Data Analysis and Fish Tumor BUI Assessment

For the Lower Great Lakes and Interconnecting Waterways

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Introduction and History:

Tumor epizootics in fish were first linked to environmental contaminants in the sixties (Dawe et al., 1964). In the seventies the first study was published implicating environmental carcinogens as part of the etiology of papillomas in white suckers in the Great Lakes (Sonstegard, 1977). In the 1980s the first liver cancer epizootic in brown bullhead from the Great Lakes drainage basin was reported in the Black River, Ohio (Baumann, et al., 1982). Research since that time has demonstrated elevated tumor prevalence in a variety of species across North America (Baumann 1998), including brown bullhead and white sucker populations from a wide range of urbanized areas in bays and tributaries of the Great Lakes in both Canadian and United States waters (Baumann et al. 1996). Concern over these discoveries resulted in fish tumors being designated as a Beneficial Use Impairment (BUI) used to determine Areas of Concern (AOC) in Annex 2 of the 1987 Protocol Amending the Great Lakes Water Quality Agreement. The IJC delisting guidelines from 1991 state that this Beneficial Use may be deemed to be Not Impaired "when the incidence rates of fish tumors or other deformities do not exceed rates at unimpacted control sites or when survey data confirm the absence of neoplastic or preneoplastic liver lesions in bullheads or suckers" (International Joint Commission, 1991). Details about the actual methodology used to establish this criterion were not provided, and as time has passed the understanding of what comprises accurate methodology in fish tumor surveys has changed (Blazer et al. 2006).

This report deals with the lower Great Lakes Canadian Areas of Concern with fish tumor BUIs or an unknown fish tumour status (Table 1). Wheatley Harbour, located in the Lake Erie basin, is also included. However, it should be noted that fish tumors were not a BUI for the Wheatley Harbour AOC when it was designated an AOC. All the lower lakes AOCs and their associated far field and reference sites used brown bullhead (*Ameiurus nebulosus*) as a sentinel species. Of these locations only Hamilton Harbor had been listed as having a brown bullhead population with external and liver tumor epizootics during studies carried out prior to the mid 1990s. Bullheads captured in 1985 were diagnosed with a 6.4% incidence of combined biliary and hepatic cancers (Baumann et al. 1996). Hamilton Harbour also had a 55% prevalence of external neoplasms (Smith et al. 1989), which was matched only by Presque Isle Bay, PA (56%); the next highest external neoplasm prevalence recorded was 25% from the Black River, OH (Baumann et al. 1996). Sampling for the current monitoring project took place between 2001 and 2008, with many locations being sampled in two different years and Hamilton Harbour having been sampled in three different years.

Table 1. AOC locations and their associated far field and reference locations with the years sampled for brown bullhead tumor studies (from west to east).

AOC Location	Far Field Site	Reference Site	Years Sampled
Detroit River	**Grosse Isle**	**Peche Isle**	**2002**
Wheatley Harbour	**NA**	**Hillman Marsh, Port Rowan**	**2002, 2006**
Niagara River	**Queenston**	**Point Abino**	**2004, 2008**
Hamilton Harbour	**NA**	**Jordan Harbour**	**2001, 2005, 2007**
Toronto and Region	**NA**	**Frenchman's Bay**	**2003, 2006**
Bay of Quinte	**Belleville**	**Prince Edward Bay, Deseronto**	**2004, 2005**
St. Lawrence River (Cornwall)	**Gray's Creek**	**Morrisburg**	**2004, 2005**

Methodology:

A sample size of one hundred brown bullhead (Ameiurus nebulosus) was set for collection in all Areas of Concern and their corresponding reference locations. Wheatley Harbour and the Hillman Marsh reference bullhead were collected using overnight hoop net sets and the 2006 Long Point fish were purchased from a commercial fisherman that used overnight trap net sets. Hamilton Harbour bullhead were captured in 2005 using a Smith Root Electrofishing boat while the spring 2007 fish were captured using an overnight trap net set. The Jordan Harbour reference fish were purchased from a commercial fisherman using overnight trap net sets. All other bullhead were captured using a Smith Root electrofishing boat. The Prince Edward's Bay reference fish were collected and sampled by Environment. The Toronto and Region AOC fish used in this study were separate from fish collected for other studies published by the Toronto Conservation Authority.

