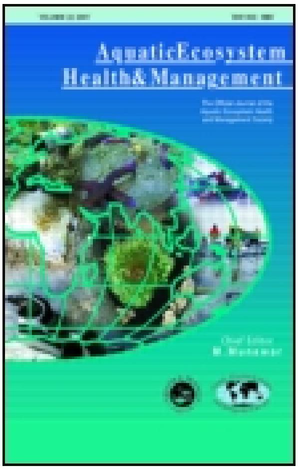

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Assessing the fish consumption beneficial use impairment in the Bay of Quinte

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Assessing the fish consumption beneficial use impairment in the Bay of Quinte

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The state of contamination in Bay of Quinte fish was assessed to determine whether delisting criteria have been met, and to recommend further studies/actions to be undertaken. We examined fish contaminant data collected by the Ontario Ministry of the Environment between 1975 and 2008 for seven sites in Lake Ontario including the Bay of Quinte. Where sufficient data was available, we tested for differences in recent years by examining the post-1998 data for Walleye, Smallmouth Bass, Yellow Perch and Brown Bullhead. Our analysis specifically focused on known contaminants of concern within the Bay of Quinte: polychlorinated biphenyls (PCBs), mercury (Hg), as well as Mirex which is known to originate from Lake Ontario. Insufficient data was available for the examination of total TEQs (dioxins, furans and dioxin-like PCBs). When appropriate, we used the general linear model (GLM) to compare contaminant concentrations among sites as a function of fish length. When no significant relationship between contaminant concentration and fish length was found, mean values among sites were compared using analysis of variance. While there were no significant differences for the majority of contaminants among sites, some species and contaminant combinations at one or more of the Bay of Quinte sites had elevated fish concentrations compared to some reference sites. For instance, mercury concentrations in Yellow Perch and Brown Bullhead at Quinte sites exceeded those from some reference sites. Current consumption restrictions for Brown Bullhead and Yellow Perch are more severe in the Upper Bay of Quinte compared to the other sites, indicating impacts of local sources. As a result, the fish consumption beneficial use impairment continues to be classified as impaired for the Bay of Quinte. As many sport fish such as Walleye and Smallmouth Bass are large, long-lived and potentially wide-ranging species, it is difficult to link contaminant concentrations to local sources. To investigate the impact of sources within the Upper Bay of Quinte, comparison of contaminants in sentinel fish collected on the same scale as the source of the contamination is recommended.

Keywords: contaminants, bioaccumulation, delisting criteria, Area of Concern, Great Lakes fish

Introduction

In the 1980s the International Joint Commission (IJC) identified 43 Areas of Concern (AOCs) in the Great Lakes and their connecting channels. At the request of the IJC, federal, provincial/state and First Nations governments initiated a series of investigations to further define the environmental problems and prepare Remedial Action Plans (RAPs) for each AOC. These assessments and the RAPs focused on fourteen beneficial uses defined by the IJC. Each beneficial use was examined to determine whether

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or not it was impaired. One of the beneficial uses against which these assessments were compared was restrictions on the consumption of fish resulting from elevated concentrations of contaminants. This beneficial use is considered impaired in the majority (12 of 15) of remaining Canadian AOCs, including the Bay of Quinte.

In this study, data from the Sport Fish Contaminant Monitoring Program of Ontario Ministry of the Environment (OMOE) was analyzed to compare concentrations of contaminants in four key species of sport fish (Walleye *Sander vitreus*, Smallmouth Bass *Micropterus dolomieui*, Yellow Perch *Perca flavescens* and Brown Bullhead *Ameiurus nebulosus*) from the Bay of Quinte AOC to concentrations in the same species captured outside the AOC at nearby Lake Ontario reference sites. Our analysis focused primarily on those contaminants that previous investigations had shown to be elevated in the AOC compared to locations outside the AOC. The contaminants which are bioaccumulative and sourced in the Bay are polychlorinated biphenyls (PCBs), dioxin-like (DL)-PCBs, and dioxins and furans (Thorburn, 2004; Fletcher and Petro, 2005; Diamond et al., 1996; Milani and Grapentine, 2007; Cruickshank, 2007; Dillon Consulting, 2007; Gandhi et al., 2011a). Mercury was also added to the analysis because it is a major contributor to fish consumption advisories in North America. Mirex, a contaminant with no known source in the AOC, was also examined as a control, since any fish caught in the AOC with elevated concentrations of the chemical likely represent migratory populations that are exposed to Lake Ontario sources (Apeti and Lauenstein, 2006).

