REMEDIAL ACTION PLAN UPDATE
for the
MILWAUKEE ESTUARY AREA OF CONCERN

December 2016

Wisconsin Department of Natural Resources
Office of Great Waters - Mississippi River, Lake Superior & Lake Michigan

Remedial Action Plan Update
for the
Milwaukee Estuary Area of Concern
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Compiled by Stacy Hron, **WDNR** Milwaukee Estuary Area of Concern Coordinator

With Input and Contributions From:

The Milwaukee Estuary Fish and Wildlife Technical Advisory Committee (Tech Team)
Coordinated by Stacy Hron

Aaron Zeleske, Milwaukee River Greenway Coalition, River Revitalization Foundation
Andrew Struck, Ozaukee County
Angie Tornes, NPS
Brian Russart, Milwaukee County Parks
Cheryl Nenn, Milwaukee Riverkeeper
Daniel Sullivan, USGS
Dianne Robinson, WDNR
Faith Fitzpatrick, USGS
Gary Casper, UWM Field Station/Milwaukee River Greenway Coalition
Heather Williams, USEPA – GLNPO
John Janssen, UWM
John Masterson, WDNR
Julia Robson, Milwaukee County Parks
Kim Forbeck, Urban Ecology Center
Kristina Betzold, WDNR
Marsha Burzynski, WDNR
Matt Magruder, MMSD
Patrick Elliott, MMSD
Rick Fox, NRT
Steven Choy, USFWS
Todd Polacek, Applied Ecological Services
Tom Burzynski, WDNR
Tom Sear, SEH
Tom Slawski, Southeast WI Regional Planning Commission
Vic Pappas, WDNR
Will Wawrzyn, Citizen

The Milwaukee Estuary Community Advisory Committee
Aaron Zeleske, Milwaukee River Greenway Coalition, River Revitalization Foundation
Andrew Struck, Ozaukee County*
Bob Paulson, WE Energies
Chris Litzau, Citizen* (Chairperson)
Cheryl Nenn, Milwaukee Riverkeeper*
Elizabeth Hittman, City of Milwaukee
Janee Pederson, GZA*
Joan Herriges, Southeast WI Watersheds Trust
John Hacker, Citizen*
Lilith Fowler, Harbor District Inc.
Linda Reid, Southeast WI Watersheds Trust
Lindsay Frost, Harbor District Inc.*
Rick Fox, NRT

*Denotes Leadership Team Member

Disclaimer
The Great Lakes Water Quality Agreement is a non-regulatory agreement between the U.S. and Canada, and criteria developed under its auspices are non-regulatory. The actions identified in this document as needed to meet beneficial use impairment (BUI) delisting targets are not subject to enforcement or regulatory actions.

The actions identified in this Remedial Action Plan Update do not constitute a list of preapproved projects, nor is it a list of projects simply related to BUIs or generally to improve the environment. Actions identified in this document are directly related to removing a BUI and are needed to delist the Area of Concern.

Cover photo: Lake Michigan. Photo taken by Stacy Hron.

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PURPOSE STATEMENT

This Remedial Action Plan (RAP), which updates the 2015 RAP, documents and communicates progress made in the Area of Concern (AOC) in the last year and shares the path forward with our partners and stakeholders. The RAP includes a concise summary of beneficial use impairment (BUI) status and tracks progress on specific actions that are important for reaching the delisting targets. These “actions” may include on-the-ground restoration projects, monitoring and assessment projects, and stakeholder engagement processes. As the primary agency with the responsibility to develop and implement the RAP, the Wisconsin Department of Natural Resources and the Office of Great Waters is committed to making progress in remediating and restoring Wisconsin’s Areas of Concern. In order to be lasting and effective, the AOC program must continuously improve, evaluating its course as new information and technology become available. Subsequent RAP updates will be produced as needed to incorporate new information.

Remedial Action Plans are required by Annex 1 of the Great Lakes Water Quality Protocol of 2012 (which replaced the 1987 Protocol amending the Revised Great Lakes Water Quality Agreement of 1978). The 2012 Protocol indicates that Remedial Action Plans must include the following elements:

1. Identification of BUIs and causes;
2. Criteria for the restoration of beneficial uses that take into account local conditions and established in consultation with the local community;
3. Remedial measures to be taken, including identification of entities responsible for implementing these measures;
4. A summary of the implementation of remedial measures taken and the status of the beneficial use; and
5. A description of surveillance and monitoring processes to track the effectiveness of remedial measures and confirm restoration of beneficial uses.

Figure 1: The boundaries of the Milwaukee Estuary Area of Concern. For additional information about the history of the AOC and a narrative description of the AOC boundary, please refer to previous RAP documents which are available online: http://WDNR.wi.gov Search "Milwaukee Estuary AOC"; RAP documents are stored on the "AOC Plans" tab. A listing of previous RAPs, RAP Updates, and important historical documents is included in the References section.

2016 PROGRESS SUMMARY

The Wisconsin Department of Natural Resources (WDNR) and partners are working to improve conditions in the Milwaukee Estuary AOC. During the past year progress has been made on moving sediment remediation forward, completing assessments to gather information on BUI status and support decision making, and continuing to make progress on habitat restoration management actions. Details about projects in the AOC are included in Appendix C.

Sediment

Contaminated sediments contribute to the majority of BUIs in the Milwaukee Estuary AOC. Therefore, remediating contaminated sediment sites is necessary in making progress in addressing this impairment. A memo documenting the strategy for addressing contaminated sediment is included in Appendix D. A map illustrating contaminated sediment progress in the AOC is included in Figure 2. Since the last RAP Update, the following dredging related actions occurred:

- Work continued on the characterization of sediments throughout the AOC via the Great Lakes Legacy Act Program. Through this program the state requests the U.S. Environmental Protection Agency (USEPA) to investigate and characterize the extent of sediment contamination in the AOC, which can position them for future cleanups. This work is completed by USEPA contractors at full federal expense, and is dependent on funding levels. In July, a report detailing the 2015 Legacy Act sediment characterization sampling in the Menomonee River from the Little Menomonee to the confluence with the Milwaukee was completed (link included in the reference section). In November the Milwaukee River from Estabrook Dam to the confluence with the Menomonee River was sampled, with results expected in 2017. Also, a request was submitted for additional characterization work in the selected areas in the Kinnickinnic River, nearshore waters, inner and outer harbors of the AOC. This request builds on several successful requests in the past three years.
- WE Energies submitted an application to the USEPA Great Lakes National Program Office (GLNPO) for a Great Lakes Legacy Act betterment project in portions of the Milwaukee and Menomonee Rivers. A project agreement was signed in late 2016 for conducting a focused remedial investigation and feasibility study for portions of the Menomonee River and Milwaukee River for addressing sediments adjacent to two former coal gasification facilities (West Side manufactured gas plant, or MGP, and Third Ward MGP). The Menomonee River site characterization work conducted by USEPA GLNPO last year filled in the data gaps for the Menomonee River Portion. WE Energies, as part of an in-kind contribution, will hire a contractor to conduct monitoring on the Milwaukee River portion of the project area. USEPA GLNPO is in the process of hiring a consultant to prepare the feasibility study for the entire project area to determine options for remediation of the sediments. A schedule for preparation and completion of the feasibility study will be prepared after USEPA GLNPO has a contractor on board. This is a joint project between WE Energies and USEPA GLNPO.
- Miller Compressing has continued planning for remediation at the Burnham Canal Superfund site. The review and approval of design plans is currently underway at the regulatory agencies – USEPA and WDNR.
- Dredging began at the Cedar Creek Superfund Alternative site by contractors for Mercury Marine in November. This followed several years of planning for this site to address polychlorinated biphenyl (PCB) contamination. Remediation of sediments from the Ruck Raceway was completed in December of 2016. About 5000 cubic yards of contaminated sediment was mechanically removed and disposed of in landfills in state and out of state, when required. Work continues on upland remediation and restoration work in land adjacent to the Raceway. Mercury Marine's contractors are in the process of submitting final plans for the remediation of Columbia and Wire and Nail Ponds on Cedar Creek. They anticipate starting in the spring and will hydraulically

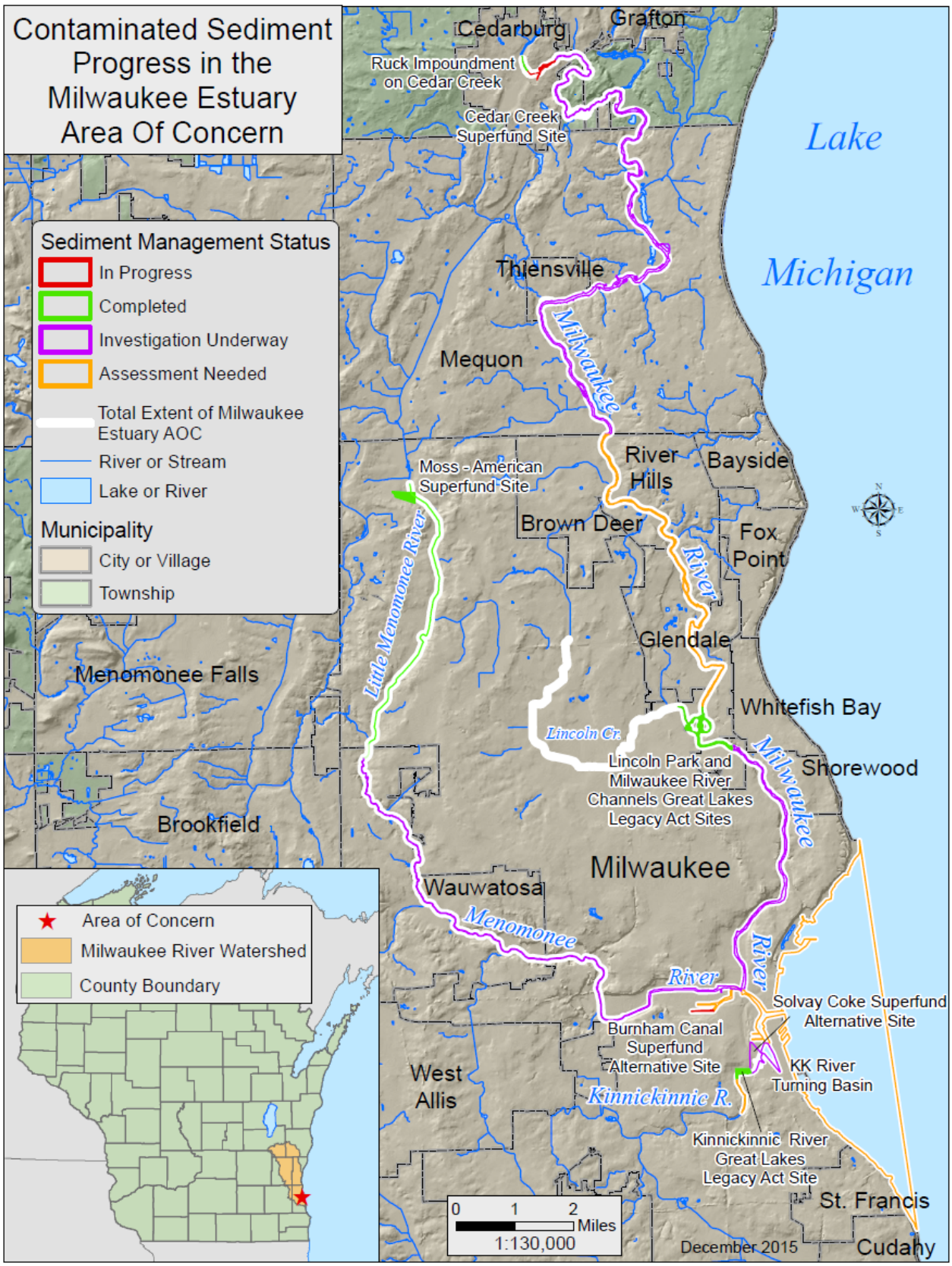

Figure 2: Contaminated Sediment Progress in the Milwaukee Estuary AOC

dredge the sediments (estimated about 50,000 cubic yards). There will be an onsite wastewater treatment facility to handle the water generated by the dredging operations. In addition to the dredging, contaminated upland sites will also be remediated and restored. Mercury Marine anticipates the work to be completed by the end of 2017.

- WDNR and U.S. Geological Survey (USGS), along with partner Milwaukee Metropolitan Sewerage District (MMSD), worked to develop a project proposal to assess non-point source polycyclic aromatic hydrocarbon (PAH) loading to the Milwaukee Estuary in 2016. This information would be valuable for AOC related sediment management action planning. The proposal will be submitted to USEPA for possible Great Lakes Restoration Initiative (GLRI) funding by USGS. If funded, the mass balance-based assessment would be piloted in the Kinnickinnic River portion of the AOC, which could begin as soon as 2017.

Assessments

This year, there are many assessment projects underway, nearing completion or publishing reports. These include several projects which WDNR received GLRI funding to carry out in previous years. Reports for the fish tumor rate assessment as well as the waterfowl consumption assessment were published by USGS and WDNR respectively. Those publications are included as appendices E and F in this RAP Update. An interpretive report on the 2012 plankton and benthos sampling was completed in July, and a report for the 2014 sampling is in draft awaiting publication. Reporting out on work completed under a WDNR/GLRI grants to University of Wisconsin – Milwaukee (UWM) School of Freshwater Sciences (tracking sources of sewerage and bacterial contamination) and Milwaukee Riverkeeper (citizen based aesthetics monitoring) are due by the end of the year. USGS also published some results from their tree swallow studies in AOCs, including Milwaukee. All of these reports are being used to determine status and/or next steps that are needed for the following BUIs, respectively: fish tumors or other deformities, restrictions on fish and wildlife consumption, degradation of benthos, degraded phytoplankton and zooplankton populations, beach closings/recreational restrictions, degradation of aesthetics, and bird or animal deformities or reproductive problems.

In addition, several fish and wildlife population assessments are underway. These are to assist in determining management actions and metrics for the degradation of fish and wildlife populations impairment. Most are scheduled to be completed by the end of September 2017. Reporting out is expected to begin in spring 2017. This coincides with the work that the Fish and Wildlife Technical Advisory Committee (Tech Team) will do to start ramping up work on this BUI. The assessments in progress include the following:

- Staff from the UWM Field Station and Milwaukee County Dept. of Parks, Recreation & Culture are completing comprehensive wildlife surveys throughout the AOC. WDNR received GLRI funding for assessments, scheduled to be completed by September 2017. A report for the majority of the AOC is due in March 2017, with a report for the remaining work due in September 2017. This work will include mapping and identify potential opportunities and metrics for AOC habitat projects.
- Ozaukee County Planning & Parks Dept. and WDNR Fisheries Bureau are collecting and assessing data for the wadeable portions of the AOC. This will include a compilation of existing and new data along with modeling to assist with habitat project planning. Additional mapping will be produced by WDNR Office of Great Waters staff.
- USGS completed the third and final year of field work in fall 2016 for a non-wadeable fisheries assessment. This project reproduces much of a study completed by WDNR in the early 1980s, and will be used to compare current and past conditions. The information will also be used for habitat planning and BUI metric setting.

- UWM School of Freshwater Sciences received funding from Fund for Lake Michigan and WDNR for an assessment of habitat in the Milwaukee harbor. They will be completing their field work in 2017.

Habitat Restoration and Management Action Implementation

Throughout the year, the AOC coordinator worked with partners to continue to develop project proposals and make progress on projects identified as management actions. The majority of these were habitat restoration projects and one was a beach remediation. In addition, partners made great strides in implementing some projects. The City of Milwaukee/the Redevelopment Authority of the City of Milwaukee have been ramping up work on the restoration of the Bay View/Grand Trunk wetland restoration. A feasibility study is underway, building upon a Master Plan for the site, both funded by Fund for Lake Michigan. The AOC Coordinator and Fish and Wildlife Technical Advisory Committee have been providing technical support for the effort. WDNR applied for and received funding for the City to begin final design and permitting for the project in 2017. MMSD has been working on planning for two habitat projects (Burnham Canal Wetland Restoration and Kinnickinnic River Rehabilitation) as well as implementing two others (Five Low Flow Barriers Removal and Menomonee River Concrete Removal). Both the low flow barrier and concrete removal projects were completed this year. WDNR worked with MMSD to develop a project proposal for moving on to the next steps for the Kinnickinnic project. WDNR received the funding this fall and design work is scheduled to begin in 2017. Working with Milwaukee County Dept. of Parks, Recreation & Culture, WDNR applied for and received funding to further two other habitat projects, the Kletzsch Dam Fish Passage and the Little Menomonee Corridor Restoration. In addition, working with Milwaukee County Dept. of Parks, Recreation & Culture, WDNR applied for and received funding to continue work on remediating South Shore Beach. This builds upon a recent master plan that was completed for part of the park as well as improvements aimed at reducing bacterial loading that are underway.

Next Year

In the next year the AOC Coordinator and WDNR staff will continue to make progress on many fronts in the Milwaukee Estuary AOC. The following activities are planned for 2017:

- Work with the Fish and Wildlife Technical Advisory Committee to begin reviewing and synthesizing data for the degradation of fish and wildlife populations impairment. This will be followed by working on developing metrics and management actions for the impairment.
- Continue to work on habitat project planning, design and construction.
- Work with the Community Advisory Committee to review Aesthetics data and determine next steps for the degradation of aesthetics impairment.
- Review the results of the plankton and benthos assessments completed by USGS and determine next steps for the degradation of benthos and degradation of phytoplankton and zooplankton populations impairments.
- Review total maximum daily load (TMDL) and bacteria source tracking outputs and consider next steps for the eutrophication or undesirable algae and beach closings/recreational restrictions impairments.
- Continue sediment characterization and evaluate data to determine where additional cleanups might be necessary.
- Work with new and ongoing sediment cleanup projects to assure AOC goals and targets are met.

Table 1. Current Status of Beneficial Use Impairments in the Milwaukee Estuary AOC (Refer to Appendix C for more detail).