Fish were captured, then placed into a live well for transportation to the sampling site. Fish were anaesthetized in a clove oil bath (~0.05% + ~0.025% ethanol to aid emulsification), then were sacrificed using standard operating procedures, and their physical state was assessed using a visual examination of physical abnormalities. Fork length (mm) and weight (g) were measured and pectoral fin rays were collected for aging. The liver was removed and separated into sections for histology (Blazer et al., 2007) and were stored in Davidson's Fixative and transferred to 70%

ethanol 1-4 weeks after collection. Fish aging was conducted by North Shore Environmental, Thunder Bay, Ontario.

Histological Evaluation:

Prior to processing, the liver tissues were trimmed into an appropriate number of sub-samples (1 to 7) based on the original size of the sample. A small slice of tissue, between adjacent sub-samples, was removed and discarded. The sub-samples were processed in a routine ethanol/toluene series and individually embedded in paraffin blocks. The embedded tissues were sectioned at 4 – 6 microns and one slide, each with three tissue sections, was prepared from each block. The slides were stained with Harris hematoxylin and eosin.

Slides were examined with a Zeiss Photomicroscope III with Plan lenses and an Olympus Q-Color 3 digital camera. Images were captured from the system using QCapture Suite (Q-Imaging Corp.) software (Version 2.70.0 for Windows) at 2082 x 1542 pixel resolution. Brightness/contrast adjustments were performed in Adobe Photoshop 6.0 for Windows (Adobe Systems, Inc., San Jose, CA).

The data were presented with a “1” indicating the presence of a particular lesion and “0” indicating the absence of the indicated lesion. The proliferative lesions of the Brown Bullhead liver were categorized as non-neoplastic or neoplastic as described by Blazer et al., (2007).

The non-neoplastic hepatocellular lesions included the 4 types of foci of cellular alteration based on tinctorial characteristics of the hepatocyte cytoplasm. The non-neoplastic biliary lesion included only bile duct hyperplasia.

The neo-plastic hepatocellular lesions included hepatocellular adenoma and hepatocellular carcinoma. The neoplastic biliary lesions included cholangioma and cholangiocarcinoma.

In addition, the presence of non-proliferative liver lesions were noted. Small accumulations of lymphocytes/leucocytes were recorded as “Inflammation”, melanomacrophage aggregates in numbers in excess of the norm were recorded as “Excess MA’s”, and focal areas (minor) of necrosis were noted as “Necrosis”.

The visible presence of any parasite(s) in each liver was noted (“Parasites”), as were granulomata (”Granuloma”), which were generally associated with parasites. Although many livers had minor areas of blood congestion (increased blood vessel size and blood flow to an area), those with excessive areas were noted (“Congestion”). Instances of cholangiofibrosis (Baumann et al. 1990) were reported (“Cholangiofibrosis”). This was largely composed of large encapsulating masses that encircled six or more normal-appearing bile ductules. Under “Other Lesions” minor biliary fibrosis and other anomalies were reported.

The 38 liver samples from the Prince Edward Bay reference site were processed by the Histology lab, Animal Health Laboratories, University of Guelph were they were processed by routine paraffin embedding followed by staining with hematoxylin and esoin for examination by light microscopy. All of these samples were examined by J.S. Lumsden, Associate Professor, Department of Pathobiology, University of Guelph (Toronto and Region Conservation Authority (TRCA). 2006).

Types of Lesions:

