TITLE

THE USE OF GREAT LAKES FISH SPECIES AS BIOINDICATORS OF ENVIRONMENTAL CONTAMINATION AND THE EFFECT OF FOOD PROCESSING ON THE REDUCTION OF POLYCHLORINATED BIPHENYL (PCB) CONGENERS, HOMOLOGS AND TOTAL PCBs

By

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ABSTRACT

THE USE OF GREAT LAKES FISH SPECIES AS BIOINDICATORS OF ENVIRONMENTAL CONTAMINATION AND THE EFFECT OF FOOD PROCESSING ON THE REDUCTION OF POLYCHLORINATED BIPHENYL (PCB) CONGENERS, HOMOLOGS AND TOTAL PCBs

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The purpose of this project was to determine the concentration and distribution pattern of PCB congeners and homologs in fish species: carp, chinook salmon, lake trout (siscowets), walleye, and white bass. These were harvested from Lake Huron, Ontario, Michigan, Erie and Superior. The fish were processed into skin-on and skin-off fillets and deep fat fried, pan fried, baked, charbroiled, salt boiled, smoked and canned. The effect of food processing -trimming, skin removal and cooking- on the reduction of total PCBs and their homologs was evaluated. Physical parameters of the fish - length, weight, age and sex - were measured. An average of 50% of lipid content and 10% of total fish weight was eliminated from raw fish fillets through skin removal procedure. The results showed that skin removal, fat trimming, and the cooking process did not alter the distribution patterns of PCB congeners. Prominent congeners 87, 158, 66/95/121, 42, 84/101 and 118 were observed in both skin-on and skin-off carp fillets. PCB homologs grouped by

chlorination for the Great Lakes fish had a distribution pattern similar to Aroclor® 1254. Concentration of total PCBs for walleye gave a linear relation between GC-capillary column analysis and GC-packed column analysis without influence of fat content. Only six out of one hundred and twenty-seven fish fillets had total PCBs above FDA action level (2 ppm) based on GC-packed column analyses. Fish harvested at the same location had at least 20% less total PCBs when processed as skin-off fillets than those processed as skin-on fillets. Skin removal before cooking enhanced the reduction of PCB concentration, but the average reduction of PCBs through cooking and skin removal after cooking was 28% to 40%. The most effective cooking method in this study was smoking, which caused a 48% reduction of PCBs in lake trout, and the least effective in lake trout was salt boiling (21%). The relationship between size of the fish and levels of total PCBs is predominated more by length than by weight.

To Jesus Christ my Lord as the Life-Giving Spirit
And His Body as the Bride

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INTRODUCTION

Polychlorinated biphenyls (PCBs) are the complex chemical mixtures of 209 possible PCB congeners which widely used in capacitors, transformers, lubricants and other industrial applications between 1929 and 1972. Their low aqueous solubility, hydrophobicity and resistance to degradation resulted in the aerial transport to atmosphere, to aquatic and sedimental environment (Eisenreich et al., 1981; Hermanson et al., 1991) including fish (Mac and Schwartz, 1992), wildlife, even to plant (Shane and Bush, 1989), human adipose tissues (Schmid et al., 1992), serum (Schwartz et al., 1983; Jacobson et al., 1989), and milk (Dewailly et al., 1989; Hong et al., 1992a). Currently PCBs are present throughout the global ecosystem (Ravid et al., 1985; El Nabawi et al., 1987; Satsmadjis et al., 1988; Leonzio et al., 1992).

Even after use of PCBs were commercially banned, PCB congeners continue to translocate in the environment by atmospheric transport and deposition, point source discharge, agriculture run-off, sewage waste, paper mill effluent into aquatic system and dredging with existing polluted sediment (Seelye et al, 1982). Scientists (Thomann and Connolly, 1984; Borlakoglu et al., 1988) have proved that the mechanism of PCB congeners in aquatic ecosystem is modelled as the bioconcentration of PCB congeners in water, and biota (Wang et al., 1982), bioaccumulation of PCBs in plankton, and biomagnification of PCB congeners concentration in predators (Oost et al, 1988). Since PCBs can bioaccumulate in the aquatic ecosystem, species such as lake trout, chinook salmon, which are near the top of the food chain, can be useful as indicators of contaminant levels in the aquatic ecosystem. As the angler and sportsman seemingly consumed the highest level of PCBs in the food chain, the risk of consuming PCBs contaminated fish has been under investigation through various monitoring programs, such as the Remedial Action Plan (RAP) in Michigan (MDNR, 1992).

The toxicity of PCB congeners has been studied in the past decade (Tanabe et al., 1987a) and the studies of biochemistry, toxicology and the mechanism of action of PCBs, and related toxic compounds have also been performed extensively (Safe, 1984 and 1990). They have focused on the structure-activity relationships (SARs) of PCBs with 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD) for the development of toxic equivalency factors (TEFs) in order to predict the toxicity of PCBs from total PCBs concentration which are commonly used in the hazard and risk assessment of toxic halogenated aromatics in fish fillet (Williams and Giesy, 1992; Williams et al., 1992). The toxic effects of PCBs occurred in several accidental exposures which included the Yusho (Kashimoto et al., 1981) and Yu Cheng poisoning (Chen et al., 1980) have provided important knowledge on the toxic effects of PCB congeners on human health and also generated pressure to government and regulatory agencies to take action on the assessment of PCBs.

The initial step for hazard and risk assessment of any toxic compound is to determine and verify the qualitative and quantitative analyses. The determination of PCBs in the aquatic environment is possible through the analysis of water, sediments, biota and bioindicators such as birds and fish. The method of extraction of sample varies; up-to-date identification and quantitative analyses have mostly been measured by gas liquid chromatography and mass spectrometry (GC/MS)(Bush et al., 1989, Bush et al., 1990, Draper and Koszdin, 1991). The progression of packed columns into capillary column enables the analysts to study the PCB congeners specific instead of total PCBs concentration (McFarlan and Clarke, 1989).

Knowing the levels of PCB congeners in the environment samples and the effect of PCBs in animal experiments, government and regulatory agencies set up action level - i.e., 2 ppm by FDA - for the protection of the public health in compliance with food safety requirements. Locally the Michigan Department of Natural Resources and Public Health issues fish guides to provide significant information for the sportsmen's protection from consuming contaminated species of Great Lakes fish. Nationally the Environmental Protection Agency (EPA)(Clark et al., 1984; Capel and Eisenreich, 1985) and Food & Drug Administration (FDA) have surveyed the contaminants in the environment and in manufactured products. All the above agencies have impacted on the establishment of the fish consumption advisories (Clark et al., 1987). Globally USA, Canada and the Eurporean countries had various collaborated studies on PCBs in wildlife and fish (Falandysz, 1985; Marthinsen et al., 1991; Teschke et al., 1993).

The utilization of food processing and cooking methods on the reduction of PCBs congeners levels in fish tissue or marine products seemed to become applicable in compliance with food safety issues (Smith et al., 1973; Zabik et al., 1979; Hora, 1981; Zabik et al., 1982; Armbruster et al., 1987; Sanders and Haynes, 1988; Stachiw et al., 1988; Armbruster et al., 1989; Trotter et al., 1989; Voiland et al., 1991, Zabik et al., 1992; Zabik et al., 1993). They all strongly agreed that effects of fat trimming procedures, skin removal and cooking are feasible to maximize the loss of PCBs and/or other organic toxicants in fish fillet.

The purpose of the study was to examine the concentration of congener specific and distribution pattern of polychlorinated biphenyl homologs in five species of Great Lakes fish as bioindicators in order to provide data for public health and other agencies to quantitate the degree of exposure a human might receive from consumption of each of five commonly caught open water fish species prepared and cooked by commonly used methods or methods which offer potential for significant contaminant reduction. The specific objectives were the following:

1). To investigate the distribution pattern of congener specific and homologs in raw and cooked fish fillets;

2). To determine the effect of trimming and cooking methods on reduction of total PCBs and PCB homologs in the Great Lakes fish species;

3). To correlate the measurements of physical parameters - length and weight with chemical parameters - levels of PCB homologs and total PCBs of fish species.

LITERATURE REVIEW

Polychlorinated Biphenyls (PCBs)

Polychlorinated biphenyls are a class of halogenated aromatic hydrocarbons that possess high thermal and chemical stability. They were formerly used in capacitors, transformers, hydraulics, carbonless copy paper and other industrial equipments as lubricants. The nature of PCBs is a mixture of PCB congeners. Congener is defined as a PCB compound with a specific chlorine substitution pattern. The possible numbers of congeners existing in PCBs are 209 based upon the locations and orders of chlorines. According to International Union of Pure and Applied Chemistry (IUPAC) definitive rules for nomenclature of organic chemistry, one ring system in the biphenyl ring assembly is assigned unprimed numbers and the other primed numbers (Figure 1). The groups with the same number of chlorines in PCB congeners are called homologs, such as 2,4,6-trichlorinated biphenyls (IUPAC # is 30) and 2,4',5-trichlorinated biphenyls (IUPAC # is 31) are grouped as tri-chlorinated biphenyls (Tri-CBs) homolog.

Prior to 1977, PCBs manufactured by Monsanta Chemical Co. in USA were sold under the tradename Aroclor® until the prohibition on PCBs manufacture and uses under Toxic

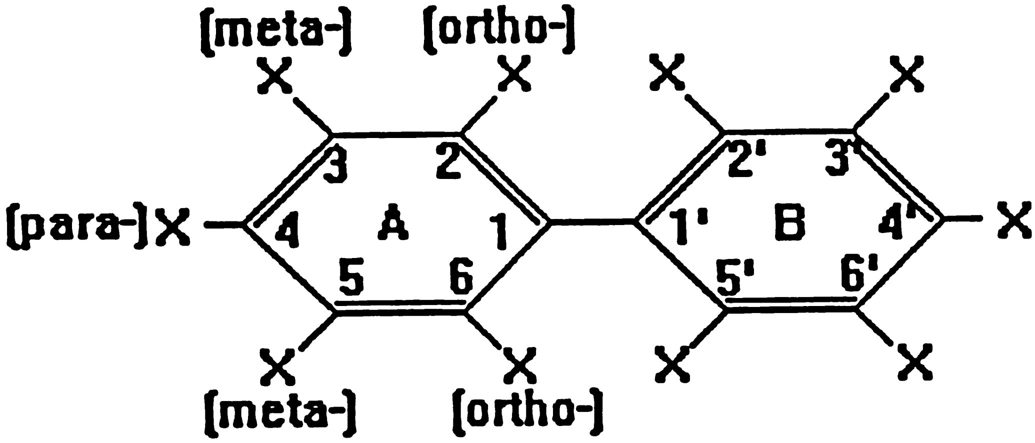

Figure 1. Basic structure of polychlorinated biphenyls and numbering of carbon atoms and position of chlorine atom in biphenyl ring system

Substances Control Act (TSCA) of 1976. Nevertheless, in the commercial preparation of Aroclor®, a four digit code was given to the product; the first two digits are the number of carbon atoms in the biphenyl group and the last two digits indicate the percentage by weight of chlorine in the mixture. Aroclor® 1254 denotes a polychlorinated biphenyl mixture having 12 carbon atoms and containing 54% chlorine content by weight. Table 1 states the approximate composition of Aroclor® 1254 with the groups of PCB homolog and their numbers of isomers. Tetra-CBs, Penta-CBs and Hexa-CBs are considered to be the predominant homologs in Aroclor® 1254. Scientists (Maack and Sonzogni, 1988; Draper and Koszdin, 1991) 2,2',3,4,5'- (87), 2,2',4,5,5'- (101), 2,3,3',4',6- (110),

Table 1. Approximate composition of Aroclor® 1254 (Composed from Waid, 1986)

Empirical Formula	PCBs Homolog	# of Isomers	Composition(%)
$C_{12}H_9Cl$	Mono-CBs	3	<0.1
$C_{12}H_8Cl_2$	Di-CBs	12	0.5
$C_{12}H_7Cl_3$	Tri-CBs	24	1.0
$C_{12}H_6Cl_4$	Tetra-CBs	42	21.0
$C_{12}H_5Cl_5$	Penta-CBs	46	48.0
$C_{12}H_4Cl_6$	Hexa-CBs	42	23.0
$C_{12}H_3Cl_7$	Hepta-CBs	24	6.0
$C_{12}H_2Cl_8$	Octa-CBs	12	-
$C_{12}HCl_9$	Nona-CBs	3	-
$C_{12}Cl_{10}$	Deca-CBs	1	-

identified that 2,2'5,5'- (52) from tetra-CBs homolog, 2,3',4,4',5- (118) and 2,3,3',4,4'- (105) from penta-CBs homolog, and 2,2',3,4,4',5'- (138) from hexa-CBs homolog are the predominant congeners in Aroclor® 1254 mixtures. Bush et al. (1989) stated that the quantities of 2,4,5,3',4'- (118) and 2,3,6,3',4'- (110) which account for 5% and 2% of total PCBs weight, respectively, in an environmental residue were the indicator congeners for Aroclor® 1254 in a mixture of Aroclors 1221, 1016, 1242, 1254, and 1260.

Properties of Polychlorinated Biphenyls

Typical properties of PCBs are hydrophobic, low water solubility, high lipophilicity, high density, low vapor pressure, high dielectric constant and high octanol/water partition coefficient. The degree of lipophilicity is increased with increasing ring chlorination. The average boiling point of PCBs is about 360 °C which makes the compound very stable and resistant to the breakdown by acids, bases, heat and hydrolysis. Viscosity of PCBs resembles a mobile oil or liquid oil at room temperature. Color of PCBs might be yellow or clear. Vapor pressure of PCBs and solubility of PCBs in water decrease with the increased chlorination. With the combination of low water solubility and high octanol/water partition coefficients, PCBs have a high affinity for suspended solids, especially those high in organic carbon (Chou and Griffin, 1986). Their physical and chemical stability may be the contributing factors for the transport and fate of PCBs into environment, even for bioaccumulation in the food chain. Table 2 lists some characteristics of Aroclor® 1254.

Table 2. Characteristics of Aroclor® 1254 (Composed from Waid, 1986)

Characteristics	
Color	Light yellow viscous oil
Specific gravity	1.495-1.505
Molecular weight(average)	328.4
Boiling point (°C)	365 - 390
Density	1.53
Dielectric constant (at 25°C)	5.0
Aqueous solubility (ppb)	42
n-Octanol/water partition coefficient (K_{ow})	1,288,000
Soil sorption constant (K_{oc})	63,914

Toxicity of PCBs

The toxicity of PCBs is a function of the structure of the individual congener which depends upon the numbers and position of the chlorine. The stereochemistry of the PCB molecules possess planar and non-planar conformations which relate to the positions of the chlorine substitution at the ortho, meta or para substitution. When the chlorine atom substituted in the either or both ortho positions causes the bond between two benzene rings to rotate and changes their configurations. Those congeners appear in their non-planar conformations. Studies (Safe, 1984 and 1990) proved that PCB congeners elicit many of their toxicological effects through the same receptor-mediated mode of action as 2,3,7,8-TCDD (tetrachlorodibenzo-*p*-dioxin). The toxicity of PCB congeners is the greatest for those congeners which are stereochemical most similar to TCDD based upon the structure-activity relationships (SARs), and which can assume a planar structure. These planar congeners elicit adverse effects at concentrations many orders of magnitude less than non-planar congeners (Williams, 1993). Out of 209 possible PCB congeners, four co-planar PCB congeners have been recognized as the most toxic congeners which 3,3',4,4'-tetraCBs (77), 3,4,4',5-tetraCBs (81), 3,3',4,4',5-pentaCBs (126) and 3,3',4,4',5,5'-hexaCBs (169) are approximate isostereomers of 2,3,7,8-TCDD in their coplanar conformation (Safe, 1990). The planar PCB congeners appear to elicit their toxicity through the same mode of action as 2,3,7,8-TCDD. Safe (1990) summarized the mechanism of action as 2,3,7,8-TCDD and planar PCBs bind to the *Ah* receptor induce the cytochrome P-4501A1 and cytochrome P-4501A2 hemoproteins and their associated hepatic microsomal monooxygenases, which include aryl hydrocarbon hydroxylase (AHH) and ethosyresorufin O-deethylase (EROD) activities in laboratory animals and mammalian cells in culture.

In the risk assessment of toxic substances, Toxic Equivalency Factors (TEF) has extensively been used which is defined as the potency of the each congener to elicit toxic effects relative to the potency of TCDD. The potency of a mixture of the AHH-active compounds can be expressed as TCDD Equivalents (TEQs) which derives from multiplying molar concentrations of PCBs congeners by the corresponding TEF for that congener (Williams, 1993). According to Safe (1990), a TEF value of 0.1 is recommended for 126, 0.05 is for 169 and 0.01 is for 77, 0.001 is for 114 and other mono-ortho coplanars, and 0.00002 is assigned to diortho-coplanar PCBs which are major components of the commercial products and extracts from environmental samples. The target organ in most mammalian species is the liver and the reproductive system in mammalian species is also affected (U.S. EPA, 1993). High concentrations of PCBs were also found in adipose tissue (Tanabe et al., 1987b; Williams and LeBel, 1991) and breast milk of humans (Hong et al., 1992a).

Mechanisms of PCBs in The Aquatic Environment

PCBs were discharged into the environment through leaking of capacitors, transformers or by product of paper mills (Rastogi, 1992). Often, PCBs can be detected in the lakes or atmosphere. When hydrophobic chemicals such as PCBs are found dispersed in lakes, the compounds partition between water and various non-aqueous compartments such as biotic lipids, organic phases of sediments or suspended particles which are not fully known (Oost et al., 1988). Generally, it is assumed that these partitioning processes can be described by first order kinetics.

For the partitioning of chemicals between water and lipid phases of organisms, the bioconcentration is defined as the uptake of substance by an organism from the surrounding medium through gill membrane or other external body surfaces or from food consumed. Normally, PCB contaminated particles or sediments in the aquatic ecosystem can act as a source of this contaminant which then can be bioconcentrated in the organism. The bioaccumulation is defined as the uptake and retention of substances by an organism from its medium and from food. Bruggeman et al.(1984) stated that PCBs are released into the environment as mixtures, containing many congeners; therefore, the bioaccumulation capabilities of the individual congeners are determined by their physico-chemical properties and their molecular configuration. Bioaccumulation of the higher chlorinated PCBs increases with higher trophic level organisms. For the lower chlorinated compounds, both the elimination rate in organisms and the rate of desorption are relatively high; thus, equilibrium will be achieved relatively fast (Wang et al., 1982, Bush et al., 1989). Bioaccumulation is predominantly controlled by equilibrium partitioning of the chemical between the internal lipids of the biota and ambient water (Shaw and Connell 1984). Maack and Sonzogni (1988) found that PCB levels in water are several orders of magnitude less than those found in fish. Meantime, Oost et al. (1988) reported that there were no detectable concentrations of PCBs congeners (IUPAC # 28, 52, 101, 138, 153 and 180) in the water samples in their investigation; however, PCBs congeners were found in most of the sediment and organisms samples in a freshwater near Amsterdam (i.e., plankton, molluscs, crustaceans and eel). It is consistent with the fact that fish readily bioaccumulate PCBs. They concluded that the process by which the concentration of PCBs increasing in different organisms, occupying successive trophic levels refers to biomagnification process. The biomagnification factor denotes the ratio between the concentration of chemicals in organisms to the concentration of chemicals by fish from food in food chain. Biomagnification factor increases with increasing hydrophobicity of PCBs specific congeners which causes the decreasing elimination rate constant. Oliver and Niimi (1988) also confirmed that biomagnification is generally the major mechanism of PCB deposition at higher trophic level.

Great Lakes Monitoring Programs on PCBs

International Joint Commission

The Great Lakes contain 20% of the world's surface fresh water, they are one of unique and rich natural resources of Michigan. In addition, these waters border with seven other states and also form a portion of the international boundary between the United States and Canada. Eight states and one province all have jurisdictions over the use of The Great Lakes. In order to protect the resource, International Joint Commission (IJC) was organized to surveillance the extent and cause of pollution in the Great Lakes. Out of IJC, Great Lakes Water Quality Agreement (GLWQA) was signed between two federal governments in order to coordinate and monitor the restoration and enhancement of water quality in the Great Lakes system. A variety of federal and state agencies including the U.S. Environmental Protection Agency, the U.S. Fish and Wildlife Service, state departments of natural resources and/or universities, and Michigan Department of Natural Resources are the representatives in IJC committees.

International Joint Commission has classified nine organic compounds and two heavy metals of 362 toxic substances in the Great lakes ecosystem as Critical Pollutants because of their toxic effects to the human health, environmental persistence, and widespread occurrence throughout the Great Lakes ecosystem (MDNR, 1992). Besides total PCBs, there are dichlorodiphenyltrichloroethane (DDT) and metabolites, dieldrin, toxaphene, 2,3,7,8-TCDD, 2,3,7,8-tetrachlorodibenzofuran (2,3,7,8-TCDF), mirex, mercury, alkylated lead, benzo(a)pyrene and hexachlorbenzene (HCB). Since most of the Critical Pollutants have the ability to be bioconcentrated by aquatic organisms and to bioaccumulate up the food chain, species such as lake trout and chinook salmon, which are near the top of the food chain, are often used as indicators of contaminant levels in the aquatic ecosystem.

According to the report from Michigan Department of Natural Resources (MDNR)(1992), levels of PCBs in waters and lake trout of the Great Lakes between 1980 to 1986 (Table 3) were decreased through the restriction and implementation of environmental protection programs. Table 3 also indicated that PCBs level in open water of the Great Lakes were not

Table 3. Morphometric characteristics of the Great Lakes and means of total PCBs concentration in waters, lake trout and coho salmon of the Great Lakes

	Water Surface Area (ml^2)	Average Depth (ft)	Total PCBs in water (ng/l)	Total PCBs: in [2]lake trout(ug/g) [3](1980→1984)	Total PCBs: in coho salmon [5](ug/g)
Superior	31,700	489	0.325 [1](1983)	2.0 → 1.0	traces
Michigan	22,300	279	1.200 [1](1980)	10.0 → 4.5	1.93
Huron	23,000	195	0.573 [1](1984)	3.5 → 2.0	1.95
Erie	9,910	62	1.159 [1](1986)	[4]NA	1.07
Ontario	7,340	283	1.201 [1](1983)	[4]NA	2.90

[1] indicates the surveyed year
[2] whole fish analysis
[3] monitering year; from DeVault et al. (1986)
[4] data not available
[5] from Clark et al., (1984)

below analytical detection limits, total PCBs levels in fish accumulated to high concentrations corresponding to the concentrations found in the environment. MDNR fish contaminant monitoring program for Lake Michigan from 1984 data revealed that contaminants in coho salmon and lake trout less than 20 inches in length had decreased to the point where 90% or more of the fish tested did not exceed FDA action levels (2ppm). But, contaminant levels in lake trout over 25 inches in length and in carp and brown trout, remained high (MDNR, 1992). Total PCBs levels in lake trout from Lake Michigan are higher than in lake trout from either Lake Huron or Lake Superior. Lake trout from Lakes Superior, Michigan and Huron had higher total PCBs than coho salmon sampled from those Lakes (Table 3).

Remedial Action Plan for Areas of Concern

Michigan in conjunction with seven other states and Ontario, all of which have jurisdiction over a portion of the Great Lakes, developed and implemented a Remedial Action Plan (RAP) for specific Area of Concern (AOC) in 1985. The RAP monitors the change in the chemical, physical or biological integrity of the Great Lakes ecosystem sufficient to cause the damage to the water and environmental quality. A portion of fish harvested from the Great Lakes in this study was from the AOC, such as carp, walleye and white bass from both Saginaw Bay in Lake Huron and River Raisin into Lake Erie, and siscowet from Lake Superior near Marquette.

Great Lakes Protection Fund

The Great Lakes Protection Fund (GLPF) was jointly established by the eight Great Lakes states in order to provide a sustained level of financial resources to address the issues identified in the Toxic Substances Control Agreement (TSCA) and Great Lakes Water Quality Agreement, it acts as a "shared resource pool" to fund activities which are not normally covered by state or federal appropriated funds (GLNPO, 1981). The present research project was endowed by GLPF in Chicago to enhance the food safety issues in consuming Great Lakes fish.

National Wildlife Federation's Great Lakes Natural Resources Center in Michigan

The function of National Wildlife Federation (NWF) monitors the areas not covered by the U.S. Food and Drug Administration which mainly monitors and regulates levels of toxic chemicals in fish that are commercially marketed. The main objective of NWF is developing an uniform approach based on scientific methods to evaluation the health risks of eating sport fish in order to protect sport anglers and their families who may be consuming contaminated fish (Schmidt, 1989). Locally the Federation's Great Lakes Natural Resource Center in Michigan summarizes the research results and offers advice about ways to reduce exposure to the toxic substances contaminating Lake Michigan fish for Lake Michigan sport anglers (Anonymous, 1989).

Biological Variability and Environmental Fluctuation

Biological variability and environmental fluctuation should be considered in the assessment of the data generated from monitoring programs on PCBs contamination in fish species. Comparing the research data from different laboratories may misinterpret the results which often vary by the fish species, age and size of specimens, timing of collection, sex of fish, collection sites, tissues sampled, number of specimens and pooling, procedures of chemical analyses and statistical analyses, etc.. The uniformity of the above parameters in the experimental design may enhance the valid comparisons between fish monitoring contaminant data sets from individual Great Lakes generated as part of independent agency programs (Clark et al., 1984)

Fish Species

Table 4 lists some characteristics of carp, chinook salmon, lake trout, walleye and white bass to illustrate the biological variabilities.

Carp (*Cyprinus carpio*) Carp accepts almost any type of food and obtains bulk of their nourishment by sucking organic material from bottom of lakes or rivers (Song, 1994). The spawning period for carp lasts from April to August, but generally spawning occurs in late May and June.

Chinook salmon *(Oncorhynchus tshawytscha)* Chinook salmon belongs to the *Oncorhynchus* branch of the *Salmonidae* family, commonly known as the king salmon. The flesh tissue is between bright red to yellowish-red depending upon the specie

Table 4. Characteristics of carp, chinook salmon, lake trout, walleye and white bass on length, weight, spawning period and water temperature for growth (Rodger, 1991)

Fish Species	Length (cm)	Weight (kg)	Spawning Period	Water Temp.(°F)
Carp	NA[1]	NA	April to August	NA
Chinook salmon	90	8.0 - 10.0	Spring to early fall	NA
Lake trout	40-50	2.3 - 4.6	every second Autumn	40 - 50
Walleye	40-60	0.9 - 1.6	Spring to early summer	45 - 48
White bass	50-60	0.9 - 3.6	April to June	63 - 70

[1] not available

and harvesting time. They often migrate great distances and return to spawn at varying ages, from 2 to 8 years.

Lake trout (*Salvelinus namaycush)* Lake trout belongs to the char (*Salvelinus*) branch of the *Salmonidae* family. The difference between lean lake trout *(Salvelinus namaycush namaycush*) and siscowet (*Salvelinus namaycush siscowet*) is lipid content. Miller et al. (1992) reported that total PCB accumulation rates were not significantly different between lean trout and siscowet collected from Lake Superior, despite a two-fold greater mean concentration of lipids in the siscowet than in the lean trout. The higher contaminant burden in lake trout are partly related to their longevity because it takes up 6 - 12 years for lake trout to reach sexual maturity.

Miller and Jude (1984) found that chinook salmon and carp contained in general higher concentration of PCBs than did whitefish fillet harvested from Lake Huron. Both salmon and lake trout are in the top predators which are often used as reflectors for the concentrations of contaminants in lower trophic levels.

Collection Sites

Scientists (Marcus and Mathews, 1987; Swackhamer and Armstrong, 1987; Bush et al., 1989; Miller et al., 1992) found that there is a general trend in reduction of the amount of PCBs in water and in fisheries with increased distance from the point source discharge and/or with increased depth of water offshore. Miller et al. (1992) found that PCB concentrations in lake trout were higher in Lake Michigan, relative to similarly aged fish from Lake Superior. Clark et al. (1984) found that skin-on fillets of coho salmon from Lake Ontario (2.90 ppm wet weight basis) are more heavily burdened with PCBs than samples from other lakes (<2.00 ppm). However, Maack and Sonzogni (1988) reported that there was no correlation observed for total PCB concentrations and species or location of fish collected from various Wisconsin waters, including from Lake Michigan.

Age and Size of Samples

Fish consumption advisories are generally based on fish length alone as a predictor of total concentrations of PCBs in

Michigan (Clark et al., 1987). However, scientists (Zabik et al., 1982; Miller and Jude, 1984; Kuwabara et al. 1986; Voiland et al., 1991; Williams et al., 1992) proposed that size (length and weight) could be good predictor of total concentrations of PCBs. The finding from the study of Zabik et al. (1982) using carp harvested from Saginaw Bay of Lake Huron indicated that length of fish correlated better with total PCBs for carp which ranged in size between <2 kg and >5.5 kg, while weight correlated better for carp which weighed between 4 to 5.5 kg. Miller and Jude (1984) concluded that based on analyses of whitefish fillets from Saginaw Bay that PCBs displayed a strong direct relationship with fish length, especially in males. Kuwabara et al. (1986) reported that total PCB levels in peeled shellfish was significantly correlated to shell length and weight (r= 0.78 and 0.77, respectively). Voiland et al. (1991) indicated that length, weight and age are highly correlated to the levels of PCBs in untrimmed and trimmed fish fillets of brown trout from Lake Ontario. Williams et al. (1992) reported that fish length is a more positive indicator of PCB concentration for the skin-on fillets of chinook salmon from Lake Michigan, while fish weight is a slightly better predictor than fish length in skin-off trimmed fillets of chinook salmon from Lake Michigan. Miller et al. (1992) used length of lean and siscowet lake trout from Lake Michigan and Lake Superior to estimate the age in lake trout and concluded that the concentrations of PCBs in lake trout are significantly influenced by age (exposure time)

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of lake trout.

Collection Time and Environmental Fluctuation

Some research (Zabik et al., 1982; Greig and Sennefelder, 1987) indicated that the total PCB concentrations were higher in fish before spawning time than other seasons, especially in the reproductive tissues of the fisheries. Lake environmental fluctuation often results in resuspension of sediments from storms, currents, passing ships, dredge as well as direct inputs from populated areas which caused some significant increase of PCB levels in some nearshore areas (Capel and Eisenreich, 1985). They proposed that total PCB concentration in the water column in Great Lakes increases in the winter due to the resuspension of contaminated sediments and the decline of volatilization from the surface water due to the cold water temperature and ice cover. The level of PCBs in the water column reaches the yearly maximum in spring then declines during the next few months. But many other factors, such as sunlight, snowmelt, growth of microorganisms, types of soils (Hankin and Sawhney, 1984) and rate of atmospheric deposition may also affect the photolysis and biodegradation of PCBs.

Tissue Sampled

Various studies (Zabik et al., 1982; Greig and Sennefelder, 1987; Sanders and Haynes, 1988; Gundersen and Pearson, 1992) found that total PCB concentration is the function of lipid content in tissue samples. Total levels of PCBs increased with the increase of the lipid values. Gundersen and Pearson (1992) stated that in sturgeon both the

mean percentage of lipid content and the PCB concentration in reproductive tissues were more than two times the values in muscle tissues. Greig and Sennefelder (1987) reported that levels of PCBs (0.30-2.70 ppm, wet weight basis) in livers of winter flounder were significantly higher than the levels of PCBs (0.03-0.43 ppm) in ovaries of winter flounder at the average fish length of 32 cm. Sanders and Haynes (1988) observed that red muscle tissue stores more lipid than white muscle tissue in bluefish fillets. They found that skin-on (untrimmed) fish fillets had 38% more lipid content than skin-off (trimmed) fish fillets according to the modified trimming fish method of Skea et al. (1979). Smith et al. (1973) stated that average fat content from anterior halves of raw (3.0%) and cooked (4.2%) fillets of chinook salmon were higher than posterior halves of raw (2.4%) and cooked (3.1%) fillets. The same trend was reported by Sanders and Haynes (1988) that the rib cage and the belly flap in the trunk of the fish had the highest (average 13.0%) lipid content in skin-off bluefish fillets compared to the lipid content of the caudal zone in the posterior of the fish (5.0%). Recent study by Zabik et al. (1992) found that total PCBs level in raw body muscle of blue crabs harvested from U.S. east coast with or without tissue of hepatopancreas was 0.31 or 0.27 ppm (wet wt. basis), respectively. The average total PCBs in raw claw of blue crab was only 0.18 ppm.

Analytic Procedures and Methodology for PCBs

The validity of analytical data strictly relies upon the chemical analytic procedures and methodology which are the crucial factors toward the determination and quantitation of congeners specific PCBs. Price et al. (1986) modified the methodology for cleanup of extracts contaminated by chlorinated pesticides in fish adipose tissue from acetonitrile liquid-liquid partitioning to Florisil® chromatography and silica gel column chromatography in order to obtain additional recoveries of the 6% Florisil® fraction and separation of PCBs from toxaphene and chlordane which often coelute on most packed GC columns. Ribick et al. (1982) studied the differences between packed column gas chromatography-mass spectrometry (GC-MS) with well-coated open-tubular (WCOT) capillary column GC. They found that capillary column GC yielded accurate and more precise values for the spiked catfish samples than packed-column GC techniques due to inadequate resolution to separate specific chemical compounds from interferences in the chromatogram. Electron capture detector is selective toward halogenated compounds according to the solubility of individual PCB congener in the liquid phase and its volatility. The interaction of the compounds with the gas (mobile phase) and liquid phase (stationary phase) in the separation of individual specific congener of PCBs affects the retention time of the specific PCB congener. Rentention time determines individual congeners identification. Williams et al.(1992)

reported that total PCB values from packed column techniques is 16% less than capillary column values obtained in their study. Maack and Sonzogni (1988) found that a linearly correlation coefficient of 0.9854 between the concentration of total PCBs obtained from capillary column versus packed column analysis for fish from Lake Michigan and the Wisconsin River.

Capel et al. (1985) investigated that the application of data generated from capillary GC of Aroclor® standards into a multiple-linear regression analysis to calculate the total PCB concentration in environmental samples. These authors found that calculated PCB values were in accordance with the sum of the individual congener concentrations. More recently, scientists (Hong and Bush, 1990; Hong et al., 1992a,b; Williams, 1993) are able to determine and quantitate mono- and non-ortho coplanar PCBs in fish with the additional step of carbon chromatography on the basis of molecular planarity and degree of chlorination besides the separation on solute polarity through Florisil® and silica gel chromatography.

In spite of the complex procedures, the analytical identification of congener specific PCBs is simply to match the relative retention time of each peak in the chromatogram of fish sample against peak in the authentic standard PCB congeners run under the same conditions. Recoveries for the specific PCB congener is determined based on response factors and the peak area of the quantitation standard.

In the past, the results of the total concentrations of PCBs in raw and cooked fish fillets (Smith et al., 1973; Zabik et al., 1978 and 1982) were based upon ppm lipid content. In early studies, scientists (Skea et al., 1979; Zabik et al., 1982) stated the extractable lipid content in cooked fish fillets is higher than extractable content in raw fish fillets, especially for deepfat fried fish fillets which have the higher fat adsorption on the tissue and greater moisture loss in the tissue. One mechanism proposed for this phenomena is cooking causes an increase in the amount of ether extractable material in the lean portion of meat over that found in raw meat, since sulfhydryl-disulfide interchange during heat aggregation of myofibrillar proteins allows for release of phospholipid bound to protein in the raw muscle thus increasing the proportion of phospholipid in lipid extracts from cooked meat (Zabik et al., 1982) which leads to the better fat extraction from cooked fish fillets.

In recent publications (Voiland, et al., 1991; Zabik et al., 1992; Zabik et al., 1993), total concentrations of PCBs or of PCB homologs in raw and cooked fish fillets were expressed as ppm in wet tissue, ppm in dry weight tissue and/or the total micrograms in the fish samples. The comparison between cooked fillet to paired raw fillet in total micrograms of PCBs determined percentage change in fillet due to the effect of trimming, skin removal or cooking (Zabik et al., 1993).

Effects of Processing and Cooking on the Reduction of PCBs Levels in Raw and Cooked Fish Fillets

Many studies have proved the effect of processing and cooking on the reduction of PCBs congeners levels in raw and cooked fish fillets or marine products. The principle of the effect of processing on the reduction of PCBs concentration in fish fillets is to minimize the PCBs residues in the uncooked edible tissue through trimming processings which include removal of head and tail portions, skin removal plus trimming off belly fat and all adipose tissues. Afterward the process of cooking which applies heat in various forms for selected times on trimmed fish fillet enhances the reduction of PCBs levels through fat leaching, protein denaturization, evaporation of moisture or PCBs (Armbruster, et al., 1989) and volatization of volatile compounds, etc. So far, the removal of skin and associated fat combined with the selected cooking method prior to consumption of fish has been highly recommended in the fish consumption advisories to the sports fisherman in compliance with food safety issues for the public health (Sherer and Price, 1993; Song, 1994; Zabik et al., 1995) in addition to avoiding consuming larger and older fish (Voiland et al., 1991).

Effect of Trimming Procedures

PCB mixture is non-polar compound, is mostly lipid-soluble. Concentrations of PCB residues were the highest in parts of fish with the highest lipid content, such as dorsal, ventral, medial and belly flap areas. To minimize ingestion of fat-contaminants in high fat tissues, trimming is the most effective process to reduce the health risk of anglers and their families. In the early study done by Zabik et al., (1978) found that head sections of freshwater mullet from upper Great Lakes (Lakes Huron, Michigan and Superior) had the highest PCB levels as compared to other portions of the whole mullet. Hora (1981) concluded that the effectiveness of removal of the skin alone resulted in 26% to 30% of PCBs and lipids losses respectively in carp fillets from upper Mississippi river. Skea et al. (1979) stated that removal of the skin, dorsal and ventral fat, and the entire lateral line from Lake Ontario smallmouth bass and brown trout resulted in 64% and 43% reduction of Aroclor® 1254 in fish fillets, respectively. A similar investigation by Sanders and Haynes (1988) showed that total PCB level in bluefish fillets reduced 27% after the removal of belly flap adipose tissues which was close to the 28 percent reduction of lipid. Armbruster et al. (1989) found that trimming bluefish fillets resulted in an average reduction of PCB residues of 59%. They also indicated that concentration of PCBs in skin contained about twice that found in the fillet muscle expressed on a ppm wet weight basis. Voiland et al. (1991) reported that percent loss of total PCBs and fat content in brown trout from Lake Ontario through skinning and fat trimming procedures was 46% and 62%, respectively. It may be said that more than 1/4 to 1/2 of total PCBs concentration found in the raw fish fillet is feasible to be eliminated through recommended trimming procedures. Voiland et al. (1991) also confirmed that the effectiveness of the fat trimming procedure on the reduction of PCBs in fish fillet is consistent despite wide variation in the initial (untrimmed fillet) levels of contamination. Song (1993) reported that skin removal in carp fillets from the Great Lakes reduced 35% of total PCBs concentration which was from 1.90 ppm down to 1.24 ppm (wet wt.), the highest reduction percent was for hexa-CBs homolog (42%), followed by hepta-CBs (38%), penta-CBs (34%), the least reduction was for octa-CBs. The presence or absence of skin and adipose tissues significantly affected the total PCBs and its homologs in the raw fish fillets.

Effect of Cooking Methods

The effectiveness of cooking on PCB reduction in fish has differed substantially in various reports. Smith et al. (1973) found that a small decrease in the PCB levels in Lake Michigan chinook and coho salmon occurred through baking and poaching. Statistical comparison showed no consistent pattern for PCBs residue removal due to cooking. Fish fillets of salmon baked in nylon bags lost 11-16% of PCBs, while samples baking or poaching were reduced by only 2-8%. In was noted that posterior halves of fish fillets of chinook salmon lost more PCBs through cooking procedure than anterior halves, possibly due to the greater leaching of fat during cooking. Skea et al. (1979) tested smoking, broiling, and baking methods in relation to the reduction of total PCBs in Lake Ontario brown trout and smallmouth bass. They found that there were zero reductions of PCBs in untrimmed brown trout and smallmouth bass during baking or broiling fish fillets, 12% reduction of PCBs during smoking untrimmed brown trout fillets. Zabik and coworkers (1979) found that broiling fat lake trout (siscowets) reduced PCBs by 53% while roasting or cooking by microwave resulted in losses ranging from 34 to 26%, respectively. However, there were not significant differences in these values due to cooking method.

In contrast, Cin and Kroger (1982) reported that baking, frying, poaching, and baking without skin in brown trout did not cause significant decreases of insecticide mirex. Similar study by Zabik et al. (1982) showed that various cooking methods (poaching, roasting, deepfat frying, charbroiling and microwaving) did not significantly affect the level of PCBs in carp. Song (1994) indicated that there were no significant differences between deepfat frying and pan frying carp fillets in relation to total PCBs reduction, but both methods reduced PCBs by an average of 34%. Armbruster et al. (1989) found that there was an average 7.5% reduction from baking, broiling, frying or poaching on trimmed bluefish fillets. They suggested that vaporization of PCBs during the various cooking procedures contributes the major portion of the total loss from cooking. Stachiw et al. (1988) pointed that fat rendering and moisture evaporation during cooking contributed to the majors factors in xenobiotic reduction in fish. They also found that increasing the end point cooking temperature and surface area of fillets statistically increased the percentage of TCDD loss in roasted and charbroiled restructured carp fillets. It seems that the effectiveness of reducing PCBs from fish during cooking depends largely on the species, its fat content, end point cooking temperature or surface area and depends less on the specific cooking method used.

Effect of Trimming and the Selected Cooking Method

Many studies have indicated the effects of trimming and the selected cooking method in the reduction of DDT and PCBs level (Reinert et al., 1971; Skea, et al., 1979; Zabik, et al., 1982; Armbruster et al., 1987 and 1989; Zabik, et al., 1992; Sherer and Price, 1993; Song, 1994). Zabik et al. (1979) reported that removal of skin from fat lake trout combined with roasting enhanced reduction by an additional 10% total PCBs loss. Armbruster et al. (1989) found that the mean percentage reduction in PCB levels in both trimmed and cooked bluefish fillets was 66.9%. The orders of cooking methods in terms of PCBs reduction percent were as follows: broiled, 71%; baked, 68%; fried, 68% and poached, 60%. The combined effect of trimming and cooking methods resulted in 7.5% further reduction in bluefish fillets. Puffer and Gossett (1983) confirmed that the combined effect of skin removal and pan-fried in white croaker from southern California on PCBs reduction ranged from 28% to 65%. A current study (Zabik et al., 1995) showed walleye and white bass from the Great Lakes obtained further reduction of 1/4 to 1/3 of PCBs level during baking, charbroiling, and deepfat frying skin-on fillet after trimming belly flap.

Based upon the statement from the Great Lakes sport fish consumption advisory (GLSFATF, 1993), a contaminant reduction factor of 50% due to trimming and cooking is a realistic expectation for all the lipophilic contaminants of concern in the Great Lakes. Skin removal prior to cooking appears preferable; however, the further reduction of the contaminant can also be compensated by simply discarding the skin after cooking (GLSFATF, 1993).

MATERIAL AND METHODS

Fish Procurement

Carp (*Cyprinus carpio*), chinook salmon (*Oncorhyncush tshawytscha*), lake trout (lean) (*Salvelinus namaycush namaycush*), siscowet (*Salvelinus namaycush siscowet*), walleye (*Stizotedium vitreum vitreum*) and white bass (*Morone chrysops*) were chosen to be representative of the mean Creel census data from sports fisherman for 1990 for all fish except siscowets (Rakoczy, 1992). Siscowet size was based on average catch data of Native American fisheries. A total of thirty carp, seventy-one chinook salmon, seventy-one lake trout, thirty-five siscowet, thirty-nine walleye and sixteen white bass were collected on designated days and locations by the Michigan Department of Natural Resources (MDNR), New York Department of Natural Resources and private companies. Table 5 summarized the information of five fish species harvested from Great Lakes.

All fish were assigned non-duplicated random numbers and weighed (grams), measured (centimeters) and sex identified after the catch. In order to maintain the fish in food grade condition, fish were deheaded and detutted (scrapin kindneys and viscera from the abdominal wall) within eighteen hours of collection. Flake ice was packed into the body cavity of fish

Table 5. Summary of the information on fish species, source of lake (# fish), location of catch and date of catch

Species	Lakes (# fish)	Locations	Date
Carp	Erie (15)	41°51.5N,83°20.1W (near Monroe, MI)	4-22-91
	Huron(15)	Saginaw, MI	7-22-91
Chinook salmon	Huron(35)	SwanRiverWeir, MI	9-12-91
	Michigan(11)	Manistee Weir, MI	9-12-91
	Michigan(25)	Consumers Power, Ludington & grid 1509 off Pentwater, MI	4-19-91 to 7-19-91
Lake trout	Huron(8)	South Point, MI	6-04-91
	Ontario(8)	Cape Vincent, NY	9-04-91
	Michigan(20)	Pentwater, MI grid 1409,1509	4-17/19-91 & 5-14/15-91
Siscowet	Superior(35)	46°41.6N,87°19.2W (near Marquette, MI)	6-19-91
Walleye	Erie(12)	41°51.5N,83°20.1W (near Monroe, MI)	4-22-91
	Huron(11)	Saginaw Bay, MI	7-25-91
	Michigan(16)	north end of Little Bay de Noc, MI	4-12-91
White bass	Erie(8)	41°51.5N,83°20.1W (near Monroe, MI)	4-22-91
	Huron(8)	Saginaw Bay, MI	7-22-91

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and the fish were placed in ice in an Igloo cooler for transport to Michigan State University Meat Laboratory.

Processing of Fish Fillets

Fish were processed within 24 hours of receipt at the Meat Laboratory. According to experimental design, carp, chinook salmon, and lake trout were processed into skin-on and skin-off fillets. Walleye and white bass were processed into skin-on fillets. Skin-on fillets had the belly flap trimmed off, while skin-off fillets had the belly flap as well as dark tissue from the lateral line and associated fat tissue removed. Using red meat techniques, the fish will be identified as to right and left side, i.e., a person with left hand at the head and right hand at the tail of the fish (belly down) will reckon the left side as the side visible or facing the individual. Left side of fish would be cooked and right side would be used in a raw state to compare the PCBs level between the raw and the cooked fish. Each side of fish fillet of the species of carp, lake trout, chinook salmon, and walleye were processed into head and tail pieces. White bass and siscowet were used as whole fillet due to the small size of fish fillet. All processed fish fillets were wrapped in aluminum foil, labeled with assigned random numbers, and vacuum packaged. Labels were placed both in the interior and on the outside of the package. The packages were blast frozen at -34°C for further use. The fish scales were also placed in prelabeled plastic bags and used for the determination of the age of the fish.

Processing data included sex, age, length, weight and percentage carcass yield and percentage AP (As Prepared) yield. Carcass yield was based on the deheaded and degutted weight of each fish species to the whole fish weight as well as AP yield was the ratio of total weight of both sides of trimmed fillet to the total fish weight. AP yield would be similar to an "As Purchased" yield for commercial fish.

Sample Preparation

Preparation of Raw Sample

The frozen fillet of right side (skin-on or skin-off) was coarsely chopped by a hammer. The broken pieces of fish tissue were crushed with dry-ice in a high speed Tekmar analytical mill and pulverized for 2 minutes. The powdered sample was mixed thoroughly and placed in glass containers, covered with aluminum foil, labeled and capped. All samples were stored at -30°C.

Preparation of Cooked Sample

Commercial no stick cooking spray Pam® was used on fish samples to reduce the surface loss and the variation. A thermocouple was inserted into the center of the thickest portion of the fish fillets for samples cooked by baking, charbroiling, pan frying, deepfat frying, and salt boiling was applied to ensure the internal temperature reached 80°C. A thermocouple was also used to monitor the temperature of the heating medium. All equipment which was in contact with fish was washed with soap and water and then rinsed with acetone.

Before cooking and after cooking, the weights of fish sample (skin-on and skin-off) were recorded to be able to calculate the total cooking loss and cooking yield. When a cooked skin-on sample was prepared, the skin was peeled off so only the cooked muscle tissue weight was recorded as the edible weight. This muscle tissue was used as the edible portion for chemical analyses for all the skin-on fillets for all cooking methods except deepfat frying to maximize residue reduction. The logic for treating skin-on deep fat fried fillet differently was that the public consumers would generally eat a deepfat fried fish fillet with a batter or breading coating and thus always consume the skin as well as muscle tissue. The calculation of percentage total cooking loss was the ratio of the difference between raw and cooked fillet weight to the raw fish fillet weight times 100. Cooking yield percent was based on the relation of the cooked edible weight to the raw fillet weight times 100.

After cooked fish fillet cooled on the wire cooling rack, cooked fish fillet or edible portion of fillet was placed into an Omnimixer to be homogenized. The homogenization consisted of mixing on low speed initially and then gradually increasing the speed until the desired fineness of the sample had been reached. The ground sample which had a paste-like consistency was mixed thoroughly and then placed into 3-4 separate glass jars (prerinsed with acetone and hexane) which were covered with aluminum foil, labeled on the cap and sealed for moisture determination, PCB analyses, fat analyses and the use of Department of Michigan Public Health, respectively. All samples were frozen and stored at -34°C.

Cooking Methods for Fish Fillets

Lake trout, chinook salmon, siscowet and walleye fillets were baked and charbroiled according to the procedure described by Stachiw et al (1988). Carp and white bass were pan fried as outlined in Puffer and Gossett (1983). Carp and walleye fillets were deep fat fried following the procedure of Morehouse and Zabik (1989). Lake trout and siscowet fillets were smoked as outlined in the Michigan State University Cooperative Extension Bulletin E-1180, entitled "Processing Great Lakes Chub (*Leucichtys hoyi)*" by Bratzler and Robinson (1967). Canning chinook salmon fillets following standard USDA procedures (1988) were used. Table 6 summarized the cooking methods of skin-on or skin-off fillets in five species harvested from Great Lakes.

Baking Each fillet was removed from the freezer shortly before the oven was up to 177°C. Then, the sprayed fillet was placed on the broiler rack which was in the pan. Each fillet was cooked until the internal temperature of 80°C was reached.

Charbroiling Each fillet was prepared as above and was placed in the preheated charbroiler at 250°C. Each fillet was turned after the half-way temperature (40°C) was reached, cooked until the fish fillet reached 80°C.

Deepfat Frying The oil (Mikado, commercial soybean oil) was placed in the frier and heated to 180-195° C. The fillet

Table 6. Summary of processing and cooking methods of fish fillets in five species harvested from Great Lakes

Species	Lakes	Process	Cooking Method	Number
Carp				
	Erie	skin-on & -off	deepfat frying	12
	Huron	skin-on & -off	deepfat frying	12
	Erie	skin-on & -off	pan frying	12
	Huron	skin-on & -off	pan frying	12
Chinook salmon				
	Huron	skin-on & -off	baking	12
	Huron	skin-on & -off	charbroiling	12
	Huron	skin-on & -off (increased surface)	charbroiling	12
	Michigan	skin-on & -off	baking	12
	Michigan	skin-on & -off	charbroiling	12
	Michigan	skin-on & -off (increased surface)	charbroiling	12
	Huron	skin-off	canning	6
	Michigan	skin-off	canning	6
Lake trout				
	Huron	skin-off	baking	6
	Huron	skin-off	charbroiling	6
	Michigan	skin-off	baking	6
	Michigan	skin-off	charbroiling	6
	Michigan	skin-off	salt boiling	6
	Michigan	skin-on	smoking	6
	Ontario	skin-off	baking	6
	Ontario	skin-off	charbroiling	6
Siscowet				
	Superior	skin-off	baking	6
	Superior	skin-off	charbroiling	6
	Superior	skin-off	salt boiling	6
	Superior	skin-on	smoking	6
Walleye				
	Erie	skin-on	baking	6
	Erie	skin-on	charbroiling	6
	Huron	skin-on	baking	6
	Huron	skin-on	charbroiling	6
	Michigan	skin-on	baking	6
	Michigan	skin-on	charbroiling	6
	Michigan	skin-on	deepfat frying	6
White bass				
	Erie	skin-on	pan frying	6
	Huron	skin-on	pan frying	6

was placed in the preheated frier and frying temperature was kept at 180±5°C. Each fillet was cooked until the internal temperature reached 80±3°C; afterwhich it was drained and cooled in deepfat frying basket for five minutes.

<u>Pan Frying</u> Each fillet was placed in the pregreased frying pan with PAM® and preheated pan at 185±5°C. Each fillet was turned when the internal temperature had increased 20°C and was cooked until the internal temperature reached 80°C. For the skin-on fillets, the skin side was cooked first for heat to penetrate the fillet because skin acts as an insulator to keep the temperature from increasing.

<u>Salt Boiling</u> The frozen fish fillet was placed in basket and submerged into a 5% NaCl boiling liquid (1.5 inches above fish). The liquid was kept at a gentle boil (99°C) during cooking. Fish fillet reached an internal temperature of 80°C before removal.

<u>Smoking</u> Skin-on fish fillets were thawed in a cooler(4-5°C) for 24-36 hours prior to brining. The fillets were brined in a 30° salimeter brine containing 7.89% salt, 92.11% water for 14 hours at 4°C (Cuppett et al., 1989). The ratio of fish fillet weight to brine volume was 1:2. Afterward, the fillet was rinsed in cold running water and placed on cooking racks coated with lecithin to minimize sticking. Using hickory sawdust for wood smoking, smoke-cooking was accomplished in a stainless steel smokehouse, until fish reached an internal temperature of 80°C for 30 minutes (Bratzler and Robinson, 1967).

Pressure Canning The skin-on fillet was placed in pint size glass canning jar covered with distilled water leaving one inch head space. After the jars were sealed in an appropriate manner, they were placed into the pressure cooker and processed for 100 minutes at 11 lb psi.

Analysis of Solids

Solids were determined using AOAC method 24.002 (AOAC, 1984) oven drying method in order to express PCB congeners data on dry weight as well as wet weight basis.

Lipid Analysis

The determination of lipid content followed the procedures modified by Price et al (1986). Fish homogenate (20g) was thoroughly mixed with 80 g anhydrous Na_2SO_4 in a 250 ml beaker until the sample was dry, afterwhich the dry mixture was lightly packed into a 400 mm x 19 mm chromatography column. The beaker then was rinsed with 10 ml of 50% ethyl ether/petroleum ether(v/v) and the rinse quantitatively transferred to column, followed by remaining 190 ml of extracting solvent at an adjusted flow rate of 3-5 ml/min. The extract was collected in a tared 250 ml beaker and evaporated to dryness on top of a moderately heated water bath under a gentle stream of nitrogen to determine the lipid weight.

Congener Specific Polychlorinated Biphenyl Analyses

Glassware Preparation

All glassware used in the residue analyses (Erlenmeyer flasks, reservoir columns, Turbo-Vap evaporator tubes, chromatographic columns and 1 ml and 5 ml volumetric flasks, etc.) were washed with detergent, rinsed with hot tap water, and distilled water, then with acetone, followed by hexane. The cleaned glassware were dried in an oven at 110°C overnight.

Solvents and Reagent Preparation

Solvents: All solvents were pesticide quality.

Acetone - 99.8%, Mallinckrodt Specialty Chemicals Co. (Paris, KY)

Dichloromethane, Isooctane, and Toluene - 99.9%, Mallinckrodt Specialty Chemicals Co.(Paris, KY)

Hexane - 85.0%, EM Science

Diethyl ether - 99.9%, Baxter Burdick & Jackson Laboratories, Inc. (Muskegon, MI)

Petroleum ether - 99.9% EM science

Solvent mixture: Prepared by volume.

50% Hexane : 50% Dichloromethane

6% Diethyl ether in Petroleum ether

0.5% Toluene in Hexane

Reference PCB internal standards (Table 7):

99% pure

From AccuStandard, New Haven, CT.