We tested the hypothesis that restrictions on consumptions of fish from the Bay of Quinte AOC are the result of elevated concentrations of contaminants from sources within the AOC. From this general hypothesis, the following predictions were considered:

- Fish from the AOC will have elevated concentrations of PCBs compared to reference sites.
- Fish from the AOC will have similar or lower concentrations of Mirex compared to reference sites, since there is no documented source in the AOC.

For mercury, no specific source of contamination was identified by the Bay of Quinte RAP, although contamination exists as the result of most industrial and urban activities and inputs from tributaries and atmospheric deposition. Therefore, the lack of point source of contamination for mercury limited our ability to provide a similar hypothesis to that of PCBs. Finally, we used these data to comment on the appropriateness of the delisting criteria to address questions about impairments caused by local sources in AOCs and other locations impacted by localized contamination, and the current status of the delisting criteria within the Bay of Quinte AOC based on recently revised delisting criteria.

Method

Study sites

The Bay of Quinte is located on the northeastern shore of Lake Ontario (Figure 1). It is approximately 100 km long, extending in a Z-shape from Trenton to the lake, with a surface area of 254 km^2. The bay has a watershed with an area of 18,200 km^2 (Bay of Quinte RAP Stage I) and drains four major rivers—the Trent River, Moira River, Salmon River and Napanee River.

Three subsections of the bay can be distinguished: the Upper, Middle, and Lower Bay of Quinte. The Upper Bay of Quinte extends east from Trenton to Napanee and corresponds to sport fish contaminant monitoring region 9 (Figure 1). The area between Napanee and Glenora containing Mallory Bay and Hay Bay is the Middle Bay of Quinte and corresponds to sport fish contaminant monitoring region 10. The waters northeast of Glenora containing Adolphus Reach and the North Channel are the Lower Bay of Quinte within the Bay of Quinte AOC. However, the corresponding sport fish contaminant monitoring program collection region 11 includes these waters and extends into Lake Ontario past Amhurst Island. Despite this lack of precise concordance between the AOC and fish contaminant monitoring areas, data from Region 11 were considered Lower Bay of Quinte fish in this study. Lake Ontario regions 6 and 8 were considered as reference sites as indicated by the delisting criteria applicable at the time of this analysis. Data from a third reference site indicated in the delisting criteria, the upper Otonabee River was excluded due to low sample size.

Historically, the Bay of Quinte has received discharges from a variety of industrial sources, including three paper mills (Domtar Packaging in

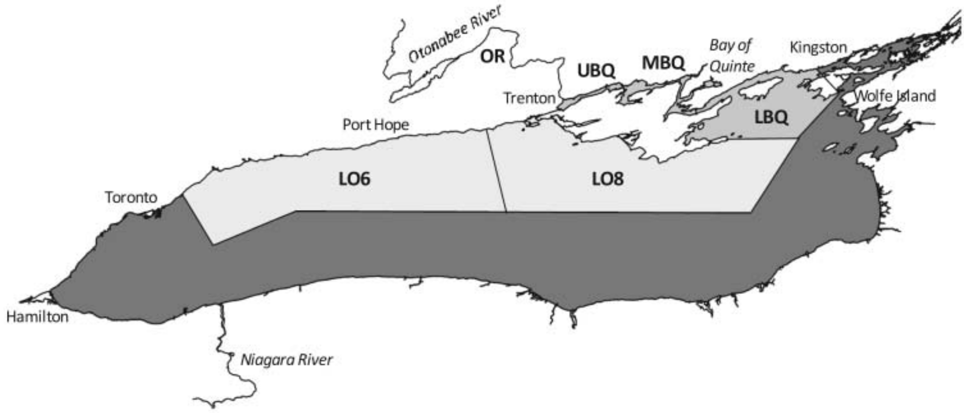

Figure 1. Map of Bay of Quinte and Lake Ontario references zones as delineated by the Sport Fish Contaminant Monitoring Program of the OMOE for the data analysed. Test sites are Blocks 9 (Upper Bay; UBQ), 10 (Middle Bay; MBQ), and 11 (Lower Bay; LBQ) and Lake Ontario reference sites 6 (LO6) and 8 (LO8). Beginning in 2007, Block 9 includes sub-regions 9a (Trenton waterfront) and 9b (Belleville waterfront).

