



Significance of toxaphene in Great Lakes fish consumption advisories



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ABSTRACT

Fish consumption advisories have been issued for the Great Lakes generally based on the most restrictive contaminant. For the Canadian waters of the Great Lakes, toxaphene causes minor restrictions only in Lake Superior, i.e., 3% of the total (restrictive + unrestrictive) advisories issued. However, the significance of the hazard posed by toxaphene in fish is not clear since more restrictive advisories due to other priority contaminants may be masking the less restrictive advisories. We simulated fish consumption advisories for the Toxaphene-only scenario by neglecting the presence of contaminants other than toxaphene, and compared with the issued advisories as well as with the published simulated Mercury-only scenario. Restrictive advisories under the Toxaphene-only scenario compared to the issued toxaphene related advisories would increase from 3% to 14%, <1% to 4%, and 0% to 2% for Lakes Superior, Huron and Ontario, respectively, and remain at 0% for Lake Erie. For Lake Superior, most of the restrictive Toxaphene-only advisories would be for fatty fish. Overall, the Toxaphene-only advisories would be significantly less restrictive compared to the issued advisories, and also generally less restrictive compared to the Mercury-only scenario. These results suggest that toxaphene is less of a concern than PCBs (including dioxin-like PCBs), dioxins–furans and mercury from the perspective of health risk to humans consuming Great Lakes fish; elevated toxaphene is mainly a concern for human consumers of Lake Superior fatty fish. Our results suggest that the routine monitoring of toxaphene in other Canadian waters of the Great Lakes and Lake Superior lean/pan fish could be discontinued.

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Introduction

Toxaphene was used as an insecticide in the southern and midwest U.S. agricultural areas (Muir et al., 2006; Murphy et al., 2012). Toxaphene use began in the late 1940s, peaked in the early 1970s, and was banned in Canada and the United States in the mid-1980s (Muir et al., 2006; Murphy et al., 2012). Long-range atmospheric transport of toxaphene applied in these areas resulted in the detection of toxaphene in various matrices including fish of the Great Lakes (Muir et al., 2006; Murphy et al., 2012). Toxaphene is a probable human carcinogen, and can damage the immune system, liver and kidneys (ATSDR, 2010). The major route for human exposure to toxaphene is through fish consumption (ATSDR, 2010).

For most Canadian waters of the Great Lakes, fish consumption advisories are issued by the Province of Ontario based on benchmarks developed using Health Canada's health protection guidelines, which are applied to a series of priority contaminants measured in individual fish species, fish size classes and water bodies. For a given sample set of fish species, size classes and water body, the contaminant which

produces the most restrictive advice (i.e., lowest number of recommended meals per month) is used and identified as the contributing contaminant in the Guide to Eating Ontario Sport Fish (OMOE, 2009). For the Canadian waters of the Great Lakes, PCBs and dioxins/furans currently generate most (84–99%) of the restrictive advisories. In contrast, toxaphene contributes 8% to restrictive advisories for Lake Superior fish only and is not listed as a contributor to the restrictive advisories for Lakes Huron, Erie or Ontario fish (OMOE, 2009). However, if PCBs and dioxins–furans decreased below their fish consumption advisory benchmarks, it is not clear whether current fish toxaphene levels would replace some, most or all current PCB- and dioxin-driven fish consumption restrictions with similar or less restrictive advice. This research question is supported by the fact that the contribution of toxaphene to restrictive fish consumption advisories for the Canadian waters of the Great Lakes dropped significantly between 2003 and 2005: from 71% to 6% in Superior, 10% to <1% in Huron, and 2% to 0% in Ontario (Environmental Defence, 2009; OMOE, 2003, 2005). This drop was largely due to adoption of more stringent fish consumption benchmarks for PCBs and dioxins/furans (OMOE, 2003, 2005).

The reduction in the contribution of toxaphene to restrictive fish consumption advisories gives a false impression that the toxaphene levels significantly declined below its benchmark levels for fish consumption advisories. A recent study has reported declines in the fish toxaphene levels between the mid-1990s and 2010 (Xia et al., 2012).

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However, it is currently unclear how these declines would be reflected in risk to human fish consumers.

The goal of this study was to examine the significance of current toxaphene levels in fish consumption advisories for the Canadian waters of the Great Lakes. Fish consumption advisories were simulated for a Toxaphene-only scenario by neglecting the presence of contaminants other than toxaphene. This approach isolated the true impact of toxaphene levels in fish on consumption advisories because advisory information under the Toxaphene-only scenario would not be superseded by more restrictive advice information generated by other contaminants present within fish samples. These simulated Toxaphene-only advisories were then compared with the corresponding published fish consumption advisories, which are issued by the government authority based on the most restrictive contaminant out of all contaminants measured. In general, published restrictive advisories for the Great Lakes are largely due to elevated levels of PCBs (including dioxin-like PCBs) and dioxins/furans. The Toxaphene-only advisories were then compared with the previously published advisories for the Mercury-only scenario (Bhavsar et al., 2011) in which the presence of all contaminants except mercury was neglected.

Methods

Dataset

The Great Lakes are shared by the U.S. and Canada. For the Canadian waters of the Great Lakes, fish consumption advisories have been consistent because for the most part only one government agency, Ontario Ministry of the Environment (OMOE), is responsible for collecting comprehensive contaminant monitoring data for edible portion of fish and then issuing consumption advisories. On the U.S. side, eight state agencies along with tribal agencies have monitored contaminants in edible portion of fish and issued advisories. For this study we used the data collected by OMOE considering consistency of monitoring data and the fish consumption advisory benchmarks used.

The OMOE, in partnership with Ontario Ministry of Natural Resources, monitors contaminants in sport fish collected from the Canadian waters of Lakes Superior, Huron (including North Channel and Georgian Bay), Erie and Ontario (OMOE, 2013). The samples are analyzed for a variety of contaminants including toxaphene, mercury, polychlorinated biphenyls or PCBs, dioxins/furans, and other organochlorine pesticides as well as contaminants of emerging concern such as polybrominated diphenyls (PBDEs) and perfluorinated alkyl substances (PFASs) (OMOE, 2013). The monitoring results are used to advise the public on safe consumption of sport fish.

