

PRESQUE ISLE BAY AREA OF CONCERN
Final Stage 3 Remedial Action Plan: Delisting



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EXECUTIVE SUMMARY

This Stage 3 RAP presents specific targets and supports a petition to delist the final beneficial use impairment (BUI), fish tumors or other deformities, and the Presque Isle Bay Area of Concern (AOC). Pennsylvania's Department of Environmental Protection (PADEP) with the concurrence of the Presque Isle Bay Public Advisory Committee recommends delisting both fish tumor impairment and the AOC.

Development of the fish tumor delisting target for the Presque Isle Bay AOC was an iterative process. Based upon the recommendations of researchers and other experts during a series of workshops between 2003 and 2006, PADEP sampled a number of inland lakes and non-AOC locations in Lake Erie to identify a "least-impacted" reference site for comparison. All of the candidate reference sites sampled were known to have brown bullhead populations but no known direct discharges of contaminants. In order to compare the sites over a period of years, a statistical methodology was developed that normalized the tumor rates to those of fish at age 7, the approximate mean age of the bullheads in the full data set. The surveys showed that neither the non-AOC locations in Lake Erie nor the inland Pennsylvania lakes were free of bullhead tumors. Additionally, locations where liver tumors were high had low external rates and vice versa. Long Point Inner Bay was identified as the least-impacted reference site for comparison against Presque Isle Bay. The delisting target selected for Presque Isle Bay is met when "the incidence rate of liver and external tumors is statistically equivalent or lower than the incidence rates at Long Point Inner Bay as confirmed by histopathology".

PADEP used data collected in the post-Recovery Stage to test the delisting target. Comparison of Presque Isle Bay to Long Point Inner Bay showed that the liver tumor rates were not statistically different. In fact, when statistically adjusted for age, it appears that the incidence of liver tumors in Presque Isle Bay bullhead may be a reflection of the broader Lake Erie background rate. The external tumor rate in Presque Isle Bay, however, was statistically significantly higher than Long Point but comparable to all but one of the potential Lake Erie "least impacted" reference sites evaluated. Based on the limited sample sizes from the potential reference sites, it is difficult to determine whether or not the age-adjusted external tumor rate in Presque Isle Bay is significantly higher, lower, or the same as the background rate elsewhere in Lake Erie. It is true that similar to

Presque Isle Bay, incidences of unexplained external tumors are occurring in populations of brown bullheads in both AOC and non-AOC locations as well as inland Pennsylvania lakes.

PADEP turned its focus to investigating the cause of the external tumors and evaluating the appropriateness of using the tumors as an indicator of environmental degradation. A study designed to detect viruses in external bullhead tumors was inconclusive. A study evaluating whether the bay's bullheads were hybrids and, therefore, potentially predisposed to tumors found little evidence of atypical hybridization. An eighteen month laboratory exposure study did not find biomarkers signifying early stage cancer on any fish exposed to Presque Isle Bay sediment.

PADEP's recommendation to delist the fish tumors or other deformities BUI is grounded on the best science and technology available today. The decision is based on numerous investigations, sampling events, and consultation with the leading experts in brown bullhead investigations. While there is year-to-year variation, since the Recovery Stage designation in 2002 the incidence of liver and external tumors the bay's brown bullhead population has remained stable with little statistical difference in rates between sampling years. Incidence rates of both liver and external tumors remain well below the high levels seen in the early 1990s. Liver tumor rates, the end-point for which exposure to environmental contaminants is more clearly linked to sediment PAH contamination, are statistically indistinguishable from the Long Point Inner Bay reference site. The incidence of external tumors, however, remains elevated when compared to the reference site.

Because there are known legacy contaminants in the sediment regardless of their relationship to the bullhead tumors, PADEP commissioned ecological and human health risk assessments. Using appropriately conservative assumptions and existing data, both risk assessments concluded that cancer and noncancer risks posed by legacy contaminants in the Bay's sediment and fish are below targets for human health and ecosystem protection.

It may not be possible ever to fully restore this BUI due to the external tumors. Reviewing both the International Joint Commission and United States Policy Committee guidelines and principles, it seems clear that external tumors and, to some extent liver tumors, are a lakewide phenomenon. Based upon the data evaluated to select the Lake Erie "least impacted" reference site and

information from other AOCs, whatever is happening in Presque Isle Bay is occurring elsewhere in both AOC and non-AOC locations. The rest of the bay's fishery, however, is diverse, abundant, and healthy, appearing unimpacted by whatever is affecting the bullheads.

In recommending the delisting of the AOC, PADEP determined that removal of sediment by dredging the bay is unnecessary, remedial measures with the greatest direct benefit to the bay are done, other watershed measures that positively impact the bay are ongoing, air and water discharges are permitted and monitored, no other species of fish or benthic organism appear to be impacted, and both the human health and ecosystem health assessment concluded that the existing conditions in the bay do not increase either cancer or noncancer risks to people or the environment.

The goal of the AOC program as defined under the Great Lakes Water Quality Agreement is to insure that AOCs, which have been defined as areas where human activities have caused or are likely to cause significant impairment of local beneficial uses of water resources, are improved to the point where their environmental conditions are equal to other non-AOC locations across the Great Lakes. Those conditions may not be pristine but are consistent with the ambient environmental conditions elsewhere in the Great Lakes.

PADEP believes that the RAP process has accomplished its goal to the maximum extent practicable and the ultimate identification of the causes of the external tumors needs to be addressed outside the scope of the AOC program. Based on the decreased and stable tumor rates, review of the available scientific evidence, and in close consultation with local and national experts and the concurrence of the Presque Isle Bay Public Advisory Committee, PADEP recommends delisting the Presque Isle Bay AOC.

1. INTRODUCTION

In 1984, the United States Fish and Wildlife Service received reports from local anglers of brown bullhead catfish (*Ameiurus nebulosus*) with external lesions and/or tumors caught in Presque Isle Bay, Erie, Pennsylvania. In 1991, due in part to concerns about these external anomalies, the United States Department of State designated Presque Isle Bay the 43rd Area of Concern (AOC) under the Great Lakes Water Quality Agreement. Over the next twenty years, federal, state, and local government and academic researchers carried out numerous surveys and investigations of Presque Isle Bay, looking at fish, sediment, water quality, and other indicators of ecosystem health.

As the lead agency for addressing the AOC, Pennsylvania's Department of Environmental Protection (PADEP) is responsible for developing quantifiable targets to measure progress towards restoring the AOC. Working closely with members of the Presque Isle Bay Public Advisory Committee (PAC) and research partners including Pennsylvania Sea Grant, Erie County Department of Health, United States Geological Survey's Lectown Science Center, Texas A & M University, and Pennsylvania State University, PADEP collected considerable evidence to determine whether targets are met and support delisting Presque Isle Bay as an AOC.

This document serves as the Stage 3 Remedial Action Plan (RAP) and provides the data and rationale to support the delisting decision. The focus of this RAP is on the one remaining beneficial use impairment - fish tumors or other deformities. The RAP presents specific targets, summarizes investigations and research, and provides the rationale for delisting the remaining impairment and Presque Isle Bay as an AOC.

2. BACKGROUND

2.1 Great Lakes Approach to Restoring Beneficial Uses

Two agreements between the United States and Canada form the governing framework for monitoring and improving the quality of Great Lakes water resources. First, the 1909 Boundary Waters Treaty set the tone with the creation of the International Joint Commission (IJC). The IJC is an independent, joint Canadian and American federal government agency that provides oversight of the two countries shared water resources. Second, the Great Lakes Water Quality Agreement (Agreement) signed in 1972 expresses the commitment of both countries to restore and maintain the chemical, physical, and biological integrity of the Great Lakes.

A 1987 amendment to the Agreement established criteria for identifying geographical AOCs based on the presence of conditions that “caused or are likely to cause impairment of the area’s ability to support aquatic life” (United States and Canada, 1987). The Agreement further defined a beneficial use impairment (BUI) as a “change in the chemical, physical, or biological integrity” of the ecosystem that causes one or more of fourteen listed impairments. The impairments range from the loss of wildlife habitat and the presence of tumors or deformities on fish, to human health conditions related to water contact issues and drinking water standards. The amendment also established the RAP process for systematically restoring impaired beneficial uses in these areas.

The Agreement defines three stages for reporting progress at AOCs: (1) identification of BUIs; (2) selection of remedial and regulatory measures to address the cause(s) and source(s) of the BUIs; and (3) restoration of impairments. In 2001, the United States Policy Committee developed interim milestones to recognize progress between the three stages and provided a set of delisting principles to improve consistency across the Great Lakes basin. The Policy Committee created a “Recovery Stage” designation to acknowledge AOCs where implementation of remedial measures is complete and only time is needed for the ecosystem to respond prior to delisting the individual BUI and/or the AOC (USPC, 2001).

2.2 Presque Isle Bay Area of Concern

Located in northwestern Pennsylvania on the southern shore of Lake Erie, Presque Isle Bay is a 3718 acre shallow embayment with an average depth of 13 feet (Figure 1). It is 4.5 miles long and

1.5 miles across at its widest point. Presque Isle, a seven mile long recurved sand spit, forms the bay. The southeastern end of the bay connects to Lake Erie through a narrow channel that is maintained by the United States Army Corps of Engineers for navigation. The City of Erie forms the southern and eastern borders of the bay.

The Presque Isle Bay drainage basin is approximately 25 square miles and includes much of the City of Erie as well as portions of Millcreek, Summit, Greene, and Harborecreek townships. The principal tributary streams are Mill Creek including Garrison Run, and Cascade Creek, which together account for two thirds of the water flowing into the bay. Approximately 80% of the watershed is urbanized. The bay is a relatively closed system, and exchange of water with the outer harbor and Lake Erie is restricted by the small harbor opening and low inflow to total volume ratio (PADEP, 1993).

In the 1980s, anglers reported external sores and tumors on brown bullhead catfish caught in Presque Isle Bay. These reports served as a catalyst for concerned citizens to petition for the inclusion of the bay as an AOC. Without citing specific reasons, the United States Department of State designated Presque Isle Bay as the 43rd AOC on January 30, 1991.

PADEP, as the lead regulatory agency for addressing the AOC, proceeded with the RAP process to identify BUIs and explore remedial and regulatory measures to address the cause(s) and source(s) of the BUIs. The evaluation described in the Stage 1 RAP used existing information to identify potential pollution sources and loadings. PADEP identified impaired uses by comparing available data with the fourteen beneficial use impairment guidelines developed by the IJC's Water Quality Board (IJC, 1991). To make these comparisons, PADEP used all relevant data and based impairments on the most compelling set of data or the collective weight of multiple data sets. Through this process, PADEP identified chemicals of potential concern (COPCs), including ten heavy metals, nutrients, chemical oxygen demand, cyanide, oil and grease, and polycyclic aromatic hydrocarbons (PAHs) and concluded that two of the fourteen beneficial use impairments existed: restrictions on dredging activities and fish tumors or other deformities (PADEP, 1993).

Additionally, PADEP noted a limited beach closing beneficial use impairment due to fecal coliform levels at the discharge of the Mill Creek Tube and other stormwater discharge points. A determination could not be made for the guideline addressing plankton populations as no data were available.

PADEP updated the RAP in 1995 to address the outstanding BUI determinations, respond to comments on the 1993 RAP, and clarify that the AOC did not include the outer harbor. Further investigation confirmed the impairment of the dredging and fish tumors beneficial uses and removed the beach closing and plankton population BUIs (PADEP, 1995).

Since the 1980s, PADEP and its partners collected information on fish tumor incidence rates and sediment quality conditions within the bay. Sediment chemistry samples were collected at a number of locations in the bay in 1982, 1986, 1990, 1992, 1993, 1994, 2000, and 2001 (PADEP, 2002). In addition, whole-sediment toxicity tests were conducted on samples collected within the AOC in 1982, 1986, 1994, and 2000 (PADEP, 2002). The sediments were found to contain low level contamination, primarily metals and PAHs, spread throughout the bay. The investigations also indicated that sediment quality conditions were improving in the bay. As a result, PADEP, in conjunction with the AOC's PAC, determined that monitored natural attenuation, rather than active remediation within the AOC, would provide the most cost-effective and practical method for restoring the restrictions on dredging beneficial use. PADEP and the PAC made continuing the reduction of sediment and contaminant loading to the bay a priority, focusing resources on restoration projects within the watershed.

State, federal, and local government agencies conducted numerous studies of the bay's brown bullhead catfish beginning in 1985. In the early 1990s, tumor rates were calculated as a percentage of the total fish collected without accounting for age. Rates were as high as 86% for grossly observable external tumors and 22% for liver tumors. Over the next ten years, tumor rates steadily declined to 19% for grossly observable external tumors and a reported zero percent for liver tumors. Investigators concluded that the overall health of the bay's brown bullhead population had

improved dramatically and that external and liver tumor rates were comparable to inland reference lake sites in Pennsylvania. The bullhead population was stable and reproducing (PADEP, 2002).

The improvements in sediment quality, the decade-long downward trend in fish tumors, and the decision not to pursue active remedial measures within the AOC led to the redesignation of Presque Isle Bay to the Recovery Stage in 2002. The new status was a direct result of changes in the watershed, the most significant of which was the \$100 million upgrade to the City of Erie's wastewater collection, treatment, and conveyance system. In 1985, the City undertook studies to determine and address the sources of pollution, added a parallel outfall into the Lake, and reduced the number of combined sewer overflows (CSOs) from more than 70 to five. Four of the CSOs discharge into the Mill Creek Tube which empties into the bay. All have screens and flow monitors. Additionally, the City of Erie maintains a litter trap at the end of Mill Creek that catches oil and debris from the CSOs and the stream. The City of Erie reports a CSO capture rate in excess of 99.9%. Additionally, there are no known unpermitted industrial waste discharges to the bay.

Other factors contributing to environmental improvements in the bay include the removal of a coal-fired power plant and wastewater discharge, the shift from industrial to more commercial activities along the bayfront and within the City, and restoration actions taken by local environmental groups throughout the watershed

2.3 Delisting Restrictions on Dredging Activities BUI

In 2005, a comprehensive sediment study began to assess the restrictions on dredging activities BUI. It incorporated a review of all existing sediment data, particularly data used to make dredging and disposal decisions, collection of surface and subsurface sediment samples, and identification of both delisting and ecosystem health targets. The assessment of the restrictions on dredging activities BUI included both practical and ecological perspectives. The practical restriction is based on Pennsylvania's laws and regulations, which preclude the disposal of the dredged material in the open lake regardless of contaminant presence or absence. This restriction is due to the fact that dredged material is defined as a solid waste and there are limitations associated with locating a disposal

facility in waters of the Commonwealth. Disposal to the Confined Disposal Facility (CDF) or an upland site are the only allowable options. Because the restrictions on disposal of dredged material are not related to sediment contamination, but rather laws preventing the disposal of solid waste in waters of the Commonwealth, from the practical perspective the beneficial use is not considered impaired (PADEP, 2006).

From an ecological perspective, the sediment in the Presque Isle Bay AOC was evaluated against a delisting target based on discharges from the disposal of dredged material in the CDF (Table 1). The target takes into account the limitation on disposal options and current permitting practices by evaluating discharges from the CDF. The delisting target requires concentrations of chemicals of potential concern in the CDF's mixing zone to be below Pennsylvania Water Quality Standards at the 15-minute compliance point for acute criteria and the 12-hour compliance point for chronic criteria. Using elutriate data for areas routinely dredged within the AOC and calculations to predict concentrations in the CDF discharge based on concentrations in the sediment, it was determined that sediment dredged from any location within the AOC could be placed in the CDF.

The 2005 survey data was also used to evaluate sediment quality following the 2002 Recovery Stage designation. Ecosystem health targets were identified for benthic organisms, fish, and aquatic-dependent wildlife (Table 1). While concentrations of individual contaminants did, in limited locations, exceed sediment quality guidelines, and there is a potential for PAHs to be bioavailable to benthic organisms, actual toxicity tests did not confirm the predicted toxicity. The evaluation concluded that existing sediment quality conditions are sufficient to support benthic invertebrate communities and risks to fish and aquatic-dependent wildlife using habitats within the AOC are unlikely to be higher than that elsewhere in Lake Erie (PADEP, 2006). As a result of both the practical and ecological evaluations, the restrictions on dredging activities BUI was delisted in 2007.

In August and September 2009, to monitor ongoing compliance with the delisting target and ecosystem health targets, surficial sediment samples were collected from seven historical sampling locations within Presque Isle Bay, two historical sampling sites outside of the bay, and three

locations within the bay where brown bullhead are routinely collected for tumor analysis. In addition, sediment samples were collected from the mouths of Mill Creek, Scott Run, and Cascade Creek in an effort to characterize the concentrations of contaminants deposited in the streams following rain events.

The sedimentation rate in the bay averages one centimeter per year, suggesting that approximately four centimeters of new sediment accumulated in the four years between sampling events. As a result, a significant change in sediment quality was not expected or observed. Analysis of data showed that the delisting target for the restrictions on dredging BUI continues to be met. There were no exceedences calculated for the discharge from the CDF (Rafferty and Boughton, 2012). Concentrations of Chemicals of Potential Concern (COPCs) varied between sampling events and the same PAH compounds were found to exceed Sediment Quality Guidelines (SQGs) in both events. Overall, sediment quality was seen to improve as evidenced by the fewer number of samples with contaminants exceeding SQGs in 2009. Pesticides, PCBs, and arsenic were not detected in concentrations exceeding SQGs in any of the 2009 samples, indicating that these compounds are not present at levels that would impact ecosystem health. The contaminant mixtures present did not contain COPCs in concentrations that would cause adverse impacts on benthic organisms. Metals present are binding to organic carbon and not bioavailable. There is a potential for PAHs to be bioavailable to benthic organisms. However, this measure has improved since 2005 where a higher number of sites exceeded ecosystem health targets. The ecosystem health target evaluating the potential of COPCs to be present at levels toxic to fish remained unchanged between the two sampling events.

Samples collected from the tributaries above the mixing zone with the bay had more exceedences of SQGs for PAHs than locations in the AOC. However, measures of bioavailability were similar to that found at the long term monitoring sites, indicating that particle size and total organic carbon are limiting the availability of the contaminants to benthic organisms. The 2009 study confirmed that sediment quality continued to improve, the delisting target was being met, and the restriction on dredging activities beneficial use continued to be unimpaired (Rafferty and Boughton, 2012).

3.0 UPDATING THE BENEFICIAL USES EVALUATION

The 1993 Stage 1 RAP presents a detailed evaluation of the fourteen BUIs. That assessment is now more than twenty years old and conditions within the bay and its watershed have changed. While more than twenty years of data is available on the fish tumors or other deformities and restrictions on dredging activities impairments, the other twelve BUIs have not been reassessed. Over the years, surveys and studies for other purposes have collected data that can be used to re-evaluate the twelve BUIs not considered impaired in the 1993 RAP. PADEP reexamined those twelve beneficial uses using the most recent data available and confirmed that these BUIs remain unimpaired.

3.1 Restrictions on Fish and Wildlife Consumption IJC Listing Criteria

When contaminant levels in fish or wildlife population exceed current standards, objectives, or guidelines, or public health advisories are in effect for human consumption of fish or wildlife. Contaminant levels in fish and wildlife must be due to contaminant input from the watershed.

Assessment

PADEP conducts routine analyses of fish flesh for the presence of PCBs, metals, and pesticides in both Presque Isle Bay and the open waters of Lake Erie as part of its base fish consumption advisory program. PADEP does not assess wildlife tissue. Consumption advisories based on elevated levels of PCBs and mercury are in place for fishes in both Presque Isle Bay and Lake Erie. While comparisons between the bay and open lake are difficult due to differences in species composition and migrations into and out of the bay by common species, there is no evidence that fish species in Presque Isle Bay are more contaminated than in Lake Erie.