Trenton, Trent Valley Paperboard in Glen Miller, and Strathcona Paper in Strathcona), a chemical plant (Bakelite Thermosets Limited in Belleville), a wood preserving operation (Domtar Wood Preserving in Trenton), and a distillery (Corby Distilleries in Corbyville) (Bay of Quinte Remedial Action Plan Coordinating Committee, 1990). In addition, several historical mining sites and sewage treatment plants are located in the Bay of Quinte watershed. Heavy metal contamination from the Deloro Mine which discharged into the Moira River system that empties into the Bay of Quinte at Belleville does not include mercury or other species of metals that tend to bioaccumulate to concentrations that cause fish consumption restrictions (Golder Associates and GlobalTox International, 2001).

Data sources

The fish contaminant data for Bay of Quinte (Upper, Middle, and Lower) and reference sites (Lake Ontario 6 and 8 and the Otonabee River) was provided by the Ontario Sport Fish Contaminant Monitoring Program of the OMOE. The Otonabee River was not considered as a reference site for PCBs due to historical contamination of the river (Ferguson and Metcalfe, 1989). Overall, the database consisted in a total of 81,744 records representing 192 contaminants in 26 species of fish covering a range of body size from 42 sampling locations in the Bay of Quinte and surrounding reference areas. From this large dataset, records for mercury, total PCBs, and total TEQs were extracted. Total TEQs are a sum of 17 toxic forms of dioxins and furans and 12 dioxin-like PCBs (MOE, 2009). Mirex was also selected as it represents a source of contamination from Lake Ontario sources, as a result of discharges into the Niagara and Oswego Rivers (Apeti and Lauenstein, 2006).

We combined the 42 initial locations into 7 sites: Lower Bay of Quinte (LBQ), Middle Bay of Quinte (MBQ), Upper Bay of Quinte (UBQ), Otonabee River (OR), Lake Ontario 6 (LO6), and Lake Ontario 8 (LO8) (Figure 1). These sites were used for all further statistical analyses. Fish examined were key species for the Bay of Quinte: Smallmouth Bass, Yellow Perch, Brown Bullhead and Walleye (<55 cm) which are known species resident of the Bay (Bowlby et al., 2010).

Statistical analysis

To examine the change in concentrations over time, we plotted concentrations versus sampling year for a narrow size range of fish to control for potential effect of fish length and age (e.g. 30–40 cm Smallmouth Bass, Figure 2). Based on these results and similar evaluations for other contaminants and fish species, we selected the 1999–2008 data for further analysis as the period which consistently showed minimal change in concentrations. Relationships between contaminants and fish length for each site were explored using a general linear model (GLM). Sites were added to the length/contaminant regression to verify whether a single relationship

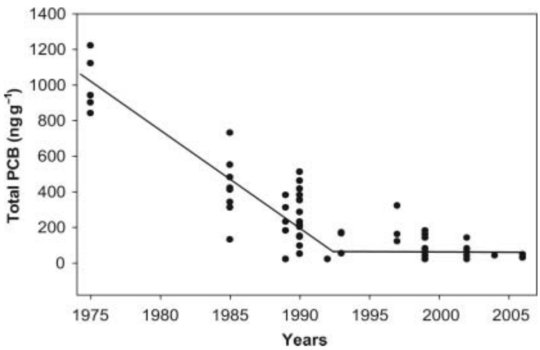

Figure 2. Mean PCB concentrations in Bay of Quinte Smallmouth Bass (30–40 cm size range) plotted against sampling year. Break point was defined using tree regression analysis (break point shown here at 1992/1993).

was valid for all sites (ANCOVA). All contaminant data were log-transformed.

A significant interaction between sites and length implied that that the slope of at least one regression differed from others (i.e. the rate of accumulation differed from other sites). A HSD Tukey post-hoc test was performed to identify differing sites or groups of sites. At the opposite, a non significant interaction between sites and length indicated that regression from each site had a similar slope (i.e. rates of accumulation were homogenous). In this case, a significant site effect indicated contaminant concentrations differed among sites (i.e. the slopes are equal but the y-intercepts differ), whereas a non significant site effect indicated that a single simple model could be used for all sites.

When no significant relationship between contaminant concentration and fish length was found, mean values between sites were compared using analysis of variance (ANOVA) followed by a Tukey HSD post-hoc test to localize differences. A value for $p < 0.05$ was taken as significant difference for all analyses. Statistical comparisons could not be made for all site, fish and contaminant combinations because of small sample sizes and/or contaminant concentrations were at the detection limits. In particular, insufficient total TEQ data was available for the species selected for further analysis. All analyses were performed using JMP 7.0 (SAS Inc.).