Table 7. IUPAC numbers and structure of the PCB congeners

Homolog	IUPAC Number	Structure
Tri-CBs	31	2,4',5
Tetra-CBs	42	2,2',3,4'
	44	2,2',3,5'
	47	2,2',4,4'
	49	2,2',4,5'
	52	2,2',5,5'
	55	2,3,3',4
	66	2,3',4,4'
	70	2,3',4',5
	72	2,3',5,5'
	76	2,3,4,5
	79	3,3',4,5'
Penta-CBs	83	2,2',3,3',5
	84	2,2',3,3',6
	85 (96%)	2,2'3,4,4'
	87	2,2',3,4,5'
	91	2,2',3,4',6
	92	2,2',3,5,5'
	95	2,2',3',4,5
	97	2,2',3',4'5
	99	2,2',4,4',5
	101	2,2',4,5,5'
	103	2,2',4,5',6
	105	2,3,3',4,4'
	108	2,3,3',4,5'
	110	2,3,3',4',6
	114	2,3,4,4',5
	118	2,3',4,4',5
	120	2,3',4,5,5'
	121	2,3',4,5',6
	122	2',3,3',4,5
	123	2,3,4,4',5
Hexa-CBs	128	2,2',3,3',4,4'
	132	2,2',3,3',4,6'
	136	2,2',3,3',6,6'
	137	2,2',3,4,4',5
	138	2,2',3,4,4',5'
	141	2,2',3,4,5,5'
	149	2,2',3,4',5',6
	153	2,2',4,4',5,5'
	156	2,3,3',4,4',5
	157	2,3,3',4,4',5'
	158	2,3,3',4,4',6
	167	2,3',4,4',5,5'
Hepta-CBs	171	2,2',3,3',4,4',6
	179 (95%)	2,2',3,3',5,6,6'
	180	2,2',3,4,4',5,5'
	181	2,2',3,4,4',5,6
	183	2,2',3,4,4',5',6
	185	2,2',3,4,5,5',6
	190	2,3,3',4,4',5,6
Octa-CBs	198	2,2',3,3',4,5,5',6
	200	2,2',3,3',4,5',6,6'

Chemicals: All chemicals were pesticide grade.

Sodium sulfate - granular anhydrous, activated and stored at 130°C (J.T. Baker Chemical Co.,Phillipsburg, NJ).

Florisil® - 60~80 mesh, activated at 130°C Fisher Scientific, Fair Lawn, NJ).

Silica gel 60 - 70~230 mesh, activated at 130°C (Sigma Chemical Co., St. Louis, MO).

Extraction and cleanup of samples for PCB congener specific analyses were performed using the column extraction with Dichloromethane ($MeCl_2$), Gel Permeation Chromatography (GPC), Florisil® and silica gel chromatography. Identification and quantification of specific PCB congeners were done by capillary column gas chromatography according to the modification of Ribick et al (1982)(Figure 2). An internal standard addition, 0.375 ug of congener 2,4,6 trichlorobiphenyl (IUPAC # 30) was added to be able to correct for losses during the entire extraction procedure. This PCB congener was selected as an internal standard because it does not occur in commercial Aroclor® mixtures nor has it been detected in environmental samples (Williams, 1989). The advantages of using column extraction are time efficiency, application of single solvent, equipment replaceable and multiple samples performance.

Lipid Extraction

Each sample of fish (10.0 g) and 1 ml of internal standard PCB congener #30 (concentration 5ppm) was homogenized

Homogenated fish tissue sample (10g)
added internal standard (congener #30)

⇓

Spiked fish sample

⇓

Dry with Na_2SO_4
Extracted with $MeCl_2$

⇓

Lipids and xenobiotics concentrate

⇓

Gel permeation chromatography (GPC)

⇓

PCBs and pesticides concentrate

⇓

Florisil® chromatography

⇓

PCBs and some pesticides concentrate

⇓

Silica gel chromatography

⇓

PCBs

⇓

Gas chromatography
Equipped with ^{63}Ni ECD

⇓

Identification & quantification
of individual
congener specific PCBs

Figure 2. Simplified chemical analytical procedures for PCBs congener specific from fish tissue

in a mortar and ground to a fine powder with 40 g of granular anhydrous sodium sulfate (Na_2SO_4) which had been activated and stored overnight at 130°C in order to remove water from the sample. The ground dry fish mixture was eluted in a 1 cm i.d. reservoir column with 200 ml of $MeCl_2$ mobile phase at a flow rate of 3-5 ml/min, collected and reduced in the Turbo-Vap evaporator (Zymark) to approximately 0.5 ml volume at ambient temperature.

Cleanup of Lipid Extract

Gel Permeation Chromatography The concentrated lipid extract was then diluted with 1:1 (v/v) hexane and $MeCl_2$ mixture into 5 ml volumetric flask for the cleanup by GPC. Four ml concentrated extract was pipetted quantitatively into GPC vial. Afterwhich, 2 ml aliquot was automatically injected into GPC column (19 mm i.d. x 300 mm Ultrastyragel 500 A resin) attached to a Waters/590 Programmable HPLC pump and Waters fraction collector (Millipore, Co., Milford, MA). The mobil phase $MeCl_2$ was pumped through the column at 3 ml/min. The automated GPC system provided for unattended operation with time control (35 min/sample) to separate lipids and PCBs fraction. The lipid was discarded and the fraction which contained congener specific PCB and pesticides was collected and reduced as above to 1 ml afterwhich the volume was adjusted to 5 ml with hexane.

Florisil® Column Chromatography The Florisil® glass chromatography column (1 cm i.d. x 51 cm) was packed as 1 g Na_2SO_4, 5 g of Florisil® (activated at 130°C for 16 hours), 1 g Na_2SO_4 and solvent-extracted glass wool in reservoir column. The prepared column was rinsed with 20 ml of hexane before the extract was applied. When the hexane reached the top of the upper layer of Na_2SO_4, the GPC concentrated extract was pipetted into the column and onto a Florisil® bed and was collected into a Turbo-Vap flask. Forty ml elution solvent of 6% (v/v) diethyl ether in petroleum ether was portioned into 5 and 35 ml. The first 5 mL of eluent was used to rinse the column walls before the remaining volume (35 ml) was added to the reservoir column. In this step, 6% (v/v) diethyl ether in petroleum ether was used as mobile phase and the Florisil® column as the stationary phase. Most of chlorinated pesticides and PCBs (nonpolar pesticides) were eluted. The collected fraction was reduced to 5 ml volume in the Turbo-Vap evaporator.

Silica Gel Column Chromatography The preparation of silica gel column was the same as the Florisil® column only replacing Florisil® with silica gel 60 (70~230 mesh, activated at 130°C for 16 hours). After the column was rinsed with 20 ml hexane, the collected concentrate was pipetted onto the column. Fifty ml of 0.5% toluene in hexane served as mobile phase with silica gel as the stationary phase to separate PCBs and other non-polar or less polar pesticides. The eluent was reduced to 0.5 ml volume in the Turbo-Vap evaporator and pipetted to the 1 ml volumetric flask, using hexane as a rinsing solvent. The concentrate was reduced to 0.5 ml volume, under a gentle stream of N_2 gas and isooctane was added to make a final volume of 1 ml.

Identification and Quantitation

Individual PCB congeners in the PCB concentrate were separated and quantitated by gas chromatography (Hewlett Packard Model 5890 Series II) equipped with ^{63}Ni electron capture detector (ECD), and a DB-5 capillary column (60 m x 0.25 mm i.d.). The detector was operated at 300°C and a split/splitless injector at 220°C. Aliquots of 3 ul volume of PCB extract were injected by an autosampler. Helium at 20.0 psi, flow rate of 1 ml/min was used as the carrier gas. The column temperature was temperature programmed from 160°C at 8°C/min until 200°C and then held for 5 min after which the temperature was programmed to 280°C at 2°C/min and then held a final 5 minutes. The complete run time was 55 min. The injection of standard was required prior to the analyses of every three pairs of samples (cooked and raw fish samples). Each standard congener was injected separately to determine retention times for peak identification, then all congeners were combined into one standard and injected at three levels of concentration (standard/50, standard/10, standard concentration) in order to calculate the slope of each congener standard curve. These linear regressions have R^2 values of .99 and higher. The integration was performed by the Hewlett Packard software.

The stored data was transferred from the Hewlett Packard software to an Excel spreadsheet (Microsoft windows 3.1) and corrected retention times were calculated based on the so

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retention time of the internal standard, congener 30. All quantitation was based on peak areas relative to the individual congener standards and the area corrected to the internal standard congener 30. The coeluting p,p'-DDE peak was omitted from all calculations. The individual congener was quantified by comparison of peak area with appropriate standards of known concentration with following equations.

$$\text{Recovery \%} = \frac{\text{Detected conc. of 30 in extraction}}{\text{Conc. of internal std. 30 in fish sample}} \times 100$$

$$\text{Concentration (ppm in wet tissue)} = \frac{\text{LS of congener} \times \text{RA of congener}}{\text{LS of 30} \times \text{RA of 30}}$$

LS : Line Slope

RA : Retention Area

The results were expressed as ppm in wet tissue, ppm solids as well as the micrograms in the raw and cooked samples which derived from weights of raw or cooked fish fillets times the ppm on a wet weight basis. The percentage change was calculated by the difference between the micrograms of each congener in the raw and cooked fish fillets. Positive values are percentage reductions. Values for PCB congeners which were below the reported detection limit, i.e. non-detectable

(ND), are not included in the average or standard deviations. If the cooked sample had a ND level and the raw sample had a numerical value, the percent loss was arbitrarily set at 100%. In contrast, if the cooked sample had a higher numerical value than the raw sample, the normal equation was used to calculate the negative loss. Thus, any negative loss was not limited to 100%. The homolog of PCBs was determined by summing the concentration of the same chlorination group of PCB isomers. The total concentration of PCBs was determined by summing the concentration of the homologs of PCB isomers.

Statistical Analysis

All statistical analyses were performed with the Statistical Analysis System version 6.04 for Personal Computers (SAS Institute, 1987) or SYSTAT for Windows 5.03 (SYSTAT, 1993). The level of significance of main effects that was used in ANOVA was $p < 0.2 - 0.05$ for the specific fish specie harvested at the same location. T-test was selected for the comparison with fillets processed from the same fish. Information on correlations among variables, including Pearson product moments and p values, was obtained using the CORR procedure in SYSTAT. The REG procedure was used to determine the combination of physical measurements for predicting the concentration of total PCBs. Response surface graphic representatives was also carried out by SYSTAT to visually demonstrate relationship among variables.

The project was designed to test the null hypotheses:

1. The lakes origin and fish biological variability do not influence the levels of total PCBs and its congeners.
2. The processing and cooking procedures do not reduce the levels of total PCBs and its congeners and homologs.
3. There is no difference among cooking methods in the reduction of the levels of total PCBs and its homologs.

The expressions of PCB levels in wet tissue, ppm solids as well as the micrograms per fish fillets were applied in all the statistical analyses and modellings; however, only the optimum result from those three expressions was stated here. Some significant information will be listed in appendix.

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RESULTS AND DISCUSSION

Procurement Data for the Great Lakes Fish Species

Source and Size of Fish Data

The source and size of fish were chosen based on the Creel Census data from sports fisherman for 1990 so the fish would be representative of the most commonly caught by sport fishermen. Raw data of physical and chemical parameters of fish species were recorded in appendix 1 - 5. Some of the results quoted here were also reported in detail with standard deviation by Zabik et al. (1993). The mean length of carp harvested from Lake Erie were measured as 51.8 centimeter(cm) with a range in length from 45.7 to 56.5 cm and the mean weight of carp was 1834.2 gram (g) with a range in weight from 1340.0 to 2520.0 g. Lake Huron carp ranged in length from 40.6 to 55.9 with a mean length of 46.6 cm, and in weight from 890.0 to 2710.0 g with a mean weight of 1581.7 g.

Chinook salmon harvested from Lake Huron were measured from 70.0 to 91.5 cm with a mean length of 80.8 cm, and from 3860.0 to 7700.0 g with a mean weight of 5689.7 g. Lake Michigan chinook salmon were measured as 76.0 cm with a range in length from 67.0 to 91.5 cm, and weighed a mean of 4798.5 g with a range in weight from 2720.0 to 8415.0 g.

Lake Huron lake trout ranged in length from 59.5 to 66.5

cm with a mean length of 63.7 cm, and in weight from 2000.0 to 3150.0 g with a mean weight of 2666.7 g. Lake trout harvested from Lake Michigan were measured in length from 54.2 to 71.5 cm (mean 63.6 cm), and in weight from 1460.0 to 3620.0 g (mean 2677.1 g). Lake Ontario lake trout were measured with a mean length of 64.7 cm (ranging from 62.4 to 66.0 cm), and a mean weight of 2756.7 g (ranging from 2365.0 to 2985.0 g). Lake Superior lake trout (siscowet) ranged in length from 49.0 to 56.0 cm with a mean length of 52.8 cm, and ranged in weight from 1078.0 to 1492.0 g with a mean of 1271.6 g.

Walleye from Lake Erie were measured in length from 41.9 to 48.3 cm with a mean length of 46.1 cm, and in weight from 750.0 to 1010.0 g with a mean weight of 896.7 g. Lake Huron walleye ranged in length from 48.3 to 50.8 cm with a mean of 48.6 cm, and in weight from 940.0 to 1230.0 g with a mean of 1064.2 g. Walleye from Lake Michigan had a mean length of 46.5 cm (ranging from 41.3 to 49.4 cm) and a mean weight of 775.0 g (ranging from 620.0 to 865.0 g).

White bass from Lake Erie averaged 31.0 cm in length with a range from 26.7 to 34.3 cm, and averaged 676.7 g in weight with a range from 290 to 1140 g. Lake Huron white bass ranged in length from 27.9 to 34.3 cm with a mean of 31.5 cm, and in weight from 270.o to 520.0 g with a mean of 381.7 g.

Based upon the average and range data in length and in weight of the Great Lakes fish species, chinook salmon from Lake Huron and Lake Michigan possessed the longest length and the heaviest weight, followed by lake trout, carp, walleye.

White bass was the smallest fish specie used in the project. Because the specified lengths and weights of the Lake Superior siscowets were chosen to be representative of Native American fisheries, these were significantly smaller than those of the lake trout from Lakes Huron, Michigan and Ontario (Table 8).

Age and Sex of Fish Data

The effect of sex on contaminant level was also under examination in this experiment. The actual data on sex of the Great Lakes fish species was listed in Table 9. Half of the Lake Erie and Lake Huron carp were male. Sixty-seven percent and fifty-seven percent of chinook salmon from Lake Huron and Lake Michigan were male, respectively. Half of the lake trout from Lake Huron and Lake Superior were male. Sex was not recorded for the Lake Ontario lake trout. Eighty-three percent of Lake Michigan lake trout were female. All of the walleye from Lake Erie and Lake Michigan were male, and eighty-four percent of Lake Huron walleye were male. All of the Lake Erie white bass were male, while all of the Lake Huron white bass were female. Table 9 also presented the average age and the range of the ages for fish species from the Great Lakes used in this study. Lake Superior siscowets were the oldest fish with an average age of 9.2 years with a range of 8-11 years, compared to a mean age of lake trout harvested from Lake Huron (6.2 years), Lake Michigan (6.4 years) and Lake Ontario (5.3 years). The mean age of the Great Lakes fish species from greatest to smallest was in the

Table 8. Source and size of the Great Lakes fish species

Species	Lakes	Size (Mean Values) Length (cm)	Weight (gm)	Fish (No.)
Carp	Erie	51.8	1834.2	24
	Huron	46.6	1581.7	24
Chinook salmon	Huron	80.8	5689.7	42
	Michigan	76.0	4798.5	42
Lake trout	Huron	63.7	2666.7	12
	Michigan	63.6	2677.1	24
	Ontario	64.7	2756.7	12
Siscowet[1]	Superior	52.8	1271.6	23
Walleye	Erie	46.1	896.7	12
	Huron	48.6	1064.2	12
	Michigan	46.5	775.0	17
White bass	Erie	31.0	676.7	6
	Huron	31.5	381.7	6

[1] Siscowet is fat lake trout. Size was based on catch data of Native American and other fishermen from the Upper Peninsula of Michigan.

Table 9. Sex and age of the Great Lakes fish species

Species	Lakes	Sex (%male : %female)	Age(Range)	Fish (No.)
Carp	Erie	50:50	3.5(3-5)	24
	Huron	54:46	3.2(2-7)	24
Chinook salmon	Huron	67:33	3.6(3-5)	41
	Michigan	57:43	2.6(2-4)	29
Lake trout	Huron	50:50	6.2(6-7)	12
	Michigan	17:83	6.4(5-8)	24
	Ontario	NA[1]	5.3(5-6)	12
Siscowet[2]	Superior	54:46	9.2(8-11)	24
Walleye	Erie	100:0	5.1(3-7)	12
	Huron	84:16	4.2(3-6)	12
	Michigan	100:0	4.1(3-5)	18
White bass	Erie	100:0	2.8(2-4)	6
	Huron	0:100	2.7(2-4)	6

[1] Not Available

[2] Siscowet is fat lake trout. Size was based on catch data of Native American and other fishermen from the Upper Peninsula of Michigan.

following order: lake trout, walleye, carp and chinook salmon, white bass.

There were some significant correlations observed among age, length and weight of fish species from the Great Lakes based uponthe Pearson correlation coefficient (P<0.001) (Appendix 6). All fish species had a positive correlation coefficient between the length and weight. White bass had no significant correlations among age, length and weight. The length of walleye was significantly correlated with the weight of walleye; however, the age of walleye was not strongly correlated with either walleye length or weight. The explanation of these phenomena could have been the small sample size, i.e., white bass had only twelve fish. It was found for carp, chinook salmon and some of lake trout in this project that the older the fish, the greater in length and weight they were. Since Lake Superior siscowet had the older age (8 - 11 years) with a shorter length (49.0 - 56.0 cm) and lighter weight (1078.0 - 1492.0 g) range than all other lake trout, Pearson correlation coefficient had a negative correlation between age/length and age/weight for lake trout.

Processing Data of the Great Lakes Fish Species

According to the experimental design, carp, chinook salmon, and lake trout were processed into skin-on and skin-off fillets. Walleye and white bass were processed into skin-on fillets. Skin-on fillets had the belly flap trimmed off, while skin-off fillets had both the belly flap trimmed off and dark tissue from the lateral line and associated fat tissue removed. The right side of a fillet was used in a raw state as a control sample and the left side as cooked samples. Carcass yield (%) was based on the deheaded and degutted weight of each fish species to the whole fish weight, while the As Prepared (AP) yield (%) was the total weight of both sides of trimmed fillets to the total fish weight (Zabik et al., 1993). Summaries of processing data along with the analyses of solid and lipid contents on raw fillets for five fish species from the Great Lakes are presented in Tables 10 - 14.

Regardless of the size or species of the fish, carcass yield ranged in percentage from 57% to 71% which means at least one-third portion of fish discarded at the initial processing of the fish. The further belly flap trimming of fish fillets resulted in another one-fourth to one-half reduction on carcass yield which varied according to the skin conditions. Skin-on fish fillets had a range of 29% to 50% AP yield with an average AP yield of 40%, and skin-off fish fillets had a range of 22% to 33% AP yield with an average AP yield of 30%. Walleye skin-on fillets had the highest yield (50%) from Lake Michigan; carp skin-off fillets from Lake Huron had the lowest AP yield (21.7%) because carp has very thick and coarse skin tissue. Therefore, skin removal processing had a significant effect on the fillet weights of carp, chinook salmon and lake trout fillets; another ten percent of total fish weight was trimmed off from the fish tissue during skin removal procedures. Carp skin-on and skin-off fillets weighed about one-third and one-fourth of the total weight of fish, respectively. Chinook salmon and lake trout skin-on fillets in AP yields were equal to two-fifth of the total fish weight, and skin-off fillets in AP yields were equivalent to less than one-third of total fish weight. The origins of lakes also had some effects on carcass yield and AP yield (Table 10-14).

There were no weight differences between left-side fillets and right-side fillets of the fish, which meant that the fish fillet samples were processed in a uniform condition facilitating comparison between the control group and the treatment group. However, the weights of either skin-on or skin-off fish fillets for carp, chinook salmon, and lake trout differed among the lakes. Fillets processed from chinook salmon had the heaviest skin-on (over 1000 g) and skin-off fillets weights (approximate 760 g), and fillets processed from white bass had the lowest skin-on fillets weights (70 g) which were due mainly to the original small size of fish.

Analyses of Solids and Lipids on Raw Fish Fillets

All solids of raw fish fillets ranged in percentage from 22 to 35 in skin-on fillets, and from 21 to 30 in skin-off fillets, which indicated that skin-off fillets had a higher water content than the skin-on fillets. Skin removal and the lake from which the fish were harvested had significant effects on the solid contents of skin-on and skin-off fish

Table 10. Processing data as well as solid and lipid contents of raw fillets for carp from Lakes Erie and Huron

Carp	Fillets	Lakes		Skin Removal Effect[1]	Lake Effect[2]
		Erie	Huron		
Carcass Yield %	skin-on	57.51	58.19	Yes	No
	skin-off	NA[3]	61.79		
As Prepared Yield %	skin-on	36.26	29.07	Yes	Yes
	skin-off	25.62	21.70		
Right-Side Fillet (g)	skin-on	323.80	243.80	Yes	Yes
	skin-off	239.60	171.90		
Left-Side Fillet (g)	skin-off	331.30	226.40	Yes	Yes
	skin-off	237.70	169.50		
Solids %	skin-on	26.21	26.38	Yes	Yes
	skin-off	21.27	24.57		
Lipids %	skin-on	7.75	6.44	Yes	No
	skin-off	2.82	2.34		

[1] ANOVA indicated the effect of skin removal on skin-on fillets significant at the $P \leq 0.001$ level
[2] ANOVA indicated the effect of lakes significant at the $P \leq 0.05$ level
[3] not available

Table 11. Processing data as well as solid and lipid contents of raw fillets for chinook salmon from Lakes Huron and Michigan

Chinook salmon	Fillets	Lakes: Huron	Lakes: Michigan	Skin Removal Effect[1]	Lake Effect[2]
Carcass Yield %	skin-on	62.75	66.43	No	Yes
	skin-off	63.76	66.76		
As Prepared Yield %	skin-on	38.99	46.20	Yes	Yes
	skin-off	28.22	33.60		
Right-Side Fillet (g)	skin-on	1105.70	1174.70	Yes	Yes
	skin-off	755.80	761.90		
Left-Side Fillet (g)	skin-on	1217.90	1183.90	Yes	Yes
	skin-off	791.50	750.40		
Solids %	skin-on	25.41	28.20	Yes	Yes
	skin-off	23.21	25.74		
Lipids %	skin-on	4.17	11.63	Yes	Yes
	skin-off	1.82	5.71		

[1] ANOVA indicated the effect of skin-on or skin-off significant at the $P < 0.001$ level

2 ANOVA incidated the effect of lakes at the $P < 0.001$ level

Table 12. Processing Data as well as Solid and Lipid Contents of Raw Fillets for Lake Trout from Lakes Huron, Michigan, Ontario and Superior

Lake Trout	Fillets	Lakes				Skin Removal Effects[1]	Lake Effect[2]
		Huron	Michigan	Ontario	Superior		
Carcass Yield %	skin-on		67.35		67.17	Yes	Yes
	skin-off	64.46	67.68	71.16	65.35		
As Prepared Yield %	skin-on		42.22		38.77	Yes	Yes
	skin-off	31.82	32.62	33.27	27.48		
Right-Side Fillet (g)	skin-on		519.60		239.50	Yes	Yes
	skin-off	431.00	463.50	460.60	175.30		
Left-Side Fillet (g)	skin-on		521.00		252.50	Yes	Yes
	skin-off	417.00	434.60	458.70	170.70		
Solids %	skin-on		31.98		35.13	Yes	Yes
	skin-off	26.52	30.70	25.15	26.53		
Lipids %	skin-on		11.45		36.52	Yes	Yes
	skin-off	6.62	8.71	5.53	8.49		

[1] ANOVA indicated the effect of skin removal on skin-on fillets significant at the $p < 0.05$ level

[2].ANOVA indicated the effect of lakes significant at the $P \leq 0.05$ level

Table 13. Processing data as well as solid and lipid contents of raw fillets for walleye from Lakes Erie, Huron and Michigan

Walleye	Fillets	Lakes			Lake Effect[1]
		Erie	Huron	Michigan	
Carcass Yield %	skin on	66.45	59.73	63.40	Yes
As Prepared Yield %	skin on	40.93	40.89	50.08	Yes
Right-Side Fillet (g)	skin on	185.20	221.90	191.90	Yes
Left-Side Fillet (g)	skin on	181.40	213.60	193.10	Yes
Solids %	skin on	22.47	22.57	21.01	Yes
Lipids %	skin on	1.65	3.03	1.08	Yes

[1] ANOVA indicated the effect of lakes significant at the $P \leq 0.001$ level

Table 14. Processing data as well as solid and lipid contents of raw fillets for white bass from Lakes Erie and Huron

White bass	Fillets	Lakes: Erie	Lakes: Huron	Lake Effect[1]
Carcass Yield %	skin on	59.46	64.48	Yes
As Prepared Yield %	skin on	25.78	34.14	No
Right-Side Fillet (g)	skin on	74.20	62.20	No
Left-Side Fillet (g)	skin on	74.80	64.20	No
Solids %	skin on	23.64	23.63	No
Lipids %	skin on	4.38	2.57	No

[1] indicated the effect of lakes source significant at the $P \leq 0.001$ level

fillets. Lake trout skin-on fillets had the highest solid contents (34%) when compared to carp (26%), chinook salmon (27%), walleye (22%) and white bass (24%) fillets. Skin-off Lake Erie carp fish fillets had the lowest solids content (21%) and the highest water content.

Lipids of raw fish fillets had a wide range from 1% to 36.5% in skin-on fish fillets. Siscowets from Lake Superior skin-on fish fillets had the highest lipids content (36.5%), while Lake Erie walleye skin-on fillets had the lowest lipids content (1.08%). Trimming off belly flap and associated fat tissue showed significant reduction in lipid content. There was an almost 75% reduction of lipid content observed in siscowet skin-off fillets from Lake Superior. An average of 50% of lipid reduction was achieved through skin removing processes for all fish fillets, which is an important value on the assessment of PCBs consumption. Because most of the PCBs were extracted from the fatty tissue of fish, skin removal procedures eliminated the majority of contaminated substances in fatty tissue up to 50%. This figure has been used by the Great Lakes Fish Advisories Committee (GLSFATF, 1993).

Cooking Data of the Great Lakes Fish Species

The weights of fish sample (skin-on and skin-off) were recorded before cooking and after cooking in order to calculate the total cooking loss (%) and cooking yield (%). When cooked skin-on fillet sample was prepared, the skin was peeled off so only the cooked muscle tissue weight was recorded as the edible weight. The one exception was for deep fat fried skin-on fillets; skin was not removed since deep fat fried fish would normally be battered or breaded and thus eaten with the skin-on. The calculation of percentage total cooking loss was the ratio of the difference between raw and cooked fillet weights to the raw fish fillet weight times 100. Cooking yield percent was derived from the relation of the cooked edible weight of fillet to the raw fillet weight times 100. Sum of total cooking loss and cooking yield are 100% in all skin-off fish fillets. Totality of cooking loss and cooking yield is less than 100% in all skin-on fish fillets due to the fact that the weight of skin was excluded. Summaries of cooking data along with the analyses of solid and lipid contents on cooked skin-on and skin-off fillets for five fish species from the Great Lakes are presented at Tables 15 - 19. Regardless of the fillet size or species of the fish, cooking loss of skin-on fillets and skin-off fillets ranged in percentage from 17-36 and 12-36 with average of 26.5% and 24.0%, respectively, which means nearly one-fourth portion of fillet weight lost during cooking. The further skin removal after cooking of fish fillets resulted in lower cooking yield than cooked skin-off fillets in all fish species from the Great Lakes. Skin-on fish fillets had a range of 54% to 76% cooking yield with an average of 65% cooking yield and skin-off fish fillets had a range of 64% to 88% cooking yield with an average of 76% cooking yield. Approximately 10% of the total fillet weight was lost from cooked skin-on fillets

Table 15. Cooking data[1] and solid[1] and lipid[2] contents of cooked skin-on and skin-off fillets for carp from Lakes Erie and Huron

		Cooking Methods	
Carp	Fillets	Panfry	Deep-fat Fry
Lake Erie			
Cooking Loss %	skin-on	22.60	32.93
	skin-off	21.61	36.47
Cooking Yield %	skin-on	68.51	67.07
	skin-off	78.39	63.53
Solids %	skin-on	32.45	44.61
	skin-off	29.96	41.31
Lipids %	skin-on	7.65	17.27
	skin-off	3.80	7.21
Lake Huron			
Cooking Loss %	skin-on	20.10	30.17
	skin-off	15.14	30.37
Cooking Yield %	skin-on	68.91	69.83
	skin-off	84.86	69.63
Solids %	skin-on	31.66	42.94
	skin-off	30.52	42.38
Lipids %	skin-on	7.20	13.80
	skin-off	3.72	10.36

[1] n=6
[2] n=3

Table 16. Cooking[1] data and solid[1] and lipid[2] contents of cooked skin-on and skin-off fillets for chinook salmon from Lakes Huron and Michigan

Chinook Salmon	Fillets	Cooking Methods: Bake	Charbroil: Regular	Charbroil: Surface Increased	Can
Lake Huron					
Cooking Loss %	skin-on	21.32	27.37	35.15	
	skin-off	23.58	27.96	28.82	26.84
Cooking Yield %	skin-on	72.20	65.20	54.58	
	skin-off	76.42	72.04	71.18	73.16
Solids %	skin-on	31.16	33.96	35.02	
	skin-off	32.15	32.54	33.96	27.42
Lipids %	skin-on	5.10	5.70	5.23	
	skin-off	2.82	3.18	2.93	1.80
Lake Michigan					
Cooking Loss %	skin-on	19.70	29.28	25.73	
	skin-off	21.10	24.24	25.28	25.96
Cooking Yield %	skin-on	76.01	66.66	69.02	
	skin-off	78.90	75.76	74.72	74.04
Solids %	skin-on	34.59	37.29	32.43	
	skin-off	32.07	32.86	35.85	31.59
Lipids %	skin-on	11.87	9.63	9.10	
	skin-off	5.08	7.78	6.02	5.25

[1] n=6
[2] n=3

Table 17. Cooking[1] data and solid[1] and lipid[2] contents of cooked skin-on and skin-off fillets for lake trout from Lakes Huron, Michigan, Ontario and Superior

Lake Trout	Fillets	Cooking Methods			
		Bake	Char-broil	Salt Boil	Smoke
Lake Huron					
Cooking Loss %	skin-on				
	skin-off	23.70	24.22		
Cooking Yield %	skin-on				
	skin-off	76.30	75.78		
Solids %	skin-on				
	skin-off	34.38	35.20		
Lipids %	skin-on				
	skin-off	9.05	8.52		
Lake Michigan					
Cooking Loss %	skin-on				33.95
	skin-off	17.62	23.88	12.25	
Cooking Yield %	skin-on				57.61
	skin-off	82.38	76.12	87.75	
Solids %	skin-on				38.65
	skin-off	34.00	35.14	31.54	
Lipids %	skin-on				9.13
	skin-off	7.41	9.78	8.68	
Lake Ontario					
Cooking Loss %	skin-on				
	skin-off	17.26	19.92		
Cooking Yield %	skin-on				
	skin-off	82.74	80.08		
Solids %	skin-on				
	skin-off	30.83	31.28		
Lipids %	skin-on				
	skin-off	8.80	6.83		
Lake Superior					
Cooking Loss %	skin-on				36.24
	skin-off	26.01	25.18	13.06	
Cooking Yield %	skin-on				53.61
	skin-off	73.99	74.82	86.94	
Solids %	skin-on				41.91
	skin-off	35.03	32.42	32.38	
Lipids %	skin-on				22.36
	skin-off	9.38	7.96	11.64	

[1] n=6
[2] n=3

Table 18. Cooking[1] data and solid[1] and lipid[2] contents of cooked skin-on fillets for walleye from Lakes Erie, Huron and Michigan

Walleye	Cooking Methods	Lakes		
		Erie	Huron	Michigan
Cooking Loss %	Bake	23.48	19.18	28.95
	Charbroil	21.03	21.94	26.22
	Deepfat fry			35.70
Cooking Yield %	Bake	69.74	71.79	62.56
	Charbroil	71.89	70.73	67.89
	Deepfat fry			64.30
Solids %	Bake	28.43	27.32	27.50
	Charbroil	27.18	27.96	26.06
	Deepfat fry			38.82
Lipids %	Bake	2.20	3.03	1.53
	Charbroil	2.45	2.08	1.70
	Deepfat fry			8.89

[1] n=6
[2] n=3

Table 19. Cooking[1] data and solid[1] and lipid[2] contents of cooked pan fried skin-on fillets for white bass from Lakes Erie and Huron

		Lakes	
White bass	Fillets	Erie	Huron
Cooking Loss %	skin on	21.27	16.70
Cooking Yield %	skin on	68.33	73.66
Solids %	skin on	28.48	29.79
Lipids %	skin on	5.14	3.18

[1] n=6
[2] n=3

during the combination of cooking and skin removal processes. Skin-on smoked lake trout fillets had the highest averaged cooking loss (35%), and lake trout skin-off salt-boiled fillets had the lowest averaged cooking loss (13%), all from Lakes Michigan and Superior. The differences of cooking loss between smoking and salt boiling were possibly related to the cooking time, cooking atmosphere and the presence of skin.

According to the experimental design, all fillets either skin-on or skin-off were cooked to an internal temperature of 80°C, which resulting in the variations with the median cooking temperature and the appropriate cooking time. By monitoring the internal temperature, the variation of cooking loss between skin-on and skin-off fillets of the same cooking method was reduced. This phenomena was observed in cooked fillets for carp and chinook salmon. However, the effect of cooking methods on cooking loss of fillets was significantly less for pan-fried cooking method than deep-fat fried cooking method on skin-on and skin-off carp harvested from Lakes Erie and Huron ($P<0.05$)(Table 15). Baked skin-on and skin-off chinook salmon fillets also had significantly less cooking loss than charbroiled (regular and surface increased) chinook salmon fillets from Lakes Huron and Michigan ($P<0.05$)(Table 16). Skin-off salt-boiled lake trout fillets had significantly less cooking loss than skin-off baked lake trout fillets, and skin-off charbroiled lake trout fillets ($P<0.05$)(Table 17). Smoked skin-on lake trout fillets, deep-fat fried skin-on walleye fillets and deep-fat fried skin-on and skin-off carp fillets had similar values of the cooking loss, which were 35%, 36% and 33%, respectively. Lake effect on cooking loss and cooking yield of skin-on carp and skin-on chinook salmon fish fillets did not possess the same pattern as their skin-off fillets which were in the same trend within each species.

Analyses of Solids and Lipids of Cooked Fish Fillets

All solids of cooked fish fillets ranged in percentage from 26 to 45 in skin-on fillets, and from 30 to 42 in skin-off fillets with an average of 36% on both skin-on and skin-off fillets. As mentioned above, fillets cooked to the same internal temperature also reduced the variation of solid contents between skin-on and skin-off fillets. Deep-fat fried skin-on and skin-off carp fillets from Lakes Erie and Huron had significantly higher solid contents (43%) than lake trout skin-on and skin-off fillets (34%), skin-on and skin-off chinook salmon (33%), walleye skin-on fillets (29%) and white bass skin-on fillets (29%). Walleye charbroiled skin-on fillets from Lake Michigan had the lowest solid contents (26%) and the highest water content. Solid contents were significantly higher in cooked fillets than in raw fillets (Appendix 7). This mechanism is due mainly to the loss of water content (Zabik et al., 1993). Effects of cooking methods on solid contents of fillets were significantly higher for deep-fat fried carp (43%), smoked lake trout (40%), and deep-fat fried walleye than baked (32%) or charbroiled (regular (33%) and surface increased (34%)) chinook salmon; baked (34%), charbroiled (34%) or salt-boiled (32%) lake trout; and baked (28%) or charbroiled (27%) walleye ($P<0.005$). Smoked skin-on lake trout had the least water content among all the cooked fillets (Table 17).

Lipid of cooked fish fillets ranged from 2% to 22% compared to the range of lipid content (1% to36%) of raw skin-on and skin-off fillets. Smoked skin-on siscowets from Lake Superior had the highest lipid content (22%), while baked skin-on walleye from Lake Michigan fillets had the lowest lipid content (2%). Lipid content of skin-on smoked lake trout fillets from Lake Superior (22%) was significantly higher than lipid content of panfried (6%) or deep-fat fried (12%) carp fillets; baked (7%), charbroiled (6%) or canned (4%) chinook salmon fillets; baked (9%), charbroiled (8%) or salt boiled (10%) lake trout fillets; baked (2%), charbroiled (2%) or deep-fat fried (9%) walleye fillets; and panfried (4%) white bass fillets. In addition, the lipid content of skin-on chinook salmon was significantly higher than that of skin-off chinook salmon in their specific cooking method (Table 16). Lipid content was significantly higher in cooked fillets than in raw fillets (Appendix 7).

In this study, cooking media consisted of liquid cooking oil, corn oil spray, distilled water or a solution for brining containing lecithin. Cooking medium varied with the designed cooking method. The mechanisms of the adsorption of lipid, extraction of lipid, cooking time, and cooking temperature caused some changes of the lipid contents in a specific cooked skin-on or skin-off fillets; deep-fat frying caused four times the increase in the lipid content in cooked fillets compared to the raw fillets; however, smoking caused the 14% decrease of lipid content in cooked Lake Superior skin-on lake trout fillets significantly compared to the raw fillets.

Distribution Pattern of PCB Specific Congeners in Fish Fillets from the Great Lakes

In order to produce the accurate risk assessment of PCB toxicity, there is a need to quantitate individual PCB specific congeners. Based upon their chlorination and chlorine substituted position, the separation of individual PCB congeners became visible in GC-capillary column analysis. In this study, there were 53 specific congeners selected which are existing in the commercial Aroclor® 1254. PCB congeners 66/95/121, 84/101, 79/99, 123/149, 105/132, 128/167, 156/171, and 157/200 were co-elutions based upon their retention time. All concentrations are reported on a wet weight basis. The proportion of individual congener was derived from each specific congener concentration to the total PCB concentration. Out of all specific congeners, 55, 76 and 120 were under the limit of quantitation in all samples; thus, the values for these congeners did account as zero. This was also applied to any congener below the level of detection. The statistical analysis was done by ANOVA, using Tukey test with significant level of $p < 0.2$ to find the effects of lake, skin removal, cooking, and species.

<u>Lake Effect</u> Table 20 represented the mean concentration of 53 secific PCB congeners for raw skin-on and skin-off chinook salmon harvested from Lakes Huron (42 fillets) and Michigan (42 fillets). Total PCBs for chinook salmon fillets were not affected by lakes. However, concentration of PCB 31, 52, 49, 47, 44, 42, 72, 70, 66/95/121, 91, 92, 84/101, 79/99, 87, 110, 153, 141, 137, 138, 183, 171/156, and 180 were significantly different between lakes for chinook salmon (ANOVA $p<0.2$). Of the individual congeners and co-eluting congeners found, 87, 66/95/121, 118 and 138 were most prominent (each comprised > 5% of total PCBs), followed by, in decreasing order, 84/101, 153, 110, 79/99, 180, 105/132 (2.72%) in Lake Huron chinook salmon. Of Lake Michigan chinook salmon, the prominent congeners were 87, 66/95/121, and 84/101 (each comprised > 5% of total PCBs), followed by, in decreasing order, 118, 110, 79/99, 42, 83, 138 and 70 (2.93%). Maack and Sonzogni (1988) reported that the prominent congeners found in Wisconsin fish species were 153/132 (9-19% of total PCBs), followed by 138, 66/95, 110, 101, 180, 70/76, 146, 28/31, 149,118 and 105(1-5%). Oliver and Niimi (1988) found that congeners 153, 101, 84, 110, 180, 87+97, 149, 187+192 and 105 constituted over half the total PCBs in salmonids from Lake Ontario. The above results indeed revealed that concentration of PCB specific congeners provided much more detailed information toward distribution pattern of PCBs in the aquatic species than just concentration of total PCB alone. However, chinook salmon

Table 20. Mean concentration of PCB specific congeners and their percentage for raw skin-on and skin-off chinook salmon harvested from Great Lakes

PCB congeners	Lake Huron (ppm,wet wt.)	Lake Michigan (ppm,wet wt.)	Lake Huron %	Lake Michigan %
31	**0.021***	**0.041**	0.85	1.41
52	**0.043**	**0.066**	1.72	2.28
49	**0.039**	**0.057**	1.55	1.98
47	**0.028**	**0.045**	1.14	1.57
44	**0.031**	**0.056**	1.23	1.94
42	**0.058**	**0.105**	2.34	3.63
72	**0.005**	**0.008**	0.18	0.27
103	0.011	0.010	0.45	0.34
70-	**0.063**	**0.085**	2.52	2.93
76	n.d.	n.d.	n.d.	n.d.
66/95/121	**0.136**	**0.173**	5.45	5.99
91	**0.021**	**0.032**	0.86	1.11
55	n.d.	n.d.	n.d.	n.d.
92	**0.065**	**0.088**	2.60	3.06
84/101	**0.122**	**0.151**	4.87	5.22
79/99	**0.081**	**0.101**	3.26	3.49
83	0.072	0.103	2.36	3.37
97	0.040	0.049	1.60	1.68
87	**0.605**	**0.748**	24.25	25.86
120	n.d.	n.d.	n.d.	n.d.
85	0.029	0.033	1.15	1.13
136	0.000	0.019	0.00	0.66
110	**0.085**	**0.103**	3.41	3.58
108	0.017	0.021	0.69	0.73
149/123	0.034	0.033	1.35	1.13
118	0.132	0.139	5.30	4.81
114	0.056	0.057	2.23	1.97
122	0.016	0.000	0.66	0.00
153	**0.113**	**0.074**	4.52	2.56
105/132	0.068	0.080	2.72	2.75
141	**0.019**	**0.026**	0.75	0.89
179	0.019	0.017	0.78	0.60
137	**0.010**	**0.015**	0.40	0.50
138	**0.127**	**0.092**	5.11	3.19
158	0.044	0.027	1.78	0.93
183	**0.018**	**0.007**	0.73	0.25
167/128	0.033	0.040	1.33	1.39
185	0.008	0.011	0.32	0.39
181	0.055	0.062	2.19	2.13
171/156	**0.027**	**0.011**	1.07	0.38
157/200	0.007	0.005	0.27	0.18
180	**0.073**	**0.027**	2.92	0.92
190	0.031	0.035	1.25	1.22
198	0.046	0.048	1.83	1.64
TOTAL	2.495	2.893	100	100

***Bolded number means lake effect at significant level ($p < 0.2$)**

harvested from Lake Michigan had significantly higher tri-, tetra- and penta-CBs, but significantly lower hexa-, hepta-, and octa-CBs than chinook salmon harvested from Lake Huron. Lower chlorinated biphenyls were significantly affected by the origin of lakes; and the persistence of PCB congeners remained in the environment and detected in chinook salmon fillets more likely came from the higher chlorinated biphenyls, such as hexa-, hepta-, and octa-CBs.

Skin Removal Effect Skin-removal effect on PCB specific congeners from 36 raw skin-on and 48 raw skin-off chinook salmon fillets as well as 24 raw skin-on and 24 raw skin-off carp fillets was presented in Table 21. These skin-on and skin-off chinook salmon fillets were not processed from the same fish, but from the same location as well as carp skin-on and skin-off fillets. The result showed that the concentrations of over 30 PCB specific congeners and total PCBs were significantly reduced by removing skin and trimming adipose tissue under skin for chinook salmon fillets; particularly on the prominent congeners, such as 66/95/121, 87, 118, 84/101 and 83. Figure 3 demonstrated that the reduction of concentration of PCB specific congeners was very effective through skin-removal and fat trimming, not only on the lower chlorinated biphenyls, such as 42 (35% reduction) but also on the higher chlorinated biphenyls, such as 181 (50% reduction) for chinook salmon fillets which normally have higher fat content than carp fillets (Tables 10 and 11). Levels of PCB specific congeners on 70, 92, 84/101, 99/79, 87

Table 21. Mean concentration of PCB specific congeners and total PCBs from raw skin-on and raw skin-off fillets for carp and chinook slamon harvested from the Great Lakes

	Total PCB concentration (ppm, wet wt.)			
PCB Congener	**Chinook salmon raw skin-on**	**Chinook salmon raw skin-off**	**Carp raw skin-on**	**Carp raw skin-off**
31	0.031	0.031	0.039	0.030
52	***0.070**	**0.046**	0.091	0.074
49	**0.060**	**0.040**	0.086	0.067
47	**0.044**	**0.031**	0.054	0.040
44	0.046	0.042	0.067	0.051
42	**0.105**	**0.068**	0.143	0.100
72	**0.008**	**0.005**	0.021	0.005
103	**0.013**	**0.010**	0.018	0.044
70	**0.088**	**0.066**	**0.047**	**0.030**
76	n.d.	n.d.	n.d.	n.d.
66/95/121	**0.192**	**0.128**	0.173	0.117
91	**0.032**	**0.023**	0.027	0.019
55	n.d.	n.d.	n.d.	n.d.
92	**0.094**	**0.065**	**0.074**	**0.048**
84/101	**0.162**	**0.115**	**0.137**	**0.098**
99/79	**0.110**	**0.076**	**0.084**	**0.055**
83	**0.107**	**0.056**	0.032	0.022
97	**0.053**	**0.039**	0.041	0.028
87	**0.830**	**0.556**	**0.227**	**0.137**
120	n.d.	n.d.	n.d.	n.d.
85	**0.039**	**0.026**	0.027	0.017
136	n.d.	0.100	n.d.	0.012
110	**0.116**	**0.080**	**0.092**	**0.059**
108	**0.024**	**0.016**	0.017	0.047
149/123	**0.047**	**0.058**	0.063	0.040
118	**0.172**	**0.110**	0.110	0.080
114	**0.090**	**0.041**	0.037	0.018
122	**0.018**	**0.006**	0.029	0.009
153	0.087	0.098	0.095	0.062
132/105	**0.090**	**0.064**	0.060	0.038
141	0.025	0.022	0.028	0.017
179	**0.025**	**0.017**	0.021	0.009
137	**0.016**	**0.010**	0.009	0.004
138	0.108	0.113	0.108	0.077
158	0.031	0.052	0.203	0.151
183	0.015	0.014	0.020	0.011
167/128	**0.044**	**0.032**	0.030	0.018
185	**0.015**	**0.008**	0.005	0.003
181	**0.082**	**0.040**	0.101	0.077
171/156	0.024	0.022	0.024	0.011
157/200	0.005	0.009	0.008	0.005
180	0.034	0.069	0.083	0.041
190	**0.036**	**0.032**	0.035	0.037
198	0.047	0.050	0.026	0.011
TOTAL	**3.195**	**2.333**	**2.387**	**1.561**

***Bolded number means skin removal effect at significant level ($p < 0.2$)**

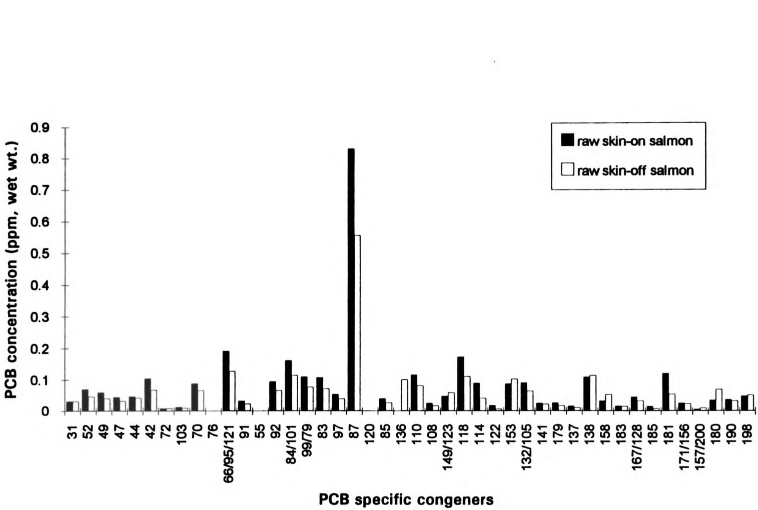

Figure 3. Mean concentration of PCB specific congener for raw skin-on and raw skin-off chinook salmon fillets harvested from the Great Lakes

and 110 and total PCBs were also significantly reduced by removing skin and trimming fat for carp fillets (Table 21). The distribution pattern of individual congeners was not affected by skin-removal process because the prominent congeners were 87, 158, 66/95/121, 42, 84/101, and 118 for skin-on carp fillets and 158, 87, 66/95/121, 42, 84/101, and 118 for skin-off fillets according to the decreasing order of their concentration; however, specific concentration of those prominent congeners was reduced through skin-removal and trimming fat process before cooking.

<u>Cooking Effect</u> Figures 4 and 4a represented the mean concentration of PCB congeners for raw and cooked skin-off chinook salmon harvested from Lakes Huron and Michigan. Most congeners had higher concentrations in raw fillets than cooked fillets with the exceptions of 72, 83, 120, 137, 158 and 167/128 measured in ppm wet tissue (Figure 4). A comparison graph (Figure 4a) on percentage of individual congener to the total concentration of PCBs showed that more congeners in cooked chinook salmon were a higher % of the total PCBs (31, 52, 49, 44, 42, 72, 66/95/121, 91, 92, 84/101, 99/79, 83, 87, 120, 85, 108, 118, 122, 132/105, 179, 137, 158, 183, and 167/128) than in raw salmon; despite this, the level of the specific congener had a higher ppm in raw wet tissue than in the cooked wet tissue, except for 72, 83, 120, 137 and 158. This occurrence was mainly because the total concentration of PCBs measured in ppm wet cooked tissue was reduced through the cooking process, including cooking losses and evaporation; the

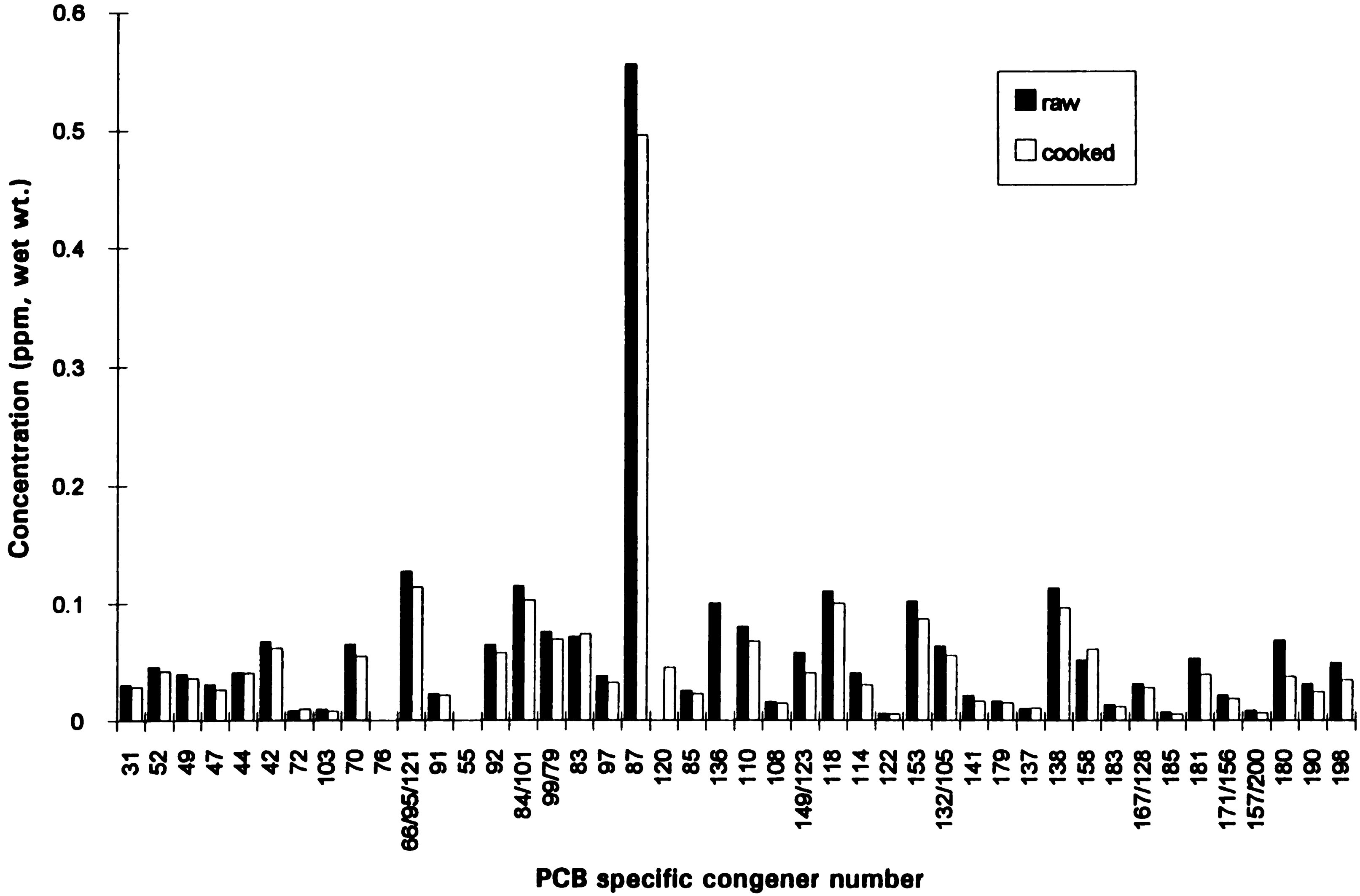

Figure 4. Mean concentration of PCB specific congeners for raw and cooked skin-off chinook salmon harvested from Great Lakes

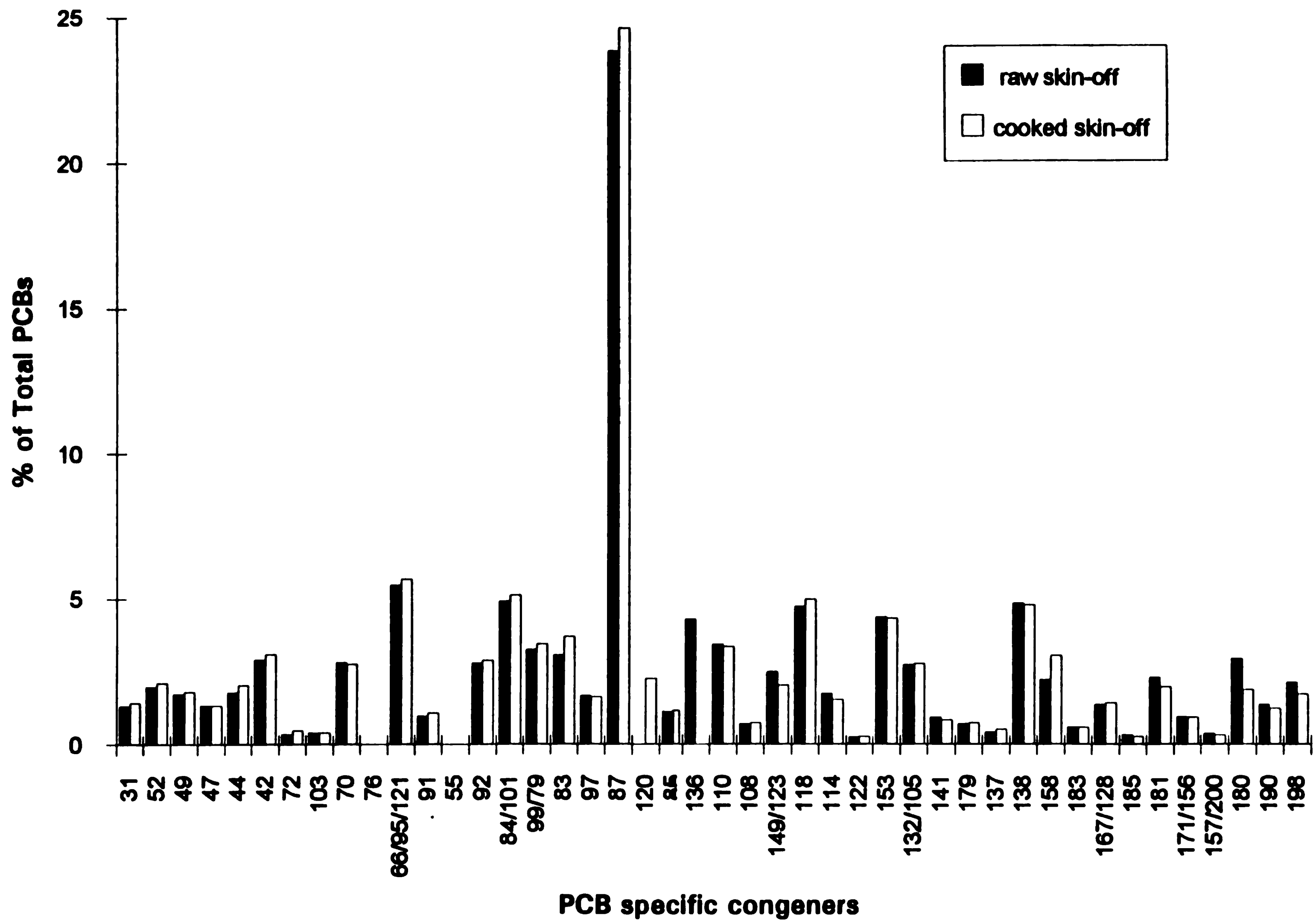

Figure 4a. Percentage of individual PCB specific congener to total PCB concentration for raw and cooked skin-off chinook salmon from Lakes Huron and Michigan

proportion of individual congener to total PCBs in cooked chinook salmon appeared higher than the proportion of individual congener to total PCBs in raw tissue. However, this phenomena occurred particularly in the lower chlorinated congeners instead of the higher chlorinated congeners, which might mean that the cooking process facilitates the reduction of higher chlorinated biphenyls instead of lower chlorinated biphenyls. Figure 5 also represented the cooking effect on the reduction of PCB congener levels during the cooking of carp fillets. Even though expressing the congeners on a wet weight basis does not account for differences in fillet weight between raw and cooked samples, most of the congener concentrations were reduced through the panfrying or deepfat frying procedure.