Advisory calculations

The Great Lakes cover a wide geographical area (244,100 km²) and contaminant levels in fish can vary from one location to another. To capture spatial variability, the Canadian waters of the Great Lakes have been divided by OMOE into 60 smaller areas (called blocks) for consumption advisory purposes (Fig. 1). The OMOE fish consumption advisory benchmarks are generally based on the tolerable daily intake (TDI) values developed by the Food Directorate of Health Canada. Separate benchmarks are used for the general population (GP) and the sensitive population (SP) of children and women of child-bearing age. The benchmarks used for the 2009–2010 edition of the Guide to Eating Ontario Sport Fish have been presented by Bhavsar et al. (2011). Toxaphene related 2009–2010 OMOE advisory benchmarks have been listed in Table 1. Due to limitations of the current state of the science on toxicity of chemical mixtures, the advisories are issued based on the most restrictive contaminant. The dioxin and dioxin-like chemicals such as furans and dioxin-like PCBs are considered as a group and assessed using a 2,3,7,8-TCDD Toxic Equivalent (TEQ) concentration concept, which allows converting concentrations of various chemicals in a

group into one value that is equivalent to concentration of the most toxic chemical in the group (van den Berg et al., 2006).

It is well established that levels of major contaminants of concern for the Great Lakes generally increase with fish size and vary by fish species (Gewurtz et al., 2011a; Gewurtz et al., 2011b). To incorporate such variability in the advisory calculations, the OMOE calculates levels of each contaminant for each 5-cm length interval of every fish species with available data using power regressions of fish length versus contaminant concentration. These values are then compared with the advisory benchmarks, and population- (i.e., GP or SP), location-, species- and size-specific advisories are issued in terms of recommended meals per month (8 = unrestricted, 4, 2, 1, 0 = do not eat). Because not all fish species are found at various locations in the Great Lakes, the availability of advisories for fish species also varies (Bhavsar et al., 2011).

When historical advisories for fish lengths outside of a size range for the latest advisories exist, these older measurements are considered to expand the size range in the new advisories (Bhavsar et al., 2011). The decision to include older data/advisories depends on various factors including the size range in question (larger or smaller fish size), how the older advisories compare with the new advisories, as well as the general temporal trends of the contaminant that are causing the restrictive advisories. An example of the advisory tables listed in the 2009–2010 Guide to Eating Ontario Sport Fish (Guide) has been included in the Electronic Supplementary Information (SI) Table S1.

Toxaphene-only advisories

For the Toxaphene-only advisory scenario, we neglected the presence of all other chemicals in the Great Lakes fish. The advisories were calculated using the same OMOE approach as described above. In addition to the fish species for which OMOE issues fish consumption advisories (OMOE, 2013), we also considered alewife, American eel, humpback (banker) lake trout, lake chub, mooneye, shorthead redhorse, and other species of the sucker family to better understand the toxaphene significance even though the OMOE no longer issue advisories for these species mainly because of their low populations or it is illegal to keep them.

Using 21,800 fish toxaphene measurements for the main basins of the Great Lakes, 4716 advisories were simulated for 446 species–location combinations at each 5 cm fish length interval. For statistical comparison purpose, each advisory was classified into one of the three categories: (1) no restriction (i.e., “unrestricted” = 8 meals/month), (2) partial restriction (1, 2 and 4 meals/month), and (3) complete restriction (0 meal/month or “do not eat”). The total restrictions are the sum of the partial and complete restrictions. The statistics are then presented as a percentage of simulated advisories in the abovementioned three categories on a lake-wide basis for all species combined as well as individual species, and block-specific basis for all species combined. The advisories statistics for the Toxaphene-only scenario are also compared with the published advisories (OMOE, 2009) as well as the Mercury-only scenario presented by Bhavsar et al. (2011). Because currently there are no restrictions for consuming fish from the connecting rivers of the Great Lakes due to elevated toxaphene levels as advised by OMOE, measurements collected from these locations were analyzed separately. Toxaphene measurements for 2480 fish samples collected recently (2000–2012; SI Table S2) were assessed against the OMOE fish consumption advisory benchmarks to investigate potential risk to human consumers of these fish.

Results

Basin-wide advisories

The Toxaphene-only advisories were substantially less restrictive compared to the overall published 2009–2010 advisories (Figs. 2 and 3). A comparison of percentage of the simulated advisories that



Fig. 1. Map of the Canadian waters of the Great Lakes showing blocks within lakes considered by the OMOE for fish consumption advisory purposes by the OMOE (2009).

are restrictive (i.e., *do not eat* plus partially restrictive) for the GP under the Toxaphene-only scenario versus the 2009–2010 published advisories stands at 14% vs. 39% for Superior, 4% vs. 43% for Huron, 0% vs. 59% for Erie, and 2% vs. 66% for Ontario (Fig. 2). The corresponding differences for the SP were even more dramatic at 14% vs. 52% for Superior, 4% vs. 54% for Huron, 0% vs. 64% for Erie, and 2% vs. 71% for Ontario (Fig. 2). It is noteworthy that the percentages of simulated lake wide Toxaphene-only advisories that are restrictive are the same for the SP and GP, while they differ for the published advisories. This highlights that most of the simulated Toxaphene-only advisories are at lower restriction level in the partial restriction category. When compared to the Mercury-only scenario, the Toxaphene-only advisories are generally less restrictive except for the GP advisories for Lake Superior (Figs. 2 and 3). This suggests that mercury, in addition to PCBs and dioxins–furans, is generally more of a concern than toxaphene from the perspective of health risk to humans consuming fish from the Canadian waters of the Great Lakes.

Table 1

Concentration ranges (in ng/g on a wet weight basis) for toxaphene-related fish consumption advisories used by the OMOE for the sensitive and general populations for the advisories published in the 2009–2010 Guide to Eating Ontario Sport Fish (OMO, 2009).

Meals/month	General population	Sensitive population
8	0–235	0–235
4	235–469	235–469
2	469–939	
1	939–1877	
0	>1877	>469

Basin-wide *do not eat* advisories (i.e., complete restrictions) for the GP under Toxaphene-only scenario would be only 2% for Lake Superior and <1% for Lakes Huron, Erie and Ontario (Fig. 2). The corresponding *do not eat* advisories for the SP would be 7% for Superior, 1% for Huron and <1% for Erie and Ontario. The unrestricted advisories for Lakes Superior, Huron, Erie and Ontario for both GP and SP would be 86%, 96%, ~100% and 97%, respectively (Fig. 2).