Beneficial Use Impairment	Beneficial Use Remains Impaired	Summary Status
Fish tumors or other deformities	Yes	The fish tumor study publication was published in 2016. As stated in the previous RAPs the assessment indicates this BUI is impaired. Work on removing contaminants from the AOC continues as discussed in the 2016 Progress Summary.
Bird or animal deformities or reproductive problems	Suspected	Tree swallow monitoring, which is the selected indicator organism for the Milwaukee Estuary AOC, continues by USGS researchers. The results of this monitoring effort will be used to assess the BUI status when complete.
Restrictions on fish and wildlife consumption	Yes	Results of the waterfowl consumption assessment project indicate that an advisory will remain in place. Fish consumption advisories also remain in place.
Restrictions on dredging activities	Yes	While progress on dredging projects continues, more work is still needed.
Degradation of benthos	Yes	Results from the USGS benthos and plankton study are pending. Next steps will be determined after conclusions are reviewed.
Degradation of phytoplankton and zooplankton populations	Yes	Results from the USGS benthos and plankton study are pending. Next steps will be determined after conclusions are reviewed.
Loss of fish and wildlife habitat	Yes	Progress continues on implementing the management actions including feasibility, design and implementation of projects. Some management actions are complete.
Degradation of fish and wildlife populations	Yes	Fish and wildlife population assessments are almost complete. The process to determine management actions will begin in 2017.
Beach closings	Yes	The outputs from both the TMDL and bacterial contamination source tracking are due in early 2017. Work continues with Milwaukee County on beach improvements, focusing on South Shore Beach.
Eutrophication or undesirable algae	Yes	TMDL studies will inform nutrient sources and loading, with outputs expected in 2017.
Degradation of aesthetics	Yes	The target was adjusted in 2016. Ongoing citizen-based monitoring will characterize the impairment to assist in determining if further action is needed.

BENEFICIAL USE IMPAIRMENT UPDATES

FISH TUMORS OR OTHER DEFORMITIES

Target (Updated 2011)	Status
Removal may occur if:	
• All known major sources of PAHs and chlorinated organic compounds within the AOC and tributary watershed have been controlled or eliminated.	In Progress & Action Needed
• A fish health survey of resident benthic fish species, such as white suckers, finds incidences of tumors or other deformities at a statistically similar incidence rate of minimally impacted reference sites.	Assessment Complete (2015) Reassess Post Remediation
OR, in cases where tumors have been reported:	
• A comparison study of resident benthic fish such as white suckers of comparable age and maturity, or of fish species found with tumors in previous fish health surveys in the AOC, with fish at minimally impacted reference sites indicate that there is no statistically significant difference (with 95% confidence) in the incidence of liver tumors or deformities.	Assessment Complete (2015) Reassess Post Remediation

Status

An assessment of this impairment was completed in 2013 by USGS in the Milwaukee Estuary AOC and 2014 at the Root River reference site. Presence of neoplastic liver tumors in white suckers is the indicator which is used in the Milwaukee Estuary AOC to assess fish tumor rates. Researchers found that 15% of the white suckers in the Milwaukee Estuary had neoplastic liver tumors, above the 8.5% rate for the Root River (Racine, WI) and above documented background rates. As a result of this assessment, the status of this BUI was confirmed as “Impaired” and the suspected/potentially impaired was removed from the BUI status in 2014. The publication associated with this assessment was published by USGS in 2016. A copy of that publication is included in Appendix E.

The results indicate that more work needs to be done to control or eliminate the sources of contaminants in the Milwaukee Estuary AOC. Sites with elevated amounts of PAHs, metals, and other substances must be addressed before removal of this impairment can occur. The BUI will be reassessed when a sufficient amount remediation of contaminants has occurred that may result in a decrease in fish tumor rate.

Management Actions

Management actions for this impairment are those projects which control or eliminate contaminants of issue from the AOC. These actions are usually sediment remediation or dredging projects. The first step in determining the management actions is to adequately characterize the conditions within the AOC. This information can then be used to determine management actions that need to be taken. The following actions need to be completed in order to determine contamination related management actions:

- Assess potential impacts to sediments from the remainder of the AOC that is currently uncharacterized. This includes the Milwaukee River downstream of the confluence with the Menomonee River, the south Menomonee Canal and upper Burnham Canal, portions of the Kinnickinnic River, inner harbor, and selected sites in the outer harbor and nearshore waters of Lake Michigan.
- Review and act upon Legacy Act sediment assessment data from other areas of the AOC. This includes, but is not limited to, Kinnickinnic River/Turning Basin, Menomonee River from

confluence with Little Menomonee to the harbor, Milwaukee River between Estabrook Dam and confluence with Menomonee River and existing Milwaukee River data.

The following management actions are necessary to move towards removing this impairment. This list is not complete. The actions that have been implemented are italicized.

1) Sources of contamination within the AOC need to be remediated.
    a. Complete the assessment and cleanup of PCBs at the Cedar Creek Superfund Alternative Site.
    b. Complete the management of sediments containing PAHs and metals from the Burnham Canal Superfund Alternative Site.
    c. Complete the assessment of contaminated sediment and evaluate and implement cleanup related to the Solvay Coke Superfund Alternatives Site.
    d. Blatz Pavilion, Lincoln Park Phase 1 and Phase 2 Contaminated Sediment Remediation
    e. Kinnickinnic River Legacy Act Cleanup

BIRD OR ANIMAL DEFORMITIES OR REPRODUCTION PROBLEMS (POTENTIALLY IMPAIRED)

Target (Updated 2011)	Status
This BUI can be removed if:	
• Studies conducted in the AOC indicate that the beneficial use should not be considered impaired, or	In Progress (2010-2017)
• If studies conducted in the AOC determine that this use is impaired, then two approaches can be considered for delisting: o Approach 1 – Observational Data and Direct Measurements of Birds and other Wildlife ▪ Evaluate observational data of bird or other animal deformities for a minimum of two successive monitoring cycles in indicator species identified in the initial studies as exhibiting deformities or reproductive problems. If deformity or reproductive problem rates are not statistically different than those at minimally impacted reference sites (at a 95% confidence interval), or no reproductive or deformity problems are identified during the two successive monitoring cycles, then the BUI can be removed. If the rates within the AOC are statistically higher than the reference site, it may indicate a source from either within or from outside the AOC. Therefore, if the rates are statistically higher or the data are insufficient for analysis to achieve agreed upon statistical power, then… ▪ Evaluate tissue contaminant levels in egg, young and/or adult wildlife. If contaminant levels are lower than the Lowest Observable Effect Level (LOEL) for that species for a particular contaminant that are not statistically different than those at minimally impacted reference sites (at a 95% confidence interval), then the BUI can be removed.	TBD (based on results of study)
• Where direct observation of wildlife and wildlife tissue data are not available, the following approach should be used: o Approach 2 – Fish Tissue Contaminant Levels as an Indicator of Deformities or Reproductive Problems ▪ If fish tissue concentrations of contaminants known to cause deformities or reproductive suppression identified in the AOC are at or lower than the LOEL known to cause reproductive or developmental problems in fish-eating birds and mammals, the BUI can be delisted, or ▪ If fish tissue concentrations of contaminants known to cause deformities or reproductive suppression identified in the AOC are not statistically different than Lake Michigan (at 95% confidence interval with sufficient and agreed upon statistical power), then the BUI can be removed. Fish of a size and species considered prey for the wildlife species under consideration must be used for the tissue data.	TBD (based on results of Approach 1)

Status

This BUI is listed as potentially impaired, as sufficient data does not exist to definitively list it as impaired or unimpaired. Due to the presence of contaminants such as PCBs and metals in sediments in the AOC, which have the potential to impair the reproduction and development of wildlife, this BUI is considered impaired.

USGS researchers have been using tree swallows as indicators of environmental contamination in areas across the Great Lakes and United States. The tree swallow is the organism that is being used to assess this BUI in the Milwaukee Estuary AOC. Since 2010 researchers have sampled five sites in the Milwaukee Estuary including Cedar Creek, Lincoln Park, Three Bridges Park, Lakeshore State Park and Baran Park. This represents one site each on Cedar Creek, Milwaukee River, Menomonee River, Kinnickinnic River and in the Estuary. This sampling will provide data robust enough to determine if this beneficial use is impaired. However, as this is a Great Lakes wide project, there has not been funding to sample the Milwaukee Estuary at each site, in each year. Work will continue in 2017 to collect and analyze an adequate amount of data to use in determining the status of this impairment.

Management Actions

Management actions have not been defined for this impairment. Management actions will be determined if studies indicate the BUI is impaired. If management actions are defined, they would likely be very similar to sediment management actions defined for other BUIs.

RESTRICTIONS ON FISH AND WILDLIFE CONSUMPTION

Target (Updated 2011)	Status
Fish Approach to be used with current level of monitoring for fish consumption advisories within the AOC (every five years):	
• All known man-made sources of BCOCs (including PCBs, mercury, dioxins, and furans) within the AOC and tributary watershed have been controlled or eliminated; and	In Progress & Action Needed
• State fish tissue monitoring confirms that waterbody-specific fish consumption advisories are no longer needed for PCBs for waters in the AOC.	Action Needed
• Waters within the Milwaukee Estuary AOC are not listed as impaired due to fish consumption advisories in the most recent Clean Water Act 303(d) and 305(b) Wisconsin Water Quality Report to Congress (submitted to USEPA every two years).	In Progress (ongoing monitoring)
Approach to be used with funding to support additional monitoring:	
• All known man-made sources BCOCs (including PCBs, mercury, dioxins, and furans) within the AOC and tributary watershed have been controlled or eliminated; and	In Progress & Action Needed
• A multi-year comparison study of fish tissue contaminant levels demonstrates that there is no statistically significant difference (with a 95% confidence interval) in fish tissue BCOC concentrations in the AOC compared to fish tissue BCOC concentrations in a representative non-impacted control site within the Lake Michigan Basin.	TBD (based on results of current monitoring)
Wildlife There are no waterfowl consumption advisories for resident waterfowl due to contamination originating within the AOC.	Assessment Complete (2015) Reassess Post Remediation

Status

This BUI remains impaired for both Fish and Wildlife. WDNR wildlife staff completed a grant-funded assessment of the wildlife consumption advisory in 2015. This project was shortened from three years to two based on the results from the first two seasons of sampling. It was determined that additional sample collection would not change the consumption advisory determination, and not worth the investment of additional resources. The results were reviewed by both WDNR and Wisconsin Department of Health Services. Based on the findings, the agencies concur that a consumption advisory for waterfowl will remain in place in the Milwaukee Estuary AOC at this time. The report is included in Appendix F. WDNR Fisheries Management samples waterbodies every 5 years in order to assess consumption advisories. The Milwaukee River and Cedar Creek are due for resampling in 2017 and 2018, respectively.

Areas of the AOC contaminated with PCBs or other bioaccumulative chemicals of concern (BCOCs) need assessment and remediation to address this impairment. This process is ongoing as discussed in the 2016 Progress Summary. As the progress continues to address the contaminants, the consumption advisories for fish and wildlife need to be reassessed until delisting targets are met. Consumption advisories are not removed until data shows fish and wildlife are healthy to eat without restriction.

Management Actions

Management actions for this impairment are those projects which control or eliminate contaminants of issue from the AOC. These actions are usually sediment remediation or dredging projects. The first step in determining the management actions is to adequately characterize the conditions within the AOC. This information can then be used to determine management actions that need to be taken. The following actions need to be completed in order to determine contamination-related management actions:

- Assess potential impacts to sediments from the remainder of the AOC currently uncharacterized. This includes the Milwaukee River downstream of the confluence with the Menomonee River, the south Menomonee Canal and upper Burnham Canal, portions of the Kinnickinnic River, inner harbor, and selected sites in the outer harbor and nearshore waters of Lake Michigan.
- Review and act upon Legacy Act sediment assessment data from other areas of the AOC. This includes, but is not limited to, Kinnickinnic River/Turning Basin, Menomonee River from confluence with Little Menomonee to the harbor, Milwaukee River between Estabrook Dam and confluence with Menomonee River and existing Milwaukee River data.

The following management actions are necessary to move towards removing this impairment. This list is not complete. The actions that have been implemented are italicized.

1) Sources of contamination within the AOC need to be remediated.
    a. Complete the assessment and cleanup of PCBs at the Cedar Creek Superfund Alternative Site.
    b. Complete the management of sediments containing PAHs and metals from the Burnham Canal Superfund Alternative Site.
    c. Complete the assessment of contaminated sediment and evaluate and implement cleanup related to the Solvay Coke Superfund Alternatives Site.
    d. Blatz Pavilion, Lincoln Park Phase 1 and Phase 2 Contaminated Sediment Remediation
    e. Kinnickinnic River Legacy Act Cleanup

RESTRICTIONS ON DREDGING ACTIVITIES

Target (Updated 2011)	Status
Removal of this BUI can occur when:	
• Contaminated sediment hotspots within and upstream from the AOC have been identified.	In Progress & Action Needed
• Implementation actions to remediate contaminated sites have been completed. As a source control measure and for AOC remediation, known contaminated sites must be addressed before BUI removal is possible.	In Progress & Action Needed
• There are no special handling requirements of material from routine navigational dredging due to contamination originating from controllable sources within the AOC.	In Progress & Action Needed

Status

This BUI remains impaired in the Milwaukee Estuary AOC. While progress continues as described in the 2016 Progress Summary, there is still much work to be done before all known sites and impacts to future dredging operations are addressed.

Management actions

Management actions for this impairment are those projects which control or eliminate contaminants of issue from the AOC. These actions are usually sediment remediation or dredging projects. The first step in determining the management actions is to adequately characterize the conditions within the AOC. This information can then be used to determine management actions that need to be taken. The following actions need to be completed in order to determine contamination related management actions:

- Assess potential impacts to sediments from the remainder of the AOC currently uncharacterized. This includes the Milwaukee River downstream of the confluence with the Menomonee River, the south Menomonee Canal and upper Burnham Canal, portions of the Kinnickinnic River, inner harbor, and selected sites in the outer harbor and nearshore waters of Lake Michigan.
- Review and act upon Legacy Act sediment assessment data from other areas of the AOC. This includes, but is not limited to, Kinnickinnic River/Turning Basin, Menomonee River from confluence with Little Menomonee to the harbor, Milwaukee River between Estabrook Dam and confluence with Menomonee River and existing Milwaukee River data.

The following management actions are necessary to move towards removing this impairment. This list is not complete. The actions that have been implemented are italicized.

1) Sources of contamination within the AOC need to be remediated.
    a. Complete the assessment and cleanup of PCBs at the Cedar Creek Superfund Alternative Site.
    b. Complete the management of sediments containing PAHs and metals from the Burnham Canal Superfund Alternative Site.
    c. Complete the assessment of contaminated sediment and evaluate and implement cleanup related to the Solvay Coke Superfund Alternatives Site.
    d. Blatz Pavilion, Lincoln Park Phase 1 and Phase 2 Contaminated Sediment Remediation
    e. Kinnickinnic River Legacy Act Cleanup

DEGRADATION OF BENTHOS

Target (Updated 2011)	Status
Removal may occur if:	
• Known contaminant sources contributing to sediment contamination and degraded benthos have been identified and control measures implemented; and	In Progress & Action Needed
• All remediation actions for contaminated sediments are completed and monitored according to an approved plan; or	In Progress & Action Needed
• The benthic community within the site being evaluated is statistically similar to a reference site with similar habitat and minimal sediment contamination.	Assessment In Progress (2012-2016)

Status

The status of this impairment is currently being assessed. USGS was contracted to assess both the planktonic and benthic communities of the Lake Michigan AOCs and reference rivers. Sampling was completed in 2012 and 2014. The 2012 report is complete and a draft of the 2014 report is currently under review. When the reports and the conclusions are fully evaluated, next steps for this BUI will be determined.

At a minimum, sources of contamination to the benthic community within the AOC need to be remediated. The status and condition of the benthic community in the entire AOC needs to be determined. There may be a need to supplement the USGS study to adequately characterize the range of benthic conditions in the AOC. Given the disturbance found in some of the AOC waterways, it is unlikely that high quality benthic communities can be established at all sites. For instance, the inner harbor has high degrees of disturbance, sediment deposition and lack of suitable habitat that tend to be dominated by very tolerant organisms. Changes in the habitat in this area are unlikely. Refinement of the target may be needed, taking into consideration the achievability of targets for BUI removal and the varied benthic conditions throughout the AOC.

Management Actions

Management actions for this impairment are those projects which control or eliminate contaminants of issue from the AOC. These actions are usually sediment remediation or dredging projects. The first step in determining the management actions is to adequately characterize the conditions within the AOC. This information can then be used to determine management actions that need to be taken. The following actions need to be completed in order to determine contamination related management actions:

- Assess potential impacts to sediments from the remainder of the AOC currently uncharacterized. This includes the Milwaukee River downstream of the confluence with the Menomonee River, the south Menomonee Canal and upper Burnham Canal, portions of the Kinnickinnic River, inner harbor, and selected sites in the outer harbor and nearshore waters of Lake Michigan.
- Review and act upon Legacy Act sediment assessment data from other areas of the AOC. This includes, but is not limited to, Kinnickinnic River/Turning Basin, Menomonee River from confluence with Little Menomonee to the harbor, Milwaukee River between Estabrook Dam and confluence with Menomonee River and existing Milwaukee River data.

The following management actions are necessary to move towards removing this impairment. This list is not complete. The actions that have been implemented are italicized.

1) Sources of contamination within the AOC need to be remediated.
    a. Complete the assessment and cleanup of PCBs at the Cedar Creek Superfund Alternative Site.
    b. Complete the management of sediments containing PAHs and metals from the Burnham Canal Superfund Alternative Site.
    c. Complete the assessment of contaminated sediment and evaluate and implement cleanup related to the Solvay Coke Superfund Alternatives Site.
    d. *Blatz Pavilion, Lincoln Park Phase 1 and Phase 2 Contaminated Sediment Remediation*
    e. *Kinnickinnic River Legacy Act Cleanup*

DEGRADATION OF PHYTOPLANKTON AND ZOOPLANKTON POPULATIONS

Target (Updated 2012)	Status
A stepped approach is needed for delisting for this impairment:	
1. The first step toward delisting will be to establish a baseline condition for the estuary to evaluate the extent of this impairment. Phytoplankton and zooplankton community surveys should be conducted and compared to a non-impacted or minimally impacted reference site to set the baseline condition. If the community structure is statistically different than the reference conditions, this BUI should be considered impaired.	Assessment In Progress (2012-2016)
2. Identify the factors leading to this impairment. a. Ambient water chemistry sampling should be conducted to determine if nutrient enrichment is the main contributor. If nutrients are the main contributor, sources causing nutrient enrichment to the outer harbor and nearshore waters are identified and controlled. b. If nutrient enrichment is not considered the cause of the impairment, conduct bioassays to determine if ambient water toxicity is causing impairment.	Action Needed (based on results of current assessment)

Status

The status of this impairment is currently being assessed. USGS was contracted to assess both the planktonic and benthic communities of the Lake Michigan AOCs and reference rivers. Sampling was completed in 2012 and 2014. The 2012 report is complete and a draft of the 2014 report is currently under review. When the reports and the conclusions are fully evaluated, next steps for this BUI will be determined.