Species Effect Figure 6 presents the comparison of the effect of species on the distribution pattern of PCB specific congeners. In general, chinook salmon had a higher concentration of specific congener than walleye and white bass. White bass also had higher concentrations than walleye; this may have something to do with the fat content of a fish species because the lipid content of skin-on chinook salmon, white bass and walleye was 8%, 3.5% and 2%, respectively. There were significant differences between residues in the raw skin-on chinook salmon and the residues in the raw skin-on walleye for congeners 31, 52, 49, 47, 44, 42, 103, 70, 66/95/121, 91, 84/101, 99/79, 83, 97, 87, 85, 136, 110, 108, 118, 114, 132/105, 141, 179, 137, 167/128, 181, 198 and total

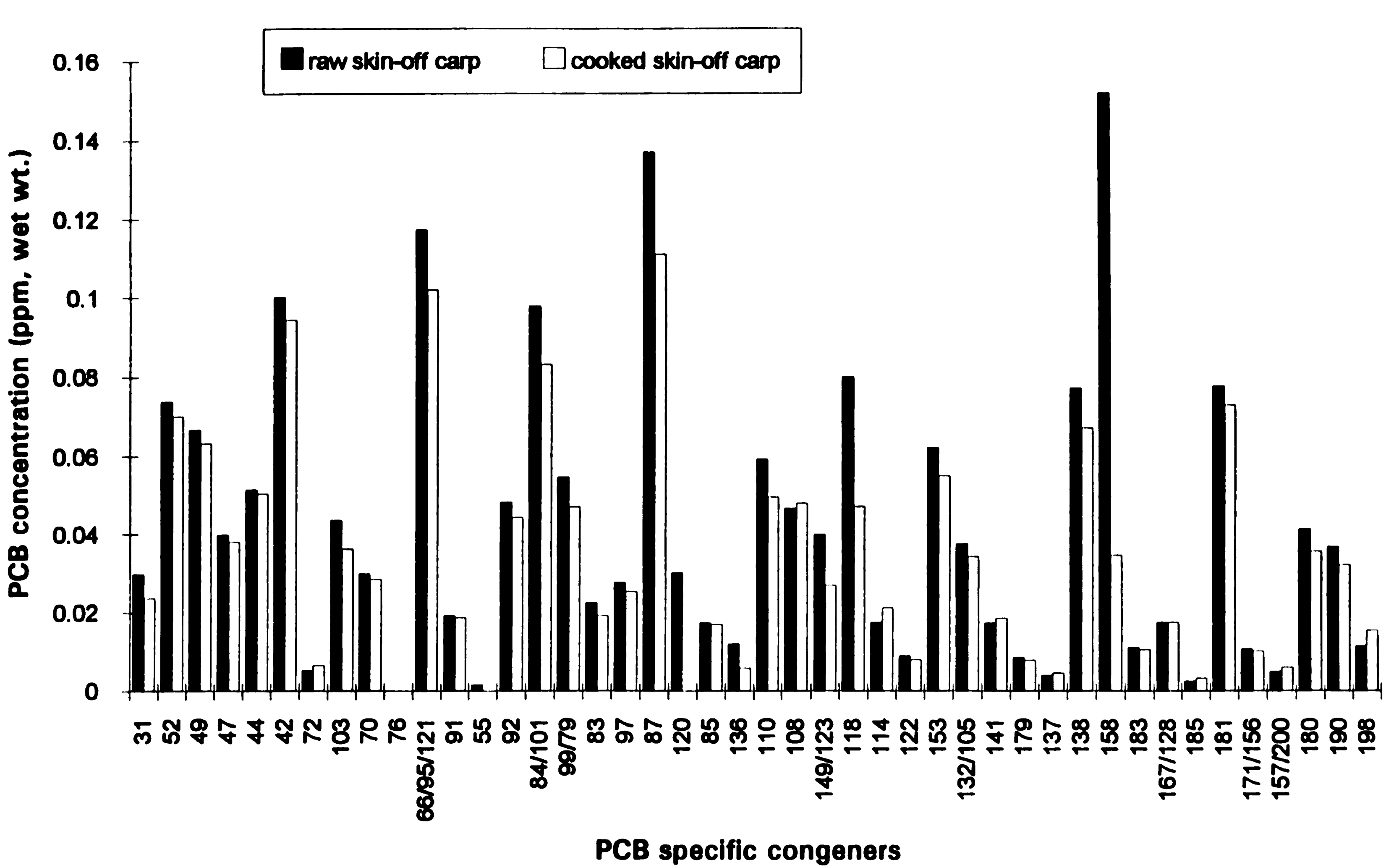

Figure 5. Mean concentration of PCB specific congener for raw skin-off and cooked skin-off carp fillets harvested from the Great Lakes

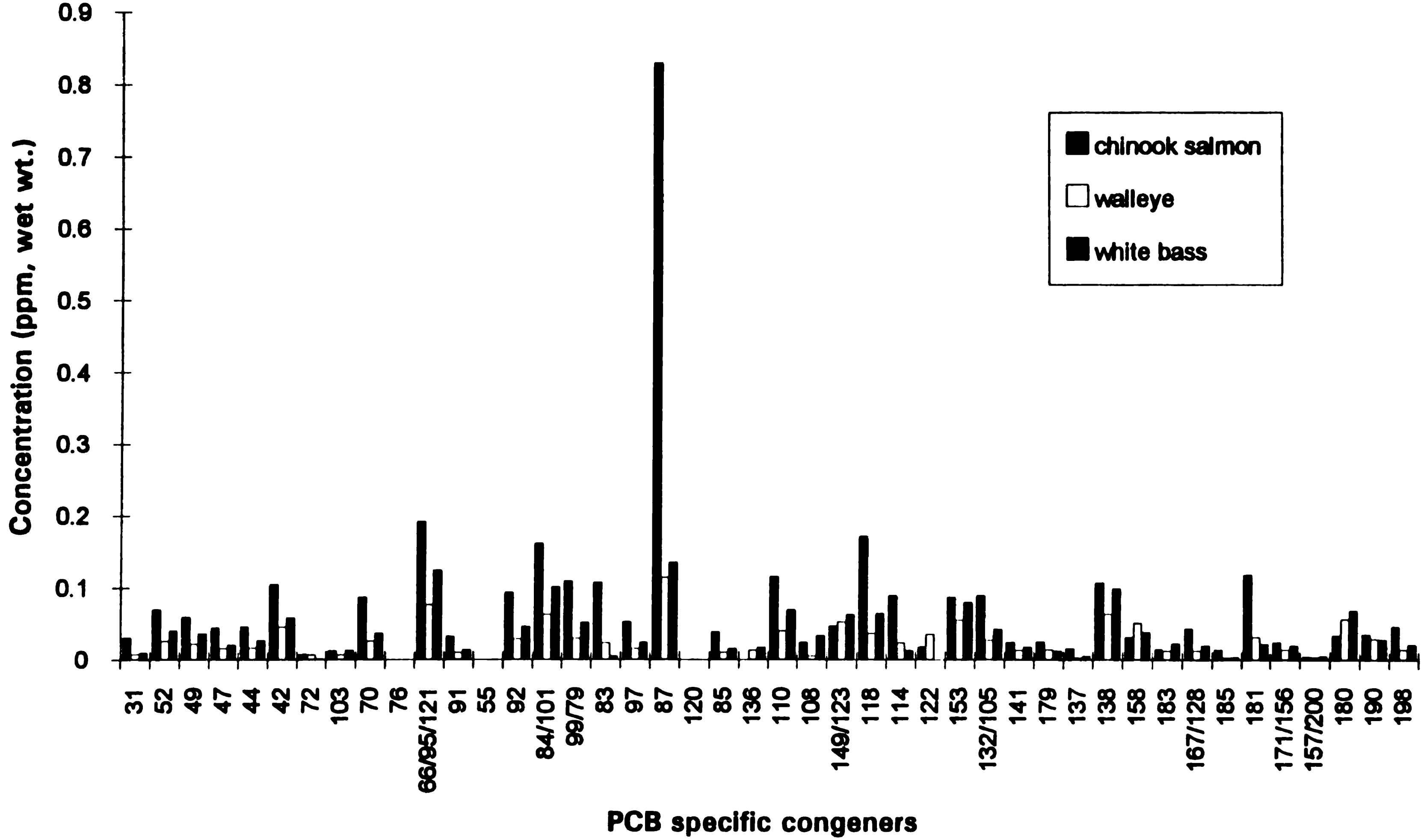

Figure 6. Mean concentration of PCB specific congeners for raw skin-on chinook salmon, walleye and white bass harvested from Great Lakes

PCBs with the exception of congeners 72, 123/149, 122, 153, 138, 158, 183, 185, 171/156, 157/200, 180, and 190. As compared between the residues in raw chinook salmon to the residue in raw white bass fillets, there were over 20 congeners significantly different, such as 52, 49, 47, 44, 66/95/121, 91, 84, 99/79, 83, 97, 87, 85, 136, 110, 118, 114, 132/105, 179, 137, 167/128, 181, and 198 with exceptions of 31, 42, 72, 103, 108, 149/123, 122, 153, 141, 138, 158, 185, 171/156, 157/200, 180, and 190. Significant differences between congener specific PCB residues in walleye fillets and in white bass fillets occurred only for congeners 66/95/121, 110, 108, and 132/105. The prominent congeners for chinook salmon are 87, 65/95/121, 118, 84/101, 110, 181, 99/79, 83, and 138; for walleye are 87, 66/95/121, 149/123, 153, 138, 158, and 189; for white bass are 66/95/121, 87, 84/101, 110, 153, 138 and 189. The common prominent congeners are 87, 66/95/121 and 138. As mentioned before, the higher chlorinated biphenyls persisted in the environment longer than lower chlorinated biphenyls, particularly because fish species on the top of the food chain may have the effect of biomagnification on concentrations of higher chlorinated biphenyls. Oliver and Niimi (1988) found that the chlorine content of the PCBs was observed to increase with trophic level in the Lake Ontario ecosystem.

Distribution Pattern of PCB Homologs in Fish Fillets from the Great Lakes

The PCB patterns that are found in fish tend to have greater concentrations of the more chlorinated PCB homologs (congeners with five to seven chlorine substitutions), while water has been reported to have greater amounts of less chlorination biphenyls (Bush et al. 1989; Oliver and Niimi, 1988). Grouping the congeners together makes the identification of the specific Aroclor® products visible. In this study, PCB homologs were grouped by the same chlorination for 53 individual congeners analyzed in fish tissue. For each species of fish, samples analyzed in the EPA "National Study of Chemical Residues in Fish" (1992) were from sites in Michigan, and are illustrated in the graphs 7, 9a, 10 and 11. Figures 7-11 demonstrated the distribution pattern of PCB homologs which was derived from the concentration of PCB homologs to the total PCB concentration (ppm, wet wt. basis) for five fish species harvested from the Great Lakes. Based upon the experimental design, data were generated from all the fillets both raw and cooked in these analyses. Ninety-six carp fillets, one hundred sixty-eight chinook salmon fillets, one hundred forty-four lake trout fillets, eighty-four walleye fillets and twenty-four white bass fillets were used.

The homolog pattern of carp harvested from Lakes Erie and Huron possessed tri-, tetra-, penta-, hexa-, hepta-, and octa-CBs (2%, 30%, 35%, 23%, 9%, and 1%) and (2%, 27%, 48%, 17%, 5% and 1%), respectively. Penta-CBs homolog in carp

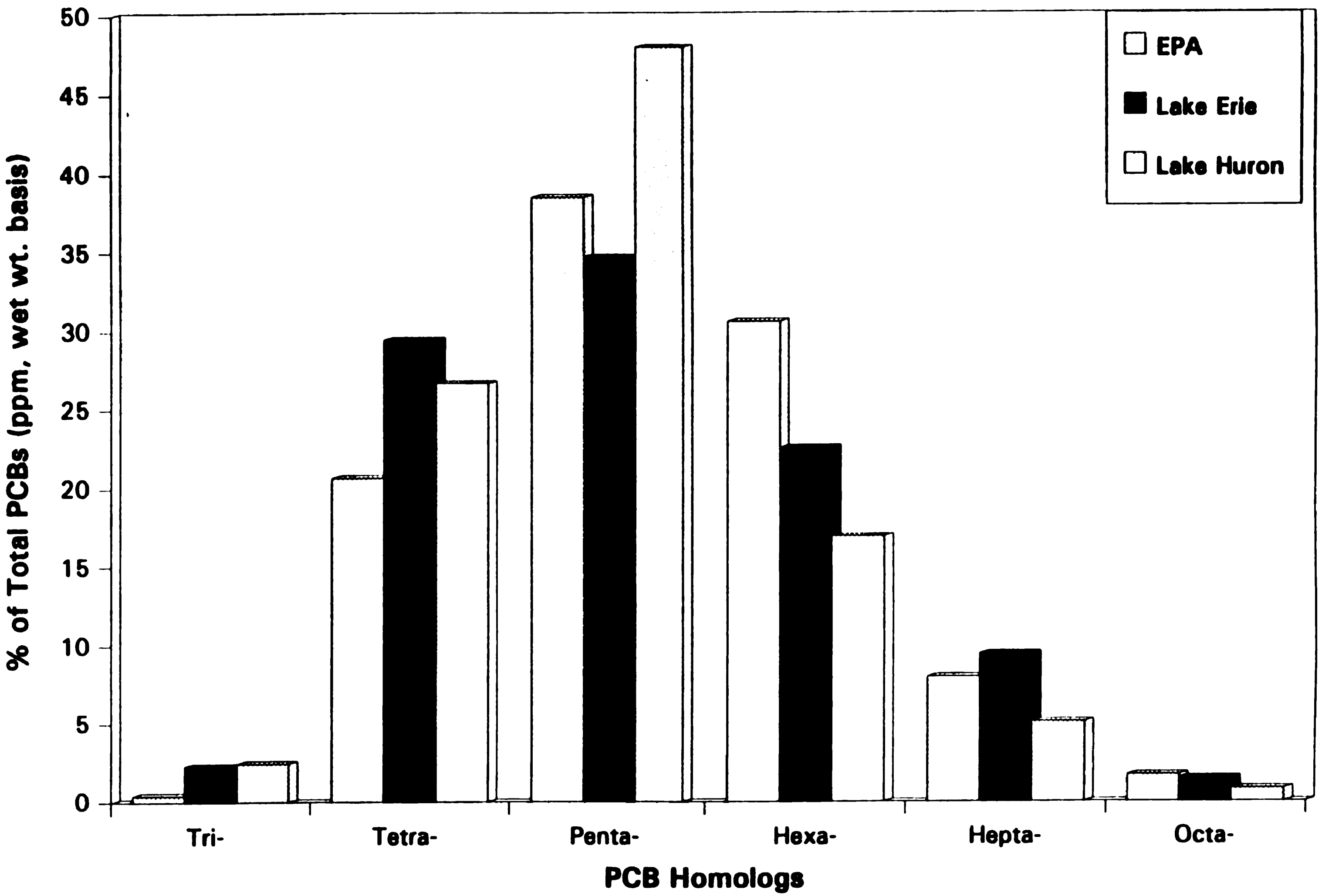

Figure 7. Distribution pattern of PCB homologs for carp

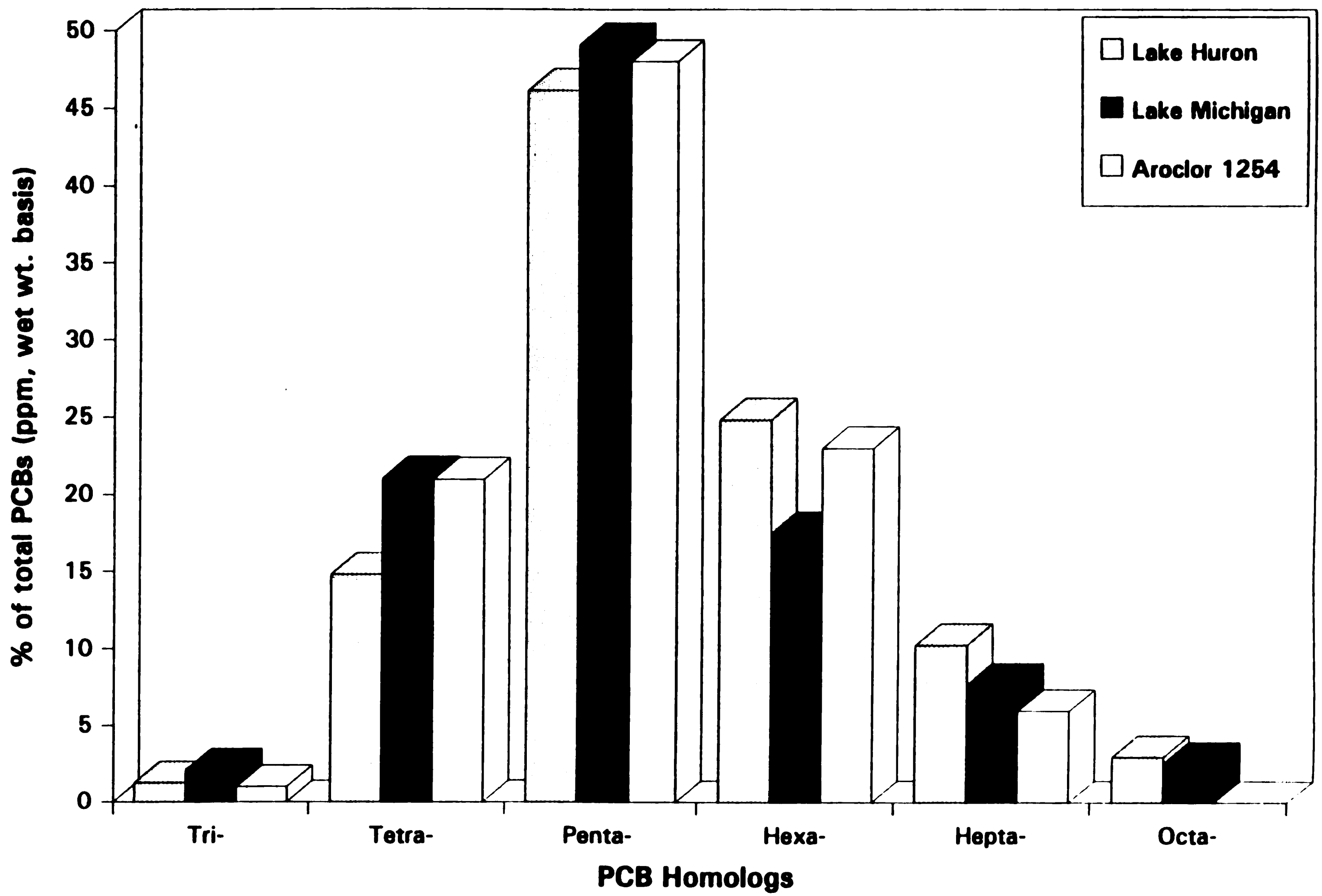

Figure 8. Distribution pattern of PCB homologs for chinook salmon fillets

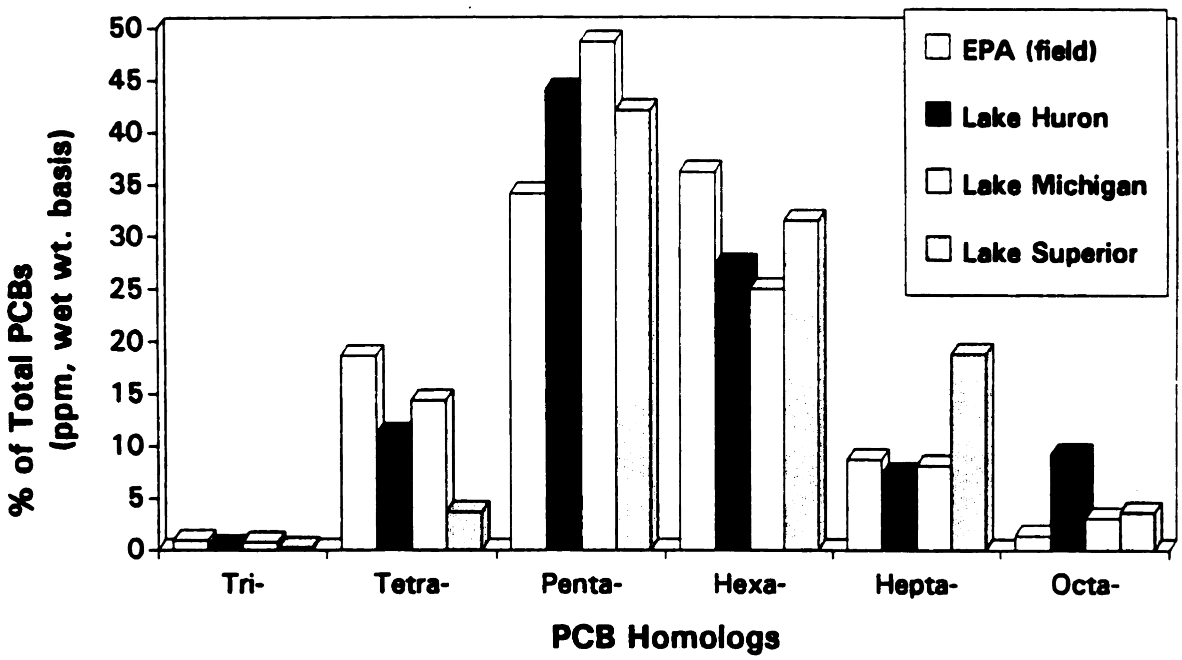

Figure 9a. Distribution pattern of PCB homologs for lake trout fillet

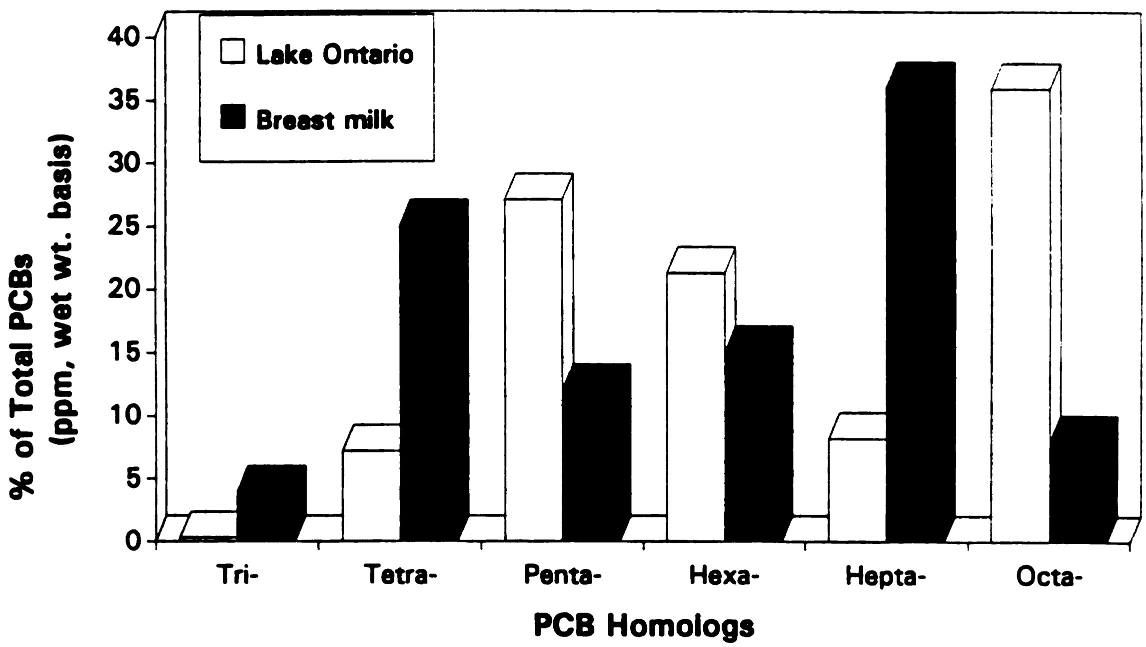

Figure 9b. Distribution pattern of PCB homologs for lake trout fillet (Breast milk data quoted from Waid, 1986)

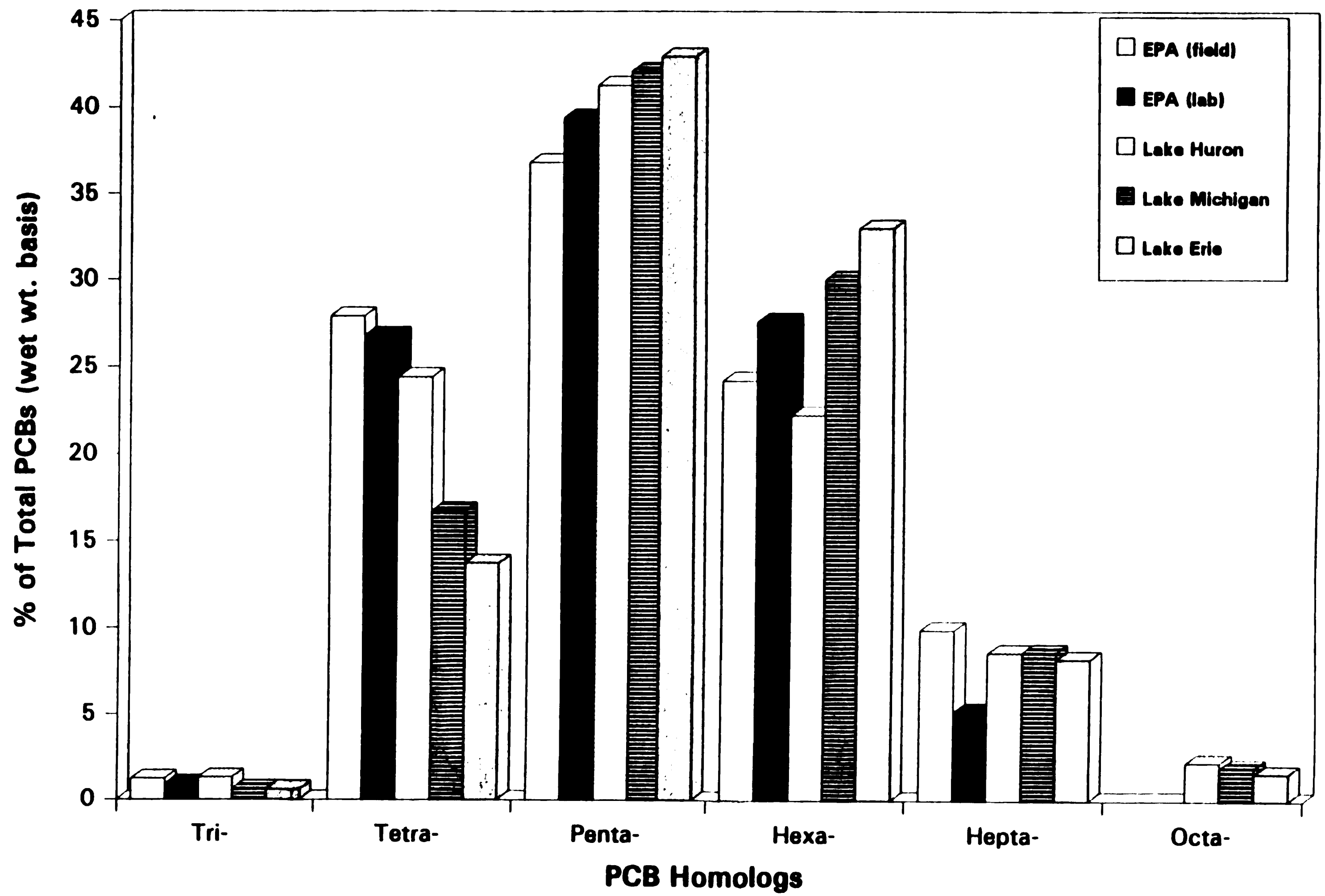

Figure 10. Distribution pattern of PCB homologs for walleye fillet

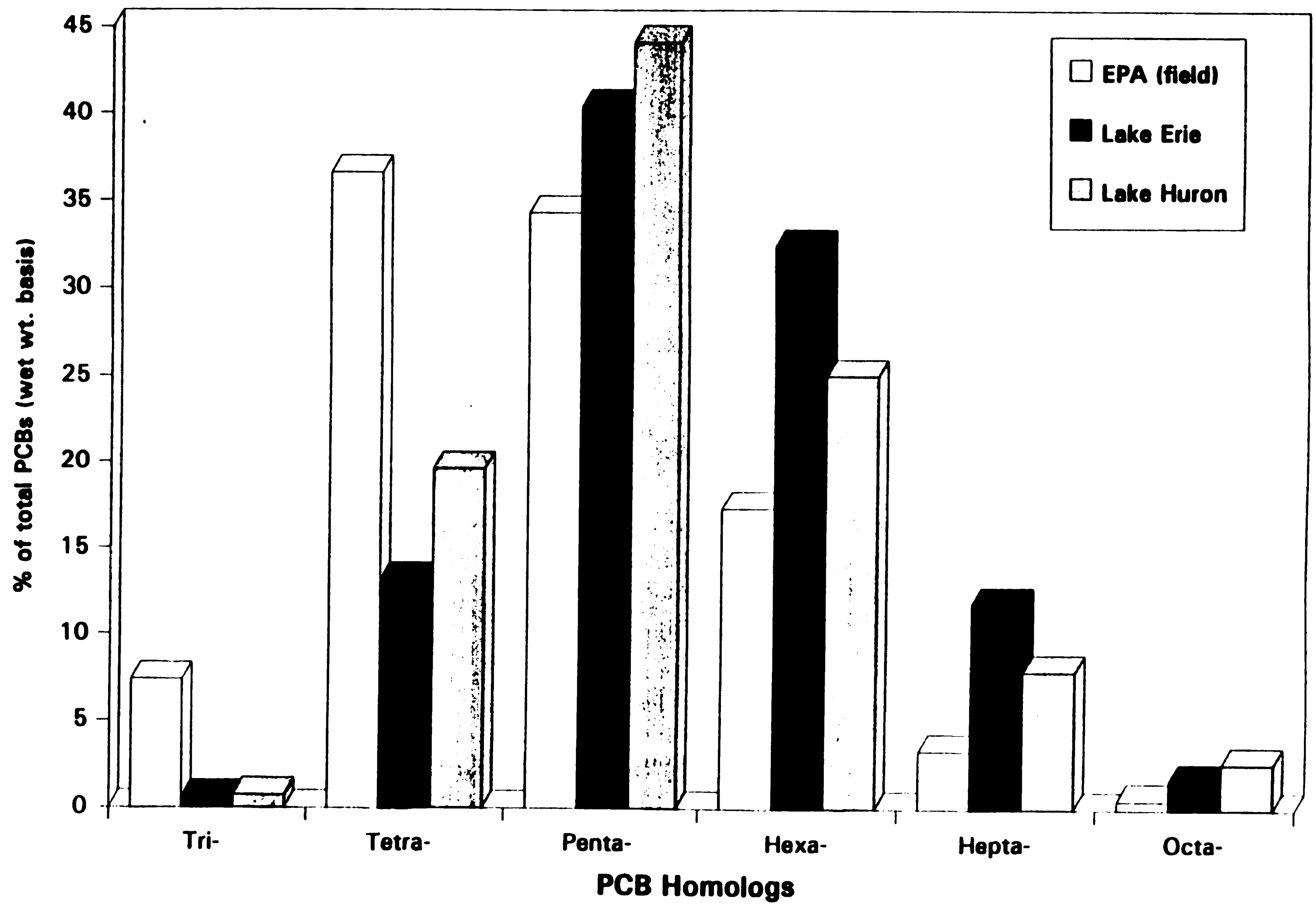

Figure 11. Distribution pattern of PCB homologs for white bass fillet

fillets from Lake Huron had the same proportion as Aroclor® 1254 (48%) as well as hexa-CBs homolog for carp fillets from Lake Erie had the same composition as Aroclor® 1254 (23%)(Table 1). It was noted that carp, as a bottom feeder fish from Lakes Erie and Huron, had higher tetra-CBs (29% and 27%, respectively) instead of hexa-CBs (23% and 17%, respectively). The distribution pattern of tetra-, penta-, hexa-, and hepta-CBs for carp collected from Escanaba River, Escanaba, Michigan (U.S. EPA, 1992) was 21%, 39%, 31% and 8%, respectively (Figure 7), which had the same tetra-CB proportion as Aroclor® 1254. Penta- and hexa-CBs were the dominant homologs (69%) in whole-body carp collected from Escanaba which was a historical PCB contaminated site.

Chinook salmon fillets had a distribution pattern very similar to Aroclor® 1254 in the composition of tetra- and penta-CBs from Lake Michigan (21% and 49%) and penta- and hexa-CBs from Lake Huron (46% and 25%)(Figure 8). It was quite clear that chinook salmon fillet can be a good indicator for Aroclor® products in the aquatic environment. Both proportions of hepta- and octa-CBs were detected at 13% and 10% of total PCB concentration, respectively, from Lakes Huron and Michigan instead of trivial levels in commercial Aroclor® 1254. The higher levels of hepta- and octa-CBs could indicate that concentration of higher chlorination homologs may be biomagnified in predator fish tissue.

The distribution pattern of PCB homologs for lake trout caught from four large lakes was illustrated in Figures 9a and

9b. Lake trout (U.S. EPA, 1992) collected from Lake Michigan at Waukegan Harbor in Illinois, which was described as a Superfund site, had a high proportion of hexa-CBs (36%). Lake Michigan lake trout fillets possessed some similar pattern as Aroclor® 1254 in proportions of penta- and hexa-CBs (47% and 25%). Lake trout caught from Lake Huron and Superior had proportions of penta-CBs 44% and 42%, respectively. Lake Superior siscowet had a lower proportion of tri-CBs (4%) and a greater proportion of hepta-CBs (19%) than lake trout caught from other lakes. Lake trout caught from Lake Ontario had the highest octa-CBs (36%) compared to the other lake fish fillets (Figure 9b). It might indicate that the persistent and less biodegradable congeners exist in Lake Superior and Lake Ontario regions. Lake trout is also a predator in the food chain which carries a similar pattern as chinook salmon from the same lake origin.

Walleye harvested from Lakes Erie, Huron and Michigan all had penta-CBs as the dominant homolog, 43%, 41% and 42%, respectively (Figure 10). Particularly, walleye from Lake Huron demonstrated the distribution pattern of Aroclor® 1254 in fillets, tri-, tetra-, penta-, hexa-, hepta- and octa-CBs (1%, 24%, 41%, 22%, 9% and 2%, respectively). Walleye harvested from Lakes Erie and Michigan had higher total proportions of hexa-, hepta-, and octa-CBs (about 10%) than total proportions of hexa-, hepta-, and octa-CBs to Aroclor® 1254. EPA (1992) tested walleye fillets from Escanaba River, Escanaba, Michigan and reported that these walleye also possessed a distribution pattern similar to Aroclor® 1254.

White bass from Lakes Erie and Huron had different distribution patterns than those of white bass caught from Kalamazoo River, Saugatuck, Michigan (EPA, 1992)(Figure 11). Moreover, the order of proportion of PCB homologs for white bass from the current study was penta- > hexa- > tetra > hepta > octa-, then tri-CBs instead of tetra- > penta- > hexa- > tri- > hepta >, then octa-CBs for white bass caught from Kalamazoo, Michigan.

Evaluation of Total PCBs by GC-Capillary and GC-Packed Column in Raw Fish Fillets From the Great Lakes

According to the experimental design, Michigan Department of Public Health (MDPH) analyzed fifty percent of each specified fish groups from this project in order to determine the levels of the priority pesticides commonly found in the aquatic environment. GC-packed column was used by MDPH to quantitate the total PCBs. The average of total PCB concentration (ppm, wet basis) in raw skin-on and skin-off fish fillets which had PCBs determined both by GC-packed column and GC-capillary column is shown in Table 22. Table 23 presents the total PCB data based on summing the 53 individual congeners determined by capillary column GC for all raw fish from the study. Figures 12 - 16 represented the distributions of total PCB concentration for fish species determined by GC-packed column and GC-capillary column in relation to their fat contents which were determined by MDPH following the

Table 22. Comparison of total PCBs determined by GC-packed column and GC-capillary column of the same raw fish fillets for carp, chinook salmon, lake trout, walleye and white bass from the Great Lakes

Fish Species	Fillets	Total PCBs (ppm, wet basis)	(Range)(S.D.)	No. of Fish to Total Fish No.[1]
GC-capillary column				
Carp	skin-on	1.92	(0.853-3.071)(0.781)	6/12(50%)
	skin-off	1.117	(0.431-3.726)(0.856)	1/12(8%)
Chinook salmon	skin-on	2.28	(1.519-3.171)(0.497)	12/18(67%)
	skin-off	1.547	(0.738-3.014)(0.536)	5/24(21%)
Lake trout	skin-on	2.544	(1.490-3.466)(0.775)	4/6 (67%)
	skin-off	1.703	(0.824-3.084)(0.656)	8/27(30%)
Walleye	skin-on	0.673	(0.252-1.604)(0.391)	0/20(0%)
White bass	skin-on	1.047	(0.547-1.924)(0.538)	0/6(0%)
GC-packed column				
Carp	skin-on	1.891	(0.283-6.620)(1.760)	4/12(33%)
	skin-off	0.611	(0.267-2.078)(0.484)	1/12(8%)
Chinook salmon	skin-on	1.368	(0.593-2.173)(0.361)	1/18(5%)
	skin-off	0.813	(0.287-1.721)(0.388)	0/24(0%)
Lake trout	skin-on	0.928	(0.536-1.422)(0.322)	0/6(0%)
	skin-off	0.76	(0.269-1.940)(0.439)	0/28(0%)
Walleye	skin-on	0.277	(0.100-0.938)(0.196)	0/21(0%)
White bass	skin-on	0.63	(0.242-1.379)(0.463)	0/6 (0%)

[1] number of fish on total PCB concentration (ppm, wet weight) exceeding 2.0 ppm

Table 23. Total PCB concentrations based on summing 53 congeners determined by GC-capillary column in all raw fish fillets for carp, chinook salmon, lake trout, walleye and white bass from the Great Lakes

Fish Species	Fillets	Total PCBs (ppm,wet)	(Range)	# of Fish[1] to Total Fish # (Ratio)
Carp	skin-on	2.015	(0.618 - 7.556)	11/24 (46%)
	skin-off	1.303	(0.419 - 5.872)	2/24 (8%)
Chinook salmon	skin-on	2.161	(1.306 - 3.110)	23/36 (64%)
	skin-off	1.681	(0.738 - 3.014)	15/47 (32%)
Lake trout	skin-on	2.398	(1.193 - 4.735)	5/12 (42%)
	skin-off	1.547	(0.583 - 4.324)	11/59 (19%)
Walleye	skin-on	0.850	(0.252 - 2.435)	2/41 (5%)
White bass	skin-on	1.279	(0.547 - 2.110)	1/12 (8%)

[1] Number of fish on total PCB concentration (ppm,wet weight) exceeding 2.0 ppm

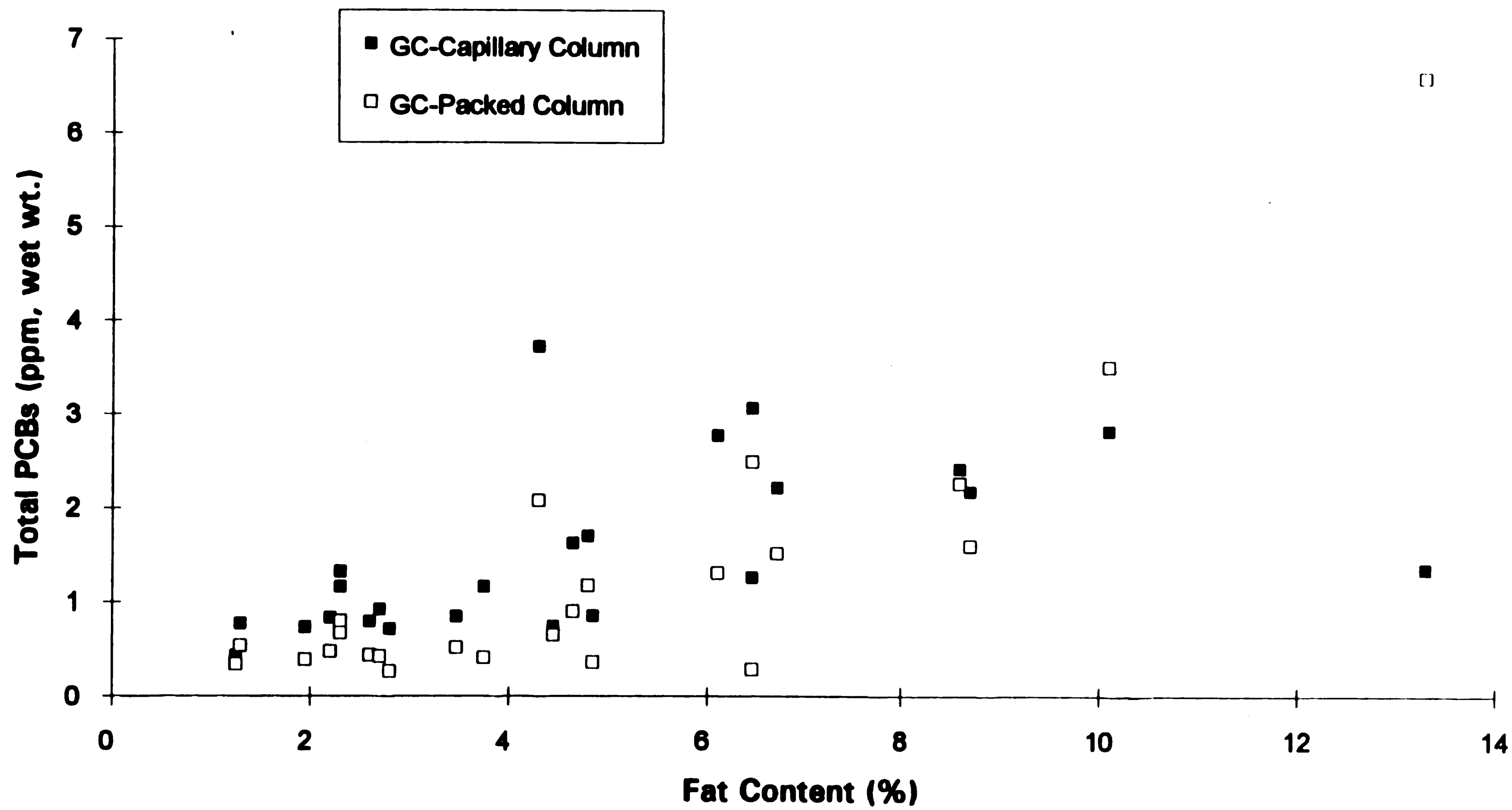

Figure 12. Comparison of total PCB concentration in raw skin-on and skin-off carp fillets determined by GC-capillary column and GC-packed column in relation to their fat content

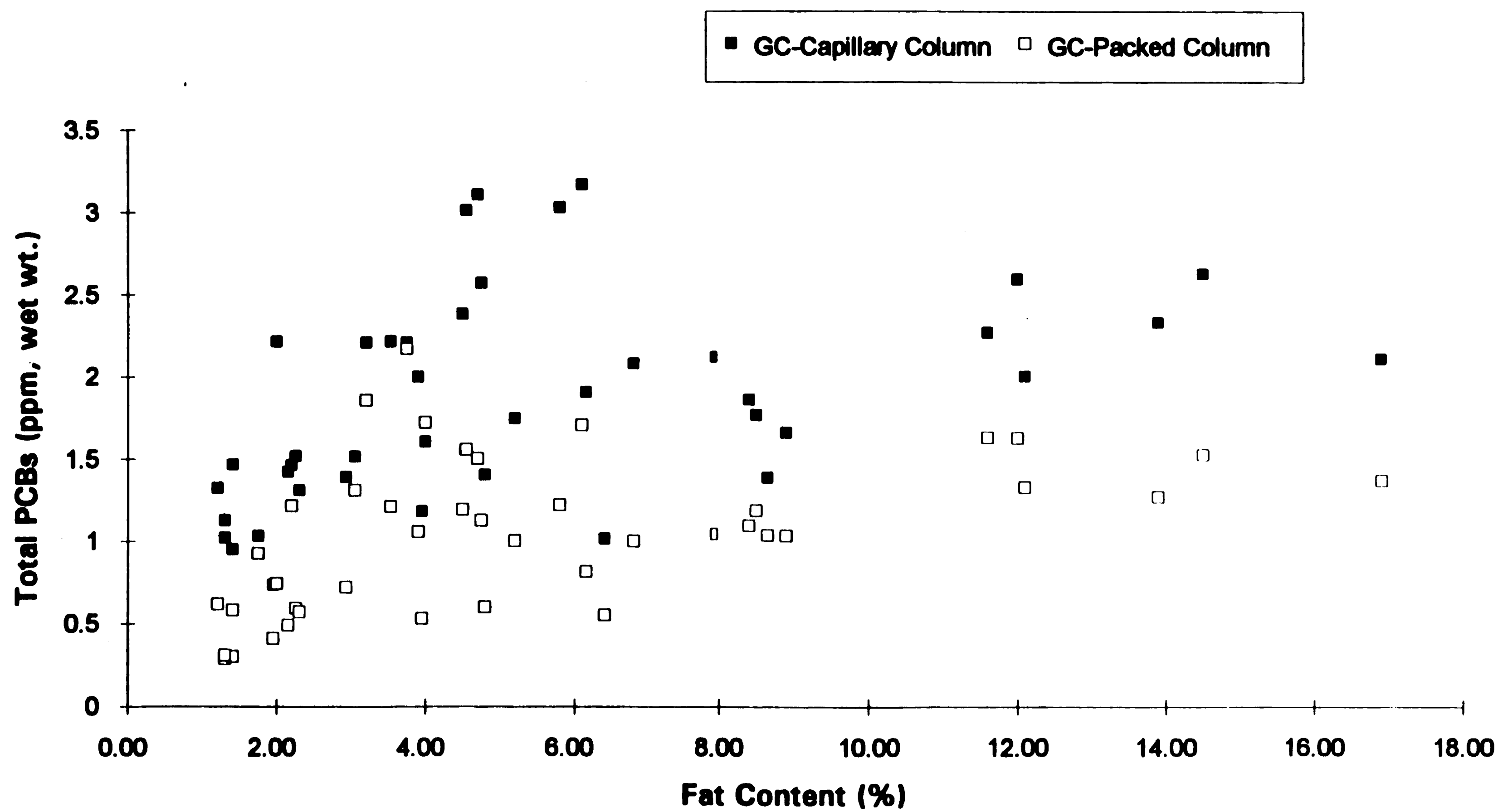

Figure 13. Comparison of total PCB concentration in raw skin-on and skin-off chinook salmon determined by GC-capillary column and GC-packed column in relation to their fat content

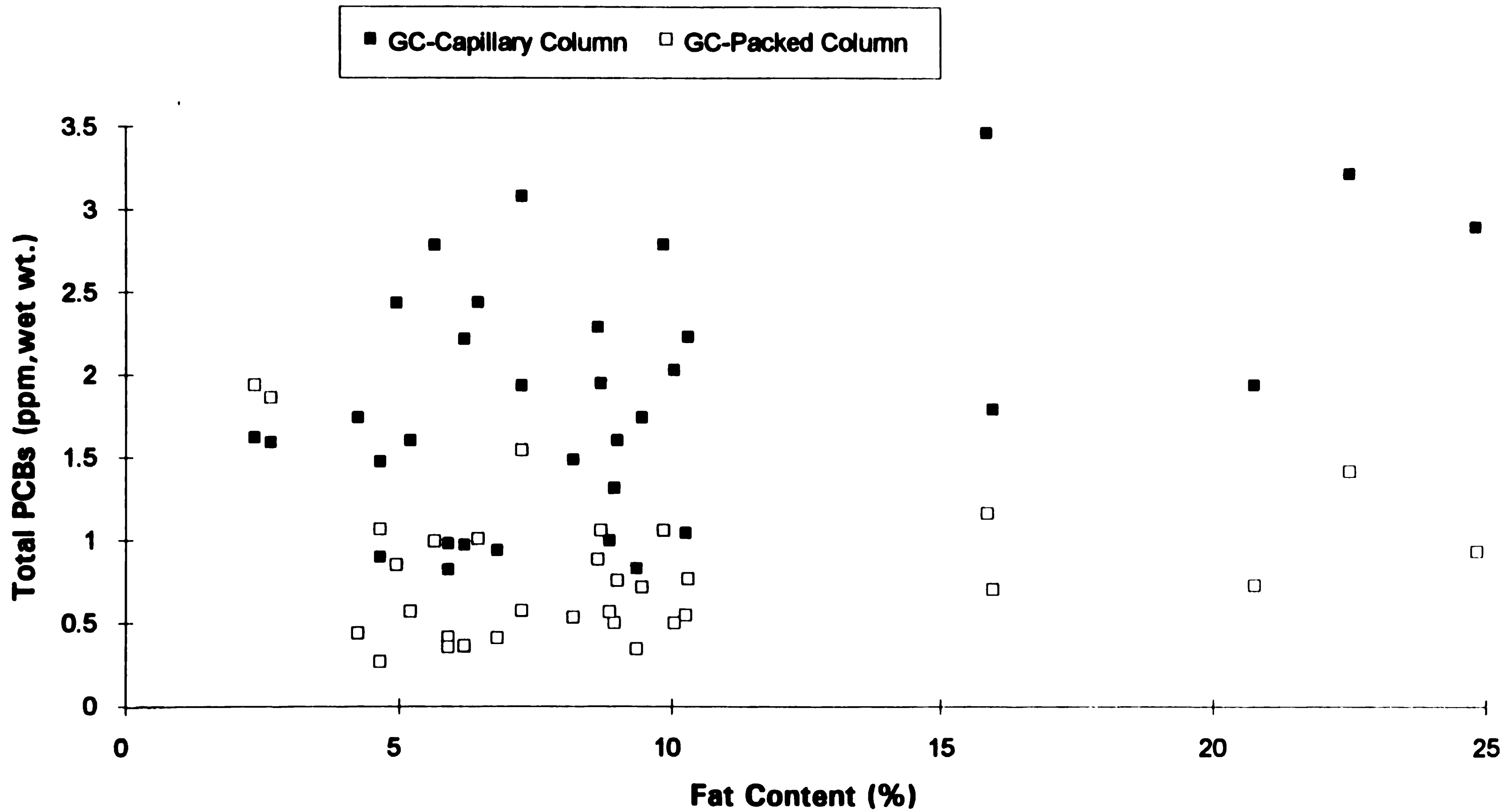

Figure 14. Comparison of total PCB concentration in raw skin-on and skin-off lake trout fillets determined by GC-capillary column and GC-packed column in relation to their fat content

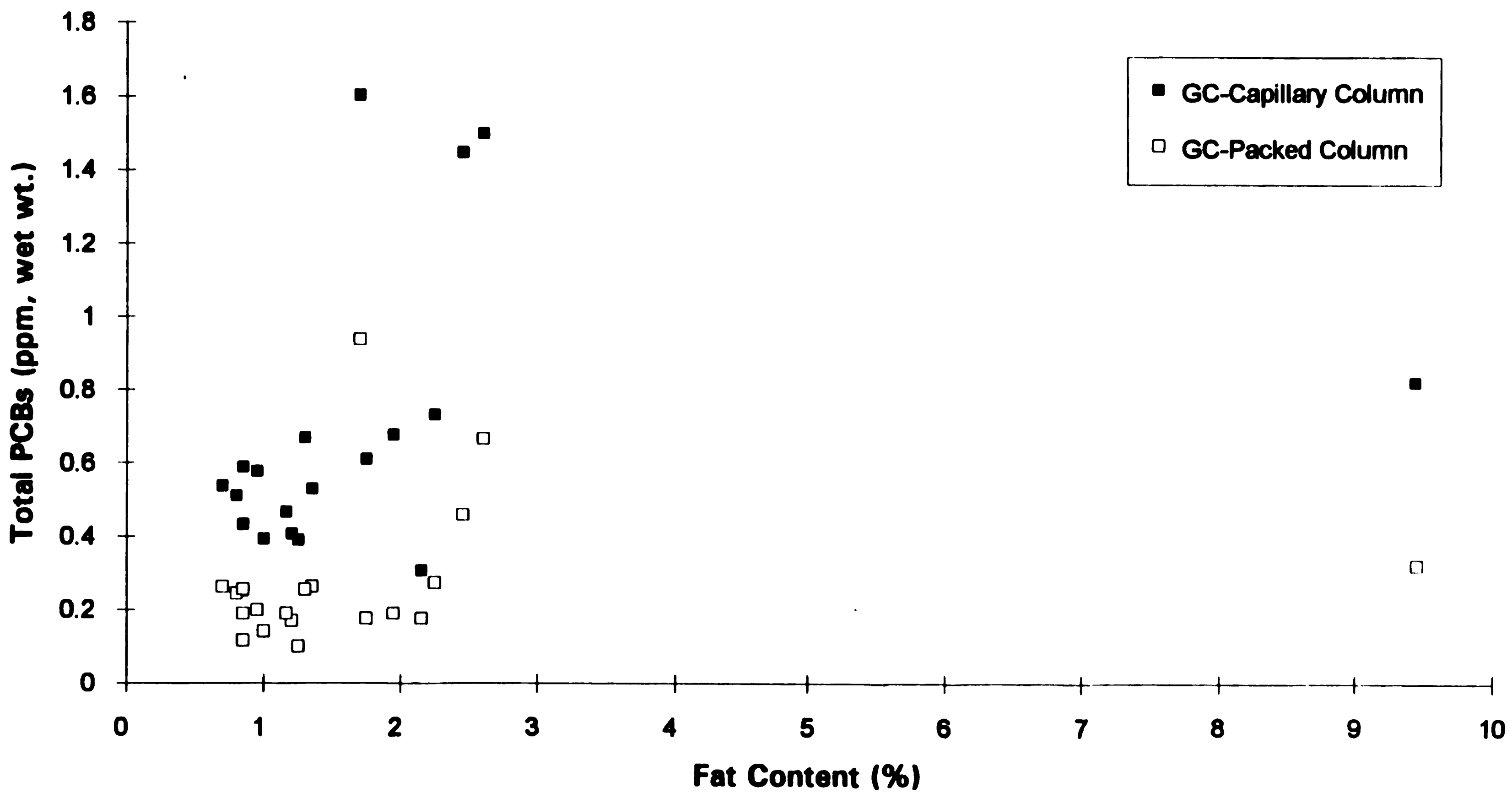

Figure 15. Comparison of total PCB concentration in raw skin-on walleye fillets determined by GC-capillary column and GC-packed column in relation to their fat content

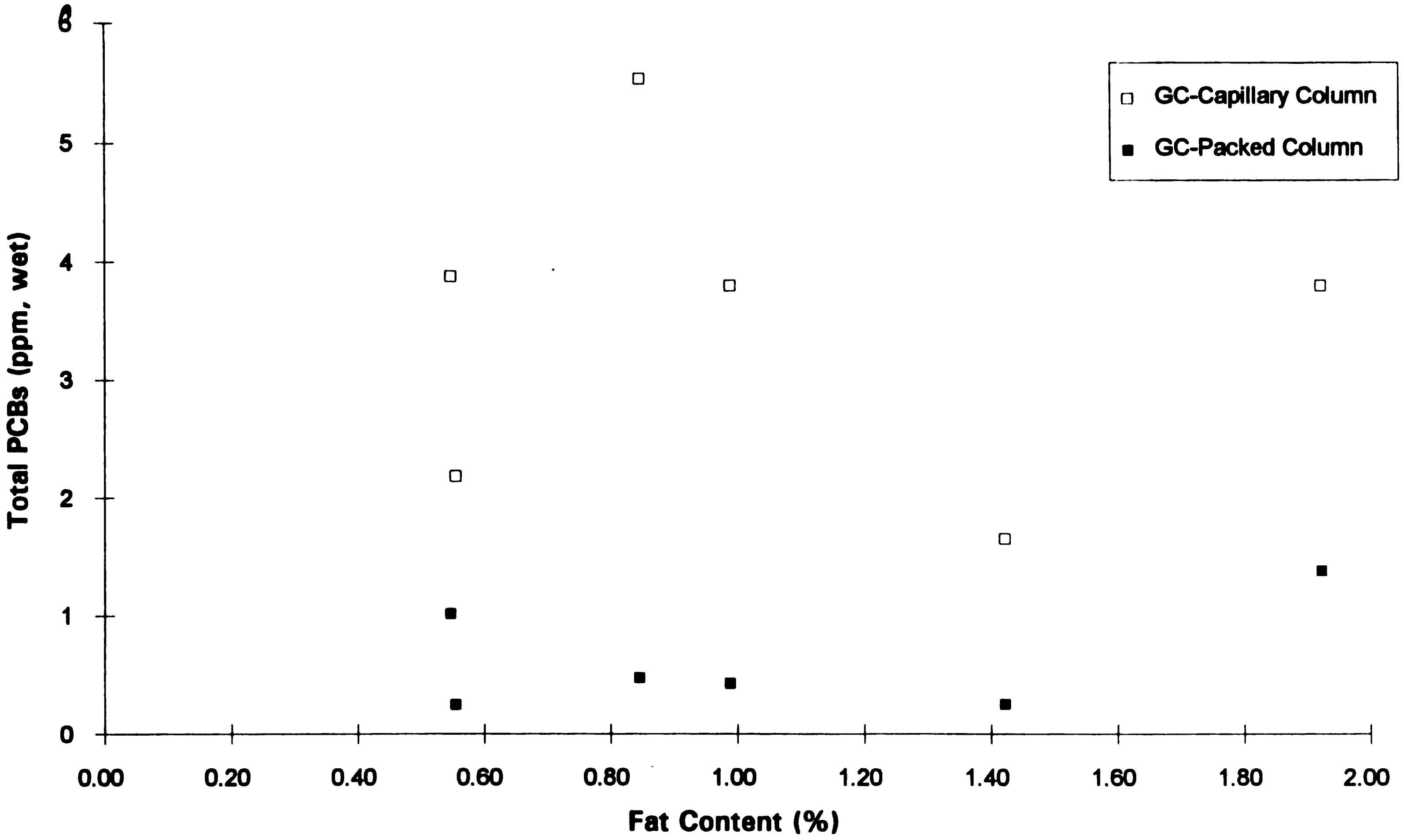

Figure 16. Comparison of total PCB concentration in raw skin-on white bass fillets determined by GC-capillary column and GC-packed column in relation to their fat content

procedures of Price et al. (1986). GC-capillary column resulted in higher values than GC-packed column in total PCBs for fish fillets from the Great Lakes, but two results were significantly correlated with the exception of white bass, which had small sample size (Table 24). In the studies of Maack and Sonzogni (1988), Bush et al. (1989) and Williams et al. (1992), they showed that GC-packed column analysis for the determination of total PCBs yielded lower levels of total PCBs than the result obtained from GC-capillary column analysis. The author considered that the cause might come from the extraction of fat content and more accurate quantitation of individual peaks from capillary column analysis. Lipid was extracted with 50% ethylether/petroleum ether on a chromatography column and quantitated for GC-packed column analysis; fat content was not quantitated for fish tissue extracted with dichloromethane in GPC column and by HPLC pump for GC-capillary column analysis. Mainly fat content in which PCBs and xenobiotics partitioned with could be influenced by solubility of solvent and sensitivity of chromatography column.