Results

Concentration of most contaminants in Bay of Quinte fish have declined appreciably since 1975. For example, PCB concentrations in Smallmouth Bass (30–40 cm TL) have declined approximately 5-fold between 1975 and 2006 for Bay of Quinte (Figure 2). In recent years, post 1998 concentrations declines have stabilized and therefore data after 1998 were chosen for further analysis of differences between Bay of Quinte and reference sites.

Comparisons between Sites

PCBs

The only site and fish combinations for which PCB concentrations varied significantly with length, and therefore amenable to ANCOVA analysis, were Brown Bullhead from LBQ and OR sites and Smallmouth Bass from LBQ, OR and LO6 sites (Figures 3). All other sites and fish combinations were examined by comparing means (Figure 4; Table 1). These comparisons indicate that concentrations of PCBs in Bay of Quinte fish were either lower or equal to reference sites. PCB concentrations in Walleye from the LBQ were significantly greater than UBQ and MBQ fish (Table 2).

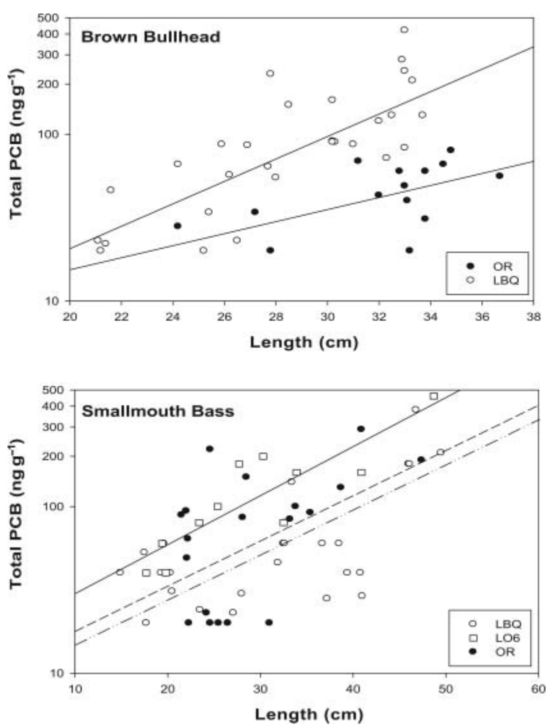

Figure 3. Comparison of log (PCB)-length relationships for Brown Bullhead and Smallmouth Bass by ANCOVA analysis. Refer to Tables 1 and 2 for summary of the statistical results.

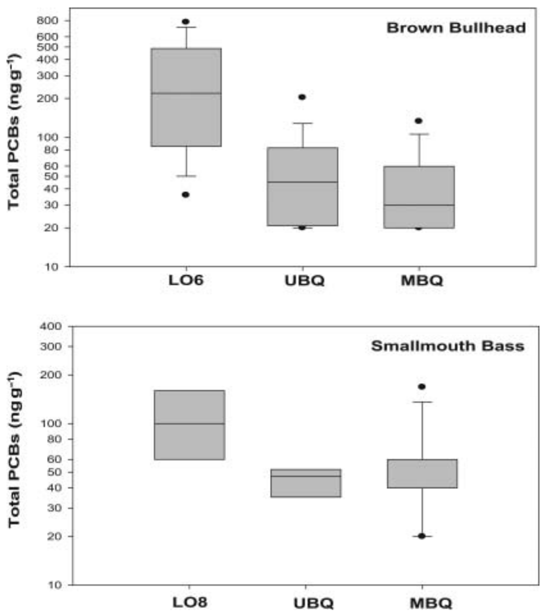

Figure 4. Comparison of PCB concentrations for those species that do not show significant relationships between log concentration and length. Indicated in the boxplots are the median (line), and 25% and 75% quartiles (bottom and top of box, respectively). Whiskers extend to the lowest and highest data within 1.5 times the inter-quartile range of the lower and upper quartiles. Refer to Tables 1 and 2 for summary of the statistical results.