If the planktonic community is found to be impaired compared to other Lake Michigan rivers, based on the target there is a need to investigate if nutrient enrichment and/or toxicity are causes of the plankton impairment. This determination would inform any additional necessary management actions. A target adjustment may also be needed depending on the results of the study.

Management Actions

No management actions have been defined for this impairment. Management actions will be determined if studies indicate the BUI is impaired. If management actions are defined, they would likely be very similar to sediment or nutrient management actions defined for other BUIs.

LOSS OF FISH AND WILDLIFE HABITAT

Target (Updated 2011)	Status
This BUI will be considered to be eligible for removal when the following have occurred:	
• All contaminated sediment hotspots within the AOC have been identified, and implementation actions to remediate contaminated sites have been completed.	In Progress & Action Needed
• A local fish and wildlife management and rehabilitation plan has been compiled for the estuary that: o Defines the causes of all habitat impairments within the AOC o Establishes site-specific habitat and population targets for native indicator fish and wildlife species within the AOC o Identifies all fish and wildlife habitat rehabilitation programs/activities within the AOC and establishes a mechanism to assure coordination among all these programs/activities, including identification of lead agencies o Establishes a time table, funding mechanism, and lead agency or organization responsibility for all fish and wildlife habitat rehabilitation activities needed within the AOC.	In Progress
• The programs and actions necessary to accomplish the recommendations of the fish and wildlife habitat plan are implemented, and modified as need to ensure continual improvement.	In Progress

Status

Significant progress has been made on this BUI in the past several years. A management action list of habitat projects was finalized and all projects are in some phase of implementation (planning, design or construction) or complete. Progress on these habitat projects as well as the sediment remediation actions are discussed in the 2016 Progress Update section.

WDNR applied for and received grant funding to move implementation forward for several habitat management action projects including: Kletzsch Dam Fish Passage, Bay View Wetland Restoration, Little Menomonee Corridor Restoration and the Kinnickinnic River Habitat Rehabilitation. In the coming year, WDNR will work with partners to continue making progress on these and other management actions.

Management Actions

The first set of management actions for this impairment are habitat restoration projects that address one or more of the physical or biological habitat goals, as determined in consultation with the Fish and Wildlife Technical Advisory Committee. Details on these management actions, and the related items listed above in the target are in the Draft Fish and Wildlife Plan for the Milwaukee Estuary Area of Concern and the 2015 RAP Update. Another draft of the plan will be completed when the process for selecting management actions for the “Degradation of Fish and Wildlife Populations” BUI is almost complete.

The second set of management actions for this impairment are those projects which control or eliminate contaminants of issue from the AOC. These actions are usually sediment remediation or dredging projects. The first step in determining the management actions is to adequately characterize the conditions within the AOC. This information can then be used to determine management actions that

need to be taken. The following actions need to be completed in order to determine contamination related management actions:

- Assess potential impacts to sediments from the remainder of the AOC currently uncharacterized. This includes the Milwaukee River downstream of the confluence with the Menomonee River, the south Menomonee Canal and upper Burnham Canal, portions of the Kinnickinnic River, inner harbor, and selected sites in the outer harbor and nearshore waters of Lake Michigan.
- Review and act upon Legacy Act sediment assessment data from other areas of the AOC. This includes, but is not limited to, Kinnickinnic River/Turning Basin, Menomonee River from confluence with Little Menomonee to the harbor, Milwaukee River between Estabrook Dam and confluence with Menomonee River and existing Milwaukee River data.

The following management actions are necessary to move towards removing this impairment. This list is not complete as all sediment projects have not been identified and defined. The actions that have been implemented are italicized.

1) Implement habitat restoration projects defined in the fish and wildlife management and rehabilitation plan.
    a. *Little Menomonee Grassland Restoration*
    b. *Milwaukee River Fish Habitat Enhancement and Expansion*
    c. *Wheelhouse Gateway Riparian Restoration*
    d. *Menomonee River Concrete Removal*
    e. *Five Low Flow Barriers Removal*
    f. Kinnickinnic River Habitat Rehabilitation (in design)
    g. Burnham Canal Wetland Restoration (in design)
    h. Little Menomonee Corridor Restoration (in planning)
    i. Bay View Wetland Restoration (in planning)
    j. Estabrook Park Dam Fish Passage
    k. Kletzsch Park Dam Fish Passage (in planning)
2) Sources of contamination within the AOC need to be remediated.
    a. Complete the assessment and cleanup of PCBs at the Cedar Creek Superfund Alternative Site.
    b. Complete the management of sediments containing PAHs and metals from the Burnham Canal Superfund Alternative Site.
    c. Complete the assessment of contaminated sediment and evaluate and implement cleanup related to the Solvay Coke Superfund Alternatives Site.
    d. *Blatz Pavilion, Lincoln Park Phase 1 and Phase 2 Contaminated Sediment Remediation*
    e. *Kinnickinnic River Legacy Act Cleanup*

DEGRADATION OF FISH AND WILDLIFE POPULATIONS

Target (Updated 2011)	Status
Fish This BUI will be considered to be eligible for removal when the following have occurred:	
• All contaminated sediment hotspots within the AOC have been identified, and implementation actions to remediate contaminated sites have been completed.	In Progress & Action Needed
• A local fish and wildlife management and rehabilitation plan has been compiled for the estuary that: o Defines the causes of all population impairments within the AOC o Establishes site specific local population targets for native indicator fish and wildlife species within the AOC o Identifies all fish and wildlife population rehabilitation programs/activities within the AOC and establishes a mechanism to assure coordination among all these programs/activities, including identification of lead and coordinative agencies o Establishes a time table, funding mechanism, and lead agency or organization responsibility for all fish and wildlife population activities needed within the AOC. o The actions/projects necessary to accomplish the recommendations of the fish and wildlife management and restoration plan are implemented.	In Progress
• Populations for native indicator fish species are statistically similar to populations in reference sites with similar habitat but little to no contamination.	Unknown
Wildlife Assess wildlife populations and the possible extent of any impairment within the AOC before setting specific wildlife population targets.	In Progress

Status

Currently, information is being collected that will inform our decision making process for this BUI. There are several fish and wildlife population assessments and habitat mapping underway which will provide the data, suggested metrics and suggested actions for this impairment. These projects are discussed in the 2016 Progress Summary. These projects will be wrapping up in 2016 and 2017. Following reporting out, the AOC Coordinator will consult with the Fish and Wildlife Technical Advisory Committee to determine the necessary management actions. Given the size and complexity of the AOC, it is expected that this process will take at least 12-18 months to complete. The goal is to include management actions in the 2018 RAP. The draft Fish and Wildlife Plan will also be completed once all management actions and metrics are determined.

Management Actions

The first set of management actions for this impairment will be projects that address the goals and metrics for this BUI, to be determined in consultation with the Fish and Wildlife Technical Advisory Committee.

The second set of management actions for this impairment are those projects which control or eliminate contaminants of issue from the AOC. These actions are usually sediment remediation or dredging projects. The first step in determining the management actions is to adequately characterize the

conditions within the AOC. This information can then be used to determine management actions that need to be taken. The following actions need to be completed in order to determine management actions:

- Complete the fish and wildlife population assessments and associated mapping. Review the final products with the Fish and Wildlife Technical Advisory Committee and consult on proposed management actions.
- Assess potential impacts to sediments from the remainder of the AOC currently uncharacterized. This includes the Milwaukee River downstream of the confluence with the Menomonee River, the south Menomonee Canal and upper Burnham Canal, portions of the Kinnickinnic River, inner harbor, and selected sites in the outer harbor and nearshore waters of Lake Michigan.
- Review and act upon Legacy Act sediment assessment data from other areas of the AOC. This includes, but is not limited to, Kinnickinnic River/Turning Basin, Menomonee River from confluence with Little Menomonee to the harbor, Milwaukee River between Estabrook Dam and confluence with Menomonee River and existing Milwaukee River data.

The following management actions are necessary to move towards removing this impairment. This list is not complete as all sediment projects have not been identified and defined. The actions that have been implemented are italicized.

1) Sources of contamination within the AOC need to be remediated.
    a. Complete the assessment and cleanup of PCBs at the Cedar Creek Superfund Alternative Site.
    b. Complete the management of sediments containing PAHs and metals from the Burnham Canal Superfund Alternative Site.
    c. Complete the assessment of contaminated sediment and evaluate and implement cleanup related to the Solvay Coke Superfund Alternatives Site.
    d. *Blatz Pavilion, Lincoln Park Phase 1 and Phase 2 Contaminated Sediment Remediation*
    e. *Kinnickinnic River Legacy Act Cleanup*

BEACH CLOSINGS

Target (Updated 2011 & 2012)	Status
This BUI will be considered removed when:	
• All known sources of bacterial contamination to the AOC and tributary watersheds have been identified and, if feasible, have been controlled or treated to reduce possible exposures; and	Assessment in Progress & Action Needed
• No unpermitted overflows (either from sanitary sewers or combined sewers) have occurred within the AOC during the previous five year period.	Unknown
• All municipalities within the AOC have adopted and are implementing storm water reduction programs including an illicit discharge elimination program; and	Complete
• No water bodies within the AOC are included on the list of impaired waters due to contamination with pathogens or chemicals having a public health concern (i.e., carcinogenic, mutagenic) in the most recent Wisconsin Impaired Waters list that is submitted to USEPA every two years; and	In Progress & Action Needed
• No local or state contact advisories related to the presence of a chemical contaminant have been issued within the AOC during the previous five years.	Unknown
• No water bodies (including beaches) within the AOC are included on the list of impaired waters for recreational restrictions in the most recent Wisconsin Impaired Waters list.	In Progress & Action Needed
• Implementation of the Milwaukee River Total Maximum Daily Load Study for bacteria is complete.	In Progress & Action Needed

Status

Progress has been made on this impairment in 2016, but more work is needed to further define the target and management actions based on work currently underway. Reviewing the outputs from the TMDL for bacteria and the Identification and Quantification of Sanitary Sewage Contamination in the Milwaukee Estuary AOC will elucidate what is needed to address this impairment. Both of these products should be available by early 2017. After reviewing and disseminating this information, the next steps for this impairment will be determined. It is likely that a target adjustment will be called for based on this new information.

At the same time, Milwaukee County has continued their work on planning improvements to beaches in the AOC. Right now the focus is high bacterial levels at South Shore Park Beach. Milwaukee County Dept. of Parks, Recreation & Culture has undertaken a Master Planning and redesign of park elements. Designs are currently being developed for the parking lot and green infrastructure at the park. WDNR applied for and received funding to assist Milwaukee County Dept. of Parks, Recreation & Culture in continuing work to address bacterial levels and closings in the beach area. This work will continue in 2017.

Management Actions

Management actions have not been defined for this impairment. Management actions will be determined after review of pertinent information and in consultation with stakeholders.

EUTROPHICATION OR UNDESIRABLE ALGAE

Target	Status
Removal of this BUI can occur when:	
• Total phosphorus (TP) concentrations within the AOC rivers, harbors, and nearshore waters meet the criteria recommended for the State of Wisconsin, as established by WDNR.	In Progress & Action Needed
• When the results from the total maximum daily load study for phosphorus, total suspended solids, and bacteria are completed for the Menomonee, Kinnickinnic, and Milwaukee Rivers.	In Progress
• Measures to meet the Total Maximum Daily Loading Implementation Plan are being completed.	Action Needed
• No water bodies within the AOC are included on the list of impaired waters due to nutrients or excessive algal growths in the most recent WI Impaired Waters list.	Action Needed
• Chlorophyll-a concentrations within the AOC lake and impoundment areas do not exceed 4.0 µg/L.	Unknown
• There are no beach closures in the AOC due to excessive nuisance algae growth.	Unknown

Status

There is much ongoing work in the Milwaukee Estuary to address eutrophication and nutrient loading into the rivers and Lake Michigan. Much of this work is currently associated with the TMDL study and subsequent implementation planning. As these efforts evolve, work is still needed in the AOC to further define the target and management actions. Reviewing the outputs from the TMDL in 2017 will assist in determining the next steps for this impairment. It is likely that a target adjustment will be called for based on this new information.

Management Actions

Management actions have not been defined for this impairment. Management actions will be determined after review of pertinent information and in consultation with stakeholders.

DEGRADATION OF AESTHETICS

Target (Updated 2016)	Status
This delisting target is consistent with Chapter NR 102, Wisconsin Administrative Code, Water Quality Standards for Surface Waters. Delisting shall occur when monitoring data within the AOC and/or surveys collected by multiple observers for any two consecutive year period indicates that water bodies in the AOC do not exhibit unacceptable levels of the following properties in quantities which interfere with the Water Quality Standards for Surface Waters:	
a) Substances that will cause objectionable deposits on the shore or in the bed of a body of water shall not be present in such amounts as to interfere with public rights in waters of the state.	Assessment in Progress
b) Floating or submerged debris, oil, scum, or other material shall not be present in such amounts as to interfere with public rights in waters of the state.	Assessment in Progress
c) Materials producing color, odor, taste, or unsightliness shall not be present in such amounts as to interfere with public rights in waters of the state.	Assessment in Progress
The following target will also be met to determine when restoration has occurred:	
• Corrective action plans are in-place and being implemented for significant, persistent issues contributing to the degradation of aesthetics within the AOC identified via aesthetics monitoring/surveys.	Action Needed

Status

The target for this BUI was adjusted in 2016, in consultation with the Community Advisory Committee. These changes were crafted to include the monitoring strategy developed with stakeholders over the past several years. This included adding language regarding multiple observers, two consecutive survey seasons, and identification of significant or persistent issues identified by the surveys. These changes bring the target in line with the current knowledge and approach to this impairment. The previous target and new target are compared in Appendix G.

WDNR has received funding to support citizen-based monitoring efforts for this BUI, and continued with the second year of monitoring in 2016. Milwaukee Riverkeeper coordinated the volunteers, who use a survey based on the target to assess AOC waterways. This survey data will then be used to assess the impairment in 2017 to determine if management actions or more monitoring is needed.

Management Actions

Management actions have not been defined for this impairment. Management actions will be determined after review of pertinent information and in consultation with stakeholders.

REFERENCES

Janish, T., D. Kaemmerer, A. O'Brien, T. Sheffy and A. Stenstrup. 1991. Milwaukee Estuary Remedial Action Plan: A Plan to Clean Up Milwaukee's Rivers and Harbor. Wisconsin Department of Natural Resources. Publication PUBL-WR-276-91

Galarneau, S., J. Harschlip, M. Jones, R. Sternkopf and R. Cors. 1994. Milwaukee Estuary Remedial Action Plan: progress through January 1994: A Plan to Clean Up Milwaukee's Rivers and Harbors. Wisconsin Department of Natural Resources.

Wisconsin Department of Natural Resources. 1999. Milwaukee Estuary Remedial Action Plan Progress Update. Wisconsin Department of Natural Resources.

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Hron, S. 2014. Remedial Action Plan Update for the Milwaukee Estuary Area of Concern. Wisconsin Department of Natural Resources

Hron, S. 2015. Remedial Action Plan Update for the Milwaukee Estuary Area of Concern. Wisconsin Department of Natural Resources

Other Resources:
Cedar Creek Superfund:
https://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=0506429
https://cumulis.epa.gov/supercpad/SiteProfiles/index.cfm?fuseaction=second.scs&id=0506429&doc=Y&colid=30181&requestTimeout=480
https://cumulis.epa.gov/supercpad/SiteProfiles/index.cfm?fuseaction=second.ars&id=0506429&doc=Y&colid=5044&requestTimeout=480

Moss-American Superfund:
https://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=0505024
https://cumulis.epa.gov/supercpad/SiteProfiles/index.cfm?fuseaction=second.scs&id=0505024&doc=Y&colid=30328&requestTimeout=480

Burnham Canal Superfund:
https://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=0510222
https://cumulis.epa.gov/supercpad/SiteProfiles/index.cfm?fuseaction=second.ars&id=0510222&doc=Y&colid=62088&requestTimeout=480
https://cumulis.epa.gov/supercpad/SiteProfiles/index.cfm?fuseaction=second.scs&id=0510222&doc=Y&colid=30273&requestTimeout=480

Blatz/Lincoln Park Legacy Clean-up: http://dnr.wi.gov/topic/greatlakes/lincolnpark.html

Kinnickinnic River Legacy Clean-up: http://dnr.wi.gov/topic/greatlakes/KKRiver.html

Turning Basin Characterization Report:
http://dnr.wi.gov/topic/greatlakes/documents/TurningBasinSiteCharacterizationReport.pdf

Menomonee River Characterization Report:
http://dnr.wi.gov/topic/greatlakes/documents/MenomoneeMilwaukeeSiteCharacterizationReport.pdf

Wildlife Consumption Advisory: http://dnr.wi.gov/files/PDF/pubs/wm/WM0010.pdf

USGS Tree Swallow Study: https://www.umesc.usgs.gov/wildlife_toxicology_team.html

Benthos and Plankton Study:
https://pubs.er.usgs.gov/publication/ds824
https://pubs.er.usgs.gov/publication/sir20165090
https://pubs.er.usgs.gov/publication/ds1000

Fish Consumption:
http://dnr.wi.gov/topic/fishing/documents/consumption/MilwaukeeAreaFishConsumptionAdvisories2016.pdf
http://dnr.wi.gov/topic/fishing/consumption/

TMDL: http://dnr.wi.gov/topic/TMDLs/Milwaukee/

Built on Water Documentary:
http://www.wiseye.org/Programming/A-City-Built-On-Water
https://www.youtube.com/watch?v=VuD6IA3_X3I&feature=youtu.be

South Shore Beach Planning: http://county.milwaukee.gov/SouthShoreParkSchematicDesignProject

APPENDICES

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Appendix A

List of Acronyms

AOC	Area of Concern
BCOC	Bioaccumulative chemicals of concern
BUI	Beneficial Use Impairment
GLNPO	Great Lakes National Program Office
GLRI	Great Lakes Restoration Initiative
µg/L	Micrograms per liter
mg/L	Milligrams per liter
MMSD	Milwaukee Metropolitan Sewerage District
PAH	Polycyclic aromatic hydrocarbon
PCB	Polychlorinated biphenyl
ppm	Part per million
RAP	Remedial Action Plan
TMDL	Total Maximum Daily Load
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
USFWS	U.S. Fish and Wildlife Service
UWM	University of Wisconsin – Milwaukee
WDNR	Wisconsin Department of Natural Resources

Appendix B

Definitions

Area of Concern (AOC)
Defined by Annex 2 of the 1987 Protocol to the U.S.-Canada Great Lakes Water Quality Agreement as "geographic areas that fail to meet the general or specific objectives of the Agreement where such failure has caused or is likely to cause impairment of beneficial use of the area's ability to support aquatic life." These areas are the "most contaminated" areas of the Great Lakes, and the goal of the AOC program is to bring these areas to a point at which they are not environmentally degraded more than other comparable areas of the Great Lakes. When that point has been reached, the AOC can be removed from the list of AOCs, or "delisted."