Based upon the results of total PCBs obtained from MDPH, out of the entire raw fish samples (127 fish), there were only four skin-on carp, one skin-off carp and one skin-on chinook salmon exceeding 2.0 ppm; the rest of the fish species (95%) harvested from the Great Lakes were all below the FDA action level. The average total PCBs from the Great Lakes fish species determined by GC-packed column were all below the FDA

Ta

Fi

Ca

Ch

La

Wa

Wh

Table 24. Correlation coefficent values of total PCBs determined between GC-capillary and GC-packed column among fish species from the Great Lakes

Fish Species	Correlation coefficient	p value
Carp	0.485	0.016
Chinook salmon	0.730	0.000
Lake trout	0.546	0.001
Walleye	0.921	0.000
White bass	0.447	0.377

action level (Table 22). Skin-on carp (33%) had the total PCBs level above the FDA action level which is probably a reasonable estimation for bottom-feed fish species.

In this research, using the average level of total PCBs determined by summing individual PCB congeners determined by using GC-capillary column in skin-on carp from Lakes Erie and Huron, there were a total of eleven out of twenty-four skin-on carp fish fillets (nearly 50%) having PCBs above 2 ppm; one as high as 7.6 ppm. By removing skin, the number of carp exceeded 2 ppm were down to two of the twenty-four carp skin-off fillets (less than 10%). Approximatly one-fourth of carp harvested from the Lakes Erie and Huron exceeded FDA action level. Eight of the contaminated carp were from Lake Erie and five of the contaminated carp were from Lake Huron. Sixty-four percent of chinook salmon skin-on fillets from Lakes Huron and Michigan had an average of total PCBs 2.2 ppm which was also exceeded FDA action level. Sixteen lake trout from Lake Huron and twenty-two lake trout from Lake Michigan had PCB level above FDA action level. Lake trout skin-on and skin-off fillets had total PCBs ranged from 1.2 to 4.7 ppm (average 2.3 ppm) and 0.6 to 4.3 ppm (average 1.1 ppm), respectively. Total PCB level in skin-off lake trout fillet is 35% less than the concentration in skin-on lake trout fillet which supports the value on the reduction of lipid contents (ave. 50%) through skin removal and trimming off fatty areas under skin, lateral line, and dorsal fat. All skin-on walleye and skin-on white bass had average PCB concentration less than 2 ppm. Although walleye had the lowest average level (0.8 ppm) of PCBs of any of the fish used in this study, two of the forty-one walleyes (5%) were detected with total PCBs above 2.0 ppm, followed by one skin-on white bass (8%) with total PCBs above 2.0 ppm. An average of 50% of carp, chinook salmon and lake trout in their natural condition (skin-on) had total sums of individual congeners of PCBs above 2.0 ppm in this study. Due to the skin removal, the contamination level of PCBs reduced significantly in chinook salmon and lake trout ($P < 0.005$) and in carp ($P < 0.08$).

Twenty-eight fish species harvested from Lake Michigan had the total sums of individual PCB congeners above FDA action level, followed by twenty-two fish species harvested from Lake Huron. The percentage of fish harvested from the Great Lakes exceeding FDA action level were in the order of Lake Ontario (42%), Lake Michigan (33%), Lake Huron (23%), Lake Superior (21%), and Lake Erie (19%). The results indicated that fish harvested from the Great Lakes are the sensitive biological indicators for PCB contamination in aquatic life. The determination of individual congener analysis appeared to be a detailed qualitative and quantitative analytical approach resulting in higher levels of total PCBs in raw fish species. The advantage of GC-capillary column could be used for assessing total PCBs and specific congeners which can not be accurately determined by GC-packed column. The justification of the discrepancies of total PCBs obtained from GC-capillary and GC-packed column in relation to the risk assessment will not be addressed here. So far, GC-packed column is still the official method for the determination of total PCBs in fish according to the FDA procedure; mainly, due to the involvement of resources and their tolerances are focused on total PCBs instead of individual congeners (U.S. EPA, 1993). The predicted equations for the concentration of total PCBs from GC-capillary column based upon total PCBs determined by GC-packed column and the fat content for each species were also calculated (Table 24a). Walleye's total PCBs was the only fish species' which was not influenced by fat content (1-3%) of tissue; total PCBs from chinook salmon and lake trout both were significantly affected by fat content of tissue. In the equations, total PCBs from GC-packed column constant for chinook salmon (0.864) and lake trout (0.512) had values lower than 1.0; this might be due to the high content of fat in lake trout (11.45-36.52%) and chinook salmon (4.17-11.63%). Through the conversion of predicted equations, total PCB concentration can be adjusted according to the regulatory requirement of risk assessment and agencies. Nevertheless, for the safety of the anglers and their families, the awareness of the contamination of PCBs in sports fishing needs to be addressed in risk assessment, risk management, and risk communication in order to preserve the environmental, recreational, and economic resources of the Great Lakes as well as the nourishment and enjoyment of fish-eating.

Table 24a. Predicted equations for total PCBs from GC-capillary column analysis based upon total PCBs from GC-packed column analysis and fat content of fish sample

Carp

Total PCBs (GC-capillary column) = 0.111 + 2.345 * total PCBs (GC-packed column) + (-0.16) * fat * total PCBs (GC-packed column) (R^2 = 0.958)

Chinook salmon

Total PCBs (GC-capillary column) = 0.853 + 0.864 * total PCBs (GC-packed column) + (0.015) * fat * total PCBs (GC-packed column) (R^2 = 0.954)

Lake trout

Total PCBs (GC-capillary column) = 0.986 + 0.512 * total PCBs (GC-packed column) + (0.063) * fat * total PCBs (GC-packed column) (R^2 = 0.940)

Walleye

Total PCBs (GC-capillary column) = 0.17 + 1.798 * total PCBs (GC-packed column) (R^2 = 0.848)

White bass

Total PCBs (GC-capillary column) = 0.690 + 1.838 * total PCBs (GC-packed column) + (-0.327) * fat * total PCBs (GC-packed column) (R^2 = 0.87)

Remedial Actions on the Reduction of Total PCBs and PCB Homolog Concentration in Fish Species Harvested from The Great Lakes Through Food Processing Methods

Federal and local governments have spent much money and human resources to deal with eliminating PCBs and other toxic substances from the environment. However, it is difficult to prevent the mechanisms of the pollution from spreading into air, water, and land, often the contamination is without boundary. In recent years, the efforts on regulating air, surface water and environment of the Great Lakes have been remarkable. Perhaps now is the time for food scientists and environmental toxicological educators to take more action to educate consumers on safe levels of consumption and on how to reduce the contaminants in their diet. In this study, researchers proved three feasible methods to reduce the total PCBs in fish species from the Great Lakes. Though it may sound simple, it works on the reduction of the total PCBs and their homolog concentration. PCB homolog data in raw and cooked fish fillets for chinook salmon, lake trout, walleye, and white bass from the Great Lakes were recorded in Appendixes 1 - 5, with the concentration of PCB homologs expressed as ppm wet tissue, which was used for the comparison of raw fillets; ppm solids, which were used for comparison between raw and cooked fillets; micrograms per fillet in raw and cooked fillets and PCB homologs percentage change between raw and cooked fillets, which were used for comparison among cooking methods.

I. Method of Skin Removal and Trimming Before Cooking

It is positive to say that the removal of skin with the associated fatty tissue in carp and chinook salmon fillets before cooking can eliminate portions of contaminants in fish fillets and reduce the levels of contamination in fish fillets. Because the nature of PCB mixture is lipophilic, the concentrations of PCB residues are high in parts of fish with high lipid content, such as the head (Zabik, et al., 1978), or dorsal, ventral, medial and bellyflap areas (Reinert, et al., 1972). In order to compare skin-on fillets with skin-off fillets before the cooking process, 53 PCB specific congeners were grouped by the degrees of chlorination as PCB homologs. Comparisons were made from two sets of data: 36 raw skin-on chinook salmon fillets with 35 raw skin-off chinook salmon fillets, and 24 raw skin-on carp fillets with 24 raw skin-off fillets; using SYSTAT ANOVA, the levels of significance were between 0.2 - 0.001 using the Tukey test. Figures 17 and 18 demonstrate the distribution pattern of the skin removal and trimming before cooking for carp and salmon in terms of total PCB and their homolog concentrations. Tetra-, penta-, hexa-, and octa- homologs and total PCBs were significantly reduced in carp skin-off fillets through the skin removal method before cooking (Table 25). Tetra-, penta-, hepta- homologs and total PCBs were significantly reduced in chinook salmon skin-off fillets by the same method

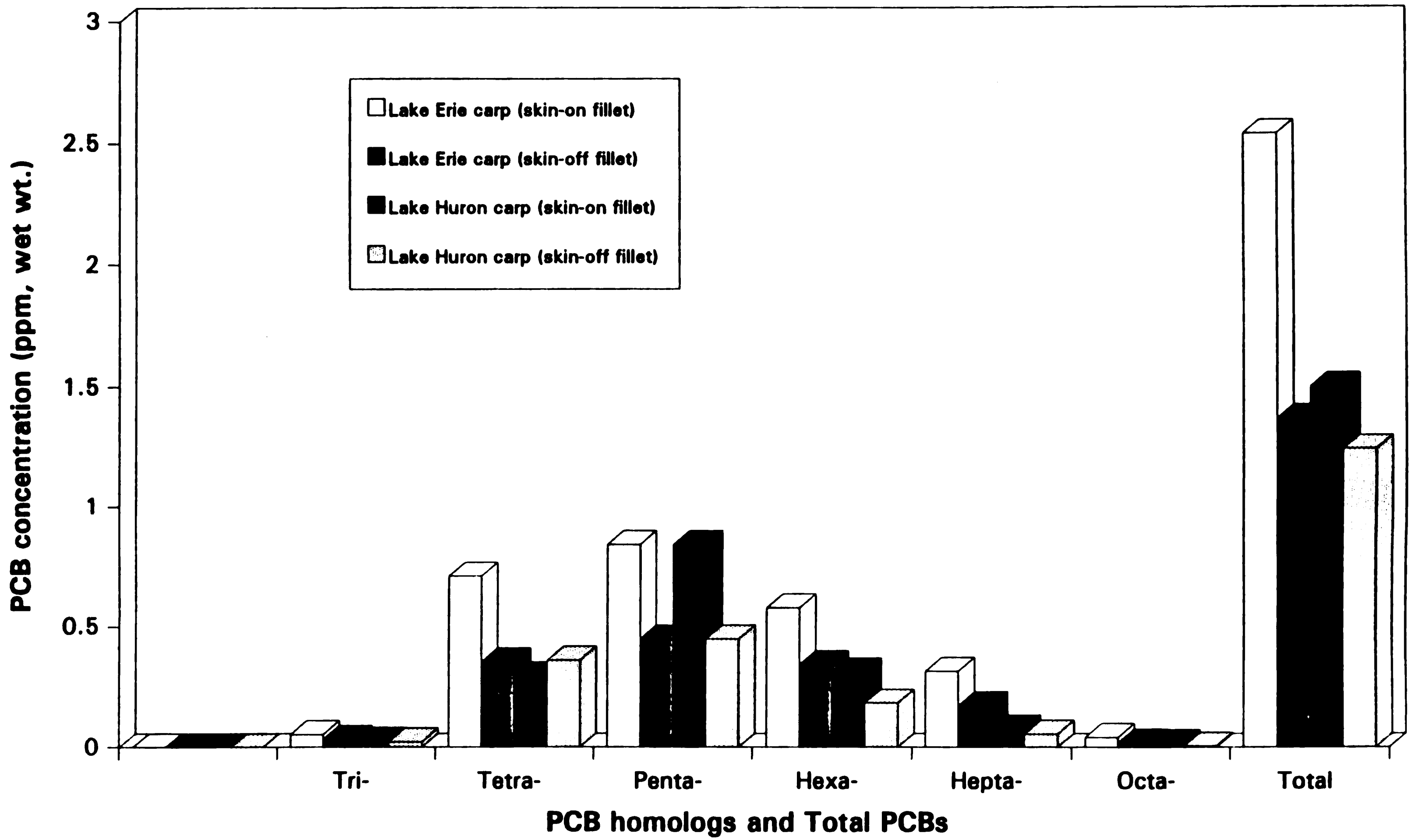

Figure 17. Levels of PCB homologs and total PCB concentration in raw skin-on and skin-off carp fillets harvested from Lakes Erie and Huron

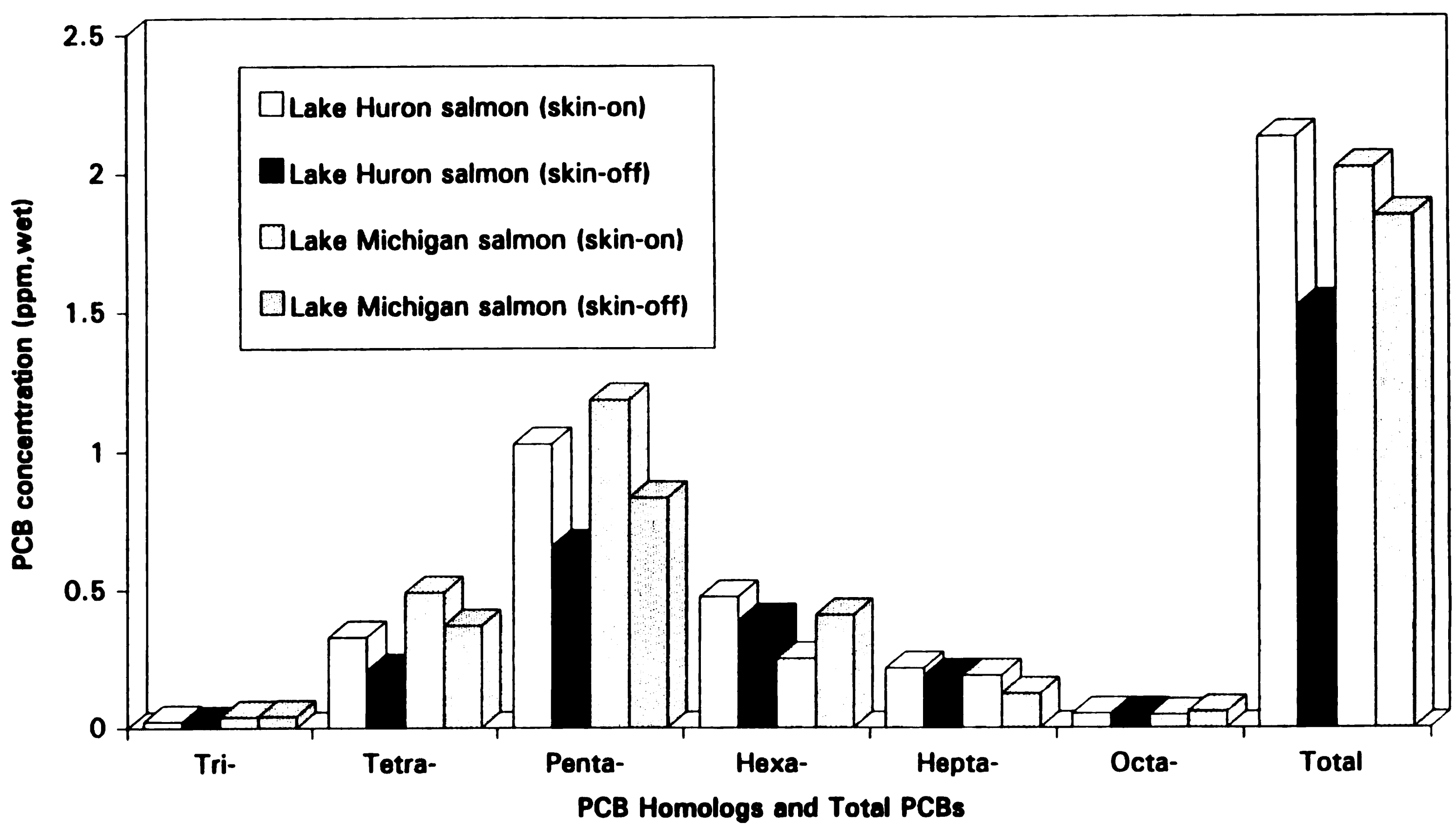

Figure 18. Levels of PCB Homologs and Total PCB Concentration in Raw Skin-on and Skin-off Chinook Salmon Fillets Harvested from Lakes Huron and Michigan

Table 25. Effectiveness of skin removal on the reduction of total PCBs and PCB homologs for raw carp fillet

	PCB Concentration (ppm, wet)		
PCB Homologs	**skin-on fillet**	**skin-off fillet**	**% difference (P^1)**
Tri-CBs	0.039	0.028	28.2 (0.230)
Tetra-CBs	0.502	0.356	50.2 (0.090)
Penta-CBs	0.806	0.530	34.2 (0.115)
Hexa-CBs	0.444	0.262	41.0 (0.078)
Hepta-CBs	0.195	0.114	41.5 (0.276)
Octa-CBs	0.029	0.012	58.6 (0.039)
Total PCBs	2.015	1.303	35.3 (0.075)

[1] Probability; significant level at $P < 0.2$

Table 26. Effectiveness of skin removal on the reduction of total PCBs and PCB homologs for raw chinook salmon fillet

	PCB Concentration (ppm, wet)		
PCB Homologs	**skin-on**	**skin-off**	**% difference (P^1)**
Tri-CBs	0.032	0.025	21.9 (0.247)
Tetra-CBs	0.410	0.273	33.4 (0.000)
Penta-CBs	1.105	0.719	34.9 (0.000)
Hexa-CBs	0.364	0.401	-10.1 (0.401)
Hepta-CBs	0.203	0.164	19.2 (0.306)
Octa-CBs	0.048	0.058	-20.8 (0.319)
Total PCBs	2.161	1.641	24.0 (0.000)

[1] Probability; significant level at $P < 0.001$

(Table 26). The presence or absence of skin and adipose tissues significantly affected the total PCBs and its homologs in the raw chinook salmon and carp fish fillets based upon the above results. About 30% of tetra- and penta- homologs deposited on the skin tissue and associated fatty tissue of carp and chinook salmon fillets, respectively, can be reduced by removal of skin and associated fatty tissue before cooking, through skin removal and trimming procedures. An average of 30% (25 - 35%) of total PCBs can be eliminated through trimming procedures; these results are similar to the Hora (1981) study that the effectiveness of removal of the skin alone resulted in 26% to 30% of PCBs and lipids losses, respectively, in carp fillets from upper Mississippi river. Skea et al. (1979) found that removal of the skin, dorsal and ventral fat, and the entire lateral line from Lake Ontario smallmouth bass and brown trout resulted in 64% and 43% reduction of Aroclor® 1254 in fish fillets, respectively. Sanders and Haynes (1988) indicated that total PCB level in bluefish fillets reduced 27% after the removal of bellyflap adipose tissues which was close to the 28 percent reduction of lipid. Armbruster et al. (1989) stated that trimming bluefish fillets resulted in an average reduction of PCB residues of 59%. They also stated that concentration of PCBs in skin contained about twice that found in the fillet muscle expressed on a ppm wet weight basis. Voiland et al. (1991) reported that percent loss of total PCBs and fat content in brown trout from Lake Ontario through skinning and fat-trimming procedures was 46% and 62%, respectively. It may be said that more than 1/4 to 1/2 of total PCBs concentration found in the raw fish fillet can be feasibly eliminated through recommended trimming procedures. Voiland et al. (1991) also confirmed that the effectiveness of the fat-trimming procedure on the reduction of PCBs in fish fillet is consistent despite wide variation in the initial (untrimmed fillet) levels of contamination. Song (1994) reported that skin removal in carp fillets from the Great Lakes reduced 35% of total PCBs concentration, which was down to 1.24 ppm from 1.90 ppm (wet wt.), that the highest reduction percent was for octa-CBs homolog (59%), followed by hexa- (42%), hepta- (38%), penta-CBs (34%), and that the least reduction was for tri-CBs (28%). Zabik et al. (1995) found that average total DDT compounds in skin-on chinook salmon and carp were 0.79 ppm and 0.21 ppm, respectively, and the average level of the DDT complex for skin-off salmon fillets and carp were 0.38 ppm and 0.08 ppm, respectively. About 50% of the total DDT was eliminated through trimming and skin removal procedures.

II. Method of the Skin Removal After Cooking

Skin removal after cooking also feasibly reduces the levels of contaminants in fish tissue. In processing, skin removal before cooking does require skillful hands and tools in order to reduce the loss of fish tissue and preserve the integrity of the fillet appearance. However, it is quite easy to peel off fish skin after cooking regardless of the cooking methods. The effectiveness of skin removal after cooking, including the effectiveness of cooking procedure, was obtained from skin-on carp (12 pairs) and chinook salmon (35 pairs), walleye (35 pairs) and white bass (11 pairs) based upon the levels of total PCBs and PCB homologs in dry fish weight by paired T-Test at level of 5%.

Through the cooking process, cooked fillets normally had less water content than uncooked fillets. Therefore, it would be inadequate to compare concentration of total PCBs and PCB homologs for raw and cooked fillets based upon their wet weight. The following tables (Tables 27-30) presented the effectiveness of skin removal after cooking on the reduction of total PCBs and PCB homologs for Great Lakes fish species based upon their concentration (ppm) in wet weight and in dry weight. The results (Tables 27-30) indicated that PCB concentration (ppm) expressed in dry weight is the more sensitive unit than ppm in wet weight for deriving the comparison between raw and cooked fish fillets from the same fish, unlike the previous comparison between raw skin-on fillets with raw skin-off fillets of which both had similar water content and solid contents, but were not processed from the same fish. It was also noted that concentration of tri- and octa-CBs homologs in dry weight for carp, chinook salmon, walleye, and white bass were significantly reduced by skin-removal after the cooking process, which was not seen as significant in the comparison of PCB concentration in wet weight. Effectiveness of skin removal after the cooking

Table 27. Effectiveness of skin removal on the reduction of total PCBs and PCB homologs for carp through cooking and skin removal after cooking process[1]

PCB Homologs	Concentration		
	ppm(wet wt)	ppm(dry wt)	ug (wet wt)
Raw skin-on carp fillet			
Tri-CBs	0.026	0.105	3.180
Tetra-CBs	0.373	1.464	49.622
Penta-CBs	0.627	2.359	84.199
Hexa-CBs	0.285	1.152	37.919
Hepta-CBs	0.087	0.349	12.102
Octa-CBs	0.018	0.070	2.551
Total PCBs	1.416	5.500	189.574
Carp fillet skin removal after cooking[1]			
Tri-CBs	0.024	0.077*	2.313*
Tetra-CBs	0.318	0.995*	32.721*
Penta-CBs	0.558	1.691*	59.658*
Hexa-CBs	0.254	0.793*	27.053*
Hepta-CBs	0.081	0.250*	8.767*
Octa-CBs	0.019	0.058*	1.935*
Total PCBs	1.254	3.865*	132.447*

[1]panfrying
*significant level at $p<0.05$

Table 28. Effectiveness of skin removal on the reduction of total PCBs and PCB homologs for chinook salmon through cooking and skin removal after cooking process[1]

PCB Homologs	Concentration		
	ppm(wet wt)	ppm(dry wt)	ug (wet wt)
Raw skin-on chinook salmon fillet			
Tri-CBs	0.032	0.118	18.310
Tetra-CBs	0.410	1.508	244.587
Penta-CBs	1.105	4.099	647.269
Hexa-CBs	0.364	1.374	211.570
Hepta-CBs	0.203	0.761	118.242
Octa-CBs	0.048	0.180	27.746
Total PCBs	2.161	8.041	1268.001
Chinook salmon fillet skin removal after cooking[1]			
Tri-CBs	0.031	0.094*	13.234*
Tetra-CBs	0.378	1.127*	165.079*
Penta-CBs	0.971	2.916*	414.322*
Hexa-CBs	0.312	0.963*	133.456*
Hepta-CBs	0.162	0.493*	67.587*
Octa-CBs	0.044	0.135*	18.826*
Total PCBs	1.897	5.727*	812.504*

[1]either baking or charbroiling
*significant level at $p<0.05$

Table 29. Effectiveness of skin removal on the reduction of total PCBs and PCB homologs for walleye through cooking and skin removal after cooking process[1]

PCB Homologs	Concentration		
	ppm(wet wt)	ppm(dry wt)	ug (wet wt)
Raw skin-on walleye fillet			
Tri-CBs	0.008	0.035	0.781
Tetra-CBs	0.158	0.716	15.821
Penta-CBs	0.368	1.670	35.497
Hexa-CBs	0.266	1.215	25.442
Hepta-CBs	0.094	0.429	9.139
Octa-CBs	0.015	0.066	1.460
Total PCBs	0.908	4.131	88.141
Walleye fillet skin removal after cooking[1]			
Tri-CBs	0.006	0.022*	0.481*
Tetra-CBs	0.134	0.493*	10.432*
Penta-CBs	0.292	1.066*	21.709*
Hexa-CBs	0.182	0.665*	13.394*
Hepta-CBs	0.049	0.181*	3.704*
Octa-CBs	0.012	0.045*	0.911*
Total PCBs	0.675	2.471*	50.632*

[1]either baking or charbroiling
*significant level at $p<0.05$

Table 30. Effectiveness of skin removal on the reduction of total PCBs and PCB homologs for white bass through cooking and skin removal after cooking process[1]

PCB Homologs	Concentration		
	ppm(wet wt)	ppm(dry wt)	ug (wet wt)
Raw skin-on white bass fillet			
Tri-CBs	0.009	0.040	0.728
Tetra-CBs	0.221	0.931	16.725
Penta-CBs	0.547	2.322	41.266
Hexa-CBs	0.357	1.519	26.610
Hepta-CBs	0.118	0.503	8.734
Octa-CBs	0.027	0.114	2.003
Total PCBs	1.279	5.428	96.066
White bass fillet skin removal after cooking[1]			
Tri-CBs	0.008	0.026*	0.469*
Tetra-CBs	0.174	0.594*	10.525*
Penta-CBs	0.451	1.551*	27.177*
Hexa-CBs	0.326	1.115*	19.571*
Hepta-CBs	0.112	0.381*	6.446*
Octa-CBs	0.024	0.082*	1.478*
Total PCBs	1.094	3.748*	65.666*

[1]panfrying
*significant level at $p<0.05$

process on total PCBs and PCB homologs for carp, chinook salmon, walleye and white bass was significantly reduced when comparing the right side fillets with the left side fillets of the same fish based upon their dry weight measurement. An average of 29% reduction of total PCBs had occurred in carp and chinook salmon through the cooking and skin removal process based on dry weight. A 40% and 31% reduction of total PCBs were found in walleye and white bass, respectively, based on dry weight. Effectiveness of cooking process on the reduction of total PCBs and PCB homologs for skin-off chinook salmon was represented in Table 31. Compared to the cooked chinook salmon from Table 28 and 31, the total PCBs for cooked chinook salmon fillets was reduced from 5.730 to 4.424 ppm on dried basis There was 23% further reduction of total PCBs based on dry weight calculation. It may indicate that skin removal before cooking can further enhance the reduction of contaminants; perhaps through the increased cooking loss, fat dripping and other mechanisms. There is a need for more studies in the effectiveness of skin removal after the cooking process to ensure the safety aspect of consuming higher levels of contaminated fish species which should have had their skin removed before cooking.

III. Selective Cooking Method to Enhance the Safety

It has been unpleasant for sportsman to catch fish and not consume them due to fear and doubt about their safety. In this section, seven different cooking methods on the reduction

Table 31. Effectiveness of cooking process[1] on the reduction of total PCBs and PCB homologs for skin-off chinook salmon

PCB Homologs	Concentration		
	ppm(wet wt)	ppm(dry wt)	ug (wet wt)
Raw skin-off chinook salmon fillet			
Tri-CBs	0.025	0.100	9.966
Tetra-CBs	0.273	1.083	101.029
Penta-CBs	0.719	2.883	260.902
Hexa-CBs	0.401	1.619	140.778
Hepta-CBs	0.164	0.764	58.586
Octa-CBs	0.058	0.239	20.153
Total PCBs	1.641	6.607	591.413
Cooked skin-off chinook salmon fillet			
Tri-CBs	0.023	0.065*	6.689*
Tetra-CBs	0.248	0.732*	68.431*
Penta-CBs	0.615	1.826*	167.607*
Hexa-CBs	0.305	0.915*	80.318*
Hepta-CBs	0.112	0.312*	27.179*
Octa-CBs	0.042	0.125*	10.865*
Total PCBs	1.337	3.974*	361.090*

[1]either baking or charbroiling
*significant level at $p<0.05$

of total PCBs and PCB homologs will be discussed. Because fish species, origin of lakes, fillet size, cooking media, and cooking methods all influence the concentration of PCBs, percentage change (%), derived from the difference between the micrograms of each congener in the raw and cooked fish fillets, was used to evaluate the effectiveness of the cooking method. Table 32 listed percentage change of total PCBs and PCB homolog concentration during the cooking process for the composite fish fillets. Positive values are percentage decreases and negative values are percentage increases. For skin-on fillets, smoked fillet (48%) had the highest total PCBs percentage change, followed by deep fat fried fillet (39%), charbroiled skin-on (38%), baked skin-on (33%) and panfried fillet (31%); among skin-off fillets, charbroiled fillets (36%) had the highest total PCBs percentage change, followed by baked fillet (32%), canned fillet (29%), deep fat fried fillet (28%), panfried fillet (27%) and salt-boiled fillet (21%). Charbroiling, baking, and deep fat frying are all convenient methods of cooking for reducing contaminants effectively. The effectiveness of cooking methods on the reduction of total PCBs and PCB homologs might be related to either long cooking time or large volume of cooking oil.

Reinert et al. (1972) found that the broiling and frying method could reduce DDT 64-72% in Great Lakes lake trout. Zabik et al.(1982) also reported that PCB, dieldrin and DDT levels had been reduced 53, 48 and 39%, respectively, in lake trout by broiling; 34, 25 and 30%, respectively, by roasting

Table 32. Percentage change of PCB homolog concentration and of total PCBs during cooking process

Methods	Skin	Samples	Tri-CBs	Tetra-CBs	Penta-CBs	Hexa-CBs	Hepta-CBs	Octa-CBs	Total PCBs
Charbroil*	off	48	26.5	33.93	32.33	35.59	37.53	30.6	36.23
Charbroil	on	42	28.34	31.76	36.56	40.45	40.39	28.72	37.62
Bake	off	36	19.84	25.97	29.16	33.97	32.8	24.97	32.43
Bake*	on	30	15.03	25.67	31.53	33.65	34.44	25.99	33.38
Pan-fry	off	12	23.04	25.22	20.91	26.92	19.01	-8.53	26.95
Pan-fry	on	24	26.17	34.66	31.81	27.01	21.78	14.94	31.03
Deep-fry	off	12	39.49	35.6	40.9	36.08	23.15	17.09	28.29
Deep-fry	on	18	37.34	35.78	37.29	39.78	41.45	24.23	38.6
Smoke	on	12	-25.94	49.99	34.1	47.32	45.71	56.41	47.8
Can	off	12	22.36	29.9	30.27	28.98	24.81	24.18	29.35
Salt-boil*	off	12	31.77	14.23	28	18.49	-15.55	28.85	21.04
Total		256							
Means			23.48	31.02	32.46	34.55	31.72	25.25	34.5

*one sample missing

lake trout; and 26, 47 and 54%, respectively, by microwaving lake trout. A current study by Zabik et al. (1993) revealed that PCB levels based on packed-column GC-quantitation in lake trout can be reduced 10-17% through baking, 12-59% through charbroiling, and 10% through salt boiling. Ambruster et al. (1989) found that there was an average reduction of 7.5% from baking, broiling, frying or poaching on trimmed bluefish fillets. Song (1994) indicated that there were no significant differences between deepfat frying and pan frying carp fillets in relation to total PCBs reduction, but that both methods reduced PCBs by an average of 34%. Shearer and Price (1993) used a mass basis to summarize PCB loss from some earlier studies. They concluded that there was an average of 22% PCB loss by baking chinook salmon, lake trout, small mouth bass, and bluefish; 27% loss by broiling lake trout and brown trout; 56% loss by frying small mouth bass and white croaker; and 26% loss by microwaving lake trout. Zabik et al (1995) studied the reductions of PCBs quantitated by packed-column GC analysis and pesticides in chinook salmon harvested from the Great Lakes; they found that average losses of pesticides, such as DDT complex, chlordane, oxychlordane, nonachlor, HCB, dieldrin, heptachlor expoxide, toxaphene and total PCBs from the chinook salmon ranged from 30 to 50%, and that those charbroiled with an increased surface area had a higher cooking loss than regular charbroiled fillets. Cooking will not alter the distribution pattern of PCB homologs; however, it facilitates the reduction of PCBs through cooking loss, liquefying of fats, and volatilization.

Relationship of Physical Parameters with Chemical Parameter of the Great Lakes Fish Species for the Consumption Advice

With all the collected data (chemical and physical parameters) of fish species from the Great Lakes, the relationship between the size of fish species and their concentration of total PCBs from specific raw skin-on fillets was determined. Linear or nonlinear regression models were used to examine the relationship between fish length, weight and total PCB concentration. The highest r^2 generated by SYSTAT, with a minimum of 0.8, was used as the best fit regression equation. Twenty-four carp skin-on fillets from Lakes Erie and Huron; 36 chinook salmon skin-on fillets from Lakes Huron and Michigan; 12 lake trout skin-on fillets from Lakes Michigan and Superior; 41 walleye skin-on fillets from Lakes Erie, Huron, and Michigan; and 12 white bass skin-on fillets from Lakes Erie and Huron were used. The concentrations of total PCBs were derived from the addition of 53 individual PCB specific congeners measured by GC-capillary column with the PCBs expressed as ppm wet basis.

The results of the nonlinear relationship between the length and the weight of fish with total PCB concentration for each of the five species are presented in Figures 19 - 23. By selecting a quadratic relationship, it resulted in increasing r^2 values from 0.1 to 0.8. Quadratic effects also influenced

Total PCBs = 58.458 + 1.331 * length - 8.846 * length² + 0.001 * weight + (-8.846) * weight²
(R^2 = 0.77)

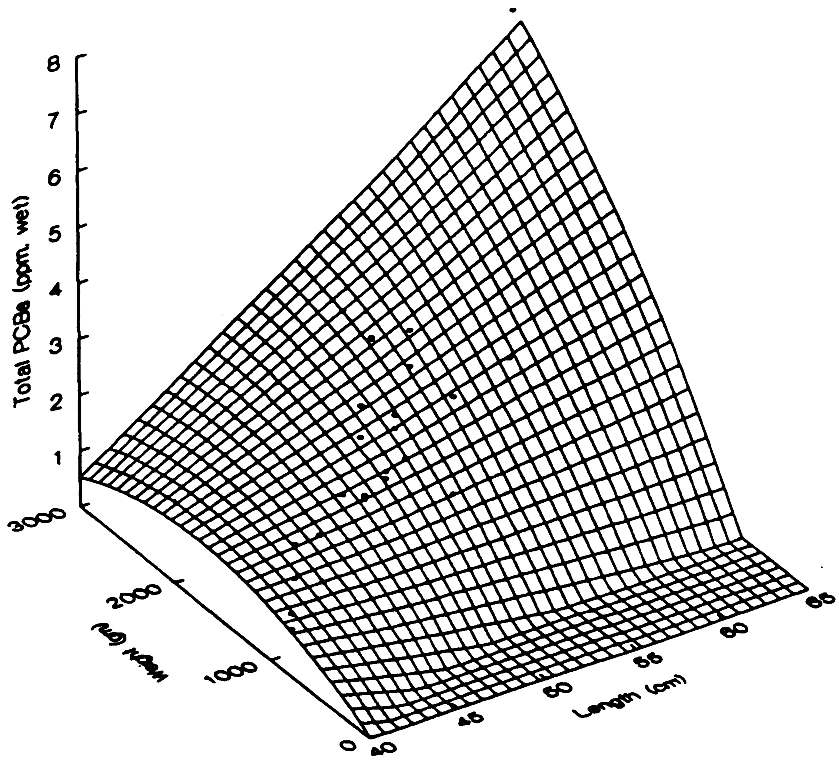

Figure 19. Concentration of total PCBs in relation to length and weight of carp harvested from Lakes Erie and Huron

Total PCBs = -1.985 + (-0.07) * length + 1.086 * length^2
(R^2 = 0.954)

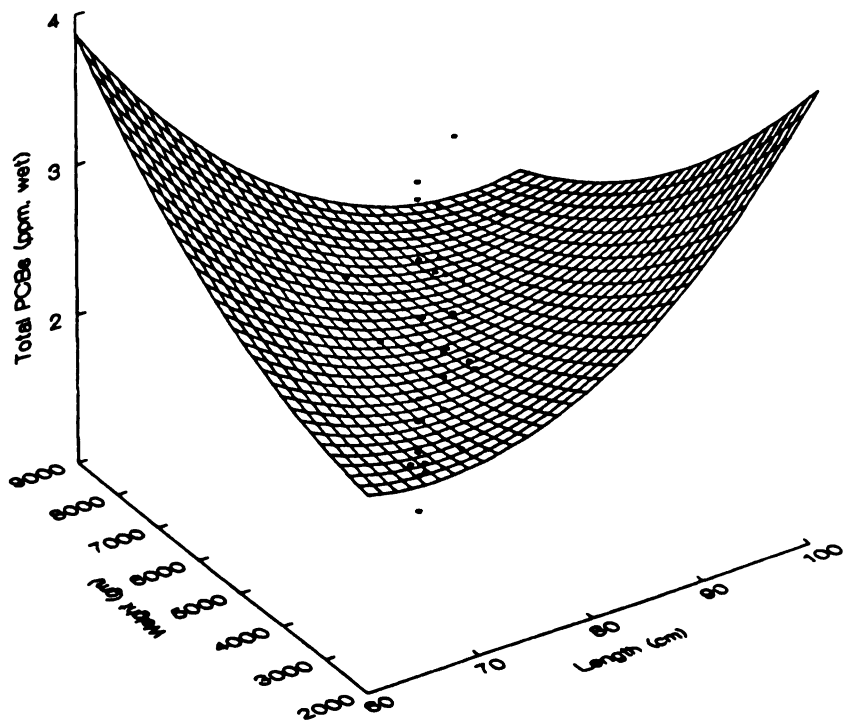

Figure 20. Concentration of total PCBs in relation to length and weight of chinook salmon harvested from Lakes Huron and Michigan

Total PCBs = (-294.196) + (-5.781) * length + 92.32 * length² + 0.035 * weight + (-3.186) * weight²
(R^2 = 0.94)

$$\text{Total PCBs} = (-294.196) + (-5.781) * \text{length} + 92.32 * \text{length}^2 + 0.035 * \text{weight} + (-3.186) * \text{weight}^2 \quad (R^2 = 0.94)$$

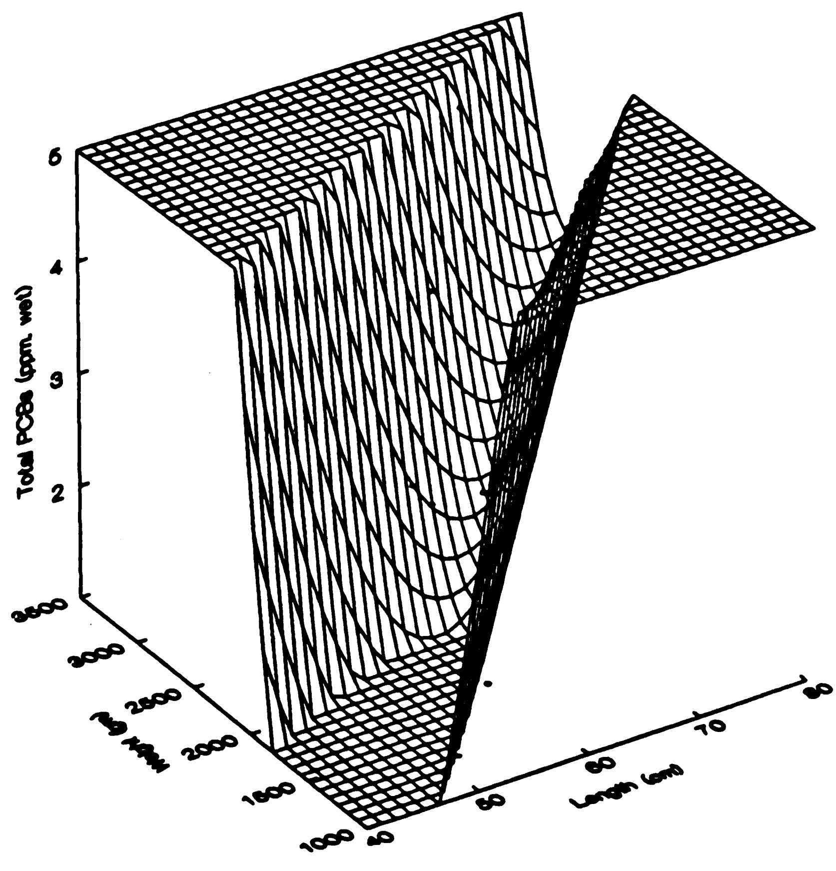

Figure 21. Concentration of total PCBs in relation to length and weight of lake trout harvested from Lakes Michigan and Superior

Total PCBs = (297.25) + 6.2 * length + (-85.584) * length^2 + 0.004 * weight + (-0.149) * weight^2
(R^2 = 0.826)

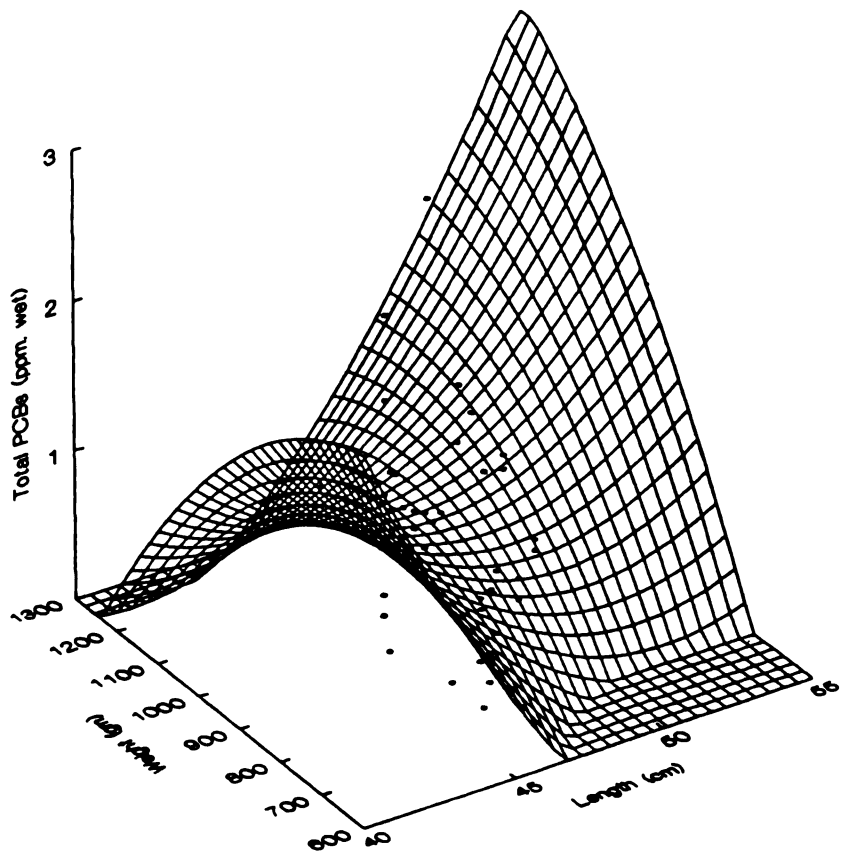

Figure 22. Concentration of total PCBs in relation to length and weight of walleye harvested from Lakes Erie, Huron and Michigan

$$\text{Total PCBs} = (137.434) + 4.751 * \text{length} + (-53.072) * \text{length}^2 + (-0.019) * \text{weight} + 0.972 * \text{weight}^2$$
$$(R^2 = 0.971)$$

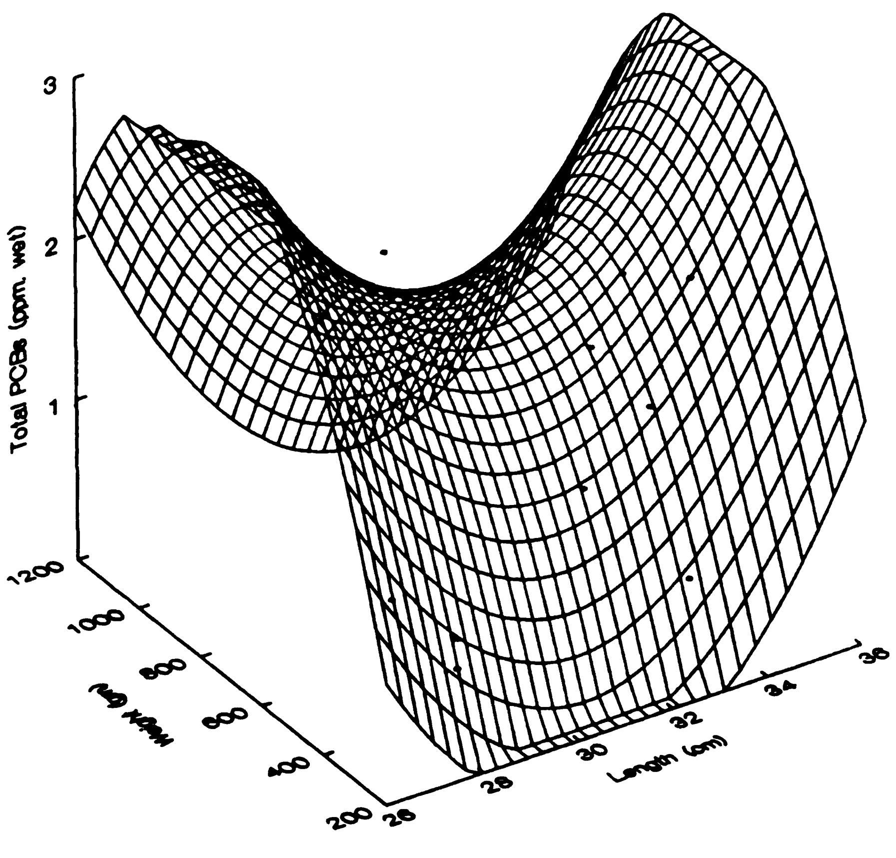

Figure 23. Concentration of total PCBs in relation to length and weight of white bass harvested from Lakes Erie and Huron

the shape of these relationships on the pattern of three-dimension graphs. The order of values of r^2 was white bass (0.971), chinook salmon (0.954), lake trout (0.94), walleye(0.826) and carp (0.767). The reason that carp had the least r^2 value was because fish ID 1109 had an extraordinary high PCBs level (7.556 ppm). If the data for this carp were deleted, the r^2 value would be increased to 0.855 which wwould be higher than 0.767. Regardless of the r^2 values, the trend of the pattern of the relationship between size and total PCBs was significantly determined by fish length instead of fish weight for carp, lake trout and white bass ($P \leq 0.2$). The length of chinook salmon was the sole predictor of total PCB concentration for skin-on fillets from Lakes Huron and Michigan. This finding was also supported by William et al. (1992); the length of chinook salmon from Lake Michigan is a more positive indicator of PCB concentration for the skin-on chinook salmon fillets. Miller and Jude (1984) reported that fish length displayed a strong direct relationship with PCB concentration for whitefish fillets from Saginaw Bay. Our results also revealed that the length of fish species for carp, lake trout, walleye and white bass is a better indicator than weight of fish in relation to its specific total PCBs. Length and weight of walleye both had significant effects on total PCBs ($P < 0.05$). The weight of fish alone is not a good predictor of total concentrations of PCBs for carp, chinook salmon, lake trout and white bass.

The correlation between size and total PCBs plus their homologs was analyzed by Pearson correlation coefficient with chi-square $P < 0.05$ as a significant correlation. The average length for carp was 50 cm and average weight for carp was 1.7 kg, both correlated significantly with total PCBs (2.015 ppm), and their tetra-, penta-, hexa-, hepta-, and octa- homologs. Zabik et al. (1982) indicated that length of fish correlated better with total PCBs for carp ranging in size from lighter than 2 kg to heavier than 5.5 kg, while weight correlated better for carp which weighed between 4 to 5.5 kg. The average length and weight for chinook salmon were 78 cm and 5.5 kg, respectively; however, length and width did not show significant correlation with total PCBs (2.161 ppm) and their individual homologs. Tri-, tetra-, penta-CBs and total PCBs (1.088 ppm) for lake trout were significantly correlated with their length (58 cm) and weight (1.9 kg). The average length (47 cm) of walleye was only significantly correlated with octa-CBs, and the average weight (0.9 kg) of walleye was significantly correlated with tri-, and octa-CBs. The mean length (31 cm) and weight (0.5 kg) of white bass did not show any significant correlation with total PCBs (1.279 ppm) and their homologs; however, total PCBs correlated significantly with their individual homologs.

At the present, Great Lakes Sport Fish Advisory Task Forces (GLSFATF, 1993) and Michigan Fishing Guide (MDNR, 1993) based fish length alone as a predictor of total concentrations of PCBs in Great Lakes Regions. As mentioned earlier, length and weight of fish species from Great Lakes were significantly correlated to each other (Appendix 6). This study further validates that fish advisories in various states use restrictions on fish length, for the protection of the public health of anglers and their families. The length of fish is much more important in predicting PCB residue levels than the weight of the fish.

Application of Measurement of Correlation

From the above results, the application should be carried out without much difficulty. Fish consumers should be aware that increases of length and weight will result in the increases of not only total PCBs, but also certain concentrations of PCBs congeners. For example, tetra-, penta-, hexa-, hepta-, and octa-CBs for carp will be increased with the increase of length and weight of carp. For lake trout, as the length and weight of lake trout increases, tri-, tetra-, and penta-CBs also increase. The increases of length and weight of walleye may not correlate with total PCBs but they correlate with the concentration of octa-CBs. Based upon the result of this study, the extended educational information needs to be continued and be made available for recreational fishermen and their families in order to protect their health and quality of life.

SUMMARY AND CONCLUSIONS

Great Lakes fish species (carp, chinook salmon, lake trout, walleye and white bass), whose sizes are based upon the Creel Census data from sports fisherman, have been chosen as bioindicators for environmental contaminants in order to monitor the levels of contaminants and to protect the health of sport fishermen. Carp harvested from Lakes Erie and Huron were processed into skin-on and skin-off fillets and cooked by deep fat and pan frying. Chinook salmon harvested from Lakes Huron and Michigan were baked and charbroiled as skin-on and skin-off fillets. In addition, skin-off chinook salmon fillets were canned. Lake trout (lean) from Lakes Huron, Michigan, and Ontario and lake trout (fat-siscowets) from Lake Superior were processed as skin-off fillets and cooked by baking and charbroiling. Skin-off lake trout from Lake Michigan and siscowets from Lake Superior were salt boiled while skin-on lake trout from Lake Michigan and skin-on siscowets from Lake Superior were smoked. Walleye harvested from Lakes Erie, Huron and Michigan were baked and charbroiled as skin-on fillets, while additional walleye from Lake Michigan were cooked by deep fat frying. White bass from Lakes Erie and Huron were processed into skin-on fillets and pan fried.

The purpose of the experimental research was to determine the concentration and the distribution pattern of PCB congeners and homologs of selected fish fillets harvested from Great Lakes. Also evaluated were the effects of food processing through trimming, skin removal and commonly used cooking methods on the reduction of total PCBs and their homologs for those specific fish fillets.

