4	MI4	597	.	11.0	2288	25.4	.	.	.	3.82
Lake Trout	Fat	1	WI2	68	0.32	11.4	3022	27.5	0.133	0.28	21.5	11.1
Lake Trout	Skin	1	WI2	67	0.14	11.4	3022	27.5	.	.	.	5.03
Lake Trout	Muscle (edible portion)	1	WI2	556	0.074	11.4	3022	27.5	0.133	0.054	5.41	1.70
Lake Trout	UTSO	1	WI2	691	.	11.4	3022	27.5	.	.	.	2.95
Siscowet Trout	Fat	1	MI4	91	0.30	16.5	2223	25.1	0.423	0.31	79.7	45.8
Siscowet Trout	Skin	1	MI4	56	0.15	16.5	2223	25.1	0.131	0.14	16.8	7.18
Siscowet Trout	Muscle (edible portion)	1	MI4	356	0.17	16.5	2223	25.1	0.133	0.18	22.4	5.70
Siscowet Trout	UTSO	1	MI4	503	.	16.5	2223	25.1	.	.	.	13.1
Siscowet Trout	Fat	2	MI4	108	0.32	14.6	2098	25.0	0.287	0.48	218	101
Siscowet Trout	Skin	2	MI4	56	0.13	14.6	2098	25.0	0.134	0.13	31.3	13.4
Siscowet Trout	Muscle (edible portion)	2	MI4	369	0.17	14.6	2098	25.0	0.133	0.15	21.1	5.37
Siscowet Trout	UTSO	2	MI4	533	.	14.6	2098	25.0	.	.	.	25.7
Siscowet Trout	Fat	3	MI4	99	0.35	17.6	2280	24.9	0.132	0.48	212	81.0
Siscowet Trout	Skin	3	MI4	60	0.14	17.6	2280	24.9	0.132	0.14	19.8	8.49
Siscowet Trout	Muscle (edible portion)	3	MI4	379	0.16	17.6	2280	24.9	0.129	0.16	22.4	5.69
Siscowet Trout	UTSO	3	MI4	538	.	17.6	2280	24.9	.	.	.	19.9
Siscowet Trout	Fat	4	MI4	119	0.34	19.4	2448	25.0	0.131	0.62	150	57.4
Siscowet Trout	Skin	4	MI4	59	0.15	19.4	2448	25.0	0.132	0.15	25.3	10.8
Siscowet Trout	Muscle (edible portion)	4	MI4	402	0.19	19.4	2448	25.0	0.131	0.20	34.6	8.79
Siscowet Trout	UTSO	4	MI4	580	.	19.4	2448	25.0	.	.	.	19.0
Lake Sturgeon	Muscle (edible portion)	1	MI2	.	0.059	3.5	.	22.1	0.130	0.041	1.63	0.376
Lake Sturgeon	Muscle (edible portion)	2	MI2	.	0.055	5.0	.	25.1	0.129	0.064	1.01	0.232
Lake Sturgeon	Muscle (edible portion)	3	MI2	.	0.10	9.0	.	39.1	0.131	0.088	1.83	0.421

APPENDIX 3

Lake Superior Fish Fillet Data and Dioxin/Furan (CDD/CDF) Toxic Equivalency (TEQ) Concentrations Calculated Using World Health Organization (WHO) Toxic Equivalency Factors (TEFs) and Zero Inserted for Non-Detected Congeners