Beneficial Use Impairment (BUI)
A "beneficial use" is any way that a water body can improve the quality of life for humans or for fish and wildlife (for example, providing fish that are safe to eat). If the beneficial use is unavailable due to environmental problems (for example if it is unsafe to eat the fish because of contamination) then that use is impaired. The International Joint Commission provided a list of 14 possible beneficial use impairments in the 1987 Great Lakes Water Quality Agreement amendment.

Delisting Target
Specific goals and objectives established for beneficial use impairments, with measurable indicators to track progress and determine when BUI removal can occur.

Remedial Action Plan (RAP)
According to the 1987 Protocol to the U.S.-Canada Great Lakes Water Quality Agreement, a RAP is a document that provides "a systematic and comprehensive ecosystem approach to restoring and protecting beneficial uses in Areas of Concern…" RAPs were required by the 1987 Protocol to be submitted to the International Joint Commission at three stages:

- Stage 1: Problem definition
- Stage 2: When remedial and regulatory measures are selected
- Stage 3: When monitoring indicates that identified beneficial uses have been restored

Note that a renegotiated Great Lakes Water Quality Agreement was signed in 2012 by the U.S. and Canada which removed the "stage" terminology from the AOC Annex, and simply requires Remedial Action Plans to be "developed, periodically updated, and implemented for each AOC."

Total Maximum Daily Load (TMDL)
A TMDL is the amount of a pollutant a waterbody can receive and still meet water quality standards. It can be thought of as a pollution "budget" for a water body or watershed that establishes the pollutant reduction needed from each pollutant source to meet water quality goals.

Appendix C

BUI Tracking Matrix

Appendix C

Note that projects listed in the table below are the next clearly delineated action steps that have been identified by WDNR in collaboration with AOC partners and stakeholders to make progress toward delisting the AOC. This list does not necessarily reflect all actions that will ultimately be needed to remove impairments, and will be updated as more information is collected and as actions are completed.

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Project Title/Name	BUI Addressed	Project Type	Action Type	Action Modifier	Project Status	Project Start Date	Project End Date	Project Cost	Primary Funding Source	Project Lead Organization
Assess Menomonee River downstream of its confluence with the Little Menomonee River to the estuary	BUI 1, BUI 3, BUI 4, BUI 6, BUI 7, BUI 14	Sediment	Remediation	Screening Level Assessment	In Progress	2015	2016	Unknown	Great Lakes Legacy Act [GLRI]	USEPA
Assess portions of the Kinnickinnic River, Inner Harbor, South Menomonee Canal, Outer Harbor and Nearshore Waters of the Milwaukee Estuary	BUI 1, BUI 3, BUI 4, BUI 6, BUI 7, BUI 14	Sediment	Remediation	Not Started	Submitted			Unknown		
Assess the Milwaukee River downstream of Estabrook Dam to the confluence with the Menomonee River	BUI 1, BUI 3, BUI 4, BUI 6, BUI 7, BUI 14	Sediment	Remediation	Screening Level Assessment	In Progress	2016	2017	Unknown	Great Lakes Legacy Act [GLRI]	USEPA
Assess the Milwaukee River downstream of its confluence with Cedar Creek to the Milwaukee River Channels/Lincoln Park Great Lakes Legacy Act projects	BUI 1, BUI 3, BUI 4, BUI 6, BUI 7, BUI 14	Sediment	Remediation	Not Started	Established			Unknown		
Assessment of Benthos and Plankton in Wisconsin's Lake Michigan Areas of Concern	BUI 6	Fish and Wildlife	Assessment	Reporting	In Progress	2013	2016	$414,300	USGS [GLRI]	USGS
Bayview Grand Trunk Wetland Restoration	BUI 14	Fish and Wildlife	Restoration	Project Design	In Progress	2015	2020	$398,400	USEPA [GLRI]	City of Milwaukee
Benthos & Plankton BUIs Evaluation in Wisconsin's Lake Michigan Areas of Concern	BUI 6	Fish and Wildlife	Assessment	Completed	COMPLETED	2011	2015	$451,500	USGS [GLRI]	USGS
Blatz Pavilion Remediation	BUI 1, BUI 3, BUI 4, BUI 6, BUI 7, BUI 14	Sediment	Remediation	Completed	COMPLETED	2005	2009	$1,300,000	WDNR [Non-GLRI]	WDNR
Burnham Canal Superfund Alternative Remediation	BUI 1, BUI 3, BUI 4, BUI 6, BUI 7, BUI 14	Sediment	Remediation	Remedial Implementation	In Progress	2012		Unknown	Responsible Party [Non-GLRI]	USEPA
Burnham Canal Wetland Restoration	BUI 14	Fish and Wildlife	Restoration	Project Design	In Progress	2014		$300,000	USACE [GLRI]	MMSD
Cedar Creek Superfund Alternative Remediation	BUI 1, BUI 3, BUI 4, BUI 6, BUI 7, BUI 14	Sediment	Remediation	Remedial Implementation	In Progress	2015		Unknown	Responsible Party [Non-GLRI]	USEPA
Contaminant exposure of tree swallows to contaminants in the Milwaukee Estuary: An expnasion of sites (sp)	BUI 5	Fish and Wildlife	Assessment	Implementation	In Progress	2014	2016	Unknown	USEPA [GLRI]	USGS
Developing TMDLs for the Milwaukee River, Menomonee River, Kinnickinnic River and Milwaukee Estuary	BUI 8, BUI 10	Nonpoint	Assessment	Reporting	Submitted	2010	2017	$878,698	USEPA [GLRI]	MMSD
Estabrook Dam Fish Passage	BUI 14	Fish and Wildlife	Restoration	Not Started	Proposed			Unknown		MMSD
Fish Population Assessment	BUI 3	Fish and Wildlife	Assessment	Reporting	In Progress	2014	2017	$330,360	USEPA [GLRI]	WDNR

Project Title/Name	BUI Addressed	Project Type	Action Type	Action Modifier	Project Status	Project Start Date	Project End Date	Project Cost	Primary Funding Source	Project Lead Organization
Fisheries Population Target Refinement	BUI 3	Fish and Wildlife	Assessment	Completed	COMPLETED	2013	2014	$24,000	WDNR [GLRI]	WDNR
Identification and Quantification of Sanitary Sewage Contamination in the Milwaukee Estuary Area of Concern	BUI 10	Nonpoint	Assessment	Reporting	In Progress	2014	2016	$502,266	USEPA [GLRI]	UW-Milwaukee
KK River Habitat Restoration from Becher St to Chase Ave	BUI 14	Fish and Wildlife	Restoration	Project Design	In Progress	2014		$1,175,000	USEPA [GLRI]	MMSD
Kletzsch Dam Fish Passage	BUI 14	Fish and Wildlife	Restoration	Project Design	Established	2017	2019	$750,000	USEPA [GLRI]	Milwaukee County
Lincoln Park/Milwaukee River Channels Remediation-Phase 1	BUI 1, BUI 3, BUI 4, BUI 6, BUI 7, BUI 14	Sediment	Remediation	Completed	Completed	2011	2012	$25,000,000	Great Lakes Legacy Act [GLRI]	USEPA
Lincoln Park/Milwaukee River Channels Remediation-Phase 2	BUI 1, BUI 3, BUI 4, BUI 6, BUI 7, BUI 14	Sediment	Remediation	Confirmation Monitoring & Reporting	In Progress	2014	2015	$18,000,000	Great Lakes Legacy Act [GLRI]	USEPA
Little Menomonee Corridor Restoration	BUI 14	Fish and Wildlife	Restoration	Project Design	Established	2015		$500,000	USEPA [GLRI]	WDNR
Little Menomonee Grassland Restoration	BUI 14	Fish and Wildlife	Restoration	Completed	COMPLETED	2013	2015	$37,000	USEPA [GLRI]	Milwaukee County
Menomonee River Concrete Removal upstream of Soo Line RR Bridge to 1-94 (Phase 1)	BUI 14	Fish and Wildlife	Restoration	Confirmation Monitoring & Reporting	In Progress	2013	2016	$5,400,000	MMSD [GLRI]	MMSD
Menomonee River Concrete Removal upstream of Soo Line RR Bridge to 1-94 (Phase 2)	BUI 14	Fish and Wildlife	Restoration	Confirmation Monitoring & Reporting	In Progress	2014	2016	$6,800,000	USACE [GLRI]	USACE
Milwaukee Estuary AOC Aquatic Habitat and Wadeable Fisheries Assessment	BUI 3	Fish and Wildlife	Assessment	Reporting	In Progress	2016	2017	Unknown	USEPA [GLRI]	WDNR
Milwaukee Estuary Fish Tumor Evaluation	BUI 4	Fish and Wildlife	Assessment	Completed	COMPLETED	2013	2015	$138,485	USEPA [GLRI]	WDNR
Milwaukee Estuary Wildlife Consumption Advisory Evaluation	BUI 1	Fish and Wildlife	Assessment	Completed	In Progress	2013	2016	$1,458,360	USEPA [GLRI]	WDNR
Milwaukee Harbor Habitat Mapping	BUI 3	Fish and Wildlife	Assessment	Implementation	In Progress	2015	2018	$255,723	Fund for Lake Michigan [Non-GLRI]	UW-Milwaukee School of Freshwater Sciences
Milwaukee River Fish Habitat Enhancement and Expansion	BUI 14	Fish and Wildlife	Restoration	Completed	COMPLETED	2014	2014	$63,310	Fund for Lake Michigan [GLRI]	WDNR
Moss-American/Little Menomonee Superfund	BUI 1, BUI 3, BUI 4, BUI 6, BUI 7, BUI 14	Sediment	Remediation	Completed	COMPLETED	1990	2009	Unknown	Responsible Party [Non-GLRI]	USEPA
Removal of Five Low Flow Barriers on the Menomonee River	BUI 14	Fish and Wildlife	Restoration	Confirmation Monitoring & Reporting	In Progress	2014	2016	$1,942,000	MMSD [Non-GLRI]	MMSD
Sediment Characterization in the KK River turning basin	BUI 1, BUI 3, BUI 4, BUI 6, BUI 7, BUI 14	Sediment	Remediation	Completed	COMPLETED	2015	2016	Unknown	Great Lakes Legacy Act [GLRI]	USEPA
Solvay Coke Superfund Alternative Remediation	BUI 1, BUI 3, BUI 4, BUI 6, BUI 7, BUI 14	Sediment	Remediation	Feasibility Study	In Progress	2012		Unknown	Responsible Party [Non-GLRI]	USEPA
South Shore Beach Rehabilitation	BUI 10	Beaches	Restoration	Project Design	Submitted	2016	2018	$350,000	USEPA [GLRI]	Milwaukee County Parks

Project Title/Name	BUI Addressed	Project Type	Action Type	Action Modifier	Project Status	Project Start Date	Project End Date	Project Cost	Primary Funding Source	Project Lead Organization
Volunteer Aesthetics Monitoring Program	BUI 11	Aesthetics	Assessment	Reporting	In Progress	2015		$22,500	USEPA [GLRI]	WDNR
WE Energies Legacy Project	BUI 1, BUI 3, BUI 4, BUI 6, BUI 7, BUI 14	Sediment	Remediation	Screening Level Assessment	Submitted	2016		Unknown	USEPA [GLRI]	USEPA
Wheelhouse Gateway Riparian Restoration	BUI 14	Fish and Wildlife	Restoration	Completed	COMPLETED	2013	2014	Unknown	USEPA [GLRI]	River Revitalization Foundation
Wildlife Population Target Refinement	BUI 3	Fish and Wildlife	Assessment	Completed	COMPLETED	2013	2014	$30,000	USEPA [GLRI]	Milwaukee River Greenway Coalition
Wildlife Population Assessment	BUI 3	Fish and Wildlife	Assessment	Implementation	In Progress	2014	2017	$409,997	USEPA [GLRI]	WDNR

BUI Number Key

BUI #	BUI Name	BUI#	BUI Name
BUI 1	Restrictions on Fish and Wildlife Consumption	BUI 8	Eutrophication or Undesirable Algae or Excessive Loading of Sediments and Nutrients
BUI 2	Tainting of Fish and Wildlife Flavor	BUI 9	Restrictions on Drinking Water Consumption or Taste and Odor Problems
BUI 3	Degraded Fish and Wildlife Populations	BUI 10	Beach Closings and Body Contact Restrictions
BUI 4	Fish Tumors and Other Deformities	BUI 11	Degradation of Aesthetics
BUI 5	Bird or Animal Deformities or Reproductive Problems	BUI 12	Added Costs to Agriculture or Industry
BUI 6	Degradation of Benthos	BUI 13	Degradation of Phytoplankton and Zooplankton Populations
BUI 7	Restrictions on Dredging Activities	BUI 14	Loss of Fish and Wildlife Habitat

Appendix D

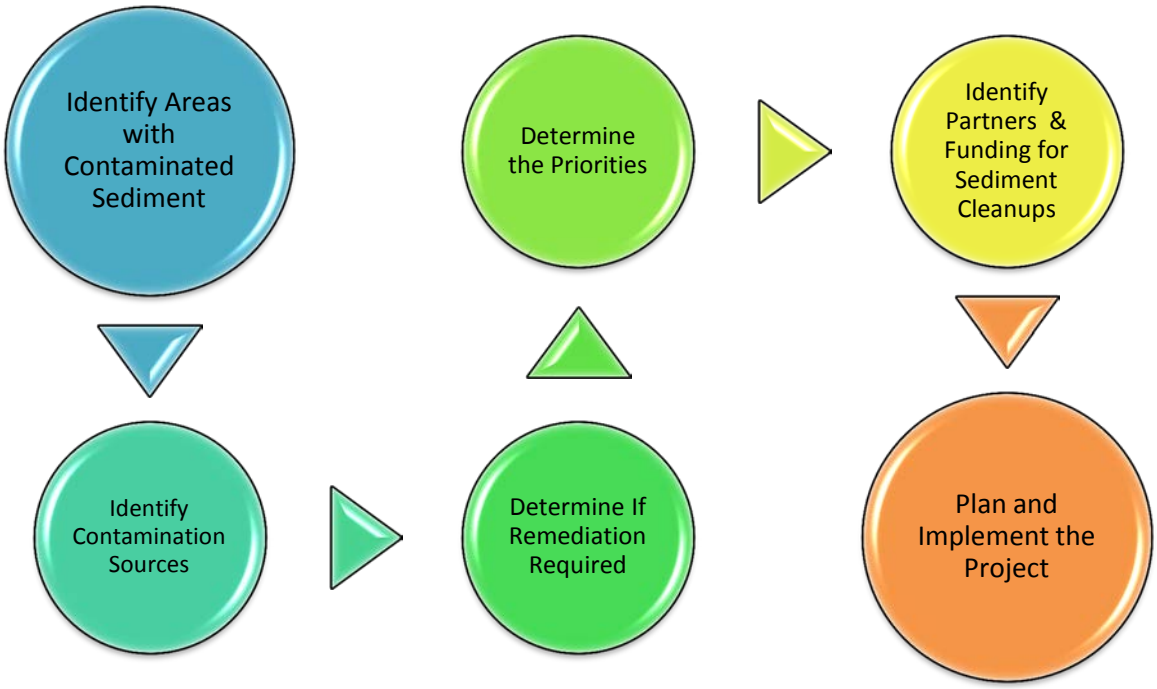
Sediment Strategy

Milwaukee Estuary Area of Concern
Sediment Strategy

Overview

Contaminated sediments contribute to at least 7 of the 11 beneficial use impairments identified in the Milwaukee Estuary Area of Concern. A crucial part of delisting these contaminated sediment related BUIs is to identify the areas with contaminated sediment requiring remediation, identify sources, control sources (if possible) and implement sediment management strategies to address the contamination. This document outlines the process the Wisconsin Department of Natural Resources (WDNR) is using to meet the goals of eventually delisting these BUIs.

Sediment Management Action Project Process



Identify Areas with Contaminated Sediment

Fish consumption advisory monitoring beginning in the 1980s helped identify several river reaches in or adjacent to the AOC with fish contaminated with polychlorinated biphenyls (PCBs). These efforts helped DNR to determine that contamination in Cedar Creek, and the Milwaukee River contributed to fish consumption advisories. Subsequent studies in the late 1980s through the mid-1990s help to narrow down specific river reaches that may require remediation. More recent studies show that sediments contaminated with other compounds, such as polycyclic aromatic hydrocarbons (PAHs) likely contribute to the higher incidence of fish tumors and other deformities in the Milwaukee Estuary AOC compared to urbanized reference sites (Blazer 2016 – Appendix E).