The use of external lesions including lip papillomas as criteria related to carcinogen exposure is not recommended. Certain types of papilloma have been demonstrated conclusively to be caused by a retrovirus (Baumann and Okihiro 2000), including one type of papilloma occurring on white sucker (Premdas and Metcalfe, 1996). Papilloma prevalence in brown bullhead does not correlate well with liver tumor prevalence either across locations or on individual fish within locations (Baumann et al. 1987). It is our current inability to tease apart the interaction of contaminants (both carcinogens and promoters) and virus infection that prevents us from confidently using external lesions as a criterion for BUI evaluation. On the other hand, liver lesions in wild fish including brown bullhead from the Great Lakes are caused by chemical contaminants (Baumann et al. 1996, Baumann and Okihiro 2000). In particular, polynuclear aromatic hydrocarbons (PAHs) have been proven by an extensive array of laboratory experiments to induce liver cancer in fish (Baumann and Okihiro 2000). Also no liver cancer in any species of fish has ever been diagnosed with a viral etiology (Dr. John Harshbarger, Director of the Tumor Registry in Lower Animals, Smithsonian Institution, Washington, DC, personal communication). Furthermore, field studies have correlated a decline in tumor incidence with a decline in PAH contamination in sediment (Baumann and Harshbarger, 1995) and have shown that fish exposed to elevated PAH concentrations in the wild had significantly higher liver neoplasm prevalence than those that were not (Vogelbein et al. 1990; Baumann and Okihiro 2000). Thus liver neoplasms are the most consistent markers of carcinogen exposure.

The original wording of the ‘Fish Tumors or Other Deformities’ BUI included the occurrence of “neoplastic or preneoplastic liver tumors in brown bullhead or suckers”. However, no specifics were given for the definition of preneoplastic lesions. Foci of cellular alteration, depending upon morphological and staining characteristics, can be classified as basophilic, eosinophilic, vacuolated, and clear cell. Basophilic foci have been reported to advance to hepatocellular carcinoma in several species of fish (Blazer et al. 2006). However not all basophilic foci advance (Hinton et al. 1988, Baumann and Okihiro 2000). There is no definitive evidence that other types of altered foci progress to neoplasia (Bunton, 1996). No studies on progression of any foci of cellular alteration have been performed on suckers or bullhead. Liver tumors in fish are, with rare stem cell exceptions, derived from either liver cells (hepatocellular) or bile duct cells (cholangiocellular). A proliferation of bile duct cells has been demonstrated following laboratory carcinogen exposure in a number of species (Blazer et al. 2009). Similarly such lesions (bile duct hyperplasia and cholangiocellular fibrosus) have been reported along with tumors in wild populations from contaminated locations (Blazer et al. 2009). However none of these non-neoplastic cholangiocellular changes have been experimentally demonstrated as progressing to tumors. Also, at least in bullhead, a myxozoan parasite has been implicated in bile duct proliferation and fibrosus (Baumann et al. 2008). Because of the uncertainties concerning progression of both foci of cellular alteration (hepatic) and cholangiocellular proliferation and fibrosus (biliary), it is best that none of these preneoplastic lesions be used as an actual impairment criterion.

Age and Gender:

Two variables which might influence tumor prevalence are the age of the fish and fish gender. Age has long been recognized as being positively correlated with tumor prevalence (Baumann, 1992). This is not only because fish that have lived longer have usually been exposed to environmental contaminants longer, but also because there is a latent period between induction and tumor development. For instance the prevalence of spontaneous neoplasms in medaka (*Oryzias latipes*) of ages 1 through 5 was greatest in females of age 4 and 5 and males of age 5 (Masahito et al. 1989). This same positive correlation between age and tumor prevalence has also been noted in wild populations of several species exposed to contaminants. English sole from contaminated locations in Puget Sound had a nearly 40% increased probability for having a hepatic neoplasm with each additional year lived (Rhodes et al. 1987). Similarly bullhead from the Potomac River also had an increased risk of hepatic carcinomas with age (3.5 times greater per year) (Pinkney et al. 2001). Brown bullhead from the Black River, Ohio were found to have a significantly ($p<0.05$) higher prevalence of biliary liver cancers at ages 4 and 5 (35.5%) than at ages 2 and 3 (18.4%) (Baumann et al. 1990). Blazer (2009) also reported an increasing prevalence of liver tumors with age in bullhead from Presque Isle Bay, particularly at ages 8 and older. Furthermore Slooff (1983) found that of 7,209 bream necropsied in Europe, all fish with grossly visible tumors were age 7 or older. White sucker have also shown this age and neoplasm link. In samples from five locations in the St. Lawrence Basin lip neoplasms occurred almost exclusively in fish >350mm (length being an age surrogate) (Mikaelian et al. 2000). Thus it is important to consider age when comparing neoplasm prevalence among populations.