Mercury levels in the bay's largemouth bass fell from over 0.3 ppm in 1996 to less than 0.25 ppm in samples taken in 2001, 2005, and 2006. Because of this trend, the consumption advisory was adjusted from two meals per month to one meal per week beginning in 2007 (Figure 2). Mercury and PCB concentrations in Presque Isle Bay yellow perch, believed to be a resident population, are comparable to concentrations in perch collected from Lake Erie (Figure 3). PCB concentrations in Presque Isle Bay common carp, believed to be resident population, are lower than concentrations in carp collected from Lake Erie. However, sample sizes are very small (two from each location) and the Lake Erie fish in particular need to be resampled due to data quality issues with the laboratory.

Generally, the species with the highest contaminant burdens (walleye, steelhead, lake trout, and smallmouth bass) reside either exclusively or primarily in the open lake.

Conclusion

While contaminant levels in fish do exceed current standards and there are consumption advisories, concentrations of PCBs and mercury in fish sampled from the bay are equal to or less than the same species sampled from the open waters of Lake Erie. The IJC's listing and delisting guidelines (IJC, 1991) specifically states "when a health advisory on fish in a localized area is no different from the health advisory for the whole lake and this area is not contributing to a whole lake problem, then it would not be recommended for identification of an AOC". Because the consumption advisories are not a result of bay-specific conditions, the Restrictions on Fish and Wildlife Consumption beneficial use is not considered impaired in Presque Isle Bay.

3.2 Tainting of Fish and Wildlife Flavor

IJC Listing Criteria

When ambient water quality standards, objectives, or guidelines, for anthropogenic substances(s) known to cause tainting, are being exceeded or survey results have identified tainting of fish or wildlife flavor.

Assessment

Impairment of this guideline is indicated if (1) water quality standards for tainting substances are being exceeded or (2) tainting of fish or wildlife flavor is determined through surveys. PADEP consulted the Pennsylvania Fish and Boat Commission (PFBC) regarding any complaints or notes of fish or wildlife with undesirable taste or odor. As of June 2012, the Commission's local Waterways Conservation Officer reported no public complaints in the thousands of angler surveys conducted during the past two decades.

In order to be consistent with the original assessment of this BUI, Presque Isle Bay Water Quality Network Station 632 trend data for copper and zinc levels were compared to PADEP's 25 Pa Code Chapter 16 Water Quality Criteria (WQC). Copper was below analytical quantification levels for 40 network water samples collected between 2002 and 2011. Detectable levels of zinc were present in

15 of 40 samples for the same time period. PADEP's WQC for metals are calculated based on the hardness of the ambient water. Given the average CaCO₃ hardness of 117 mg/L in the bay for this period, Chapter 16 standards were exceeded for two of these samples (Figure 4).

Conclusion

Based on the ten most recent years of data from the Water Quality Network Station within the bay, there is no evidence of chronic or acute violation of taste and odor standards indicated by concentrations of copper and zinc. Therefore, the Tainting of Fish and Wildlife beneficial use is not impaired in Presque Isle Bay.

3.3 Degraded Fish and Wildlife Populations

IJC Listing Criteria

When fish and wildlife management programs have identified degraded fish or wildlife populations due to a cause within the watershed. In addition, this use will be considered impaired when relevant, field validated, fish or wildlife bioassays with appropriate quality assurance/quality controls confirm significant toxicity from water column or sediment contaminants.

Assessment

PADEP and PFBC fish survey data were used to ascertain the diversity and abundance of the fish populations in Presque Isle Bay (Figure 5). PADEP has documented 54 species of fish in the bay, most of which are minnows and other small forage fishes, including the Brook Silverside, a Pennsylvania endangered species that is uncommon outside the bay. Surveys have also found a number of other state-endangered species, including bigmouth buffalo, warmouth, and spotted gar—a species which occurs nowhere else in the Commonwealth. A 2012 survey by PADEP suggests that the state endangered Iowa Darters are increasing in relative abundance.

Evidence of the health of the bay's fishery is further demonstrated by the PFBC's 2008 black bass assessment. Over a three day period, a total of 693 bass were captured consisting of 675 largemouth bass and 18 smallmouth bass. Spring 2008 marked the highest number of bass ever sampled in Presque Isle Bay and the total number captured was a 65% increase over 2007. The occurrence of largemouth bass 12 inches and longer increased 150% from 2007 and the occurrence of largemouth

bass 15 inches and longer increased 245%. The catch rate for largemouth over 15 inches was the highest observed in the last 18 years. The biggest risk to the bay's fishery is the continued introduction of non-native invasive species (Figure 6). In 2011, the tubenose goby, a cousin of the invasive round goby, was documented in the bay.

In 1992 and 1999 researchers conducted population studies on the bay's brown bullheads. Using mark-recapture methods, the 1992 estimate was 31,715 and the 1999 estimate was 30,950, suggesting a stable population.

Conclusion

There is no evidence of population level impacts for any fish species found in Presque Isle Bay, including brown bullhead catfish. Therefore, the Degraded Fish and Wildlife Populations beneficial use is not considered impaired in Presque Isle Bay.

3.4 Bird or Animal Deformities or Reproductive Problems

IJC Listing Criteria

When wildlife survey data confirm the presence of deformities (e.g., cross-bill syndrome) or other reproductive problems (e.g., egg-shell thinning) in sentinel wildlife species.

Assessment

While no formal surveys have been conducted in the last twenty years, the bay and Presque Isle State Park are extensively visited by both amateur and professional nature watchers. The bay and park are part of an important migratory path for birds. Since 2008, the Presque Isle Audubon Society sponsors a one day bird count on Presque Isle State Park. Over three days, volunteers tally the number and species of birds on and over the park. In 2012, volunteers identified 146 species with 25 species of warblers. A running list of species identified at the park is posted on the Society's web site. There are no indications of either deformities or reproductive problems noted. A number of researchers from local and state academic institutions conduct research within the bay and on the park. No reports or other evidence of deformities or reproductive problems have been documented. Populations of other animals at the park are thriving, requiring a deer hunt every year to thin the herd.

Conclusion

There is no evidence of bird or animal deformities or reproductive health problems in the Presque Isle Bay AOC or surrounding watershed. Therefore, the Bird or Animal Deformities or Reproductive Problems beneficial use is not considered impaired.

3.5 Degradation of Benthos

IJC Listing Criteria

When the benthic macroinvertebrate community structure significantly diverges from unimpacted control sites of comparable physical and chemical characteristics. In addition, this use will be considered impaired when toxicity (as defined by relevant, field-validated, bioassays with appropriate quality assurance/quality controls) of sediment associated contaminants at a site is significantly higher than controls.

Assessment

In evaluating this beneficial use, it is important to note that benthic macroinvertebrate community composition in lakes and bays is very different from that in streams. As a result of habitat differences, even healthy lake communities will be dominated by midges and aquatic worms rather than the mayflies, stoneflies, and caddisflies that dominate healthy flowing streams. PADEP reviewed two different assessments of the bay's benthic macroinvertebrate community. The first (Diz, 2002), examined the benthic community structure, looked for chironomid mouthpart deformities, and conducted sediment toxicity bioassays using the benthic macroinvertebrates *Hyallela arctica* and *Chironomus tentans* and the planktonic crustacean *Daphnia magna*. The author concluded:

- The Presque Isle Bay benthic community is dominated by pollution-tolerant organisms, such as worms, midges, and snails, and is relatively lacking in those species which are known to be sensitive to stressful conditions, such as mayflies and caddisflies. However, the taxa found in Presque Isle Bay are typical of the benthic fauna found in northwestern Pennsylvania lakes.
- Bioassays showed no impact to the survival of the test organisms

- The occurrence of mouthpart deformities in midges is an indication of sediment toxicity. From each of nine sediment sample sites in Presque Isle Bay, 10 *chironomid* individuals were chosen at random. Of the 90 total chironomids examined, only one exhibited a mouthpart deformity.

In 2005, ten day and 28-day whole sediment toxicity tests were conducted with the midge *Chironomus dilutes* and the amphipod *Hyalloa Azteca*. Thirty four surficial sediment samples were used to evaluate survival and growth endpoints. None of the samples were toxic to amphipods for either endpoint. One sample from the center of the AOC was toxic to midges when the survival endpoint was considered and three were designated toxic using the growth endpoint (PADEP, 2006). Three of the four samples toxic to midges did not have measured concentrations of contaminants expected to be toxic to the benthic organisms. At these locations, factors such as ammonia or hydrogen sulfide in the pore-water or other factors not related to the chemical contaminants in the sediment were believed to cause the observed toxicity.

Conclusion

Presque Isle Bay's benthic macroinvertebrate community is dominated by pollution-tolerant organisms, such as worms, midges, and snails which is typical for an environment of fine, organic-rich sediment. Direct testing found a limited number of sediment samples were toxic and it is believed the toxicity is due to non-contaminant related factors. Based on these studies, the Degradation of Benthos beneficial use is not considered impaired in the Presque Isle Bay AOC.

3.6 Eutrophication or Undesirable Algae

IJC Listing Criteria

When there are persistent water quality problems (e.g. dissolved oxygen depletion of bottom waters, nuisance algal blooms or accumulation, decreased water clarity, etc.) attributed to cultural eutrophication.

Assessment

PADEP conducts periodic trophic state index (TSI) assessments, annual summer plankton (zooplankton and phytoplankton/algae) sampling, and dissolved oxygen monitoring in Presque Isle Bay. TSI surveys involve collecting measures of plant productivity such as phosphorus levels,

chlorophyll-a levels (the photosynthetic pigment in plants and algae), and the clarity of the water. TSI results are used to classify lakes and bays as either oligotrophic (“poorly fed”), mesotrophic (“moderately fed”) to eutrophic (“well fed”) to hypereutrophic (“beyond well fed”).

The Carlson TSI score for the bay was last determined in 2005. The bay received a TSI score of 52 at that time, placing it in the *low eutrophic* range (Figure 7). This score suggests that the bay has good biological productivity but may be vulnerable to problems related to nutrient enrichment. This score does not suggest conditions are currently suitable for nuisance plant and algae growth.

One of the simplest ways to track the trophic state of a lake is to track the water clarity over time. Clearer water has less algae and suspended particles, while “cloudier” water tends to have more algae and suspended material. Trends indicate that water clarity has improved slightly during the past two decades (Figure 8).

Unlike most Pennsylvania lakes, Presque Isle Bay does not completely stratify into a warmer upper bay and cooler lower bay in the summer. While it functions somewhat independently of the rest of Lake Erie, Presque Isle Bay is actually part of the warmer “epilimnion”, or upper lake, of Lake Erie. Therefore, unlike the central basin of Lake Erie proper, there is always some dissolved oxygen present in the bottom of the bay for fish and other aquatic life.

Bluegreen cyanobacteria blooms (especially *Microcystis aeruginosa*) typically comprise Harmful Algal Blooms in the Great Lakes. Nuisance levels of *Microcystis* have not been reported from Presque Isle Bay. Nonetheless, trend monitoring for the bluegreens *Anabaena* and *Microcystis* show that periodic blooms have occurred in Presque Isle Bay at levels approaching those in the western basin of Lake Erie. Most recently, elevated levels of *Microcystis* were noted in 2005, 2006, and 2011 (Figure 9).

Conclusion

This guideline evaluates whether there are persistent water quality problems due to nutrient enrichment. The bay is indicative of the larger lake and that there is not an excessive runoff of nutrients into the bay from Erie or the surrounding area. Algal blooms are the same in the bay as lakewide conditions. Annual assessments of water quality, algae, and oxygen levels in the bay have

confirmed that cultural eutrophication is not occurring. In fact, there has been a trend of improving water clarity over the last two decades. Based on the trophic status of the bay, the increased water clarity, and lack of persistent algal blooms, Presque Isle Bay is not considered impaired for Eutrophication or Undesirable Algae.

3.7 Restrictions on Drinking Water, or Taste and Odor Problems

IJC Listing Criteria

When treated drinking water supplies are impacted to the extent that: 1) densities of disease-causing organisms or concentrations of hazardous or toxic chemicals or radioactive substances exceed human health standards, objectives, or guidelines; 2) taste and odor problems are present; or 3) treatment needed to make raw water suitable for drinking is beyond the standard treatment used in comparable portions of the Great Lakes which are not degraded (i.e., settling, coagulation, disinfection).

Assessment

Presque Isle Bay is not used as a source of drinking water. The City of Erie's drinking water intakes are both located in Lake Erie west and north of the Presque Isle Peninsula. Additionally, the City has an ordinance that prohibits the use of wells or springs located on a property to be used as a source of drinking water.

Conclusion

The Restrictions on Drinking Water Consumption, or Taste and Odor Problems beneficial use is not applicable or impaired in Presque Isle Bay.

3.8 Beach Closings

IJC Listing Criteria

When waters, which are commonly used for total-body contact or partial-body contact recreation, exceed standards, objectives, or guidelines.

Assessment

Although there are no designated public beaches within Presque Isle Bay, water samples are collected bi-weekly or weekly during the summer months, depending upon the location within the bay, and analyzed for *E. coli*. The monitoring began in 2007 with three sets of samples and has, in the last five years, expanded to sampling at twelve different locations. The Department of Conservation and Natural Resources (DCNR) issues beach advisories for Lake Erie Beaches when *E. coli* counts exceed 235 CFU/100 mL and restrict swimming when counts exceed 1000 CFU/100 mL. PADEP used these standards to compare the AOC to Lake Erie. Samples from Presque Isle Bay, collected at the mouth of Cascade Creek, south of the City of Erie's Wastewater Treatment Plant in Garrison Run, and at the mouth of Scott Run are consistently higher than other locations in the bay (Figure 10). Since 2009 the yearly average concentrations of *E. coli* in samples from these locations exceed the level for beach advisories but not the level for restricted swimming. No other locations exceeded either criterion. As a testament to the improved water quality conditions, the Presque Isle Partnership sponsors a one mile swim across the Bay from Presque Isle State Park to the Erie Yacht Club. Since its inception in 2008, every year 200 swimmers participate in the swim.

Conclusion

There are no public beaches within the Presque Isle Bay AOC and therefore, this beneficial use does not apply. However, comparison of the last five years of *E. Coli* sampling with the criteria for restricting swimming at the public beaches on Presque Isle State Park show that the beach closing beneficial use would not be impaired in Presque Isle Bay.

3.9 Degradation of Aesthetics

IJC Listing Criteria

When any substance in water produces a persistent objectionable deposit, unnatural color, or turbidity, or unnatural odor (e.g., oil slick, surface scum).

Assessment

PADEP is occasionally called upon to investigate an unusual odor, color, or plume within the bay. In many cases, the conditions are natural due to weather (i.e., seiche, heavy rain storm or high wind)

which may cause turbid conditions. There are also occasions when a surface sheen is noted due primarily to boater use, marinas, and inputs from the watershed.

Conclusion

Temporary impacts to aesthetics typical of urban embayments are noted within Presque Isle Bay. Because the conditions are not persistent and do not significantly impact the bay, the degradation of aesthetics beneficial use is not considered impaired.

3.10 Added Costs to Agriculture or Industry

IJC Listing Criteria

When there are additional costs required to treat the water prior to use for agricultural purposes (i.e., including, but not limited to, livestock watering, irrigation and crop-spraying) or industrial purposes (i.e., intended for commercial or industrial applications and noncontact food processing).

Assessment

Water from Presque Isle Bay is not used by agricultural or industrial operations.

Conclusion

The beneficial use associated with costs to agriculture and industry is not impaired in Presque Isle Bay.

3.11 Degradation of Phytoplankton and Zooplankton Populations

IJC Listing Guideline

When phytoplankton or zooplankton community structure significantly diverges from unimpacted control sites of comparable physical and chemical characteristics. In addition, this use will be considered impaired when relevant, field-validated, phytoplankton or zooplankton bioassays (e.g. Ceriodaphnia; algal fractionation bioassays) with appropriate quality assurance/quality controls confirm toxicity in ambient waters

Assessment

PADHAP samples the plankton community at WQN monitoring stations in Presque Isle Bay (WQN 632) and Lake Erie (WQNs 601 and 622). It is difficult to compare plankton trends due to natural annual and seasonal variation in the community composition. The plankton communities at all three monitoring sites have been degraded by the establishment of non-native species. These include the cyanobacteria (bluegreen algae) *Lyngbya* which is known to cause harmful algal blooms in the western basin in Lake Erie as well as the planktonic larvae of zebra and quagga mussels. The mean number of plankton taxa in Presque Isle Bay (25.25) is not significantly different than Lake Erie WQNs 601 (25.5) or 622 (25.75) and the qualitative list of taxa present is virtually identical to Lake Erie. However, Presque Isle Bay is warmer, shallower, and more productive than the open waters of Lake Erie. As a result, the plankton in the bay is more abundant than in the open lake. The annual timing and succession of phytoplankton blooms in the bay is also somewhat accelerated relative to the open lake (Figure 11). *Microcystis* blooms are larger in the warmer waters of Presque Isle Bay than in the open lake. However, *Microcystis* is present at all the monitored sites (Figure 12). Plankton communities in the both bay and lake are degraded to a degree due to non native species. Despite the presence of non-native species, the plankton communities in Presque Isle Bay are sufficient to support one of the most diverse and abundant fisheries in the Commonwealth.

In 2002, the planktonic crustacean *Daphnia magna* along with the benthic macroinvertebrates *Chironomus tentans* and *Hyallela azteca* were used in a bioassay of the sediment quality in Presque Isle Bay. Nine replicate toxicity tests were conducted. There was no significant difference in survival between *Daphnia* exposed to Presque Isle Bay sediment and the control. However, reproduction was significantly less for *Daphnia* exposed bay sediment in 7 of the 9 bioassays.

Conclusion

Despite some evidence of reduced *Daphnia* reproduction in the bioassay by Diz (2002), Presque Isle Bay plankton populations are as taxonomically rich as in Lake Erie and abundance/biomass is greater. Therefore, the Degradation of Phytoplankton and Zooplankton Populations BUI does not occur in Presque Isle Bay.

3.12 Loss of Fish and Wildlife Habitat IJC Listing Delisting Criteria

When fish and wildlife management goals have not been met as a result of loss of fish and wildlife habitat due to a perturbation in the physical, chemical, or biological integrity of the Boundary Waters, including wetlands.

Assessment

The 1993 Stage 1 RAP states that the PFBC is the agency involved in setting fish and wildlife management goals. The PFBC manages Presque Isle Bay as a sport fishery and conducts periodic surveys. As discussed under the Degraded Fish and Wildlife Populations BUI, the bay's fishery is very diverse and high quality, meeting management goals as a sport fishery.

Conclusion

Based upon the most recent survey data from PFBC and PADEP, the Loss of Fish and Wildlife Habitat beneficial use is not considered impaired in Presque Isle Bay.

4. FISH TUMORS OR OTHER DEFORMITIES BUI

4.1 Historical Perspective

Beginning in the late 1980s, Great Lakes researchers attempted to define quantifiable delisting targets for the fish tumors or other deformities BUI based primarily on the incidence rate of liver tumors and external deformities. Researchers considered fish tumors an indicator of both environmental degradation and a measure of health impairment to fish populations (Baumann, 1992a). Of the original 42 AOCs, 17 had fish with readily identifiable tumors or deformities.

The first attempt to define the fish tumor impairment in “precise set of scientifically defensible” criteria resulted in an IJC recommendation that “the incidence rate of neoplastic and preneoplastic liver tumors in bottom-feeding fishes not exceed 2 percent” (Hartig et al, 1990). The basis for this recommendation was the assumption that certain contaminants cause tumors in fish and a presumption that fish from uncontaminated locations should have a zero liver tumor incidence rate. A review of existing data from the Great Lakes and Puget Sound; however, showed that liver tumors develop in fish from uncontaminated sites. A two percent tumor rate accounts for this fact as well as uncertainties in fish movement and factors other than exposure to contaminants that promote tumors (Michael J. Mac, 2009 personal communication).