Several land based cleanup sites have identified contaminated sediment components and are under study by the responsible parties. These small scale site characterizations, while useful,

only give us part of the overall picture of the status of sediment contamination in the AOC. In the navigational channels maintained by the US Army Corps of Engineers (ACOE), periodic sediment sampling is completed to determine the quality of sediment to be dredged and placed in the Milwaukee confined disposal facility adjacent to the Port of Milwaukee. Like the smaller scale studies, this gives us a partial view of the status of sediment contamination in the AOC.

Fortunately, the Great Lakes Legacy Act site characterization program is helping to augment the information WDNR and other entities have collected to provide the big picture overview of AOC contaminated sediment status. DNR has been submitting requests to utilize this program for the past several years in an effort to move systematically through the AOC. In 2015, the Kinnickinnic River Mooring Basin and the Menomonee River downstream from Little Menomonee River to the confluence with the Milwaukee River were sampled through the site characterization program. For the Menomonee River, this is the most comprehensive study of contaminated sediment in the AOC ever collected. These data combined with smaller studies from some responsible parties and the ACOE will help WDNR determine areas that may require some type of sediment management actions. A characterization, with sampling completed in 2016 of the Milwaukee River downstream from the Estabrook Park Dam to the confluence with the Menomonee River will help to complete the contaminated sediment process in this portion of the AOC. Similar characterization sampling has been requested for selected areas in the remainder of the AOC, specifically inner and outer harbor and near shore Lake Michigan, for 2017.

Identify Sources of the Sediment Contamination

The source of the contamination needs to be determined in order to determine what program and or regulatory measures need to be taken to cleanup an area, and also to ensure that sources are controlled before implementing sediment management strategies. Discharges from industry, stormsewers, spills, known contaminated sites, landfill records or other historic documents showing potential contributors need to be examined. Possible sources need to be vetted and investigated.

The WDNR maintains a database with known contaminated sites that can provide valuable information for understanding potential sources of contamination to the AOC. The records contained in the database (BRRTS) contain information about source of contamination (i.e. spill, underground storage tank, industrial site…) as well as contaminants of concern from each site.

Determine if Areas within the AOC Require Remediation

The WDNR sediment management and AOC programs are in the process of examining the information collected from the recent characterizations as well as the smaller scale studies mentioned earlier to determine if additional sediment remediation within the AOC is warranted. In addition to looking for possible sources, identification of background concentrations of contaminants is important for establishing remediation needs and also clean up goals.

Determine the Priorities for Sediment Management Actions

For contaminated sediment cleanups, when possible, upstream sources/sites should be addressed before addressing sites further downstream. This helps avoid recontamination of downstream areas. However, anytime opportunities present themselves to address contamination, they should be taken, even if a downstream site is cleaned up ahead of a site further upstream as long as the potential for recontamination is low. Sediment projects are often complicated and costly to implement, so getting it right the first time is extremely important. The potential for recontamination of sites is a major driver for determining clean up priorities. It does

not make sense to remediate a site if sources that can re-contaminate the area following remediation are not first controlled.

Identify Potential Partners, Cooperators and Funders to Assist with Sediment Cleanups
Generally, anybody can be a partner on sediment management projects. In some cases responsible parties are easily identifiable and are required through various laws to address the contamination they have caused. However, in complicated areas with long histories of industrial uses, it is not always possible to identify those solely responsible for causing the pollution. Therefore it is important that we examine all options to fund successful projects. These include, but are not limited to:

- Responsible Parties
- State, County and other Municipal Partners
- Adjacent Landowners
- Federal partners (Legacy Act, Corps of Engineers)
- Nonprofit organizations

Plan and Implement the Project
Once a potential project has been identified, it is important to thoroughly plan the clean-up strategy due to the cost, complexity and time needed to complete projects. In some cases enough information is available to identify the degree and extent of contamination and set clean up goals. However, if more information is needed it might be appropriate to conduct a focused remedial investigation that fills in data gaps, ensures all sources have been identified and controlled and helps ensure the overall success of the remedial action. Other steps in the process include conducting a feasibility study, which looks at all the available techniques, management options (including disposal options) as well as implementability and community acceptance to select the best option for implementation. This is the stage where identification of regulatory requirements is also accomplished (permits needed, etc).

Once a remedial option has been selected, it's on to designing the project. This can take several months to a year depending on the complexity and size of the project. Following design is implementation, which also includes sampling following the remedial action to ensure short term goals are met. In some cases, especially with contaminants like PCBs that accumulate and magnify in fish and other wildlife it is also desirable to conduct some long-term monitoring to ensure that the concentrations of these contaminants are declining.

Status of AOC Sediment Sites and Projects

The following are known sites and or projects within the AOC, which may expand based on characterizations or new investigations. The following map (Figure 2 from 2016 RAP Update) illustrates the current status of sediment projects in the Milwaukee Estuary AOC as of December 2016. More information on the projects can also be found in Appendix C BUI Tracking Matrix in the 2016 RAP Update.

Superfund or State-Lead Regulatory Actions

- Cedar Creek Superfund Alternative Site – Upland site remediation complete in some areas, dredging in some areas is underway.
- Burnham Canal Superfund Alternative Site – Design in approval process with regulatory agencies.
- Third Ward MGP and West Side MGP – Legacy Act Project with Responsible Party and US EPA/GLNPO to conduct focused remedial investigation and feasibility study.

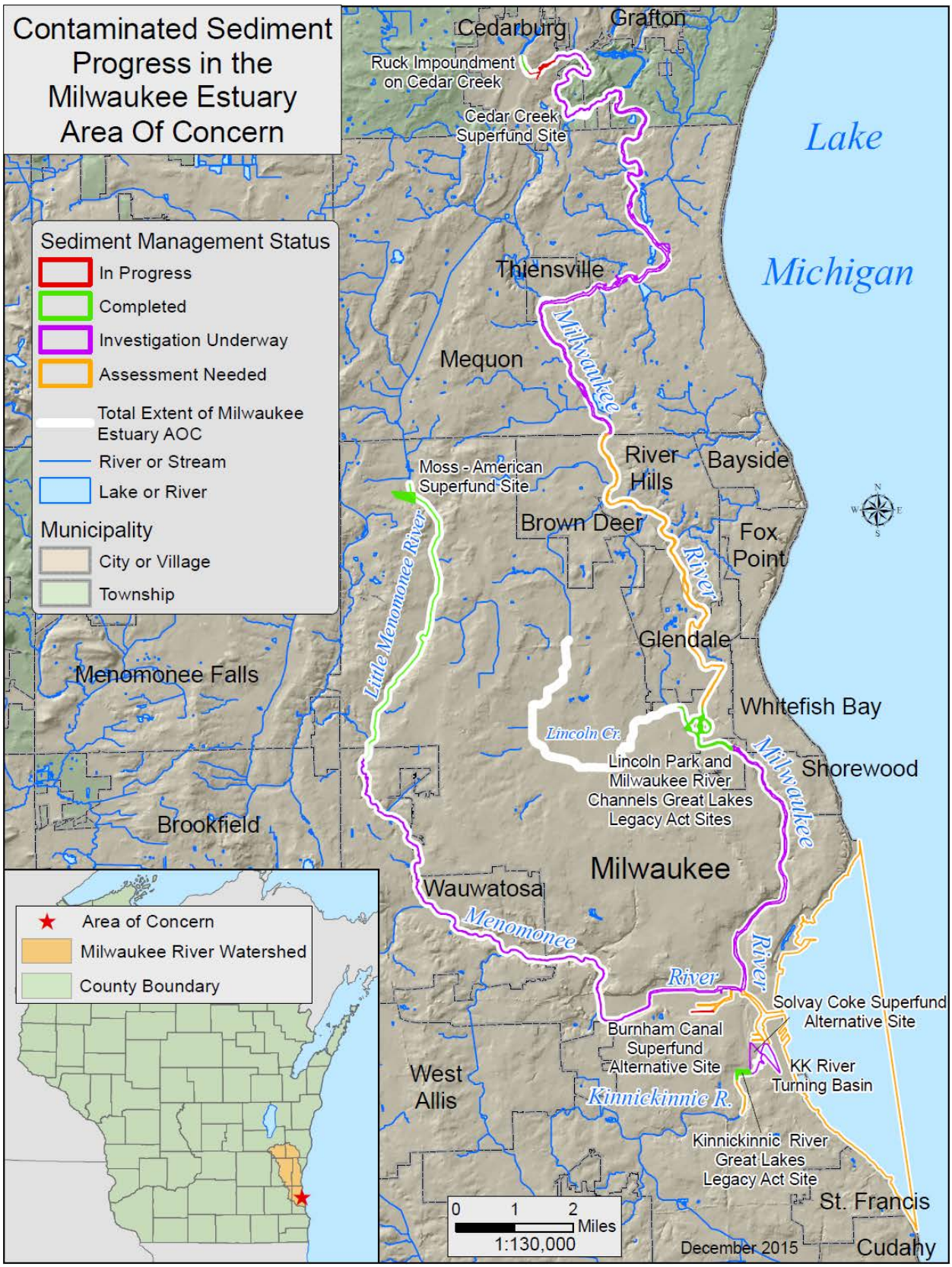
- Solvay Coke Superfund Alternative Site– Remedial investigation complete with feasibility study process underway.
- Milwaukee River PCB – Site assessment underway by regulatory agencies.
- Moss American Superfund Site – Remedial action complete, additional source area work underway by regulatory agencies.

Characterization

- Milwaukee River from Cedar Creek to Lincoln Park – Some sampling completed, gap analysis needed to determine if additional sampling is necessary.
- Milwaukee River from Estabrook Dam to confluence with Menomonee River – Sampling completed in Fall 2016. Characterization Report due mid-2017.
- Menomonee River from Little Menomonee River to confluence with Milwaukee River – Sampling completed in Fall 2015, report complete Summer 2016.
- South Menomonee Canal & Upper portions of Burnham Canal – More investigation needed, requested for 2017.
- Kinnickinnic River from Chase to Becher – More investigation needed, requested for 2017.
- KK River Mooring Basin Characterization – Sampling completed spring 2015, report completed fall 2015.
- Inner and Outer Harbors – More investigation needed, requested for 2017.
- Nearshore Waters – More investigation needed in select areas, requested for 2017.

Legacy or Voluntary/Cooperative Dredging Projects

- Blatz Pavilion (state funded), Lincoln Park Phases I and 2 (Legacy Act) – Remediation complete, some ongoing work to establish and maintain vegetation for phase 2.
- Kinnickinnic River Legacy Project – Complete


Contaminated Sediment Progress in the Milwaukee Estuary Area Of Concern
Sediment Management Status
In Progress
Completed
Investigation Underway
Assessment Needed
Total Extent of Milwaukee Estuary AOC
River or Stream
Lake or River
Municipality
City or Village
Township
Area of Concern
Milwaukee River Watershed
County Boundary
Cedarburg
Grafton
Ruck Impoundment on Cedar Creek
Cedar Creek Superfund Site
Lake Michigan
Thiensville
Mequon
Milwaukee River
Moss - American Superfund Site
River Hills
Bayside
Brown Deer
Fox Point
Little Menomonee River
Glendale
Menomonee Falls
Whitefish Bay
Lincoln Cr.
Lincoln Park and Milwaukee River Channels Great Lakes Legacy Act Sites
Shorewood
Brookfield
Milwaukee
Wauwatosa
Menomonee River
Solvay Coke Superfund Alternative Site
Burnham Canal Superfund Alternative Site
KK River Turning Basin
West Allis
Kinnickinnic R.
Kinnickinnic River Great Lakes Legacy Act Site
St. Francis
0 1 2 Miles
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December 2015
Cudahy

Appendix E

Fish Tumor Publication

 doi:10.1111/jfd.12520

Tumours in white suckers from Lake Michigan tributaries: pathology and prevalence

V S Blazer[1], H L Walsh[2], R P Braham[1], C M Hahn[1], P Mazik[3] and P B McIntyre[4]

1 Fish Health Branch, Leetown Science Center, U.S. Geological Survey, Kearneysville, WV, USA
2 Division of Forestry and Natural Resources, West Virginia University, Morgantown, WV, USA
3 West Virginia Cooperative Fish and Wildlife Unit, U.S. Geological Survey, West Virginia University, Morgantown, WV, USA
4 Center for Limnology, University of Wisconsin-Madison, Madison, WI, USA

Abstract

The prevalence and histopathology of neoplastic lesions were assessed in white sucker *Catostomus commersonii* captured at two Lake Michigan Areas of Concern (AOCs), the Sheboygan River and Milwaukee Estuary. Findings were compared to those observed at two non-AOC sites, the Root and Kewaunee rivers. At each site, approximately 200 adult suckers were collected during their spawning migration. Raised skin lesions were observed at all sites and included discrete white spots, mucoid plaques on the body surface and fins and large papillomatous lesions on lips and body. Microscopically, hyperplasia, papilloma and squamous cell carcinoma were documented. Liver neoplasms were also observed at all sites and included both hepatocellular and biliary tumours. Based on land use, the Kewaunee River was the site least impacted by human activities previously associated with fish tumours and had significantly fewer liver neoplasms when compared to the other sites. The proportion of white suckers with liver tumours followed the same patterns as the proportion of urban land use in the watershed: the Milwaukee Estuary had the highest prevalence, followed by the Root, Sheboygan and Kewaunee rivers. The overall skin neoplasm (papilloma and carcinoma) prevalence did not follow the same pattern, although the percentage of white suckers with squamous cell carcinoma exhibited a similar relationship to land use. Testicular tumours (seminoma) were observed at both AOC sites but not at the non-AOC sites. Both skin and liver tumours were significantly and positively associated with age but not sex.

Keywords: environmental health, liver neoplasms, skin neoplasms, tumours, White sucker.

Correspondence V S Blazer, Fish Health Branch, Leetown Science Center, U.S. Geological Survey, 11649 Leetown Road, Kearneysville, WV 25430, USA (e-mail: *vblazer@usgs.gov*)

Introduction

Gross external abnormalities and liver diseases, particularly of benthic fishes, are widely associated with the presence of environmental contaminants and utilized to assess ecological health in monitoring programmes worldwide (Myers *et al.* 1994; Fournie, Summers & Weisberg 1996; Feist *et al.* 2004; Vogelbein & Unger 2006; Vethaak, Jol & Pieters 2009). In the Great Lakes region of North America, skin and liver tumours of brown bullhead *Ameiurus nebulosus* and white sucker *Catostomus commersonii* have long been associated with environmental degradation (Hayes *et al.* 1990; Baumann 1992; Baumann, Smith & Metcalfe 1996; Rafferty *et al.* 2009). Areas of Concern (AOCs) within the Great Lakes watershed were defined by the U.S.-Canada Great Lakes Water Quality Agreement (Annex 2) as 'geographic areas that fail to meet the general or specific objectives of the agreement where such failure has caused or is likely to cause impairment of beneficial use of the area's ability to support aquatic life'. Fourteen

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beneficial use impairments (BUIs) were defined, a number of which focus on the health of fish and wildlife populations. These include the fish tumours or other deformities, degraded fish and wildlife populations and bird or animal deformities or reproductive problems. The fish tumour BUI is described as occurring 'when the incidence rates of fish tumours or other deformities exceed rates at unimpacted control sites or when survey data confirm the presence of neoplastic or preneoplastic liver tumours in bullheads or suckers' (IJC 1989).

White sucker are considered an indicator species and are widely used with regard to environmental health monitoring within the Great Lakes watershed and elsewhere (Munkittrick & Dixon 1989; Doherty *et al.* 2005; Dorval *et al.* 2005; Woodling *et al.* 2006; Vajda *et al.* 2008; Bowron *et al.* 2009). The benefits of white sucker as an indicator to assess the health of aquatic ecosystems within the Great Lakes tributaries include (i) a wide distribution; (ii) indigenous species; (iii) known habitat requirements and niche characteristics; (iv) benthic forage species in direct contact with contaminated sediment; (v) dependence on invertebrates for food throughout their life cycle; and (vi) sensitivity to elevated contaminant levels (Munkittrick & Dixon 1989; Bowron *et al.* 2009).

The Great Lakes Restoration Initiative, a multiagency effort that began in 2010, specifically targets certain priorities including cleaning up toxic substances, promoting nearshore health by protecting watersheds from polluted run-off, and evaluating and monitoring progress in AOCs (www.glri.us). With this initiative has come a renewed interest in delisting AOCs, requiring assessment of the status of the various BUIs. Delisting targets for individual AOCs are set by Remedial Action Plans (RAPs), developed and implemented through federal, state, community and private cooperation (www.epa.gov/grtlakes/aoc/rapselistingfinal02.pdf; accessed August 3, 2015).

Two AOCs with the fish tumour BUI, located on the Wisconsin shore of Lake Michigan, are the Sheboygan River and the Milwaukee Estuary. In 1985, the lower 14-mile section of the Sheboygan River and Harbor was designated an AOC due to water quality and habitat problems associated with the historical discharge of pollutants. The AOC encompasses the lower Sheboygan River downstream from the Sheboygan Falls Dam, including the entire harbour and nearshore waters of Lake Michigan. Historically, pollutants of concern included suspended solids, faecal coliform bacteria, phosphorus, nitrogen, polychlorinated biphenyls (PCBs), polyaromatic hydrocarbons (PAHs) and heavy metals. The high levels of nutrients, solids and toxics entering the river caused a series of problems including nuisance algal blooms, fish consumption advisories and contaminated sediments (www.epa.gov/greatlakes/aoc/sheboygan/pdfs/Sheboygan-AOC_BUIs.pdf; accessed October, 2015). The Sheboygan River RAP states that the AOC should be considered impaired if surveys of 50 or more fish show a tumour incidence of greater than 5% of the population surveyed. If considered impaired, comparisons to non-impacted reference sites should be conducted (dnr.wi.gov/topic/Greatlakes/documents/RAP-UpdatedSHEB2012Final.pdf; accessed August 2015).