Gender related differences in tumor prevalence have been less consistently reported than age related differences, particularly in wild exposed populations. Several species of laboratory fish have been reported to have a higher prevalence of spontaneous tumors in females (Baumann 1992). However gender was not a significant factor in the prevalence of hepatic lesions in

English sole from Puget Sound (Rhodes et al. 1987). Female brown bullhead from the Black River, Ohio had a significantly higher ($P<0.05$) incidence of hepatocellular carcinoma only, but not of any other neoplasms. A review of Great Lakes brown bullhead data taken at United States locations since 1991 reinforces the view that gender differences are not discernable. However, an analysis of the brown bullhead data base for Chesapeake Bay found that being female was a significant ($P<0.001$) positive co-variant for liver neoplasms (Pinkney et al. 2009). Gender equivalency among samples should be considered for comparative purposes.

Variability and Statistics:

Determining whether a fish has a tumor provides a “yes” or “no” answer (binary response) rather than a number. Thus contingency table analysis is required for statistical differentiation of population values. Such statistics will test if tumor incidence is similar or different at two locations at some level of confidence. The level of confidence is determined by selecting a P value to indicate significance. The typical P value for biological studies is 0.05 (a 5% or one in twenty random chance of being wrong). Thus P values less than or equal to 0.05 would indicate a real difference between the tumor prevalence at the sites being compared.

There are two methods which are commonly used to compute a P value from a contingency table: Chi-square and Fisher’s exact test. Fisher's exact test gives the exact P value, while the Chi-square test calculates an approximate P value (Graphpad Software 2009). Chi-square often works better with multiple rows and columns, but the data here only has two of each. Additionally, Fisher’s exact test is supposed to perform better when the expected values are small, which is the case here. Thus Fisher’s exact test was used to determine the P values when comparing tumor prevalence at AOC locations and reference sites. Statistical calculations were done using a QuickCalcs online calculator by GraphPad Software (Graphpad Software 2009). This software includes a statement acknowledging that the Fisher's test actually has three methods that can be used to compute the two-sided (two-tailed) P value. The software used here incorporated the method of summing small P values.

Determining Background Tumor Prevalence: Reference and Urban Non-Point Sites:

Theoretically one reference location should have the same tumor prevalence as any other reference location (given a certain variation around the true mean, and if age and gender are not badly skewed). In fact reference site liver neoplasm prevalence by location seems to be very consistent (Table 2). The only reference location not included was Hillman Marsh at Wheatley Harbour, since that location had 9% neoplasm prevalence which would exclude its use as a reference site. The eight remaining locations only varied from 0% to 2%. Median ages ranged from 5 to 7 except for Jordan Harbour (age 4), with an overall median age of 6. Females comprised 46% of the fish sampled across locations. Nothing prevented combining the reference locations into a single data set. Thus brown bullhead in the combined reference data base have a liver neoplasm prevalence of 1% (n=701). This is a considerably lower prevalence than the 5% figure from Baumann et al. (1996). However this change was not unexpected, given the much expanded data base of cancer surveys in Great Lakes fish in the last fifteen years.

The same sort of calculation was made using the Far Field locations sampled (Table 3). The number of bullhead with neoplasms in the four locations varied between 0% and 4% (Gross Isle with a very small sample size). The average median age was slightly younger (age 4) than at the reference locations, but the fish sampled for the group as a whole were evenly split between males and females. Again nothing prevented numbers from being combined, giving a combined prevalence of 2% (n=267). A data set of United States locations which correspond in some ways to the Canadian Far Field sites have a similar tumor prevalence (Table 4). The locations in this set include a "reference" location with modest PAH spikes near a railway bridge and a highway bridge (Old Woman Creek); two urbanized locations without a major point source (the Huron and Conneaut Rivers); and an AOC location that had undergone extensive remediation (the United States side of the Niagara River). The bullhead in this data set also have a liver neoplasm prevalence of 2% (n=204). This group from the United States combined with the Canadian Far Field locations would be best characterized as urban or having a low/moderate pollution level without a major point source. This combined group would have a liver tumor prevalence of 2% (n=471).

Table 2. List of reference locations including number of fish sampled and number of fish with neoplasms.