The IJC modified this recommendation, publishing guidelines that suggest the fish tumor or other deformities beneficial use impairment exists when “the incidence rates of fish tumors or other deformities exceeds rates at unimpacted control sites or when survey data confirm the presence of neoplastic or preneoplastic liver tumors in bullheads or suckers” (IJC, 1991). The IJC listing/delisting guidelines were developed to assist in making recommendations for listing new AOCs and in reviewing Remedial Action Plans. The intention was to establish a “set of yardsticks” that could be applied throughout the basin and keep the Remedial Action Plan program focused. They are written as guidelines to serve as a common starting point for each AOC. The IJC constructed the guideline to allow each AOC to adapt it to site-specific conditions in setting delisting targets (e.g., selection of unimpacted control site and which fish species to use as an indicator).

Subsequent studies throughout the 1990s, by both American and Canadian researchers recommended specific numeral targets for liver and external tumor incidence rates as indicators of environmental degradation. For example, a review of data collected between 1984 and 1993 from ten contaminated and three reference locations from across the Great Lakes concluded that liver tumor incidences above 5% and external tumor incidences in excess of 25% were evidence of impairment (Baumann et al., 1996). A comparison of “least impacted control sites” and contaminated embayments, river mouths, and nearshore areas within Lake Erie defined impairments when liver tumor incidences were above 5-7% and external tumor incidence were above 13-15% (Baumann et al., 2000).

4.2 Delisting Target for the Presque Isle Bay AOC

Development of the fish tumor delisting target for the Presque Isle Bay AOC has been an iterative process. Following the recommendations of Great Lakes researchers, delisting criteria were based on having a liver and external tumor incidence rate on brown bullhead below a specified target number. The 1993 RAP concluded that the fish tumor or other deformities beneficial use was impaired because liver tumor rates exceeded the IJC’s 2% benchmark and external abnormalities were in excess of 10-12% (PADEP, 1993). The 2002 Recovery Stage redesignation was due in part to the decreasing liver and external tumor rates. Additionally, the tumor rates were below the recommended indicators of environmental degradation of 25% for external tumors and 5% for liver tumors. While these targets represented good starting points for developing delisting criteria, a number of questions were raised regarding the comparability of data from different years and locations and whether contaminants in the sediment were the cause of the tumors. Through a series of workshops between 2003 and 2006, PADEP and the PAC sought advice from experts including fishery and wildlife biologists, pathologists, representatives from other AOCs, and researchers. Consensus was reached on a broad range of sampling and analysis issues, including the following recommendations:

- Samples should include only brown bullheads that are a minimum length of 250 mm (9.9 inches) to exclude younger specimens. Length and age studies show that brown bullheads greater than 250 mm are at least age three and likely to be reproductively mature (Maccina and Sammons, 2006).

- Ages should be determined for all necropsied bullhead using otoliths rather than pectoral spines because otolith-based ages are more accurate.
- Given the strong positive correlation between bullhead age and tumor development, it is important to compare fish of the same age to evaluate temporal trends and differences between locations.
- Examination of the fish should include both gross visual observation and histopathology.
- Both external and liver tumor incidence rates should be determined for beneficial use restoration purposes. However, special studies may look at other internal organs as well.
- It is important to examine multiple sections from each liver to ensure that any tumor present in the organ will be detected.

One of the major outcomes of the workshops was the decision to compare tumor incidence rates in Presque Isle Bay to that of reference sites using comparable fish collection (e.g., Rafferty and Grazio, 2006) and histopathology methods (e.g., Blazer et al., 2006). Unfortunately, the majority of data from past studies at the reference locations could not be used as the collection and histopathology methods employed in those studies are not comparable to those used in Presque Isle Bay. In particular, the majority of past studies used pectoral spine-based age determinations and these age determinations are not comparable to the otolith-based age determinations used in the bay. In addition, histopathological methods varied among studies. A consequence of this decision was the need to determine new, more realistic delisting tumor incidence targets.

Following expert recommendations, PADEP decided not to select any of the specific incidence rates recommended historically because those rates did not account for important factors such as the age of the fish population. Instead, PADEP chose to focus the delisting target on a comparison of the liver and external tumor incidence in Presque Isle Bay to an appropriate Lake Erie reference or “least-impacted control site”. In order to identify the least-impacted reference site, PADEP sampled a number of candidate sites from across Lake Erie. All candidate sites were non-AOCs that lacked point-source discharges of pollutants or known sediment contamination and had a resident bullhead population.

Based on this premise, PADEP collected samples in 2004, 2005, and 2007 from Dunkirk Harbor, NY; Long Point Inner Bay, ON; Old Woman's Creek, OH; and Sandusky Bay, OH (Figure 13). Sample evaluation included gross visual observation for all fish collected and histopathological analysis of any raised external or mouth lesions and all livers for a subset of 30-50 fish at each location.

In evaluating the data, PADEP incorporated recommendations from the expert workshops, specifically the need to compare fish of the same age to evaluate temporal trends and differences between locations. Historically, PADEP reported tumor incidence rates based on dividing the number of fish with tumors by the number of fish sampled. This approach did not take into account the demographics (e.g., age, length, gender, etc.) of the sample. A statistical model was developed that used logistic regression which allowed for the comparison of tumor incidence between sites by taking the age and length of each bullhead into consideration when determining the probability of a tumor (Rutter, 2010). Applying a Bayesian hierarchical model, the results of the logistic regression can be easily presented as point estimates and intervals of biological terms (i.e., the probability that a bullhead has a tumor).

In Presque Isle Bay, tumor rates increase with fish age. PADEP used logistic regression to measure tumor incidence rates as a function of age and Bayesian statistical analysis was used to compare incidence rates between ages, and account for multiple sampling locations and dates. This approach does not directly compare cohorts of fish, but rather allows for the determination of a point estimate of tumor incidence rates for fish of a given age. Age seven was chosen because this was the approximate mean age of bullhead in the full dataset (Rutter, 2010). The 95% confidence interval describes the "certainty" of the point estimate with narrow intervals indicating a more accurate point estimate for the tumor incidence rate.

The candidate site with the lowest liver tumor incidence (0.0%) was Dunkirk Harbor and the candidate site with the lowest external tumor incidence was Long Point Inner Bay (6.4%; Table 2). A closer examination of the Dunkirk Harbor tumor incidence indicated a high level of uncertainty in the estimate based on the 95% confidence intervals around the mean incidence rate (0.0%, 56.0%). Dunkirk Harbor also had the highest incidence of external tumors (22.5%). The second lowest liver

tumor incidence among the reference sites was Long Point Inner Bay (1.2%) and the 95% confidence interval (0.0%, 14.9%) was much narrower indicating less uncertainty in the estimate. Based on combined external and liver tumor incidence rates, Long Point Inner Bay was selected as the least-impacted Lake Erie reference site and the appropriate reference site for Presque Isle Bay

Proposed Presque Isle Bay Delisting Target

The fish tumor or other deformities beneficial use is no longer considered impaired when the incidence rate of liver and external tumors is statistically equivalent or lower than the incidence rates at Long Point Inner Bay as confirmed by histopathology.

4.3 Testing the Delisting Target

Following the 2002 Recovery Stage designation, PADEP conducted annual monitoring surveys through 2010 to assess tumor trends. The assessment included both gross visible observation and histopathology of raised external lesions and livers. Applying the same logistic regression and Bayesian statistical analysis developed in evaluating the Lake Erie potential reference sites, the data were normalized to age seven years for consistency in reporting and comparability between sampling years and with Long Point Inner Bay.

Both the liver and external tumor incidence rates were found to be stable throughout the Recovery Stage monitoring period (Table 3; Figures 14 and 15). The incidence rate of liver tumors ranged from 1.1% in 2002 to 3.9% in 2007 with a median liver tumor incidence rate for this period of 2.8 % (Table 3). It is important to note that the five years of data does not provide enough data points to determine a trend, rather it shows inter-annual variation which is most likely an artifact of the random sampling methodology than a true difference in tumor incidence rates. Also, when the yearly estimates are examined, there is no statistically significant trend. Using the Bayesian 95% confidence intervals to measure certainty, there were no statistical differences in the liver tumor incidence rates among years or among the various Presque Isle Bay collection sites.

Brown bullhead from Presque Isle Bay sites had similar grossly observed external lesion incidence rates to those collected at the Lake Erie potential reference sites. External tumor rates confirmed by histopathology ranged from 11.9% in 2005 to 18.9% in 2004 with a median external tumor

incidence rate for this period of 15.4 %.(Table 3). As was the case with the bay's liver tumor rates, there was not enough data to report a downward or upward trend and there were no statistical differences in the external tumor rates among years or among collection sites.

PADEP conducted gross visual observations of the bullheads collected in the AOC following the Recovery Stage designation through 2010 (Figure 16). While not confirmed by histopathology, looking at the combined external and mouth tumors, the data shows a relatively stable, downward trend in external tumors over time. Looking first at the post-Recovery Stage between 2002 and 2007, the median external tumor rate grossly observed for bullheads estimated by length to be age seven was 20.5%. This is considerably higher than the rate as confirmed by histopathology, illustrating how gross visual observation overestimates the actual tumor incidence rate.

Over the five years in which Presque Isle Bay was sampled, 222 brown bullheads from the bay were necropsied and analyzed for liver and external tumors. Sampling of Long Point Inner Bay occurred in 2004, 2005, and 2007 with a total of 193 brown bullheads collected for analysis. Statistically, there were enough samples from each location to evaluate whether the tumor rates were equivalent. Rather than compare the two medians, the confidence interval estimating the difference in true tumor rates was determined (Rutter, 2010). When the confidence interval contained zero and was small, the two tumor rates could be considered statistically equivalent. The narrowness of the confidence interval was also important in determining whether the tumor rates were equivalent or different. If the confidence interval describing the difference in tumor rates was too large or did not contain zero, then the tumor rates were considered statistically significantly different (Rutter, 2010).

Looking first at the median liver tumor rates and confidence intervals on Tables 2 and 4, Presque Isle Bay and Long Point Inner Bay's 95% confidence intervals were narrow and overlap. The results of the statistical analysis indicated that the distribution of liver incidence on a standardized brown bullhead (300 mm and age 7) in Presque Isle Bay was almost identical to Long Point Inner Bay's rate when the confidence interval describing the difference in tumor rates was examined. This means the liver tumor incidence rates at these locations were statistically equivalent and the delisting target was being met.

The same was not true for the external tumors. The confidence intervals for external tumor incidence in Presque Isle Bay and Long Point Inner Bay overlap, but the interval for Presque Isle Bay was much wider and the median tumor incidence rate at 15.4% was much higher. When the confidence interval describing the difference in tumor rates between Presque Isle Bay and Long Point Inner Bay was examined it was too large to indicate that two tumor rates were statistically equivalent. So, the differences in external tumor rates in Presque Isle Bay and Long Point Inner Bay were not within the range of values that would be considered statistically equivalent (Rutter, 2010). Therefore, the delisting target for external tumors was not being met.

A further examination of the confidence intervals for liver and external tumor incidence showed that the uncertainty in the external tumor incidence on standardized bullheads was greater than for liver tumor incidence. The wider confidence interval observed for external tumors could not be explained by differences in sample size, as the same fish were used for both analyses. Therefore this increase in uncertainty may be attributed to the hypothesis that the relationship between external tumor presence and the covariates age and length is not as strong as it is for liver tumors.

5. APPROACH TO DELISTING THE FISH TUMOR BUI

Assessing the fish tumor or other deformities BUI required examination of more than twenty years of data from sampling, analysis, research, and discussions. To organize the information and findings, PADEP developed a decision tree (Figure 17) based on the United States Policy Committee's *Delisting Principles and Guidelines* (USPC, 2001). The guidelines recommend delisting a BUI when one of the following conditions is demonstrated:

- A delisting target has been met through remedial actions which confirm that the beneficial use has been restored.
- It can be demonstrated that the impairment is not limited to the local geographic extent, but rather is typical of lakewide, region-wide, or area-wide conditions
- The impairment is caused by sources outside the AOC.
- It can be demonstrated that the beneficial use impairment is due to natural rather than human causes.

PADEP evaluated Presque Isle Bay's fish tumors through the filter of each of these conditions to determine whether or not to recommend delisting the BUI.

5.1 Has the Delisting Target Been Met?

The delisting target for the Fish Tumors or Other Deformities BUI in Presque Isle Bay states that:

The fish tumor or other deformities beneficial use is no longer considered impaired when the incidence rate of liver and external tumors is statistically equivalent or lower than the incidence rates at Long Point Inner Bay as confirmed by histopathology.

As noted previously, PADEP monitored the incidence of tumors and other deformities in the bay's brown bullhead population annually throughout the Recovery Stage for comparison against the delisting target. Based on the statistical analysis, liver tumor incidence in Presque Isle Bay is statistically equivalent to Long Point Inner Bay while external tumor incidence is elevated compared to Long Point Inner Bay. The delisting target is only partially met.

5.2 Is the Impairment Widespread?

The guidelines recognize that certain use impairments may, in fact, be regional or lake-wide in nature rather than confined within the boundaries of the AOC. PADEP investigated the geographic extent of the bullhead tumor problem by sampling bullhead from both inland Pennsylvania lakes and sites throughout Lake Erie. PADEP sampled brown bullhead from three inland Pennsylvania lakes, Canadohta Lake, Sugar Lake, and Eaton Reservoir, in 2002, 2003, and 2004 (Table 5). Both liver and external tumor rates varied over time and between lakes, however, all were consistently below Presque Isle Bay for those same years. Integrating data from the three inland lakes, the median liver tumor rate was 1.5% and the median external tumor rate was 2.3% compared to the bay which had a median liver tumor rate of 1.9% and an median external tumor rate of 18.1% during this same time frame.

As discussed in Section 4, PADEP also sampled sites across Lake Erie sites as part of the effort to identify a reference site or background rate. Liver tumor rates ranged from a low of zero percent in Dunkirk Harbor to a high of 28.7% in Sandusky Bay. External tumor rates ranged from 6.4% in Long Point Inner Bay to 22.5% in Dunkirk Harbor (Table 2). Although some bullhead populations in Lake Erie experience elevated incidences of liver and external tumors at levels equal to or exceeding levels found in Presque Isle Bay, the incidence rates in other populations are quite low. It is also noteworthy that Dunkirk Harbor had both the lowest incidence of liver tumors and the highest incidence of external tumors, underscoring the poor correlation between these BUI listing criteria at certain sites.

The Department's findings are consistent with those reported by others. Poulet et al. (1994) documented the presence of external tumors on bullhead collected from 17 water bodies (both contaminated and uncontaminated) throughout New York State. Spitzbergen and Wolfe (1995) similarly investigated nine protected reservoirs and ponds in New York State where there was no reported evidence of elevated levels of anthropogenic contamination confirmed by sediment sampling but over 30% of mature brown bullheads had liver tumors and up to 100% exhibited external tumors.

While tumors on brown bullhead occur in various locations throughout Lake Erie and inland Pennsylvania reference lakes, it is not clear whether the tumor rates in Presque Isle Bay are a reflection of some lakewide or basinwide background rate due anthropogenic activities or indicative of a locally degraded environment. Interestingly, none of the non-AOC locations, which were chosen because there were no known discharges of contaminants, had a zero tumor rate for both external and liver tumors. Additionally, the three inland lakes sampled do not have discharges or contaminated sediment and one is a drinking water reservoir. Whatever is happening in Presque Isle Bay appears to be occurring elsewhere in both AOC and non-AOC locations to a greater and lesser extent.

5.3 Is the Source of the Impairment Outside the AOC?

Presque Isle Bay's sediment contains organic contaminants and heavy metals in concentrations similar to other urban harbors. Given the moderate levels of contaminants present, it is reasonable to consider that bullhead may seasonally migrate into and out of the bay and are exposed to sources of contamination located elsewhere in Lake Erie. In 1994 PADEP conducted a large-scale mark-recapture study of Presque Isle Bay bullhead that suggested limited movement with only two fish migrating into the bay and one out (Obert, 1994). Building on that work, the United States Geologic Survey (USGS) conducted an updated radio-telemetry study of Presque Isle Bay bullhead migration (Millard et al., 2009). Forty-nine brown bullhead were collected from various sites within the bay, radio tagged, and released unharmed at the point of capture. Both fixed-station receivers and manual tracking were used to relocate tagged fish. As was the case with in the previous study, USGS found little evidence of migration out of Presque Isle Bay. The telemetry study also supported the conclusion that some bullheads do move among sites within Presque Isle Bay, although most tagged specimens return to the same sites repeatedly. The lack of migration suggests that, the factors influencing or causing the development of the liver and external tumors are present in Presque Isle Bay.

5.4 Is the Impairment Due to Natural Causes?

The occurrence of tumors in brown bullhead catfish is most frequently attributed to exposure to environmental carcinogens—in particular PAHs. Nonetheless, bullheads with tumors are found in both contaminated and uncontaminated waterbodies throughout the northeastern United States

(Pinkney and Harshbarger, 2005, Poulet et al., 1994, Spitzbergen and Wolfe, 1995). Perhaps it is not surprising, then, that tumored bullheads were found during PADIIP's sampling in presumed uncontaminated sites like Old Woman's Creek in Ohio and Pennsylvania's inland Eaton Reservoir. The occurrence of tumored bullhead in unpolluted waters calls into question the cause and effect relationship between contaminants and tumors. In fact, tumors in many species of fish are known to have natural causes (c.f., Baumann 1992a). Certain hybrid fishes (e.g., carp-goldfish hybrids and swordtail-platyfish hybrids) are known to have elevated incidences of "spontaneous" tumors. In addition, certain tumors in several fish species (northern pike, muskellunge, walleye, and drum, are known to be caused by viruses. PADIIP and its research partners investigated the potential role of genetic predisposition and viruses as causes of the bullhead tumors in the bay.

5.4.1 Genetic predisposition to tumors through hybridization

Studies of hybrid fishes have shown that hybrids and succeeding backcross generations are highly sensitive to pollutants (Setlow et al., 1989). Given that brown bullhead are known to hybridize with black bullhead (*Ameiurus melas*), and that certain hybrids are known to have elevated incidences of spontaneous tumors, the extent of potential hybridization among these species in Presque Isle Bay was investigated by Cingolani et al. (2007). Samples were collected from Dunkirk Harbor, NY, Old Woman Creek, OH, Long Point Bay, ON, Tamarack Lake, PA, and Presque Isle Bay. Reference brown bullhead samples were obtained from a reservoir in Huntington County, PA and black bullhead reference specimens were obtained from Clear Lake, IA. More than 20 specimens from each location were included in the study.

Researchers compared aspects of the outward appearance (shape, structure, color, and pattern) as well as the form and structure of the internal parts like bones and organs of the two species. Any external deformities or tumors were noted. Additionally, the genetic make up was compared using nuclear DNA microsatellites to identify differences among these two species. Looking at the outward appearance and internal structure, the study concluded that the majority of Presque Isle Bay brown bullhead matches the reference brown bullhead population and not the reference black bullhead. Evidence of black bullhead genes in the brown bullhead samples and vice versa was found in the Presque Isle Bay bullheads as well as in fish from other locations in Lake Erie. However, the bay's fish are not different from brown bullhead collected in other Lake Erie locations. Based on

this study, hybridization is not valid as a causal explanation for tumors in Presque Isle Bay brown bullhead. (See Appendix A for the full report).

5.4.2 The Role of Viruses

The USGS's Lcetown Science Center used molecular techniques to investigate the role of viruses as a causal agent for external tumors in brown bullhead. The analysis included samples from both Presque Isle Bay and the South River in the Chesapeake Bay watershed. No viral DNA or RNA was directly detected. While definitive viral sequences were not identified, a number of gene transcripts associated with cellular responses to viral infection were observed. The investigators found insufficient evidence of viral involvement in the tumors (Iwanowicz et al., 2012). However, it should be noted that the RNA quality of both the Presque Isle Bay and walleye tumor samples used as positive controls was very low and sample sizes were small. Furthermore, the report suggested sampling brown bullhead tumors during multiple seasons would increase the likelihood of detecting a viral pathogen, since retroviruses (one virus type that commonly causes external tumors in other fish species) cannot be detected unless they are in their replication phase, which may occur during a “narrow window” of the annual cycle (See Appendix B for the full report). The results of the study are inconclusive due primarily to the poor quality of the small sample of fish evaluated.