Approximately 3%, <1%, 0% and 0% of the advisories for Lakes Superior, Huron, Erie and Ontario, respectively, published in the 2009–2010 Guide had some level of restriction because of elevated toxaphene levels (Fig. 3). Under the Toxaphene-only scenario, these values increase to 14%, 4% and 2% for Lakes Superior, Huron and Ontario, respectively, and remain the same at 0% for Lake Erie (Fig. 3).

The spatial trend of restrictive advisories in the 2009–2010 Guide is in the order of Lakes Superior < Huron < Erie < Ontario (Fig. 3). In contrast, the trend under Toxaphene-only scenario would be Erie < Huron ≈ Ontario < Superior (Fig. 3). This trend is similar to the trend observed for the Mercury-only scenario (Fig. 3). These results reflect reported lower toxaphene levels in fish from Lake Ontario compared to Lake Superior and vice versa for PCB that is the major restrictive contaminant for the Great Lakes fish consumption advisories (Bhavsar et al., 2011; Bhavsar et al., 2007; Xia et al., 2012).

Regional- and species-specific advisories

An analysis of Toxaphene-only advisories on block-by-block basis for each lake suggests that the restrictive advisories for Lake Superior are more widespread than those for Lakes Huron and Ontario (Fig. 4).

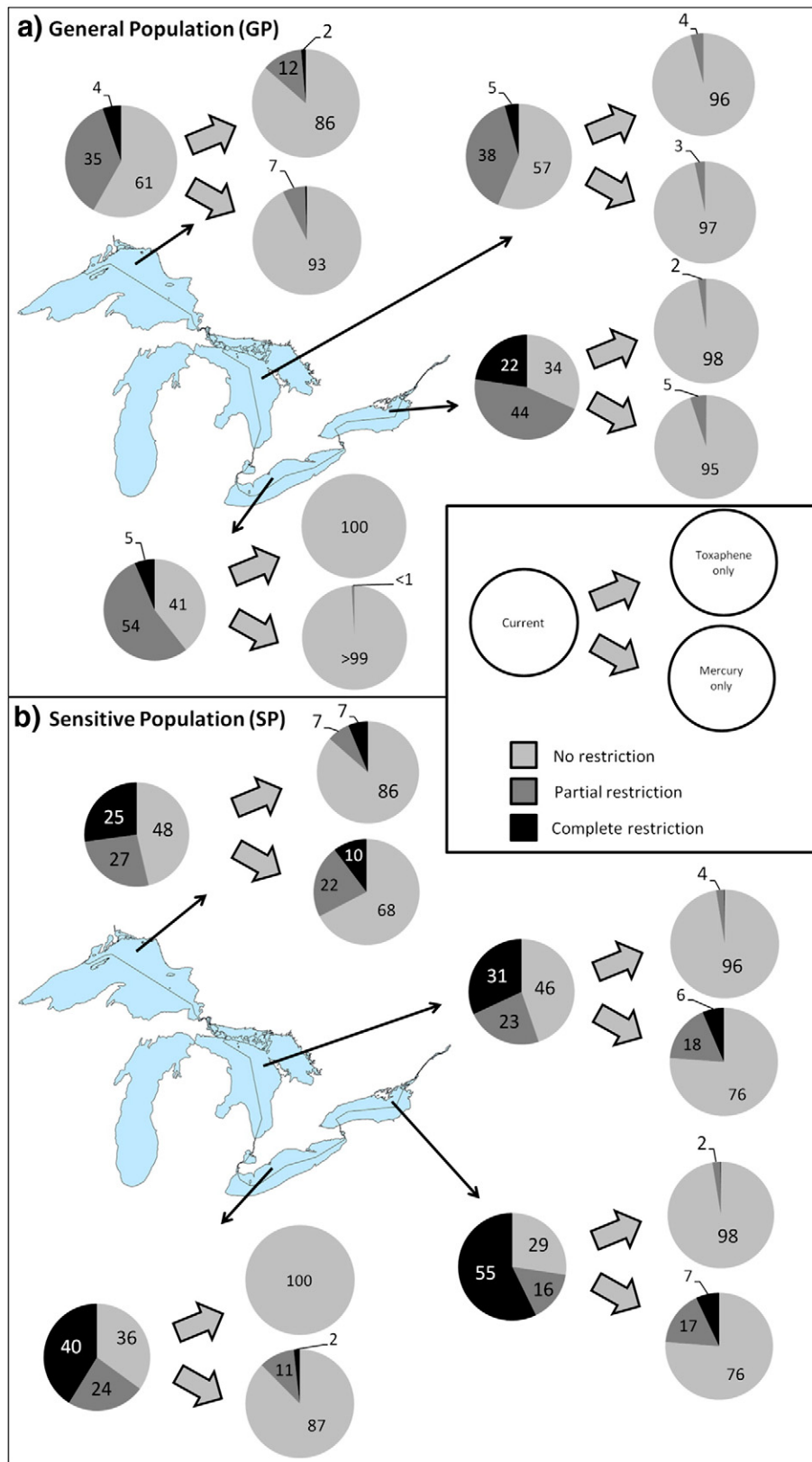


Fig. 2. Breakdown (in %) of overall lake-wide fish consumption advisories for three scenarios (current, Toxaphene-only scenario, and Mercury-only scenario) for the (a) general and (b) sensitive populations for Lakes Superior, Huron (including North Channel and Georgian Bay), Erie (without the St. Clair River–Lake St. Clair–Detroit River corridor) and Ontario (including Niagara River but excluding the St. Lawrence River). Values are rounded. Values are from OMOE (2009) and Bhavsar et al. (2011) for the current (2009–2010) advisories, from this study for the Toxaphene-only scenario, and from Bhavsar et al. (2011) for the Mercury-only scenario.