The original boundaries of the Milwaukee Estuary AOC included the lower 5 km of the Milwaukee River, the lower 4.8 km of the Menomonee River, the lower 4 km of the Kinnickinnic River, the inner and outer harbours and the nearshore waters of Lake Michigan. It was designated an AOC in the mid-1980s because of sediments contaminated with PCBs, PAHs and heavy metals. Urbanization, terrestrial and aquatic fragmentation, combined sewer overflows from wastewater treatment plants, soil erosion and nutrient enrichment throughout the watershed contribute to degraded water quality. The fish tumour BUI is listed as 'potentially impaired' due to run-off pollution and toxic substances; however, there are no data to determine the status of this BUI. The RAP states that the BUI can be removed if the incidence of tumours or other deformities is statistically similar (with 95% confidence) to the rate of minimally impacted reference sites (http://dnr.wi.gov/topic/Greatlakes/documents/rap-datemke2012final.pdf; accessed September 2015).

The objectives of this study were to (i) evaluate the current health of the white sucker populations within the Sheboygan River and Milwaukee Estuary AOCs, (ii) compare the findings to two nearby non-AOC sites (Root and Kewaunee rivers) and (iii) describe the various lesion types to better understand contributing risk factors in carcinogenesis. These results will aid in determining whether the fish tumour BUI could be removed, or instead requires continued monitoring in conjunction with ongoing remediation efforts. Our

overall goal was to provide a baseline to guide further research and evaluate the efficacy of restoration efforts.

Materials and methods

Study sites and fish collections

Two AOC sites and two non-AOC sites on the Wisconsin shore of Lake Michigan were compared during 2012–2014 (Fig. 1). Staff from the Wisconsin Department of Natural Resources (WDNR) and University of Wisconsin attempted to collect 200 white suckers at each site using electrofishing and fyke nets. Adults (total length >250 mm) age 3 years and older were targeted to focus on sexually mature individuals (Becker 1983) that had been exposed to the environmental conditions present in each area for multiple years. Collections were made during the spring spawning migration, when fish are easily accessible and abundant. Fish were processed as they were collected; therefore, the samples are considered to be a random sample of each population.

A total of 193 white suckers were collected from the Sheboygan River AOC 31 March–1 April, 2012. Ten were collected immediately below the Kohler Dam, and the remaining 183 were collected lower in the river near Kiwanis Park, Sheboygan, WI, USA (Fig. 2A). Two hundred white suckers were collected from the Milwaukee Estuary AOC (Fig. 2B) 10–11 April 2013 and from the Kewaunee River below the C.D. 'Buzz' Besadny Anadromous Fish Facility dam, 23–24 April 2013 (Fig. 2C). Two hundred white suckers were collected from the Root River, 22–23 April 2014, downstream of the Root River Steelhead Handling Facility (Fig. 2D).

Land cover/land use varied greatly among the four watersheds. The per cent developed land

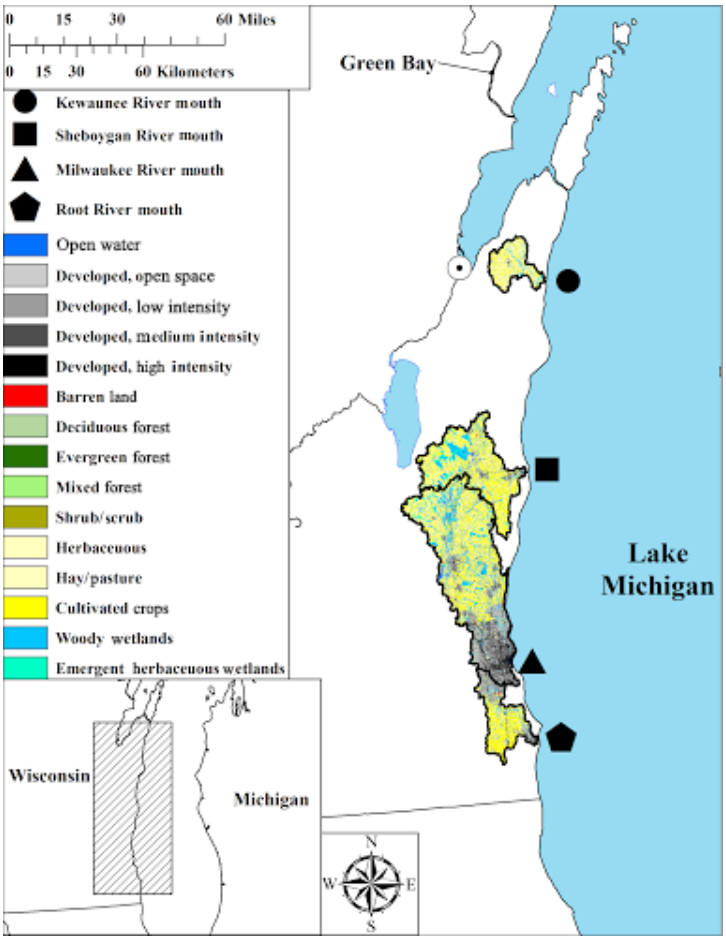

Figure 1 Watersheds sampled for white sucker on the western shore of Lake Michigan, Wisconsin, Spring 2012–2014.

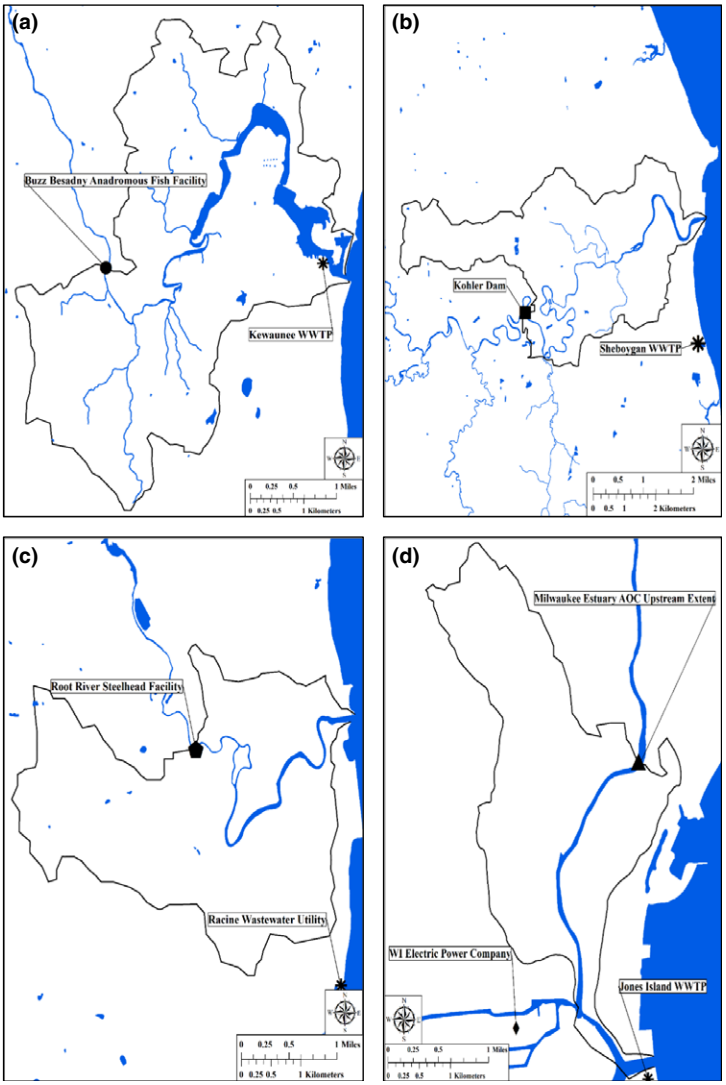

Figure 2 Sampling locations for white sucker in each of the four watersheds: (A) Kewaunee River, (B) Sheboygan River, (C) Root River and (D) Milwaukee River.

ranged from a low of 10.7% for the Kewaunee watershed to 97.2% for the Milwaukee watershed. There was less difference in forested land which ranged from 0% for the Milwaukee to 9.1% for the Kewaunee which was primarily (63.3%) agricultural (Table 1).

Field sampling

Fish were killed (Tricaine-S; Western Chemical Inc.), weighed (to the nearest g) and measured (total length, nearest mm). A comprehensive necropsy-based assessment, documenting external and internal abnormalities, was completed on each fish immediately after death. Skin abnormalities (raised lesions, red/eroded areas, pigmented spots) were sampled and preserved for histopathology in Z-Fix™ (Anatech Ltd), as were five to seven pieces of normal and abnormal liver tissue. Both lapillus otoliths were removed from each fish for age determination. At all sites, pieces of testes and abnormal ovary were preserved for microscopic evaluation, and at the Sheboygan site, gill tissue from the first 20 suckers was also preserved.

Laboratory analyses

Lapillus otoliths were prepared for ageing using a modification of the multiple stage process described by Koch & Quist (2007). Briefly, single lapilli were placed into the clay such that the 'thumb' of the otoliths was embedded into the

Table 1 Land-use characteristics of four watersheds on Lake Michigan in Wisconsin

Land cover type	Sheboygan	Milwaukee	Root	Kewaunee
Drainage area[a] km^2	26 334.0	10 542.6	14 894.1	26 112.6
% Urban[b]	60.0	97.4	92.5	10.7
% Forest[c]	7.8	0.0	4.4	9.1
% Agriculture[d]	24.5	0.0	2.1	63.3
% Wetlands[e]	6.6	0.2	0.7	14.2
% Open water	1.1	2.7	0.3	2.7

[a]Drainage area primarily below the area of collection.
[b]Includes developed open space, developed low, medium and high intensity.
[c]Includes deciduous, evergreen, mixed forests, shrub/scrub and herbaceous.
[d]Includes hay/pasture and cultivated crops.
[e]Includes both forested and nonforested wetlands.

clay. The otoliths were mounted in epoxy (Buehler Inc.), sectioned at 7.6 mm thickness and read using a stereo microscope.

Histology slide preparations were completed in the Histology Laboratory at the USGS Leetown Science Center, Fish Health Branch. Tissues were routinely processed, embedded into paraffin, sectioned at 5 μm and stained with haematoxylin and eosin (Luna 1992). A variety of microscopic changes including inflammatory, proliferative, preneoplastic and neoplastic changes in the skin and liver were documented following the diagnostic criteria developed for brown bullhead and other fish species (Boorman *et al.* 1997; Wolf & Wolfe 2005; Blazer *et al.* 2006, 2007). All pathology slides were read by two of the coauthors and a subset verified by an independent fish pathologist. Observations were scored as absent (0) or present (1) and the type of tumour was also determined microscopically.

Statistical analyses

The effects of age and sex on tumour prevalence were examined using logistic regressions in the form of generalized linear models (R Development Core Team 2010). Tests were performed separately for the presence of skin or liver neoplasia as the dependent variable. Independent variables for each test were age and sex (0 = female, 1 = male). To determine whether the relationship between tumour prevalence and age differed by sex, we first tested the interaction between age and sex for each type of tumour. If the interaction was not significant, the interaction was dropped and the generalized linear model was recalculated with only age or sex as the dependent variable. Site comparisons using Fisher's exact test compared the prevalence at the least impacted site (Kewaunee) with the prevalence at the other sites. An α-level of 0.05 was used to indicate significance in all tests.

Results

Summary statistics of sampled populations

White suckers ranged in age from 3 to 28 years at the Sheboygan River, 3–18 years at Milwaukee, 3–21 at Root and 3–22 at Kewaunee. There was no difference in mean age between the sexes at Sheboygan, Milwaukee or Kewaunee; however, the males were shorter and lighter than females. At the Root, there was a difference between the sexes in mean age ($P = 0.006$), length ($P < 0.001$) and weight ($P < 0.001$), with males older but shorter and lighter (Table 2).

The mean age of white suckers from the Sheboygan and Milwaukee was not different than each other but was older ($P < 0.05$) than those from both the Root and Kewaunee which were similar (Table 2).

Gross pathology

A variety of external abnormalities was observed on the body surface, fins and lips (orocutaneous). Discrete, slightly raised white spots were only noted on the body surface and appeared as small areas involving a single scale (Fig. 3A) and appeared to progress to larger, creamy white raised lesions (Fig. 3B). Translucent mucoid plaques ranged from slightly raised, smooth and pale (Fig. 3C) to larger, grey, rough lesions on the body surface and fins (Fig. 3D). Lip lesions ranged from small, slightly raised (Fig. 4A) to larger

Table 2 Characteristics of white sucker populations sampled from four rivers in Wisconsin

Parameter	Sheboygan	Milwaukee	Root	Kewaunee
Age (years)				
All	10.2 ± 4.4[A]	10.2 ± 3.0[A]	8.8 ± 3.4[B]	8.9 ± 3.0[B]
Male	9.9 ± 4.4[a]	10.2 ± 3.2[a]	9.4 ± 3.5[b]	8.5 ± 3.4[a]
Female	10.3 ± 4.6[a]	10.1 ± 2.9[a]	8.2 ± 3.1[a]	9.2 ± 2.7[b]
Length (mm)				
All	458.8 ± 63.6[A]	469.9 ± 46.0[A]	465.0 ± 39.3[A]	472.0 ± 35.6[A]
Male	435.4 ± 49.4[a]	442.5 ± 31.0[a]	447.1 ± 27.8[a]	443.6 ± 28.9[a]
Female	475.8 ± 67.6[b]	494.7 ± 43.2[b]	483.9 ± 41.0[b]	487.7 ± 28.5[b]
Weight (g)				
All	1036.4 ± 370.1[AB]	1174.6 ± 432.5[BC]	1016.7 ± 253.2[A]	1110.8 ± 273.8[B]
Male	850.3 ± 227.7[a]	912.2 ± 192.3[a]	892.1 ± 169.0[a]	857.6 ± 154.6[a]
Female	1170.9 ± 395.0[b]	1412.1 ± 452.4[b]	1149.0 ± 261.2[b]	1250.1 ± 219.9[b]

[a]Values followed by the same lower case letter indicate no significant difference between males and females at the same site.
[A]Values followed by the same uppercase letter indicate no significant difference among sites.

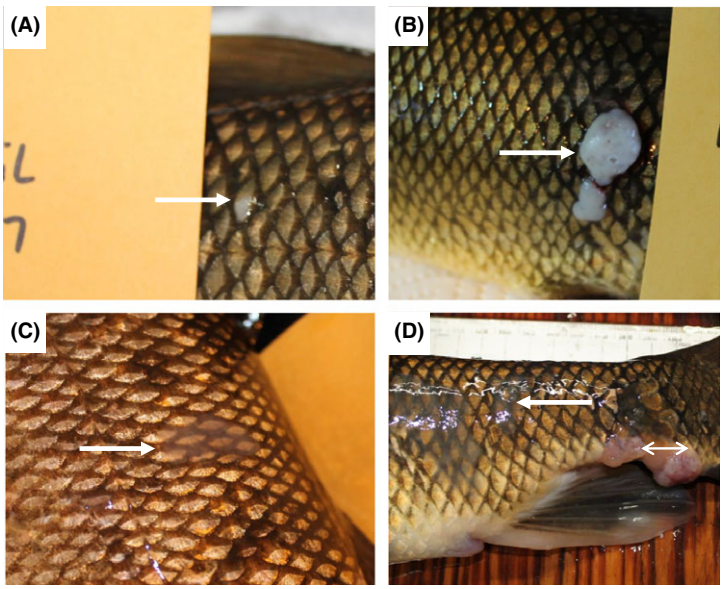

Figure 3 Raised lesions observed on white sucker. (A) Discrete white area on a single scale (arrow). (B) Large white raised lesion covering multiple scales (arrow). (C) Slightly raised smooth, clear, mucoid plaque (arrow). (D) Raised greyish mucoid plaque (arrow) and raised multilobed clear to whitish raised lesions (double arrow head).

multilobular papillomatous lesions (Fig. 4B). Multilobed, irregular raised lesions were also observed on the body surface (Fig. 4C,D).

The percentage of fish with orocutaneous lesions ranged from 33.0% at the Root River to 58.0% at Milwaukee. A number of fish at each site had multiple lesion types. The prevalence of individual lesion types varied among sites (Table 3) as did the size of the lesions, but notably the AOC sites had more and larger raised body surface and lip lesions. Lip lesions at Kewaunee were small, slightly raised areas. Only one fish from Kewaunee had a large papillomatous lip tumour.

Gross abnormalities were also observed in the liver and the testes. Pale or discoloured (green), firm nodules (Fig. 4E) were observed in the liver of four suckers from Sheboygan, six from Milwaukee and three from Kewaunee. Twelve fish from Sheboygan, 10 from Milwaukee and three from the Root had firm nodules (Fig. 4F) and/or discoloured areas within testicular tissue. Three females from Milwaukee had discoloured ovaries and at Kewaunee two suckers (one male, one female) had discoloured gonads.

Histopathology – liver

A number of proliferative but non-neoplastic lesions were observed at all sites. These included increased number and/or size of macrophage aggregates, periductal inflammation, bile duct

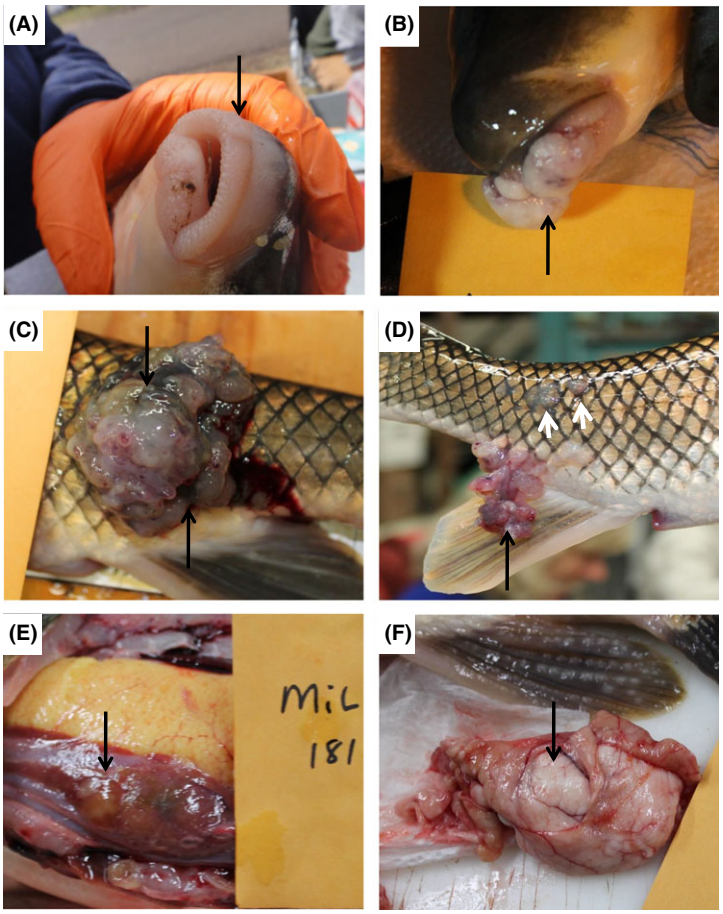

Figure 4 Proliferative lesions observed on white sucker. (A) Slightly raised lip lesion (arrow). (B) Multiple, large, irregular, papillomatous lip lesions (arrow). (C) Large, greyish-red, multilobed body surface lesions (arrows). (D) Large, irregular, raised, pedunculated lesion (black arrow) and smaller pale, raised lesions (white arrowheads) on the body. (E) Raised nodule (arrow) within the liver. (F) Large, solid, white nodule (arrow) within the testes.

proliferation (Fig. 5A) and cholangiofibrosis. Eosinophilic, basophilic and vacuolated foci of cellular alteration were noted. It is currently unknown whether any types of foci of cellular alteration are preneoplastic in white suckers; however, they are indicators of chemical exposure and so were enumerated. Plasmodia of a myxozoan parasite were observed in the lumen of many of the proliferating and fibrotic bile ducts (Fig. 5B).