5.4.3 Exposure to Contaminants

Numerous field studies have suggested a correlation between exposure to chemicals, most frequently PAHs, in the sediment of lakes and rivers and an increased prevalence of liver tumors in brown bullhead (Baumann et al., 1987, 1991; Baumann and Harshbarger, 1995, 1998; Brown et al., 1973; Harshbarger et al., 1984; Leadley et al., 1998; Pinkney et al., 2001, 2004a; Pyron et al., 2001; Smith et al., 1994). There is less field evidence linking chemicals in the environment to external tumors in brown bullhead (Bowser et al., 1991; Poulet et al., 1994; Spitsbergen and Wolfe, 1995). While there is experimental evidence linking PAH exposure to tumors in other fish (Bunton 1996), relatively little experimental work has been done with the brown bullhead and the strength of correlation between PAHs and tumors has varied among studies. In general, the evidence linking PAH-contaminated sediment with liver tumors is much stronger than the evidence associating PAHs with external tumors (Rafferty et al 2009).

Recognizing the limitations of the research to date, PADEP undertook a whole sediment exposure study in order to better understand the causal relationship between exposure to Presque Isle Bay sediment and the development of tumors in brown bullhead. In a laboratory setting, fifty-six juvenile brown bullhead were exposed to sediment collected from either Presque Isle Bay (19.41 mg/Kg total PAHs) or Canadohta Lake, the sediment control condition (1.49 mg/Kg total PAHs). Ten additional bullhead were held in aquaria containing laboratory water only (water control condition). The experiment continued for 556 days. Periodically, the fish were grossly observed for the development of visible tumors and other lesions and liver samples were obtained and analyzed for biomarkers of early stage carcinogenesis (DNA adduct) and histopathological evaluations for tumors and pre-cancerous cells.

None of the bullhead developed grossly observable raised tumors and fish in all conditions appeared to thrive. A single liver tumor developed in a fish exposed to the sediment control condition. There were no other differences in the histopathological evaluation among the fish exposed to Presque Isle Bay sediment, Canadohta Lake sediment control, or the water control conditions. DNA adduct results were similarly negative. No PAH-DNA adducts formed in any experimental condition, indicating that the PAH carcinogens present in Presque Isle Bay sediment are not bioavailable to bullhead, or the experimental regimen was not able to adequately represent the exposure scenario that may operate in Presque Isle Bay. The bay's sediment did contain higher concentrations than Canadohta Lake for seven of eight detected PAHs, yet exposure to Presque Isle Bay sediment had no detected adverse effects on brown bullhead.

From a BUI delisting standpoint, the critical dependent variable in this study is the development of tumors. None of the bullhead developed raised external lesions. The only specimen diagnosed with liver tumors was from the low PAH control sediment condition. The most sensitive biomarkers of early-stage cancer also failed to indicate that carcinogenesis had been initiated in exposed fish. Livers of specimens in all conditions had a heavy parasite burden, but this burden did not vary among conditions. Even with some of the experimental limitations, this work strongly suggests that simple exposure to Presque Isle Bay sediment is not responsible for the tumors and other deformities seen in the brown bullhead population. (Experiment Results in Appendix C).

5.5 Evaluating the Fish Tumor BUI

Using the United States Policy Committee's guidelines, PADEP consolidated all known information about the fish tumor or other deformities BUI in Presque Isle Bay (Table 6). PADEP used data collected in the post-Recovery Stage to identify and test a delisting target, which incorporated both liver and external tumors. Comparison to a selected "least impacted control site" showed that the liver tumor incidence in Presque Isle Bay met the delisting target. This is not the case for the external tumors. Data collected from Lake Erie sites did indicate that the liver tumor rate in Presque Isle Bay may be a reflection of a background rate for this species in the Great Lakes. The incidence of external tumors across the Lake Erie sites fluctuated more, with Presque Isle Bay incidence rates in the middle of the spectrum for those sites evaluated. The bullheads do not appear to routinely or consistently migrate outside the bay, which suggests that there is something in the bay's ecosystem causing the tumors. Because bullhead tumors are found in varying incidence rates across Lake Erie, it is clear that the conditions causing the tumors in the bay are present elsewhere at inland lakes and both AOC and non-AOC locations. PADEP evaluated the possibility that the bay's bullhead are hybrids between two species and thus, potentially predisposed to tumor formation, or that the tumors are caused by a naturally occurring virus. Studies did not support the genetic hybrid hypothesis and the viral study while limited by the small number of samples, did not identify any viral sequences. The exposure study did not establish a cause and effect relationship between chemicals in the sediment and tumors, even at the earliest detectable stage. It is possible that the tumors are a result of multiple factors, including naturally occurring viruses and chemical contaminants that interact to produce tumors. These facts call into question the validity of the external tumors as an indicator of environmental degradation.

6.0 Risk Assessment

It was the external tumors found on the bay's brown bullheads in the late 1980s that galvanized the public and resulted in the listing of Presque Isle Bay as an AOC. Despite the absence of scientific data to support a causal relationship between contaminants in the bay's sediment and external tumors, it is known that PAHs, metals, and other legacy COPCs are present. More than 20 years of studies document the concentrations of contaminants in the sediment, water, and fish, yet there is no clear understanding of the risk posed by these contaminants. Prior to recommending any delisting action, PADEP wanted to ensure that the contaminants in the bay's sediment do not pose an unacceptable level of risk to the bay's ecosystem or to the health and welfare of the people who enjoy it.

6.1 Ecological Risk Assessment

PADEP commissioned an ecological risk assessment to determine whether contaminants within the bay pose a significant risk to the benthic macroinvertebrates, fish, birds, and other animals in the food web. The assessment used a mix of existing data, conclusions, and recommendations from sediment, fish tumor, and other environmental studies conducted in the bay over the past twenty years. A conceptual site model identified potential ecological receptors and the sources and exposure paths for contaminants (Figure 18). COPCs are the legacy contaminants, including heavy metals and specific PAHs selected because of their frequency in exceeding toxicity thresholds in surficial sediment.

The assessment was built around the question "Do legacy contaminants continue to pose a risk to ecosystem receptors within Presque Isle Bay"? The evaluation focused on three objectives: (1) to maintain and protect the benthic invertebrate community; (2) to maintain a quality fishery; and (3) to protect and improve the near-shore habitat in support of aquatic-dependent wildlife. These objectives were originally identified by the PAC as part of the 2005 sediment survey. Because the available data on Presque Isle Bay was not collected to support a formal risk assessment of exposure pathways, a weight-of-evidence approach was taken as a screening level ecological risk analysis. The risk characterization integrated the exposure and effects characterizations to assess whether COPCs are sufficiently high to pose unacceptable risks to ecological receptors. The weight-of-evidence concluded:

- Surface sediment COPCs appear to be the primary chemical stressor in this system, although habitat (substrate) and invasive species may be additional stressors on the ecological community that may be challenging to tease apart.
- The potential risk of COPC exposure to benthic invertebrates across the AOC is generally low based on the whole sediment toxicity test. Isolated areas may pose a moderate to high risk of exposure.
- Benthic invertebrate exposure risk decreased through time and is generally meeting toxicity targets.
- The probable effect concentration (PEC) targets are generally met across the AOC for most COPCs. Exceedences do occur for metals like barium and cadmium and for some PAHs. Studies focused on high concentration areas tend to exceed PEC in most cases but skew the AOC-wide results.
- Metal bioavailability across the AOC appears to be decreasing through time, with recent samples meeting low toxicity thresholds.
- The quality fishery objective within the AOC is supported by good water quality, a low risk of prey base (benthic invertebrates) exposure to COPCs, and fish tissue concentrations of monitored compounds that are similar to background levels.
- Water quality conditions are based on qualitative evaluations and fish tissue concentrations for monitored contaminants (e.g., mercury and PCBs) and are similar to or better than Lake Erie.
- Near-shore sediment habitats suggest that ingestion exposure risks to wildlife are moderate to low, and the elevated surface sediment concentrations of PAHs and metals in the AOC tend to be in the vicinity of the docks and shipping channel.

The weight-of-evidence indicates that targets supporting the Presque Isle Bay ecosystem are being met. While gaps in data do exist, this evaluation suggests that the risk to ecosystem receptors with the AOC is improving through time and currently rates low to moderate risk (LimnoTech, 2012).

More specifically, the assessment drew three conclusions: first, that the PAHs and metals within the bay do not appear to pose a significant risk to receptors in the ecosystem; second, that liver tumors may be a better indicator of sediment conditions than external tumors, as liver tumors have been

shown to correlate with PAHs and metal concentrations in surface sediment; and third, that the presence of external tumors does not appear to be a health threat to fish or to humans or wildlife that consume them. (See Appendix D for the full report.)

6.2 Human Health Risk Assessment

PADEP also commissioned a Human Health Risk Assessment. This assessment estimated human health risks due to contact with COPCs in bay sediments and from eating fish caught in Presque Isle Bay. Consistent with United States Environmental Protection Agency's (USEPA) protocols, estimating the risk to human health followed a four stage process: hazard identification, exposure assessment, toxicity assessment, and risk characterization (Figure 19). Data collected between 2004 and 2010 for metals, PAHs, PCBs, and pesticides in the bay's surface sediment and fish were first compared to the USEPA screening levels to determine which contaminants should be included in the risk estimate process. Screening identified arsenic, lead, total PCBs, and six PAH compounds as COPCs for the sediment and mercury, selenium, mirex, pesticides, and PCBs as the COPC in fish. Estimation of the human health risks was conservative in terms of the exposure scenarios and estimates of exposure. Both cancer and non-cancer (e.g., toxicity) risks were calculated for adults and children exposed to sediment through dermal contact or ingestion and eating fish. The evaluation included fourteen separate fish species collected in Presque Isle Bay and Lake Erie.

The main exposure route for contaminants in Presque Isle Bay is through fish consumption. These risks were several orders of magnitude greater than those associated with direct contact with contaminated sediments. On the other hand, contaminant levels in bay fishes were generally found to be comparable to or lower than those found in Lake Erie fishes. The cancer and non cancer risk estimates generated from consumption of fish tissue were highly dependent on the fish species. Based on the dataset, lake trout and smallmouth bass represented the species with the highest cancer and noncancer risk estimates. However, these species occur either exclusively (lake trout) or primarily (smallmouth bass) in Lake Erie proper rather than Presque Isle Bay. The contaminants with the highest contribution to the non cancer and cancer risk estimates for lake trout and smallmouth bass were PCBs. The assessment of cancer and noncancer risks included the assumption of a single species diet and that all fish consumed originated from the AOC. These

assumptions are conservative and likely to overestimate the risks from consumption of fish (Homan, 2012).

The cancer and non-cancer risk estimates for direct contact with contaminated sediments were generally below the target risk levels set by USEPA for all exposure groups evaluated. All chemical-specific and cumulative excess lifetime cancer risk estimates were below 1×10^{-5} and all chemical-specific and cumulative hazard indices were below 1.0. Again, these estimates are conservative and likely to overestimate the risk (Homan, 2012). (See Appendix E for the full report).

7. RECOMMENDATION TO DELIST

7.1 Delisting Guidelines

The goal of the AOC program as defined under the Great Lakes Water Quality Agreement is to insure that AOCs, which have been defined as areas where human activities have caused or are likely to cause significant impairment of local beneficial uses of water resources, are improved to the point where their environmental conditions are equal to other non-AOC locations across the Great Lakes. Those conditions may not be pristine but are consistent with the ambient environmental conditions elsewhere in the Great Lakes.

The International joint Commission (IJC) issued listing/delisting criteria for Great Lakes Areas of Concern in 1991 (IJC, 1991). The criteria serve as guidelines for the fourteen beneficial use impairments (BUIs) contained in Annex 2 of the Great Lakes Water Quality Agreement. The IJC listing/delisting guidelines were developed to assist in making recommendations for listing new AOCs and in reviewing RAPs. The intention was to establish a “set of yardsticks” that could be applied throughout the basin and keep the RAP program focused. They are written as guidelines to serve as a common starting point for each AOC with the clear expectation that specific delisting goals and targets are derived locally to address BUIs. In 2001, the United State Policy Committee (USPC) provided a set of “Delisting Principles and Guidelines” to update the IJC’s general criteria for American AOCs. The USPC’s guidelines state explicitly that delisting targets are locally derived, premised on local goals and related environmental objectives for the watershed, and consistent with federal and state regulations and policies, when available.

Both the IJC’s guidance and the USPC’s principles state that RAPs are intended to address use impairments of local, geographical extent and cause, rather than lakewide or basinwide phenomena. The USPC principles provide more explicit direction regarding delisting either an AOC or individual BUI. According to those principles, RAPs can only address impairments caused by local sources and impacts from outside the AOC should not preclude delisting. Under these circumstances, an external impairment and its sources should be addressed by another environmental program such as the Lakewide Management Plan (LaMP). Additionally, both the IJC and USPC guidances note that it may not be possible to fully restore some beneficial uses even though all remedial actions are

implemented. For example, there may be natural factors or social or economic factors that prevent full restoration of the BUI. Under these circumstances, delisting can and should proceed. PADEP used both the IJC and USPC guidelines in evaluating potential BUIs in the Stage 1 RAP, setting delisting targets in the Stage 2 and 3 RAPs, and determining whether to delist in the Stage 3 RAP.

7.2 Status of the BUIs

The Presque Isle Bay AOC had two BUIs: restrictions on dredging activities and fish tumors or other deformities. Both BUIs were believed to be a result of the PAHs found in sediment throughout the bay. For the restrictions on dredging activities, the IJC criterion for delisting is “when contaminants in sediments do not exceed standards, criteria, or guidelines such that there are restrictions on dredging or disposal activities”. Pennsylvania’s laws regulate dredged material as a solid waste and place restrictions on disposal options. To address the BUI within the context of Pennsylvania’s laws, a delisting target was developed based on the process Pennsylvania uses to determine whether material can be disposed of in Erie’s Confined Disposal Facility. Because dredging only occurs in limited areas within the bay, ecosystem health targets were added to ensure environmental improvements could be monitored throughout the AOC. PADEP delisted the restrictions on dredging BUI in 2007 after a comprehensive sediment survey in 2005 showed that the delisting and ecosystem health targets were being met. A 2009 sediment survey also confirmed that the delisting target is being met and samples from the majority sites from the AOC and its tributaries met the ecosystem health targets.

For the fish tumors or other deformities BUI, the IJC delisting guideline is “when the incidence rates for fish tumors or other deformities do not exceed rates at unimpacted control sites or when survey data confirm the absence of neoplastic or pre-neoplastic liver tumors in bullheads or suckers”. PADEP chose a delisting target based on comparison of external and liver tumors from Presque Isle Bay to a selected “least-impacted” reference site.

Based upon the recommendations of researchers and other experts during a series of workshops between 2003 and 2006, PADEP sampled a number of inland lakes and non-AOC locations in Lake Erie to identify a “least-impacted” reference site. All of the candidate reference sites sampled were known to have brown bullhead populations but no known direct discharges of contaminants. In

order to compare the sites over a period of years, a statistical methodology was developed that normalized the tumor rates to those of fish at age 7, the approximate mean age of the bullheads in the full data set. Interestingly, the surveys showed that neither the non-AOC locations in Lake Erie nor the inland Pennsylvania lakes were free of bullhead tumors. Additionally, locations where liver tumor rates were high often had low external rates and vice versa. For example, between 2004-2007 median external tumor rates in Dunkirk Harbor were 22.5% while median liver tumor rates were 0% and Sandusky Bay had a 9.3% median external tumor rate and a 28.7% median liver rate. The exception was Long Point Inner Harbor which had both low external (6.4%) and liver (1.2%) tumor rates. As a result, Long Point Inner Bay was identified as the least-impacted reference site for comparison against Presque Isle Bay. The delisting target selected for Presque Isle Bay is met when “the incidence rate of liver and external tumors is statistically equivalent or lower than the incidence rates at Long Point Inner Bay as confirmed by histopathology”.

Comparison of Presque Isle Bay to Long Point Inner Bay showed that the liver tumor rates were not statistically different. In fact, when statistically adjusted for age, it appears that the incidence of liver tumors in Presque Isle Bay bullhead may be a reflection of the broader Lake Erie background rate. The same was not true for the external tumors where Presque Isle Bay was statistically significantly higher than Long Point. Still the external tumor rate in the Presque Isle Bay bullhead was comparable to all but one of the potential Lake Erie “least-impacted” reference sites evaluated. Based on the limited sample sizes from the potential reference sites, it is difficult to determine whether or not the age-adjusted external tumor rate in Presque Isle Bay is significantly higher, lower, or the same as the background rate elsewhere in Lake Erie. It is true that similar to Presque Isle Bay, incidences of unexplained external tumors are occurring in populations of brown bullheads in both AOC and non-AOC locations as well as inland Pennsylvania lakes.

7.3 Causes of Fish Tumors

PADEP turned its focus to investigating the cause of the external tumors and evaluating the appropriateness of using the tumors as an indicator of environmental degradation. PADEP’s approach included investigating pathogens as potential natural causes of the tumors; evaluating the role that the genetics of the bay’s bullheads may play; conducting its own experimental investigation into the relationship between exposure to bay sediment and the development of tumors; and

conducting an extensive review of the scientific literature. A study designed to detect viruses in external bullhead tumors was inconclusive. A study evaluating whether the bay's bullheads were hybrids and, therefore, potentially predisposed to tumors found little evidence of atypical hybridization. An eighteen month laboratory exposure study did not find biomarkers signifying early stage cancer on any fish exposed to Presque Isle Bay sediment.

As was the case in its own investigations, a review of the scientific literature revealed inconsistent relationships between exposure to environmental contaminants and the development of tumors in bullhead. The preponderance of the published literature focuses on the role of PAHs as the cause of tumors in brown bullhead. While there is a sound scientific basis for the role of PAHs as fish carcinogens in general, the causal role of PAHs in bullhead tumors remains unclear. Studies such as the work of Baumann in the Black River and other locations in the Great Lakes have shown an apparent relationship between sediment PAHs and bullhead tumors, particularly liver tumors, while others such as the work of Pinkney in the Chesapeake Bay tributaries and Spitsbergen in New York ponds and reservoirs have shown inconsistent associations between PAHs and tumor rates or no correlations at all. PADEP's own work in sampling potential non-AOC reference sites showed inconsistencies between external and liver tumor rates within the same locations. If the hypothesis is that exposure to contaminated sediment causes external and liver tumors, then bullheads collected from locations without known sources of contamination should have few, if any external or liver tumors and locations with contaminated sediment should have elevated levels of both external and liver tumors. That was not the case. Bullhead from the site with the highest external tumor rate, Dunkirk Harbor, had a zero percent liver tumor rate. Conversely, the site with the highest liver tumor incidence rate, Sandusky Bay, had one of the lowest external tumor rates.

The scientific literature supports a stronger causal relationship between PAH exposure and liver tumors than external tumors. It seems apparent, based on the recent work reported by Pinkney (2011) and Baumann (2010), that if PAHs play a causal role in bullhead tumors they are a subset of a more complicated and multifactorial etiology. While the exposure route for liver tumors is primarily thought to be via ingestion of contaminated sediments and aquatic organisms, external tumors have been attributed to factors including various direct and indirect-acting carcinogens in the water column and sediment, solar radiation, abrasions, viruses, or some combination of all of these.

The inconsistencies in incidence rates coupled with the lack of a direct link with exposure to PAHs or the ability to isolate the factors resulting in the formation of external tumors makes the external tumor rate an unreliable measure of environmental degradation.