Each fish was measured for length, weight and age, which demonstrated the biological variability of fish species. Based upon the average data in length and in weight of the Great Lakes fish species, chinook salmon from Lakes Huron and Michigan (78.4 cm and 5244 g; respectively) possessed the longest length and the heaviest weight; it was followed by lake trout (64 cm and 2700 g), siscowet (52.8 cm and 1272 g), carp (49.2 cm and 1708 g), walleye (47.2 cm and 912 g), and white bass (31.3 cm and 529 g). Age is significantly correlated with length and weight of fish among carp, chinook salmon and lake trout. Due to the specified lengths and weights of the Lake Superior siscowet, which were chosen to be representative of Native American fisheries, these species were the oldest (8 - 11 years), with the shortest length (49.0 - 56.0 cm) and lightest weight (1078.0 - 1492.0 g) range among all other lake trout; therefore, Pearson correlation coefficient showed a negative correlation between age/length and age/weight for lake trout.

All fish fillets were processed using uniform conditions, in order to facilitate comparison between the control (right-side fillet) and treatment (left-side fillet) groups. Skin-on fillets had the belly flap trimmed off, while skin-off fillets also had the belly flap trimmed off, in addition to dark tissue from the lateral line and associated fat tissue. The origin of lakes and the presence or absence of skin did affect processing parameters, such as carcass yield, As Prepared yield, fillet weight, lipid content and solid content. Regardless of the fish species, the head and guts, which possessed approximately 1/3 of the total fish weight, and skin, which possessed 10% of the total fish weight, were discarded during processing. An average of fifty percent of the lipid content was eliminated from raw fish fillets through the skin removal procedure. By monitoring the internal temperature, the variation of cooking loss, using the same cooking method for skin-on and skin-off carp and chinook salmon fillets, was reduced. Cooking methods had effects on cooking loss, cooking yield, lipid content and solid content.

A mixture of polychlorinated biphenyl (PCB) consisting of 53 selected specific congeners existing in commercial Aroclor® 1254 was one of the major chemicals determined in this project. PCBs were extracted with dichloromethane, were cleaned up by GPC, florisil®, and silica gel chromatographic columns, and were analyzed by capillary column GC. The total PCBs were the summation of detectable congeners. PCB congeners 66/95/121, 84/101, 79/99, 123/149, 105/132, 128/167, 156/171, and 157/200 were co-elutions according to their retention time. All concentrations are reported on wet weight basis, dry weight basis, and total microgram per fillet on wet weight basis. The quantitation of PCB specific congeners was analyzed in raw and cooked fish fillets, according to the experimental design. Distribution patterns of PCB specific congeners in fish fillets were significantly affected by the origin of lakes for chinook salmon and significantly differed among species; carp, a bottom-feeder species in the food chain, had a higher portion of lower chlorinated biphenyls (tri- and tetra-CBs) than chinook salmon, which is a predator fish at the top of the food chain, with higher portions of higher chlorinated biphenyls (hexa-, hepta, and octa-CBs) and total PCBs. Concentration of PCB specific congeners for chinook salmon was significantly reduced by skin-removal with trimming fat and cooking processes; it is likely that the cooking process facilitated the reduction of the higher chlorinated biphenyls' portion more than the lower chlorinated biphenyls. Although the distribution pattern of PCB specific congeners for chinook salmon and carp were not altered by the cooking process, the cooking process reduced the concentration of congeners 87, 158, 66/95/121, 42, 84/101 and 118 for skin-off carp fillets. This individual congener data was grouped by chlorination in order to investigate distribution pattern of PCB homologs based upon lakes and species. Carp, chinook salmon, lake trout and walleye from the Great Lakes possessed some patterns similar to Aroclor 1254 in proportions of either tetra-, or penta-, or hexa-CBs or at least two of the above homologs. The distribution pattern of Aroclor® 1254 (tri-, tetra-, penta-, hexa-, hepta- and octa-CBs (1%, 24%, 41%, 22%, 9%, and 2%, respectively) was observed in walleye fillets from Lake Huron. The results indicate that PCB specific congeners in fish fillets provide more detailed information on the mechanisms of PCBs in the aquatic environment than total PCBs from GC-packed column analysis alone.

The equations on total PCBs for GC-capillary column predicted from packed column GC analyses and fat content of fish sample were evaluated. Concentration of total PCBs for walleye showed a linear relationship between GC-capillary column analysis and GC-packed column analysis without the influence of fat content. Fat content significantly influenced the constant of the prediction equation and the slope of total PCBs from GC-packed column in the equations for chinook salmon and lake trout. The results from GC-packed column method and GC-capillary column method were highly correlated for carp, chinook salmon, lake trout and walleye. White bass data was not significantly correlated, but this is due to the very small number of samples analyzed. Total PCB concentration from GC-packed column analyses for fish fillet was lower than the result from GC-capillary column analyses for the same fish fillet. The reason for this might be due to better lipid extraction, such as differences between the solubility of solvents (dichloromethane and ether) and sensitivity of column to have more separation of individual peaks and more accurate quantitation. Only six out of one hundred and twenty-seven fish fillets had total PCBs above FDA action level (2 ppm) based on GC-packed column analyses.

The effect of food processing on the reduction of total PCBs and their homologs was determined. Since PCBs are lipid soluble and concentrated in fat portions of fish, it is possible to remove or eliminate a certain portion of the PCBs through trimming belly flap and the lateral line, skin removal and cooking. Fish harvested at the same location had at least 20% less PCBs when processed as skin-off fillets than those processed as skin-on fillets, and this difference in PCB level of reduction was through skin-removal and fat trimming before cooking.

The reduction ot total PCBs between raw fillets and cooked fillets based upon fish species were 34.2% for carp, 35.2% for chinook salmon, 32.9% for lake trout, 37.5% for walleye and 28.6% for white bass. The effect of cooking and skin-removal after cooking on PCB homologs and total PCBs for carp, chinook salmon, walleye and white bass were significant. The reduction of 29%, 29%, 40% and 31% of total PCBs on dry basis was observed in carp, chinook salmon, walleye as well as white bass, respectively. Removing skin before cooking seemingly enhanced the reduction of total PCBs (35%) in chinook salmon fillet which normally had higher levels PCBs than the other fish species.

Seven most common cooking methods were selected to evaluate the effect of cooking methods on the reduction of PCB concentrations from composite fish fillets. There were some variations among the effect of cooking methods on the reduction of total PCBs; the trend was in order: smoke (48%) > deep fry with skin-on (39%) > charbroil (37%) > bake (33%) > panfry (29%), can (29%) > deep fry with skin-off (28%) and salt-boil (21%) based on total micrograms per fillet. The differences of cooking methods on the reduction of total PCBs are related to fish species, lake effects, cooking media, cooking time and lipid adsorption on fish tissue.

In order to protect the health of anglers and their family members, state and federal agencies have monitored Great Lakes fish continually, and fish consumption advisories implement guidance in order to reduce the risk of consuming contaminated fish. The most accessible method for the sports fishermen is to follow the fishing guide based upon the size of fish. The study validating the relationship between size of fish and levels of total PCBs is predominated by length more than by weight. Also, there are some other toxic chemicals existing in the Great Lakes ecosystem, including pesticides, dieldrin, transnonachlor, lindane, DDT and mercury, which all can pose as hazards to the public and Great Lakes fish eaters. States and local public health agencies will need to provide extended information and education to the public and anglers on the effects of belly flap trimming and skin removal before cooking or skin removal after cooking, as well as propagating the most effective cooking methods for maximum residue reduction.

RECOMMENDATIONS

Since Great Lakes fish species are very sensitive bio-indicators for aquatic contaminants, some future research should be implemented:

1. Determination of the effects of cooking time and volume of cooking oil used on the reduction of total PCBs.
2. Establishment of a standardized procedure for the determination of total PCBs and PCB congeners by federal regulatory agencies to be made available through the Internet for the public and private sectors.
3. Improvement of measurement of fat content in fish fillets based on gel permeation chromatography and high pressure liquid chromatography.
4. More studies on the effectiveness of skin-removal on the reduction of PCB specific congeners, after cooking by microwave. This is a simple and easy procedure for consumers.
5. More research on toxicity of individual congeners and combinations of specific congeners.
6. Future risk assessments should be established on congener specific environmental data and the health effects of exposure of individuals to specific congeners for more

accurate fish consumption advisory.

7. Studies on the acceptance of fish advisory recommendations by sports fishermen and their families for the protection of their health; particularly among young children, females especially pregnant or lactating; Native American Indians, and other minority and ethnic population who consume whole fish instead of fish fillet.

APPENDICES

Appendix 1. Physical and chemical parameters of carp harvested from Great Lakes

	fish ID (raw)	fish ID (cooked)	cooking methods	lakes	specie	skin (raw)	skin (cooked)	sex	age	length (cm)	whole wt (gm)	degutted wt. (gm)	carcus (%)	right fillet wt. (gm)	left fillet wt. (gm	AP yield (%)	wt. before cooking (gm)
1	9905	7107	panfry	Huron	carp	on	off	male	3	50.3	1740	1000	57.47	245.5	271.5	29.71	137.41
2	3444	9353	panfry	Huron	carp	on	off	male	3	48.3	1630	960	58.9	251	253.4	30.94	109.24
3	5360	2073	panfry	Huron	carp	on	off	male	3	52.1	2220	1310	59.01	364.8	338.2	31.67	178.05
4	8262	9787	panfry	Huron	carp	on	off	female	3	43.2	1350	740	54.81	182.3	137	23.65	57.53
5	2794	4440	panfry	Huron	carp	on	off	male	2	40.6	900	550	61.11	138.9	142.2	31.23	72.11
6	9567	5444	panfry	Huron	carp	on	off	female		45.7	1560	920	58.97	238.9	178.6	26.76	124.11
7	7013	8225	panfry	Erie	carp	on	off	female	4	48.9	1920	990	51.56	272	293.6	29.46	152.1
8	9717	4849	panfry	Erie	carp	on	off	male	4	61	2370	1390	58.65	421.9	432	36.03	234.25
9	5247	1224	panfry	Erie	carp	on	off	male	5	53.3	1570	950	60.51	317.7	305.8	39.71	156.6
10	7457	2844	panfry	Erie	carp	on	off	male	4	53.3	2040	1240	60.78	379.2	398.3	38.11	192.42
11	8320	7832	panfry	Erie	carp	on	off	female	3	47	1350	730	54.07	239.6	240.4	35.56	125.62
12	7029	5399	panfry	Erie	carp	on	off	male	3	50.2	1630	970	59.51	312.6	317.8	38.67	145.1
13	7865	2310	panfry	Huron	carp	off	off	female	2	40.6	1070	670	62.62	111.5	122	21.82	65.87
14	3148	5896	panfry	Huron	carp	off	off	male	3	41.9	1290	830	64.34	156	135.9	22.63	60.78
15	8816	1836	panfry	Huron	carp	off	off	male	3	47	1480	890	60.14	169.8	157.9	22.14	93.43
16	1306	1808	panfry	Huron	carp	off	off	female	7	55.9	2710	1700	62.73	324.6	326.1	24.01	150.25
17	7185	3517	panfry	Huron	carp	off	off	male	3	47	1450	880	60.69	141.3	129.5	18.68	73.68
18	2076	7499	panfry	Huron	carp	off	off	female		40.6	890	560	62.92	87.8	113.4	22.61	42.67
19	6112	8652	panfry	Erie	carp	off	off	male	3	50.2	1710	.	.	236.1	216.5	26.47	104.33
20	7336	5393	panfry	Erie	carp	off	off	female	3	56.5	2250	.	.	329.5	342.4	29.86	158.92
21	2215	3738	panfry	Erie	carp	off	off	male	3	53.3	2520	.	.	311.3	316.6	24.92	128.9
22	2740	2072	panfry	Erie	carp	off	off	female	3	48.3	1340	.	.	184.2	182.9	27.4	84.11
23	1928	4370	panfry	Erie	carp	off	off	female	4	53.3	1740	.	.	187.6	180.8	21.17	96.21
24	6545	7843	panfry	Erie	carp	off	off	female	3	45.7	1570	.	.	188.7	186.9	23.92	93.05
25	3503	8523	deepfat fry	Huron	carp	on	on	male	3	50.3	1740	1000	57.47	245.5	271.5	29.71	131.16
26	7553	5111	deepfat fry	Huron	carp	on	on	male	3	48.3	1630	960	58.9	251	253.4	30.94	137.32
27	7695	2351	deepfat fry	Huron	carp	on	on	male	3	52.1	2220	1310	59.01	364.8	338.2	31.67	155.52
28	9520	2087	deepfat fry	Huron	carp	on	on	female	3	43.2	1350	740	54.81	182.3	137	23.65	76.02
29	1252	1441	deepfat fry	Huron	carp	on	on	male	2	40.6	900	550	61.11	138.9	142.2	31.23	66.3
30	9132	2756	deepfat fry	Huron	carp	on	on	female		53.3	2080	1180	56.73	322	253.3	27.66	128.3
31	3277	8317	deepfat fry	Erie	carp	on	on	female	4	48.9	1920	990	51.56	272	293.6	29.46	152
32	1109	6157	deepfat fry	Erie	carp	on	on	male	4	61	2370	1390	58.65	421.9	432	36.03	192.23
33	2546	6921	deepfat fry	Erie	carp	on	on	male	5	53.3	1570	950	60.51	317.7	305.8	39.71	140.6
34	1030	8099	deepfat fry	Erie	carp	on	on	male	4	53.3	2040	1240	60.78	379.2	398.3	38.11	190.63
35	8008	7962	deepfat fry	Erie	carp	on	on	female	3	47	1350	730	54.07	239.6	240.4	35.56	105.6
36	1180	7854	deepfat fry	Erie	carp	on	on	male	3	50.2	1630	970	59.51	312.6	317.8	38.67	159.98

	actual fillet wt. (gm)	edible wt. (gm)	% cooking loss in fillet	% cooking yield in fillet	% solids in raw fillet	% solids in cooked fillet	% fat in raw fillet	% fat in cooked fillet	tri-cbs,ppm in wet wt. (raw fillet)	tri-cbs,ppm in dry wt. (raw fillet)	tri-cbs,ug in fillet (raw fillet)	tetra-cbs,ppm in wet wt. (raw fillet)	tetra-cbs,ppm in dry wt. (raw fillet)
1	117.79	104.1	14.28	75.75	26.74	28.47	6.45	11.4	0.026	0.098	3.589	0.294	1.099
2	80.28	69.6	26.51	63.71	26.25	32.9	6.7	6	0.012	0.045	1.299	0.362	1.379
3	135.3	116	24.01	65.16	29.99	34.95	.	.	0.009	0.031	1.673	0.403	1.344
4	43.33	36.43	24.68	63.32	25.06	34.41	.	.	0.035	0.138	1.986	0.169	0.674
5	60.99	52.73	15.42	73.12	25.82	30.41	.	.	0.022	0.086	1.601	0.157	0.607
6	104.65	89.86	15.68	72.4	25.53	28.84	4.85	4.2	0.025	0.1	3.164	0.172	0.674
7	104.5	100.7	31.3	66.21	32.2	39.97	.	.	0.014	0.044	2.157	0.239	0.741
8	188.9	165.8	19.36	70.79	29.52	33.88	13.3	11.9	0.034	0.115	7.94	0.666	2.257
9	127.6	112	18.52	71.51	25.06	28.6	.	.	0.011	0.043	1.68	0.222	0.887
10	143.14	125.7	25.61	65.33	23.7	32.97	.	.	0.042	0.179	8.161	0.535	2.257
11	96.5	81.4	23.18	64.8	23.47	29.22	4.65	3.25	0.029	0.122	3.607	0.536	2.284
12	119.5	105.1	17.64	72.43	26.63	30.08	8.7	7.8	0.062	0.234	9.057	0.882	3.313
13	56.8	56.8	13.77	86.23	24.23	30.15	3.47	4.1	0.066	0.271	4.32	0.362	1.496
14	54.06	54.06	11.06	88.94	21.99	26.56	1.25	2.85	0.018	0.084	1.123	0.128	0.583
15	75.2	75.2	19.51	80.49	22.14	29.28	.	.	0	0	0	0.08	0.363
16	128.89	128.9	14.22	85.78	34.96	40.33	.	.	0.065	0.186	9.783	1.281	3.665
17	59.57	59.57	19.15	80.85	20.98	29.36	1.3	4.2	0.009	0.042	0.657	0.179	0.852
18	37.08	37.08	13.1	86.9	22.17	27.42	.	.	0.021	0.095	0.902	0.342	1.542
19	73.2	73.2	29.84	70.16	21.77	33.98	.	.	0.024	0.112	2.538	0.382	1.756
20	126.1	126.1	20.65	79.35	21.66	29.82	2.7	3.85	0.017	0.079	2.715	0.306	1.415
21	94.82	94.82	26.44	73.56	21.3	31.61	.	.	0.014	0.066	1.81	0.289	1.357
22	65.66	65.66	21.94	78.06	21.57	28.95	.	.	0.045	0.209	3.796	0.508	2.353
23	81.2	81.2	15.6	84.4	20.22	26.57	2.2	2.85	0.016	0.079	1.53	0.259	1.28
24	78.9	78.9	15.21	84.79	20.69	28.8	2.8	4.7	0.013	0.064	1.232	0.2	0.967
25	92.2	92.2	29.7	70.3	26.57	44.39	.	.	0.014	0.053	1.835	0.263	0.992
26	80.42	80.42	41.44	58.56	25.68	44.15	6.1	15.7	0.017	0.065	2.303	0.548	2.136
27	111.62	111.6	28.23	71.77	29.02	44.94	10.1	17.8	0.044	0.153	6.914	0.499	1.718
28	52.68	52.68	30.7	69.3	25.5	43.7	.	.	0.062	0.244	4.735	0.355	1.392
29	49.1	49.1	25.94	74.06	25.87	43.53	.	.	0.034	0.132	2.27	0.178	0.687
30	86.2	86.2	25.02	74.98	24.53	36.94	4.45	7.91	0.007	0.027	0.865	0.131	0.535
31	95.02	95.02	37.49	62.51	29.77	45.67	.	.	0.177	0.595	26.927	1.195	4.013
32	108.21	108.2	43.71	56.29	28.17	45.81	.	.	0.072	0.256	13.851	1.369	4.861
33	97.22	97.22	30.85	69.15	23.67	44.76	.	.	0.043	0.18	6	0.803	3.391
34	140.1	140.1	26.51	73.49	23.48	40.8	6.45	15.1	0.054	0.228	10.221	0.652	2.776
35	75.07	75.07	28.91	71.09	23.29	42.83	4.8	15.3	0.029	0.126	3.09	0.505	2.167
36	111.78	111.8	30.13	69.87	25.51	47.8	8.59	21.4	0.065	0.253	10.323	0.902	3.537

	tetra-cbs,ug in wet wt. (raw fillet)	penta-cbs,ppm in wet wt. (raw fillet)	penta-cbs,ppm in dry wt. (raw fillet)	penta-cbs,ug in wet wt. (raw fillet)	hexa-cbs,ppm in wet wt. (raw fillet)	hexa-cbs,ppm in dry wt. (raw fillet)	hexa-cbs,ug in wet wt. (raw fillet)	hepta-cbs,ppm in wet wt. (raw fillet)	hepta-cbs,ppm in dry wt. (raw fillet)	hepta-cbs,ug in wet wt. (raw fillet)
1	40.377	0.572	2.139	78.601	0.268	1.002	36.829	0.064	0.24	8.8
2	39.538	1.227	4.675	134.058	0.472	1.798	51.548	0.104	0.394	11.307
3	71.741	1.482	4.942	263.875	0.663	2.21	117.997	0.156	0.521	27.81
4	9.722	0.304	1.212	17.471	0.096	0.384	5.538	0.021	0.083	1.2
5	11.305	0.315	1.219	22.7	0.101	0.39	7.26	0.022	0.086	1.593
6	21.34	0.43	1.686	53.412	0.183	0.715	22.659	0.036	0.141	4.462
7	36.297	0.313	0.971	47.543	0.116	0.361	17.662	0.049	0.153	7.511
8	156.068	0.415	1.407	97.328	0.154	0.523	36.153	0.068	0.231	15.946
9	34.795	0.359	1.432	56.19	0.134	0.536	21.019	0.049	0.196	7.684
10	102.926	0.891	3.759	171.41	0.647	2.728	124.414	0.269	1.133	51.675
11	67.326	0.596	2.538	74.817	0.327	1.392	41.038	0.122	0.519	15.304
12	128.021	0.738	2.771	107.079	0.368	1.381	53.353	0.114	0.427	16.516
13	23.878	0.315	1.301	20.759	0.073	0.303	4.834	0.019	0.076	1.22
14	7.788	0.215	0.978	13.066	0.052	0.237	3.162	0.011	0.049	0.661
15	7.505	0.162	0.734	15.181	0.512	2.31	47.792	0.035	0.158	3.263
16	192.493	3.591	10.27	539.473	0.665	1.903	99.934	0.255	0.729	38.273
17	13.166	0.428	2.041	31.549	0.113	0.537	8.307	0.038	0.183	2.829
18	14.586	0.346	1.56	14.756	0.06	0.27	2.557	0.021	0.094	0.891
19	39.887	0.492	2.261	51.349	0.381	1.752	39.784	0.156	0.715	16.235
20	48.704	0.317	1.465	50.429	0.2	0.923	31.773	0.066	0.305	10.489
21	37.258	0.571	2.68	73.579	0.576	2.703	74.214	0.25	1.174	32.236
22	42.687	0.46	2.131	38.661	0.264	1.223	22.187	0.055	0.256	4.647
23	24.91	0.275	1.359	26.437	0.217	1.075	20.904	0.053	0.26	5.067
24	18.613	0.226	1.094	21.055	0.206	0.994	19.137	0.052	0.251	4.825
25	34.554	0.586	2.205	76.843	0.19	0.715	24.918	0.071	0.268	9.333
26	75.32	1.437	5.594	197.282	0.623	2.425	85.529	0.146	0.57	20.108
27	77.546	1.372	4.727	213.326	0.73	2.516	113.553	0.169	0.584	26.338
28	26.987	0.625	2.452	47.532	0.136	0.535	10.369	0.047	0.186	3.605
29	11.786	0.522	2.017	34.597	0.114	0.44	7.541	0.039	0.152	2.603
30	16.831	0.385	1.571	49.436	0.163	0.664	20.91	0.045	0.185	5.81
31	181.572	1.21	4.063	183.848	0.824	2.769	125.321	0.55	1.846	83.539
32	263.238	2.381	8.381	458.844	2.06	7.314	396.044	1.528	5.424	293.701
33	112.847	0.82	3.463	115.241	0.586	2.478	82.459	0.217	0.919	30.58
34	124.25	1.074	4.576	204.799	0.895	3.811	170.582	0.349	1.488	66.589
35	53.303	0.634	2.724	66.987	0.383	1.644	40.422	0.133	0.569	14.006
36	144.364	0.686	2.686	109.563	0.432	1.695	69.159	0.314	1.231	50.256

	octa-cbs,ppm	octa-cbs,ppm	octa-cbs,ug	total pcbs, ppm	total pcbs, ppm	total pcbs, ug	tri-cbs, ppm	tri-cbs, ppm	tri-cbs, ug	tri-cbs
	in wet wt.	in dry wt.	in wet wt.	in wet wt.	in dry wt.	in wet wt.	in wet wt.	in dry wt.	in wet wt.	% change
	(raw fillet)	(raw fillet)	(raw fillet)	(raw fillet)	(raw fillet)	(raw fillet)	(cooked fillet)	(cooked fillet)	(cooked fillet)	(cooked fillet)
1	0.038	0.142	5.221	1.262	4.72	173.417	0.009	0.03	1.021	71.57
2	0.04	0.153	4.386	2.217	8.444	242.137	0.032	0.098	2.598	-100
3	0.075	0.25	13.326	2.788	9.297	496.421	0.024	0.068	3.237	-93.48
4	0.003	0.01	0.149	0.627	2.502	36.067	0.039	0.112	1.672	15.79
5	0.002	0.007	0.135	0.618	2.395	44.594	0.018	0.058	1.075	32.84
6	0.007	0.028	0.884	0.853	3.343	105.922	0.018	0.064	1.928	39.08
7	0.022	0.07	3.422	0.753	2.34	114.593	0.008	0.02	0.855	60.37
8	0.021	0.07	4.874	1.359	4.603	318.309	0.01	0.03	1.915	75.88
9	0.009	0.038	1.482	0.784	3.13	122.85	0.009	0.03	1.09	35.13
10	0.039	0.165	7.538	2.422	10.221	466.124	0.046	0.14	6.608	19.03
11	0.019	0.08	2.37	1.628	6.935	204.462	0.015	0.052	1.452	59.73
12	0.019	0.072	2.793	2.183	8.199	316.819	0.056	0.186	6.703	26
13	0.013	0.053	0.841	0.848	3.499	55.852	0.059	0.196	3.352	22.39
14	0.006	0.027	0.367	0.431	1.958	26.167	0.017	0.065	0.934	16.89
15	0	0	0	0.789	3.565	73.741	0.005	0.019	0.41	.
16	0.015	0.044	2.307	5.872	16.796	882.272	0.076	0.188	9.792	0.01
17	0.003	0.014	0.217	0.77	3.67	56.724	0.009	0.031	0.549	16.44
18	0.001	0.006	0.061	0.791	3.568	33.753	0.015	0.054	0.554	38.64
19	0.021	0.095	2.155	1.456	6.69	151.948	0.016	0.048	1.195	52.93
20	0.009	0.04	1.391	0.916	4.227	145.502	0.012	0.04	1.51	44.36
21	0.032	0.15	4.132	1.732	8.13	223.228	0.017	0.053	1.588	12.26
22	0.012	0.057	1.029	1.344	6.229	113.007	0.048	0.166	3.163	16.69
23	0.012	0.062	1.198	0.832	4.115	80.047	0.016	0.061	1.323	13.56
24	0.01	0.049	0.947	0.707	3.418	65.809	0.013	0.044	0.994	19.31
25	0.007	0.028	0.962	1.132	4.26	148.444	0.011	0.025	1.034	43.66
26	0.009	0.035	1.223	2.78	10.826	381.766	0.013	0.029	1.02	55.72
27	0.011	0.037	1.661	2.825	9.735	439.338	0.035	0.078	3.924	43.25
28	0.004	0.016	0.313	1.23	4.825	93.542	0.037	0.085	1.959	58.63
29	0.002	0.008	0.141	0.889	3.436	58.937	0.024	0.055	1.172	48.38
30	0.003	0.011	0.343	0.734	2.993	94.195	0.006	0.017	0.588	31.98
31	0.055	0.185	8.363	4.01	13.471	609.569	0.164	0.359	15.566	42.19
32	0.166	0.588	31.841	7.558	26.823	1452.52	0.054	0.118	5.849	57.77
33	0.048	0.202	6.712	2.517	10.632	353.839	0.046	0.103	4.495	25.08
34	0.047	0.201	9.012	3.071	13.08	585.464	0.06	0.146	8.363	18.18
35	0.021	0.089	2.181	1.704	7.318	179.989	0.035	0.083	2.665	13.76
36	0.024	0.094	3.854	2.422	9.495	387.518	0.063	0.132	7.03	31.9

	tetra-cbs, ppm	tetra-cbs, ppm	tetra-cbs, ug	tetra-cbs	penta-cbs, ppm	penta-cbs, ppm	penta-cbs, ug	penta-cbs	hexa-cbs, ppm	hexa-cbs, ppm
	in wet wt.	in dry wt.	in wet wt.	% change	in wet wt.	in dry wt.	in wet wt.	% change	in wet wt.	in dry wt.
	(cooked fillet)	(cooked fillet)	(cooked fillet)	(cooked fillet)	(cooked fillet)	(cooked fillet)	(cooked fillet)	(cooked fillet)	(cooked fillet)	(cooked fillet)
1	0.119	0.418	14.008	65.31	0.295	1.036	34.729	55.82	0.153	0.539
2	0.374	1.137	30.019	24.07	1.237	3.76	99.301	25.93	0.51	1.55
3	0.289	0.828	39.155	45.42	1.249	3.574	169.026	35.94	0.556	1.592
4	0.153	0.442	6.608	32.02	0.262	0.761	11.372	34.91	0.081	0.234
5	0.189	0.621	11.512	-1.83	0.282	0.927	17.196	24.25	0.086	0.282
6	0.144	0.5	15.092	29.28	0.404	1.401	42.288	20.83	0.188	0.653
7	0.172	0.431	18	50.41	0.276	0.69	28.834	39.35	0.102	0.256
8	0.239	0.705	45.109	71.1	0.351	1.035	66.235	31.95	0.128	0.378
9	0.217	0.757	27.628	20.6	0.3	1.05	38.309	31.82	0.136	0.476
10	0.588	1.784	84.193	18.2	1.036	3.142	148.273	13.5	0.759	2.301
11	0.323	1.105	31.164	53.71	0.35	1.198	33.786	54.84	0.206	0.704
12	0.789	2.623	94.288	26.35	0.708	2.353	84.594	21	0.345	1.148
13	0.237	0.787	13.482	43.54	0.204	0.677	11.599	44.13	0.047	0.157
14	0.112	0.421	6.047	22.36	0.182	0.685	9.836	24.72	0.053	0.201
15	0.063	0.217	4.772	36.41	0.3	1.025	22.569	-48.67	0.106	0.363
16	1.256	3.116	161.948	15.87	3.112	7.716	401.082	25.65	0.665	1.649
17	0.182	0.621	10.856	17.55	0.512	1.743	30.481	3.38	0.129	0.44
18	0.243	0.885	9.002	38.28	0.304	1.11	11.285	23.53	0.048	0.173
19	0.276	0.812	20.208	49.34	0.468	1.378	34.263	33.27	0.354	1.043
20	0.226	0.756	28.444	41.6	0.272	0.912	34.289	32	0.214	0.716
21	0.448	1.417	42.482	-14.02	0.37	1.169	35.047	52.37	0.546	1.726
22	0.539	1.862	35.395	17.08	0.412	1.424	27.072	29.98	0.278	0.962
23	0.249	0.936	20.192	18.94	0.282	1.062	22.916	13.32	0.231	0.869
24	0.199	0.691	15.703	15.63	0.221	0.766	17.415	17.29	0.18	0.626
25	0.212	0.477	19.524	43.5	0.439	0.988	40.43	47.39	0.135	0.305
26	0.385	0.872	30.953	58.9	0.89	2.015	71.553	63.73	0.413	0.935
27	0.415	0.923	46.282	40.32	1.147	2.553	128.046	39.98	0.612	1.362
28	0.167	0.382	8.793	67.42	0.407	0.932	21.462	54.85	0.081	0.185
29	0.233	0.535	11.437	2.96	0.462	1.062	22.701	34.38	0.099	0.228
30	0.141	0.382	13.565	19.41	0.249	0.674	23.959	51.54	0.099	0.269
31	1.12	2.452	106.418	41.39	1.186	2.597	112.68	38.71	0.82	1.795
32	1.057	2.307	114.378	56.55	1.836	4.008	198.667	56.23	1.538	3.357
33	0.853	1.905	82.903	26.54	0.979	2.187	95.186	17.4	0.605	1.352
34	0.738	1.809	103.408	18.77	1.3	3.187	182.187	11.04	1.092	2.677
35	0.645	1.507	48.453	9.1	0.777	1.813	58.294	12.98	0.473	1.105
36	0.89	1.863	99.532	31.05	0.836	1.748	93.41	14.74	0.457	0.957

	hexa-cbs, ug in wet wt. (cooked fillet)	hexa-cbs % change (cooked fillet)	hepta-cbs, ppm in wet wt. (cooked fillet)	hepta-cbs, ppm in dry wt. (cooked fillet)	hepta-cbs, ug in wet wt. (cooked fillet)	hepta-cbs % change (cooked fillet)	octa-cbs, ppm in wet wt. (cooked fillet)	octa-cbs, ppm in dry wt. (cooked fillet)	octa-cbs, ug in wet wt. (cooked fillet)	octa-cbs % change (cooked fillet)
1	18.052	50.98	0.05	0.174	5.844	33.5	0.013	0.046	1.551	70.29
2	40.934	20.59	0.112	0.34	8.992	20.4	0.053	0.16	4.238	3.37
3	75.269	36.21	0.126	0.361	17.078	38.5	0.059	0.168	7.939	40.42
4	3.495	36.89	0.019	0.056	0.837	30.3	0.004	0.011	0.166	-11.22
5	5.238	27.85	0.041	0.136	2.519	-58.1	0.009	0.029	0.533	-293.33
6	19.711	13.01	0.048	0.168	5.074	-13.7	0.004	0.015	0.439	50.35
7	10.705	39.39	0.027	0.067	2.78	63	0.011	0.028	1.177	65.61
8	24.177	33.13	0.031	0.091	5.847	63.3	0.011	0.032	2.028	58.4
9	17.356	17.42	0.037	0.13	4.76	38	0.012	0.043	1.552	-4.75
10	108.606	12.71	0.32	0.972	45.849	11.2	0.048	0.144	6.809	9.67
11	19.853	51.62	0.077	0.264	7.443	51.3	0.012	0.042	1.193	49.67
12	41.249	22.69	0.126	0.42	15.088	8.6	0.017	0.057	2.054	26.46
13	2.682	44.52	0.013	0.043	0.73	40.2	0	0	0	100
14	2.888	8.67	0.014	0.054	0.774	-17.1	0.012	0.046	0.66	-80.1
15	8.002	83.26	0.023	0.08	1.759	46	0.016	0.055	1.212	
16	85.74	14.2	0.261	0.647	33.65	12	0.017	0.041	2.146	6.96
17	7.696	7.35	0.048	0.162	2.834	-0.1	0.005	0.016	0.276	-27.56
18	1.762	31.09	0.02	0.073	0.744	16.5	0.003	0.012	0.126	-106.26
19	25.936	34.81	0.146	0.429	10.666	34.3	0.021	0.063	1.573	27
20	26.934	15.23	0.096	0.323	12.159	-15.9	0.01	0.033	1.237	11.05
21	51.739	30.28	0.137	0.435	13.033	59.5	0.071	0.224	6.708	-62.35
22	18.278	17.62	0.07	0.242	4.609	0.8	0.014	0.049	0.933	9.29
23	18.739	10.36	0.05	0.189	4.075	19.5	0.015	0.058	1.244	-3.87
24	14.225	25.67	0.041	0.143	3.257	32.4	0.008	0.028	0.644	31.99
25	12.484	49.9	0.041	0.093	3.822	59	0.004	0.01	0.395	58.94
26	33.19	61.19	0.104	0.236	8.37	58.3	0.007	0.016	0.566	53.7
27	68.319	39.84	0.131	0.291	14.62	44.4	0.009	0.021	1.032	37.91
28	4.257	58.95	0.021	0.048	1.098	69.5	0.002	0.006	0.129	58.94
29	4.864	35.5	0.044	0.101	2.152	17.3	0.004	0.009	0.203	-43.83
30	9.542	54.37	0.041	0.11	3.919	32.5	0.005	0.013	0.45	-31.29
31	77.879	37.86	0.293	0.641	27.804	66.7	0.052	0.115	4.979	40.47
32	186.414	57.98	1.086	2.371	117.514	59.9	0.12	0.262	12.965	59.28
33	58.853	28.63	0.226	0.505	21.961	28.1	0.035	0.079	3.449	48.61
34	153.001	10.31	0.436	1.068	61.055	8.3	0.087	0.214	12.223	-35.63
35	35.537	12.09	0.165	0.386	12.401	11.4	0.031	0.073	2.338	-7.2
36	51.129	26.07	0.274	0.573	30.819	39	0.049	0.103	5.529	-43.45

	total pcbs, ppm in wet wt. (cooked fillet)	total pcbs, ppm in dry wt. (cooked fillet)	total pcbs, ug in wet wt. (cooked fillet)	total pcbs % change (cooked fillet)
1	0.638	2.244	75.205	56.63
2	2.318	7.045	186.083	23.15
3	2.304	6.592	311.703	37.21
4	0.557	1.616	24.151	33.04
5	0.624	2.053	38.074	14.62
6	0.808	2.801	84.53	20.2
7	0.597	1.493	62.351	45.59
8	0.769	2.271	145.311	54.35
9	0.711	2.485	90.696	26.17
10	2.797	8.483	400.338	14.11
11	0.983	3.365	94.891	53.59
12	2.042	6.787	243.976	22.99
13	0.561	1.86	31.845	42.98
14	0.391	1.472	21.139	19.22
15	0.515	1.759	38.724	47.49
16	5.387	13.358	694.358	21.3
17	0.885	3.013	52.692	7.11
18	0.633	2.309	23.472	30.46
19	1.282	3.773	93.842	38.24
20	0.829	2.781	104.574	28.13
21	1.588	5.024	150.597	32.54
22	1.362	4.706	89.45	20.85
23	0.843	3.175	68.489	14.44
24	0.662	2.299	52.238	20.62
25	0.843	1.898	77.689	47.66
26	1.811	4.102	145.651	61.85
27	2.349	5.228	262.223	40.31
28	0.716	1.637	37.697	59.7
29	0.866	1.99	42.529	27.84
30	0.641	1.464	52.023	44.77
31	3.634	7.958	345.326	43.35
32	5.691	12.422	615.786	57.61
33	2.745	6.132	266.848	24.58
34	3.713	9.101	520.236	11.14
35	2.127	4.967	159.687	11.28
36	2.67	5.376	287.249	25.87

Appendix 1. Physical and chemical parameters of carp harvested from Great Lakes

	fish ID (raw)	fish ID (cooked)	cooking methods	lakes	specie	skin (raw)	skin (cooked)	sex	age	length (cm)	whole wt (gm)	degutted wt. (gm)	carcus (%)	right fillet wt. (gm)	left fillet wt. (gm	AP yield (%)	wt. before cooking (gm)
37	2115	6087	deepfat fry	Huron	carp	off	off	female	2	40.6	1070	670	62.62	111.5	122	21.82	53.22
38	3710	3821	deepfat fry	Huron	carp	off	off	male	3	41.9	1290	830	64.34	156	135.9	22.63	74.93
39	1892	7138	deepfat fry	Huron	carp	off	off	female	3	45.7	1580	920	58.23	177.9	162.2	21.53	64.49
40	2874	7610	deepfat fry	Huron	carp	off	off	female	7	55.9	2710	1700	62.73	324.6	326.1	24.01	173.05
41	8723	4651	deepfat fry	Huron	carp	off	off	male	3	47	1450	880	60.69	141.3	129.5	18.68	55.1
42	9118	2831	deepfat fry	Huron	carp	off	off	female	3	45.7	1650	980	59.39	160.9	173.8	20.28	91.39
43	7034	1123	deepfat fry	Erie	carp	off	off	male	3	50.2	1710	.	.	236.1	216.5	26.47	96.84
44	8302	4426	deepfat fry	Erie	carp	off	off	female	3	56.5	2250	.	.	329.5	342.4	29.86	172.3
45	3391	3318	deepfat fry	Erie	carp	off	off	male	3	53.3	2520	.	.	311.3	316.6	24.92	174.43
46	1791	2955	deepfat fry	Erie	carp	off	off	female	3	48.3	1340	.	.	184.2	182.9	27.4	87.81
47	3840	2799	deepfat fry	Erie	carp	off	off	female	4	53.3	1740	.	.	187.6	180.8	21.17	75.15
48	5068	5173	deepfat fry	Erie	carp	off	off	female	3	45.7	1570	.	.	188.7	186.9	23.92	91.81

	actual fillet wt. (gm)	edible wt. (gm	% cooking loss in fillet	% cooking yield in fillet	% solids in raw fillet	% solids in cooked fillet	% fat in raw fillet	% fat in cooked fillet	tri-cbs,ppm in wet wt. (raw fillet)	tri-cbs,ppm in dry wt. (raw fillet)	tri-cbs,ug in fillet (raw fillet	tetra-cbs,ppm in wet wt. (raw fillet)	tetra-cbs,ppm in dry wt. (raw fillet)
37	35.73	35.73	32.86	67.14	24.23	48.53	3.75	17.7	0.038	0.155	1.998	0.55	2.27
38	51.2	51.2	31.67	68.33	21.99	39.89	.	.	0.008	0.034	0.565	0.136	0.616
39	49.2	49.2	23.71	76.29	22.68	34	1.95	2.68	0.009	0.039	0.565	0.224	0.989
40	111.5	111.5	35.57	64.43	34.96	49.71	.	.	0.021	0.061	3.68	0.466	1.333
41	39.75	39.75	27.86	72.14	20.98	38.42	2.3	10.7	0.02	0.093	1.079	0.429	2.045
42	63.46	63.46	30.56	69.44	23.55	43.76	.	.	0.006	0.026	0.552	0.146	0.62
43	56.38	56.38	41.78	58.22	21.11	44.05	.	.	0.027	0.13	2.653	0.498	2.357
44	111.93	111.9	35.04	64.96	21.49	43.28	2.6	7.55	0.048	0.223	8.258	0.268	1.249
45	101.34	101.3	41.9	58.1	22.59	42.66	4.3	9.78	0.026	0.116	4.576	0.525	2.326
46	58.35	58.35	33.55	66.45	20.98	39.82	2.3	4.31	0.118	0.56	10.324	0.494	2.354
47	46.18	46.18	38.55	61.45	20.1	40.38	.	.	0.017	0.085	1.281	0.291	1.449
48	66.11	66.11	27.99	72.01	21.76	37.65	.	.	0.034	0.156	3.113	0.199	0.913

	tetra-cbs,ug in wet wt. (raw fillet)	penta-cbs,ppm in wet wt. (raw fillet)	penta-cbs,ppm in dry wt. (raw fillet)	penta-cbs,ug in wet wt. (raw fillet)	hexa-cbs,ppm in wet wt. (raw fillet)	hexa-cbs,ppm in dry wt. (raw fillet)	hexa-cbs,ug in wet wt. (raw fillet)	hepta-cbs,ppm in wet wt. (raw fillet)	hepta-cbs,ppm in dry wt. (raw fillet)	hepta-cbs,ug in wet wt. (raw fillet)
37	29.274	0.417	1.721	22.197	0.107	0.441	5.683	0.044	0.18	2.319
38	10.157	0.202	0.919	15.139	0.051	0.231	3.807	0.023	0.106	1.747
39	14.466	0.306	1.351	19.756	0.122	0.537	7.854	0.066	0.29	4.248
40	80.645	0.517	1.48	89.548	0.184	0.526	31.84	0.07	0.199	2.069
41	23.641	0.476	2.271	26.25	0.169	0.807	9.334	0.064	0.306	3.538
42	13.353	0.378	1.606	34.575	0.089	0.377	8.109	0.028	0.118	2.538
43	48.189	0.593	2.811	57.466	0.434	2.056	42.035	0.299	1.417	28.967
44	46.23	0.3	1.397	51.732	0.142	0.662	24.497	0.034	0.16	5.925
45	91.658	1.094	4.841	190.742	1.139	5.044	198.743	0.867	3.839	151.28
46	43.367	0.474	2.257	41.581	0.181	0.863	15.891	0.044	0.21	3.873
47	21.883	0.317	1.575	23.788	0.212	1.053	15.903	0.163	0.812	12.264
48	18.234	0.251	1.152	23.016	0.148	0.682	13.631	0.032	0.146	2.91

	octa-cbs,ppm in wet wt. (raw fillet)	octa-cbs,ppm in dry wt. (raw fillet)	octa-cbs,ug in wet wt. (raw fillet)	total pcbs, ppm in wet wt. (raw fillet)	total pcbs, ppm in dry wt. (raw fillet)	total pcbs, ug in wet wt. (raw fillet)	tri-cbs, ppm in wet wt. (cooked fillet)	tri-cbs, ppm in dry wt. (cooked fillet)	tri-cbs, ug in wet wt. (cooked fillet)	tri-cbs % change (cooked fillet)
37	0.005	0.022	0.287	1.16	4.789	61.758	0.026	0.054	0.933	53.31
38	0	0	0	0.419	1.907	31.415	0.005	0.014	0.279	50.7
39	0.002	0.008	0.114	0.729	3.214	47.003	0.01	0.028	0.472	16.52
40	0.006	0.016	0.976	1.264	3.616	218.768	0.035	0.071	3.912	-6.28
41	0.005	0.025	0.286	1.164	5.547	64.128	0.035	0.091	1.396	-29.39
42	0	0	0	0.647	2.747	59.126	0.005	0.012	0.345	37.36
43	0.031	0.147	3.001	1.883	8.918	182.311	0.029	0.065	1.611	39.27
44	0.002	0.01	0.36	0.795	3.7	137.002	0.036	0.083	4.022	51.3
45	0.075	0.33	12.997	3.726	16.496	649.995	0.024	0.056	2.43	46.89
46	0.014	0.065	1.196	1.325	6.309	116.232	0.038	0.095	2.203	78.66
47	0.013	0.067	1.009	1.013	5.041	76.129	0.012	0.031	0.569	55.58
48	0.002	0.009	0.183	0.665	3.058	61.087	0.009	0.025	0.626	79.9

	tetra-cbs, ppm in wet wt. (cooked fillet)	tetra-cbs, ppm in dry wt. (cooked fillet)	tetra-cbs, ug in wet wt. (cooked fillet)	tetra-cbs % change (cooked fillet)	penta-cbs, ppm in wet wt. (cooked fillet)	penta-cbs, ppm in dry wt. (cooked fillet)	penta-cbs, ug in wet wt. (cooked fillet)	penta-cbs % change (cooked fillet)	hexa-cbs, ppm in wet wt. (cooked fillet)	hexa-cbs, ppm in dry wt. (cooked fillet)
37	0.413	0.852	14.765	49.56	0.311	0.64	11.102	49.98	0.064	0.132
38	0.084	0.211	4.314	57.52	0.194	0.486	9.925	34.44	0.131	0.329
39	0.254	0.746	12.475	13.76	0.341	1.004	16.799	14.97	0.089	0.26
40	0.768	1.544	85.583	-6.12	0.554	1.114	61.744	31.05	0.151	0.304
41	0.496	1.291	19.723	16.57	0.444	1.157	17.666	32.7	0.134	0.348
42	0.171	0.39	10.826	18.92	0.291	0.666	18.485	46.53	0.078	0.178
43	0.452	1.026	25.49	47.1	0.546	1.241	30.811	46.38	0.433	0.983
44	0.208	0.48	23.239	49.73	0.231	0.533	25.84	50.05	0.105	0.242
45	0.48	1.126	48.693	46.88	0.943	2.21	95.561	49.9	1.007	2.36
46	0.451	1.132	26.308	39.34	0.457	1.148	26.683	35.83	0.209	0.525
47	0.207	0.513	9.567	56.28	0.212	0.525	9.781	58.88	0.143	0.354
48	0.172	0.457	11.378	37.6	0.209	0.554	13.797	40.06	0.1	0.266

	hexa-cbs, ug in wet wt. (cooked fillet)	hexa-cbs % change (cooked fillet)	hepta-cbs, ppm in wet wt. (cooked fillet)	hepta-cbs, ppm in dry wt. (cooked fillet)	hepta-cbs, ug in wet wt. (cooked fillet)	hepta-cbs % change (cooked fillet)	octa-cbs, ppm in wet wt. (cooked fillet)	octa-cbs, ppm in dry wt. (cooked fillet)	octa-cbs, ug in wet wt. (cooked fillet)	octa-cbs % change (cooked fillet)
37	2.293	59.64	0.015	0.03	0.527	77.2	0.005	0.011	0.189	34.19
38	6.725	-76.66	0.107	0.269	5.498	-214.6	0	0	0	0
39	4.355	44.55	0.041	0.12	2.005	52.7	0.005	0.015	0.247	-115.87
40	16.84	47.11	0.06	0.12	6.669	44.7	0.007	0.014	0.792	18.9
41	5.316	43.04	0.049	0.127	1.946	45	0.005	0.014	0.211	26.37
42	4.93	39.2	0.038	0.087	2.427	4.3	0	0	0	0
43	24.411	41.93	0.288	0.653	16.226	43.9	0.037	0.084	2.094	30.24
44	11.734	52.1	0.024	0.055	2.664	55	0.003	0.006	0.293	18.54
45	102.017	48.67	0.753	1.766	76.352	49.5	0.071	0.166	7.188	44.69
46	12.189	23.3	0.058	0.146	3.394	12.3	0.004	0.011	0.244	79.56
47	6.594	58.54	0.105	0.259	4.832	60.6	0.017	0.043	0.799	20.85
48	6.611	51.5	0.023	0.062	1.534	47.2	0.001	0.004	0.096	47.61

	total pcbs, ppm in wet wt. (cooked fillet)	total pcbs, ppm in dry wt. (cooked fillet)	total pcbs, ug in wet wt. (cooked fillet)	total pcbs % change (cooked fillet)
37	0.834	1.719	29.808	51.73
38	0.522	1.309	26.742	14.88
39	0.739	2.173	36.353	22.66
40	1.574	3.167	175.539	19.76
41	1.164	3.029	46.257	27.87
42	0.583	1.333	37.014	37.4
43	1.785	4.052	100.643	44.79
44	0.606	1.399	67.792	50.52
45	3.278	7.685	332.241	48.89
46	1.217	3.057	71.021	38.9
47	0.696	2.053	32.142	57.78
48	0.515	1.368	34.041	44.27

Appendix 2. Physical and chemical parameters of chinook salmon harvested from Great Lakes

	fish ID (raw)	fish ID (cooked)	cooking methods	lakes	specie	skin (raw)	skin (cooked)	sex	age	length (cm)	whole wt. (gm)	degutted wt. (gm)	carcus (%)	right fillet wt. (gm)	left fillet wt. (gm)
1	6911	8441	bake	Huron	ch. salmon	on	off	female	.	84.0	6590	3610	54.78	1118.0	1199.0
2	8384	6889	bake	Huron	ch. salmon	on	off	female	4	81.0	6320	3500	55.38	1068.0	1176.0
3	2953	6650	bake	Huron	ch. salmon	on	off	female	3	77.0	5360	3300	61.57	1033.0	1115.0
4	6198	9980	bake	Huron	ch. salmon	on	off	male	3	78.0	5130	3250	63.35	997.0	1064.0
5	7442	8990	bake	Huron	ch. salmon	on	off	male	.	79.0	5480	3550	64.78	1056.0	1177.0
6	1798	8232	bake	Huron	ch. salmon	on	off	male	.	84.0	6370	4130	64.84	1133.0	1313.0
7	9818	3899	bake	Huron	ch. salmon	off	off	female	4	82.0	5830	3310	56.78	679.0	830.0
8	2905	2921	bake	Huron	ch. salmon	off	off	male	3	79.0	5100	3410	66.86	704.0	790.0
9	2822	9605	bake	Huron	ch. salmon	off	off	male	3	70.0	3860	2620	67.88	494.0	529.0
10	7141	8541	bake	Huron	ch. salmon	off	off	male	3	74.0	4549	3050	67.05	675.0	553.0
11	5934	4987	bake	Huron	ch. salmon	off	off	male	3	77.5	4770	3270	68.55	674.0	725.0
12	1954	2680	bake	Huron	ch. salmon	off	off	female	4	85.0	6070	3670	60.46	795.0	918.0
13	1872	1083	charbroil	Huron	ch. salmon	on	off	female	.	84.0	6590	3610	54.78	1118.0	1199.0
14	3770	1490	charbroil	Huron	ch. salmon	on	off	female	4	81.0	6320	3500	55.38	1068.0	1176.0
15	6424	9011	charbroil	Huron	ch. salmon	on	off	female	3	77.0	5360	3300	61.57	1033.0	1115.0
16	3344	1819	charbroil	Huron	ch. salmon	on	off	male	3	78.0	5130	3250	63.35	997.0	1064.0
17	8949	2979	charbroil	Huron	ch. salmon	on	off	male	.	79.0	5480	3550	64.78	1056.0	1177.0
18	6857	7212	charbroil	Huron	ch. salmon	on	off	male	.	84.0	6370	4130	64.84	1133.0	1313.0
19	3815	1542	charbroil	Huron	ch. salmon	off	off	female	4	82.0	5830	3310	56.78	679.0	830.0
20	7179	9453	charbroil	Huron	ch. salmon	off	off	male	3	79.0	5100	3410	66.86	704.0	790.0
21	9121	1259	charbroil	Huron	ch. salmon	off	off	male	3	70.0	3860	2620	67.88	494.0	529.0
22	7893	8449	charbroil	Huron	ch. salmon	off	off	male	3	74.0	4549	3050	67.05	675.0	553.0
23	1437	8211	charbroil	Huron	ch. salmon	off	off	male	3	77.5	4770	3270	68.55	674.0	725.0
24	6820	4546	charbroil	Huron	ch. salmon	off	off	female	4	85.0	6070	3670	60.46	795.0	918.0
25	6946	3043	charbroil*	Huron	ch. salmon	on	off	male	4	84.0	5830	4040	69.30	1251.0	1298.0
26	2305	9724	charbroil*	Huron	ch. salmon	on	off	male	.	84.0	6570	4450	67.73	1213.0	1359.0
27	6510	8694	charbroil*	Huron	ch. salmon	on	off	male	.	81.0	5560	3750	67.45	1081.0	1219.0
28	3167	3985	charbroil*	Huron	ch. salmon	on	off	female	4	91.0	7030	4150	59.03	1283.0	1298.0
29	7377	7673	charbroil*	Huron	ch. salmon	on	off	male	.	86.0	7130	4880	68.44	1418.0	1659.0
30	7025	8969	charbroil*	Huron	ch. salmon	on	off	male	3	78.0	4920	3350	68.09	847.0	1002.0
31	9699	3786	charbroil*	Huron	ch. salmon	off	off	male	.	83.0	6820	4440	65.10	1020.0	879.0
32	2346	5900	charbroil*	Huron	ch. salmon	off	off	male	3	75.0	4920	3290	66.87	604.0	791.0
33	1744	7239	charbroil*	Huron	ch. salmon	off	off	male	4	81.0	6070	4050	66.72	868.0	703.0
34	1534	5052	charbroil*	Huron	ch. salmon	off	off	female	4	82.5	7160	4330	60.47	923.0	1087.0
35	1508	2247	charbroil*	Huron	ch. salmon	off	off	male	.	82.0	6310	4260	67.51	1063.0	1060.0
36	5821	3897	charbroil*	Huron	ch. salmon	off	off	female	5	89.0	7700	4540	58.96	1119.0	1281.0
37	1796	8580	can	Huron	ch. salmon	off	off	female	4	80.0	5560	3120	56.12	740.0	782.0