Bile duct neoplasms, cholangiomas and cholangiocarcinomas were documented and were more common than hepatocellular neoplasms (Table 3). The cholangiomas observed at all sites were generally small and not observed grossly. Two of the grossly visible nodules (one at Sheboygan and one at Milwaukee) were hepatocellular carcinomas, while seven (three from Sheboygan, two from Milwaukee, two from Kewaunee) were cholangiocarcinomas. Cholangiocarcinomas ranged from large areas of proliferating ducts with irregular, poorly defined borders (Fig. 5C,D) to more anaplastic ductal cells invading large portions of the hepatic parenchyma (Fig. 5E,F).

Neoplastic lesions of hepatocytes included hepatocellular adenoma and hepatocellular carcinoma. The adenomas were characterized by expansive nodules of hepatic cords with relatively normal architecture and a distinct border. The neoplastic cells were well differentiated and generally stained more basophilic than surrounding normal cells. Macrophage aggregate and bile ducts were absent (Fig. 6A,B). The majority of the carcinomas were distinct nodules of atypical, basophilic cells with irregular borders (Fig. 6C). Lipofuscin/ceroid accumulation was present within cells on the periphery of the neoplastic areas (Fig. 6D) and within the neoplastic nodule, suggesting oxidative damage. At the Sheboygan and Milwaukee sites, a subset of the carcinomas, observed visually as large masses or discoloured areas, replaced much of the normal liver with no obvious border (Fig. 6E). Normal architecture was not apparent, cell

Table 3 Percentage of white sucker collected in four river systems of Wisconsin with skin and liver lesions

Parameters	Sheboygan	Milwaukee	Root	Kewaunee
Grossly observable orocutaneous				
White spots on body	3.1	5.0	9.0	16.0
Smooth mucoid on body	9.8	30.5	9.5	20.0
Papillomatous lip/body	29.5	40.0	16.0	22.5
Percentage with any lesion	38.3	58.0	33.0	46.0
Liver foci of cellular alteration	5.2	19.0	10.5	5.5
Microscopically verified neoplasms				
Papilloma	30.5	37.5	16.0	21.0
Squamous cell carcinoma	2.1	10.5	2.5	0.0
Skin (total)[a]	32.6	48.0	18.5	21.0
Liver (hepatocyte)	2.1	8.0	2.5	1.0
Liver (bile duct)	6.2	9.5	6.5	2.5
Liver (total)[b]	8.3	15.0	9.0	3.5

[a]Includes papilloma and squamous cell carcinoma.
[b]Includes hepatocellular adenoma, hepatocellular carcinoma, cholangioma and cholangiocarcinoma.

outlines were indistinct and nuclear abnormalities including multiple nucleoli were present (Fig. 6F), but few mitotic figures were observed.

A number of fish had more than one tumour type. One of the Sheboygan suckers with a hepatocellular carcinoma had a papilloma, while another had a hepatocellular carcinoma and seminoma. At the Milwaukee site, eight fish with hepatocellular carcinomas had papillomas and one had a co-occurring seminoma. One sucker from Kewaunee had a hepatocellular carcinoma and a papilloma.

Liver neoplasms – site comparison

The prevalence, lesion type and age at which tumours occurred varied among sites. The overall prevalence of liver neoplasms ranged from 3.5% at the Kewaunee River to 15% at the Milwaukee River (Table 3). Neoplasms occurred in fish 3 years and older from the Root River, 6 years and older from the Sheboygan and Milwaukee rivers, and 9 years and older from the Kewaunee River. At the Milwaukee site, the majority of liver neoplasms were carcinomas. Hepatocellular carcinoma was observed in 5.5% of the white sucker and 6% had cholangiocarcinomas, while five fish (2.5%) had both hepatocellular carcinomas and bile duct neoplasms. No hepatocellular adenomas and two (1.0%) cholangiomas were observed at Milwaukee. At Sheboygan, 3.6% had cholangiocarcinoma and 2.6% had cholangioma while hepatocellular carcinoma and adenoma were each observed in 1.0% of the fish. Cholangiocarcinoma was observed in 4.0% and hepatocellular adenoma in 3.5% of the white sucker from the Root River, while 0.5% had cholangioma or hepatocellular carcinoma and one fish (0.5%) had both cholangioma and hepatocellular adenoma. At the Kewaunee, five fish (2.5%) had cholangiocarcinoma, while one fish had a hepatocellular adenoma and one fish had a hepatocellular carcinoma.

The two AOCs, Sheboygan and Milwaukee rivers as well as the non-AOC Root River had liver neoplasm prevalence greater than 5%, while the prevalence at the Kewaunee River was less than 5% (Table 3). Based on tumour prevalence, as well as land use (Table 1), we utilized the Kewaunee River as the 'minimally impacted' reference site. Fisher's exact test indicated the proportion of the Kewaunee white sucker population with liver tumours was significantly less than the Milwaukee ($P < 0.0001$), Root ($P = 0.0370$) and Sheboygan ($P = 0.0529$) populations.

Liver neoplasm – age and sex effects

Combining fish from all sites, the interaction between age and sex on liver neoplasms was not significant (*d*.f. = 789, Z = 0.189, $P = 0.850$). The generalized linear model that included only age or sex as independent variables demonstrated that age was significantly and positively related to liver tumour prevalence (*d*.f. = 789, Z = 5.727, $P < 0.001$), while sex was not (*d*.f. = 789, Z = −0.835, $P = 0.404$). The same was true when sites were analysed individually, with neither the interaction of sex and age or sex alone significantly associated with liver neoplasms. Age was significantly and positively correlated at Kewaunee (*d*.f. = 197, Z = 2.76, $P = 0.006$), Root (*d*.f. = 199, Z = 2.770, $P = 0.006$), Sheboygan (*d*.f. = 192, Z = 3.057, $P = 0.002$) and Milwaukee (*d*.f. = 198, Z = 2.755, $P = 0.006$).

Histopathology – skin

The various types of raised orocutaneous abnormalities observed grossly exhibited differing

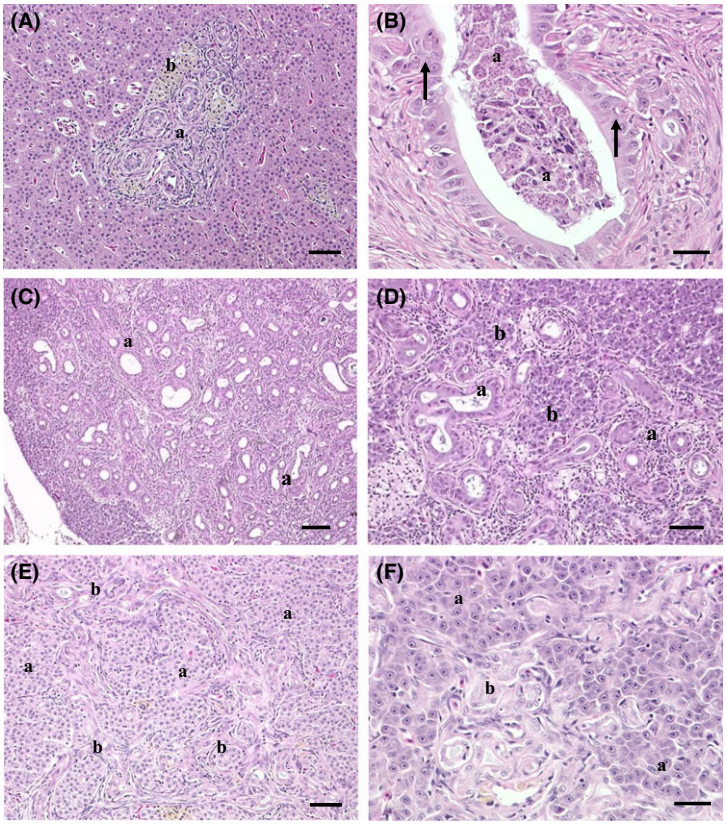

Figure 5 Lesions associated with bile ducts of the liver in white sucker. (A) Focus of bile duct proliferation and inflammation (a) with associated macrophage aggregates (b). Scale bar = 50 μm. (B) Plasmodia (a) of a myxozoan parasite in the lumen of a bile duct with abnormal proliferation (arrow) of epithelial cells and an apparent loss of polarity. Scale bar = 30 μm. (C) Large nodular cholangiocarcinoma (a). Scale bar = 100 μm. (D) Higher magnification of cholangiocarcinoma with irregularly shaped, proliferating bile ducts (a) invading into hepatic tissue (b). Scale bar = 50 μm. (E) Cholangiocarcinoma with hepatic tissue (a) infiltrated by anaplastic bile ductules (b). Scale bar = 50 μm. (F) Higher magnification of cholangiocarcinoma with areas of abnormally arranged hepatocytes (a) as well as neoplastic bile ductules (b). Scale bar = 30 μm. Haematoxylin and eosin stain.

microscopic pathology. Normal white sucker epidermis has varying cell layers and density of mucous and club cells depending on the body location (Figure 7A). The slightly raised mucoid lesions (Fig. 3c) consisted of hyperplastic epithelial cells, usually with a reduction in mucous and club cells (Fig. 7B). The epithelial cells within the hyperplastic areas were generally normal in size and shape although less organized than normal epidermis (Fig. 7C). The discrete white spots (Fig. 7D) were composed of dysplastic, often hypertrophied epithelial cells (Fig. 7E). Nuclear and cytoplasmic atypia, increased eosinophilia, abnormal size and arrangement and multinucleate cells were common (Fig. 7F). Some of the slightly raised mucoid lesions appeared to be in the early stages of papilloma development, with pegs of epithelial cells extending into the dermis and hypodermis overlaid with normal or hyperplastic epithelium (Fig. 8A). The more extensive raised white areas (Fig. 3b), larger mucoid lesions (Fig. 3d) and some of the larger, multilobed body surface and lip lesions (Fig. 4b,d) were most commonly papillomas composed of multiple raised areas of proliferating epithelial cells, also of varying size, shape and arrangement that do not extend beyond the basement membrane (Fig. 8B). Some body surface (Fig. 4c,d) and lip lesions were squamous cell carcinomas in which the neoplastic cells infiltrated through the basal lamina into underlying connective tissue (Fig. 8C). These cells were pleomorphic with nuclear atypia and occasionally focal areas of hypertrophic pale-staining cells. Mitotic figures were observed (Fig. 8D). One mixed cell tumour involving the branchial cavity and gills was observed at the Sheboygan River. Areas of the tumour resembled a squamous cell carcinoma which invaded the branchial cavity and gill filaments, while other regions of the tumour resembled a fibrosarcoma or nerve sheath tumour.

Skin neoplasms – site comparison

The prevalence of skin neoplasms ranged from 18.5% at the Root to 37.5% in the Milwaukee site (Table 3). Squamous cell carcinomas were not observed at the Kewaunee site but were observed at the Root (2.1%), Sheboygan (2.5%) and Milwaukee (10.5%). At the Sheboygan, Milwaukee

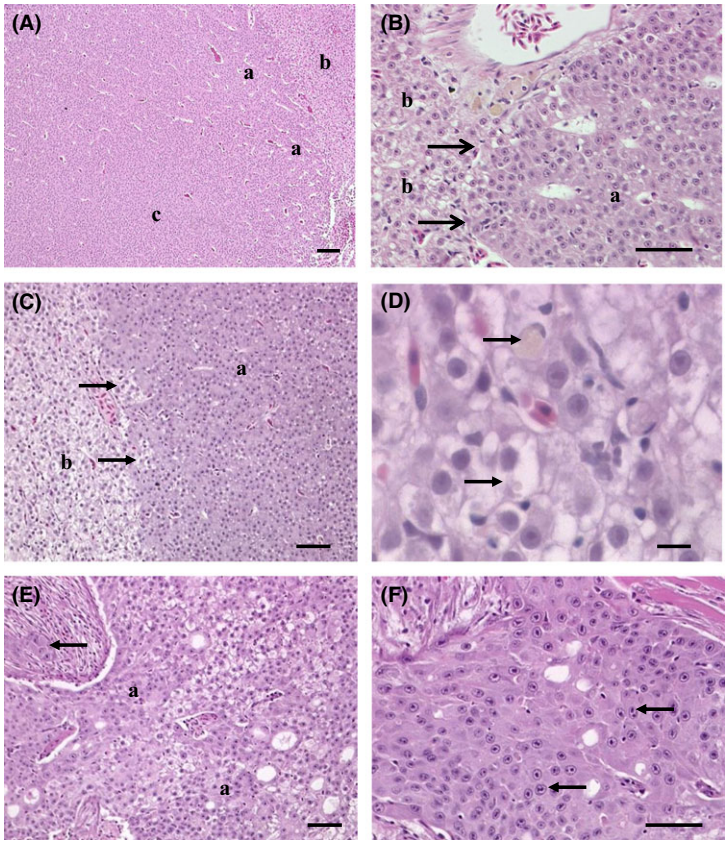

Figure 6 Hepatocellular changes in liver of white sucker. (A) A large well-differentiated adenoma (a) bordered by a small area of normal liver tissue (b). The central portion of the tumour has lost the normal architecture (c). Scale bar = 100 μm. (B) Higher magnification of an adenoma (a) illustrating a distinct border (arrow) separating normal liver tissue (b) from neoplastic cells (a). Scale bar = 50 μm. (C) Hepatocellular carcinoma in which neoplastic cells (a) are invading normal hepatic parenchyma (b). Border is irregular with areas of normal hepatocytes (arrows) surrounded by proliferating neoplastic cells. Scale bar = 50 μm. (D) Hepatocytes on the periphery of the normal tissue have cells with intracellular lipofuscin/ceroid accumulations (arrows). Scale bar = 20 μm. E. Mixed carcinoma with diffuse areas of pleomorphic neoplastic hepatocytes (a). Foci of hepatocytes were present within fibrotic areas (arrow). (F) Higher magnification of carcinoma illustrating pleomorphic neoplastic cells with abnormal nuclei sometimes having multiple nucleoli (arrows). Scale bar = 50 μm. Haematoxylin and eosin stain.

and Root rivers papillomas were observed in fish 5 years and older, while at Kewaunee, papillomas were observed in fish 6 years and older.

Skin neoplasms – sex and age associations

Combining fish from all sites, the interaction between age and sex on skin neoplasms was not significant (*d*.f. = 789, Z = −1.213, $P = 0.225$). The generalized linear model that included only age or sex as independent variables demonstrated that age was significantly and positively related to skin tumour prevalence (*d*.f. = 789, Z = 5.695, $P < 0.001$), while sex was not (*d*.f. = 792, Z = 0.098, $P = 0.922$). When sites were analysed individually, neither the interaction of sex and age nor sex alone was significantly associated with skin neoplasms. Age was significantly and positively associated with skin tumours at the Root (*d*.f. = 199, Z = 2.908, $P = 0.004$), Sheboygan (d.f. = 192, Z = 2.030, $P = 0.042$) and Milwaukee (*d*.f. = 198, Z = 3.246, $P = 0.001$), but not at Kewaunee (*d*.f. = 197, Z = −1.00, $P = 0.317$).