Despite the expenditure of considerable resources, there are still tumors on bullheads. The rest of the bay's fishery, however, is diverse, abundant, and healthy, appearing unimpacted by whatever is affecting the bullheads. Additionally, the 2005 sediment survey included direct toxicity tests to two benthic organisms and found only limited toxicity. Of 34 samples tested, one was toxic to midges using the survival endpoint and three using the growth endpoint. Based on the results of the sediment toxicity tests, it is apparent that contaminants in the bay's sediment are not particularly bioavailable and are not adversely impacting the benthic community. The fact that the bullheads have tumors does not appear to indicate any negative consequences for other fish species or benthic organisms, in fact yellow bullheads residing in Presque Isle Bay appear quite healthy. Thirty years after the discovery of external tumors on the bay's brown bullhead catfish, the environment has become cleaner, supporting a diverse fishery with both threatened and endangered species thriving, and yet the brown bullheads still have tumors. Based on the data collected in Presque Isle Bay and elsewhere, the tumors on brown bullhead do not appear to be a good indicator of an unhealthy ecosystem.

While there is stronger evidence correlating liver tumors with PAHs in sediment, the question of what is causing the tumors on this one species of fish may never be answered. Other AOCs are also struggling with this issue. In the December 2011 Stage 2 RAP for the Sheboygan River AOC, Wisconsin focused its delisting target for this BUT on neoplastic liver tumors as factors other than contamination such as viral infection and parasites have been shown to elicit external and preneoplastic tumor responses.

Comparison of Presque Isle Bay to Long Point Inner Bay showed that the liver tumor rates were statistically equivalent. In fact, when statistically adjusted for age, it appears that the incidence of liver tumors in Presque Isle Bay bullhead may be a reflection of the broader Lake Erie background rate. The same was not true for the external tumors where Presque Isle Bay was statistically significantly higher than Long Point. Based on limited sample sizes, it is unclear at present whether

or not the age-adjusted external tumor incidence rate in Presque Isle Bay is significantly higher than the background rate elsewhere in Lake Erie.

7.4 Rationale for Delisting the Fish Tumor BUI

PADEP's recommendation to delist the fish tumors or other deformities BUI is grounded on the best science and technology available today. The decision is based on numerous investigations, sampling events, and consultation with the leading experts in brown bullhead investigations. While there is year-to-year variation, since the Recovery Stage designation in 2002 the incidence of liver and external tumors the bay's brown bullhead population has remained stable with little statistical difference in rates between sampling years. Incidence rates of both liver and external tumors remain well below the high levels seen in the early 1990s. Liver tumor rates, the end-point for which exposure to environmental contaminants is more clearly linked to sediment PAH contamination, are statistically indistinguishable from the Long Point Inner Bay reference site. The incidence of external tumors, however, remains elevated when compared to the reference site.

Because there are known legacy contaminants in the sediment regardless of their relationship to the bullhead tumors, PADEP commissioned ecological and human health risk assessments. Using appropriately conservative assumptions and existing data, both risk assessments concluded that cancer and noncancer risks posed by legacy contaminants in the Bay's sediment and fish are below targets for human health and ecosystem protection.

It may not be possible ever to fully restore this BUI due to the external tumors. Reviewing both the IJC and USPC guidelines and principles, it seems clear that external tumors and, to some extent liver tumors, are a lakewide phenomenon. Whatever is happening in Presque Isle Bay is occurring elsewhere in both AOC and non-AOC locations. The best course of action for the Presque Isle Bay AOC is to delist with continued monitoring of the sediment and fish; work with the Lake Erie LaMP to include other AOCs in determining the cause(s) of the fish tumors and identification of possible remedial measures at a lakewide scale; focus on restoration projects in the bay's watershed to continue reducing sediment loading to the bay; and use existing regulatory and statutory authority to require permits, cleanup, monitoring, and restoration. PADEP, therefore, recommends delisting of the fish tumor or other deformities BUI for the Presque Isle Bay AOC.

7.5 Rationale for Delisting the Presque Isle Bay AOC

One goal of the AOC program is to address the source or sources of the beneficial use impairment. In the absence of an identified source to remediate, PADEP and its partners have taken action to address contaminant loading to the bay through permitting, infrastructure improvements, and restoration projects.

There are no wastewater treatment discharges to the bay as a result of more than \$100 million in upgrades to the City of Erie's wastewater treatment system in the 1980s and 1990s. The upgrades included the reduction of the number of combined sewer overflows from more than seventy to five. Four of the CSOs discharge into the Mill Creek Tube which empties into the bay. All have screens and flow monitors. Additionally, the City of Erie maintains a litter trap at the end of Mill Creek that catches oil and debris from the CSOs and the stream. The City of Erie reports a CSO capture rate in excess of 99.9%. Additionally, there are no known unpermitted industrial waste discharges to the bay.

In 2002, when Presque Isle Bay was designated in the Recovery Stage a decision was made not to dredge the bay. Extensive sediment sampling failed to identify contaminant "hot spots" in the bay where limited dredging could occur to remove contaminated sediment and at 3,655 acres, remedial dredging of the entire bay is cost-prohibitive and unnecessary. Instead, the remedial measure selected in 2002 was natural attenuation, allowing cleaner sediment to form a cap over contaminated sediment. With a sedimentation rate averaging 1 cm per year, this is a slow process but both the 2005 and 2009 sediment surveys confirmed it is happening.

In considering future remedial measures, there is still work to be done to mitigate the impacts of contaminant loading from stormwater runoff. This work is being done through the Integrated Water Resources Management Plan for Lake Erie and restoration projects funded under the Great Lakes Restoration Initiative (like the work done on Cascade Creek), Coastal Zone grants, and Growing Greener.

In recommending the delisting of the AOC, PADEP determined that removal of sediment by dredging the bay is unnecessary, remedial measures with the greatest direct benefit to the bay are done, other watershed measures that positively impact the bay are ongoing, air and water discharges are permitted and monitored, no other species of fish or benthic organism appear to be impacted, and both the human health and ecosystem health assessment concluded that the existing conditions in the bay do not increase either cancer or noncancer risks to people or the environment.

PADEP believes that the RAP process has accomplished its goal to the maximum extent practicable and the ultimate identification of the causes of the external tumors needs to be addressed outside the scope of the AOC program. Based on the decreased and stable tumor rates, review of the available scientific evidence, and in close consultation with local and national experts and its own PAC, PADEP recommends delisting the Presque Isle Bay AOC. This Stage 3 RAP provides the data to 1) show that 14 measures of water quality listed in the Agreement are not impaired in the AOC; 2) support PADEP's assertion that the fish tumor or other deformities beneficial use is no longer impaired; and 3) show that the Agreement's delisting criteria have been achieved for the Presque Isle Bay AOC. The removal of the final BUI indicates that environmental conditions in Presque Isle Bay are comparable to non-AOC locations in the Great Lakes. PADEP, with the concurrence of the Presque Isle Bay Public Advisory Committee, recommends delisting the AOC.

8. ROLE OF THE PAC

Beginning in 1983 with the formation of the Erie County Environmental Coalition, Erie's citizens have focused their efforts and attention on restoring Presque Isle Bay. It was members of the Coalition along with the Erie Harbor Improvement Council that petitioned for the inclusion of the bay on the list of AOCs. In 1991, the bay became the 43rd AOC and members of the Coalition and Council became the Presque Isle Bay Public Advisory Committee (PAC). Over the next twenty years, the PAC met quarterly providing advice to PADEP on priorities, studies, delisting targets, and other matters impacting the AOC. With the decision to delist the AOC, the role of the PAC becomes even more critical to ensure beneficial uses remain restored.

After twenty years of focusing on contaminants in the sediment and tumors on brown bullhead, the time has come for the PAC to broaden its involvement beyond the bay. The PAC will continue to meet regularly and provide insight and advice to PADEP on the post-delisting monitoring of the bay. It will also focus attention on the monitoring and restoration work needed in the watershed by assisting PADEP in setting priorities and communicating problems and progress to the public.

Future research, studies, and monitoring conducted in the bay will be reported through the Lakewide Management Plan for Lake Erie. It is PADEP's intention to seek the PAC's input and advice on Lake Erie issues such as strategies to reduce nutrient and other contaminant loading to the Lake, addressing invasive species, monitoring lakewide fish consumption advisories, and investigating the presence and impact of emerging contaminants.

9. POST-DELISTING RESPONSIBILITIES AND MONITORING

Annex 2 of the Great Lakes Water Quality Agreement requires formal monitoring of the recovery of impaired beneficial uses in AOCs only to the point at which the BUIs are no longer considered to be impaired. Even though this point has been attained, PADEP and the Presque Isle Bay PAC recognize that it is important to document the sustained recovery of the AOC, to continue to work to improve water quality in the Presque Isle Bay watershed, and to proactively address new environmental threats as these issues are identified.

The objective of post-delisting monitoring is to ensure that bullhead tumor rates remain stable over time and sediment quality objectives related to the delisting and ecosystem health targets continue to be met. Monitoring will continue in the bay's watershed to document sediment and contaminant loading and the health of fish and macroinvertebrate populations. Activities related to the BUI monitoring will be reported through the Lake Erie Lakewide Management Plan (LaMP). The Lake Erie LaMP is issued every three years with yearly updates in the form of fact sheet. A citizens' forum assists in the selection of priority and focus areas as well as outreach and education on the LaMP. The Triennial LaMP report includes the status and milestones for all of the Lake Erie AOCs. PADEP will continue to report through the LaMP on the environmental status of the bay as well as efforts to restore, protect, and monitor the watershed. Should data trends indicate the delisting and ecosystem health targets are not being met, PADEP will use its existing statutory and regulatory authorities (e.g., Clean Air Act, Clean Water Act, Dam Safety and Encroachments Act, and Clean Streams Law) to ensure sources of pollution are addressed.

In addition, PADEP will continue to monitor water quality and fish tissue contaminant trends in Presque Isle Bay and in Pennsylvania's open waters of Lake Erie through its Water Quality Network sampling program. Both Presque Isle Bay and Lake Erie are currently on the 303(d) list of impaired waters. The bay's listing is a result of fish consumption advisories which are not related to either the restrictions on dredging activities or fish tumors or other deformities BUIs. Monitoring and advisories will continue under the PADEP and PFBC's fish consumption advisory program.

PADEP intends to turn the focus to non-AOC issues, emerging contaminants, and supporting further research into the non-contaminant related factors playing a role in fish tumors. The post-

delisting monitoring plan spans a ten year period and is considered a “living document” that will be periodically reviewed by the PADEP and PAC. Monitoring activities may be expanded, revised, or deleted over time. Specific activities and timeframes may be modified following consultation with the PAC due to resource constraints, advances in analytical methods, or new scientific research findings from other studies.

9.1 Beneficial Use Impairments

9.1.1 Restrictions on Dredging Activities

Question to answer: Is the primary delisting target for the restrictions on dredging beneficial use being met?

Target: In at least 90% of samples, the concentrations of chemicals of potential concern in the confined disposal facility mixing zone are below Pennsylvania’s Water Quality Standards at the 15-minute compliance point for acute criteria and the 12-hour compliance point for chronic criteria.

To evaluate the delisting target, PADEP will use elutriate data from sediment samples collected by parties permitted under PA’s Chapter 105 program to perform dredging within the AOC. The frequency of monitoring will depend on when permitted dredging activities occur. Monitoring data and the status of dredging activities will be reviewed annually.

Question to answer: Is ecosystem health showing any change?

A. Benthos

Target: In at least 90% of sediment samples, the concentrations of chemicals of potential concern are below levels that are associated with acute or chronic toxicity in sediment dwelling organisms.

Whole sediment chemistry and whole sediment toxicity tests will be used to evaluate ecosystem health. Sampling locations will include sites within the AOC, the study area, and areas adjacent to the AOC. Specifically, samples will be collected from up to eight locations within the AOC. The locations include the areas adjacent to the mouths of Scott Run (SR-25), Mill Creek (MC-23/MC-27), and Cascade Creek (CC-26); one location in the center of the Bay (PIB 07), and one in Misery Bay (PIB-46); an additional sample will be collected from the ponds within Presque Isle State Park (i.e., study area); a sample will also be collected from the Outer Harbor and one from Thompson Bay; and a reference sample (TBD). Samples will be analyzed for PCBs, 34 PAHs, metals,

AVS/SEM, total organic carbon, and grain size. Toxicity testing using the freshwater amphipod *Hyallela aspera* or the midge *Chironomus dilutus* will also be done. Monitoring will occur every three years beginning in 2008 until 2014 and then the schedule for additional monitoring re-evaluated.

B. Fish and Wildlife Health

Target: In at least 90% of samples, the concentration of six or more chemicals of potential concern do not exceed Effects Range Median.

Whole sediment chemistry will be used to evaluate this ecosystem health target.

Target: The concentration of mercury and PCBs in tissues of fish from Presque Isle Bay should not be significantly higher than levels in fish tissue from Lake Erie.

PADEP's fish consumption advisory sampling program will be used to evaluate this target.

9.1.2 Fish Tumors or Other Deformities

Question to answer: Is the primary delisting target for the fish tumors or other deformities beneficial use being met?

Target: The bay's fish tumor or other deformities beneficial use is no longer considered impaired when the incidence rate of liver and external tumors is statistically equivalent or lower than the incidence rates at Long Point Inner Bay as confirmed by histopathology.

To evaluate the target, PADEP's Post-delisting bullhead monitoring will be consistent with the methods recommended by PADEP (2002) and Rafferty and Grazio (2007). Histopathology of liver and external tumors will be consistent with the methods described by Blazer et al, 2009(a) and (b). Beginning in 2013, monitoring for grossly observable lesions will be conducted in 2013, 2016, 2019, and 2022. Necropsies and histopathological analyses will be conducted in 2013, 2019, and 2022.

Long Point Inner Bay, the reference site for Presque Isle Bay, will be sampled using the methods described above the same years as Presque Isle Bay.

- *Target population*- Presque Isle Bay resident brown bullhead catfish (*Ameiurus nebulosus*) with a minimum total length of 250 mm. A minimum total length of 250 mm is used to increase the likelihood that sexually mature specimens will be collected for analysis.
- *Minimum sample sizes*- The minimum sample size shall consist of 200 specimens (or the total sample if $n < 200$) for gross observation of external lesions and other deformities. The minimum sub-sample size for histopathological tumor analysis shall be 30 randomly sub-sampled individuals (or the total sample if $n < 30$).
- *Necropsy and histopathology*- A minimum of 30 bullhead will be randomly sub-sampled and subjected to general necropsy. Internal organs will be observed for the presence of gross pathology. Abnormal conditions will be photographed and recorded on the field data sheet. Histopathological tumor analysis will be performed on all liver/gall bladder samples and raised external lesions. Specimens will be humanely euthanized prior to necropsy.
- *Specimen Age*- Both otoliths will be removed from each necropsied specimen for aging. In the event that neither otolith can be recovered, pectoral spines will be used for age estimation.

9.2 Presque Isle Bay Watershed Monitoring

Monitoring of both legacy and emerging contaminants in the Presque Isle Bay watershed is essential to ensure that the bay ecosystem continues to be protected. Sampling will be consistent with the QAPP entitled: GLRI State Capacity Grant – Presque Isle Bay Watershed Restoration, Protection, and Monitoring Plan (PADEP, 2011). Sixteen locations identified in the Presque Isle Bay Watershed Restoration, Protection, and Monitoring Plan (<http://pih.psu.edu>) will be sampled every five years beginning in 2015. Analysis includes the following:

- Sediment samples will be analyzed for legacy contaminants including metals, oil and grease, PAHs, PCBs, pesticides, nitrogen, phosphorus, AVS, and SEM. Particle size distribution will also be determined.

- Water samples will be analyzed for temperature, dissolved oxygen, conductivity, 5-day biological oxygen demand, total organic carbon, total nitrogen, total phosphorus, and dissolved phosphorus.
- Fish habitat and population health as well as macroinvertebrate community distribution will also be evaluated at each sampling location.

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Appendix A

Investigation into the Hybridization of *Ameiurus* Catfish in Presque Isle Bay, Erie, PA

Appendix B

Investigating the Possible Association of Virus with External Papillomas in Brown Bullhead

Appendix C

Whole-sediment exposure of brown bullhead (*Ameiurus nebulosus*) to industrially contaminated sediment

Appendix D

Presque Isle Bay Area of Concern Screening-Level Ecological Risk Assessment

Appendix E

An Evaluation of Human Health Risks from Contaminants in Presque Isle Bay

TABLES

**Table 1. Proposed Delisting and Ecosystem Health Targets for the Restrictions
on
Dredging Beneficial Use Impairment
At the Presque Isle Bay Area of Concern**

Ecosystem Goal for Presque Isle Bay Sediment: Maintain and/or restore sediment quality conditions such that human health is protected and the human uses of the aquatic ecosystem (e.g., fish and wildlife consumption; navigation and shipping, etc.) are protected and, where necessary, restored.

Ecosystem Objective for Presque Isle Bay Sediment: Maintain and protect the benthic invertebrate, fish, and wildlife communities of Presque Isle Bay.

Beneficial Use Impairment	Management Objective, Indicators, Metrics, and Targets
Restrictions On Dredging	
Sediment Management Objective	Protect human uses of the aquatic ecosystem (e.g., navigation, shipping, and recreation) and minimize the impact of dredged material discharge on water quality.
Sediment Quality Indicator	Whole sediment chemistry Elutriate test data
Metrics	Concentrations of COPCs in the confined disposal facility mixing zone as determined by application of the USACE's CDFate model using elutriate data or other model using whole-sediment chemistry data from Presque Isle Bay sediment samples.
Narrative Delisting Target	The concentrations of COPCs in the CDF mixing zone are below Pennsylvania Water Quality Standards at the 15-minute compliance point for acute criteria and the 12 hour compliance point for chronic criteria.
Numeric Delisting Target	Pennsylvania Chapter 16 and Chapter 93 Water Quality Standards.
Assumptions	No more than 10% of samples will exceed the target.

Ecosystem Health Target

Management Objective, Indicators, Metrics, and Targets

Ecosystem Health for Benthos

Sediment Management Objective:

Maintain and/or restore sediment quality conditions such that benthic communities, including epibenthic and infaunal species, are protected and, where necessary, restored.

Sediment Quality Indicator:

Whole sediment chemistry
Whole sediment toxicity

Metrics:

Concentrations of COPCs in whole-sediment samples
Whole sediment toxicity tests

1. 28-d *Hyalloella azteca* survival and growth
2. 10-d *Chironomus dilutus* survival and growth

Narrative Ecosystem Health Target:

The concentrations of COPCs (metals, PAHs, and PCBs) are below the levels that are associated with acute or chronic toxicity in sediment-dwelling organisms; The survival and growth of freshwater amphipods, *H. azteca* and midges, *C. dilutus*, exposed to sediment samples from Presque Isle Bay should be greater than or equal to the normal range of survival rates observed for appropriately selected control or reference sediment samples.

Numeric Ecosystem Health Target:

At least 90% of the sediment samples from Presque Isle Bay have the conditions necessary to support healthy benthic invertebrate communities, as indicated by: mean PEC-Q I < 1.0; SEM-AVS < 0.0; SEM-AVS/£₀₂ < 3,000; ESB-IUs < 1.0; toxicity to the freshwater amphipod *Hyalloella azteca* or the midge *Chironomus dilutus* for the survival or growth endpoints:

- Control-adjusted survival of amphipods ≥ 75%
- Control-adjusted growth of amphipods ≥ 90%
- Control-adjusted survival of midges ≥ 75%
- Control-adjusted growth of midges ≥ 70%

Ecosystem Health for Fish and Wildlife

Sediment Management Objective

Maintain and/or restore sediment quality conditions such that fish and wildlife communities, including aquatic dependent amphibians, reptiles, birds, and mammals, are protected and, where necessary, restored.

Sediment Quality Indicator

Whole-sediment chemistry
Fish health
Fish tissue chemistry

Metrics

Concentrations of COPCs in whole-sediment samples
Concentrations of bioaccumulative COPCs in fish tissue

Numeric Ecosystem Health Target

The concentrations of five or more COPCs in a sample do not exceed Effects Range Median as calculated by Long, et al. (1996); or
The concentrations of bioaccumulative COPCs in tissues of fish from Presque Isle Bay should not be significantly higher than the levels in fish tissue from Lake Erie; if COPC concentrations are elevated in PIB fish, then the levels should be lower than the toxicity thresholds for fish and aquatic-dependent wildlife.

Assumptions

No more than 10% of samples will exceed the target.