Mercury

The database for mercury was the one of the most extensive within the sport fish monitoring dataset. Concentrations of mercury in all fish species vary significantly with length and were examined by ANCOVA analysis. Concentration-length relationships in Walleye had similar slopes for all sites except for the OR (Table 1). Comparison of intercepts indicates significant differences in concentrations between sites, MBQ > LBQ = LO8 > UBQ = LO6. For Yellow Perch, Brown Bullhead and Smallmouth Bass, differences in the interaction terms (i.e. slopes of the contaminant–length relationship) between sites indicates differences in the rates of mercury accumulation (Tables 1 and 2). For Yellow Perch, rates of mercury accumulation were OR > LBQ = LO8 > MBQ = UBQ, where the pattern was LO6 > MBQ = LBQ > OR = UBQ for Brown Bullhead and LO6 > MBQ = LBQ > OR = UBQ for Smallmouth Bass. Lack of parallel slopes limits the comparisons between fish contaminant concentrations between Quinte and reference sites, however comparisons of site and fish combinations with parallel slopes indicates that MBQ > UBQ for Yellow Perch, UBQ > OR for Brown Bullhead, and OR > UBQ and LBQ > MBQ for Smallmouth Bass.

Mirex

Much of the Mirex data were near or at the detection limit for all four fish species, resulting in non-significant results for all species but Brown Bullheads, where an ANOVA indicated higher concentrations measured at the Lake Ontario site (LO6). This result was consistent with trends found for this site with other contaminants.

Discussion

For the majority of contaminants we examined, no significant differences in contaminant concentrations were found between fish from Bay of Quinte sites compared to reference sites. PCBs concentrations were either similar between sites (Yellow Perch) or if differences occurred, Bay of Quinte sites were lower or equivalent to reference sites (Walleye, Smallmouth Bass and Brown Bullhead). The current Guide to Eating Ontario Sport Fish (OMOE, 2009) indicates that consumption restrictions for total PCBs in sport fish begin at concentrations of 105 ng g^{-1} with complete restriction advised for concentrations above 211 ng g^{-1} for the sensitive population and 844 ng g^{-1} for the general population. The vast majority of PCB data for the four species examined was below 200 ng g^{-1}.

Sample sizes for total TEQs are small and the majority of values are at the detection limit and the data could not be analyzed further. Current consumption restrictions for TEQs in sport fish begin at concentrations of 2.7 pg g^{-1} with total restriction advised for concentrations above 5.4 and 21.6 pg g^{-1} for the sensitive and general population, respectively (OMOE, 2009). As TEQs are the sum of multiplications of chemical-specific Toxic Equivalency Factors with their corresponding concentrations of dioxin-like PCBs and dioxins and furans (van den Berg, 2006), fish from two sites could have similar TEQ values resulting from different mixtures of contaminants. Thus, local effects could be masked by the presence of different chemicals at reference sites. For instance, the majority of TEQs in UBQ sites appears to be attributable to dioxin-like PCBs (Dillon Consulting, 2007; Hickey et al., 2009). Bhavsar et al. (2007a, 2007b) have shown that for fish from North America total PCBs measurements correlate with TEQs

Table 1. Summary of statistical comparisons for four fish considered. Upper Bay of Quinte (UBQ, block 9), Middle Bay of Quinte (MBQ, block 10), Lower Bay of Quinte (LBQ, block 11), Otonabee River (OR), Lake Ontario block 6 (LO6) and block 8 (LO8). ns = no significant differences; Ø = test not run.

			ANCOVA	
Contaminant	Fish sp.	ANOVA	Differences between contaminant-length slopes	Differences between sites (for sites with similar slopes)
Hg	Walleye	Ø	MBQ = LBQ = LO6 = LO8 = UBQ>OR	LBQ>LO8 = MBQ>LO6 = UBQ
	Yellow Perch	Ø	OR>LBQ = LO8>MBQ = UBQ	MBQ>UBQ; LO8 = LBQ
	Brown Bullhead	Ø	LO6>MBQ = LBQ>OR = UBQ	UBQ>OR; MBQ = LBQ
	Smallmouth Bass	Ø	LO6>MBQ = LBQ>OR = UBQ	LBQ>MBQ; OR>UBQ
PCBs	Walleye	OR>LO8 = LBQ = LO6> UBQ = MBQ	Ø	Ø
	Yellow Perch	ns	ns	ns
	Brown Bullhead	LO6>MBQ = UBQ	LBQ = OR	OR>LBQ
	Smallmouth Bass	LO8>UBQ = MBQ	LO6 = LBQ = OR	LO6>LBQ = OR
Mirex	Walleye	ns	ns	ns
	Yellow Perch	ns	ns	ns
	Brown Bullhead	LO6>all others	Ø	Ø
	Smallmouth Bass	ns	ns	ns

Table 2. Statistical results from ANOVA and ANCOVA for Hg, PCBs and Mirex obtained for each fish species. Results relate to the comparisons provided in Table 1.