Appendix 3

Fish Species	Tissue Type	Comp. No.	Mgmt Unit	Mean Tissue Weight (g)	Lipid Content 1999 decimal	Age Years	Mean Round Weight (g)	Mean Length inches	Moisture Content 2003 decimal	Lipid Content 2003 decimal	Total TEQ Measured pg/g	Total TEQ Hydrated 1999 pg/g
Lake Herring	UTSO	1	MI4	.	0.0448	9.2	579	16.1	0.131	0.031	0.363	0.108
Lake Herring	UTSO	2	MI4	.	0.0502	9.1	638	16.5	0.129	0.031	0.590	0.176
Lake Herring	UTSO	3	MI4	.	0.0550	9.6	633	16.5	0.129	0.040	0.540	0.161
Lake Herring	UTSO	4	MI4	.	0.0552	9.8	604	16.5	0.129	0.046	0.608	0.181
Lake Whitefish	Fat	1	MI4	36	0.259	7.7	1496	22.6	0.130	0.29	16.0	8.57
Lake Whitefish	Skin	1	MI4	44	0.135	7.7	1496	22.6	0.129	0.091	7.05	3.42
Lake Whitefish	Muscle (edible portion)	1	MI4	350	0.0428	7.7	1496	22.6	0.131	0.034	2.00	0.595
Lake Whitefish	UTSO	1	MI4	430	.	7.7	1496	22.6	.	.	.	1.55
Lake Whitefish	Fat	2	MI4	66	0.237	8.9	1659	22.4	0.134	0.23	11.6	6.28
Lake Whitefish	Skin	2	MI4	45	0.190	8.9	1659	22.4	0.130	0.18	7.56	3.67
Lake Whitefish	Muscle (edible portion)	2	MI4	397	0.0444	8.9	1659	22.4	0.134	0.034	1.76	0.527
Lake Whitefish	UTSO	2	MI4	508	.	8.9	1659	22.4	.	.	.	1.55
Lake Whitefish	Fat	3	MI4	69	0.269	9.8	1729	22.6	0.132	0.26	13.3	7.15
Lake Whitefish	Skin	3	MI4	43	0.189	9.8	1729	22.6	0.131	0.17	9.50	4.62
Lake Whitefish	Muscle (edible portion)	3	MI4	379	0.0586	9.8	1729	22.6	0.129	0.034	1.74	0.518
Lake Whitefish	UTSO	3	MI4	491	.	9.8	1729	22.6	.	.	.	1.81
Lake Whitefish	Fat	4	MI4	77	0.303	10.8	1704	22.7	0.131	0.17	10.1	5.44
Lake Whitefish	Skin	4	MI4	42	0.186	10.8	1704	22.7	0.131	0.14	7.25	3.53
Lake Whitefish	Muscle (edible portion)	4	MI4	368	0.0565	10.8	1704	22.7	0.129	0.043	1.63	0.485
Lake Whitefish	UTSO	4	MI4	487	.	10.8	1704	22.7	.	.	.	1.53
Lake Trout	Fat	1	MI2	119	0.339	10.5	3094	27.3	0.134	0.32	20.3	10.5
Lake Trout	Skin	1	MI2	82	0.195	10.5	3094	27.3	.	.	.	7.01
Lake Trout	Muscle (edible portion)	1	MI2	517	0.0960	10.5	3094	27.3	0.132	0.081	7.85	2.46
Lake Trout	UTSO	1	MI2	718	.	10.5	3094	27.3	.	.	.	4.32
Lake Trout	Fat	1	MI3	118	0.273	9.9	3163	27.4	0.132	0.25	13.5	7.00
Lake Trout	Skin	1	MI3	75	0.167	9.9	3163	27.4	.	.	.	6.09
Lake Trout	Muscle (edible portion)	1	MI3	623	0.0734	9.9	3163	27.4	0.134	0.066	5.35	1.68
Lake Trout	UTSO	1	MI3	816	.	9.9	3163	27.4	.	.	.	2.85
Lake Trout	Fat	1	MI4	116	0.342	8.0	3033	27.5	0.133	0.33	17.1	8.86
Lake Trout	Skin	1	MI4	70	0.160	8.0	3033	27.5	0.131	0.34	8.15	3.94
Lake Trout	Muscle (edible portion)	1	MI4	578	0.0869	8.0	3033	27.5	0.133	0.080	4.88	1.53
Lake Trout	UTSO	1	MI4	764	.	8.0	3033	27.5	.	.	.	2.86
Lake Trout	Fat	2	MI4	92	0.331	9.5	2967	27.3	0.129	0.32	23.2	12.0
Lake Trout	Skin	2	MI4	67	0.140	9.5	2967	27.3	0.134	0.066	14.6	7.08
Lake Trout	Muscle (edible portion)	2	MI4	546	0.0701	9.5	2967	27.3	0.134	0.061	3.85	1.21
Lake Trout	UTSO	2	MI4	705	.	9.5	2967	27.3	.	.	.	3.17
Lake Trout	Fat	3	MI4	114	0.326	10.6	2854	27.4	0.135	0.30	16.4	8.50
Lake Trout	Skin	3	MI4	66	0.154	10.6	2854	27.4	0.133	0.14	9.88	4.78
Lake Trout	Muscle (edible portion)	3	MI4	538	0.0866	10.6	2854	27.4	0.134	0.072	6.00	1.88
Lake Trout	UTSO	3	MI4	718	.	10.6	2854	27.4	.	.	.	3.20
Lake Trout	Fat	4	MI4	106	0.259	12.8	2917	27.7	0.435	0.28	18.9	15.0
Lake Trout	Skin	4	MI4	70	0.138	12.8	2917	27.7	0.133	0.13	15.0	7.27
Lake Trout	Muscle (edible portion)	4	MI4	575	0.0746	12.8	2917	27.7	0.133	0.066	6.31	1.98
Lake Trout	UTSO	4	MI4	751	.	12.8	2917	27.7	.	.	.	4.31