Site	Liver Tumor Incidence		External Tumor Incidence	
	95% Confidence Interval	Median	95% Confidence Interval	Median
Long Point Inner Bay	(0.0%, 14.9%)	1.2%	(0.0%, 32.0%)	6.4%
Dunkirk Harbor	(0.0%, 56.0%)	0.0%	(0.0%, 73.3%)	22.5%
Old Woman Creek	(0.0%, 61.6%)	3.0%	(0.0%, 83.0%)	20.9%
Sandusky Bay	(11.4%, 47.8%)	28.7%	(0.9%, 22.0%)	9.3%

Table 2. Liver and External Tumor Rates for Potential Lake Erie Reference Sites (2004-2007).

Monitoring Year	Liver Tumor Rate	95% Bayesian Credibility Interval	External Tumor Rate	95% Bayesian Credibility Interval
2002	1.1%	(0.0%, 22.2%)	18.6%	(0.0%, 87.6%)
2003	2.4%	(0.0%, 8.6%)	16.7%	(4.4%, 33.2%)
2004	2.1%	(0.0%, 21.0%)	18.9%	(0.0%, 66.6%)
2005	2.3%	(0.0%, 32.4%)	11.9%	(0.0%, 49.3%)
2007	3.9%	(0.0%, 27.0%)	17.3%	(0.4%, 54.3%)

Table 3. Liver and External Tumor Rates for Presque Isle Bay during the Recovery Stage Monitoring. Tumors are histologically verified for an age 7 bullhead.

Site	Liver Tumor Incidence		External Tumor Incidence	
	Median	95% Bayesian Credibility Interval	Median	95% Bayesian Credibility Interval
Presque Isle Bay	2.8%	(0.0%, 18.3%)	15.4%	(0.8%, 45.8%)
Long Point Inner Bay	1.2%	(0.0%, 14.9%)	6.4%	(0.0%, 32.0%)

Table 4. Median Tumor Rates for Presque Isle Bay and Selected Lake Erie Reference Site, Long Point Inner Bay. Tumors are histologically verified for an age 7 bullhead.

Site	Liver Tumor Incidence	External Tumor Incidence
Canadohta Lake	0.8%	3.2%
Faton Reservoir	1.5%	0.5%
Sugar Lake	1.5%	3.3%

Table 5. Inland Lake Tumor Estimates for the Period 2002-2004. Incidence rates were determined using logistic regression based on a 7 year old bullhead.

Table 6. Evaluation of the Fish Tumor BUI in terms of the USPC (2001) Guidelines.

US Policy Committee Delisting Guideline (2001)	How is the Guideline evaluated wrt bullhead tumors? (Methods)	Is Delisting Guideline Met?	Current Status
<p>1. A delisting target has been met through remedial actions which confirms that the beneficial use has been restored.</p>	<p>Delisting targets developed based on tumor rates at least impacted reference site (Long point Inner Bay). Incidence rates at PIB AOC compared to reference site.</p>	<p><i>Liver Tumors</i> Yes <i>External Tumors</i> No</p>	<p><i>Liver Tumors</i> Not significantly different than reference sites (Approx. 2.80% v. 1.20%) <i>External Tumors</i>- Significantly higher than reference sites (Approx. 15.4% v. 6.4%)</p>
<p>2. It can be demonstrated that the beneficial use impairment is due to natural rather than human causes.</p>	<p>Investigated the role of pathogens (viruses) in the induction and promotion of tumors.</p>	<p>No</p>	<p>Insufficient evidence of viral involvement.</p>
<p>3. It can be demonstrated that the impairment is not limited to the local geographic extent, but rather is typical of lakewide, region-wide, or area-wide conditions (under this situation, the beneficial use may not have been originally needed to be recognized as impaired).</p>	<p>Compared the incidence of liver and skin tumors in PIB AOC to lakewide/background rates.</p>	<p><i>Liver Tumors</i>-Yes <i>External Tumors</i>-unclear</p>	<p><i>Liver Tumors</i>- Can be conceptualized as a "regional problem" or simply as the background rate for this species in the Great Lakes Region <i>Skin Tumors</i> Incidence rate elevated in PIB compared to Lake Erie reference site but comparable to all but one of the potential reference sites evaluated. Based on the limited sample sizes from the potential reference sites, it is difficult to determine whether or not PIB external tumor rates are higher, lower, or the same as background rates elsewhere in Lake Erie.</p>
<p>4. The impairment is caused by sources outside the AOC. The impairment is not restored but the impairment classification can be removed or changed to "impaired-not due to local sources". Responsibility for addressing "out of AOC" sources is given to another party (i.e., LaMPs).</p>	<p>Investigate potential for bullhead to migrate out of PIB and be exposed to remote contaminants. Determine sources and loads for contaminants of concern.</p>	<p>No</p>	<p>Migration studies show that bullhead are resident to PIB. While the cause(s) of bullhead tumors in PIB have never been definitively identified, similar to PIB incidences of unexplained external tumors are occurring in populations of brown bullheads in both AOC and non-AOC locations.</p>

Figures

Figure 1. Map of the Presque Isle Bay Area of Concern (AOC) Boundary



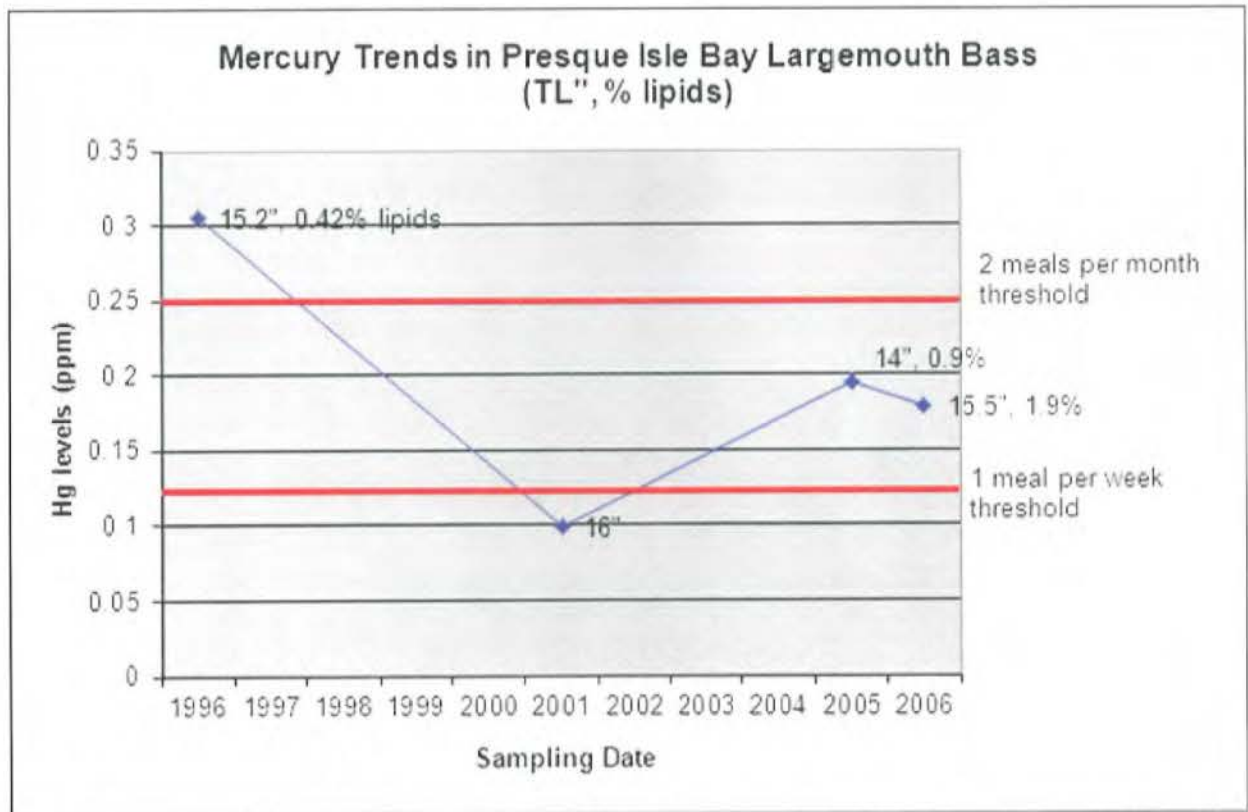


Figure 2. Mercury Trends in Presque Isle Bay Largemouth Bass.

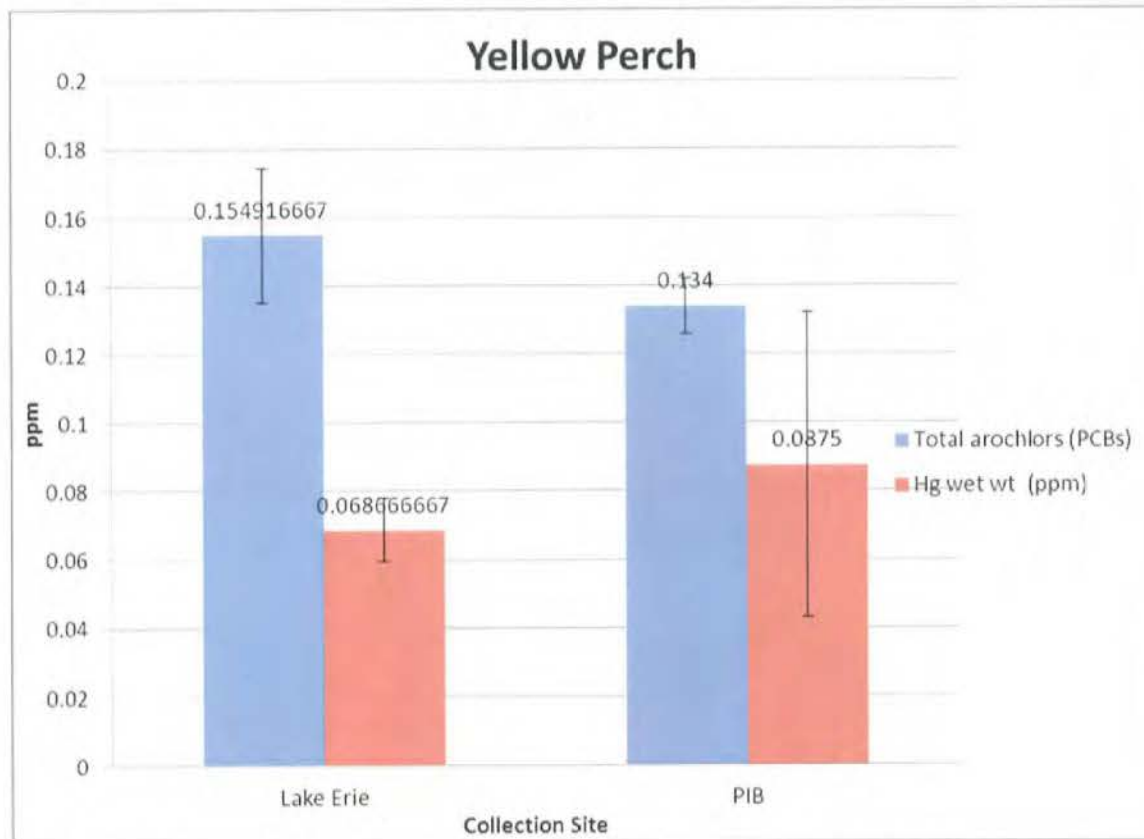


Figure 3. Mercury and PCB concentrations in Presque Isle Bay Yellow Perch.

Zn Trends WQN 632

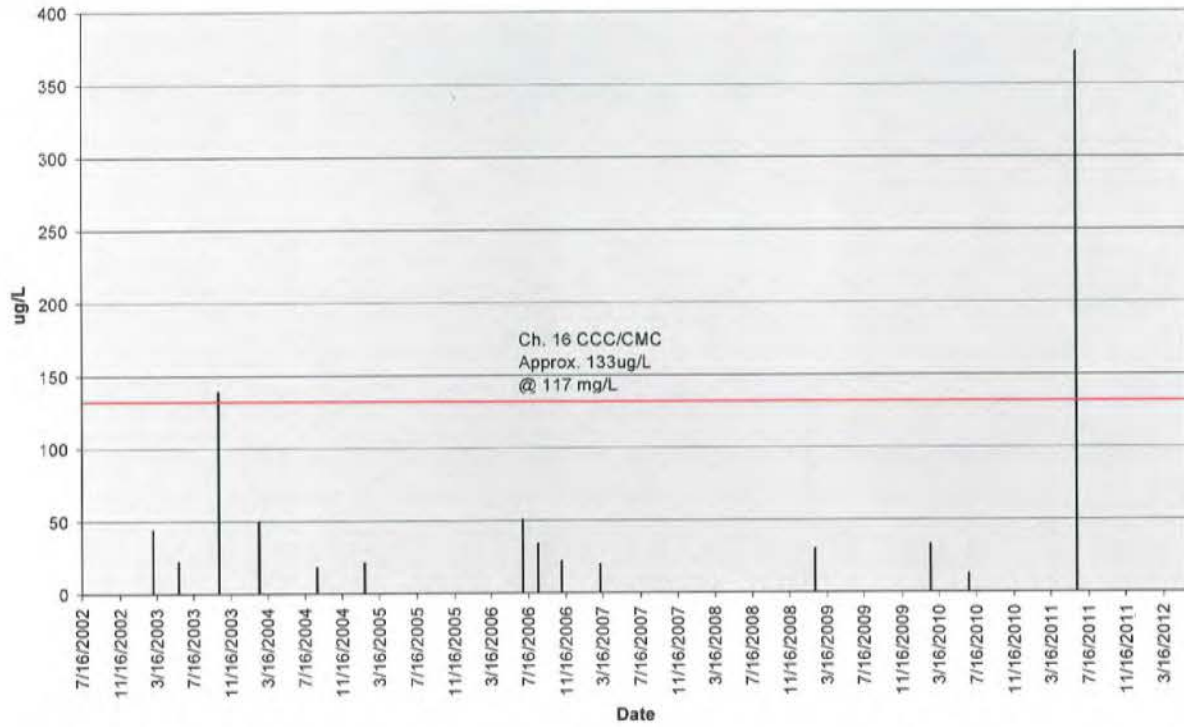


Figure 4. Detectable Levels of Zinc in Water Quality Network Samples Collected between 2002 and 2011.

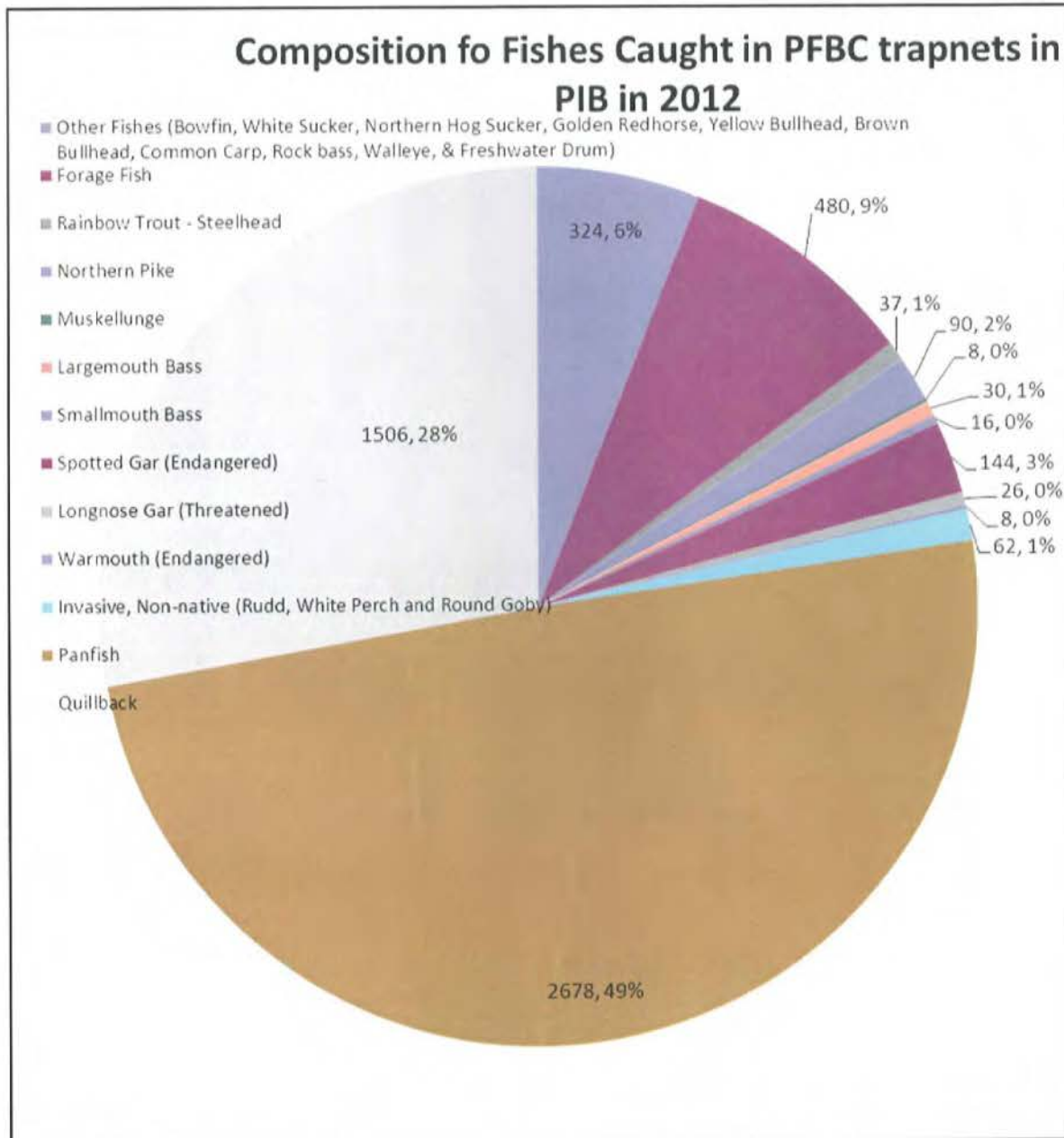


Figure 5. Diversity and Abundance of Fish Populations in Presque Isle Bay.

Non-Native Nuisance Fish caught in PFBC Trapnets in PIB in 2012

Non-native nuisance fishes made up 1.1% of the total catch.

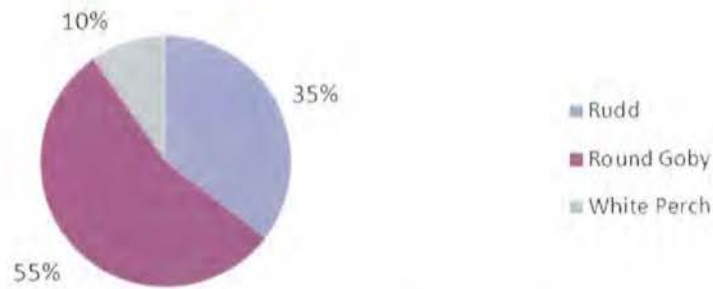


Figure 6. Non-Native Fish Found in Presque Isle Bay 2012 Survey.