All blocks of Lake Superior, except LS8 – Jackfish Bay, would have some restrictions advised on the consumption of sport fish (Fig. 4). Total restrictions (i.e., partial plus complete – *do not eat* – restrictions) are

greatest for LS9 (i.e., open water from Sewell Point to Cape Gargantua). However, the highest proportion of the *do not eat* GP advisories would be for LS7 (open water from Schreiber Point to Sewell Point) and SP

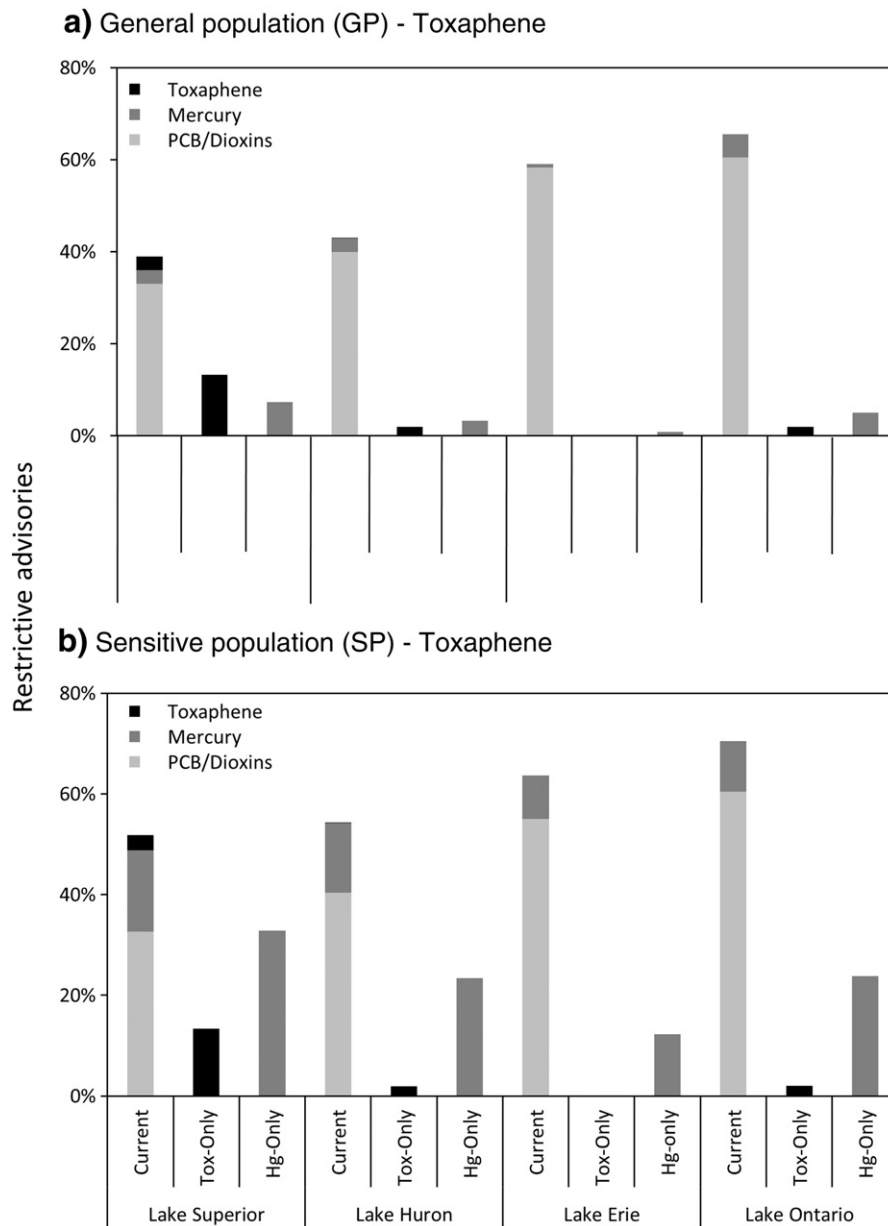


Fig. 3. Percentage of total restrictive (partial + complete *do not eat* restrictions) fish consumption advisories for the general (a) and sensitive (b) populations based on the contaminants causing the restrictions in the 2009–2010 published advisories, and Toxaphene-only and Mercury-only scenarios. Values for the Mercury-only scenario are from Bhavsar et al. (2011).

advisories would be for LS5 (i.e., open water from Pie Island to Schreiber Point). About 13–42% of the advisories for Lake Superior open water blocks (LS 5, 7, 9 and 10) would have some restrictions.

All Lake Huron blocks except open water H1, H2 and H3, would have negligible restrictions on fish consumption under the Toxaphene-only scenario (Fig. 4). Although overall toxaphene levels in Lake Huron fish do not seem to be a major health risk for human fish consumers based on the benchmarks established for toxaphene by the OMOE (Fig. 2), the central block H2 in Lake Huron would have some *do not eat* advisories due to elevated levels of toxaphene (Fig. 4).

We also compared the percentages of unrestricted advisories under the Toxaphene-only scenario to those in the 2009–2010 published advisories (Fig. 5). All Great Lakes blocks, except Lake Superior block 10 (open water from south of Cape Gargantua to Batchawana Bay), showed improvements under the Toxaphene-only scenario (Fig. 5). For Lake Superior block 10, unrestricted advisories would decline marginally from 93% to 88%. For all other Lake Superior blocks, except block 8a, unrestricted advisories would increase by 20 to 110% (Fig. 5). Lake Superior block 8a (Peninsula Harbour) is one of the Areas of Concern identified in

the Great Lakes. For this block, only 16% of the 2009–2010 published advisories were unrestricted while 96% of the advisories under the Toxaphene-only scenario were unrestricted. As such, this block would have an improvement of about 500% if other contaminants of concern would decline below their fish consumption advisory benchmarks (Fig. 5). Lake Huron blocks would have 40–150% improvement in the unrestricted advisories under the Toxaphene-only scenario (Fig. 5). In contrast, improvements in the Lakes Erie and Ontario blocks would be more dramatic because these lakes currently have relatively more restrictive advisories and the advisories under the Toxaphene-only scenario were minimally restrictive (Figs. 2, 3). For Lake Erie, the improvements would range from 55 to 430% (Fig. 5). Lake Ontario would have similar improvements ranging 44–400%, except for four blocks that would have very significant improvements (block 3, Hamilton Harbour, 25 fold from 4% to 100%; block 5, Credit River, 18 fold from 5% to 87%; block 6, open water northwestern Lake Ontario, 12 fold from 8% to 94%; block 7, Ganaraska River, from 0% to 100%; Fig. 5).