Appendix 3

Fish Species	Tissue Type	Comp. No.	Mgmt Unit	Mean Tissue Weight (g)	Lipid Content 1999 decimal	Age Years	Mean Round Weight (g)	Mean Length inches	Moisture Content 2003 decimal	Lipid Content 2003 decimal	Total TEQ Measured pg/g	Total TEQ Hydrated 1999 pg/g
Lake Trout	Fat	1	MI4	88	0.376	6.5	2421	25.3	0.503	0.15	3.44	3.10
Lake Trout	Skin	1	MI4	59	0.167	6.5	2421	25.3	.	.	.	6.09
Lake Trout	Muscle (edible portion)	1	MI4	476	0.0941	6.5	2421	25.3	0.703	0.076	2.05	1.87
Lake Trout	UTSO	1	MI4	623	.	6.5	2421	25.3	.	.	.	2.45
Lake Trout	Fat	2	MI4	89	0.353	8.1	2238	25.3	0.502	0.28	16.0	14.4
Lake Trout	Skin	2	MI4	56	0.155	8.1	2238	25.3	.	.	.	5.69
Lake Trout	Muscle (edible portion)	2	MI4	443	0.0841	8.1	2238	25.3	0.324	0.076	3.12	1.26
Lake Trout	UTSO	2	MI4	588	.	8.1	2238	25.3	.	.	.	3.67
Lake Trout	Fat	3	MI4	87	0.266	9.0	2305	25.4	0.376	0.29	15.6	11.2
Lake Trout	Skin	3	MI4	54	0.142	9.0	2305	25.4	.	.	.	5.26
Lake Trout	Muscle (edible portion)	3	MI4	447	0.0765	9.0	2305	25.4	0.785	0.048	2.84	3.59
Lake Trout	UTSO	3	MI4	588	.	9.0	2305	25.4	.	.	.	4.88
Lake Trout	Fat	4	MI4	86	0.280	11.0	2288	25.4	0.545	0.19	12.4	12.5
Lake Trout	Skin	4	MI4	56	0.150	11.0	2288	25.4	.	.	.	5.53
Lake Trout	Muscle (edible portion)	4	MI4	455	0.0746	11.0	2288	25.4	0.557	0.056	2.45	1.51
Lake Trout	UTSO	4	MI4	597	.	11.0	2288	25.4	.	.	.	3.47
Lake Trout	Fat	1	WI2	68	0.316	11.4	3022	27.5	0.133	0.28	24.6	12.7
Lake Trout	Skin	1	WI2	67	0.139	11.4	3022	27.5	.	.	.	5.17
Lake Trout	Muscle (edible portion)	1	WI2	556	0.0739	11.4	3022	27.5	0.133	0.054	5.41	1.70
Lake Trout	UTSO	1	WI2	691	.	11.4	3022	27.5	.	.	.	3.12
Siscowet Trout	Fat	1	MI4	91	0.301	16.5	2223	25.1	0.423	0.31	88.1	50.7
Siscowet Trout	Skin	1	MI4	56	0.146	16.5	2223	25.1	0.131	0.14	17.9	7.66
Siscowet Trout	Muscle (edible portion)	1	MI4	356	0.174	16.5	2223	25.1	0.133	0.18	25.1	6.40
Siscowet Trout	UTSO	1	MI4	503	.	16.5	2223	25.1	.	.	.	14.6
Siscowet Trout	Fat	2	MI4	108	0.317	14.6	2098	25.0	0.287	0.48	225	105
Siscowet Trout	Skin	2	MI4	56	0.125	14.6	2098	25.0	0.134	0.13	33.0	14.2
Siscowet Trout	Muscle (edible portion)	2	MI4	369	0.165	14.6	2098	25.0	0.133	0.15	24.1	6.15
Siscowet Trout	UTSO	2	MI4	533	.	14.6	2098	25.0	.	.	.	26.9
Siscowet Trout	Fat	3	MI4	99	0.353	17.6	2280	24.9	0.132	0.48	219	83.6
Siscowet Trout	Skin	3	MI4	60	0.140	17.6	2280	24.9	0.132	0.14	22.0	9.43
Siscowet Trout	Muscle (edible portion)	3	MI4	379	0.164	17.6	2280	24.9	0.129	0.16	23.9	6.06
Siscowet Trout	UTSO	3	MI4	538	.	17.6	2280	24.9	.	.	.	20.7
Siscowet Trout	Fat	4	MI4	119	0.340	19.4	2448	25.0	0.131	0.62	159	60.7
Siscowet Trout	Skin	4	MI4	59	0.150	19.4	2448	25.0	0.132	0.15	27.1	11.6
Siscowet Trout	Muscle (edible portion)	4	MI4	402	0.194	19.4	2448	25.0	0.131	0.20	33.8	8.60
Siscowet Trout	UTSO	4	MI4	580	.	19.4	2448	25.0	.	.	.	19.6
Lake Sturgeon	Muscle (edible portion)	1	MI2	.	0.0593	3.5	.	22.1	0.130	0.041	0.284	0.0653
Lake Sturgeon	Muscle (edible portion)	2	MI2	.	0.0550	5.0	.	25.1	0.129	0.064	0.614	0.141
Lake Sturgeon	Muscle (edible portion)	3	MI2	.	0.100	9.0	.	39.1	0.131	0.088	0.941	0.217