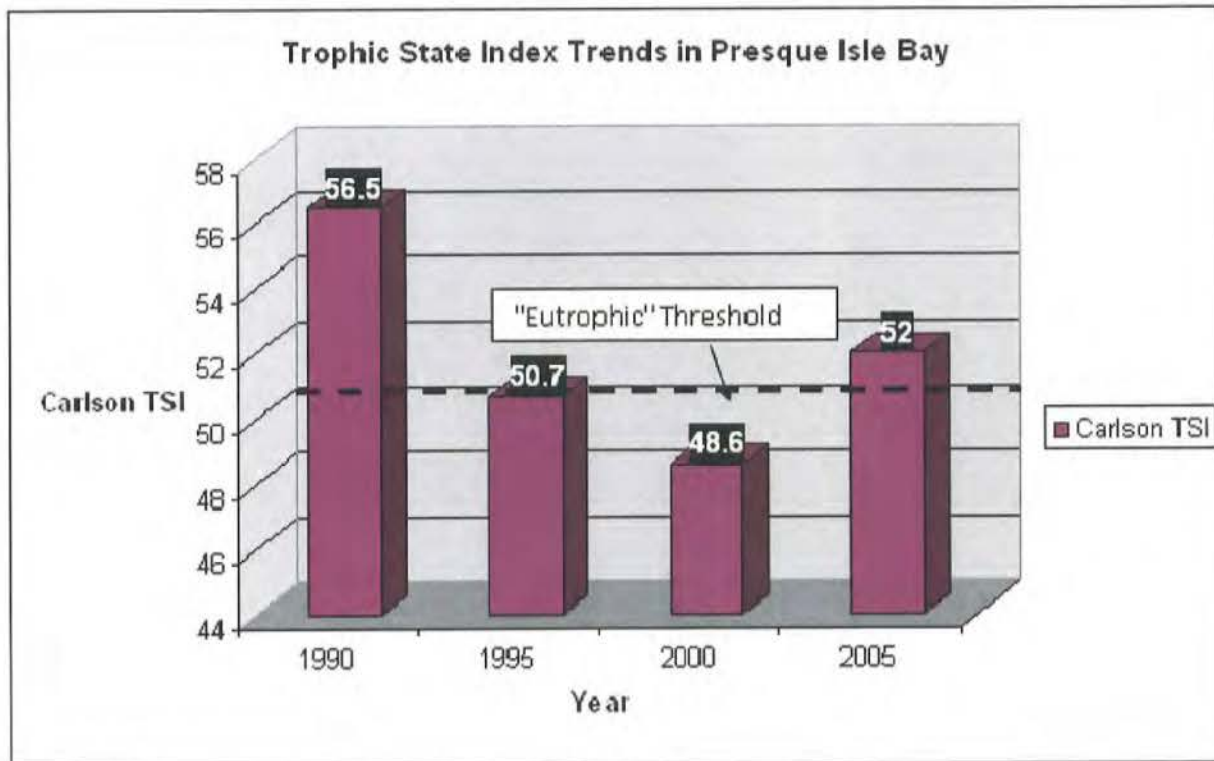


Figure 7. Trophic State Scores for Presque Isle Bay.

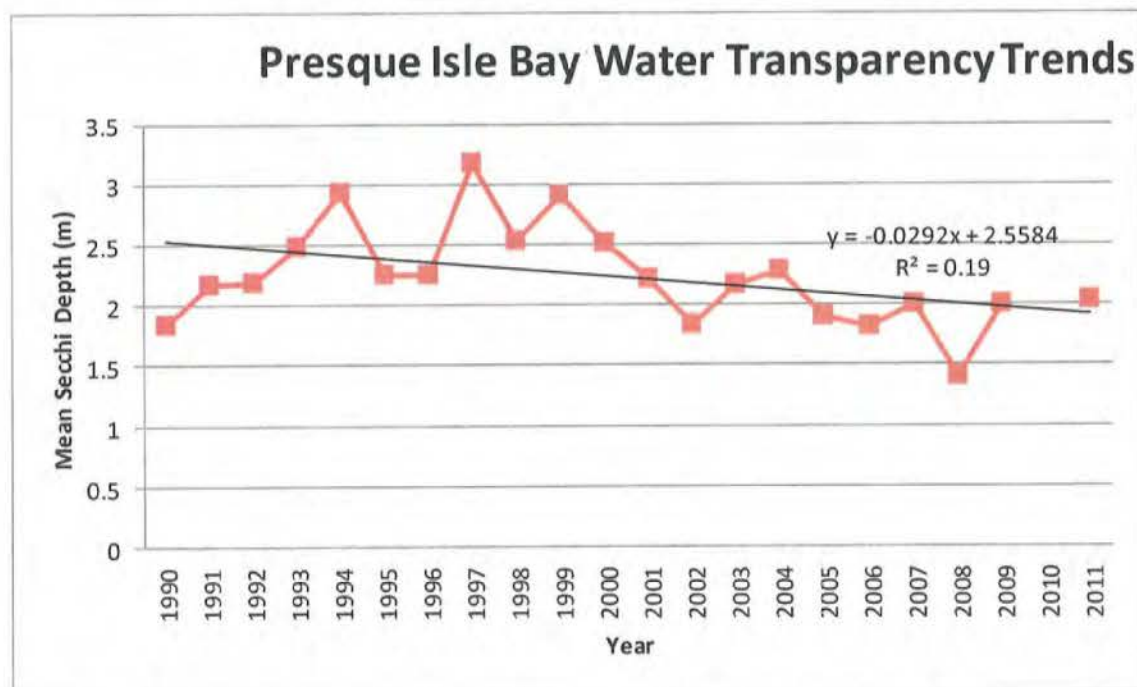


Figure 8. Water Clarity over Time in Presque Isle Bay.

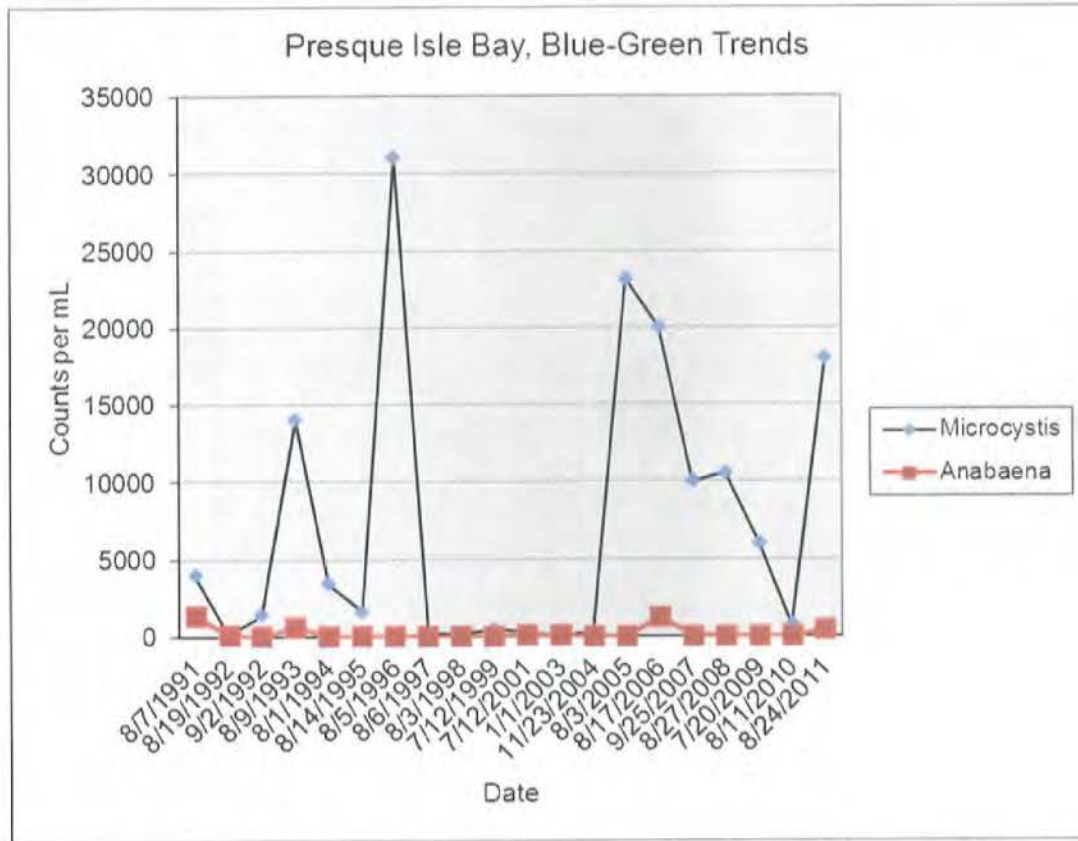


Figure 9. Counts of Blue Green Algae (*Anabaena* and *Microcystis*) in Presque Isle Bay from 1991 – 2011.

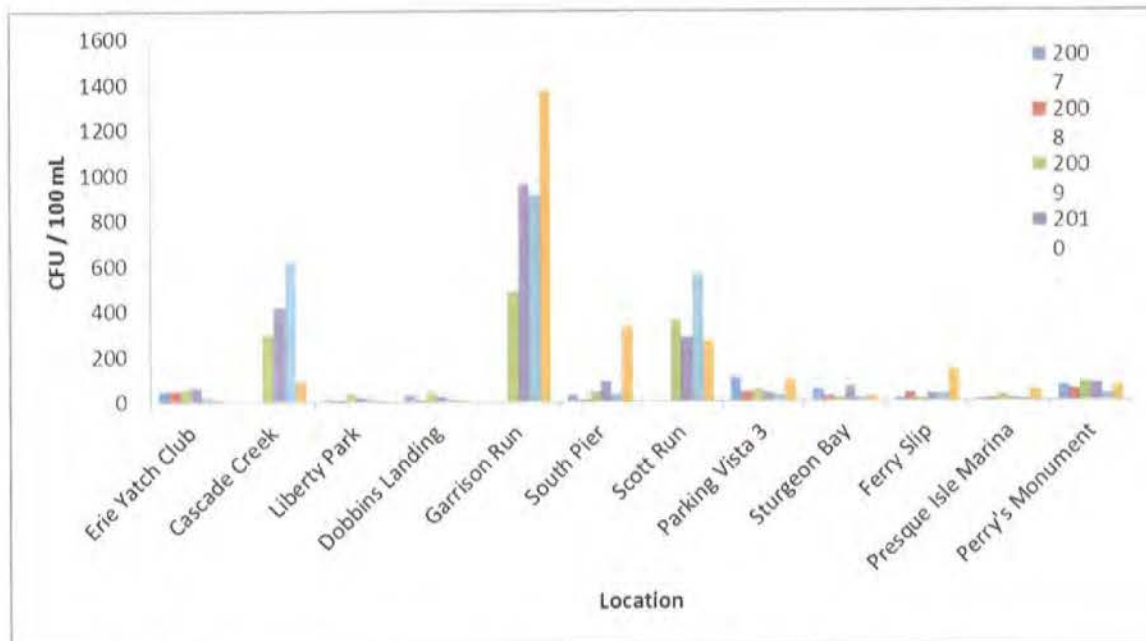


Figure 10. *E. coli* Counts in Presque Isle Bay Samples (2007-2010).

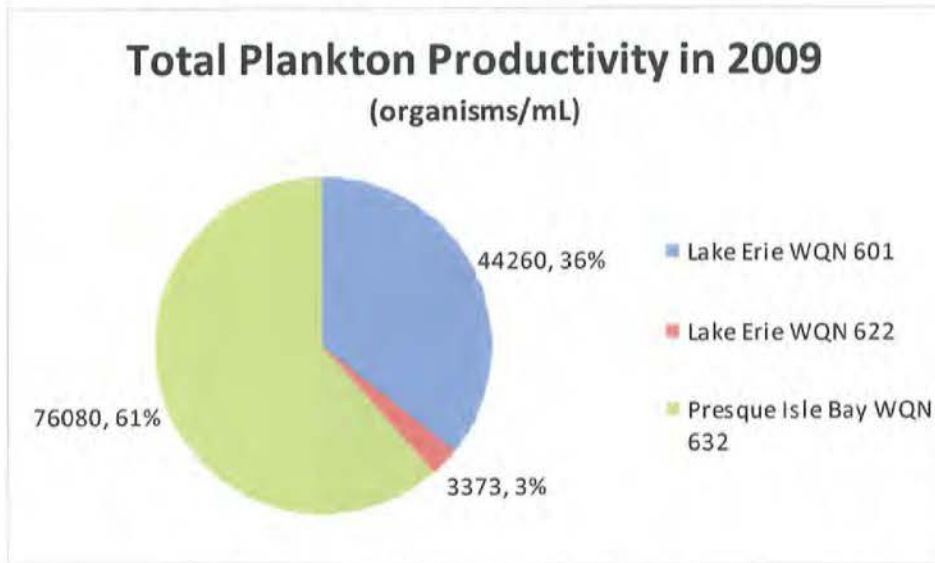


Figure 11. Relative plankton productivity at Lake Erie Water Quality Network Stations

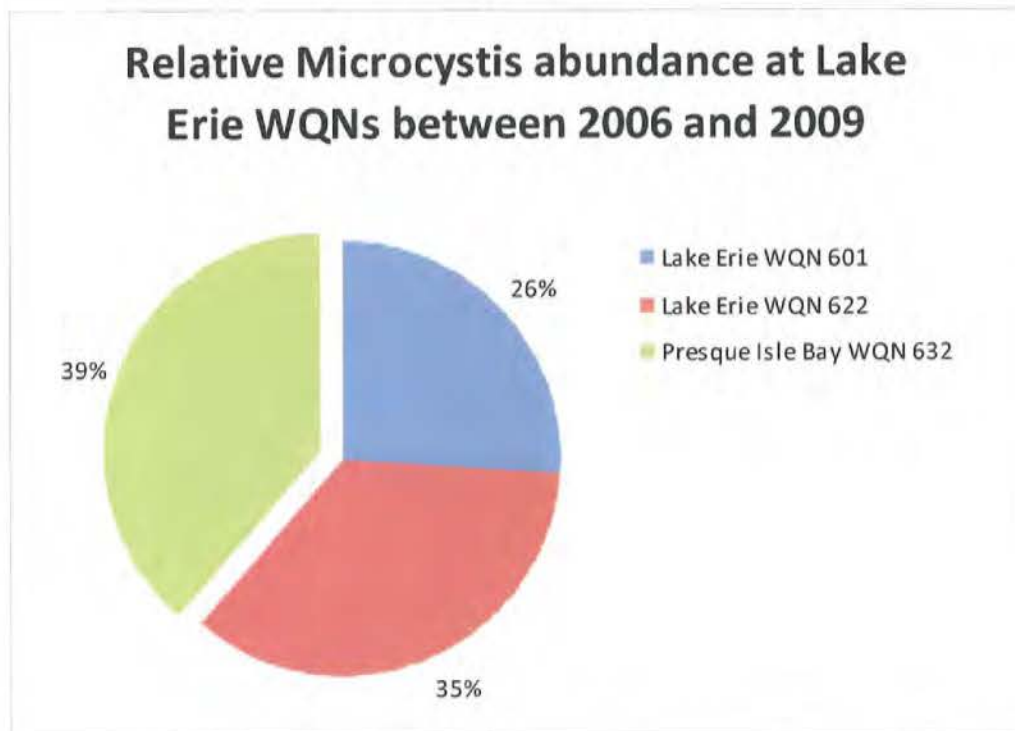
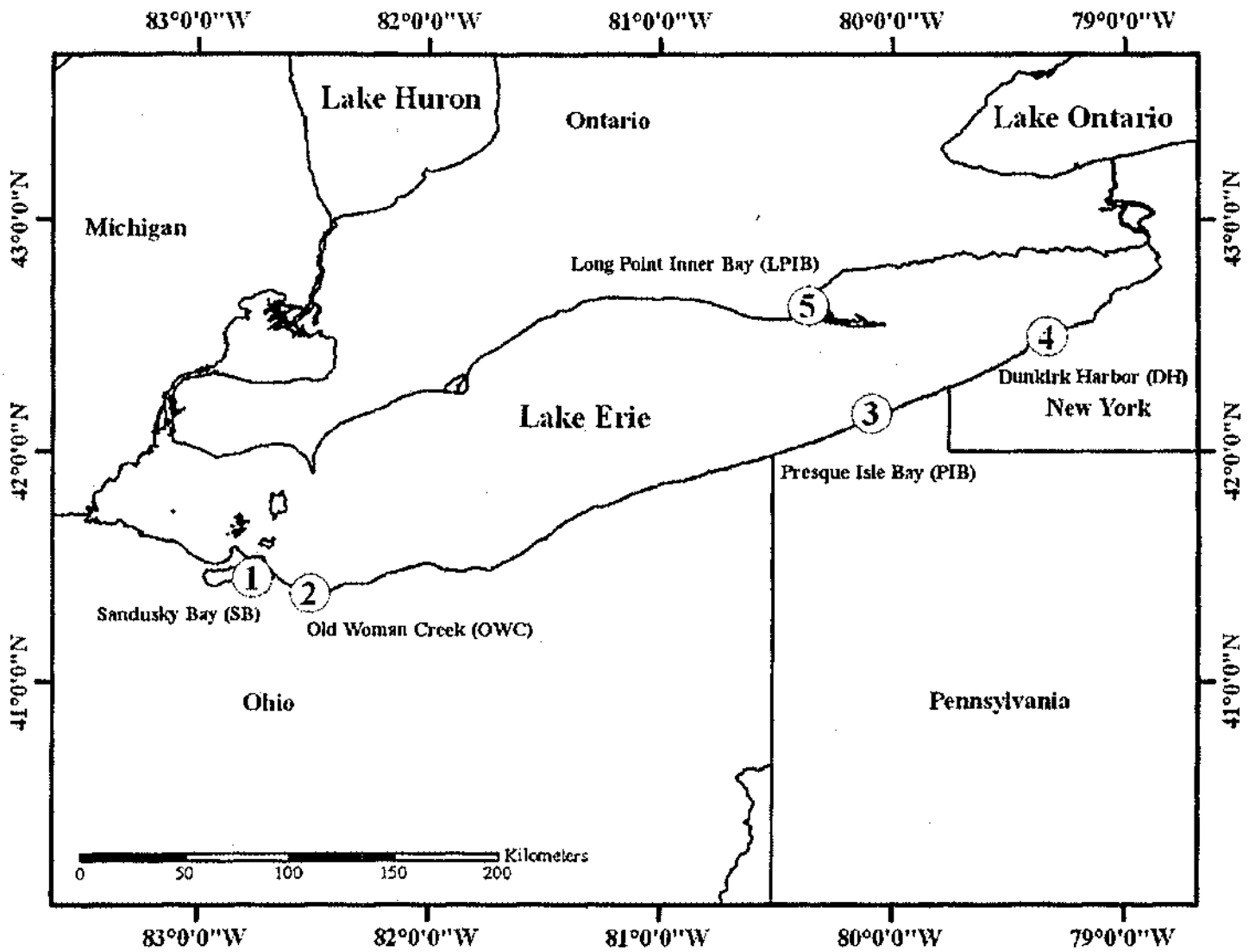


Figure 12. Relative abundance of the bluegreen *Microcystis* at Lake Erie Water Quality Network Stations, 2006-2009

Figure 13. Sampled Lake Erie Reference Locations.



Presque Isle Bay Liver Tumor Trends
Age 7 Brown Bullhead

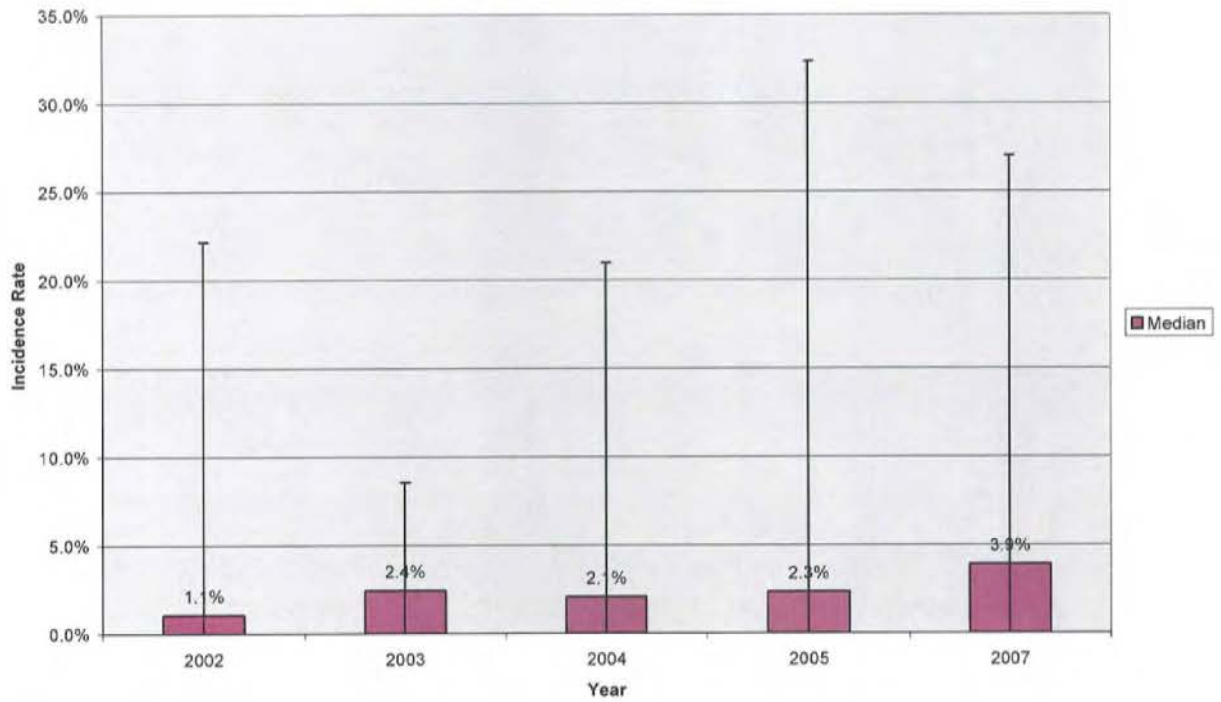


Figure 14. Recovery Period Liver Tumor Trends in Presque Isle Bay Brown Bullhead. Error Bars are \pm Bayesian 95% Credible Intervals.