	AP yield (%)	wt. before cooking (gm)	actual fillet wt. (gm)	edible wt. (gm)	% cooking loss in fillet	% cooking yield in fillet	% solids in raw fillet	% solids in cooked fillet	% fat in raw fillet	% fat in cooked fillet	tri-cbs,ppm in wet wt. (raw fillet)	tri-cbs,ppm in dry wt. (raw fillet)	tri-cbs,ug in fillet (raw fillet)
1	35.16	559.70	451.27	412.64	19.37	73.73	23.47	28.05	2.25	2.30	0.012	0.051	6.752
2	35.51	640.22	476.13	448.20	25.63	70.01	24.38	29.96	.	.	0.034	0.137	21.459
3	40.07	474.37	380.40	352.08	19.81	74.22	24.95	29.74	.	.	0.044	0.176	20.793
4	40.18	486.70	420.40	388.60	13.62	79.84	28.30	31.23	.	.	0.025	0.09	12.357
5	40.75	527.99	428.18	382.93	18.90	72.53	27.81	35.47	4.75	6.65	0.011	0.04	5.892
6	38.40	671.53	465.88	422.02	30.62	62.84	27.21	32.52	6.10	6.35	0.034	0.126	22.978
7	25.88	416.66	316.77	316.77	23.97	76.03	21.69	28.90	1.30	2.25	0.004	0.016	1.471
8	29.29	437.61	340.80	340.80	22.12	77.88	25.03	34.21	.	.	0.023	0.09	9.869
9	26.50	268.15	208.49	208.49	22.25	77.75	25.09	33.29	.	.	0.007	0.027	1.802
10	26.99	253.11	168.11	168.11	33.58	66.42	24.63	38.88	2.30	2.90	0.04	0.16	10
11	29.33	392.56	305.59	305.59	22.15	77.85	23.05	30.25	2.00	3.30	0.061	0.266	24.058
12	28.22	489.98	404.80	404.80	17.38	82.62	21.92	27.36	.	.	0.055	0.251	26.914
13	35.16	517.60	395.10	356.75	23.67	68.92	23.47	31.82	.	.	0.01	0.043	5.257
14	35.51	518.00	364.16	331.05	29.70	63.91	23.49	32.69	.	.	0.009	0.037	4.542
15	40.07	605.35	460.22	420.62	23.97	69.48	25.39	31.45	.	.	0.013	0.051	7.893
16	40.18	483.99	337.65	306.65	30.24	63.36	26.18	35.84	4.70	6.80	0.024	0.09	11.422
17	40.75	612.52	424.70	377.58	30.66	61.64	28.13	39.23	5.80	6.65	0.018	0.065	11.151
18	38.40	601.11	445.00	384.25	25.97	63.92	25.29	32.73	3.90	3.65	0.024	0.093	14.188
19	25.88	383.25	268.58	268.58	29.92	70.08	21.34	30.56	.	.	0.008	0.035	2.887
20	29.29	326.60	225.00	225.00	31.11	68.89	24.54	34.08	.	.	0.011	0.045	3.637
21	26.50	244.00	168.26	168.26	31.04	68.96	25.24	35.20	.	.	.	.	.
22	26.99	284.64	211.47	211.47	25.71	74.29	23.38	32.86	2.15	3.00	0.01	0.042	2.793
23	29.33	314.10	217.82	217.82	30.65	69.35	23.52	35.39	2.20	4.00	0.011	0.048	3.539
24	28.22	425.08	342.84	342.84	19.35	80.65	21.99	27.13	1.75	2.55	0.006	0.027	2.553
25	43.72	616.68	394.48	348.40	36.03	56.50	23.84	32.98	.	.	0.011	0.046	6.799
26	39.15	715.15	417.71	338.95	41.59	47.40	24.60	34.13	.	.	0.046	0.187	32.83
27	41.37	634.10	406.10	334.08	35.96	52.69	26.11	41.13	3.75	6.65	0.046	0.176	29.11
28	36.71	512.28	402.30	344.38	21.47	67.22	24.22	29.21	.	.	0.024	0.1	12.413
29	43.16	906.13	549.80	495.33	39.32	54.66	25.77	38.17	3.05	4.45	0.012	0.048	11.125
30	37.58	405.77	257.45	198.83	36.55	49.00	24.74	34.50	3.20	4.60	0.024	0.097	9.728
31	27.84	378.52	269.00	269.00	28.93	71.07	26.23	35.52	.	.	0.018	0.07	6.985
32	28.35	268.70	205.00	205.00	23.71	76.29	24.43	30.86	2.93	4.10	0.007	0.028	1.836
33	25.88	264.11	169.40	169.40	35.86	64.14	24.83	38.12	.	.	0.025	0.101	6.612
34	28.07	273.81	193.49	193.49	29.33	70.67	22.81	31.57	1.40	3.00	0.009	0.042	2.593
35	33.65	330.27	238.84	238.84	27.68	72.32	28.30	37.41	.	.	0.02	0.069	6.442
36	31.17	343.81	249.67	249.67	27.38	72.62	22.52	30.28	1.40	1.68	0.009	0.041	3.167
37	27.37	303.91	229.27	229.27	24.56	75.44	21.29	27.05	1.20	1.20	0.007	0.032	2.056

	tetra-cbs,ppm	tetra-cbs,ppm	tetra-cbs,ug	penta-cbs,ppm	penta-cbs,ppm	penta-cbs,ug	hexa-cbs,ppm	hexa-cbs,ppm	hexa-cbs,ug	hepta-cbs,ppm
	in wet wt.	in dry wt.	in wet wt.	in wet wt.	in dry wt.	in wet wt.	in wet wt.	in dry wt.	in wet wt.	in wet wt.
	(raw fillet)	(raw fillet)	(raw fillet)	(raw fillet)	(raw fillet)	(raw fillet)	(raw fillet)	(raw fillet)	(raw fillet)	(raw fillet)
1	0.211	0.898	117.915	0.744	3.170	416.38	0.377	1.605	210.895	0.137
2	0.23	0.942	147.006	1.049	4.301	671.34	0.476	1.954	305.004	0.199
3	0.267	1.072	126.856	0.786	3.149	372.64	0.395	1.584	187.493	0.131
4	0.496	1.754	241.636	1.437	5.079	699.6	0.553	1.956	269.387	0.179
5	0.252	0.908	133.294	1.402	5.042	740.36	0.556	2	293.706	0.24
6	0.715	2.627	480.057	1.696	6.233	1138.9	0.496	1.822	332.954	0.168
7	0.112	0.518	46.837	0.474	2.187	197.65	0.346	1.595	144.134	0.14
8	0.421	1.68	184.025	0.854	3.413	373.85	0.644	2.573	281.844	0.166
9	0.203	0.806	54.361	0.516	2.055	138.24	0.294	1.17	78.748	0.063
10	0.263	1.07	66.682	0.671	2.722	169.72	0.239	0.972	60.607	0.078
11	0.331	1.438	130.109	1.158	5.025	454.65	0.462	2.004	181.318	0.151
12	0.31	1.414	151.911	0.994	4.536	487.22	0.394	1.799	193.218	0.128
13	0.188	0.801	97.316	0.607	2.586	314.09	0.361	1.538	186.788	0.101
14	0.147	0.626	76.222	0.665	2.832	344.54	0.361	1.535	186.802	0.126
15	0.23	0.905	139.14	0.672	2.645	406.56	0.396	1.558	239.504	0.109
16	0.404	1.544	195.667	1.165	4.45	563.81	0.874	3.34	423.197	0.555
17	0.381	1.356	233.6	1.741	6.189	1066.4	0.631	2.243	386.558	0.177
18	0.43	1.7	258.428	0.907	3.585	544.97	0.473	1.869	284.175	0.124
19	0.15	0.703	57.529	0.472	2.212	180.88	0.448	2.099	171.672	1.213
20	0.232	0.945	75.774	0.543	2.211	177.24	0.339	1.382	110.763	0.094
21										
22	0.21	0.896	59.637	0.634	2.713	180.57	0.409	1.751	116.506	0.117
23	0.235	0.999	73.783	0.674	2.864	211.59	0.397	1.69	124.839	0.105
24	0.104	0.474	44.331	0.413	1.878	175.55	0.271	1.231	115.07	0.204
25	0.23	0.965	141.906	0.935	3.92	576.33	0.371	1.556	228.734	0.134
26	0.25	1.016	178.756	0.77	3.128	550.31	0.569	2.314	407.032	0.575
27	0.25	0.957	158.497	0.77	2.947	487.94	0.569	2.18	360.902	0.575
28	0.52	2.148	266.48	1.174	4.848	601.49	0.424	1.752	217.413	0.151
29	0.208	0.809	188.886	0.792	3.073	717.67	0.316	1.226	286.266	0.112
30	0.509	2.057	206.512	1.154	4.663	468.09	0.376	1.52	152.615	0.11
31	0.292	1.112	110.447	0.912	3.476	345.14	0.604	2.302	228.548	0.285
32	0.146	0.597	39.166	0.623	2.552	167.53	0.412	1.685	110.637	0.164
33	0.432	1.74	114.139	1.167	4.7	308.23	0.636	2.561	167.944	0.301
34	0.138	0.606	37.857	0.61	2.675	167.05	0.436	1.911	119.351	0.199
35	0.369	1.303	121.788	0.927	3.274	306.06	0.582	2.057	192.229	0.136
36	0.083	0.37	28.635	0.525	2.331	180.5	0.209	0.929	71.944	0.097
37	0.148	0.695	44.972	0.568	2.669	172.66	0.388	1.823	117.958	0.176

	hepta-cbs,ppm in dry wt. (raw fillet)	hepta-cbs,ug in wet wt. (raw fillet)	octa-cbs,ppm in wet wt. (raw fillet)	octa-cbs,ppm in dry wt. (raw fillet)	octa-cbs,ug in wet wt. (raw fillet)	total-cbs, ppm in wet wt. (raw fillet)	total-cbs, ppm in dry wt. (raw fillet)	total-cbs, ug in wet wt. (raw fillet)	tri-cbs, ppm in wet wt. (cooked fillet)	tri-cbs, ppm in dry wt. (cooked fillet)
1	0.585	76.911	0.038	0.163	21.361	1.519	6.472	850.218	0.029	0.103
2	0.815	127.266	0.055	0.224	34.941	2.042	8.374	1307.02	0.027	0.09
3	0.527	62.327	0.027	0.109	12.946	1.651	6.616	783.059	0.041	0.139
4	0.633	87.225	0.072	0.253	34.817	2.764	9.765	1345.025	0.074	0.238
5	0.864	126.849	0.113	0.406	59.661	2.575	9.261	1359.762	0.016	0.045
6	0.616	112.601	0.062	0.229	41.834	3.171	11.654	2129.373	0.034	0.104
7	0.644	58.156	0.052	0.239	21.59	1.128	5.199	469.832	0.007	0.025
8	0.664	72.771	0.067	0.267	29.233	2.175	8.688	951.589	0.015	0.044
9	0.333	22.386	0.043	0.172	11.6	1.145	4.565	307.133	0.011	0.033
10	0.315	19.662	0.02	0.082	5.108	1.311	5.322	331.779	0.038	0.098
11	0.656	59.366	0.051	0.219	19.84	2.215	9.608	869.344	0.032	0.106
12	0.586	62.928	0.039	0.179	19.269	1.921	8.766	941.458	0.032	0.119
13	0.43	52.271	0.04	0.169	20.488	1.306	5.566	676.214	0.011	0.035
14	0.538	65.429	0.047	0.2	24.358	1.355	5.768	701.896	0.011	0.044
15	0.427	65.701	0.03	0.117	17.95	1.448	5.704	876.744	0.035	0.125
16	2.119	268.465	0.088	0.337	42.695	3.11	11.88	1505.255	0.019	0.062
17	0.63	108.614	0.086	0.305	52.518	3.035	10.788	1858.82	0.014	0.042
18	0.489	74.289	0.042	0.168	25.501	1.999	7.904	1201.554	0.024	0.076
19	5.684	464.852	0.218	1.022	83.604	2.509	11.755	961.423	0.006	0.02
20	0.381	30.551	0.039	0.157	12.593	1.257	5.123	410.557	0.008	0.025
21	.	.	.	.	.	.	.	.	.	
22	0.499	33.234	0.044	0.19	12.665	1.424	6.092	405.401	0.01	0.03
23	0.448	33.081	0.041	0.173	12.753	1.463	6.221	459.579	0.018	0.05
24	0.93	86.891	0.034	0.156	14.595	1.033	4.696	438.99	0.009	0.032
25	0.56	82.341	0.058	0.244	35.888	1.738	7.292	1072.003	0.015	0.044
26	2.338	411.279	0	0	0	2.21	8.982	1580.208	0.016	0.046
27	2.203	364.668	0	0	0	2.21	8.463	1401.118	0.016	0.038
28	0.625	77.559	0.056	0.232	28.761	2.351	9.705	1204.116	0.023	0.078
29	0.433	101.177	0.075	0.291	68.065	1.515	5.881	1373.189	0.009	0.022
30	0.447	44.828	0.036	0.145	14.579	2.209	8.929	896.354	0.022	0.064
31	1.087	107.937	0.062	0.237	23.527	2.173	8.285	822.587	0.015	0.041
32	0.67	43.988	0.041	0.168	10.998	1.392	5.7	374.151	0.014	0.044
33	1.214	79.597	0.096	0.387	25.384	2.658	10.703	701.905	0.014	0.036
34	0.871	54.424	0.073	0.322	20.112	1.468	6.427	401.39	0	0
35	0.481	44.99	0.053	0.188	17.609	2.087	7.373	689.113	0.023	0.061
36	0.431	33.351	0.029	0.127	9.863	0.952	4.229	327.461	0.005	0.016
37	0.825	53.351	0.038	0.18	11.667	1.325	6.223	402.667	0.007	0.025

	tri-cbs, ug in wet wt. (cooked fillet)	tri-cbs % change (cooked fillet)	tetra-cbs, ppm in wet wt. (cooked fillet)	tetra-cbs, ppm in dry wt. (cooked fillet)	tetra-cbs, ug in wet wt. (cooked fillet)	tetra-cbs % change (cooked fillet)	penta-cbs, ppm in wet wt. (cooked fillet)	penta-cbs, ppm in dry wt. (cooked fillet)	penta-cbs, ug in wet wt. (cooked fillet)	penta-cbs % change (cooked fillet)
1	13.056	-93.36	0.172	0.613	77.548	34.23	0.642	2.29	289.91	30.37
2	12.843	40.15	0.165	0.55	78.49	46.61	0.809	2.701	385.29	42.61
3	15.742	24.29	0.24	0.806	91.395	27.95	0.649	2.183	246.92	33.74
4	31.235	-152.78	0.452	1.448	190.172	21.3	1.249	3.999	525.01	24.96
5	6.812	-15.61	0.314	0.884	134.243	-0.71	1.068	3.012	457.41	38.22
6	15.783	31.31	0.703	2.161	327.443	31.79	1.533	4.713	714.11	37.3
7	2.305	-56.74	0.078	0.27	24.688	47.29	0.448	1.55	141.92	28.19
8	5.134	47.98	0.26	0.76	88.663	51.82	0.658	1.923	224.19	40.03
9	2.275	-26.25	0.185	0.556	38.603	28.99	0.575	1.728	119.9	13.26
10	6.405	35.95	0.217	0.559	36.515	45.24	0.649	1.668	109.04	35.76
11	9.842	59.09	0.209	0.69	63.827	50.94	0.609	2.012	186.01	59.09
12	13.151	51.14	0.234	0.855	94.725	37.64	0.522	1.908	211.29	56.63
13	4.224	19.66	0.195	0.64	77.142	20.73	0.673	2.205	265.99	15.31
14	3.944	13.16	0.207	0.843	75.308	1.2	0.74	3.016	269.38	21.82
15	16.333	-106.94	0.213	0.75	98.193	29.43	0.642	2.256	295.46	27.33
16	6.251	45.27	0.333	1.111	112.512	42.5	0.843	2.811	284.53	49.53
17	5.849	47.54	0.254	0.767	107.761	53.87	0.728	2.2	309.25	71
18	10.473	26.18	0.455	1.465	202.607	21.6	0.934	3.005	415.66	23.73
19	1.634	43.41	0.12	0.394	32.311	43.84	0.506	1.655	135.8	24.92
20	1.899	47.78	0.175	0.514	39.408	47.99	0.469	1.375	105.43	40.51
21	.	.	.	.	.	.	.	.	.	.
22	2.056	26.39	0.213	0.649	45.083	24.4	0.649	1.976	137.34	23.94
23	3.832	-8.29	0.255	0.722	55.618	24.62	0.673	1.903	146.68	30.68
24	2.999	-17.47	0.158	0.582	54.137	-22.12	0.445	1.64	152.58	13.09
25	5.774	15.07	0.212	0.643	83.595	41.09	0.556	1.686	219.32	61.95
26	6.589	79.93	0.329	0.963	137.289	23.2	0.782	2.29	326.45	40.68
27	6.406	77.99	0.329	0.799	133.473	15.79	0.782	1.9	317.38	34.96
28	9.21	25.81	0.486	1.664	195.538	26.62	0.945	3.234	380.04	36.82
29	4.699	57.76	0.123	0.322	67.516	64.26	0.532	1.395	292.66	59.22
30	5.672	41.7	0.478	1.386	123.079	40.4	1.049	3.041	270.07	42.31
31	3.91	44.02	0.193	0.542	51.807	53.09	0.83	2.337	223.3	35.3
32	2.811	-53.08	0.182	0.591	37.363	4.6	0.438	1.419	89.77	46.41
33	2.344	64.55	0.24	0.631	40.718	64.33	0.601	1.576	101.78	66.98
34	0	100	0.051	0.162	9.91	73.82	0.229	0.725	44.26	73.51
35	5.407	16.07	0.373	0.997	89.125	26.82	1.007	2.692	240.56	21.4
36	1.176	62.85	0.086	0.285	21.547	24.75	0.312	1.03	77.86	56.87
37	1.539	25.12	0.199	0.734	45.544	-1.27	0.605	2.237	138.73	19.65

	hexa-cbs, ppm in wet wt. (cooked fillet)	hexa-cbs, ppm in dry wt. (cooked fillet)	hexa-cbs, ug in wet wt. (cooked fillet)	hexa-cbs % change (cooked fillet)	hepta-cbs, ppm in wet wt. (cooked fillet)	hepta-cbs, ppm in dry wt. (cooked fillet)	hepta-cbs, ug in wet wt. (cooked fillet)	hepta-cbs % change (cooked fillet)	octa-cbs, ppm in wet wt. (cooked fillet)	octal-cbs, ppm in dry wt. (cooked fillet)
1	0.333	1.186	150.139	28.81	0.131	0.466	58.944	23.36	0.039	0.139
2	0.377	1.257	179.293	41.22	0.151	0.505	72.041	43.39	0.044	0.146
3	0.32	1.075	121.59	35.15	0.109	0.365	41.346	33.66	0.024	0.08
4	0.491	1.572	206.337	23.4	0.169	0.54	70.861	18.76	0.064	0.205
5	0.347	0.978	148.544	49.42	0.148	0.417	63.373	50.04	0.065	0.183
6	0.457	1.406	213.09	36	0.165	0.508	76.913	31.69	0.057	0.177
7	0.24	0.831	76.036	47.25	0.062	0.216	19.733	66.07	0.034	0.119
8	0.383	1.119	130.46	53.71	0.105	0.308	35.876	50.7	0.045	0.131
9	0.334	1.004	69.68	11.52	0.109	0.326	22.655	-1.2	0.048	0.144
10	0.268	0.689	45.049	25.67	0.09	0.232	15.137	23.01	0.027	0.069
11	0.24	0.795	73.494	59.47	0.082	0.273	25.202	57.55	0.024	0.079
12	0.178	0.651	72.137	62.67	0.058	0.211	23.316	62.95	0.019	0.07
13	0.431	1.413	170.419	8.76	0.156	0.511	61.686	-18.01	0.063	0.206
14	0.446	1.819	162.528	12.99	0.143	0.581	51.934	20.62	0.052	0.214
15	0.347	1.221	159.897	33.24	0.114	0.399	52.277	20.43	0.031	0.108
16	0.528	1.761	178.258	57.88	0.423	1.41	142.753	46.83	0.064	0.213
17	0.456	1.377	193.556	49.93	0.24	0.724	101.722	6.35	0.056	0.171
18	0.478	1.538	212.707	25.15	0.12	0.386	53.332	28.21	0.045	0.144
19	0.331	1.082	88.774	48.29	0.097	0.318	26.091	94.39	0.046	0.15
20	0.303	0.889	68.163	38.46	0.381	0.304	23.307	23.71	0.034	0.099
21	.	.	.	.	.	.	.	.	.	
22	0.43	1.309	90.965	21.92	0.121	0.369	25.66	22.79	0.069	0.209
23	0.406	1.148	88.521	29.09	0.119	0.337	25.964	21.51	0.04	0.113
24	0.284	1.046	97.253	15.48	0.082	0.302	28.061	67.71	0.034	0.126
25	0.264	0.8	104.033	54.52	0.089	0.269	35.009	57.48	0.033	0.099
26	0.344	1.007	143.619	64.72	0.124	0.365	51.967	87.36	0.034	0.099
27	0.344	0.836	139.627	61.31	0.124	0.302	50.522	86.15	0.034	0.082
28	0.457	1.564	183.747	15.48	0.196	0.67	78.789	-1.59	0.046	0.158
29	0.212	0.555	116.473	59.31	0.062	0.163	34.134	66.26	0.033	0.087
30	0.347	1.007	89.447	41.39	0.102	0.296	26.335	41.25	0.032	0.094
31	0.57	1.604	153.252	32.95	0.239	0.672	64.168	40.55	0.064	0.18
32	0.256	0.83	52.531	52.52	0.115	0.371	23.497	46.58	0.038	0.124
33	0.319	0.837	54.055	67.81	0.147	0.386	24.942	68.67	0.041	0.108
34	0.174	0.553	33.76	71.71	0.053	0.168	10.268	81.13	0.031	0.098
35	0.654	1.749	156.27	18.71	0.16	0.429	38.326	14.81	0.069	0.183
36	0.225	0.744	56.277	21.78	0.059	0.196	14.788	55.66	0.032	0.104
37	0.401	1.482	91.896	22.09	0.174	0.643	39.906	25.2	0.04	0.147

	octa-cbs, ug	octa-cbs	total-cbs, ppm	total-cbs, ppm	total-cbs, ug	total-cbs
	in wet wt.	% change	in wet wt.	in dry wt.	in wet wt.	% change
	(cooked fillet)	(cooked fillet)	(cooked fillet)	(cooked fillet)	(cooked fillet)	(cooked fillet)
1	17.579	17.71	1.345	4.797	607.174	28.59
2	20.879	40.25	1.573	5.25	748.839	42.71
3	9.013	30.38	1.383	4.65	526.002	32.83
4	26.934	22.64	2.499	8.002	1050.546	21.89
5	27.759	53.47	1.957	5.519	838.139	38.36
6	26.764	36.02	2.949	9.07	1374.1	35.47
7	10.896	49.53	0.87	3.01	275.581	41.34
8	15.223	47.93	1.466	4.285	499.541	47.5
9	10.029	13.55	1.262	3.791	263.144	14.32
10	4.513	11.64	1.289	3.315	216.656	34.7
11	7.293	63.24	1.197	3.956	365.667	57.94
12	7.77	59.68	1.043	3.814	422.392	55.13
13	24.822	-21.16	1.529	5.01	604.288	10.64
14	19.092	21.62	1.599	6.517	582.185	17.06
15	14.11	21.39	1.383	4.858	636.266	27.43
16	21.577	49.46	2.209	7.368	745.881	50.45
17	23.97	54.36	1.747	5.279	742.109	60.08
18	19.88	22.04	2.055	6.613	914.654	23.88
19	12.308	85.28	1.106	3.617	296.915	69.12
20	7.577	39.83	1.092	3.205	245.788	40.13
21						
22	14.501	-14.5	1.492	4.542	315.606	22.15
23	8.702	31.77	1.512	4.272	329.313	28.34
24	11.729	19.64	1.011	3.728	346.755	21.01
25	12.918	64	1.168	3.541	460.652	57.03
26	14.081		1.628	4.77	679.999	56.97
27	13.689		1.628	3.958	661.099	52.82
28	18.588	35.37	2.152	7.369	865.911	28.09
29	18.257	73.18	0.971	2.543	533.741	61.13
30	8.335	42.83	2.031	5.888	522.933	41.66
31	17.192	26.93	1.909	5.376	513.632	37.56
32	7.835	28.76	1.043	3.38	213.811	42.85
33	6.97	72.54	1.362	3.574	230.807	67.12
34	5.985	70.24	0.538	1.706	104.183	74.04
35	16.371	7.03	2.286	6.111	546.06	20.76
36	7.866	20.25	0.719	2.374	179.51	45.18
37	9.09	22.09	1.425	5.268	326.705	18.86

Appendix 2. Physical and chemical parameters of chinook salmon harvested from Great Lakes

	fish ID (raw)	fish ID (cooked)	cooking methods	lakes	specie	skin (raw)	skin (cooked)	sex	age	length (cm)	whole wt. (gm)	degutted wt. (gm)	carcus (%)	right fillet wt. (gm)	left fillet wt. (gm)
38	8461	4548	can	Huron	ch. salmon	off	off	male	3	80.0	5100	3440	67.45	840.0	828.0
39	9487	2088	can	Huron	ch. salmon	off	off	female	5	91.5	6500	3440	52.92	741.0	719.0
40	3058	9329	can	Huron	ch. salmon	off	off	male	4	75.0	4130	2710	65.62	584.0	588.0
41	9242	3984	can	Huron	ch. salmon	off	off	male	4	85.0	5430	3410	62.80	752.0	733.0
42	6302	6240	can	Huron	ch. salmon	off	off	male	4	85.0	5370	3460	64.43	844.0	856.0
43	4080	3297	bake	Michigan	ch. salmon	on	off	female	2	68.5	3050	2120	69.51	728.3	792.2
44	6416	8187	bake	Michigan	ch. salmon	on	off	male	2	68.8	3005	2020	67.22	730.8	691.6
45	3651	6645	bake	Michigan	ch. salmon	on	off	female	2	67.2	2720	1880	69.12	654.7	644.3
46	2211	7703	bake	Michigan	ch. salmon	on	off	male	.	74.9	6538	4250	65.00	1688.9	1498.5
47	5847	5043	bake	Michigan	ch. salmon	on	off	female	.	76.8	6215	4040	65.00	1358.9	1576.9
48	9951	3953	bake	Michigan	ch. salmon	on	off	female	.	88.3	8415	5470	65.00	2101.7	1903.8
49	4896	9686	bake	Michigan	ch. salmon	off	off	male	3	75.9	4400	2840	64.55	804.3	649.8
50	5727	2226	bake	Michigan	ch. salmon	off	off	female	3	72.4	3900	2510	64.36	713.3	698.3
51	8054	2116	bake	Michigan	ch. salmon	off	off	female	3	73.7	3870	2660	68.73	701.1	691.5
52	4677	8917	bake	Michigan	ch. salmon	off	off	male	3	76.2	4030	2690	66.75	701.1	614.0
53	9934	6029	bake	Michigan	ch. salmon	off	off	female	2	67.0	3050	2050	67.21	514.2	529.5
54	1723	7422	bake	Michigan	ch. salmon	off	off	male	2	68.0	3600	2550	70.83	711.4	647.1
55	9854	9208	charbroil	Michigan	ch. salmon	on	off	female	2	68.5	3050	2120	69.51	728.3	792.2
56	8235	4114	charbroil	Michigan	ch. salmon	on	off	male	2	68.8	3005	2020	67.22	730.8	691.6
57	6168	1106	charbroil	Michigan	ch. salmon	on	off	female	2	67.2	2720	1880	69.12	654.7	644.3
58	4225	3069	charbroil	Michigan	ch. salmon	on	off	male	.	74.9	6538	4250	65.00	1688.9	1498.5
59	2104	8944	charbroil	Michigan	ch. salmon	on	off	female	.	76.8	6215	4040	65.00	1358.9	1576.9
60	5689	5383	charbroil	Michigan	ch. salmon	on	off	female	.	88.3	8415	5470	65.00	2101.7	1903.8
61	8362	6674	charbroil	Michigan	ch. salmon	off	off	male	3	75.9	4400	2840	64.55	804.3	649.8
62	4014	5643	charbroil	Michigan	ch. salmon	off	off	female	3	72.4	3900	2510	64.36	713.3	698.3
63	2276	8753	charbroil	Michigan	ch. salmon	off	off	female	3	73.7	3870	2660	68.73	701.1	691.5
64	9436	9232	charbroil	Michigan	ch. salmon	off	off	male	3	76.2	4030	2690	66.75	701.1	614.0
65	3701	9090	charbroil	Michigan	ch. salmon	off	off	female	2	67.0	3050	2050	67.21	514.2	529.5
66	3992	5403	charbroil	Michigan	ch. salmon	off	off	male	2	68.0	3600	2550	70.83	711.4	647.1
67	1540	4342	charbroil*	Michigan	ch. salmon	on	off	female	.	83.8	6110	4300	70.38	1426.6	1585.5
68	7103	4847	charbroil*	Michigan	ch. salmon	on	off	female	3	78.7	5810	3890	66.95	1400.2	1450.0
69	8295	3179	charbroil*	Michigan	ch. salmon	on	off	male	3	76.2	4080	2650	64.95	764.1	957.8
70	4155	7289	charbroil*	Michigan	ch. salmon	on	off	male	3	83.8	5920	4050	68.41	1383.5	1477.8
71	8057	1390	charbroil*	Michigan	ch. salmon	on	off	male	3	69.0	3401	1996	58.69	652.1	614.2
72	8654	7313	charbroil*	Michigan	ch. salmon	on	off	male	4	79.0	7040	4550	64.63	991.2	1010.9
73	4988	1208	charbroil*	Michigan	ch. salmon	off	off	male	3	82.0	5650	3870	68.50	996.4	1110.8
74	4072	4241	charbroil*	Michigan	ch. salmon	off	off	female	3	74.2	4200	2750	65.48	742.6	814.2

	AP yield (%)	wt. before cooking (gm)	actual fillet wt. (gm)	edible wt. (gm)	% cooking loss in fillet	% cooking yield in fillet	% solids in raw fillet	% solids in cooked fillet	% fat in raw fillet	% fat in cooked fillet	tri-cbs,ppm in wet wt. (raw fillet)	tri-cbs,ppm in dry wt. (raw fillet)	tri-cbs,ug in fillet (raw fillet)
38	32.71	355.49	248.78	248.78	30.02	69.98	23.13	30.50	1.95	2.50	0.011	0.046	3.784
39	22.46	369.20	246.10	246.10	33.34	66.66	15.99	21.23	.	.	0.014	0.067	5.111
40	28.38	297.53	227.94	227.94	23.39	76.61	22.35	28.57	.	.	0.023	0.101	6.748
41	27.35	372.29	271.83	271.83	26.98	73.02	20.17	26.04	.	.	0.026	0.127	9.525
42	31.66	338.87	261.68	261.68	22.78	77.22	23.50	31.12	1.30	1.70	0.023	0.096	7.665
43	49.85	358.14	294.56	271.87	17.75	75.91	28.68	32.24	.	.	0.014	0.048	4.949
44	47.33	377.39	292.95	277.19	22.37	73.45	26.34	30.78	.	.	0.017	0.063	6.288
45	47.76	312.26	243.82	227.69	21.92	72.92	26.74	31.01	8.40	8.30	0.016	0.058	4.855
46	48.75	672.24	554.72	525.53	17.48	78.18	29.42	37.91	16.90	15.10	0.031	0.106	20.884
47	47.24	748.83	607.44	582.02	18.88	77.72	31.22	35.04	12.10	12.20	0.023	0.075	7.487
48	47.60	1052.89	844.10	819.94	19.83	77.88	28.83	40.58	.	.	0.029	0.099	30.102
49	33.05	315.51	262.32	262.32	16.86	83.14	26.09	27.56	.	.	0.012	0.046	3.765
50	36.19	401.46	321.28	321.28	19.97	80.03	22.81	36.07	.	.	0.016	0.068	6.253
51	35.98	307.93	223.50	223.50	27.42	72.58	24.32	34.60	.	.	0.016	0.064	4.83
52	32.63	320.94	237.13	237.13	26.11	73.89	26.56	30.46	3.95	4.45	0.014	0.052	4.468
53	34.22	204.17	170.10	170.10	16.69	83.31	26.05	29.53	6.40	4.15	0.02	0.075	3.996
54	37.74	366.42	294.84	294.84	19.53	80.47	26.24	34.22	4.80	6.65	0.022	0.084	8.118
55	49.85	429.42	311.63	291.33	27.43	67.84	30.53	42.36	.	.	0.033	0.107	14.035
56	47.33	311.48	213.74	198.73	31.38	63.80	24.53	35.57	6.80	7.10	0.019	0.078	5.959
57	47.76	327.10	234.61	218.23	28.28	66.72	28.46	35.18	.	.	0.032	0.114	10.623
58	48.75	820.12	572.85	546.43	30.15	66.63	29.98	38.40	.	.	0.033	0.109	26.716
59	47.24	820.44	575.56	550.71	29.85	67.12	33.10	34.41	14.50	9.10	0.028	0.084	22.8
60	47.60	1040.55	742.95	706.05	28.60	67.85	31.08	37.81	13.90	12.70	0.029	0.094	30.479
61	33.05	325.87	249.95	249.95	23.30	76.70	24.26	30.99	5.20	6.75	0	0	0
62	36.19	293.28	216.16	216.16	26.30	73.70	23.85	33.75	.	.	0	0	0
63	35.98	379.49	277.70	277.70	26.82	73.18	26.54	34.13	7.90	9.20	0	0	0
64	32.63	288.56	214.56	214.56	25.64	74.36	27.31	29.64	.	.	0.016	0.057	4.505
65	34.22	322.16	265.22	265.22	17.67	82.33	28.13	33.23	8.65	7.40	0.017	0.06	5.437
66	37.74	276.76	205.59	205.59	25.72	74.28	26.67	35.42	.	.	0.019	0.073	5.378
67	49.30	755.22	552.35	516.07	26.86	68.33	26.71	33.81	11.60	11.30	0.077	0.287	57.816
68	49.06	586.08	435.96	395.73	25.61	67.52	27.56	32.19	12.00	7.80	0.092	0.333	53.773
69	42.20	511.42	402.82	382.18	21.23	74.73	23.91	27.55	.	.	0.043	0.178	21.784
70	48.33	729.93	513.46	475.18	29.65	65.10	26.98	31.81	8.50	8.20	0.056	0.208	40.95
71	37.23	342.70	238.88	222.06	30.29	64.80	26.30	35.65	.	.	0.076	0.288	25.99
72	28.44	381.25	302.13	280.73	20.75	73.63	27.16	33.56	.	.	0.071	0.26	26.968
73	37.30	582.74	402.22	402.22	30.98	69.02	27.36	39.35	.	.	0.091	0.332	52.94
74	37.07	401.85	290.70	290.70	27.66	72.34	24.52	34.30	4.00	6.15	0.059	0.243	23.725

	tetra-cbs,ppm in wet wt. (raw fillet)	tetra-cbs,ppm in dry wt. (raw fillet)	tetra-cbs,ug in wet wt. (raw fillet)	penta-cbs,ppm in wet wt. (raw fillet)	penta-cbs,ppm in dry wt. (raw fillet)	penta-cbs,ug in wet wt. (raw fillet)	hexa-cbs,ppm in wet wt. (raw fillet)	hexa-cbs,ppm in dry wt. (raw fillet)	hexa-cbs,ug in wet wt. (raw fillet)	hepta-cbs,ppm in wet wt. (raw fillet)
38	0.107	0.464	38.16	0.311	1.343	110.42	0.194	0.838	68.943	0.095
39	0.115	0.722	42.597	0.556	3.476	205.23	0.376	2.353	138.883	0.121
40	0.112	0.501	33.309	0.38	1.7	113.03	0.203	0.909	60.436	0.063
41	0.144	0.716	53.763	0.663	3.286	246.75	0.423	2.1	157.661	0.133
42	0.128	0.545	43.382	0.484	2.058	163.89	0.276	1.176	93.644	0.09
43	0.255	0.89	91.451	0.861	3.003	308.46	0.518	1.807	185.642	0.292
44	0.354	1.346	133.778	0.891	3.383	336.3	0.502	1.907	189.55	0.211
45	0.383	1.433	119.662	0.839	3.137	261.91	0.438	1.637	136.688	0.158
46	0.524	1.781	352.302	0.915	3.109	614.97	0.441	1.498	296.208	0.173
47	0.365	1.169	273.389	0.878	2.811	657.13	0.493	1.58	369.492	0.203
48	0.48	1.666	505.633	0.965	3.346	1015.6	0.507	1.76	534.163	0.202
49	0.154	0.591	48.615	0.508	1.946	160.15	0.334	1.28	105.354	0.093
50	0.284	1.245	114.03	0.553	2.424	221.95	0.298	1.309	119.831	0.076
51	0.279	1.149	86.057	0.625	2.568	192.33	0.358	1.471	110.181	0.16
52	0.19	0.717	61.13	0.568	2.138	182.21	0.295	1.111	94.669	0.092
53	0.163	0.626	33.269	0.449	1.725	91.73	0.28	1.074	57.137	0.082
54	0.218	0.831	79.942	0.665	2.536	243.8	0.358	1.365	131.199	0.11
55	0.681	2.23	292.302	1.591	5.213	683.38	0.275	0.902	118.22	0.227
56	0.388	1.582	120.878	1.319	5.378	410.9	0.125	0.509	38.871	0.187
57	0.678	2.381	221.624	1.508	5.299	493.25	0.141	0.496	46.193	0.213
58	0.708	2.361	580.475	1.353	4.512	1109.3	0.133	0.444	109.23	0.156
59	0.599	1.81	491.543	1.602	4.841	1314.5	0.171	0.516	140.087	0.185
60	0.629	2.024	654.552	1.375	4.424	1430.7	0.129	0.415	134.217	0.138
61	0.24	0.988	78.08	0.794	3.271	258.6	0.332	1.368	108.172	0.155
62	0.187	0.784	54.835	0.284	1.19	83.22	1.214	5.09	356.057	0.131
63	0.468	1.765	177.737	0.97	3.655	368.15	0.37	1.394	140.448	0.227
64	0.186	0.679	53.535	0.482	1.764	139.01	0.297	1.089	85.837	0.086
65	0.239	0.849	76.972	0.623	2.216	200.8	0.371	1.32	119.663	0.106
66	0.267	1	73.844	0.569	2.134	157.49	0.322	1.208	89.185	0.15
67	0.646	2.42	488.079	1.18	4.418	891.29	0.122	0.458	92.429	0.213
68	0.573	2.079	335.87	1.581	5.737	926.62	0.112	0.405	65.384	0.192
69	0.415	1.736	212.304	0.962	4.024	492.08	0.123	0.516	63.115	0.171
70	0.34	1.263	248.494	1.094	4.056	798.26	0.089	0.33	65.029	0.142
71	0.404	1.536	138.423	1.195	4.545	409.66	0.094	0.358	32.229	0.16
72	0.41	1.508	156.182	1.222	4.5	465.94	0.106	0.39	40.345	0.172
73	0.638	2.333	371.956	1.268	4.636	739.09	0.47	1.719	274.054	0.14
74	0.356	1.484	143.032	0.771	3.169	309.71	0.295	1.215	118.728	0.096

	hepta-cbs,ppm in dry wt. (raw fillet)	hepta-cbs,ug in wet wt. (raw fillet)	octa-cbs,ppm in wet wt. (raw fillet)	octa-cbs,ppm in dry wt. (raw fillet)	octa-cbs,ug in wet wt. (raw fillet)	total-cbs, ppm in wet wt. (raw fillet)	total-cbs, ppm in dry wt. (raw fillet)	total-cbs, ug in wet wt. (raw fillet)	tri-cbs, ppm in wet wt. (cooked fillet)	tri-cbs, ppm in dry wt. (cooked fillet)
38	0.412	33.852	0.02	0.087	7.179	0.738	3.191	262.34	0.012	0.04
39	0.756	44.658	0.063	0.396	23.376	1.246	7.789	459.852	0.002	0.011
40	0.261	18.705	0.017	0.074	4.915	0.797	3.566	237.147	0.021	0.075
41	0.661	49.618	0.029	0.145	10.872	1.419	7.034	528.189	0.021	0.082
42	0.363	30.539	0.022	0.093	7.399	1.023	4.351	346.516	0.021	0.066
43	1.018	104.56	0.057	0.2	20.501	1.998	6.967	715.562	0.015	0.048
44	0.802	79.704	0.045	0.172	17.108	2.021	7.673	762.724	0.013	0.042
45	0.593	49.492	0.032	0.12	10.003	1.866	6.978	582.61	0.017	0.055
46	0.587	116.055	0.035	0.12	23.811	2.119	7.201	1424.227	0.023	0.061
47	0.651	152.123	0.044	0.14	32.686	2.006	6.426	1502.302	0.023	0.065
48	0.699	212.179	0.041	0.143	43.353	2.223	7.712	2341.005	0.028	0.069
49	0.355	29.198	0.032	0.121	9.967	1.132	4.338	357.051	0.006	0.022
50	0.333	30.516	0.023	0.101	9.256	1.25	5.48	501.836	0.016	0.045
51	0.657	49.195	0.031	0.126	9.431	1.468	6.036	452.027	0.032	0.091
52	0.348	29.646	0.025	0.093	7.945	1.184	4.459	380.069	0.015	0.048
53	0.313	16.665	0.026	0.102	5.408	1.02	3.915	208.205	0.005	0.016
54	0.421	40.463	0.031	0.117	11.289	1.405	5.354	514.807	0.011	0.032
55	0.742	97.291	0.06	0.196	25.66	2.866	9.389	1230.891	0.03	0.071
56	0.762	58.184	0.045	0.183	13.987	2.083	8.491	648.774	0.017	0.048
57	0.748	69.656	0.038	0.133	12.379	2.61	9.171	853.728	0.028	0.081
58	0.519	127.532	0.031	0.102	25.154	2.412	8.046	1978.407	0.035	0.092
59	0.559	151.727	0.047	0.141	38.407	2.632	7.951	2159.103	0.019	0.055
60	0.443	143.253	0.038	0.122	39.583	2.338	7.522	2432.762	0.029	0.077
61	0.639	50.497	0.228	0.939	74.211	1.748	7.204	569.558	0	0
62	0.55	38.444	0.238	0.998	69.781	2.054	8.611	602.338	0	0
63	0.857	86.29	0.087	0.327	32.89	2.123	7.998	805.513	0.005	0.014
64	3.14	24.757	0.033	0.121	9.542	1.099	4.025	317.184	0.008	0.025
65	0.376	34.076	0.035	0.125	11.336	1.392	4.947	448.287	0.017	0.052
66	0.562	41.515	0.028	0.103	7.628	1.355	5.081	375.038	0.016	0.045
67	0.797	160.853	0.037	0.137	27.732	2.275	8.518	1718.199	0.055	0.161
68	0.698	112.721	0.05	0.18	29.019	2.599	9.431	1523.39	0.068	0.212
69	0.717	87.644	0.052	0.218	26.694	1.767	7.39	903.617	0.056	0.205
70	0.527	103.632	0.051	0.189	37.263	1.772	6.574	1293.622	0.075	0.237
71	0.608	54.792	0.052	0.199	17.929	1.981	7.534	679.022	0.065	0.183
72	0.633	65.509	0.056	0.205	21.215	2.036	7.496	776.163	0.077	0.229
73	0.513	81.829	0.053	0.192	30.604	2.661	9.725	1550.477	0.08	0.204
74	0.393	38.392	0.03	0.123	11.988	1.607	6.606	645.573	0.052	0.151

	tri-cbs, ug in wet wt. (cooked fillet)	tri-cbs % change (cooked fillet)	tetra-cbs, ppm in wet wt. (cooked fillet)	tetra-cbs, ppm in dry wt. (cooked fillet)	tetra-cbs, ug in wet wt. (cooked fillet)	tetra-cbs % change (cooked fillet)	penta-cbs, ppm in wet wt. (cooked fillet)	penta-cbs, ppm in dry wt. (cooked fillet)	penta-cbs, ug in wet wt. (cooked fillet)	penta-cbs % change (cooked fillet)
38	3.005	20.6	0.141	0.462	35.092	8.04	0.375	1.23	93.33	15.48
39	0.551	89.22	0.08	0.376	19.651	53.87	0.562	2.649	138.42	32.55
40	4.899	27.4	0.054	0.189	12.33	62.98	0.285	0.998	64.98	42.51
41	5.836	38.72	0.13	0.501	35.452	34.06	0.681	2.614	185.02	25.02
42	5.406	29.46	0.097	0.311	25.307	41.66	0.367	1.179	96	41.43
43	4.54	8.26	0.345	1.071	101.732	-11.24	0.839	2.602	247.11	19.89
44	3.806	39.47	0.204	0.663	59.819	55.28	0.864	2.806	253.03	24.76
45	4.192	13.65	0.379	1.221	92.355	22.82	0.879	2.835	214.37	18.15
46	12.86	38.42	0.465	1.228	258.213	26.71	0.848	2.237	470.49	23.49
47	13.94	20.28	0.376	1.072	228.205	16.53	0.898	2.563	545.56	16.98
48	23.514	21.89	0.428	1.055	361.435	28.52	0.957	2.359	808.01	20.44
49	1.563	58.48	0.086	0.314	22.683	53.34	0.297	1.076	77.78	51.43
50	5.157	17.53	0.25	0.693	80.263	29.61	0.388	1.075	124.56	43.88
51	7.056	-46.11	0.494	1.427	110.359	-28.24	0.573	1.657	128.11	33.39
52	3.487	21.96	0.203	0.665	48.046	21.4	0.5	1.641	118.51	34.96
53	0.787	80.31	0.108	0.367	18.433	44.59	0.324	1.097	55.09	39.94
54	3.247	60	0.146	0.426	42.961	46.26	0.408	1.191	120.15	50.72
55	9.378	33.18	0.641	1.513	199.708	31.68	1.48	3.495	461.37	32.49
56	3.614	39.36	0.268	0.754	57.321	52.58	1.223	3.438	261.41	36.38
57	6.646	37.44	0.544	1.548	127.743	42.36	1.491	4.237	349.72	29.1
58	20.2	24.39	0.611	1.592	350.157	39.68	1.185	3.085	678.58	38.83
59	10.971	51.88	0.392	1.14	225.708	54.08	0.945	2.747	543.99	58.62
60	21.718	28.74	0.629	1.663	467.086	28.64	1.34	3.543	995.23	30.44
61	0	0	0.436	1.408	109.064	-39.68	0.461	1.487	115.19	55.45
62	0	0	0.296	0.877	64.012	-16.74	0.724	2.145	156.46	-88.01
63	1.287		0.315	0.924	87.586	50.72	1.372	4.02	381.04	-3.5
64	1.614	64.17	0.141	0.477	30.316	43.37	0.335	1.13	71.89	48.29
65	4.578	15.81	0.247	0.742	65.38	15.06	0.565	1.701	149.87	25.37
66	3.26	39.39	0.165	0.465	33.858	54.15	0.481	1.359	98.94	37.18
67	30.108	47.92	0.451	1.335	249.29	48.92	1.229	3.635	678.81	23.84
68	29.816	44.55	0.642	1.985	279.999	16.63	1.544	4.798	673.05	27.37
69	22.716	-4.28	0.3	1.088	120.71	43.14	0.879	3.189	353.87	28.09
70	38.677	5.55	0.428	1.338	218.552	12.05	1.036	3.257	532.03	33.35
71	15.575	40.07	0.4	1.123	95.608	30.93	1.014	2.844	242.21	40.88
72	23.267	13.72	0.45	1.34	135.884	13	1.132	3.372	341.9	26.62
73	32.284	39.02	0.574	1.458	230.778	37.96	1.082	2.749	435.14	41.12
74	15.036	36.62	0.336	0.979	97.649	31.73	0.676	1.97	196.48	36.57

	hexa-cbs, ppm in wet wt. (cooked fillet)	hexa-cbs, ppm in dry wt. (cooked fillet)	hexa-cbs, ug in wet wt. (cooked fillet)	hexa-cbs % change (cooked fillet)	hepta-cbs, ppm in wet wt. (cooked fillet)	hepta-cbs, ppm in dry wt. (cooked fillet)	hepta-cbs, ug in wet wt. (cooked fillet)	hepta-cbs % change (cooked fillet)	octa-cbs, ppm in wet wt. (cooked fillet)	octal-cbs, ppm in dry wt. (cooked fillet)
38	0.235	0.77	58.406	15.28	0.107	0.351	26.614	21.38	0.022	0.072
39	0.449	2.115	110.482	20.45	0.214	1.009	52.712	-18.03	0.058	0.272
40	0.164	0.573	37.291	38.3	0.075	0.264	17.182	8.14	0.049	0.172
41	0.372	1.428	101.057	35.9	0.13	0.501	35.443	28.57	0.036	0.14
42	0.21	0.673	54.835	41.44	0.067	0.214	17.402	43.02	0.015	0.05
43	0.481	1.493	141.803	23.62	0.266	0.826	78.409	25.01	0.048	0.15
44	0.544	1.768	159.38	15.92	0.238	0.772	69.639	12.63	0.051	0.167
45	0.473	1.524	115.218	15.71	0.194	0.625	47.233	4.56	0.04	0.13
46	0.42	1.109	233.171	21.28	0.112	0.296	62.241	46.37	0.039	0.102
47	0.519	1.482	315.339	14.66	0.142	0.404	86.015	43.46	0.051	0.144
48	0.505	1.246	426.645	20.13	0.197	0.486	166.35	21.6	0.041	0.1
49	0.208	0.756	54.631	48.15	0.067	0.241	17.457	40.21	0.027	0.098
50	0.2	0.555	64.277	46.36	0.059	0.163	18.871	38.16	0.02	0.055
51	0.407	1.176	90.917	17.48	0.082	0.236	18.238	62.93	0.037	0.106
52	0.315	1.035	74.729	21.06	0.102	0.334	24.123	18.63	0.036	0.119
53	0.203	0.688	34.544	39.54	0.089	0.301	15.13	9.21	0.021	0.07
54	0.239	0.698	70.444	46.31	0.075	0.218	21.981	45.68	0.023	0.066
55	0.278	0.657	86.781	26.59	0.233	0.55	72.662	25.31	0.051	0.12
56	0.112	0.314	23.867	38.6	0.173	0.486	36.964	36.47	0.042	0.118
57	0.123	0.349	28.783	37.69	0.189	0.538	44.391	36.27	0.039	0.112
58	0.047	0.121	26.711	75.55	0.117	0.303	66.742	47.67	0.031	0.082
59	0.091	0.265	52.434	62.57	0.133	0.388	76.753	49.41	0.038	0.111
60	0.157	0.415	116.67	13.07	0.185	0.49	137.6	3.95	0.038	0.1
61	0.367	1.183	91.667	15.26	0.181	0.585	45.333	10.23	0.101	0.326
62	0.178	0.528	38.516	89.18	0.151	0.447	32.58	15.25	0.118	0.349
63	0.418	1.226	116.152	17.3	0.179	0.524	49.63	42.49	0.053	0.155
64	0.208	0.701	44.607	48.03	0.065	0.221	14.025	43.35	0.025	0.085
65	0.319	0.961	84.674	29.24	0.09	0.271	23.874	29.94	0.032	0.097
66	0.281	0.793	57.775	35.22	0.131	0.369	26.838	35.35	0.032	0.09
67	0.088	0.261	48.676	47.34	0.181	0.535	99.916	37.88	0.052	0.154
68	0.102	0.318	44.577	31.82	0.181	0.562	78.923	29.98	0.043	0.133
69	0.068	0.246	27.305	56.74	0.129	0.469	52.095	40.56	0.049	0.178
70	0.078	0.244	39.834	38.74	0.13	0.408	66.574	35.76	0.047	0.148
71	0.086	0.242	20.649	35.93	0.137	0.384	32.668	40.38	0.039	0.108
72	0.077	0.23	23.277	42.3	0.113	0.336	34.021	48.07	0.038	0.114
73	0.445	1.131	179.062	34.66	0.151	0.384	60.733	25.78	0.078	0.199
74	0.288	0.839	83.628	29.56	0.1	0.292	29.069	24.28	0.042	0.123

	octa-cbs, ug	octa-cbs	total-cbs, ppm	total-cbs, ppm	total-cbs, ug	total-cbs
	in wet wt.	% change	in wet wt.	in dry wt.	in wet wt.	% change
	(cooked fillet)	(cooked fillet)	(cooked fillet)	(cooked fillet)	(cooked fillet)	(cooked fillet)
38	5.469	23.82	0.892	2.925	221.911	15.41
39	14.199	39.26	1.365	6.431	336.013	26.93
40	11.209	-128.07	0.649	2.271	147.889	37.64
41	9.877	9.15	1.371	5.265	372.682	29.44
42	4.056	45.19	0.776	2.493	203.002	41.42
43	14.263	30.43	1.996	6.19	587.855	17.85
44	15.062	11.96	1.914	6.219	560.732	26.48
45	9.862	1.41	1.982	6.391	483.229	17.06
46	21.407	10.09	1.908	5.033	1058.383	25.69
47	30.715	6.03	2.008	5.731	1219.778	18.81
48	34.211	21.09	2.156	5.314	1820.162	22.25
49	7.091	28.86	0.691	2.506	181.208	49.25
50	6.409	30.75	0.932	2.585	299.541	40.31
51	8.215	12.9	1.624	4.693	362.892	19.72
52	8.577	-7.95	1.17	3.842	277.476	26.99
53	3.492	35.42	0.749	2.538	127.48	38.77
54	6.637	41.2	0.9	2.631	265.421	48.44
55	15.851	38.22	2.714	6.407	845.745	31.29
56	8.978	35.81	1.835	5.158	392.154	39.55
57	9.218	25.53	2.415	6.864	566.502	33.64
58	18.02	28.36	2.026	5.275	1160.406	41.35
59	21.94	42.87	1.619	4.705	931.792	56.84
60	28.013	29.23	2.377	6.288	1766.317	27.39
61	25.284	65.93	1.546	4.99	386.54	32.13
62	25.481	63.48	1.467	4.346	317.053	47.36
63	14.722	55.24	2.342	6.862	650.42	19.25
64	5.422	43.18	0.782	2.64	167.87	47.07
65	8.534	24.72	1.27	3.823	336.907	24.85
66	6.529	14.4	1.105	3.12	227.2	39.42
67	28.673	-3.39	2.056	6.08	1135.479	33.91
68	18.628	35.81	2.58	8.016	1124.998	26.15
69	19.795	25.84	1.481	5.375	596.496	33.99
70	24.1	35.32	1.791	5.631	919.772	28.9
71	9.238	48.48	1.741	4.884	415.947	38.74
72	11.528	45.66	1.866	5.62	569.875	26.56
73	31.468	-2.82	2.41	6.125	969.467	37.47
74	12.285	-2.58	1.493	4.354	434.133	32.75