Location	Sample Size	Median Age	% Female	Neoplasm (# /%)
Peche Island	**34**	**5**	**56**	**0 / 0%**
Port Rowan	**99**	**6.5**	**35**	**1 / 1%**
Point Abino	**40**	**5**	**50**	**0 / 0%**
Jordan Harbour	**193**	**4**	**53**	**3 / 1.6%**
Frenchman's Bay	**101**	**7**	**50**	**1 / 1%**
Prince Edward Bay	**38**	**No age data**	**38**	**0 / 0%**
Deseronto	**96**	**5**	**41**	**2 / 2.1%**
Morrisburg	**100**	**5**	**49**	**0 / 0%**
Total /average	**701**	**6**	**46**	**7 / 1%**

Table 3. List of far field locations including number of fish sampled and number of fish with neoplasms.

Location	Sample Size	Median Age	% Female	Neoplasms (# / %)
Gross Isle	**25**	**5.5 (n=4)**	**56**	**1 / 4%**
Queenston	**43**	**4**	**48**	**0 / 0%**
Belleville	**99**	**4**	**51**	**2 / 2%**
Gray's Creek	**100**	**4**	**48**	**2 / 2%**
Total/average	**267**	**4**	**50**	**5 / 2%**

Table 4. Urbanized, reference (Old Woman Creek) and reclaimed AOC (Niagara) locations in the United States, including number of fish sampled and number of fish with neoplasms.

Location	Sample Size	Neoplasms (# / %)
Huron River	**62**	**1**
Old Woman Creek	**59**	**1**
Conneaut River	**43**	**1**
Niagara River (US side)	**40**	**1**
Total	**204**	**4 (2%)**

Criterion Selection:

The crux of criterion selection decision rests on being able to combine the reference location neoplasm data. With a data base of 700 reference fish, comparisons made with AOC locations are much more likely to be significant. The same is true of combining the Far Field and United States locations to achieve an n value of 471. The 1991 IJC guidelines state that locations determined to be impaired might be designated as restored when "tumors…do not exceed rates at unimpacted control sites". However in decades since then there has been much discussion of how bullhead from more urbanized areas might have an increased probability of tumors even if point sources had been eliminated and exposed contaminated sediments eliminated. In other words, holding urban areas to pristine standards might not be achievable. Our list of mixed far field and other lower level polluted locations suggests that even in urbanized areas without a major point source we could reasonably expect to have a liver neoplasm prevalence of 2% or less. This leads to the question of whether the 1% prevalence seen in true reference sites can really be distinguished from the 2% prevalence in the urbanized areas with realistic manpower (budget) restraints. To answer this question we need to choose a P value to indicate significance. The typical P value for biological studies is 0.05. Using this value, even if we combine the reference data sets and then combine the far field data and United States data sets, the difference between the 1% and 2% tumor frequencies of these two groups is not significant according to Fisher's exact test.

Based on these data, the best choice for a criterion would be the 2% prevalence level, which should be achievable even in more urbanized locations. Furthermore if we apply a bootstrapping technique to the reference site data base, the 95% confidence interval within which the true mean prevalence should exist, ranges from 0.73% to 1.5% (Figure 1). The 1.5% upper bound for the 95% confidence interval validates the choice of 2% as a delisting criterion. Since we have already sampled over 700 reference fish and over 450 far field and urban fish with a combined tumor prevalence of under 2%, we can use the combined sample size from these two groups (rounded to 1,150) as our "background prevalence" sample size for determining significant differences at the AOC locations. In order to clarify further fish tumor impairment discussions of the AOCs, this 1,150 fish data base with the assigned 2% tumor prevalence will be referred to in the rest of this report as the Impairment Criterion (IC) data base. In creating a contingency table for Fisher's exact test, the IC number for fish with neoplasms would be (2% x 1,150) or 23 and the IC number for normal fish would be (1,150 – 23) or 1,127. A hypothetical site having a hundred fish sample and a 5% liver tumor prevalence would have a P value of 0.066%, or just barely non-significant.