APPENDIX 4

Lake Superior Fish Fillet Data and Dioxin/Furan (CDD/CDF) Toxic Equivalency (TEQ) Concentrations Calculated Using World Health Organization (WHO) Toxic Equivalency Factors (TEFs) and ½ Detection Limit Inserted for Non-Detected Congeners

Appendix 4

Fish Species	Tissue Type	Comp. No.	Mgmt Unit	Mean Tissue Weight (g)	Lipid Content 1999 decimal	Age Years	Mean Round Weight (g)	Mean Length inches	Moisture Content 2003 decimal	Lipid Content 2003 decimal	Total TEQ Measured pg/g	Total TEQ Hydrated 1999 pg/g
Lake Herring	UTSO	1	MI4	.	0.0448	9.2	579	16.1	0.131	0.031	0.928	0.277
Lake Herring	UTSO	2	MI4	.	0.0502	9.1	638	16.5	0.129	0.031	1.67	0.497
Lake Herring	UTSO	3	MI4	.	0.0550	9.6	633	16.5	0.129	0.040	1.47	0.439
Lake Herring	UTSO	4	MI4	.	0.0552	9.8	604	16.5	0.129	0.046	1.30	0.387
Lake Whitefish	Fat	1	MI4	36	0.259	7.7	1496	22.6	0.130	0.29	16.4	8.81
Lake Whitefish	Skin	1	MI4	44	0.135	7.7	1496	22.6	0.129	0.091	7.44	3.61
Lake Whitefish	Muscle (edible portion)	1	MI4	350	0.0428	7.7	1496	22.6	0.131	0.034	2.21	0.657
Lake Whitefish	UTSO	1	MI4	430	.	7.7	1496	22.6	.	.	.	1.64
Lake Whitefish	Fat	2	MI4	66	0.237	8.9	1659	22.4	0.134	0.23	12.1	6.55
Lake Whitefish	Skin	2	MI4	45	0.190	8.9	1659	22.4	0.130	0.18	7.94	3.86
Lake Whitefish	Muscle (edible portion)	2	MI4	397	0.0444	8.9	1659	22.4	0.134	0.034	1.93	0.577
Lake Whitefish	UTSO	2	MI4	508	.	8.9	1659	22.4	.	.	.	1.64
Lake Whitefish	Fat	3	MI4	69	0.269	9.8	1729	22.6	0.132	0.26	14.0	7.53
Lake Whitefish	Skin	3	MI4	43	0.189	9.8	1729	22.6	0.131	0.17	9.81	4.78
Lake Whitefish	Muscle (edible portion)	3	MI4	379	0.0586	9.8	1729	22.6	0.129	0.034	1.93	0.575
Lake Whitefish	UTSO	3	MI4	491	.	9.8	1729	22.6	.	.	.	1.92
Lake Whitefish	Fat	4	MI4	77	0.303	10.8	1704	22.7	0.131	0.17	10.3	5.54
Lake Whitefish	Skin	4	MI4	42	0.186	10.8	1704	22.7	0.131	0.14	7.64	3.72