Regional differences in the results for the Toxaphene-only scenario are reflected in the species-specific findings with all or most of the

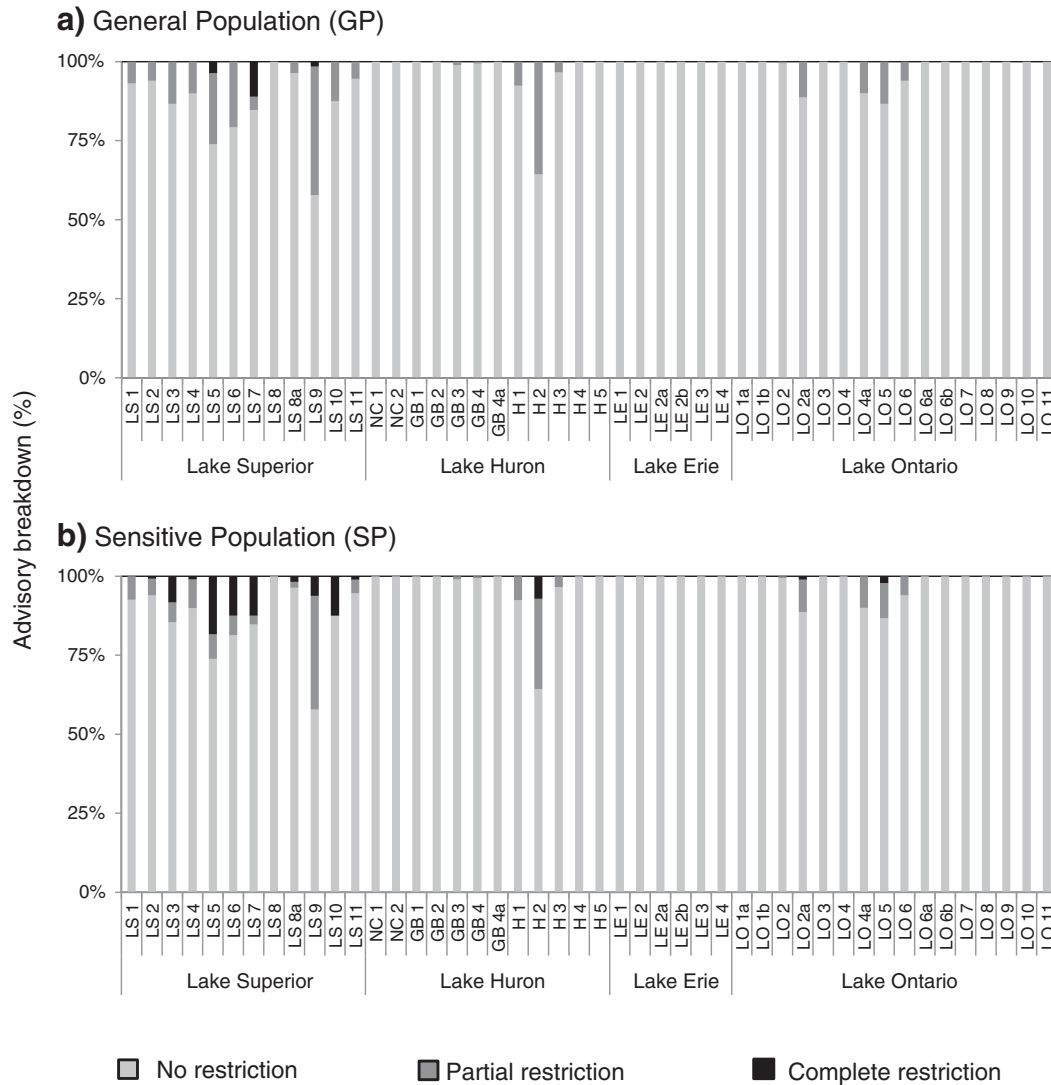


Fig. 4. Block-specific breakdown of Toxaphene-only based fish consumption advisories for the general (a) and sensitive (b) populations.

species sampled from Lakes Huron, Erie and Ontario having none or minor restrictive advisories under this scenario (Fig. 6). For Lake Superior, most of the restrictive advisories would be for fatty fish such as siscowet, lake trout, salmon and cisco (lake herring) (Fig. 6). Other Lake Superior species including walleye and yellow perch, which are very popular sport fish in Ontario, would not have any *do not eat* advisories (Fig. 6). These findings are in contrast to those for the Mercury-only scenario (Bhavsar et al., 2011), for which species such as walleye, bass and yellow perch would have more restrictive advisories compared to fatty species such as trout and salmon.

Toxaphene in fish from the connecting rivers

Out of total 2480 measurements, only 2 measurements for common carp collected in 2002 from the upper Niagara River exceeded the first consumption advisory level of 235 ng/g. Further, all 35 subsequent measurements for common carp samples collected from this river segment in 2004, 2006 and 2009 were below the method detection limit of 50 ng/g. These results show that there is no apparent health risk due to elevated toxaphene levels for the human consumers of fish from these locations.

Significance

Overall, the results suggest that toxaphene is a concern only for Lake Superior fish consumers. These results are in agreement with observed higher toxaphene levels in Lake Superior compared to other Great Lakes (Muir et al., 2006; Xia et al., 2012). The major portion of toxaphene loadings to the Great Lakes has been proposed to have originated from remote locations from where toxaphene was atmospherically transported to the Great Lakes region (Muir et al., 2006). Air–water exchange of toxaphene through wet and dry deposition, which was enhanced by a larger surface area and lower temperature of Lake Superior, resulted in the highest levels in various matrices of Lake Superior including fish (Muir et al., 2006). Because the toxaphene levels in fish from the Great Lakes (including Lake Superior) are declining (Muir et al., 2006; Xia et al., 2012), we can expect a lower significance of toxaphene in future Great Lake fish consumption advisories.

Lake Erie currently does not have any restriction on consuming fish due to elevated toxaphene and would not have any restrictive advisory caused by toxaphene even if the currently restrictive contaminants PCBs, dioxins–furans and mercury decline below their benchmarks. As such, we conclude that monitoring of toxaphene in Lake Erie fish can be discontinued.