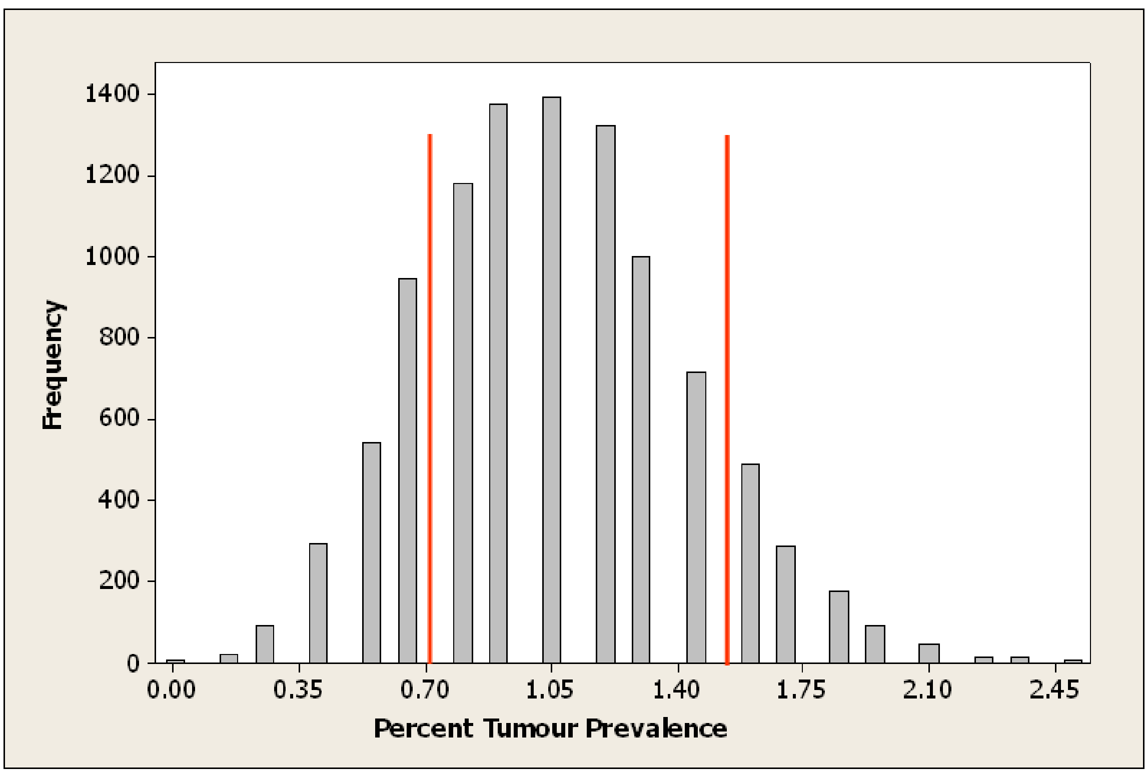


Figure 1. Bootstrapped 95% confidence interval (0.73 to 1.5% as indicated by the two vertical lines) determined for the liver tumor prevalence of bullhead at reference locations. This confidence interval was estimated using 10,000 iterations.

AOC Neoplasm Prevalence:

All AOC locations except for Detroit River had a sample size of 100 fish or more (Table 5). Median ages ranged from 5 to 8, mimicking the distribution of the reference locations. Similarly females made up 42% to 50% of the populations sampled. The prevalence of liver neoplasms at these Areas of Concern ranged from 2% to 5.5%. When the numbers for normal and neoplasm fish were compared for each individual location with the IC data base (2% neoplasms in a survey of 1,150 fish), all locations were not significantly different from this reference set except one, Hamilton Harbour, which had the 5.5% liver tumor incidence.

Table 5. Canadian AOCs with completed surveys (sub-locations and multiple year samplings combined) with sample sizes, ages, gender percentage, neoplasm numbers and prevalence, and significantly differences (S), or not (N), from the impairment criterion.