		ANOVA			ANCOVA		
Contaminant	Fish species	r^2	p	n	r^2	p	n
Hg	Walleye	—	—	—	0.71	<0.0001	198
	Yellow Perch	—	—	—	0.59	<0.0001	270
	Brown Bullhead	—	—	—	0.49	<0.0001	222
	Smallmouth Bass	—	—	—	0.70	<0.0001	139
PCB	Walleye	0.40	<0.0001	91	—	—	—
	Yellow Perch	—	—	—	—	—	—
	Brown Bullhead	0.25	0.0016	47	0.63	<0.0001	54
	Smallmouth Bass	?	?	?	0.41	<0.0001	70
Mirex	Walleye	—	—	—	—	—	—
	Yellow Perch	—	—	—	—	—	—
	Brown Bullhead	0.23	<0.0001	103	—	—	—
	Smallmouth Bass	—	—	—	—	—	—

for dioxin-like PCBs. It would therefore be expected that concentrations of total TEQs in the fish species examined would be similar between UBQ and reference sites to the results obtained for total PCBs.

Comparisons between mercury concentrations for Bay of Quinte and reference site fish are limited because the slopes of the mercury-length relationships are different for many sites considered. However, with the exception of OR, mercury-length relationships are similar for Walleye. Mercury in Walleye from the LBQ is higher than UBQ, MBQ, and LO6 and LO8 reference sites, while mercury in MBQ fish is higher than the LO6 reference site. Although we limited our analysis to Walleye <55 cm which have been found to be resident primarily in the Bay (Bowlby et al., 2010), even smaller Walleye can forage over large areas and it is difficult to attribute mercury sources to specific areas of the Bay.

We observed that Brown Bullhead from the UBQ have higher mercury values than at the OR reference site. The Upper Bay is shallow and eutrophic, conditions that may promote mercury methylation and enhanced mercury uptake through the food web. On the other hand, mercury in the Smallmouth Bass were higher at the OR reference site than UBQ. Mercury concentrations in the piscivorous Smallmouth Bass ranged up to 0.70 μg g^{-1} and much higher than the values found for Brown Bullheads which were typically below 0.25 μg g^{-1}. The upper range of mercury concentrations in Smallmouth Bass exceed the fish consumption limit which starts at 0.26 μg g^{-1} for sensitive populations (OMOE, 2009).

Mirex concentrations in fish from the Bay of Quinte were generally lower than the LO6 reference sites, as expected since Mirex is a contaminant with specific Lake Ontario sources (Apeti and Lauenstein, 2006). The post-1998 data do not exceed the consumption restriction threshold of 82 ng g^{-1} used in the 2009–2010 Guide to Eating Ontario Sport Fish (MOE, 2009). Total restriction is advised for concentrations above 164 and 657 ng g^{-1} for the sensitive and general populations, respectively. Most recent data (post 1998) are at the detection limit and Mirex has not been detected in forage fish from the Bay of Quinte (OMOE, unpublished data) suggesting Mirex in Quinte fish likely is sourced from outside the AOC.

Assessing the Bay of Quinte fish consumption delisting criteria

The delisting target, as originally set out by the Bay of Quinte Restoration Council's 2001–2005 work plan, "is a downward trend in concentrations of contaminants in fish from the Bay of Quinte that are sourced in the Bay of Quinte and are identified in the 1999–2000 Guide to Eating Ontario Sport Fish. These species include: Walleye, Yellow Perch, American Eel, Smallmouth Bass, Lake Trout, Whitefish, Freshwater Drum, and Gizzard Shad. The target is met when the frequency of consumption restrictions in the Bay of Quinte fish are comparable to fish from Lake Ontario or upper Otonabee River reference sites" (Hickey et al., 2006, p. 5).

Some data sets show an apparent decline in contaminant concentrations over time; for example PCB concentrations in Smallmouth Bass from the Upper Bay of Quinte have declined from upper values near 1200 ng g^{-1} in the early 1980s to present day concentrations below 200 ng g^{-1} (Figure 2). However, a comparative analysis of time trend data for all fish is hindered by the limited data and gaps in the data series where no fish were sampled for a given year.