Presque Isle Bay Skin Tumor Trends
Age 7 Brown Bullhead

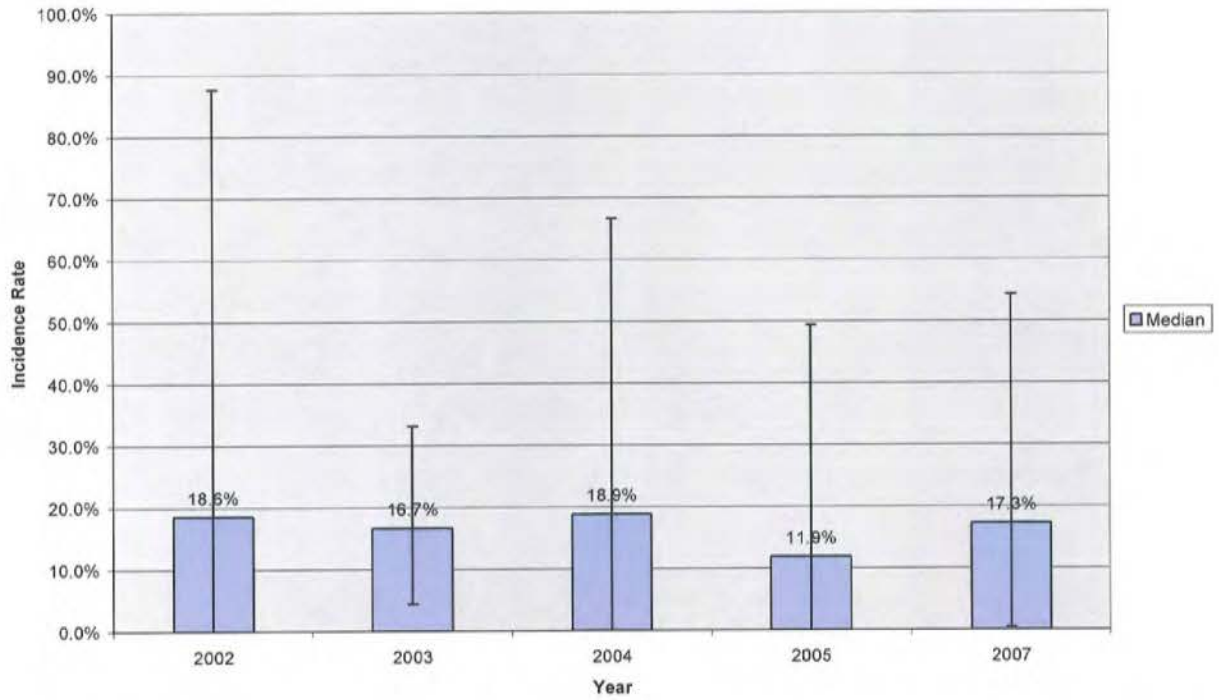


Figure 15. Recovery Period External Tumor Trends in Presque Isle Bay Brown Bullhead. Error Bars are \pm Bayesian 95% Credible Intervals.

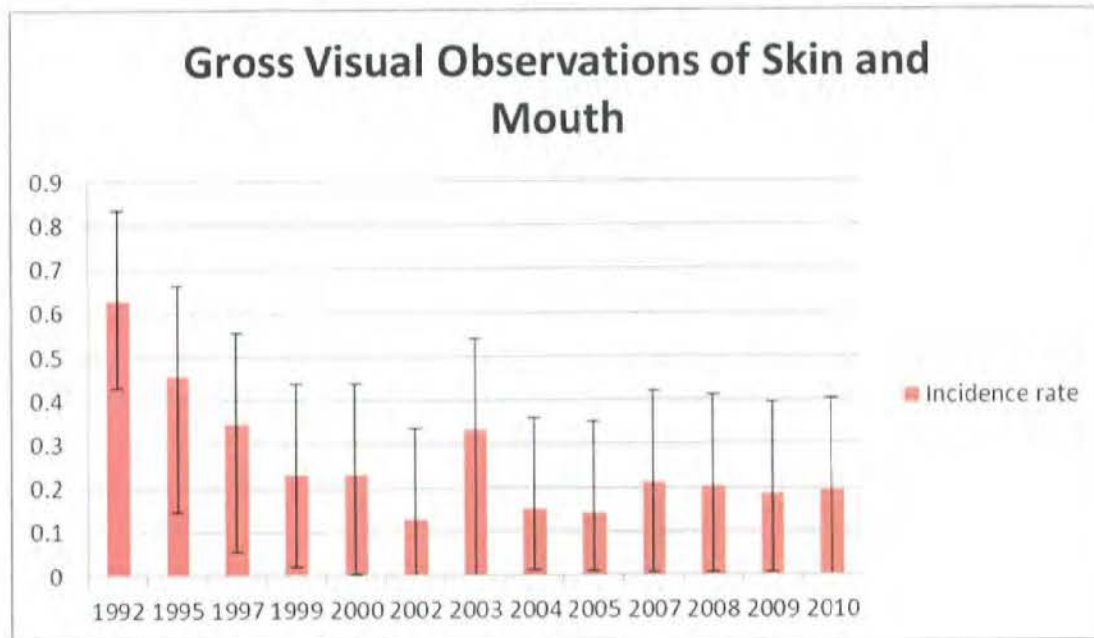
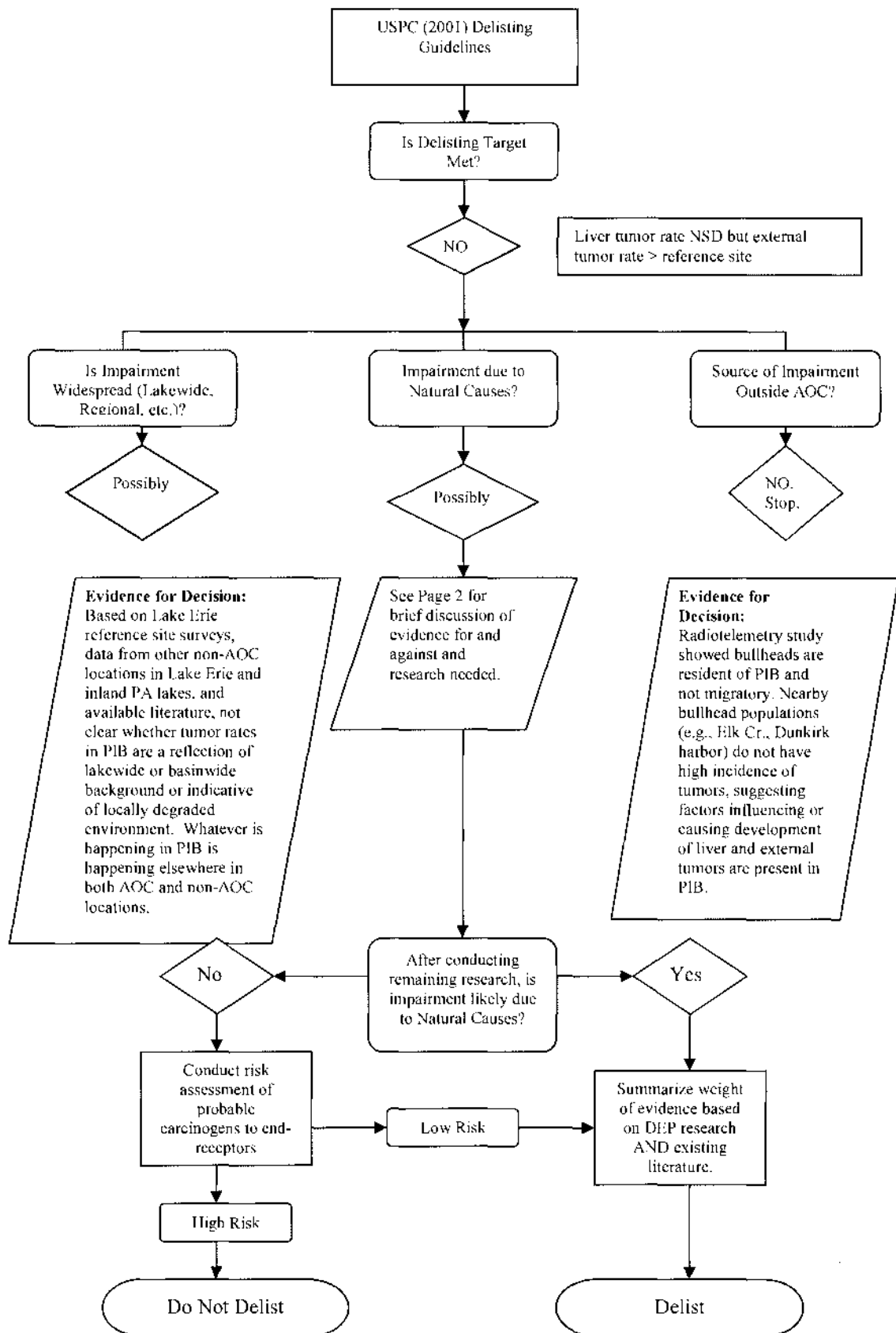


Figure 16. Incidence of Grossly Observed External Tumors on Presque Isle Bay Brown Bullhead (not confirmed with histopathology)

Figure 17. PADEP Delisting Process Decision Tree



Impairment due to
Natural Causes?

**Evidence For Natural
Causes:**

- High tumor rates documented in bullhead populations in some uncontaminated sites
- Lack of correlation between contaminants and bullhead tumors in several field studies
- Poor correlation between liver tumor and skin tumor incidence rates
- Natural and/or multiple causes *surmised* for external tumors in several recent studies
- 30-d sediment exposure study by Grady et al. (1992) was negative showed no effect
- DEP sediment exposure study (>450-d; ongoing) has been negative for grossly visible lesions
- Viruses, parasites, and other pathogens known to cause tumors in other species

**Evidence Against Natural
Causes:**

- Numerous field studies showing a correlation between tumors and contaminants in bullhead and other species.
- One lab study (J. Black) showed relationship between application of contaminated sediment and skin tumor formation
- Lab studies with other species show association between contaminants and tumors (esp. liver tumors)
- Hybridization (and resulting genetic predisposition to tumors) has been ruled out.
- Attempts to identify viruses to date have been negative (mainly electronmicroscopy; molecular pilot study (PEER) by USGS also negative
- Attempts to isolate parasites to date have been inconclusive

Future Research Needed:

- Funding is needed to test for biomarkers of early-stage carcinogenesis (DNA adducts and histopathology) in bullhead in the DEP sediment exposure study. Otherwise, several additional years of exposure will be necessary before negative results can be accepted as valid.
- Viral analysis via contemporary molecular techniques is essential for definitive answers on this potential cause of tumors. We have partnered with USGS Leetown to conduct viral research this year.
- Microsporidian and Myxosporidian parasites are known to cause tumors in some fish species. We believe that additional work needs to be done to rule in or out these organisms as potential causes of the tumors.

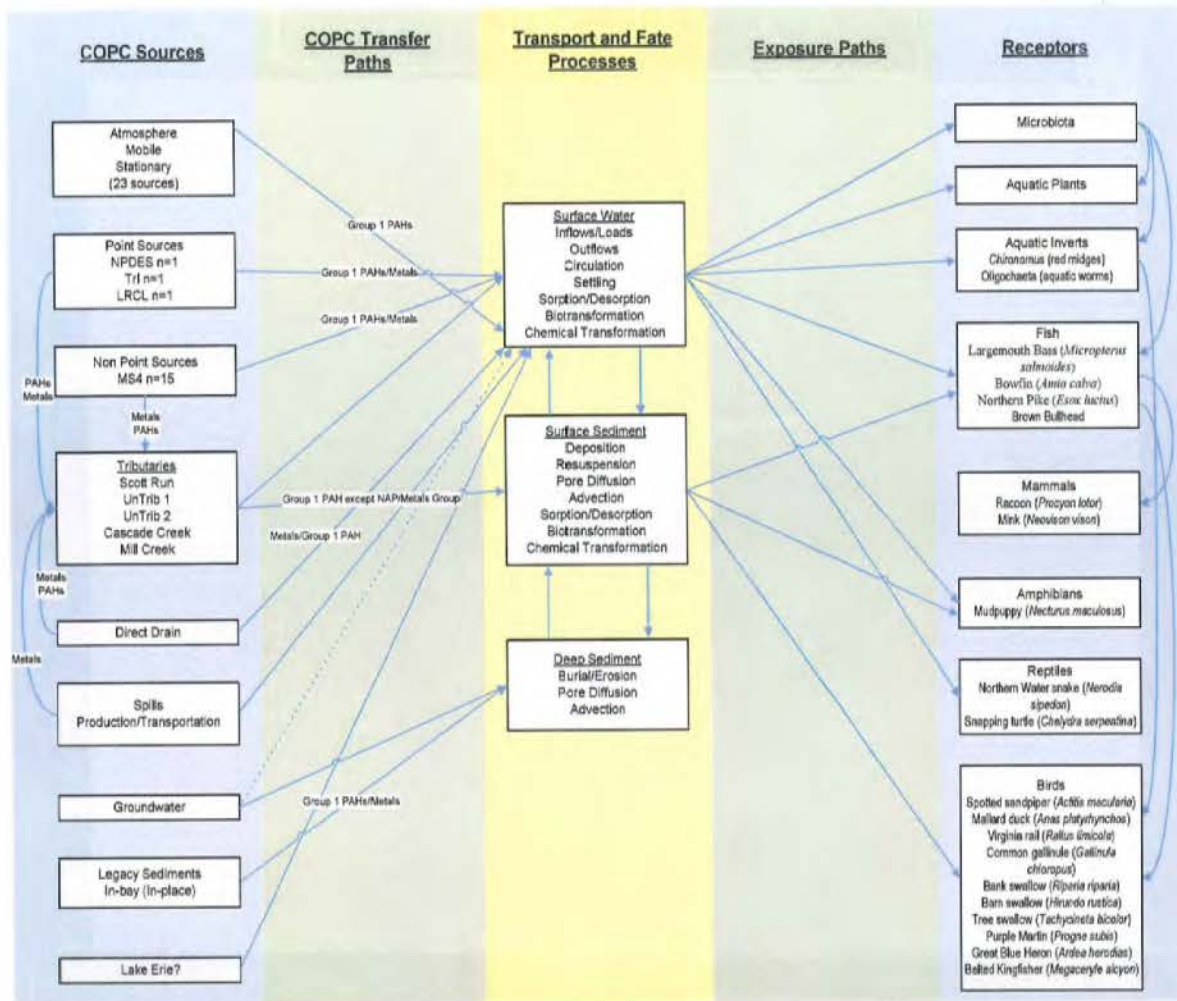


Figure 18. Conceptual site model for the Presque Isle Bay Ecological Risk Assessment.

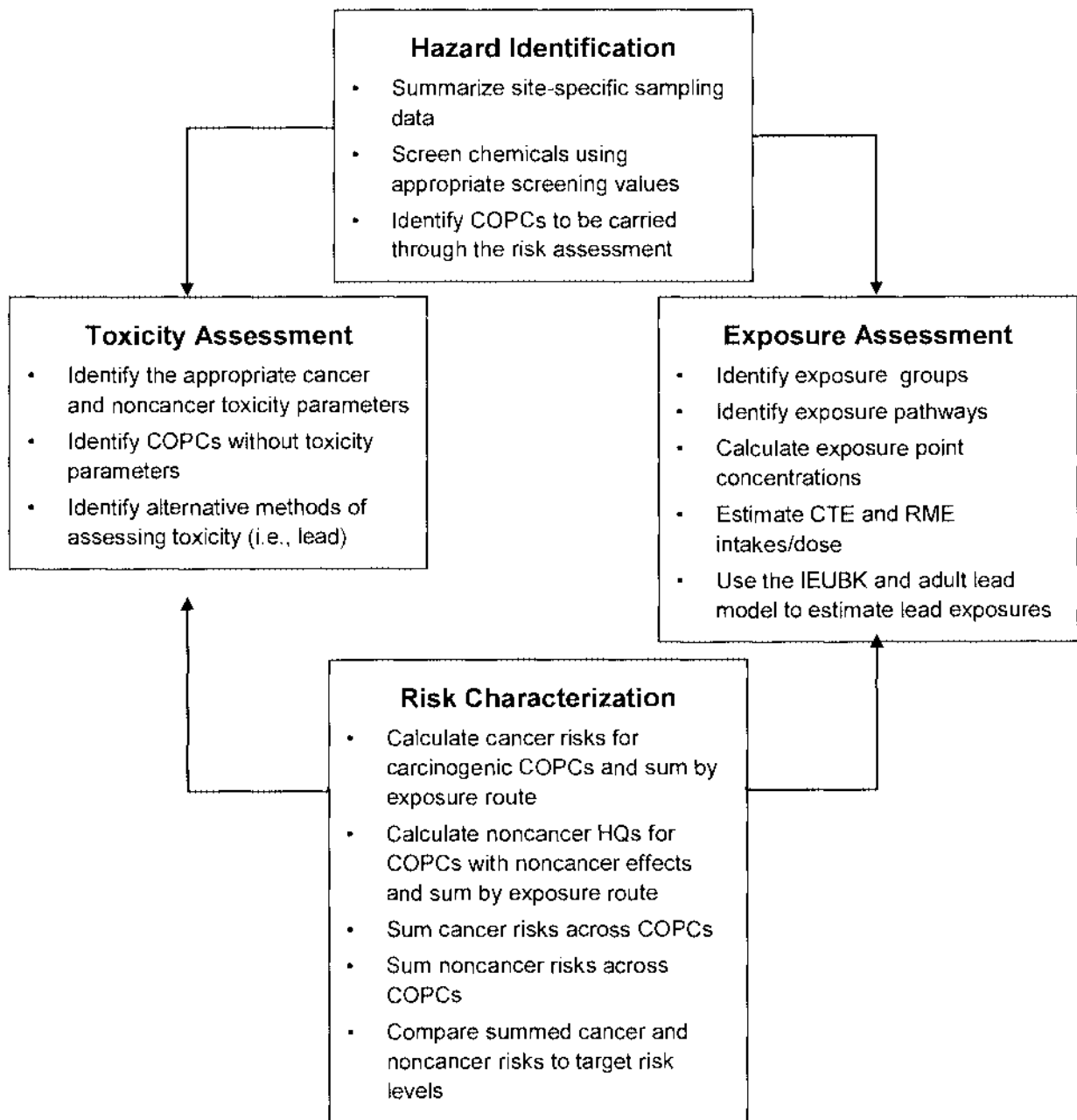


Figure 19. Overview of the four stage risk assessment process for the Presque Isle Bay Human Health Risk Assessment.