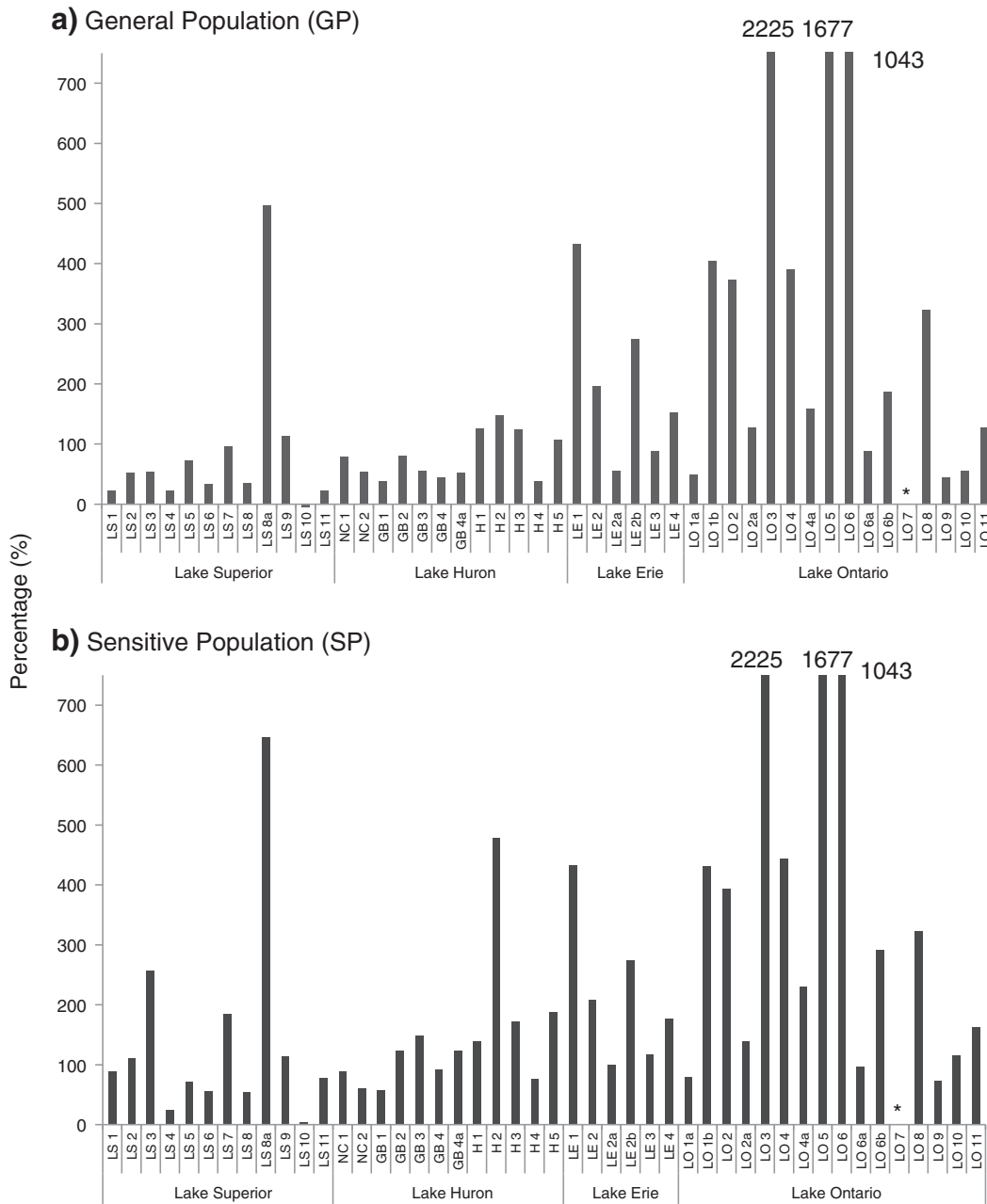


Fig. 5. Percentage improvements in the block-specific unrestricted advisories for the (a) general and (b) sensitive populations under the Toxaphene-only scenario compared to the published advisories in the 2009–2010 Guide to Eating Ontario Sport Fish (OMOE, 2009). The improvement in the LO7 (* in table) unrestricted advisories was from 0% unrestricted to 100% unrestricted.

For Lakes Ontario and Huron, only selected species such as lake trout, common carp and channel catfish collected from certain locations such as open water Lake Huron blocks H1, H2 and H3, and Jordon Harbour, Credit River, Toronto Harbour and open water block 6 in Lake Ontario had elevated fish toxaphene levels that would result in a restrictive advisory. A close examination of monitoring data revealed that those species–locations were last sampled during the 1980s/1990s. Because the toxaphene levels in fish from the Great Lakes have generally declined during the last three decades (Xia et al., 2012), it is likely that the levels in these species–locations with restrictive advisories under the Toxaphene-only scenario have also declined below the concern levels. Further, these species (except lake trout) are not popular sport fish consumed by Ontarians (Awad, 2006). Finally, the most restrictive fish consumption advisories for Lakes Ontario and Huron are due to elevated PCBs, especially for fatty species. As such, discontinuation of monitoring

toxaphene levels in Lake Huron and Ontario fish in addition to Lake Erie fish should free up resources for other monitoring needs (e.g., contaminants of emerging concern).

For the GP fish consumption advisories published in 2003–2004, 25.8% of the Lake Superior advisories had some level of restriction with 71% of those advisories attributed to elevated toxaphene levels (OMOE, 2003, 2005). The corresponding values for 2005–2006 were 36.8% for advisories with some restriction and 6% of those attributed to toxaphene (OMOE, 2003, 2005). This suggests that the restrictive advisories due to elevated toxaphene dropped from 18% (i.e., 71% of 25.8%) in 2003–2005 to 2.2% (6% of 36.8%) in 2005–2006. As mentioned earlier, this dramatic drop was largely due to adoption of more stringent fish consumption benchmarks for PCBs and dioxins/furans (OMOE, 2003, 2005). In 2009–2010, elevated toxaphene required 3.1% (i.e., 8% of 38.5%) of all GP advisories with some level of restriction (OMOE,