In general, temporal analysis using empirical data indicates that concentrations of most contaminants in Lake Ontario fish have been declining over the past two decades (Bhavsar et al., 2007c, 2008, 2010). Therefore, a declining trend in fish concentrations alone, while indicating improvement, does not necessarily provide information on Bay of Quinte sources of contaminants to fish, especially large fish which may travel large distances and whose contaminant body burdens integrate a variety of source conditions. In addition, a number of statistical challenges are associated with temporal trend analysis of contaminant concentrations in fish. Temporal changes in contaminant concentrations are not a simple reflection of external loading. There may be a loose coupling between external loading and fish contaminant concentrations as a result of food web dynamics and other factors that affect bioaccumulation such as fish size, age, lipid content, fish growth rates and growth efficiency (Borgmann and Whittle, 1991; Rasmussen et al., 1990; Gobas et al., 1995; Huestis et al., 1997). These factors will vary over time and sampling event.

Consumption restrictions remain in effect in the Upper Bay of Quinte for two of the species initially identified in the RAP stage II—Walleye (>50 cm) and Channel Catfish *Ictalurus punctatus* (>25 cm). American Eel *Anguilla rostrata* is not listed in the current version of the guide (Ontario Ministry of the Environment, 2009). To better distinguish the influence of the localized contaminant sources in the Bay of Quinte on fish contaminant concentrations, two new sub-regions with the Upper Bay have been added very recently (Block 9a—the Trenton nearshore area; Block 9b—the Belleville nearshore area). The only fish consumption restrictions listed for these blocks are for Yellow Perch and Brown Bullhead and are currently more restrictive than other sites in the Bay. A maximum of 4 meals per month of Yellow Perch >15 cm is the recommendation for Block 9b and no consumption of Brown Bullhead >25 cm from Block 9a and >20 cm from Block 9b. In contrast, 8 meals per month recommended for Yellow Perch from the rest of the Upper Bay, Middle and Lower Bays as well as Lake Ontario reference sites (OMOE, 2009). At both the reference sites and the Lower and Middle Bays, up to 8 meals per month of Brown Bullhead in these size ranges can be consumed.

The changes to the Guide have resulted from recent investigations of current sources of contaminants in the Upper Bay. The MOE carried out an extensive sampling effort in 2002 at the former Bakelite property and the Belleville waterfront to investigate the potential movement of contaminants in the aquatic environment on and off the former Bakelite property and determine the availability of on-site contaminants to local fish and wildlife populations (Fletcher and Petro, 2005). Concentrations of contaminants at the off-site locations in sediments, caged mussels, and young of the year fish were observed at the sites closest to the former Bakelite Property and fish tissue exceeded IJC guideline of 100 ng g^{-1} set for the protection of fish eating wildlife by a factor of up to 3. It was concluded that contaminants from the former Bakelite property were migrating off site to the Bay of Quinte.

Dillon Consulting (2007) summarized data on fish tissue concentrations obtained by the MOE and Environment Canada from samples collected in 2004 and 2005 for the Lower Trent. Mean concentrations of total TEQs in young-of the-year (YOY) Yellow Perch were approximately 2.5 times greater (0.55 pg g^{-1}, $n = 4$) for the lower Trent River and four times greater (0.83 pg g^{-1}, $n = 3$) for near the river mouth than for the upstream reference site (0.20 pg g^{-1}, $n = 2$). It was noted that the bulk of the TEQs were contributed from the DL-PCBs.

Data on dioxins, furans and DL-PCBs in Brown Bullheads collected by Environment Canada indicated that dioxin and furan TEQs were elevated in fish from Belleville and Lower Trent sampling sites compared with a sampling site near Deseronto (Hickey et al., 2009). The DL-PCB data indicated that Brown Bullhead from the Belleville area had accumulated the highest concentrations (as TEQs). Concentrations were lowest in fish from the Deseronto area. A similar pattern was noted in Yellow Perch tissue residues of DL-PCBs, suggesting site specific sources at Belleville and the Lower Trent.

Sport fish are typically large migratory species which may accumulate their contaminant burdens far from where they are eventually captured. Indeed, the species (Channel Catfish, Walleye and American Eel) identified in the Bay of Quinte stage 1 report (Bay of Quinte Remedial Action Plan Coordinating Committee, 1990) are all highly migratory species. Even if a species in question is known to be a permanent resident of the Bay of Quinte, it may still acquire contaminants by feeding on migratory species that accumulate contaminants at locations outside the Bay.