Appendix 2. Physical and chemical parameters of chinook salmon harvested from Great Lakes

	fish ID (raw)	fish ID (cooked)	cooking methods	lakes	specie	skin (raw)	skin (cooked)	sex	age	length (cm)	whole wt. (gm)	degutted wt. (gm)	carcus (%)	right fillet wt. (gm)	left fillet wt. (gm)
75	1902	3686	charbroil*	Michigan	ch. salmon	off	off	male	2	72.5	3850	2830	73.51	768.4	763.0
76	2059	2957	charbroil*	Michigan	ch. salmon	off	off	male	2	71.1	3700	2210	59.73	498.6	369.7
77	5681	9826	charbroil*	Michigan	ch. salmon	off	off	male	3	75.9	5732	4211	73.46	986.5	1057.9
78	3168	7520	charbroil*	Michigan	ch. salmon	off	off	male	.	87.0	7080	4870	68.79	969.0	1166.0
79	9516	4607	can	Michigan	ch. salmon	off	off	male	.	86.0	6110	4150	67.92	1078.0	1052.0
80	3797	3987	can	Michigan	ch. salmon	off	off	male	.	75.0	4690	3100	66.10	763.0	733.0
81	5537	4221	can	Michigan	ch. salmon	off	off	male	3	82.0	5890	3870	65.70	908.0	977.0
82	7240	3203	can	Michigan	ch. salmon	off	off	male	.	91.4	4430	2830	63.88	696.0	718.0
83	1996	8397	can	Michigan	ch. salmon	off	off	female	.	91.0	7510	4600	61.25	907.0	829.0
84	4630	9367	can	Michigan	ch. salmon	off	off	male	.	76.0	4750	3000	63.16	682.0	759.0

charbroil*: surface increased fillet

	AP yield (%)	wt. before cooking (gm)	actual fillet wt. (gm)	edible wt. (gm)	% cooking loss in fillet	% cooking yield in fillet	% solids in raw fillet	% solids in cooked fillet	% fat in raw fillet	% fat in cooked fillet	tri-cbs,ppm in wet wt. (raw fillet)	tri-cbs,ppm in dry wt. (raw fillet)	tri-cbs,ug in fillet (raw fillet)
75	39.78	375.84	297.20	297.20	20.92	79.08	29.00	33.81	6.15	9.65	0.081	0.281	30.603
76	23.47	190.31	142.70	142.70	25.02	74.98	22.81	32.65	.	.	0.053	0.234	10.166
77	35.67	544.77	419.43	419.43	23.01	76.99	30.29	41.15	.	.	0.076	0.251	41.348
78	30.16	497.71	377.85	377.85	24.08	75.92	24.73	33.84	8.90	2.25	0.052	0.212	26.111
79	34.86	351.59	266.48	266.48	24.21	75.79	25.88	34.23	4.55	6.05	0.111	0.429	39.068
80	31.90	259.73	195.19	195.19	24.85	75.15	24.97	31.88	.	.	0.069	0.276	17.89
81	32.00	414.10	326.56	326.56	21.14	78.86	25.66	30.20	4.50	5.85	0.077	0.302	32.059
82	31.92	280.81	216.20	216.20	23.01	76.99	25.83	31.15	.	.	0.075	0.289	20.942
83	23.12	361.27	223.33	223.33	38.18	61.82	24.45	31.28	3.53	3.85	0.074	0.302	26.685
84	30.34	287.21	217.15	217.15	24.39	75.61	23.55	30.82	.	.	0.027	0.114	7.729

	tetra-cbs,ppm in wet wt. (raw fillet)	tetra-cbs,ppm in dry wt. (raw fillet)	tetra-cbs,ug in wet wt. (raw fillet)	penta-cbs,ppm in wet wt. (raw fillet)	penta-cbs,ppm in dry wt. (raw fillet)	penta-cbs,ug in wet wt. (raw fillet)	hexa-cbs,ppm in wet wt. (raw fillet)	hexa-cbs,ppm in dry wt. (raw fillet)	hexa-cbs,ug in wet wt. (raw fillet)	hepta-cbs,ppm in wet wt. (raw fillet)
75	0.54	1.862	202.903	0.887	3.059	333.43	0.262	0.902	98.367	0.094
76	0.322	1.413	61.347	1.033	4.53	196.63	0.307	1.345	58.402	0.089
77	0.447	1.477	243.771	1.136	3.749	618.59	0.427	1.41	232.655	0.107
78	0.358	1.446	177.948	0.83	3.356	413.01	0.317	1.283	157.935	0.081
79	0.697	2.693	245.049	1.537	5.94	540.48	0.457	1.767	160.805	0.146
80	0.382	1.529	99.187	0.894	3.58	232.19	0.271	1.083	70.264	0.076
81	0.477	1.859	197.553	1.193	4.648	493.87	0.462	1.802	191.494	0.175
82	0.617	2.39	173.381	1.339	5.185	376.11	0.63	2.438	176.861	0.175
83	0.57	2.329	205.764	0.945	3.866	341.5	0.454	1.856	163.919	0.127
84	0.62	2.632	178.025	1.077	4.572	309.22	0.654	2.775	187.726	0.227

	hepta-cbs,ppm in dry wt. (raw fillet)	hepta-cbs,ug in wet wt. (raw fillet)	octa-cbs,ppm in wet wt. (raw fillet)	octa-cbs,ppm in dry wt. (raw fillet)	octa-cbs,ug in wet wt. (raw fillet)	total-cbs, ppm in wet wt. (raw fillet)	total-cbs, ppm in dry wt. (raw fillet)	total-cbs, ug in wet wt. (raw fillet)	tri-cbs, ppm in wet wt. (cooked fillet)	tri-cbs, ppm in dry wt. (cooked fillet)
75	0.324	35.297	0.045	0.155	16.871	1.909	6.583	717.471	0.073	0.215
76	0.389	16.876	0.031	0.135	5.855	1.835	8.046	349.271	0.05	0.155
77	0.355	58.517	0.033	0.109	18.065	2.227	7.351	1212.947	0.089	0.217
78	0.326	40.17	0.026	0.105	12.936	1.664	6.728	828.113	0.056	0.166
79	0.564	51.296	0.065	0.253	22.983	3.014	11.646	1059.677	0.116	0.339
80	0.303	19.641	0.024	0.097	6.287	1.715	6.869	445.454	0.069	0.218
81	0.683	72.621	0	0	0	2.385	9.294	987.601	0.081	0.267
82	0.678	49.145	0.077	0.297	21.507	2.913	11.277	817.947	0.071	0.227
83	0.52	45.951	0.046	0.189	16.709	2.216	9.063	800.53	0.067	0.216
84	0.962	65.095	0.162	0.687	46.472	2.765	11.743	794.264	0.07	0.226

	tri-cbs, ug in wet wt. (cooked fillet)	tri-cbs % change (cooked fillet)	tetra-cbs, ppm in wet wt. (cooked fillet)	tetra-cbs, ppm in dry wt. (cooked fillet)	tetra-cbs, ug in wet wt. (cooked fillet)	tetra-cbs % change (cooked fillet)	penta-cbs, ppm in wet wt. (cooked fillet)	penta-cbs, ppm in dry wt. (cooked fillet)	penta-cbs, ug in wet wt. (cooked fillet)	penta-cbs % change (cooked fillet)
75	21.624	29.34	0.469	1.388	139.485	31.26	0.75	2.218	222.88	33.16
76	7.201	29.17	0.307	0.94	43.797	28.61	0.899	2.755	128.34	34.73
77	37.505	9.29	0.47	1.143	197.23	19.09	1.23	2.989	515.91	16.6
78	21.254	18.6	0.395	1.166	149.144	16.19	0.853	2.52	322.2	22
79	30.932	20.82	0.702	2.051	187.106	23.65	1.458	4.258	388.44	28.13
80	13.559	24.21	0.382	1.199	74.614	24.77	0.936	2.937	182.78	21.28
81	26.362	17.77	0.498	1.647	162.475	17.76	1.086	3.596	354.6	28.2
82	15.317	26.86	0.659	2.117	142.561	17.78	0.989	3.175	213.81	43.15
83	15.071	43.52	0.517	1.652	115.401	43.92	1.002	3.204	223.83	34.46
84	15.099	-95.35	0.561	1.82	121.807	31.58	0.977	3.17	212.08	31.41

	hexa-cbs, ppm in wet wt. (cooked fillet)	hexa-cbs, ppm in dry wt. (cooked fillet)	hexa-cbs, ug in wet wt. (cooked fillet)	hexa-cbs % change (cooked fillet)	hepta-cbs, ppm in wet wt. (cooked fillet)	hepta-cbs, ppm in dry wt. (cooked fillet)	hepta-cbs, ug in wet wt. (cooked fillet)	hepta-cbs % change (cooked fillet)	octa-cbs, ppm in wet wt. (cooked fillet)	octal-cbs, ppm in dry wt. (cooked fillet)
75	0.219	0.647	65.033	33.89	0.065	0.191	19.219	45.55	0.02	0.059
76	0.266	0.814	37.946	35.03	0.074	0.228	10.603	37.17	0.025	0.076
77	0.332	0.807	139.207	40.17	0.105	0.256	44.232	24.41	0.039	0.094
78	0.203	0.599	76.644	51.47	0.066	0.253	32.342	19.49	0.031	0.091
79	0.474	1.385	126.357	21.42	0.131	0.381	34.782	32.19	0.05	0.145
80	0.356	1.115	69.395	1.24	0.091	0.285	17.723	9.76	0.023	0.071
81	0.371	1.23	121.256	36.68	0.088	0.293	28.87	60.25	0.031	0.101
82	0.546	1.751	117.939	33.32	0.278	0.892	60.057	-22.2	0.042	0.134
83	0.402	1.286	89.854	45.18	0.107	0.343	23.976	47.82	0.041	0.13
84	0.55	1.784	119.4	36.4	0.115	0.373	24.975	61.63	0.045	0.145

	octa-cbs, ug in wet wt. (cooked fillet)	octa-cbs % change (cooked fillet)	total-cbs, ppm in wet wt. (cooked fillet)	total-cbs, ppm in dry wt. (cooked fillet)	total-cbs, ug in wet wt. (cooked fillet)	total-cbs % change (cooked fillet)
75	5.909	64.97	1.595	4.719	474.149	33.91
76	3.541	39.53	1.622	4.967	231.429	33.74
77	16.239	10.11	2.266	5.506	950.324	21.65
78	11.683	9.69	1.623	4.796	613.262	25.94
79	13.228	42.44	2.93	8.56	780.845	26.31
80	4.441	29.36	1.857	5.826	362.508	18.62
81	10.007		2.154	7.134	703.569	28.76
82	9.013	58.09	2.584	8.296	558.694	31.7
83	9.101	45.53	2.137	6.831	477.229	40.39
84	9.699	79.13	2.317	7.517	503.063	36.66

Appendix 3. Physical and chemical parameters of lake trout harvested from Great Lakes

	fish ID (raw)	fish ID (cooked)	cooking methods	lakes	specie	skin (raw)	skin (cooked)	sex	age	length (cm)	whole wt. (gm)	degutted wt. (gm)	carcus (%)	right fillet wt. (gm)	left fillet wt. (gm)	AP yield (%)	wt. before cooking (gm)	actual fillet wt. (gm)
1	2747	1764	bake	Huron	lake trout	off	off	male	6	59.5	2450	1550	63.3	407.6	364.5	31.51	178.93	132.93
2	9846	6433	bake	Huron	lake trout	off	off	female	7	66.5	3150	2100	66.7	530.6	549.3	34.28	261.25	207.96
3	5820	1034	bake	Huron	lake trout	off	off	female	6	60	2000	1380	69	325.4	323.5	32.45	164.14	122.36
4	8413	9562	bake	Huron	lake trout	off	off	male	6	65.5	2950	1790	60.7	443.2	449	30.24	205.33	152.8
5	4162	7414	bake	Huron	lake trout	off	off	female	6	64.5	2800	1690	60.4	427.3	355.1	27.94	165.22	117.77
6	3749	1472	bake	Huron	lake trout	off	off	female	6	66	2650	1770	66.8	452.9	463.6	34.58	259.92	217.45
7	8776	6898	bake	Ontario	lake trout	off	off	.	6	62.4	2675	1750	65.4	422.3	413.2	31.23	196.77	164.13
8	4380	8488	bake	Ontario	lake trout	off	off	.	5	65.7	2830	2290	80.9	495.6	512.3	35.61	282.6	237.36
9	7482	3122	bake	Ontario	lake trout	off	off	.	5	66	2985	2270	76.1	555.5	548.8	36.99	243.22	204.97
10	5402	6425	bake	Ontario	lake trout	off	off	.	5	64.4	2745	1910	69.6	458.8	439.2	32.71	223.62	182.33
11	2666	2815	bake	Ontario	lake trout	off	off	.	5	64.8	2952	.	.	443.3	454.8	30.42	213.08	169.62
12	3781	3087	bake	Ontario	lake trout	off	off	.	6	64.8	2365	1510	63.9	388.4	383.8	32.65	213.21	178.28
13	1831	3670	bake	Michigan	lake trout	off	off	female	7	70.2	3550	2600	73.2	645	564.6	34.07	225.87	192.36
14	6081	2479	bake	Michigan	lake trout	off	off	female	7	60.9	2200	1500	68.2	321.7	330.3	29.64	166.53	144.13
15	2628	3021	bake	Michigan	lake trout	off	off	female	6	63.4	2550	1700	66.7	384.1	431.6	31.99	219	182.21
16	2878	4135	bake	Michigan	lake trout	off	off	female	6	62.4	2440	1640	67.2	404.4	390.3	32.57	232.28	184.36
17	9761	7748	bake	Michigan	lake trout	off	off	male	8	71.5	3620	2460	68	643.3	539.2	32.67	253.2	201.56
18	9809	9318	bake	Michigan	lake trout	off	off	female	6	58.3	2100	1320	62.9	365.8	327.6	33.02	178.76	143.49
19	1484	5379	bake	Superior	siscowet	off	off	male	9	53	1237	738	59.7	154.9	144.3	24.19	141.96	101.9
20	5720	9574	bake	Superior	siscowet	off	off	female	9	53.5	1373	909	66.2	182	188	26.95	184.66	144.69
21	2557	8963	bake	Superior	siscowet	off	off	female	11	53.5	1175	786	66.9	157.4	168.4	27.73	163.91	108.52
22	1593	9250	bake	Superior	siscowet	off	off	male	8	51	1253	821	65.5	162.8	202.3	29.14	199.61	159.57
23	2432	5892	bake	Superior	siscowet	off	off	male	9	54.5	1492	940	63	221.2	185.3	27.25	179.34	132.61
24	3778	4655	bake	Superior	siscowet	off	off	male	9	54.5	1330	868	65.3	191.7	164	26.74	160.92	118.64
25	2599	6075	charbroil	Huron	lake trout	off	off	male	6	59.5	2450	1550	63.3	407.6	364.5	31.51	186.83	144.92
26	2366	3074	charbroil	Huron	lake trout	off	off	male	7	66.5	3150	2100	66.7	530.6	549.3	34.28	272.79	196.4
27	7766	9435	charbroil	Huron	lake trout	off	off	female	6	60	2000	1380	69	323.4	323.5	32.35	154.34	115.15
28	7643	8510	charbroil	Huron	lake trout	off	off	male	6	65.5	2950	1790	60.7	443.2	449	30.24	238.47	179.55
29	8823	3843	charbroil	Huron	lake trout	off	off	female	6	64.5	2800	1690	60.4	427.3	355.1	27.94	187.18	142.9
30	5536	3669	charbroil	Huron	lake trout	off	off	female	6	66	2650	1770	66.8	452.9	463.6	34.58	200.71	158.23
31	6118	9434	charbroil	Ontario	lake trout	off	off	.	6	62.4	2675	1750	65.4	422.3	413.2	31.23	205.91	163.66
32	8152	4994	charbroil	Ontario	lake trout	off	off	.	5	65.7	2830	2290	80.9	495.6	512.3	35.61	225.65	183.77
33	7092	3055	charbroil	Ontario	lake trout	off	off	.	5	66	2985	2270	76.1	555.5	548.8	36.99	275.62	231.87
34	1339	5431	charbroil	Ontario	lake trout	off	off	.	5	64.4	2745	1910	69.6	458.8	439.2	32.71	204.15	164.69
35	1721	5003	charbroil	Ontario	lake trout	off	off	.	5	64.8	2952	.	.	443.3	454.8	30.42	229.55	180.36
36	1272	2304	charbroil	Ontario	lake trout	off	off	.	6	64.8	2365	1510	63.9	388.4	383.8	32.65	159.09	121.26
37	1772	1027	charbroil	Michigan	lake trout	off	off	female	7	67.8	3400	2250	66.2	550.5	471.5	30.06	258.87	194.3
38	8459	9997	charbroil	Michigan	lake trout	off	off	female	7	60.9	2200	1500	68.2	321.7	330.3	29.64	160.7	121.27

	edible wt. (gm)	% cooking loss in fillet	% cooking yield in fillet	% solids in raw fillet	% solids in cooked fillet	% fat in raw fillet	% fat in cooked fillet	tri-cbs,ppm in wet wt. (raw fillet)	tri-cbs,ppm in dry wt. (raw fillet)	tri-cbs,ug in fillet (raw fillet)	tetra-cbs,ppm in wet wt. (raw fillet)	tetra-cbs,ppm in dry wt. (raw fillet)	tetra-cbs,ug in wet wt. (raw fillet)	penta-cbs,ppm in wet wt. (raw fillet)
1	132.9	25.71	74.29	26.56	34.35	6.2	8.53	0.004	0.014	0.672	0.076	0.285	13.539	0.781
2	208	20.4	79.6	30.29	36.61	10.3	12.45	0.005	0.018	1.421	0.191	0.629	49.777	0.511
3	122.4	25.45	74.55	24.13	32.28	.	.	0.013	0.055	2.189	0.193	0.801	31.737	0.754
4	152.8	25.58	74.42	26.3	34.12	.	.	0.002	0.008	0.429	0.067	0.256	13.846	0.504
5	117.8	28.72	71.28	25.35	34.34	4.65	6.16	0.004	0.015	0.649	0.095	0.375	15.727	0.461
6	217.5	16.34	83.66	27.72	34.6	.	.	0.003	0.011	0.811	0.1	0.36	25.93	0.524
7	164.1	16.59	83.41	23.33	27.8	.	.	0.006	0.027	1.224	0.143	0.615	28.221	0.545
8	237.4	16.01	83.99	24.96	30.63	5.65	9.05	0.009	0.038	2.665	0.188	0.751	52.993	0.724
9	205	15.73	84.27	25.56	30.82	4.25	6	0.007	0.027	1.688	0.144	0.562	34.936	0.454
10	182.3	18.46	81.54	27.36	33.59	9.85	11.4	0.013	0.049	2.982	0.193	0.707	43.238	0.754
11	169.6	20.4	79.6	25.1	30.83	.	.	0.004	0.015	0.797	0.1	0.399	21.352	0.482
12	178.3	16.38	83.62	24.93	31.31	.	.	0.005	0.021	1.132	0.113	0.453	24.1	0.49
13	192.4	17.42	85.16	29.6	35.66	10.3	10.5	0.008	0.027	1.803	0.119	0.401	26.839	0.445
14	144.1	15.54	86.55	28.56	32.94	.	.	0.008	0.029	1.401	0.139	0.488	23.215	0.424
15	182.2	20.19	83.2	25.99	33.82	.	.	0.005	0.019	1.107	0.124	0.477	27.132	0.484
16	184.4	25.99	79.37	30.26	37.38	11.1	11.25	0.011	0.038	2.65	0.213	0.703	49.378	0.658
17	201.6	25.62	79.61	25.07	31.88	4.65	7.9	0.009	0.038	2.384	0.242	0.965	61.284	0.707
18	143.5	24.58	80.27	26	32.34	.	.	0.005	0.021	0.978	0.145	0.559	25.958	0.467
19	101.9	28.22	71.78	18.7	26.09	2.35	3.8	0.005	0.024	0.642	0.051	0.273	7.236	0.561
20	144.7	21.65	78.35	31.36	37.65	.	.	0.004	0.014	0.798	0.049	0.157	9.112	0.363
21	108.5	33.79	66.21	25.34	38.05	8.95	14.4	0.006	0.024	0.979	0.105	0.415	17.217	0.678
22	159.6	20.06	79.94	25.97	32.19	.	.	0.006	0.022	1.125	0.036	0.138	7.137	0.399
23	132.6	26.06	73.94	24.91	33.08	8.85	9.95	0.002	0.008	0.348	0.053	0.211	9.429	0.47
24	118.6	26.27	73.73	37	43.11	.	.	0	0	0	0.017	0.046	2.742	0.84
25	144.9	22.43	77.57	26.84	34.34	6.8	7.55	0.003	0.011	0.554	0.172	0.64	32.093	0.427
26	196.4	28	72	29.2	40.65	.	.	0.004	0.015	1.188	0.148	0.507	40.353	0.648
27	115.2	25.39	74.61	24.58	33.13	.	.	0.004	0.015	0.552	0.095	0.385	14.623	0.314
28	179.6	24.71	75.29	24.76	36.45	5.9	11.21	0.002	0.008	0.476	0.12	0.485	28.664	0.346
29	142.9	23.66	76.34	25.48	33.68	5.9	6.8	0.003	0.012	0.555	0.172	0.674	32.153	0.427
30	158.2	21.16	78.84	27.06	32.96	.	.	0.003	0.01	0.547	0.089	0.33	17.942	0.542
31	163.7	20.52	79.48	23.77	29.43	.	.	0.005	0.019	0.941	0.101	0.427	20.882	0.386
32	183.8	18.56	81.44	24.22	30.24	4.95	6.05	0.007	0.03	1.638	0.161	0.665	36.37	0.602
33	231.9	15.87	84.13	27.13	31.5	.	.	0.006	0.022	1.636	0.129	0.477	35.631	0.38
34	164.7	19.33	80.67	24.54	30.32	5.2	6.3	0.007	0.028	1.398	0.138	0.563	28.218	0.466
35	180.4	21.43	78.57	26.47	33.92	6.45	8.15	0.014	0.052	3.139	0.273	1.033	62.745	0.797
36	121.3	23.78	76.22	24.46	32.27	.	.	0.004	0.017	0.644	0.1	0.407	15.831	0.424
37	194.3	24.94	75.06	30.53	37.73	.	.	0.005	0.015	1.219	0.119	0.39	30.791	0.406
38	121.3	24.54	75.46	26.05	35.14	.	.	0.006	0.025	1.044	0.121	0.463	19.381	0.339

	penta-cbs,ppm in dry wt. (raw fillet)	penta-cbs,ug in wet wt. (raw fillet)	hexa-cbs,ppm in wet wt. (raw fillet)	hexa-cbs,ppm in dry wt. (raw fillet)	hexa-cbs,ug in wet wt. (raw fillet)	hepta-cbs,ppm in wet wt. (raw fillet)	hepta-cbs,ppm in dry wt. (raw fillet)	hepta-cbs,ug in wet wt. (raw fillet)	octa-cbs,ppm in wet wt. (raw fillet)	octa-cbs,ppm in dry wt. (raw fillet)	octa-cbs,ug in wet wt. (raw fillet)
1	2.939	139.68	0.863	3.25	154.439	0.242	0.912	43.347	0.255	0.959	45.558
2	1.686	133.423	0.231	0.763	60.369	0.051	0.17	13.415	0.057	0.189	14.95
3	3.126	123.826	0.643	2.665	105.535	0.454	1.88	74.443	0.734	3.042	120.473
4	1.915	103.431	0.284	1.08	58.328	0.063	0.241	13.005	0.115	0.438	23.679
5	1.818	76.126	0.23	0.908	38.023	0.047	0.185	7.732	0.064	0.253	10.602
6	1.891	136.242	0.275	0.992	71.487	0.063	0.227	16.367	0.095	0.341	24.593
7	2.337	107.275	0.391	1.676	76.933	0.15	0.642	29.482	0.728	3.12	143.249
8	2.9	204.555	0.549	2.199	155.115	0.233	0.933	65.845	1.087	4.357	307.299
9	1.778	110.534	0.466	1.825	113.442	0.135	0.527	32.743	0.537	2.102	130.675
10	2.757	168.697	0.643	2.35	143.778	0.454	1.658	101.419	0.734	2.683	164.129
11	1.92	102.708	0.362	1.44	77.1	0.201	0.802	42.9	0.643	2.561	136.982
12	1.966	104.485	0.352	1.413	75.092	0.115	0.461	24.482	0.622	2.497	132.721
13	1.503	100.486	0.224	0.755	50.5	0.07	0.235	15.707	0.017	0.058	3.849
14	1.485	70.65	0.273	0.955	45.441	0.095	0.334	15.866	0.017	0.058	2.763
15	1.863	106.043	0.275	1.058	60.194	0.061	0.233	13.253	0.097	0.374	21.278
16	2.174	152.823	0.31	1.025	72.058	0.089	0.292	20.558	0.021	0.068	4.878
17	2.82	179.008	0.362	1.444	91.631	0.066	0.262	16.605	0.093	0.372	23.624
18	1.796	83.485	0.221	0.848	39.434	0.042	0.161	7.505	0.067	0.259	12.022
19	3.001	79.662	0.634	3.39	89.993	0.262	1.4	37.163	0.113	0.603	15.998
20	1.156	66.965	0.211	0.673	38.963	0.073	0.232	13.408	0.346	1.104	63.932
21	2.674	111.067	0.397	1.567	65.093	0.094	0.369	15.339	0.037	0.148	6.131
22	1.536	79.63	0.237	0.912	47.292	0.078	0.301	15.583	0.06	0.232	12.005
23	1.886	84.247	0.3	1.202	53.716	0.123	0.493	22.005	0.054	0.219	9.772
24	2.272	135.252	1.378	3.725	221.779	2.072	5.599	333.366	0.017	0.045	2.702
25	1.589	79.704	0.264	0.985	49.405	0.073	0.273	13.681	0.004	0.013	0.668
26	2.22	176.803	0.445	1.524	121.415	0.108	0.368	29.333	0.117	0.401	31.928
27	1.278	48.489	0.247	1.006	38.183	0.057	0.23	8.724	0.071	0.288	10.934
28	1.396	82.416	0.228	0.919	54.265	0.057	0.229	13.496	0.072	0.292	17.253
29	1.674	79.853	0.302	1.184	56.447	0.073	0.287	13.707	0.004	0.014	0.67
30	2.001	108.696	0.294	1.086	59	0.073	0.271	14.699	0.116	0.428	23.228
31	1.625	79.52	0.284	1.193	58.411	0.107	0.45	22.004	0.58	2.44	119.405
32	2.484	135.774	0.471	1.946	106.364	0.204	0.841	45.979	0.992	4.094	223.761
33	1.402	104.846	0.271	0.997	74.578	0.103	0.378	28.267	0.463	1.708	127.73
34	1.899	95.156	0.366	1.49	74.671	0.109	0.442	22.152	0.521	2.124	106.395
35	3.009	182.857	0.528	1.994	121.172	0.151	0.572	34.752	0.679	2.564	155.781
36	1.733	67.427	0.311	1.271	49.467	0.104	0.424	16.499	0.561	2.293	89.216
37	1.329	105.071	0.173	0.566	44.747	0.045	0.148	11.677	0.021	0.068	5.383
38	1.301	54.477	0.177	0.68	28.456	0.045	0.172	7.182	0.014	0.054	2.25

	total pcbs, ppm in wet wt. (raw fillet)	total pcbs, ppm in dry wt. (raw fillet)	total pcbs, ug in wet wt. (raw fillet)	tri-cbs, ppm in wet wt. (cooked fillet)	tri-cbs, ppm in dry wt. (cooked fillet)	tri-cbs, ug in wet wt. (cooked fillet)	tri-cbs % change (cooked fillet)	tetra-cbs, ppm in wet wt. (cooked fillet)	tetra-cbs, ppm in dry wt. (cooked fillet)	tetra-cbs, ug in wet wt. (cooked fillet)	tetra-cbs % change (cooked fillet)
1	2.22	8.359	397.235	0.004	0.011	0.517	22.99	0.092	0.267	12.173	10.09
2	1.046	3.454	273.355	0.004	0.011	0.845	40.54	0.073	0.198	15.111	69.64
3	2.792	11.569	458.202	0.009	0.029	1.139	47.99	0.178	0.552	21.786	31.35
4	1.036	3.939	212.717	0.004	0.012	0.64	-49.08	0.073	0.214	11.137	19.57
5	0.901	3.554	148.859	0.006	0.017	0.696	-7.2	0.099	0.287	11.62	26.11
6	1.06	3.823	275.431	0.003	0.008	0.586	27.72	0.089	0.256	19.275	25.67
7	1.964	8.417	386.384	0.006	0.022	1.021	16.57	0.139	0.5	22.821	19.14
8	2.79	11.178	788.471	0.01	0.033	2.424	9.02	0.19	0.619	44.995	15.09
9	1.743	6.821	424.019	0.01	0.033	2.113	-25.15	0.167	0.543	34.318	1.77
10	2.792	10.203	624.243	0.009	0.028	1.697	43.11	0.178	0.53	32.464	24.92
11	1.792	7.139	381.839	0.005	0.015	0.784	1.64	0.112	0.363	18.957	11.22
12	1.698	6.811	362.012	0.003	0.011	0.608	46.31	0.089	0.283	15.801	34.43
13	0.882	2.979	199.183	0.005	0.015	1.009	44.06	0.1	0.28	19.24	28.31
14	0.957	3.35	159.336	0.006	0.018	0.878	37.3	0.141	0.428	20.305	12.54
15	1.046	4.023	229.007	0.01	0.028	1.734	-56.58	0.171	0.506	31.158	-14.84
16	1.302	4.302	302.346	0.006	0.017	1.189	55.13	0.132	0.354	24.383	50.62
17	1.479	5.9	374.537	0.006	0.018	1.186	50.23	0.151	0.475	30.504	50.23
18	0.948	3.644	169.383	0.006	0.02	0.915	6.43	0.113	0.348	16.147	37.8
19	1.625	8.69	230.695	0.002	0.006	0.163	74.63	0.114	0.437	11.619	-60.57
20	1.046	3.336	193.178	0.008	0.02	1.115	-39.68	0.061	0.163	8.891	2.42
21	1.317	5.196	215.825	0.003	0.008	0.334	65.91	0.073	0.192	7.922	53.99
22	0.815	3.14	162.771	0.005	0.016	0.805	28.39	0.066	0.204	10.463	-46.61
23	1.001	4.018	179.517	0.003	0.01	0.45	-29.24	0.049	0.149	6.515	30.9
24	4.324	11.687	695.841	0	0	0	0	0.006	0.015	0.759	72.34
25	0.943	3.512	176.106	0.004	0.011	0.571	-3.08	0.124	0.362	18.013	43.87
26	1.47	5.034	401.02	0.006	0.016	1.25	-5.22	0.106	0.261	20.843	48.35
27	0.787	3.203	121.506	0.005	0.014	0.528	4.4	0.101	0.306	11.673	20.18
28	0.824	3.329	196.57	0.002	0.006	0.404	15.13	0.116	0.319	20.889	27.12
29	0.98	3.845	183.385	0.002	0.007	0.329	40.69	0.106	0.315	15.164	52.84
30	1.117	4.126	224.112	0.002	0.007	0.381	30.4	0.093	0.281	14.673	18.22
31	1.463	6.153	301.163	0.003	0.012	0.572	39.26	0.088	0.299	14.379	31.14
32	2.437	10.062	549.887	0.007	0.025	1.368	16.45	0.157	0.519	28.826	20.74
33	1.352	4.984	372.688	0.003	0.011	0.81	50.48	0.088	0.279	20.372	42.82
34	1.607	6.547	327.991	0.006	0.02	0.988	29.37	0.118	0.39	19.456	31.05
35	2.441	9.224	560.446	0.009	0.025	1.544	50.82	0.193	0.569	34.783	44.56
36	1.503	6.144	239.085	0.003	0.008	0.329	48.91	0.071	0.221	8.648	45.37
37	0.768	2.517	198.887	0.004	0.011	0.818	32.89	0.101	0.267	19.542	36.53
38	0.702	2.694	112.791	0.006	0.017	0.735	29.59	0.14	0.399	17.012	12.23

	penta-cbs, ppm in wet wt. (cooked fillet)	penta-cbs, ppm in dry wt. (cooked fillet)	penta-cbs, ug in wet wt. (cooked fillet)	penta-cbs % change (cooked fillet)	hexa-cbs, ppm in wet wt. (cooked fillet)	hexa-cbs, ppm in dry wt. (cooked fillet)	hexa-cbs, ug in wet wt. (cooked fillet)	hexa-cbs % change (cooked fillet)	hepta-cbs, ppm in wet wt. (cooked fillet)	hepta-cbs, ppm in dry wt. (cooked fillet)	hepta-cbs, ug in wet wt. (cooked fillet)
1	0.525	1.528	69.779	50.04	0.324	0.942	43.009	72.15	0.109	0.318	14.54
2	0.295	0.806	61.338	54.03	0.174	0.474	36.099	40.2	0.034	0.092	7.041
3	0.719	2.227	87.964	28.96	0.596	1.845	72.875	30.95	0.278	0.862	34.045
4	0.482	1.414	73.7	28.74	0.273	0.799	41.644	28.6	0.065	0.191	9.935
5	0.461	1.342	54.257	28.73	0.204	0.594	24.005	36.87	0.042	0.124	5.002
6	0.511	1.476	111.024	18.51	0.262	0.756	56.869	20.45	0.065	0.187	14.062
7	0.546	1.963	89.587	16.49	0.408	1.468	66.997	12.92	0.157	0.565	25.798
8	0.777	2.538	184.531	9.79	0.592	1.934	140.587	9.37	0.257	0.839	61.025
9	0.518	1.681	106.176	3.94	0.349	1.133	71.561	36.92	0.14	0.455	28.719
10	0.719	2.14	131.076	22.3	0.596	1.773	108.591	24.47	0.278	0.828	50.731
11	0.491	1.593	83.32	18.88	0.343	1.114	58.261	24.43	0.122	0.396	20.7
12	0.43	1.373	76.623	26.67	0.319	1.019	56.882	24.25	0.108	0.345	19.272
13	0.321	0.9	61.706	38.59	0.147	0.411	28.201	44.16	0.033	0.092	6.298
14	0.439	1.332	63.225	10.51	0.206	0.625	29.662	34.72	0.06	0.181	8.608
15	0.511	1.512	93.186	12.12	0.233	0.689	42.44	29.49	0.047	0.14	8.64
16	0.401	1.074	73.98	51.59	0.209	0.559	38.489	46.59	0.06	0.161	11.098
17	0.515	1.615	103.745	42.04	0.224	0.704	45.228	50.64	0.046	0.144	9.24
18	0.468	1.448	67.195	19.51	0.27	0.836	38.786	1.64	0.066	0.203	9.422
19	1.217	4.665	124.031	-55.7	0.855	3.279	87.174	3.13	0.211	0.809	21.499
20	0.359	0.954	51.966	22.4	0.266	0.707	38.523	1.13	0.105	0.28	15.248
21	0.553	1.454	60.054	45.93	0.295	0.774	31.967	50.89	0.2	0.526	21.711
22	0.466	1.447	74.307	6.69	0.241	0.749	38.459	18.68	0.118	0.367	18.85
23	0.382	1.153	50.596	39.94	0.209	0.631	27.693	48.44	0.072	0.218	9.559
24	0.89	2.065	105.612	21.91	0.886	2.055	105.091	52.61	0.484	1.123	57.439
25	0.3	0.873	43.454	45.48	0.199	0.578	28.769	41.77	0.048	0.139	6.895
26	0.418	1.029	82.168	53.53	0.276	0.678	54.165	55.39	0.063	0.154	12.319
27	0.334	1.009	38.498	20.6	0.197	0.594	22.657	40.66	0.045	0.136	5.178
28	0.317	0.87	56.92	30.94	0.209	0.575	37.602	30.71	0.056	0.153	9.999
29	0.309	0.917	44.114	44.76	0.209	0.619	29.802	47.2	0.065	0.194	9.359
30	0.556	1.687	87.99	19.05	0.293	0.889	46.389	21.38	0.075	0.229	11.941
31	0.299	1.015	48.88	38.53	0.286	0.973	46.848	19.8	0.133	0.45	21.686
32	0.585	1.933	107.419	20.88	0.462	1.528	84.932	20.15	0.203	0.672	37.336
33	0.299	0.948	69.252	33.95	0.286	0.909	66.373	11	0.133	0.421	30.724
34	0.467	1.542	76.985	19.1	0.351	1.158	57.821	22.57	0.106	0.349	17.427
35	0.647	1.906	116.61	36.23	0.716	2.111	129.144	-6.58	0.142	0.419	25.659
36	0.338	1.048	41.009	39.18	0.251	0.777	30.395	38.56	0.084	0.26	10.177
37	0.272	0.722	52.943	49.61	0.138	0.367	26.91	39.86	0.031	0.082	6.025
38	0.409	1.165	49.647	8.87	0.195	0.556	23.687	16.76	0.048	0.136	5.807

	hepta-cbs % change (cooked fillet)	octa-cbs, ppm in wet wt. (cooked fillet)	octal-cbs, ppm in dry wt. (cooked fillet)	octa-cbs, ug in wet wt. (cooked fillet)	octa-cbs % change (cooked fillet)	total pcbs, ppm in wet wt. (cooked fillet)	total pcbs, ppm in dry wt. (cooked fillet)	total pcbs, ug in wet wt. (cooked fillet)	total pcbs % change (cooked fillet)
1	66.46	0.139	0.405	18.487	59.42	1.192	3.471	158.506	60.1
2	47.51	0.048	0.131	9.949	33.45	0.627	1.713	130.382	52.3
3	54.27	0.768	2.378	93.912	22.05	2.548	7.892	311.72	31.97
4	23.6	0.125	0.366	19.071	19.46	1.022	2.995	156.126	26.6
5	35.31	0.06	0.176	7.105	32.98	0.872	2.539	102.685	31.02
6	14.09	0.091	0.263	19.765	19.63	1.019	2.945	221.581	19.55
7	12.5	0.825	2.968	135.407	5.47	2.081	7.487	341.63	11.58
8	7.32	1.164	3.8	276.242	10.11	2.99	9.763	709.803	9.98
9	12.29	0.615	1.995	126.01	3.57	1.8	5.84	368.898	13
10	49.98	0.768	2.285	139.939	14.74	2.548	7.584	464.498	25.59
11	51.75	0.616	1.997	104.44	23.76	1.689	5.478	286.461	24.98
12	21.28	0.605	1.934	107.937	18.67	1.554	4.965	277.122	23.45
13	59.9	0.006	0.016	1.102	71.37	0.611	1.714	117.555	40.98
14	45.75	0.003	0.01	0.478	82.7	0.854	2.594	123.155	22.71
15	34.81	0.076	0.225	13.848	34.92	1.048	3.1	191.006	16.59
16	46.02	0.014	0.039	2.671	45.25	0.823	2.203	151.81	49.79
17	44.35	0.024	0.075	4.85	79.47	0.966	3.031	194.754	48
18	-25.54	0.103	0.32	14.847	-23.5	1.027	3.175	147.313	13.03
19	42.15	0.188	0.721	19.174	-19.85	2.587	9.917	263.66	-14.29
20	-13.72	0.05	0.133	7.232	88.69	0.85	2.257	122.973	36.342
21	-41.54	0.224	0.589	24.326	-296.77	1.348	3.543	146.313	32.207
22	-20.97	0.004	0.011	0.587	95.11	0.899	2.793	143.472	11.857
23	56.56	0.034	0.102	4.46	54.36	0.749	2.263	99.274	44.699
24	82.77	0.014	0.033	1.7	37.1	2.281	5.291	270.599	61.112
25	49.6	0.006	0.018	0.898	-34.4	0.736	2.144	106.688	39.42
26	58	0.069	0.169	13.493	57.74	0.938	2.308	184.237	54.06
27	40.65	0.054	0.162	6.185	43.43	0.736	2.221	84.718	30.28
28	25.91	0.078	0.213	13.965	19.06	0.778	2.136	139.779	28.89
29	31.72	0.007	0.02	0.979	-46.23	0.708	2.102	101.177	44.83
30	18.76	0.109	0.331	17.24	25.78	1.129	3.425	178.614	20.3
31	1.45	0.605	2.057	99.06	17.04	1.414	4.805	231.424	23.16
32	18.8	0.982	3.247	180.463	19.35	2.396	7.924	440.344	19.92
33	-8.69	0.605	1.922	140.346	-9.88	1.414	4.489	327.877	12.02
34	21.33	0.534	1.76	87.885	17.4	1.582	5.218	260.562	20.56
35	26.16	0.584	1.721	105.279	32.42	2.29	6.751	413.018	26.31
36	38.31	0.492	1.525	59.683	33.1	1.239	3.84	150.242	37.16
37	48.4	0.01	0.027	1.999	62.87	0.557	1.476	108.237	45.58
38	19.15	0.014	0.039	1.664	26.05	0.813	2.313	98.551	12.62

Appendix 3. Physical and chemical parameters of lake trout harvested from Great Lakes

	fish ID (raw)	fish ID (cooked)	cooking methods	lakes	specie	skin (raw)	skin (cooked)	sex	age	length (cm)	whole wt. (gm)	degutted wt. (gm)	carcus (%)	right fillet wt. (gm)	left fillet wt. (gm)	AP yield (%)	wt. before cooking (gm)	actual fillet wt. (gm)
39	1421	5515	charbroil	Michigan	lake trout	off	off	female	6	66.1	3250	2250	69.2	550.4	579.7	34.77	282.41	206.92
40	1503	8296	charbroil	Michigan	lake trout	off	off	female	6	62.4	2440	1640	67.2	404.4	390.3	32.57	152.96	116.74
41	8583	4247	charbroil	Michigan	lake trout	off	off	female	6	54.2	1620	1080	66.7	282.4	260.3	33.5	150.11	119
42	9762	3576	charbroil	Michigan	lake trout	off	off	female	6	58.3	2100	1320	62.9	365.8	327.6	33.02	145.09	112,16
43	9784	8370	charbroil	Superior	siscowet	off	off	male	8	54	1263	776	61.4	161.7	147.4	24.47	145.36	112.66
44	9028	6811	charbroil	Superior	siscowet	off	off	female	9	52	1282	860	67.1	182.3	149.2	25.86	146.39	98.44
45	2981	9105	charbroil	Superior	siscowet	off	off	female	9	50	1133	779	68.8	165.3	175.4	30.07	172.32	141.48
46	5497	1698	charbroil	Superior	siscowet	off	off	female	8	51.5	1163	738	63.5	145.2	150.5	25.43	146.95	110.45
47	6640	6262	charbroil	Superior	siscowet	off	off	male	9	50.5	1172	817	69.7	193.2	180.5	31.89	172.56	126.88
48	3287	2782	charbroil	Superior	siscowet	off	off	male	9	52	1110	709	63.9	151	124.6	24.83	122.45	89.86
49	1916	1105	salt boil	Michigan	lake trout	off	off	male	7	70.2	3550	2600	73.2	645	564.6	34.07	336.77	300.81
50	6218	6417	salt boil	Michigan	lake trout	off	off	male	7	68.4	3380	2300	68.1	598.9	503.7	32.62	241.26	203.7
51	7411	9312	salt boil	Michigan	lake trout	off	off	male	6	63.4	2550	1700	66.7	384.1	431.6	31.99	210.6	188.3
52	2206	6876	salt boil	Michigan	lake trout	off	off	male	6	66.1	3250	2250	69.2	550.4	579.7	34.77	294.4	262.81
53	7713	6363	salt boil	Michigan	lake trout	off	off	male	8	71.5	3620	2460	68	643.3	539.2	32.67	282.7	245.37
54	6522	4066	salt boil	Michigan	lake trout	off	off	female	6	54.2	1620	1080	66.7	282.4	260.3	33.5	106.23	92.72
55	3337	1364	salt boil	Superior	siscowet	off	off	male	10	50	1153	763	66.2	142.9	183.1	28.27	180.85	154.4
56	8697	4978	salt boil	Superior	siscowet	off	off	female	9	52.5	1327	879	66.2	200.2	211.4	31.02	208.72	179.7
57	4368	5804	salt boil	Superior	siscowet	off	off	female	9	52	1089	714	65.6	152.9	164.4	29.14	160.63	136.5
58	2220	4030	salt boil	Superior	siscowet	off	off	female	8	54.5	1340	903	67.4	185.8	160.8	25.87	156.9	137.5
59	9588	4583	salt boil	Superior	siscowet	off	off	female	10	54	1423	923	64.9	222.4	212.9	30.59	206.67	178.4
60	1118	9297	salt boil	Superior	siscowet	off	off	female	10	54	1359	887	65.3	182.7	159.5	25.18	155.8	142.13
61	1209	9954	smoke	Michigan	lake trout	on	off	female	7	63.4	2680	1800	67.2	593.2	598	44.45	647.9	432.8
62	1197	6327	smoke	Michigan	lake trout	on	off	female	6	59.2	2450	1570	64.1	494.7	529	41.78	499.9	320.9
63	8779	5290	smoke	Michigan	lake trout	on	off	male	6	64.4	2250	1440	64	523.8	458.8	43.67	572.2	388.9
64	1205	5388	smoke	Michigan	lake trout	on	off	male	6	70.5	3120	2400	76.9	675.5	664.9	42.96	723.4	481.1
65	5766	6197	smoke	Michigan	lake trout	on	off	female	5	54.7	1460	940	64.4	302.7	313.9	42.23	349.4	210
66	6360	7798	smoke	Michigan	lake trout	on	off	female	6	65.1	2850	1925	67.5	527.8	561.1	38.21	594	420
67	1290	3308	smoke	Superior	siscowet	on	off	male	11	54.8	1380	959	69.5	279.5	294.2	41.57	313.2	202.4
68	8250	1905	smoke	Superior	siscowet	on	off	male	8	49.5	1104	754	68.3	220.8	226.6	40.53	250.6	158.9
69	4136	9027	smoke	Superior	siscowet	on	off	male	10	53.5	1385	898	64.8	241.4	250.7	35.53	275	178.3
70	1408	5859	smoke	Superior	siscowet	on	off	male	10	54	1349	870	64.5	213.4	266.8	35.6	308.9	201
71	8809	6986	smoke	Superior	siscowet	on	off	male	9	56	1354	912	67.4	247.6	255.5	37.16	274.2	179.2
72	5356	9338	smoke	Superior	siscowet	on	off	male		49	1078	739	68.6	234.5	221	42.25	248.1	147

	edible wt. (gm)	% cooking loss in fillet	% cooking yield in fillet	% solids in raw fillet	% solids in cooked fillet	% fat in raw fillet	% fat in cooked fillet	tri-cbs,ppm in wet wt. (raw fillet)	tri-cbs,ppm in dry wt. (raw fillet)	tri-cbs,ug in fillet (raw fillet)	tetra-cbs,ppm in wet wt. (raw fillet)	tetra-cbs,ppm in dry wt. (raw fillet)	tetra-cbs,ug in wet wt. (raw fillet)	penta-cbs,ppm in wet wt. (raw fillet)
39	206.9	26.73	73.27	30.02	40.95	9	10.75	0.006	0.021	1.762	0.186	0.621	52.617	0.768
40	116.7	23.68	76.32	28.49	36.77	8.65	10.35	0.015	0.052	2.257	0.316	1.109	48.312	1.058
41	119	20.72	79.28	26.31	35.37	9.35	8.25	0.003	0.013	0.501	0.11	0.417	16.46	0.433
42	112.2	22.7	77.3	24.87	32.82			0.006	0.026	0.926	0.113	0.452	16.327	0.468
43	112.7	22.5	77.5	18.71	26.31	2.65	2.94	0	0	0	0.119	0.639	17.366	0.667
44	98.44	32.75	67.25	27.05	37.96	10.1	12.83	0	0	0	0.119	0.439	17.383	0.879
45	141.5	17.9	82.1	28.16	33.59			0.003	0.012	0.582	0.052	0.184	8.952	0.602
46	110.5	24.84	75.16	27.79	36.04			0	0	0	0.02	0.07	2.868	0.743
47	126.9	26.47	73.53	21.84	29.94	6.2	8.1	0.013	0.059	2.233	0.183	0.836	31.493	0.492
48	89.86	26.61	73.39	22.1	30.7			0	0	0	0.017	0.077	2.087	0.84
49	300.8	10.68	89.32	31.52	34.12			0.012	0.039	4.125	0.208	0.661	70.14	0.582
50	203.7	15.57	84.43	28.33	32.92	8.7	9.12	0.009	0.033	2.277	0.272	0.96	65.613	0.924
51	188.3	10.59	89.41	26.66	29.93			0.007	0.027	1.508	0.142	0.533	29.947	0.429
52	262.8	10.73	89.27	29.93	32.36	9.45	9.18	0.028	0.093	8.189	0.215	0.72	63.418	0.828
53	245.4	13.2	86.8	26.27	30.98	7.25	7.75	0.054	0.204	15.127	0.463	1.761	130.756	1.383
54	92.72	12.72	87.28	25.72	28.93			0.005	0.021	0.567	0.121	0.47	12.845	0.3
55	154.4	14.63	85.37	28.45	35.6			0	0	0	0.017	0.061	3.152	0.464
56	179.7	13.9	86.1	30.78	35.14	16	13.8	0	0	0	0.022	0.071	4.543	0.917
57	136.5	15.02	84.98	24.08	28.04	7.25	7.25	0	0	0	0.027	0.111	4.293	0.882
58	137.5	12.36	87.64	28.25	31.87			0.006	0.023	1.003	0.042	0.148	6.58	0.195
59	178.4	13.68	86.32	29.99	34.11	14.2	13.86							
60	142.1	8.77	91.23	27.03	29.52			0.005	0.017	0.731	0.038	0.142	5.998	0.555
61	379.1	33.2	58.51	31.26	38.2			0.007	0.022	4.502	0.241	0.771	156.19	0.934
62	273.2	35.81	54.65	30.63	38.15	10.3	8.9	0.011	0.036	5.505	0.202	0.659	100.85	1.203
63	355.6	32.03	62.15	33.27	38.85			0.005	0.016	3.057	0.165	0.497	94.603	0.61
64	416.6	33.49	57.59	33.02	38.79			0.014	0.042	10.103	0.674	2.042	487.66	2.488
65	182.6	39.9	52.26	28.56	37.27	8.2	5.05	0.007	0.025	2.495	0.122	0.427	42.561	0.797
66	359.2	29.29	60.47	35.12	40.62	15.9	13.45	0.015	0.042	8.715	0.469	1.337	278.87	1.791
67	172.1	35.38	54.95	33.55	39.34			0	0	0	0.02	0.061	6.394	0.682
68	139.9	36.59	55.83	30.84	39.99			0	0	0	0.119	0.387	29.938	0.667
69	143.6	35.16	52.22	38.98	47.34	20.8	23.69	0	0	0	0.173	0.443	47.514	0.798
70	169.8	34.93	54.97	38.72	42.64	22.5	16.8	0	0	0	0	0	0	0.289
71	150	34.65	54.7	38.9	43.7	24.8	20.9	0	0	0	0.037	0.096	10.251	1.138
72	121.5	40.75	48.97	29.81	39.09			0	0	0	0.025	0.085	6.278	0.588

	penta-cbs,ppm in dry wt. (raw fillet)	penta-cbs,ug in wet wt. (raw fillet)	hexa-cbs,ppm in wet wt. (raw fillet)	hexa-cbs,ppm in dry wt. (raw fillet)	hexa-cbs,ug in wet wt. (raw fillet)	hepta-cbs,ppm in wet wt. (raw fillet)	hepta-cbs,ppm in dry wt. (raw fillet)	hepta-cbs,ug in wet wt. (raw fillet)	octa-cbs,ppm in wet wt. (raw fillet)	octa-cbs,ppm in dry wt. (raw fillet)	octa-cbs,ug in wet wt. (raw fillet)
39	2.557	216.797	0.413	1.375	116.611	0.101	0.335	28.387	0.132	0.441	37.354
40	3.715	161.891	0.577	2.026	88.272	0.141	0.495	21.581	0.186	0.652	28.408
41	1.644	64.934	0.189	0.72	28.427	0.04	0.153	6.032	0.057	0.216	8.516
42	1.883	67.945	0.27	1.087	39.218	0.066	0.264	9.527	0.103	0.416	15.012
43	3.563	96.89	0.562	3.004	81.694	0.248	1.327	36.079	0	0	0
44	3.25	128.689	0.712	2.634	104.291	0.21	0.776	30.711	0.113	0.419	16.577
45	2.14	103.822	0.336	1.192	57.852	0.145	0.516	25.05	0.035	0.123	5.951
46	2.674	109.191	0.461	1.661	67.816	0.259	0.931	38.004	0.007	0.027	1.098
47	2.252	84.871	0.17	0.78	29.385	0.079	0.36	13.585	0.037	0.168	6.322
48	3.803	102.918	1.378	6.236	168.76	2.072	9.374	253.671	0.017	0.076	2.056
49	1.846	195.961	0.266	0.845	89.715	0.056	0.178	18.872	0.022	0.071	7.499
50	3.263	223.004	0.557	1.964	134.266	0.171	0.603	41.211	0.019	0.067	4.599
51	1.611	90.44	0.199	0.748	42.01	0.049	0.183	10.299	0.06	0.225	12.647
52	2.768	243.889	0.481	1.606	141.543	0.172	0.575	50.668	0.019	0.063	5.533
53	5.264	390.948	0.891	3.392	251.91	0.268	1.021	75.792	0.026	0.099	7.357
54	1.164	31.817	0.164	0.636	17.37	0.046	0.181	4.933	0.024	0.095	2.59
55	1.63	83.87	0.534	1.877	96.554	0.273	0.96	49.373	0.004	0.015	0.75
56	2.979	191.385	0.558	1.812	116.429	0.284	0.921	59.188	0.014	0.046	2.949
57	3.661	141.618	0.664	2.755	106.581	0.357	1.484	57.391	0.009	0.039	1.505
58	0.69	30.602	0.192	0.681	30.179	0.105	0.373	16.54	0.042	0.149	6.597
59	.	.	.	.	.	.	.	.	.	.	.
60	2.055	86.528	0.688	2.546	107.2	0.548	2.028	85.395	0.049	0.183	7.71
61	2.987	604.896	0.441	1.411	285.725	0.12	0.384	77.677	0.006	0.02	3.979
62	3.928	601.436	0.491	1.605	245.701	0.326	1.065	163.056	0	0	0
63	1.833	348.978	0.273	0.82	156.04	0.128	0.384	73.01	0.012	0.035	6.717
64	7.535	1799.802	1.072	3.246	775.337	0.47	1.423	339.979	0.017	0.051	12.3
65	2.79	278.408	0.361	1.264	126.171	0.203	0.712	71.018	0	0	0
66	5.1	1063.884	0.753	2.145	447.451	0.429	1.221	254.693	0.009	0.025	5.315
67	2.032	213.492	0.494	1.472	154.666	0.158	0.471	49.469	0.126	0.374	39.341
68	2.161	167.038	0.562	1.822	140.839	0.248	0.805	62.2	0	0	0
69	2.047	219.464	0.603	1.548	165.941	0.372	0.955	102.34	0	0	0
70	0.745	89.164	0.874	2.257	269.984	2.045	5.282	631.79	0.015	0.039	4.712
71	2.926	312.128	1.002	2.575	274.617	0.708	1.82	194.111	0.018	0.047	4.996
72	1.974	145.996	0.408	1.368	101.161	0.247	0.828	61.206	0.006	0.021	1.584

	total pcbs, ppm in wet wt. (raw fillet)	total pcbs, ppm in dry wt. (raw fillet)	total pcbs, ug in wet wt. (raw fillet)	tri-cbs, ppm in wet wt. (cooked fillet)	tri-cbs, ppm in dry wt. (cooked fillet)	tri-cbs, ug in wet wt. (cooked fillet)	tri-cbs % change (cooked fillet)	tetra-cbs, ppm in wet wt. (cooked fillet)	tetra-cbs, ppm in dry wt. (cooked fillet)	tetra-cbs, ug in wet wt. (cooked fillet)	tetra-cbs % change (cooked fillet)
39	1.606	5.35	453.528	0.01	0.025	2.143	-21.61	0.208	0.508	43.004	18.27
40	2.293	8.048	350.721	0.007	0.018	0.76	66.32	0.201	0.547	23.471	51.42
41	0.832	3.162	124.871	0.004	0.01	0.441	12	0.1	0.284	11.95	27.4
42	1.027	4.128	148.955	0.005	0.017	0.614	33.69	0.145	0.442	16.287	0.25
43	1.596	8.531	232.028	0	0	0	0	0.02	0.078	2.3	86.76
44	2.033	7.517	297.651	0.008	0.021	0.788		0.064	0.17	6.349	63.47
45	1.173	4.167	202.21	0.003	0.008	0.364	37.48	0.033	0.097	4.602	48.6
46	1.49	5.362	218.978	0	0	0	0	0.021	0.058	2.303	19.72
47	0.973	4.455	167.889	0.004	0.014	0.514	76.99	0.016	0.054	2.057	93.47
48	4.324	19.566	529.491	0	0	0	0	0.006	0.021	0.575	72.47
49	1.147	3.639	386.311	0.012	0.037	3.758	8.9	0.19	0.557	57.127	18.55
50	1.952	6.891	470.97	0.009	0.028	1.852	18.67	0.264	0.803	53.855	17.92
51	0.887	3.328	186.851	0.006	0.02	1.136	24.65	0.132	0.442	24.933	16.74
52	1.743	5.825	513.24	0.006	0.017	1.479	81.93	0.183	0.564	47.997	24.32
53	3.084	11.74	871.89	0.019	0.061	4.637	69.35	0.526	1.697	129.015	1.33
54	0.66	2.566	70.122	0.003	0.01	0.264	53.42	0.065	0.225	6.035	53.01
55	1.292	4.542	233.699	0	0	0	0	0.009	0.024	1.346	57.31
56	1.794	5.829	374.493	0	0	0	0	0.043	0.124	7.811	-71.94
57	1.939	8.05	311.387	0	0	0	0	0.048	0.172	6.595	-53.62
58	0.583	2.064	91.5	0.003	0.008	0.356	64.52	0.015	0.047	2.045	68.92
59											
60	1.884	6.971	293.562	0.004	0.013	0.526	28.02	0.032	0.109	4.559	23.99
61	1.749	5.594	1132.968	0.029	0.075	12.363	-174.61	0.344	0.9	148.75	4.76
62	2.234	7.292	1116.542	0	0	0	100	0.124	0.325	39.836	60.5
63	1.193	3.585	682.405	0.028	0.072	10.858	-255.2	0.11	0.282	42.674	54.89
64	4.735	14.339	3425.176	0.033	0.085	15.917	-57.55	0.824	2.124	396.36	18.72
65	1.49	5.218	520.654	0.005	0.013	1.041	58.27	0.113	0.303	23.702	44.31
66	3.466	9.87	2058.933	0.012	0.029	4.903	43.74	0.381	0.937	159.83	42.69
67	1.479	4.41	463.362	0	0	0	0	0.017	0.043	3.415	46.58
68	1.596	5.176	400.015	0.004	0.01	0.604		0	0	0	100
69	1.946	4.993	535.259	0	0	0	0	0.027	0.056	4.728	90.05
70	3.223	8.324	995.65	0	0	0	0	0.017	0.04	3.392	
71	2.903	7.464	796.104	0	0	0	0	0.037	0.084	6.578	35.83
72	1.275	4.276	316.226	0	0	0	0	0.021	0.053	3.042	51.54

	penta-cbs, ppm in wet wt. (cooked fillet)	penta-cbs, ppm in dry wt. (cooked fillet)	penta-cbs, ug in wet wt. (cooked fillet)	penta-cbs % change (cooked fillet)	hexa-cbs, ppm in wet wt. (cooked fillet)	hexa-cbs, ppm in dry wt. (cooked fillet)	hexa-cbs, ug in wet wt. (cooked fillet)	hexa-cbs % change (cooked fillet)	hepta-cbs, ppm in wet wt. (cooked fillet)	hepta-cbs, ppm in dry wt. (cooked fillet)	hepta-cbs, ug in wet wt. (cooked fillet)
39	0.677	1.654	140.138	35.36	0.327	0.8	67.754	41.9	0.068	0.167	14.12
40	0.788	2.144	92.036	43.15	0.374	1.018	43.704	50.49	0.079	0.214	9.179
41	0.424	1.198	50.416	22.36	0.195	0.55	23.158	18.54	0.041	0.115	4.853
42	0.467	1.423	52.382	22.91	0.221	0.672	24.742	36.91	0.042	0.128	4.709
43	0.682	2.591	76.794	20.74	0.494	1.877	55.634	31.9	0.158	0.6	17.794
44	0.49	1.291	48.228	62.52	0.208	0.548	20.462	80.38	0.085	0.224	8.383
45	0.376	1.119	53.163	48.79	0.245	0.73	34.684	40.05	0.114	0.34	16.151
46	0.646	1.794	71.403	34.61	0.444	1.232	49.028	27.7	0.21	0.584	23.246
47	0.31	1.037	39.378	53.6	0.196	0.656	24.931	15.16	0.08	0.268	10.174
48	0.89	2.9	79.992	22.28	0.886	2.885	79.598	52.83	0.484	1.577	43.505
49	0.53	1.555	159.55	18.58	0.305	0.893	91.628	-2.13	0.105	0.307	31.535
50	0.802	2.435	163.282	26.78	0.482	1.465	98.262	26.82	0.172	0.523	35.058
51	0.327	1.092	61.553	31.94	0.209	0.699	39.384	6.25	0.056	0.188	10.584
52	0.546	1.688	143.583	41.13	0.42	1.297	110.336	22.05	0.233	0.719	61.178
53	1.375	4.437	337.286	13.73	0.756	2.441	185.539	26.35	0.293	0.946	71.908
54	0.265	0.916	24.562	22.8	0.262	0.907	24.324	-40.03	0.068	0.235	6.292
55	0.462	1.298	71.352	14.93	0.543	1.525	83.811	13.2	0.625	1.755	96.456
56	0.763	2.171	137.109	28.36	0.521	1.482	93.557	19.64	0.695	1.977	124.846
57	0.765	2.728	104.411	26.27	0.637	2.271	86.924	18.44	0.414	1.477	56.541
58	0.153	0.481	21.065	31.17	0.131	0.412	18.061	40.15	0.071	0.223	9.794
59	.	.	.	.	.	.	.	.	.	.	.
60	0.29	0.983	41.258	52.32	0.207	0.7	29.37	72.6	0.054	0.181	7.614
61	0.835	2.187	361.551	40.23	0.384	1.005	166.205	41.83	0.067	0.175	28.913
62	0.805	2.11	258.341	57.05	0.418	1.096	134.219	45.37	0.32	0.839	102.762
63	0.497	1.28	193.364	44.59	0.237	0.611	92.324	40.83	0.123	0.318	47.971
64	2.685	6.921	1291.599	28.24	1.17	3.016	562.751	27.42	0.497	1.28	238.958
65	0.647	1.737	135.943	51.17	0.291	0.782	61.174	51.52	0.167	0.447	34.965
66	0.919	2.264	386.17	63.7	0.554	1.365	232.877	47.95	0.335	0.823	140.49
67	0.941	2.392	190.488	10.78	0.54	1.371	109.201	29.4	0.241	0.611	48.686
68	0.458	1.145	72.778	56.43	0.385	0.963	61.219	56.53	0.129	0.323	20.554
69	0.567	1.198	101.111	53.93	0.337	0.712	60.094	63.79	0.281	0.594	50.148
70	0.941	2.207	189.17	-112.16	0.54	1.265	108.446	59.83	0.241	0.564	48.35
71	0.841	1.924	150.668	51.73	0.937	2.143	167.834	38.88	1.033	2.365	185.165
72	0.363	0.927	53.29	63.5	0.245	0.628	35.962	64.45	0.114	0.291	16.701

	hepta-cbs % change (cooked fillet)	octa-cbs, ppm in wet wt. (cooked fillet)	octal-cbs, ppm in dry wt. (cooked fillet)	octa-cbs, ug in wet wt. (cooked fillet)	octa-cbs % change (cooked fillet)	total pcbs, ppm in wet wt. (cooked fillet)	total pcbs, ppm in dry wt. (cooked fillet)	total pcbs, ug in wet wt. (cooked fillet)	total pcbs % change (cooked fillet)
39	50.26	0.096	0.233	19.78	47.05	1.387	3.386	286.938	36.73
40	57.47	0.099	0.269	11.531	59.41	1.548	4.209	180.681	48.48
41	19.54	0.062	0.176	7.414	12.95	0.825	2.334	98.233	21.33
42	50.57	0.067	0.205	7.543	49.75	0.948	2.887	106.276	28.65
43	50.68	0.126	0.477	14.151		1.479	5.623	166.674	28.166
44	72.7	0.03	0.08	2.991	81.96	0.886	2.334	87.2	70.704
45	35.52	0.023	0.07	3.307	44.43	0.794	2.362	112.271	44.478
46	38.83	0.008	0.022	0.886	19.37	1.33	3.69	146.866	32.931
47	25.11	0.041	0.137	5.193	17.86	0.648	2.165	82.247	51.011
48	82.85	0.014	0.047	1.287	37.39	2.281	7.429	204.957	61.292
49	-67.1	0.029	0.086	8.839	-17.87	1.172	3.434	352.437	8.769
50	14.93	0.016	0.048	3.211	30.19	1.745	5.302	355.519	24.513
51	-2.76	0.018	0.059	3.347	73.54	0.748	2.501	140.936	24.573
52	-20.74	0.019	0.058	4.92	11.08	1.406	4.345	369.492	28.008
53	5.12	0.01	0.031	2.383	67.61	2.978	9.613	730.768	16.186
54	-27.56	0.018	0.064	1.709	34.03	0.681	2.356	63.186	9.891
55	-95.36	0.003	0.01	0.533	28.85	1.642	4.612	253.497	-8.472
56	-110.93	0.011	0.032	2.04	30.83	2.033	5.786	365.362	2.438
57	1.48	0.011	0.039	1.475	2	1.875	6.687	255.947	17.804
58	40.79	0.042	0.132	5.772	12.5	0.415	1.303	57.092	37.604
59									
60	91.08	0.03	0.102	4.271	44.61	0.616	2.088	87.597	70.16
61	62.78	0.001	0.003	0.466	88.29	1.66	4.344	718.247	36.6
62	36.98	0	0	0	0	1.668	4.371	535.158	52.07
63	34.29	0.004	0.009	1.386	79.36	0.999	2.572	388.577	43.06
64	29.71	0.016	0.041	7.65	37.8	5.224	13.467	2513.236	26.62
65	50.77	0	0	0	0	1.223	3.281	256.826	50.67
66	44.84	0	0	0	100	2.201	5.418	924.271	55.11
67	1.58	0.009	0.022	1.757	95.53	1.747	4.44	353.547	23.699
68	66.95	0.006	0.015	0.965		0.983	2.457	156.121	60.971
69	51	0.012	0.026	2.22		1.224	2.586	218.301	59.216
70	92.35	0.009	0.02	1.744	62.98	1.747	4.097	351.102	64.736
71	4.61	0.017	0.039	3.024	39.48	2.864	6.554	513.269	35.527
72	72.71	0.004	0.011	0.623	60.65	0.746	1.908	109.619	65.335