Exposed Site	Sample Size	Median Age	% Female	Neoplasm # (%)	P Value	Significance
Wheatley Harbour	**100**	**7**	**47%**	**4 (4%)**	**0.27**	**N**
Niagara River	**101**	**5**	**50%**	**3 (3%)**	**0.47**	**N**
Hamilton Harbour	**200**	**8**	**48%**	**11 (5.5%)**	**0.013**	**S**
Toronto and Region	**213**	**7**	**45%**	**8 (3.8%)**	**0.14**	**N**
Bay of Quinte	**100**	**5**	**42%**	**4 (4%)**	**0.27**	**N**
St Lawrence River	**100**	**5**	**46%**	**2 (2%)**	**1.0**	**N**

Conclusions by AOC:

<u>Detroit River AOC:</u>

Bullhead have been difficult to collect at the Detroit River site despite numerous attempts during the spring and fall periods. We are working in collaboration with the University of Windsor Great Lakes Institute for Environmental Research to obtain suitable sample sizes. Sampling had not been completed on the Detroit River at the time of this report.

<u>Wheatley Harbour AOC:</u>

The contaminant exposed locations at Wheatley Harbour (Wheatley Harbour/Muddy Creek) had a combined tumor prevalence of 4% based on the 2002 and 2006 samples (Table 5).

Wheatley Harbour is not significantly different from the delisting criterion data base. However Wheatley Harbor's local reference site, Hillman Marsh, had a 9% prevalence of bullhead liver tumors which prevented its inclusion in the combined reference site data base. Most of these lesions were recorded in the 2006 sample. The combined (2002 & 2006) tumor prevalence (9 of 99 fish sampled) at Hillman Marsh when compared to the reference data base using Fisher's exact test results is shown to be highly significantly different (P=0.0005). Thus further fish tumor research is recommended for Hillman Marsh. However this study confirms that the status of the fish tumor Beneficial Use for Wheatley Harbour is Not Impaired. No further monitoring specifically for tumors in this AOC is needed.

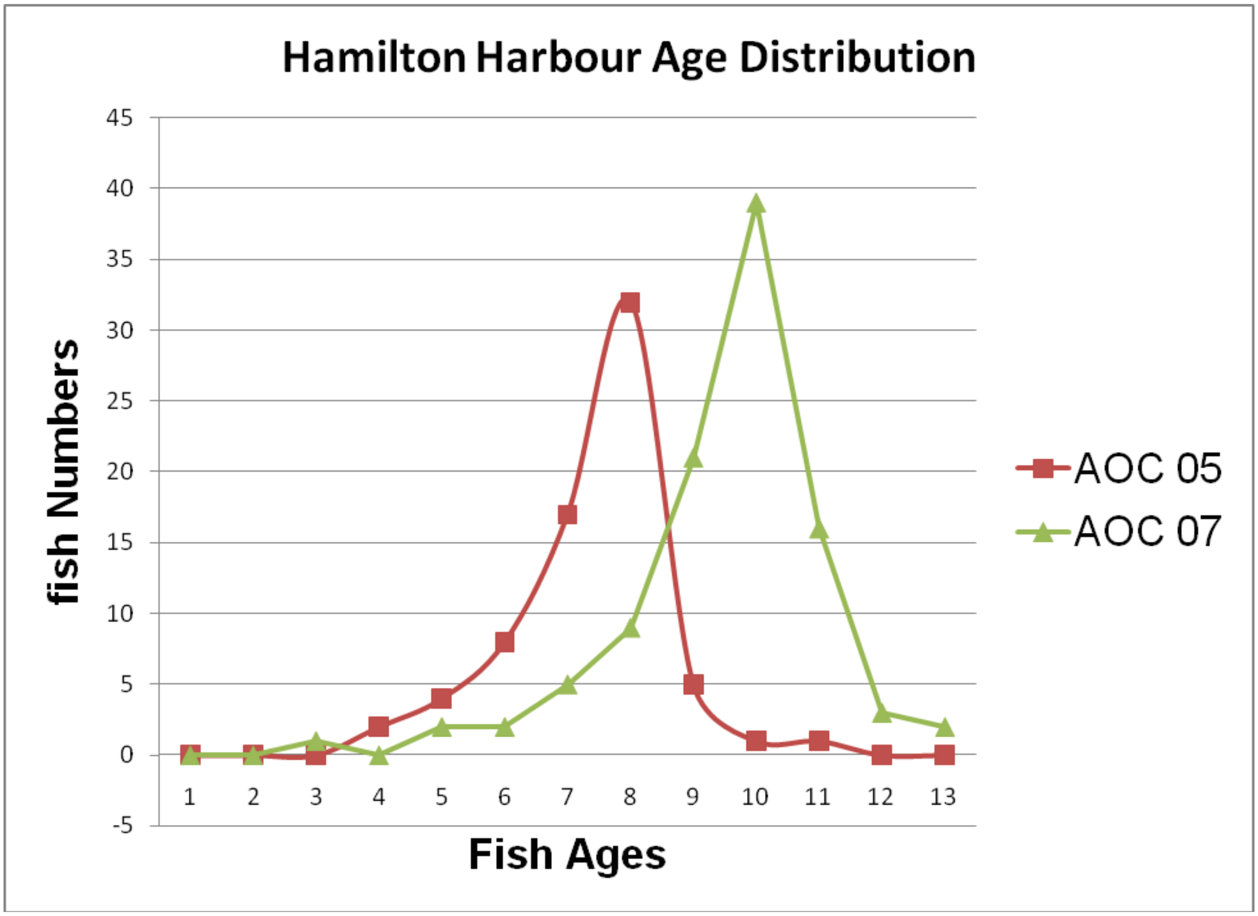
<u>Niagara River (Canadian side) AOC:</u>