Lake Whitefish	Muscle (edible portion)	4	MI4	368	0.0565	10.8	1704	22.7	0.129	0.043	1.77	0.527
Lake Whitefish	UTSO	4	MI4	487	.	10.8	1704	22.7	.	.	.	1.60
Lake Trout	Fat	1	MI2	119	0.339	10.5	3094	27.3	0.134	0.32	21.5	11.1
Lake Trout	Skin	1	MI2	82	0.195	10.5	3094	27.3	.	.	.	7.63
Lake Trout	Muscle (edible portion)	1	MI2	517	0.0960	10.5	3094	27.3	0.132	0.081	8.22	2.57
Lake Trout	UTSO	1	MI2	718	.	10.5	3094	27.3	.	.	.	4.57
Lake Trout	Fat	1	MI3	118	0.273	9.9	3163	27.4	0.132	0.25	14.7	7.62
Lake Trout	Skin	1	MI3	75	0.167	9.9	3163	27.4	.	.	.	6.73
Lake Trout	Muscle (edible portion)	1	MI3	623	0.0734	9.9	3163	27.4	0.134	0.066	6.55	2.06
Lake Trout	UTSO	1	MI3	816	.	9.9	3163	27.4	.	.	.	3.29
Lake Trout	Fat	1	MI4	116	0.342	8.0	3033	27.5	0.133	0.33	18.6	9.61
Lake Trout	Skin	1	MI4	70	0.160	8.0	3033	27.5	0.131	0.34	9.50	4.59
Lake Trout	Muscle (edible portion)	1	MI4	578	0.0869	8.0	3033	27.5	0.133	0.080	5.23	1.64
Lake Trout	UTSO	1	MI4	764	.	8.0	3033	27.5	.	.	.	3.12
Lake Trout	Fat	2	MI4	92	0.331	9.5	2967	27.3	0.129	0.32	25.3	13.0
Lake Trout	Skin	2	MI4	67	0.140	9.5	2967	27.3	0.134	0.066	17.4	8.46
Lake Trout	Muscle (edible portion)	2	MI4	546	0.0701	9.5	2967	27.3	0.134	0.061	4.06	1.28
Lake Trout	UTSO	2	MI4	705	.	9.5	2967	27.3	.	.	.	3.49
Lake Trout	Fat	3	MI4	114	0.326	10.6	2854	27.4	0.135	0.30	17.5	9.10
Lake Trout	Skin	3	MI4	66	0.154	10.6	2854	27.4	0.133	0.14	10.4	5.04
Lake Trout	Muscle (edible portion)	3	MI4	538	0.0866	10.6	2854	27.4	0.134	0.072	6.65	2.09
Lake Trout	UTSO	3	MI4	718	.	10.6	2854	27.4	.	.	.	3.47
Lake Trout	Fat	4	MI4	106	0.259	12.8	2917	27.7	0.435	0.28	19.1	15.2
Lake Trout	Skin	4	MI4	70	0.138	12.8	2917	27.7	0.133	0.13	17.4	8.43
Lake Trout	Muscle (edible portion)	4	MI4	575	0.0746	12.8	2917	27.7	0.133	0.066	6.94	2.18
Lake Trout	UTSO	4	MI4	751	.	12.8	2917	27.7	.	.	.	4.60