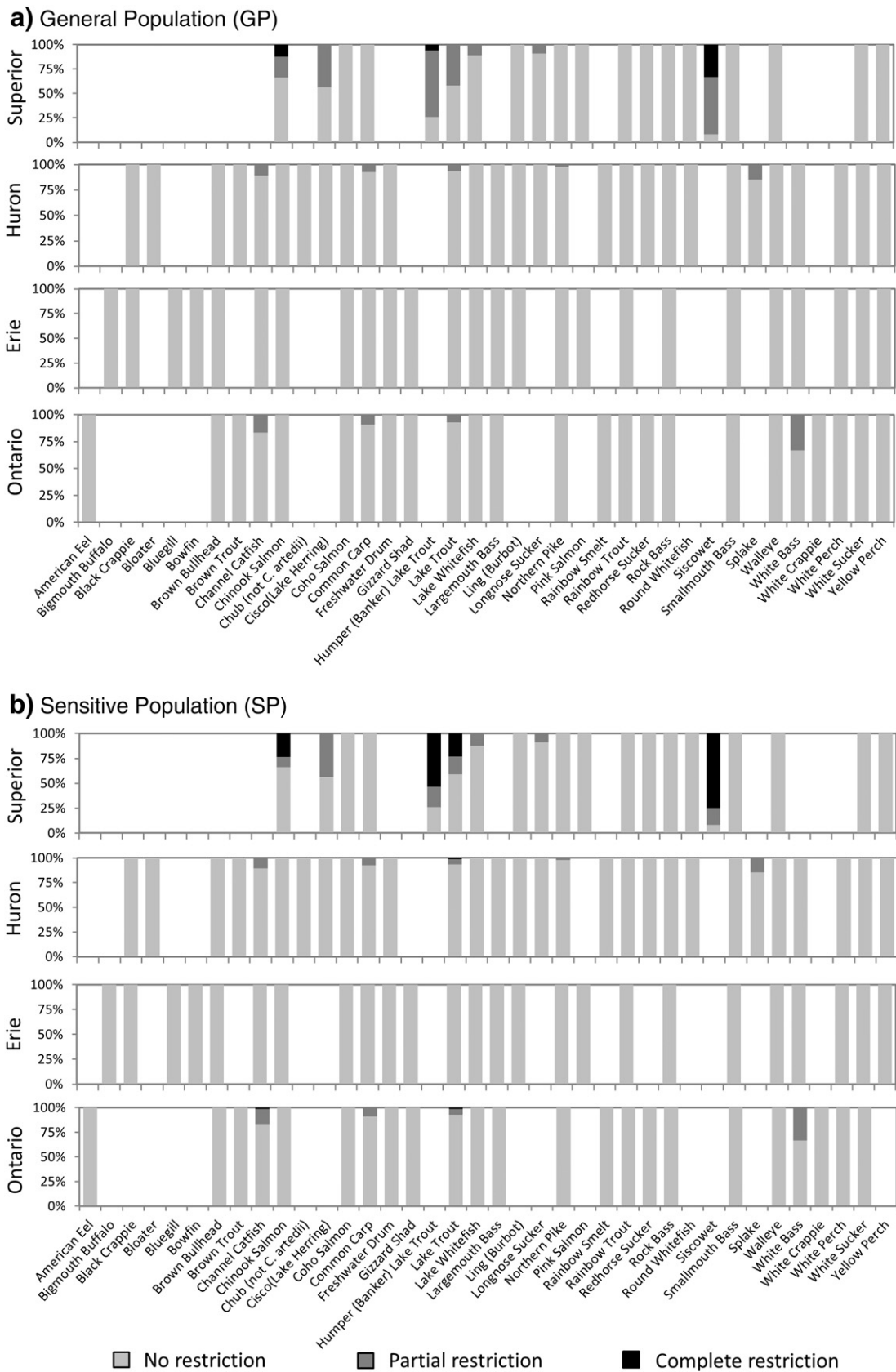


Fig. 6. Species-specific breakdown of the fish consumption advisories under the Toxaphene-only scenario presented in this study for the (a) general and (b) sensitive populations for the combined blocks of Lakes Superior, Huron (including North Channel and Georgian Bay), Erie (excluding the St. Clair River–Lake St. Clair–Detroit River corridor) and Ontario (including the Niagara River but excluding the St. Lawrence River). The absence of data bars indicates the unavailability of data to generate simulated advisories.

2009). Under the Toxaphene-only scenario explored in this study, this contribution increases to 14%. These results highlight that the values for contribution of individual contaminants in restrictive advisories for the Great Lakes that are published in the Guide to Eating Ontario Sport Fish should not be used to identify significance of individual contaminant in posing risks to fish consuming humans.

The results presented here are based on the fish consumption advisory benchmarks used by the OMOE, Canada. Because OMOE is the only government authority for issuing fish consumption advisories for a major portion of the Canadian waters of the Great Lakes, the results presented here are applicable to management actions for the Canadian side. Very limited published information is available on toxaphene-related fish consumption advisory benchmarks used by various U.S. Great Lakes state agencies. For Ohio, the benchmarks of 250 ng/g to change an advisory from unrestricted to 4 meals/month and 1094 ng/g to change an advisory from 4 meals/month to 1 meal/month are similar to those being used by OMOE and utilized in this study (Table 1; Ohio, 2010). As such, the results may also be relevant to management options for the U.S. side. However, adoption of different benchmarks, especially lower, more conservative values, would impact the significance of toxaphene in risk of consuming Great Lakes fish presented here.

In summary, based on the current OMOE fish consumption benchmarks, we studied the significance of toxaphene levels in fish from the Canadian waters of the Great Lakes by neglecting the presence of other contaminants. Although toxaphene would cause more restrictive fish consumption advisories than it is currently causing in the presence of more restrictive contaminants (e.g., PCBs), the extent of restrictive advisories under the Toxaphene-only scenario would be relatively lower than the currently issued advisories. Fatty fish from Lake Superior is generally a concern for human consumers because of elevated toxaphene levels. The results suggest that the routine monitoring of toxaphene in fish from Canadian waters of the Great Lakes, except for fatty fish from Lake Superior, could be discontinued to free up resources to address other monitoring needs.

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not indicate endorsement of the contents of this material by the Government of Ontario.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <http://dx.doi.org/10.1016/j.jglr.2013.12.017>.

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Supplementary Information:

Significance of Toxaphene in Great Lakes fish consumption advisories

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List of Tables

Table S1: An illustration of fish consumption advisory table in the 2009-2010 Guide to Eating Ontario Sport Fish published by the OMOE (OMOE, 2009). A key describing how to read the advisory table is provided on the next page. 3

Table S2: Number of toxaphene measurements for fish samples collected between 2000 and 2012 from the connecting channels of the Great Lakes. See footnote for the description of various river segments. 5

Table S1: An illustration of fish consumption advisory table in the 2009-2010 Guide to Eating Ontario Sport Fish published by the OMOE (OMOE, 2009). A key describing how to read the advisory table is provided on the next page.