Niagara River bullhead (n=101) had a liver tumor prevalence of 3%. This prevalence was not significantly different from that in the IC data base (Table 5). Therefore the status of the fish tumor Beneficial Use for the Niagara River AOC (Canadian side) can now be changed to Not Impaired. No further monitoring specifically for tumors in this AOC is needed.

<u>Hamilton Harbour AOC:</u>

The first two years in which Hamilton Harbour was sampled (2001 & 2005) resulted in a diagnosis of liver neoplasm in only 2% of the fish. However the 2007 sampling (n=100) at Hamilton Harbour resulted in a 9% neoplasm prevalence. The difference between this higher outcome and the IC data base is designated as "extremely significant" (P=.0006) by Fisher's exact test. Even combining the tumor prevalence across years results in a 5.5% liver neoplasm incidence which is significantly different from the IC data base (Table 5). However, Hamilton Harbour had the oldest mean age of any AOCs sampled. An analysis of the age distributions of the populations surveyed in 2005 and 2007 demonstrates the latter sample was composed of fish averaging about 3 years older (Figure 2).

Figure 2. Ages of fish populations which were sampled in Hamilton Harbour in 2005 and 2007.



This leads to speculation that a more age specific comparison of the Hamilton Harbour tumor data might not demonstrate such a divergence from the reference data set. However the fact that the most recent survey is so significantly elevated over the criterion data base argues for further research. Thus an additional survey is recommended with sampling techniques or size cut-offs designed to simulate, as much as possible, the IC data base age structure. Based on the current data this Hamilton Harbour Beneficial Use is determined to be Impaired.

<u>Toronto and Region AOC:</u>

The combined Toronto surveys of 2003 and 2006 had an average tumor prevalence of 3.8%, which was not significantly different from the classification criterion data base (Table 5). The status of the fish tumors Beneficial Use for the Toronto and Region AOC can now be classified as Not Impaired. No further monitoring specifically for tumors is needed.

Bay of Quinte AOC:

This site had samples taken in 2001 and 2005. The more contaminated Trenton location had a bullhead liver tumor prevalence of 4%. This value is the same as that for Wheatley Harbour, and like Wheatley Harbour there is no difference between liver neoplasm prevalence in the Bay of Quinte and that in the delisting criterion data base (Table 5). Thus the status of the fish tumors Beneficial Use for the Bay of Quinte can now be changed to Not Impaired. No further monitoring specifically for tumors is needed.

St Lawrence River (Cornwall) AOC:

Both the near field Bridge location and the far field Gray's Creek location had a 2% liver tumor prevalence in the brown bullhead samples (Tables 3 and 5). This prevalence is the same as the prevalence selected for the criterion data base. Foci of cellular alteration were somewhat higher at this location, but not to the extent that they would be cause to override the neoplasm data. The status of the fish tumor Beneficial Use for the St. Lawrence (Cornwall) AOC can now be changed to Not Impaired. No further monitoring specifically for tumors is needed.

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