Appendix 4

Fish Species	Tissue Type	Comp. No.	Mgmt Unit	Mean Tissue Weight (g)	Lipid Content 1999 decimal	Age Years	Mean Round Weight (g)	Mean Length inches	Moisture Content 2003 decimal	Lipid Content 2003 decimal	Total TEQ Measured pg/g	Total TEQ Hydrated 1999 pg/g
Lake Trout	Fat	1	MI4	88	0.376	6.5	2421	25.3	0.503	0.15	3.72	3.36
Lake Trout	Skin	1	MI4	59	0.167	6.5	2421	25.3	.	.	.	6.73
Lake Trout	Muscle (edible portion)	1	MI4	476	0.0941	6.5	2421	25.3	0.703	0.076	4.15	3.80
Lake Trout	UTSO	1	MI4	623	.	6.5	2421	25.3	.	.	.	4.01
Lake Trout	Fat	2	MI4	89	0.353	8.1	2238	25.3	0.502	0.28	16.2	14.6
Lake Trout	Skin	2	MI4	56	0.155	8.1	2238	25.3	.	.	.	6.34
Lake Trout	Muscle (edible portion)	2	MI4	443	0.0841	8.1	2238	25.3	0.324	0.076	5.62	2.26
Lake Trout	UTSO	2	MI4	588	.	8.1	2238	25.3	.	.	.	4.52
Lake Trout	Fat	3	MI4	87	0.266	9.0	2305	25.4	0.376	0.29	16.1	11.6
Lake Trout	Skin	3	MI4	54	0.142	9.0	2305	25.4	.	.	.	5.92
Lake Trout	Muscle (edible portion)	3	MI4	447	0.0765	9.0	2305	25.4	0.785	0.048	4.59	5.81
Lake Trout	UTSO	3	MI4	588	.	9.0	2305	25.4	.	.	.	6.67
Lake Trout	Fat	4	MI4	86	0.280	11.0	2288	25.4	0.545	0.19	12.7	12.8
Lake Trout	Skin	4	MI4	56	0.150	11.0	2288	25.4	.	.	.	6.18
Lake Trout	Muscle (edible portion)	4	MI4	455	0.0746	11.0	2288	25.4	0.557	0.056	4.25	2.61
Lake Trout	UTSO	4	MI4	597	.	11.0	2288	25.4	.	.	.	4.41
Lake Trout	Fat	1	WI2	68	0.316	11.4	3022	27.5	0.133	0.28	25.8	13.3
Lake Trout	Skin	1	WI2	67	0.139	11.4	3022	27.5	.	.	.	5.83
Lake Trout	Muscle (edible portion)	1	WI2	556	0.0739	11.4	3022	27.5	0.133	0.054	6.26	1.96
Lake Trout	UTSO	1	WI2	691	.	11.4	3022	27.5	.	.	.	3.46
Siscowet Trout	Fat	1	MI4	91	0.301	16.5	2223	25.1	0.423	0.31	89.3	51.4
Siscowet Trout	Skin	1	MI4	56	0.146	16.5	2223	25.1	0.131	0.14	18.5	7.93
Siscowet Trout	Muscle (edible portion)	1	MI4	356	0.174	16.5	2223	25.1	0.133	0.18	25.7	6.56
Siscowet Trout	UTSO	1	MI4	503	.	16.5	2223	25.1	.	.	.	14.8
Siscowet Trout	Fat	2	MI4	108	0.317	14.6	2098	25.0	0.287	0.48	225	105
Siscowet Trout	Skin	2	MI4	56	0.125	14.6	2098	25.0	0.134	0.13	33.4	14.4
Siscowet Trout	Muscle (edible portion)	2	MI4	369	0.165	14.6	2098	25.0	0.133	0.15	25.2	6.43
Siscowet Trout	UTSO	2	MI4	533	.	14.6	2098	25.0	.	.	.	27.2
Siscowet Trout	Fat	3	MI4	99	0.353	17.6	2280	24.9	0.132	0.48	220	84.0
Siscowet Trout	Skin	3	MI4	60	0.140	17.6	2280	24.9	0.132	0.14	22.4	9.60
Siscowet Trout	Muscle (edible portion)	3	MI4	379	0.164	17.6	2280	24.9	0.129	0.16	24.5	6.23
Siscowet Trout	UTSO	3	MI4	538	.	17.6	2280	24.9	.	.	.	20.9
Siscowet Trout	Fat	4	MI4	119	0.340	19.4	2448	25.0	0.131	0.62	159	60.9
Siscowet Trout	Skin	4	MI4	59	0.150	19.4	2448	25.0	0.132	0.15	27.5	11.8
Siscowet Trout	Muscle (edible portion)	4	MI4	402	0.194	19.4	2448	25.0	0.131	0.20	34.6	8.79
Siscowet Trout	UTSO	4	MI4	580	.	19.4	2448	25.0	.	.	.	19.8
Lake Sturgeon	Muscle (edible portion)	1	MI2	.	0.0593	3.5	.	22.1	0.130	0.041	1.63	0.376
Lake Sturgeon	Muscle (edible portion)	2	MI2	.	0.0550	5.0	.	25.1	0.129	0.064	1.14	0.262
Lake Sturgeon	Muscle (edible portion)	3	MI2	.	0.100	9.0	.	39.1	0.131	0.088	1.94	0.447