There are at least two difficulties in framing delisting criteria for addressing the fish consumption restrictions beneficial use using the broad Lake Ontario regions as defined in the Guide to Eating Ontario Sport Fish as the source of reference fish. Firstly, Lake Ontario contains a number of sites that are heavily impacted by human activities and therefore may not be appropriate as a reference site. The process of sediment focusing integrates contamination from past and on-going sources, including the Niagara River, across Lake Ontario. Deep sediments in Lake Ontario remain contaminated from the result of widespread industrial activities around the lake (Marvin et al., 2002).

Secondly, it can also be difficult to draw robust conclusions about the influence of localized contaminant sources in the Bay of Quinte on fish contaminant concentrations if fish samples are collected across an area that is many times larger than the localized areas of contamination. To address this issue, the OMOE recently delineated two new sampling Blocks (Blocks 9a and 9b) to ensure that the fish consumption guidelines distinguish between contaminated and less contaminated areas within the Bay.

It should be recognized that fish consumption restrictions between sampling blocks may be attributed to different contaminants. Fish consumption restrictions applied in the Guide are based on the most restrictive advisory. Differences in restrictions between zones may be a result of different contaminants. Any comparison of fish consumption restrictions should, therefore, ensure that the same contaminants are driving the fish consumption restrictions between reference zones and the AOC. In addition, the MOE fish consumption guidelines/methods have changed over time. Therefore, although contaminant concentrations might have decreased for a specific contaminant, more restrictive guidelines for the same or another contaminant might result in no change in fish consumption restrictions.

Based on these considerations, the Bay of Quinte Restoration Council has recently revised their strategy for delisting to targets based on the scale of the known local sources, which are primarily in the Upper Bay (Hickey et al., 2009). The criterion includes a requirement that contaminant concentrations in both Brown Bullhead and Yellow Perch (or a similar sentinel species) collected near established sources of contamination at Trenton and Belleville to result in the same or lower consumption restrictions as for fish collected elsewhere in the Upper Bay. As discussed above, sampling blocks 9a and 9b which respectively correspond to the Trenton and Belleville areas currently have more restrictive fish restrictions for Yellow Perch and Brown Bullhead than elsewhere in the Bay; therefore, the fish consumption beneficial use impairment continues to be classified as impaired for the Bay of Quinte.

Conclusions

In summary, for the majority of contaminants we examined, there were no significant differences between fish contaminant concentrations at Bay of Quinte sites compared to Lake Ontario reference sites. The instances where fish contaminant concentrations from Bay of Quinte sites exceeded those from at least one of the reference sites were: mercury in Walleye (LBQ and MBQ) and Brown Bullhead (UBQ). In some instances, Bay of Quinte sites were lower than reference sites including PCBs in Brown Bullhead, Smallmouth Bass, and Walleye.

These results do not support our initial predictions that Bay of Quinte sites would have higher fish contaminant concentrations for PCBs than reference sites. Limited data prevented similar comparisons for total TEQs. For Mirex, where sources derive from Lake Ontario concentrations were higher in Brown Bullhead from Lake Ontario (LO6) than Bay of Quinte sites.

Despite these statistical results based on 1999–2008 data, there are still some species for which fish consumption restrictions are more severe within the AOC than reference sites, including several instances where restrictions for fish from the Upper Bay are greater than other sites (within the Bay of Quinte or at reference sites). Restrictions on Yellow Perch and Brown Bullhead consumption remain more severe for fish from the Upper Bay compared to the other sites. As a result, the fish consumption beneficial use impairment continues to be classified as impaired for the Bay of Quinte.

The analysis of the sport fish contaminant data provides a very broad comparison of fish contaminant concentrations in Bay of Quinte and reference zones. Most sport fish species are large, long-lived and potentially wide-ranging species and it is difficult to conclusively link elevated concentrations to local sources. The sport fish contaminant monitoring program was not originally designed to investigate fine scale geographic differences, because the intention of the program is to protect anglers throughout a designated fishing area. To further distinguish whether specific contaminant sources within the AOC are contributing to elevated fish contaminant concentrations, current work involves focused sampling at a finer geographic scale than that typical of the broad sport fish contaminant monitoring program and includes Brown Bullhead, Sunfish spp. and young of the year which tend to be sedentary in the Bay of Quinte during summer months prior to sampling.

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