Appendix 4. Physical and chemical parameters of walleye harvested from Great Lakes

	fish ID (raw)	fish ID (cooked)	cooking methods	lakes	specie	skin (raw)	skin (cooked)	sex	age	length (cm)	whole wt. (gm)	degutted wt. (gm)	carcus (%)	right fillet wt. (gm)	left fillet wt. (gm)	AP yield (%)	wt. before cooking (gm)
1	2043	2587	bake	Huron	walleye	on	off	female	6	50.8	1040	600	57.69	201.8	182.1	36.91	99.6
2	7000	1327	bake	Huron	walleye	on	off	male	3	48.3	940	560	59.57	212.4	182.5	42.01	93.19
3	3571	1253	bake	Huron	walleye	on	off	male	3	45.7	960	560	58.33	205.6	189.3	41.14	103.22
4	5836	8255	bake	Huron	walleye	on	off	male	4	49.5	1130	710	62.83	235.6	250.8	43.04	121.17
5	5364	1978	bake	Huron	walleye	on	off	male	4	49.5	1230	760	61.79	263.8	246	41.45	143.48
6	7951	3703	bake	Huron	walleye	on	off	male	6	45.7	960	590	61.46	204.7	205.3	42.71	98.58
7	1525	4822	charbroil	Huron	walleye	on	off	female	6	50.8	1040	600	57.69	201.8	182.1	36.91	96.26
8	9037	9874	charbroil	Huron	walleye	on	off	male	3	48.3	1030	570	55.34	206.2	200	39.44	93.73
9	4189	6725	charbroil	Huron	walleye	on	off	male	3	45.7	960	560	58.33	205.6	189.3	41.14	107.01
10	4478	5130	charbroil	Huron	walleye	on	off	male	4	50.8	1150	670	58.26	226	258.8	42.16	111.18
11	4635	3230	charbroil	Huron	walleye	on	off	male	4	49.5	1230	760	61.79	263.8	246	41.45	103.44
12	6514	3792	charbroil	Huron	walleye	on	off	male	4	48.3	1100	700	63.64	235.2	230.7	42.35	123.1
13	1321	4332	bake	Michigan	walleye	on	off	male		45.4	690	446	64.64	173.5	172.7	50.17	78.87
14	5055	5107	bake	Michigan	walleye	on	off	male	4	47.5	860	542	63.02	210.7	215.9	49.6	109.11
15	2882	5742	bake	Michigan	walleye	on	off	male	3	41.3	620	398	64.19	145.6	173.8	51.52	77.16
16	5323	3872	bake	Michigan	walleye	on	off	male	4	46	730	470	64.38	187.7	194.7	52.38	97.46
17	3590	3728	bake	Michigan	walleye	on	off	male	5	47.7	850	524	61.65	199.6	204.5	47.54	92.23
18	1958	3180	bake	Michigan	walleye	on	off	male	5	47.3	840	520	61.9	193.2	201.7	47.01	101.9
19	8914	8094	charbroil	Michigan	walleye	on	off	male	3	45.4	690	446	64.64	173.5	172.7	50.17	90.27
20	4094	7022	charbroil	Michigan	walleye	on	off	male	4	48.5	840	526	62.62	212	203.6	49.48	101.93
21	5926	2777	charbroil	Michigan	walleye	on	off	male	3	41.3	620	398	64.19	145.6	173.8	51.52	91.12
22	1207	4325	charbroil	Michigan	walleye	on	off	male	4	46.6	760	482	63.42	197.3	185.6	50.38	78.1
23	2051	9271	charbroil	Michigan	walleye	on	off	male	5	47.7	850	524	61.65	199.6	204.5	47.54	105.84
24	8014	9725	charbroil	Michigan	walleye	on	off	male	5	49.4	865	535	61.85	221.4	216.7	50.65	97.2
25	1846	6882	deepfat fry	Michigan	walleye	on	on	male	4	48.5	840	526	62.62	212	203.6	49.48	93.3
26	4561	5622	deepfat fry	Michigan	walleye	on	on	male	4	47.5	860	542	63.02	210.7	215.9	49.6	100.08
27	9556	8570	deepfat fry	Michigan	walleye	on	on	male	4	46.6	760	482	63.42	197.3	185.6	50.38	100
28	4417	1935	deepfat fry	Michigan	walleye	on	on	male	4	44	605	394	65.12	158.6	147.8	50.64	63.41
29	1172	1198	deepfat fry	Michigan	walleye	on	on	male	5	49.4	865	535	61.85	221.4	216.7	50.65	115.47
30	8585	3145	deepfat fry	Michigan	walleye	on	on	male	4	45.5	720	482	66.94	194	185.2	52.67	93.89
31	3038	6220	bake	Erie	walleye	on	off	male	7	44.5	860	570	66.28	177.5	183	41.92	90.89
32	2181	3339	bake	Erie	walleye	on	off	male	5	48.3	1010	640	63.37	202.7	211.1	40.97	102.6
33	9231	6145	bake	Erie	walleye	on	off	male	4	46.7	960	620	64.58	211	188.8	41.65	106.88
34	9213	4509	bake	Erie	walleye	on	off	male	3	45	750	480	64	158.8	157.3	42.15	77.55
35	7929	2036	bake	Erie	walleye	on	off	male	5	47.2	970	630	64.95	186.6	194.6	39.3	103.66
36	2090	5976	bake	Erie	walleye	on	off	male	5	46.7	850	550	64.71	172.4	173.8	40.73	85.29
37	5659	2138	charbroil	Erie	walleye	on	off	male	7	44.5	860	570	66.28	177.5	183	41.92	85.74
38	6448	1459	charbroil	Erie	walleye	on	off	male	5	41.9	840	530	63.1	163.1	156	37.99	71.06

	actual fillet wt. (gm)	edible wt. (gm)	% cooking loss in fillet	% cooking yield in fillet	% solids in raw fillet	% solids in cooked fillet	% fat in raw fillet	% fat in cooked fillet	tri-cbs,ppm in wet wt. (raw fillet)	tri-cbs,ppm in dry wt. (raw fillet)	tri-cbs,ug in fillet (raw fillet)	tetra-cbs,ppm in wet wt. (raw fillet)	tetra-cbs,ppm in dry wt. (raw fillet)	tetra-cbs,ug in wet wt. (raw fillet)
1	78.8	67.14	20.88	67.41	23.49	27.92	9.44	4.25	0.009	0.04	0.925	0.178	0.758	17.727
2	77.01	69.8	17.36	74.9	22.77	32.93			0.003	0.014	0.299	0.054	0.236	5.01
3	89.05	81.01	13.73	78.48	21.45	23.97			0.002	0.01	0.225	0.066	0.307	6.807
4	103.6	96.29	14.5	79.47	22.03	24.89			0.043	0.195	5.215	0.797	3.617	96.557
5	113.56	100.93	20.85	70.34	22.82	28.4	2.45	4	0.022	0.096	3.128	0.417	1.828	59.851
6	83	76.52	15.8	77.62	21.51	25.65	1.25	0.85	0.008	0.036	0.756	0.162	0.754	15.984
7	71.86	65	25.35	67.53	22.67	29.82	2.25	2.85	0.005	0.022	0.486	0.134	0.593	12.946
8	72.3	63.53	22.86	67.78	23.01	27.49			0.006	0.028	0.608	0.125	0.543	11.719
9	83.86	77.81	21.63	72.71	21.69	26.78	0.85	1.15	0.002	0.009	0.202	0.059	0.27	6.267
10	90.24	80.01	18.83	71.96	23.84	27.27	1.95	2.25	0.005	0.021	0.559	0.138	0.579	15.351
11	79.65	73	23	70.57	22.98	28.17			0.008	0.035	0.821	0.158	0.686	16.317
12	94.59	85.14	23.16	69.16	22.53	28.45			0.02	0.089	2.47	0.152	0.676	18.743
13	58.65	51.21	25.64	64.93	22.78	27.87			0.003	0.013	0.23	0.08	0.352	6.323
14	78.88	69.65	27.71	63.83	19.47	26.36	1	1.11	0.002	0.013	0.266	0.06	0.31	6.577
15	54.04	46.15	29.96	59.81	21.05	27.66			0.015	0.072	1.165	0.378	1.798	29.202
16	65.43	60.06	32.86	61.63	20.63	29.05	1.2	1.89	0.002	0.01	0.209	0.075	0.365	7.346
17	67.99	57.39	26.28	62.22	21.34	27.09	1.35	1.6	0.002	0.011	0.221	0.086	0.403	7.926
18	75.84	66.98	25.57	65.73	21.67	27.83			0.002	0.011	0.249	0.089	0.413	9.117
19	66.1	61.77	26.78	68.43	21.54	26.81	1.75	2.1	0.003	0.016	0.31	0.076	0.352	6.846
20	77.65	71.65	23.82	70.29	21.2	25.15	0.95	1.61	0.003	0.014	0.299	0.069	0.324	6.991
21	68.09	63.03	25.27	69.17	20.19	25.55			0.018	0.092	1.684	0.287	1.419	26.11
22	53.3	46.12	31.75	59.05	20.44	27.39			0.012	0.061	0.976	0.226	1.104	17.621
23	76.14	68.74	28.06	64.95	20.68	26.21	0.7	1.4	0.002	0.012	0.258	0.066	0.321	7.025
24	59.83	51.47	38.45	52.95	21.17	31.11			0.005	0.021	0.438	0.146	0.688	14.167
25	61.83	61.83	33.73	66.27	21.09	38.01	0.85	8.4	0.002	0.012	0.23	0.061	0.287	5.652
26	63.81	63.81	36.24	63.76	20.96	39.31	1.16	9.68	0.003	0.013	0.264	0.063	0.3	6.299
27	62.87	62.87	37.13	62.87	19.75	39.14	0.8	8.6	0.003	0.014	0.273	0.08	0.404	7.973
28	38.3	38.3	39.6	60.4	21.29	43.75			0.003	0.014	0.185	0.087	0.407	5.491
29	74.4	74.4	35.57	64.43	21.31	40.35			0.004	0.02	0.491	0.136	0.637	15.673
30	58.49	58.49	37.7	62.3	21.63	43.1			0.003	0.012	0.235	0.094	0.434	8.822
31	73.92	65.95	18.67	72.56	22.45	26.73			0.001	0.005	0.112	0.033	0.148	3.024
32	80.89	72.78	21.16	70.94	21.9	27.67	1.3	1.88	0.003	0.014	0.324	0.068	0.311	6.979
33	83.83	73.94	21.57	69.18	23.87	29.14			0.004	0.015	0.393	0.085	0.355	9.056
34	57.58	52.48	25.75	67.67	22.87	30.07	2.15	3.06	0.002	0.007	0.118	0.046	0.201	3.565
35	79.24	69.48	23.56	67.03	21.92	27.56			0.007	0.033	0.758	0.151	0.687	15.618
36	65.21	60.22	23.54	70.61	21.73	27.55	1.3	1.66						
37	66.82	60.82	22.07	70.94	23.26	27.55	2.6	2.5	0.013	0.055	1.09	0.318	1.366	27.251
38	58.48	53.05	17.7	74.66	23.64	26.84			0.012	0.049	0.827	0.308	1.302	21.869

	penta-cbs,ppm in wet wt. (raw fillet)	penta-cbs,ppm in dry wt. (raw fillet)	penta-cbs,ug in wet wt. (raw fillet)	hexa-cbs,ppm in wet wt. (raw fillet)	hexa-cbs,ppm in dry wt. (raw fillet)	hexa-cbs,ug in wet wt. (raw fillet)	hepta-cbs,ppm in wet wt. (raw fillet)	hepta-cbs,ppm in dry wt. (raw fillet)	hepta-cbs,ug in wet wt. (raw fillet)	octa-cbs,ppm in wet wt. (raw fillet)	octa-cbs,ppm in dry wt. (raw fillet)
1	0.405	1.725	40.364	0.192	0.817	19.109	0.022	0.094	2.198	0.02	0.084
2	0.315	1.382	29.318	0.619	2.717	57.652	0.437	1.92	40.75	0.053	0.233
3	0.512	2.388	52.871	0.288	1.344	29.762	0.168	0.781	17.299	0.021	0.097
4	0.888	4.031	107.614	0.478	2.168	57.868	0.201	0.912	24.335	0.029	0.132
5	0.619	2.711	88.764	0.27	1.182	38.699	0.098	0.429	14.057	0.023	0.102
6	0.141	0.654	13.872	0.052	0.24	5.087	0.026	0.122	2.589	0.002	0.008
7	0.306	1.348	29.425	0.201	0.887	19.367	0.064	0.284	6.205	0.021	0.093
8	0.304	1.322	28.503	0.076	0.329	7.086	0.033	0.144	3.105	0.018	0.076
9	0.125	0.575	13.355	0.053	0.243	5.648	0.013	0.059	1.378	0.001	0.005
10	0.263	1.103	29.248	0.179	0.749	19.857	0.077	0.322	8.536	0.016	0.069
11	0.319	1.389	33.014	0.258	1.121	26.643	0.114	0.497	11.824	0.02	0.089
12	0.179	0.793	22.002	0.11	0.49	13.589	0.041	0.184	5.091	0.007	0.029
13	0.192	0.842	15.134	0.113	0.497	8.934	0.026	0.113	2.037	0.001	0.005
14	0.155	0.795	16.896	0.131	0.674	14.314	0.033	0.171	3.64	0.011	0.057
15	0.862	4.095	66.516	0.597	2.835	46.052	0.123	0.584	9.487	0	0
16	0.181	0.879	17.673	0.117	0.566	11.387	0.03	0.146	2.934	0.002	0.007
17	0.236	1.104	21.724	0.16	0.752	14.794	0.036	0.17	3.352	0.009	0.042
18	0.47	2.169	47.892	0.538	2.484	54.855	0.224	1.033	22.814	0.043	0.196
19	0.215	0.996	19.363	0.209	0.972	18.907	0.088	0.41	7.971	0.018	0.085
20	0.213	1.006	21.736	0.195	0.919	19.862	0.083	0.393	8.493	0.015	0.071
21	0.691	3.422	62.958	0.782	3.875	71.283	0.424	2.098	38.597	0	0
22	0.444	2.173	34.686	0.204	1	15.963	0.038	0.188	3.002	0	0
23	0.191	0.921	20.168	0.179	0.868	18.997	0.068	0.328	7.174	0.03	0.145
24	0.358	1.692	34.823	0.18	0.851	17.504	0.033	0.156	3.218	0.007	0.035
25	0.171	0.812	15.977	0.14	0.663	13.049	0.045	0.215	4.229	0.014	0.066
26	0.172	0.823	17.264	0.16	0.763	16.013	0.057	0.272	5.703	0.011	0.052
27	0.209	1.058	20.894	0.158	0.8	15.79	0.047	0.236	4.655	0.016	0.079
28	0.225	1.055	14.24	0.156	0.732	9.885	0.042	0.197	2.665	0.013	0.061
29	0.3	1.408	34.636	0.169	0.792	19.493	0.033	0.156	3.844	0.013	0.062
30	0.205	0.946	19.207	0.15	0.693	14.071	0.028	0.129	2.627	0.002	0.007
31	0.129	0.573	11.687	0.12	0.536	10.943	0.025	0.11	2.242	0.001	0.005
32	0.264	1.207	27.112	0.255	1.166	26.199	0.067	0.304	6.83	0.012	0.054
33	0.333	1.397	35.628	0.273	1.142	29.135	0.067	0.282	7.195	0.01	0.04
34	0.114	0.497	8.822	0.1	0.438	7.769	0.036	0.157	2.776	0.01	0.042
35	0.344	1.568	35.624	0.245	1.117	25.373	0.07	0.322	7.306	0.007	0.031
36											
37	0.742	3.189	63.604	0.343	1.474	29.4	0.065	0.279	5.572	0.022	0.096
38	0.727	3.075	51.648	0.454	1.921	32.268	0.089	0.375	6.301	0.025	0.105

	octa-cbs,ug in wet wt. (raw fillet)	total pcbs, pp in wet wt. (raw fillet)	total pcbs, pp in dry wt. (raw fillet)	total pcbs, ug in wet wt. (raw fillet)	tri-cbs, ppm in wet wt. (cooked fillet)	tri-cbs, ppm in dry wt. (cooked fillet)	tri-cbs, ug in wet wt. (cooked fillet)	tri-cbs % change (cooked fillet)	tetra-cbs, ppm in wet wt. (cooked fillet)	tetra-cbs, ppm in dry wt. (cooked fillet)	tetra-cbs, ug in wet wt. (cooked fillet)
1	1.969	0.826	3.517	82.292	0.005	0.018	0.395	57.32	0.129	0.462	10.174
2	4.945	1.481	6.502	137.974	0.003	0.008	0.207	30.81	0.051	0.155	3.919
3	2.148	1.057	4.928	109.112	0.002	0.01	0.209	7.07	0.071	0.298	6.361
4	3.516	2.435	11.055	295.106	0.027	0.109	2.817	45.99	0.528	2.121	54.685
5	3.351	1.449	6.348	207.849	0.016	0.057	1.85	40.85	0.325	1.143	36.858
6	0.16	0.39	1.813	38.449	0.003	0.012	0.257	65.95	0.112	0.435	9.268
7	2.035	0.732	3.229	70.464	0.004	0.014	0.305	37.31	0.101	0.34	7.279
8	1.647	0.562	2.442	52.668	0.005	0.019	0.377	38	0.128	0.466	9.269
9	0.127	0.252	1.162	26.977	0.002	0.008	0.171	15.27	0.061	0.228	5.117
10	1.818	0.678	2.844	75.369	0.008	0.029	0.707	-26.42	0.162	0.593	14.6
11	2.105	0.877	3.817	90.724	0.006	0.023	0.509	38.02	0.12	0.424	9.523
12	0.818	0.509	2.261	62.714	0.017	0.059	1.584	35.86	0.127	0.447	12.032
13	0.086	0.415	1.822	32.743	0.003	0.011	0.175	23.74	0.087	0.312	5.101
14	1.206	0.393	2.019	42.899	0.002	0.008	0.163	38.62	0.056	0.212	4.416
15	0	1.975	9.384	152.422	0.003	0.011	0.169	85.53	0.102	0.368	5.495
16	0.148	0.407	1.974	39.696	0.002	0.008	0.151	27.98	0.08	0.274	5.215
17	0.822	0.53	2.481	48.84	0.003	0.009	0.173	21.76	0.097	0.356	6.563
18	4.331	1.367	6.307	139.259	0.006	0.02	0.432	-73.55	0.141	0.506	10.67
19	1.653	0.61	2.831	55.051	0.006	0.022	0.395	-27.5	0.1	0.374	6.625
20	1.536	0.578	2.726	58.917	0.002	0.009	0.185	38.21	0.073	0.289	5.635
21	0	2.202	10.906	200.632	0.015	0.059	1.028	38.95	0.378	1.481	25.769
22	0	0.925	4.526	72.248	0.007	0.026	0.373	61.73	0.15	0.547	7.978
23	3.173	0.537	2.595	56.795	0.002	0.008	0.167	35.3	0.062	0.235	4.684
24	0.718	0.729	3.444	70.866	0.004	0.013	0.244	44.37	0.138	0.445	8.274
25	1.29	0.433	2.054	40.426	0.002	0.005	0.118	48.56	0.049	0.129	3.024
26	1.088	0.466	2.223	46.631	0.003	0.007	0.166	37.03	0.065	0.166	4.156
27	1.553	0.511	2.589	51.139	0.005	0.012	0.307	-12.3	0.107	0.273	6.723
28	0.829	0.525	2.466	33.295	0.002	0.004	0.071	61.63	0.067	0.154	2.576
29	1.517	0.655	3.075	75.654	0.004	0.009	0.268	45.38	0.113	0.281	8.432
30	0.142	0.48	2.221	45.104	0.003	0.007	0.185	21.24	0.099	0.229	5.763
31	0.107	0.309	1.378	28.116	0.001	0.004	0.076	32.19	0.033	0.124	2.446
32	1.222	0.669	3.056	68.666	0.003	0.009	0.207	36.24	0.071	0.257	5.762
33	1.026	0.771	3.231	82.434	0.004	0.013	0.312	20.48	0.085	0.291	7.101
34	0.737	0.307	1.341	23.788	0.003	0.009	0.149	-25.89	0.046	0.152	2.64
35	0.707	0.824	3.758	85.386	0.007	0.026	0.57	24.74	0.191	0.692	15.106
36											
37	1.907	1.502	6.46	128.824	0.01	0.036	0.672	38.37	0.267	0.969	17.845
38	1.762	1.614	6.826	114.675	0.009	0.033	0.525	36.49	0.26	0.968	15.192

	tetra-cbs	penta-cbs, pp	penta-cbs, pp	penta-cbs, ug	penta-cbs	hexa-cbs, ppm	hexa-cbs, ppm	hexa-cbs, ug	hexa-cbs	hepta-cbs, pp	hepta-cbs, pp
	% change	in wet wt.	in dry wt.	in wet wt.	% change	in wet wt.	in dry wt.	in wet wt.	% change	in wet wt.	in dry wt.
	(cooked fillet)	(cooked fillet)	(cooked fillet)	(cooked fillet)	(cooked fillet)	(cooked fillet)	(cooked fillet)	(cooked fillet)	(cooked fillet)	(cooked fillet)	(cooked fillet)
1	42.61	0.241	0.862	18.954	53.04	0.135	0.484	10.648	44.27	0.048	0.17
2	21.79	0.102	0.311	7.884	73.11	0.05	0.153	3.872	93.28	0.024	0.072
3	6.55	0.141	0.59	12.596	76.18	0.06	0.25	5.328	82.1	0.019	0.079
4	43.36	0.598	2.404	62.001	42.39	0.366	1.47	37.895	34.52	0.135	0.542
5	38.42	0.451	1.589	51.244	42.27	0.166	0.583	18.818	51.37	0.046	0.161
6	42.02	0.129	0.504	10.74	22.58	0.061	0.236	5.025	1.22	0.017	0.067
7	43.77	0.232	0.777	16.649	43.42	0.111	0.371	7.943	58.99	0.03	0.101
8	20.91	0.223	0.811	16.123	43.43	0.079	0.288	5.728	19.16	0.022	0.078
9	18.35	0.117	0.438	9.844	26.29	0.048	0.178	3.996	29.24	0.009	0.035
10	4.89	0.171	0.628	15.46	47.14	0.089	0.326	8.017	59.62	0.032	0.116
11	41.64	0.258	0.915	20.541	37.78	0.214	0.759	17.027	36.09	0.092	0.326
12	35.81	0.147	0.515	13.863	36.99	0.088	0.31	8.338	38.64	0.033	0.115
13	19.32	0.2	0.717	11.724	22.53	0.115	0.413	6.751	24.43	0.028	0.101
14	32.86	0.158	0.6	12.466	26.22	0.128	0.485	10.079	29.59	0.033	0.125
15	81.18	0.299	1.079	16.133	75.75	0.165	0.596	8.905	80.66	0.037	0.133
16	29	0.182	0.626	11.906	32.63	0.127	0.437	8.301	27.1	0.03	0.104
17	17.21	0.224	0.826	15.211	29.98	0.202	0.745	13.718	7.27	0.045	0.166
18	-17.04	0.626	2.248	47.449	0.93	0.314	1.127	23.781	56.65	0.048	0.173
19	3.24	0.236	0.882	15.624	19.31	0.193	0.718	12.728	32.68	0.029	0.11
20	19.39	0.195	0.777	15.175	30.19	0.126	0.5	9.76	50.86	0.034	0.136
21	1.31	0.572	2.239	38.951	38.13	0.307	1.201	20.892	70.69	0.123	0.481
22	54.72	0.275	1.005	14.676	57.69	0.182	0.666	9.717	39.13	0.056	0.204
23	33.33	0.174	0.664	13.256	34.27	0.141	0.539	10.762	43.35	0.09	0.345
24	41.59	0.357	1.149	21.386	38.59	0.174	0.56	10.432	40.4	0.029	0.093
25	46.49	0.137	0.361	8.477	46.94	0.118	0.311	7.299	44.06	0.04	0.106
26	34.02	0.171	0.435	10.921	36.74	0.135	0.345	8.645	46.01	0.041	0.105
27	15.67	0.243	0.62	15.264	26.95	0.143	0.366	8.999	43.01	0.036	0.093
28	53.08	0.195	0.446	7.478	47.49	0.169	0.386	6.464	34.61	0.037	0.084
29	46.2	0.299	0.741	22.244	35.78	0.155	0.383	11.506	40.97	0.036	0.089
30	34.67	0.216	0.501	12.625	34.27	0.157	0.365	9.191	34.68	0.032	0.075
31	19.1	0.122	0.458	9.044	22.62	0.127	0.474	9.371	14.37	0.027	0.103
32	17.44	0.274	0.989	22.136	18.35	0.215	0.776	17.378	33.67	0.05	0.182
33	21.59	0.332	1.14	27.844	21.85	0.275	0.943	23.044	20.91	0.068	0.232
34	25.96	0.138	0.458	7.934	10.07	0.111	0.368	6.379	17.9	0.035	0.115
35	3.28	0.391	1.42	31.003	12.97	0.22	0.798	17.433	31.29	0.067	0.243
36											
37	34.51	0.597	2.167	39.896	37.28	0.243	0.882	16.243	44.75	0.048	0.176
38	30.53	0.577	2.151	33.762	34.63	0.308	1.149	18.03	44.12	0.049	0.181

	hepta-cbs, ug in wet wt. (cooked fillet)	hepta-cbs % change (cooked fillet)	octa-cbs, ppm in wet wt. (cooked fillet)	octal-cbs, ppm in dry wt. (cooked fillet)	octa-cbs, ug in wet wt. (cooked fillet)	octa-cbs % change (cooked fillet)	total-pcbs, pp in wet wt. (cooked fillet)	total-pcbs, pp in dry wt. (cooked fillet)	total-pcbs, ug in wet wt. (cooked fillet)	total-pcbs % change (cooked fillet)
1	3.745	-70.39	0.034	0.122	2.685	-36.38	0.591	2.118	46.6	43.37
2	1.824	95.52	0.016	0.047	1.2	75.73	0.246	0.746	18.906	86.3
3	1.677	90.31	0.012	0.051	1.082	49.63	0.306	1.277	27.253	75.02
4	13.985	42.53	0.021	0.086	2.21	37.14	1.676	6.732	173.593	41.18
5	5.183	63.13	0.015	0.054	1.732	48.3	1.019	3.587	115.685	44.34
6	1.425	44.95	0.005	0.019	0.398	-148.92	0.327	1.274	27.114	29.48
7	2.159	65.21	0.008	0.026	0.568	72.11	0.486	1.629	34.901	50.47
8	1.556	49.89	0.007	0.027	0.541	67.17	0.465	1.69	33.594	36.22
9	0.776	43.7	0.001	0.004	0.099	21.68	0.239	0.891	20.003	25.85
10	2.845	66.67	0.011	0.039	0.962	47.1	0.472	1.731	42.591	43.49
11	7.313	38.16	0.016	0.057	1.289	38.78	0.706	2.504	56.2	38.05
12	3.088	39.34	0.005	0.018	0.495	39.48	0.417	1.464	39.4	37.17
13	1.651	18.95	0.001	0.002	0.035	59.32	0.434	1.556	25.438	22.31
14	2.596	28.68	0.002	0.009	0.193	83.97	0.379	1.439	29.914	30.27
15	1.994	78.98	0.009	0.034	0.502	0	0.614	2.221	33.198	78.22
16	1.984	32.39	0.001	0.003	0.06	59.02	0.422	1.453	27.618	30.43
17	3.066	8.56	0.009	0.033	0.603	26.66	0.579	2.135	39.333	19.47
18	3.644	84.03	0.004	0.016	0.337	92.21	1.138	4.089	86.313	38.02
19	1.944	75.61	0.051	0.19	3.37	-103.8	0.616	2.296	40.686	26.09
20	2.647	68.83	0.014	0.056	1.092	28.92	0.444	1.766	34.494	41.45
21	8.372	78.31	0	0	0	0	1.395	5.461	95.013	52.64
22	2.984	0.61	0.021	0.076	1.112	0	0.691	2.524	36.84	49.01
23	6.884	4.04	0.022	0.083	1.664	47.55	0.491	1.875	37.417	34.12
24	1.731	46.2	0.008	0.025	0.459	36.04	0.711	2.285	42.525	39.99
25	2.489	41.15	0.007	0.019	0.453	64.89	0.354	0.93	21.86	45.93
26	2.644	53.65	0.011	0.027	0.673	38.08	0.426	1.085	27.205	41.66
27	2.292	50.75	0.013	0.033	0.815	47.51	0.547	1.398	34.401	32.73
28	1.41	47.1	0.01	0.022	0.368	55.68	0.48	1.096	18.366	44.84
29	2.658	30.85	0.006	0.015	0.453	70.15	0.612	1.518	45.562	39.78
30	1.885	28.26	0.003	0.008	0.19	-36.68	0.51	1.184	29.843	33.83
31	2.033	9.33	0.001	0.004	0.079	26.32	0.312	1.167	23.049	18.02
32	4.084	40.21	0.008	0.028	0.627	48.73	0.621	2.243	50.193	26.9
33	5.662	21.31	0.011	0.039	0.943	8.03	0.774	2.657	64.907	21.26
34	1.992	28.25	0.01	0.033	0.565	23.43	0.341	1.135	19.657	17.37
35	5.296	27.51	0.007	0.026	0.573	18.99	0.883	3.204	69.981	18.04
36										
37	3.233	41.98	0.018	0.065	1.196	37.27	1.184	4.296	79.084	38.61
38	2.846	54.83	0.006	0.021	0.337	80.89	1.209	4.504	70.693	38.35

Appendix 4. Physical and chemical parameters of walleye harvested from Great Lakes

	fish ID (raw)	fish ID (cooked)	cooking methods	lakes	specie	skin (raw)	skin (cooked)	sex	age	length (cm)	whole wt. (gm)	degutted wt. (gm)	carcus (%)	right fillet wt. (gm)	left fillet wt. (gm)	AP yield (%)	wt. before cooking (gm)
39	1618	1160	charbroil	Erie	walleye	on	off	male	4	46.7	960	620	64.58	211	188.8	41.65	78.89
40	2752	6847	charbroil	Erie	walleye	on	off	male	4	46.5	760	510	67.11	163.5	160.7	42.66	83.49
41	4711	5041	charbroil	Erie	walleye	on	off	male	5	47.2	970	630	64.95	186.6	194.6	39.3	88.7
42	6344	6014	charbroil	Erie	walleye	on	off	male	7	48.3	970	810	83.51	211.6	185.2	40.91	90.58

	actual fillet wt. (gm)	edible wt. (gm)	% cooking loss in fillet	% cooking yield in fillet	% solids in raw fillet	% solids in cooked fillet	% fat in raw fillet	% fat in cooked fillet	tri-cbs,ppm in wet wt. (raw fillet)	tri-cbs,ppm in dry wt. (raw fillet)	tri-cbs,ug in fillet (raw fillet)	tetra-cbs,ppm in wet wt. (raw fillet)	tetra-cbs,ppm in dry wt. (raw fillet)	tetra-cbs,ug in wet wt. (raw fillet)
39	62.91	56.46	20.26	71.57	22.54	28.01			0.003	0.014	0.257	0.087	0.385	6.854
40	64.28	57.62	23.01	69.01	22.04	26.32			0.003	0.013	0.246	0.075	0.339	6.239
41	74.47	68.17	16.04	76.85	21.73	25.66	0.85	1.84	0.004	0.019	0.368	0.09	0.412	7.943
42	67.95	61.48	24.98	67.87	21.65	28.33	1.7	3.02	0.009	0.043	0.851	0.186	0.857	16.813

	penta-cbs,ppm	penta-cbs,ppm	penta-cbs,ug	hexa-cbs,ppm	hexa-cbs,ppm	hexa-cbs,ug	hepta-cbs,ppm	hepta-cbs,ppm	hepta-cbs,ug	octa-cbs,ppm	octa-cbs,ppm
	in wet wt.	in dry wt.	in wet wt.	in wet wt.	in dry wt.	in wet wt.	in wet wt.	in dry wt.	in wet wt.	in wet wt.	in dry wt.
	(raw fillet)	(raw fillet)	(raw fillet)	(raw fillet)	(raw fillet)	(raw fillet)	(raw fillet)	(raw fillet)	(raw fillet)	(raw fillet)	(raw fillet)
39	0.335	1.484	26.39	0.385	1.707	30.361	0.069	0.305	5.415	0.011	0.047
40	0.378	1.714	31.536	0.248	1.125	20.698	0.065	0.294	5.419	0.014	0.065
41	0.23	1.06	20.431	0.168	0.775	14.929	0.089	0.409	7.884	0.008	0.037
42	0.685	3.162	62.004	0.554	2.559	50.181	0.142	0.654	12.827	0.029	0.132

	octa-cbs,ug in wet wt. (raw fillet)	total pcbs, pp in wet wt. (raw fillet)	total pcbs, pp in dry wt. (raw fillet)	total pcbs, ug in wet wt. (raw fillet)	tri-cbs, ppm in wet wt. (cooked fillet)	tri-cbs, ppm in dry wt. (cooked fillet)	tri-cbs, ug in wet wt. (cooked fillet)	tri-cbs % change (cooked fillet)	tetra-cbs, ppm in wet wt. (cooked fillet)	tetra-cbs, ppm in dry wt. (cooked fillet)	tetra-cbs, ug in wet wt. (cooked fillet)
39	0.836	0.889	3.943	70.113	0.003	0.01	0.177	31.11	0.07	0.25	4.405
40	1.195	0.783	3.55	65.333	0.004	0.015	0.259	-5.27	0.077	0.292	4.943
41	0.71	0.589	2.712	52.264	0.004	0.015	0.289	21.42	0.034	0.132	2.529
42	2.583	1.604	7.407	145.259	0.008	0.029	0.566	33.55	0.171	0.605	11.647

	tetra-cbs % change (cooked fillet)	penta-cbs, pp in wet wt. (cooked fillet)	penta-cbs, pp in dry wt. (cooked fillet)	penta-cbs, ug in wet wt. (cooked fillet)	penta-cbs % change (cooked fillet)	hexa-cbs, ppm in wet wt. (cooked fillet)	hexa-cbs, ppm in dry wt. (cooked fillet)	hexa-cbs, ug in wet wt. (cooked fillet)	hexa-cbs % change (cooked fillet)	hepta-cbs, pp in wet wt. (cooked fillet)	hepta-cbs, pp in dry wt. (cooked fillet)
39	35.74	0.305	1.088	19.18	27.32	0.322	1.149	20.25	33.3	0.074	0.265
40	20.77	0.385	1.462	24.738	21.56	0.224	0.851	14.393	30.46	0.055	0.208
41	68.17	0.169	0.659	12.592	38.37	0.197	0.766	14.637	1.96	0.031	0.122
42	30.73	0.616	2.174	41.845	32.51	0.488	1.723	33.159	33.92	0.131	0.463

	hepta-cbs, ug	hepta-cbs	octa-cbs, ppm	octal-cbs, ppm	octa-cbs, ug	octa-cbs	total-pcbs, pp	total-pcbs, pp	total-pcbs, ug	total-pcbs
	in wet wt.	% change	in wet wt.	in dry wt.	in wet wt.	% change	in wet wt.	in dry wt.	in wet wt.	% change
	(cooked fillet)	(cooked fillet)	(cooked fillet)	(cooked fillet)	(cooked fillet)	(cooked fillet)	(cooked fillet)	(cooked fillet)	(cooked fillet)	(cooked fillet)
39	4.671	13.74	0.009	0.032	0.566	32.32	0.783	2.795	49.248	29.76
40	3.513	35.17	0.018	0.07	1.185	0.88	0.763	2.898	49.031	24.95
41	2.335	70.39	0.017	0.065	1.243	-75.18	0.452	1.76	33.624	35.67
42	8.909	30.54	0.028	0.098	1.892	26.75	1.442	5.092	98.017	32.52

Appendix 5. Physical and chemical parameters of white bass harvested from Great Lakes

	fish ID (raw)	fish ID (cooked)	cooking methods	lakes	specie	skin (raw)	skin (cooked)	sex	age	length (cm)	whole wt. (gm)	degutted wt. (gm)	carcus (%)
1	8274	1384	pan fry	Huron	white bass	on	off	female	3	33.0	520	330	63.46
2	7183	9813	pan fry	Huron	white bass	on	off	female	4	34.3	500	330	66.00
3	2062	7952	pan fry	Huron	white bass	on	off	female	3	33.0	430	.	.
4	7991	2363	pan fry	Huron	white bass	on	off	female	2	27.9	270	170	62.96
5	6142	8420	pan fry	Huron	white bass	on	off	female	2	27.9	270	180	66.67
6	8695	6012	pan fry	Huron	white bass	on	off	female	2	33.0	300	190	63.33
7	4211	3137	pan fry	Erie	white bass	on	off	male	3	31.8	460	280	60.87
8	1632	2169	pan fry	Erie	white bass	on	off	male	4	32.4	530	320	60.38
9	3501	2600	pan fry	Erie	white bass	on	off	male	2	26.7	290	170	58.62
10	4820	3763	pan fry	Erie	white bass	on	off	male	3	30.5	900	520	57.78
11	4627	8777	pan fry	Erie	white bass	on	off	male	3	30.5	740	440	59.46
12	7784	8406	pan fry	Erie	white bass	on	off	male	2	34.3	1140	680	59.65

	right fillet wt. (gm)	left fillet wt. (gm)	AP yield (%)	wt. before cooking (gm)	actual fillet wt. (gm)	edible wt. (gm)	% cooking loss in fillet	% cooking yield in fillet	% solids in raw fillet	% solids in cooked fillet	% fat in raw fillet	% fat in cooked fillet
1	93.9	92.4	35.83	90.10	73.54	64.39	18.38	71.47	25.01	30.73	.	.
2	74.2	80.9	31.02	83.33	67.87	60.21	18.55	72.25	22.59	28.35	.	.
3	69.7	76.0	33.88	79.02	67.15	59.26	15.02	74.99	22.73	26.75	1.65	3.14
4	44.7	46.6	33.81	49.90	40.00	35.37	19.84	70.88	23.22	29.05	.	.
5	50.0	47.9	36.26	50.75	43.80	38.44	13.69	75.74	24.20	28.30	3.88	3.60
6	48.3	53.1	33.80	56.55	48.22	43.33	14.73	76.62	23.12	27.73	2.18	2.80
7	82.7	83.7	36.17	83.40	68.60	59.64	17.75	71.51	21.80	25.44	3.80	4.00
8	90.9	91.5	34.42	91.20	75.90	67.03	16.78	73.50	24.73	28.93	.	.
9	52.7	53.7	36.69	53.62	39.70	34.63	25.96	64.58	23.83	32.06	.	.
10	66.5	70.0	15.17	69.10	54.12	47.44	21.68	68.65	23.70	30.26	3.80	5.33
11	60.0	60.8	16.32	59.40	47.14	40.60	20.64	68.35	22.88	29.87	.	.
12	92.5	88.8	15.90	87.63	65.90	55.54	24.80	63.38	24.90	32.18	5.55	6.10

	tri-cbs,ppm in wet wt. (raw fillet)	tri-cbs,ppm in dry wt. (raw fillet)	tri-cbs,ug in fillet (raw fillet)	tetra-cbs,ppm in wet wt. (raw fillet)	tetra-cbs,ppm in dry wt. (raw fillet)	tetra-cbs,ug in wet wt. (raw fillet)	penta-cbs,ppm in wet wt. (raw fillet)	penta-cbs,ppm in dry wt. (raw fillet)	penta-cbs,ug in wet wt. (raw fillet)
1	0.037	0.149	3.361	0.626	2.502	56.382	0.925	3.697	83.298
2	0.009	0.039	0.726	0.353	1.564	29.433	0.958	4.241	79.829
3	0.009	0.038	0.689	0.246	1.08	19.406	0.615	2.708	48.632
4	0.006	0.025	0.288	0.163	0.66	7.651	0.359	1.545	17.897
5	0.002	0.009	0.106	0.087	0.358	4.4	0.234	0.969	11.895
6	0.003	0.013	0.169	0.117	0.506	6.609	0.246	1.062	13.89
7	0.003	0.016	0.292	0.085	0.391	7.115	0.448	2.053	37.324
8	0.012	0.048	1.082	0.243	0.982	22.145	0.733	2.962	66.815
9	0.013	0.056	0.716	0.232	0.973	12.429	0.435	1.826	23.33
10	0.007	0.03	0.498	0.212	0.896	14.678	0.718	3.028	49.595
11	0.009	0.039	0.527	0.193	0.843	11.461	0.542	2.37	32.209
12	0.003	0.013	0.287	0.103	0.412	8.988	0.348	1.397	30.475

	hexa-cbs,ppm in wet wt. (raw fillet)	hexa-cbs,ppm in dry wt. (raw fillet)	hexa-cbs,ug in wet wt. (raw fillet)	hepta-cbs,ppm in wet wt. (raw fillet)	hepta-cbs,ppm in dry wt. (raw fillet)	hepta-cbs,ug in wet wt. (raw fillet)	octa-cbs,ppm in wet wt. (raw fillet)	octa-cbs,ppm in dry wt. (raw fillet)	octa-cbs,ug in wet wt. (raw fillet)
1	0.378	1.512	34.074	0.107	0.427	9.626	0.038	0.15	3.388
2	0.47	2.079	39.129	0.141	0.622	11.716	0.059	0.262	4.93
3	0.381	1.677	30.128	0.119	0.524	9.408	0.052	0.228	4.098
4	0.157	0.676	7.824	0.044	0.188	2.184	0.014	0.059	0.679
5	0.155	0.64	7.859	0.05	0.207	2.548	0.019	0.077	0.943
6	0.127	0.55	7.195	0.051	0.219	2.869	0.011	0.048	0.626
7	0.333	1.527	27.754	0.105	0.482	8.763	0.014	0.066	1.194
8	0.611	2.065	46.57	0.174	0.705	15.905	0.025	0.1	2.265
9	0.268	1.123	14.347	0.097	0.408	5.219	0.012	0.05	0.635
10	0.696	2.935	48.062	0.257	1.085	17.767	0.034	0.143	2.334
11	0.523	2.288	31.093	0.188	0.82	11.141	0.027	0.119	1.611
12	0.289	1.159	25.285	0.087	0.351	7.662	0.015	0.061	1.333

	total-cbs, ppm in wet wt. (raw fillet)	total-cbs, ppm in dry wt. (raw fillet)	total-cbs, ug in wet wt. (raw fillet)	tri-cbs, ppm in wet wt. (cooked fillet)	tri-cbs, ppm in dry wt. (cooked fillet)	tri-cbs, ug in wet wt. (cooked fillet)	tri-cbs % change (cooked fillet)	tetra-cbs, ppm in wet wt. (cooked fillet)	tetra-cbs, ppm in dry wt. (cooked fillet)
1	2.11	8.437	190.129	0.024	0.077	1.732	48.48	0.353	1.147
2	1.989	8.806	165.763	0.009	0.031	0.592	18.46	0.284	1
3	1.422	6.256	112.361	0.007	0.024	0.438	36.46	0.2	0.748
4	0.732	3.152	36.523	0.004	0.016	0.171	40.46	0.156	0.636
5	0.547	2.26	27.752	0.001	0.005	0.062	41.24	0.053	0.188
6	0.555	2.399	31.36	0.003	0.012	0.157	7.58	0.107	0.387
7	0.989	4.534	82.441	0.001	0.006	0.097	66.61	0.068	0.266
8	1.697	6.863	154.781	0.013	0.044	0.96	11.31	0.226	0.78
9	1.057	4.436	56.676	0.009	0.029	0.365	48.96	0.167	0.521
10	1.924	8.117	132.934	0.01	0.032	0.527	-5.89	0.224	0.74
11	1.482	6.478	88.042	0.007	0.025	0.347	34.04	0.164	0.548
12	0.845	3.393	74.031	0.003	0.008	0.177	38.48	0.087	0.27

	tetra-cbs, ug in wet wt. (cooked fillet)	tetra-cbs % change (cooked fillet)	penta-cbs, ppm in wet wt. (cooked fillet)	penta-cbs, ppm in dry wt. (cooked fillet)	penta-cbs, ug in wet wt. (cooked fillet)	penta-cbs % change (cooked fillet)	hexa-cbs, ppm in wet wt. (cooked fillet)	hexa-cbs, ppm in dry wt. (cooked fillet)	hexa-cbs, ug in wet wt. (cooked fillet)
1	25.923	54.02	0.544	1.77	39.994	51.99	0.46	1.495	33.792
2	19.25	34.6	0.694	2.448	47.111	40.99	0.316	1.112	21.391
3	13.428	30.8	0.472	1.766	31.717	34.78	0.279	1.042	18.725
4	6.234	18.52	0.378	1.302	15.133	15.44	0.13	0.448	6.211
5	2.327	47.12	0.181	0.639	7.927	33.36	0.196	0.693	8.592
6	5.176	21.68	0.242	0.872	11.669	16.06	0.148	0.534	7.134
7	4.639	34.8	0.373	1.466	25.58	31.46	0.282	1.108	19.336
8	17.135	22.62	0.694	2.398	52.652	21.2	0.464	1.604	35.23
9	6.628	46.67	0.337	1.051	13.382	42.64	0.203	0.632	8.042
10	12.119	17.43	0.687	2.269	37.164	25.06	0.66	2.181	35.71
11	7.71	32.73	0.499	1.67	23.513	27	0.497	1.663	23.409
12	5.736	36.18	0.308	0.957	20.297	33.4	0.277	0.862	18.276

	hexa-cbs % change (cooked fillet)	hepta-cbs, ppm in wet wt. (cooked fillet)	hepta-cbs, ppm in dry wt. (cooked fillet)	hepta-cbs, ug in wet wt. (cooked fillet)	hepta-cbs % change (cooked fillet)	octa-cbs, ppm in wet wt. (cooked fillet)	octal-cbs, ppm in dry wt. (cooked fillet)	octa-cbs, ug in wet wt. (cooked fillet)	octa-cbs % change (cooked fillet)
1	0.83	0.087	0.283	6.406	33.45	0.044	0.145	3.271	3.46
2	45.33	0.098	0.346	6.658	43.17	0.042	0.15	2.883	41.53
3	37.85	0.075	0.28	5.024	46.59	0.026	0.097	1.739	57.57
4	33.4	0.034	0.118	1.371	37.24	0.016	0.056	0.655	3.56
5	-9.32	0.097	0.343	4.248	-66.72	0.018	0.064	0.787	16.51
6	0.85	0.044	0.159	2.126	25.89	0.009	0.032	0.425	32.08
7	30.33	0.088	0.346	6.035	31.14	0.015	0.058	1.007	15.62
8	24.35	0.157	0.543	11.913	25.1	0.029	0.1	2.197	3.01
9	43.94	0.146	0.455	5.792	-10.98	0.003	0.009	0.119	81.21
10	25.7	0.248	0.819	13.406	24.55	0.042	0.14	2.288	1.98
11	24.71	0.179	0.6	8.454	24.12	0.024	0.079	1.11	31.12
12	27.72	0.09	0.279	5.919	22.74	0.019	0.059	1.253	5.97

	total-cbs, ppm in wet wt. (cooked fillet)	total-cbs, ppm in dry wt. (cooked fillet)	total-cbs, ug in wet wt. (cooked fillet)	total-cbs % change (cooked fillet)
1	1.511	4.917	111.118	41.56
2	1.442	5.087	97.884	40.95
3	1.058	3.957	71.071	36.75
4	0.719	2.476	28.774	21.22
5	0.547	1.932	23.943	13.72
6	0.553	1.995	26.677	14.93
7	0.826	3.249	56.695	31.23
8	1.582	5.469	120.086	22.42
9	0.865	2.697	34.329	39.43
10	1.87	6.18	101.215	23.86
11	1.369	4.584	64.544	26.69
12	0.784	2.436	51.659	30.22

Appendix 6. Pearson correlation matrix on age, length and weight of the great lakes fish procurement

	Pearson Correlation Coefficient		
Fish Species	Age/Length	Age/Wt.	Length/Wt.
Carp	0.605***	0.612***	0.855***
Chinook salmon	0.862***	0.840***	0.909***
Lake trout	-0.651***	-0.665***	0.972***
Walleye	0.187	0.186	0.709***
White bass	0.500	0.154	0.456

*** indicated the significant Pearson correlation ($P < 0.001$).

Appendix 7. Wilcoxon Signed Ranks Test on solids and lipid content of raw and cooked fish fillets from the Great Lakes

Fish species	Z Test[1] on Solids	Z Test on Lipids
Carp	6.031***	3.429***
Chinook salmon	7.961***	2.326**
Lake trout	6.970***	1.814*
Walleye	5.646***	3.076***
White bass	3.059***	1.782*

[1] Z= (sum of signed ranks)/ square root (sum of squared ranks)

* indicated the significant Wilcoxon Signed Ranks Test (P < 0.1).

** indicated the significant Wilcoxon Signed Ranks Test (P < 0.05).

*** indicated the significant Wilcoxon Signed Ranks Test (P < 0.005).

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