	Length/ Longueur	15 6"	20 8"	25 10"	30 12"	35 14"	40 16"	45 18"	50 20"	55 22"	60 24"	65 26"	70 28"	75 30"	>75 cm >30"
Lake Huron H1 / Lac Huron H1															
Chinook Salmon ^{2,7,8,9} Saumon quinnat ^{2,7,8,9}				8				4						2	
Rainbow Trout ² Truite arc-en-ciel ²									8					4	
Lake Trout ^{2,10} Truite de lac ^{2,10}				8	4		2							1	
Splake ² Truite moulac ²				8		4				2			1		
Bloater ² Cisco de fumage ²				8			1								
Yellow Perch ² Perchaude ²				8			0								
Whitefish ^{2,10,11} Grand corégone ^{2,10,11}				8				4						2	
Cisco ¹ Cisco ¹				8			2								
Channel Catfish ^{2,7,8,9} Barbue de rivière ^{2,7,8,9}									2					1	
Carp ^{2,7} Carpe ^{2,7}										1				0	
Ling ² Lotte ²									8					4	
White Sucker ² Meunier noir ²								8						0	
Rainbow Smelt ² Éperlan arc-en-ciel ²		8													

Key to reading advisory tables in the 2009-2010 Guide to Eating Ontario Sport Fish (OMOE, 2009).

The diagram shows a sample advisory table with the following structure:

- 1:** Region label: Southern Ontario/Sud de l'Ontario
- 2:** Water body name: Lake / Lac
- 3:** Latitude and longitude: 4537/7942
- 4:** Township/Canton, County/Cité
- 5:** Fish species: Northern Pike⁵, Brochet⁵, Walleye², Doré²
- 6, 7:** Length/Longueur: 15 6", 20 8", 25 10", 30 12", 35 14", 40 16", 45 18", 50 20", 55 22", 60 24", 65 26", 70 28", 75 30", >75 cm >30"
- 8:** Recommended number of meals per month (values: 8, 4, 0)
- 9:** Advice for general population (values: 8, 4, 0)
- 10:** Advice for women of childbearing age and children under 15 (values: 8, 4, 0)
- 11, 12:** No advice provided for these lengths (indicated by empty cells)
- 13:** Contaminant identifier (values: 5, 13, 11, 12)

- 1** The tables are divided into three sections by region: Southern Ontario, Northern Ontario and the Great Lakes, as noted along the side of each page.
- 2** Water body name.
- 3** The latitude and longitude; for example, 4537/7942 refers to 45°37'N 79°42'W
- 4** The township, county, territorial district or geographical description of the water body.
- 5** Name of fish species .
- 6, 7** The total length of the fish is measured, from the tip of the nose to the tip of the tail. The fish length is expressed in both centimetres and inches at the top and bottom of the tables.
- 8** Recommended number of meals per month
- 9** Advice for general population
- 10** Advice for women of childbearing age and children under 15 (sensitive population)
- 11, 12** No advice provided for these lengths
- 13** The number identifies the contaminant or group of contaminants for which the fish was tested

Table S2: Number of toxaphene measurements for fish samples collected between 2000 and 2012 from the connecting channels of the Great Lakes. See footnote for the description of various river segments.

	St. Marys River	Upper St. Clair River and Lake St. Clair River		Lower St. Clair River	Lake St. Clair	Upper Detroit River	Lower Detroit River	Upper Niagara River	Lower Niagara River	St. Lawrence R. 12	St. Lawrence R. 13	St. Lawrence R. 14	St. Lawrence R. 15	St. Lawrence R. 16	Grand Total
Alewife		1													1
American Eel									2						2
Atlantic Salmon	7														7
Black Crappie				5	10										15
Bluegill				8	24				4	6					42
Brown Bullhead	8	9		5	10			25	45	25	5	10			142
Channel Catfish					70	18									88
Chinook Salmon	25								6						31
Cisco(Lake Herring)	10														10
Common Carp		15	13	21	59	30	10	55	35	13	14				265
Freshwater Drum		5	3	15	35	22	31	20	16						147
Gizzard Shad		10	1	9											20
Lake Trout									19						19
Largemouth Bass		6		5	40	5	5	23	30	32			16		162
Northern Pike	5	1	7	10	54			6	12	35		12	31		173
Pink Salmon	18														18
Pumpkinseed					25					13			8		46
Rainbow Trout	4							15	10						29
Redhorse Sucker		5	5	6				8	8						32

Rock Bass		5	10	5	34	10	5	16	18	22		5	7		137
Smallmouth Bass		5	4	2	45			22	32	28		20	48		206
Walleye	4	11	4	6	100	59	41			28	4	10	33	5	305
White Bass		10	1		60	115	90								276
White Perch					30	11	20	7							68
White Sucker	6	14	15	2				15							52
Yellow Perch	5	10	10	12	21	5	5	20	29	21		5	44		187
Grand Total	92	107	73	111	617	275	207	232	266	223	23	62	187	5	2480

River Segment Descriptors:

Upper St. Clair River – from Lake Huron to just north of Ethyl Corp

Middle St. Clair River – from Ethyl Corp./Stag Island to just north of Lambton Generating Station

Lower St. Clair River – from Lambton Generating Station to Lake St. Clair

Upper Detroit River – from Lake St. Clair to Fighting Island

Lower Detroit River – from south of Fighting Island to Lake Erie

Upper Niagara River – Canadian waters from Fort Erie to above the falls

Lower Niagara River – Canadian waters from below the falls to Lake Ontario

St. Lawrence R. 12 – Thousand Islands area: St. Lawrence River from east of Kingston to Brockville

St. Lawrence R. 13 – Middle Corridor: St. Lawrence River from east of Brockville to Iroquois

St. Lawrence R. 14 – Lake St. Lawrence: St. Lawrence River from east of Iroquois to the Moses Saunders Dam

St. Lawrence R. 15 – Lake St. Francis: St. Lawrence River from downstream of the Moses Saunders Dam to Quebec border

St. Lawrence R. 16 – Raisin River: spawning run in the river including offshore area to 10 metre depth