Other tumours – testicular

Testicular tumours were observed in white sucker from the Sheboygan and Milwaukee rivers, but not from the Kewaunee or Root rivers. Four fish from Milwaukee, ranging in age from 10 to 16 years,

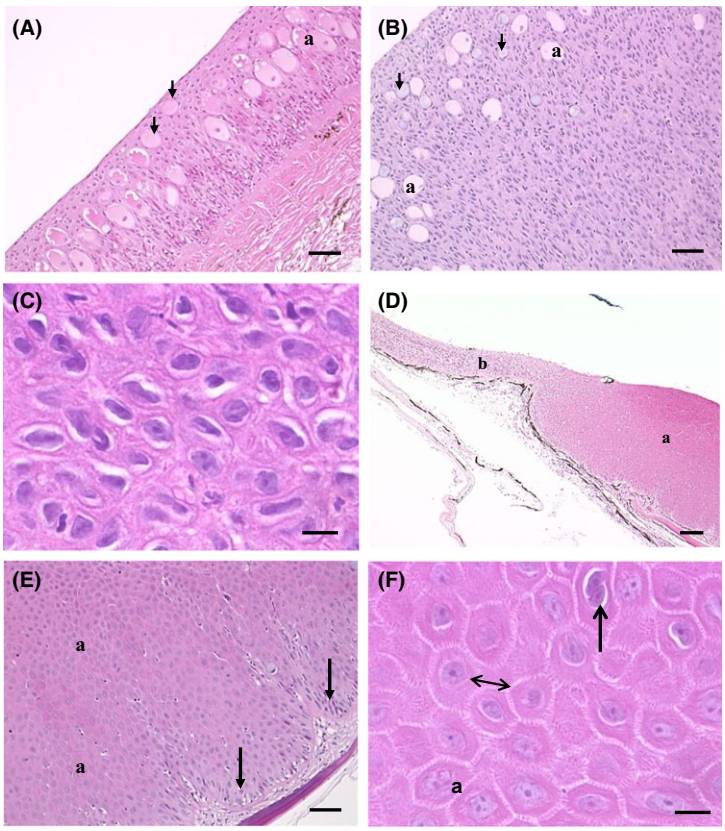

Figure 7 Microscopic appearance of raised skin lesions of white sucker. (A) Normal skin with epidermis containing club (a) and mucous cells (arrowhead) in the epidermis. Scale bar = 50 μm. (B) Hyperplastic epidermal cells forming a mucoid plaque on the body surface. Cells are generally of the same size and shape as those observed in normal epidermis and mucous (arrowhead) and club cells (a) are present Scale bar = 50 μm. (C) Higher magnification of a mucoid plaque. Cells are fairly uniform in size and elongate, although less organized than normal epidermis. Scale bar = 10 μm. (D) Hyperplastic and hypertrophic epithelial cells (a) forming a discrete white spot on the body surface, adjacent to normal skin (b). Scale bar = 100 μm. (E) Discrete white spot in which cells adjacent to the basement (arrows) are normal columnar epithelial cells, while the remaining layers are pleomorphic (a). Scale bar = 50 μm. (F) Higher magnification of the discrete white spot demonstrating the nuclear atypia (a), variation in size (double arrowhead) of cells and binucleate cells (arrow). Scale bar = 10 μm. (F) Haematoxylin and eosin stain.

and four from Sheboygan, ranging in age from 6 to 14 years, had testicular tumours. The testicular tumours were seminomas composed of primordial germ cells (Fig. 9A) with abundant mitotic figures (Fig. 9B). One fish from the Root had a large foci of testicular oocytes (Fig. 9C,D). Two fish from the Milwaukee river had testicular oocytes, although these were individual oocytes in a few sections. The remaining abnormal testes had areas of fibrosis, germ cell and/or Sertoli cell proliferation.

Discussion

Epizootics of neoplasms, including hepatocellular, cholangiocellular and epidermal, which may be causally related to contaminant exposure, have been a concern at Great Lakes AOCs and other sites for many years (Harshbarger & Clark 1990; Hayes *et al.* 1990; Black & Baumann 1991; Baumann *et al.* 1996; Rafferty *et al.* 2009). To our knowledge, testicular tumours of white sucker have not been previously reported, although testicular oocytes have been observed (Woodling *et al.* 2006; Vajda *et al.* 2008). Germ cell tumours have been induced by chronic dietary exposure of zebrafish *Danio rerio* to environmentally relevant concentrations of PAH mixtures (Larcher *et al.* 2014) and in other single compound exposures of zebrafish and other species (Bailey *et al.* 1984; Hawkins *et al.* 1996; Spitsbergen *et al.* 2000a,b; Neumann *et al.* 2009). It is of note that testicular tumours were only observed at the Sheboygan and Milwaukee AOCs.

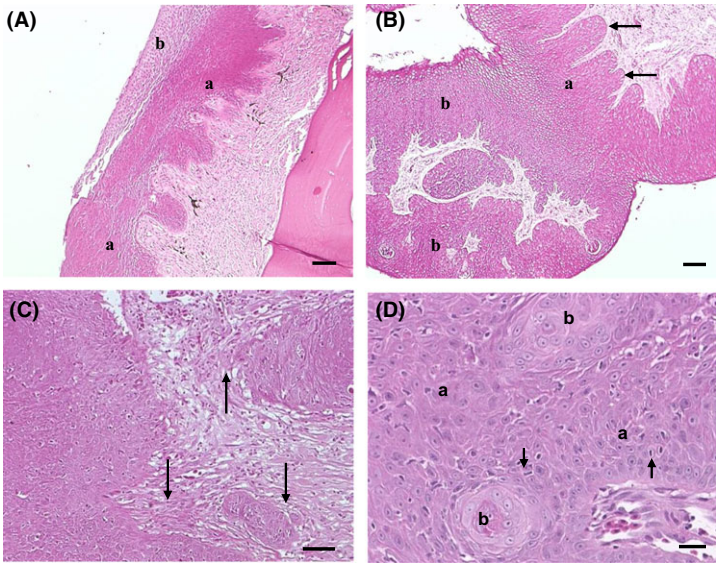

Figure 8 Microscopic appearance of skin tumours on white sucker. (A) Mucoid plaque in which pegs of proliferating neoplastic epithelial cells (a) have formed a papilloma underlying hyperplastic epidermis (b). Scale bar = 100 μm. (B) Papillomatous lesion of the skin with projections of proliferating cells into the dermis and hypodermis (a), as well as forming a raised area (b) on the body surface. Scale bar = 100 μm. (C) Section of a large squamous cell carcinoma with pleomorphic, irregularly arranged cells that locally invade through the basal lamina (arrow). Scale bar = 20 μm. (D) Section of a squamous cell carcinoma composed of pleomorphic, atypical cells (a). Foci of pale-staining, hypertrophic cells (b) and mitotic figures (arrows) are evident. Scale bar = 20 μm. Haematoxylin and eosin stain.

Liver and skin tumours were observed at all sites although prevalence varied among the sites. The Milwaukee and Root river sites are both within the Milwaukee Metropolitan Sewerage District (Baldwin *et al.* 2013) and have primarily urban/developed land use within the portion of each river between the mouth and site of collection. The Sheboygan River has a moderate level of urban and higher proportion of agricultural land use, while the Kewaunee watershed had a high (>60%) proportion of agricultural land use (Table 1). Prevalence of liver tumours and foci of cellular alteration followed the same pattern as that of urban land use, with Milwaukee having the highest, followed by the Root, Sheboygan and Kewaunee. In contrast, overall skin tumour prevalence (papilloma and carcinoma) did not follow that pattern of land use, although the prevalence of malignant tumours (squamous cell carcinoma) did, with the highest prevalence in suckers from Milwaukee, followed by Root and Sheboygan. No squamous cell carcinomas were observed in white sucker captured in the Kewaunee River.

The high prevalence of skin and liver non-neoplastic and neoplastic lesions, as well as gonadal tumours, in white sucker collected from the Sheboygan and Milwaukee rivers indicates historically and currently impaired ecosystems. While the cause(s) of these proliferative lesions are not fully understood, many such lesions have been previously associated with contaminant exposure. Liver neoplasia has a well-documented association with exposure to sediment PAHs in a number of fish species (Myers *et al.* 1990; Vogelbein & Unger 2006; Pinkney *et al.* 2011; Larcher *et al.* 2014). However, other chemicals have been experimentally shown to be initiators and promoters of liver tumours in fish (reviewed by Williams 2012) and it may be necessary to expand the list of targeted chemical analytes, as well as other initiating factors, in environmental monitoring studies.

In other animals, research has demonstrated that oxidative stress can lead to chronic inflammation and is implicated in various phases of tumorigenesis (reviewed by Reuter *et al.* 2010). In certain parts of the world, human cholangiocarcinomas are associated with an opisthorchid trematode that induces biliary fibrosis, inflammation and eventually cancer (Sripa *et al.* 2011). Plasmodia of *Zschokkella* species have been reported to cause bile duct proliferation, cholangiofibrosis, pericholangitis, desquamation and metaplastic

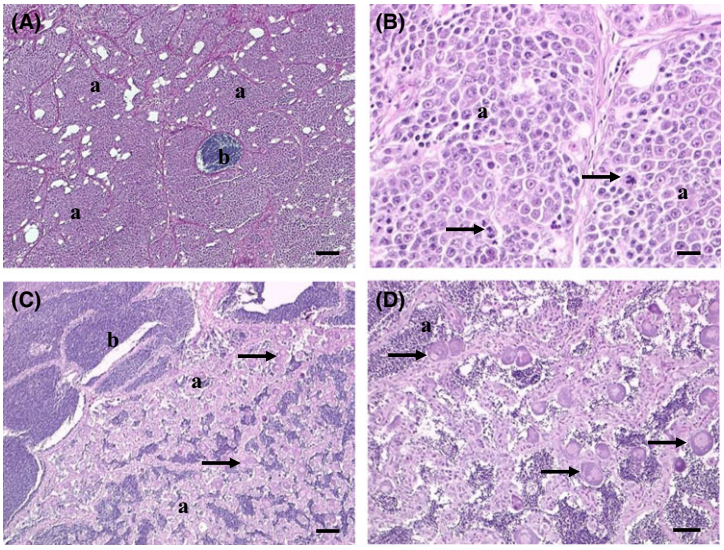

Figure 9 Histopathology of testicular lesions of white sucker. (A) Section of a seminoma (a) with islands of sperm (b) within the solid mass of neoplastic germ cells. Scale bar = 50 μm. B. The seminoma is a solid tumour filled with germ cells (a), many containing mitotic figures (arrows). Scale bar = 100 μm. (C) Large nodule of abnormal germinal epithelium (a) and testicular oocytes (arrows) adjacent to normal testicular tissue (b). Scale bar = 100 μm. (D) Higher magnification of the nodule of testicular oocytes (arrows) and sperm (b). Scale bar = 50 μm. Haematoxylin and eosin stain.

changes of the duct epithelium (Davies 1985; Bucher, Hofer & El-Matbouli 1992). These pathological changes, followed by exposure to chemical carcinogens, could contribute to the observed bile duct neoplasms of white sucker by similar mechanisms. While the pathology of the liver neoplasms observed in this study is similar to that previously described in white sucker (Dawe, Stanton & Schwartz 1964; Hayes *et al.* 1990), the myxozoan parasites had not been previously noted or identified. Hepatitis virus is also one of the major risk factors for human liver cancer worldwide (Perz *et al.* 2006). Interestingly, a hepatitis B virus was recently described from white sucker in the Great Lakes (Hahn *et al.* 2015). It is currently unknown what, if any, role this may play in the observed liver lesions.

While locations with liver tumours often have a high prevalence of skin neoplasms (Hargis *et al.* 1989; Hayes *et al.* 1990; Pinkney *et al.* 2011), much less is known regarding the carcinogenesis of orocutaneous tumours. Many of the white suckers with liver tumours also had skin tumours in our study. Hence, at least some of the risk factors may be similar. It is likely that chemical exposure as well as other factors may contribute to skin neoplasia since, unlike liver, skin is directly exposed to the complex mixtures of chemicals and other stressors present in water and sediment. Zebrafish exposed to ethylnitrosourea, an alkylating agent, developed epidermal hyperplasia and papillomas (Beckwith *et al.* 2000) and exposure to chlorinated wastewater effluent was associated with development of papillomas in black bullhead *Ictalurus melas* (Grizzle, Melius & Strength 1981). Sonstegard (1973) suggested the development of skin tumours of white sucker may be influenced by chemical contamination, since the prevalence was low in less industrialized areas. Premdas *et al.* (1995) demonstrated a correlation between papilloma prevalence and concentrations of persistent chemicals including PCBs and organochlorines. There are conflicting reports regarding the possible viral aetiology or viral association with white sucker skin tumours (Sonstegard 1973; Harshbarger & Clark 1990) and numerous studies have been unsuccessful in demonstrating the presence of a virus (Smith, Ferguson & Hayes 1989b; Smith *et al.* 1989a; Premdas & Metcalfe 1996). It is possible that viruses and associated inflammation may initiate the hyperplastic changes in the epidermis and chemical exposure by means of oxidative damage or other mechanisms may promote the development of neoplasia. The white raised lesions are somewhat similar to walleye *Sander vitreus* discrete epidermal hyperplasia associated with retroviruses (Yamamoto, Kelly & Nielsen 1985), while the mucoid lesions are more similar to the walleye diffuse epidermal hyperplasia associated with a herpesvirus (Kelly *et al.* 1983; Coffee, Casey & Bowser 2013).

Morphologically distinct raised skin lesions were often observed on white suckers in this study and the histopathology of some of them is similar to that previously reported (Smith *et al.* 1989a,b; Hayes *et al.* 1990; Premdas *et al.* 1995). These

previous reports described three types of skin lesions affecting white sucker in the Great Lakes: focal raised areas on the lips, discrete white areas on the body surface (similar to the white spots described here) and raised mucoid lesions. Apparently, the large multilobed tumours (Fig. 4C,D) were not previously observed. Smith *et al.* (1989b) note a continuum from mild hyperplasia to papilloma in the three types they observed. This is similar to what we noted; however, we also observed a difference in the microscopic appearance of the early mucoid plaques versus the discrete white spots. Whether this indicates different initiating factors is yet to be determined. Many of the white suckers had multiple lesion types in the current study. The hyperplastic nature of the small white spots and many of the mucoid plaques suggests there may be a progression from hyperplasia to neoplasia and that these may be preneoplastic lesions.

Historically, legacy contaminants such as PCBs, PAHs and heavy metals have been the focus of concern at AOCs. However, more recently, the potential effects of exposure to 'chemicals of emerging concern' (CECs) such as hormones, phytoestrogens, pharmaceuticals, flame retardants and personal care products have also been recognized as contributing to adverse health effects in the Great Lakes (Klečka, Persoon & Currie 2010; Klaper & Welch 2011; IJC 2009). Endocrine disruptors are recognized as carcinogens in mammalian species (Choi, Yoo & Lee 2004; Soto & Sonnenschein 2010) and are associated with the testicular dysgenesis syndrome, which includes testicular tumours and other male reproductive abnormalities (Bay *et al.* 2006). Estrogens, in particular, modulate the development of chemically induced skin tumours in mice (Lupulescu 1981; Mancuso *et al.* 2009). Interestingly, experimental exposure to androgens and 17β-estradiol was reported to induce papillomas in non-papillomatous white sucker, as well as increase the growth of already occurring papillomas (Premdas, Metcalfe & Brown 2001). An increased prevalence or growth of papillomas at sites impacted by industrial and/or sewage effluent (Kortet, Vainikka & Taskine 2002; Korkea-aho *et al.* 2006, 2008) and by exposure to androgens (Kortet *et al.* 2003) has been documented in other fish species. Estrogens are also known promoters of chemical carcinogenesis in the liver of fishes (Nunez *et al.* 1989; Cooke & Hinton 1999; Tilton *et al.* 2006) and are associated with testicular lesions (Rasmussen *et al.* 2005; Dietrich & Krieger 2009) similar to those observed in the white sucker.

Additional research is needed to understand the risk factors for neoplasms in fishes collected in Great Lakes AOCs. Both of the AOC sites in this study had liver tumour prevalence above the required 5% for delisting. In order to remediate and/or restore AOCs and other impaired waters, the ecosystem impacts from complex mixtures of contaminants (legacy and CECs) and other environmental stressors must be recognized and understood. The lack of knowledge on biological responses to complex chemical mixtures, influence of life stage and duration of exposure, as well as modulating effects of climatic factors, pathogens and parasites has emphasized the importance of biological effects-based tools (Ekman *et al.* 2013). Ongoing efforts to remove contaminants from portions of AOCs are likely to reduce degradation due to historical activities. This may or may not reduce tumour prevalence. Other recent and ongoing human activities and exposure to contaminants of emerging concern may well be contributing to the current tumour prevalence. It is important to determine contaminant loads of water and sediment in these rivers, where sucker reside during early life stages (Childress, Papke & McIntyre 2016), as well as in nearshore areas where they spend much of their adult lives. In addition, we recommend monitoring of chemical concentrations in specific tissue such as skin and liver tissue, use of newer molecular techniques to detect the presence of viruses and gene expression profiles associated with chemical carcinogens or inflammation. Given the diversity of the pathology presented in our study, integrating all these data types will be necessary to definitively understand factors underlying development of neoplastic lesions observed in white suckers.

Acknowledgements

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Appendix F

Waterfowl Consumption Assessment Report

CONTAMINANT CONCENTRATIONS IN WATERFOWL

FROM THE MILWAUKEE ESTUARY AREA OF CONCERN

Sean M. Strom
WI Department of Natural Resources
Bureau of Wildlife Management

February 9, 2016

INTRODUCTION

Waterfowl consumption advisories within the Milwaukee Estuary Area of Concern (AOC) have been in place since 1987. These advisories are the result of contamination from persistent, bioaccumulative, and toxic chemicals, primarily polychlorinated biphenyls (PCBs). However, these consumption advisories have not been re-evaluated since their inception. As part of the AOC de-listing process, we re-examined the state of the advisories to determine if any of the existing advisories can be removed or if any additional advisories are warranted.

Persistent, bioaccumulative, and toxic (PBT) chemicals are of concern because of evidence that they cause long-term harm to human health and the environment. Examples of PBT chemicals include PCBs, dioxins, organochlorine pesticides, and mercury). Although many chemicals can have toxic effects on humans and the environment, PBTs pose a special challenge primarily because of their unique properties. PBTs do not break down or become diluted in the environment as easily as some chemicals. PBTs also tend to bioaccumulate in the bodies of humans, fish, and other wildlife. As they slowly accumulate through the food chain, PBTs become increasingly concentrated, and may reach very high levels in both humans and wildlife that are at the top of the food chain. Although it may take months or years of regularly eating contaminated waterfowl or fish to build up amounts which are a health concern, the risk should not be ignored. Health problems which may result from the contaminants found in waterfowl range from small changes in health that are hard to detect to birth defects and cancer. Mothers who eat highly contaminated fish for many years before becoming pregnant may have children who are slower to develop and learn.

Polychlorinated biphenyls are considered a PBT chemical which are ubiquitous in the Wisconsin Great Lakes and have been shown to biomagnify up the food chain. PCBs are considered to be probable human carcinogens based on its association with liver tumors of laboratory rats (USEPA 1997). Recent EPA documents have termed the findings of some human studies as “suggestive” of an association between human cancer and PCB exposure (USEPA 1997). PCBs are also associated with immunological effects in animals and some developmental effects in humans. All of the current consumption advisories within the WI AOCs are the direct result of PCB contamination.

Advisories currently in place for the Milwaukee Estuary AOC include an advisory not to eat mallards, black ducks, ruddy ducks and scaup. The primary objective of this study was to determine whether any existing waterfowl consumption advisories can be removed or if any new advisories are necessary.

METHODS

The current consumption advisories within the Milwaukee AOC are species specific. However, based on the similar feeding habits of some species, and in consultation with the Department of Health Services, we decided to collect ducks based on feeding habits (dabbler vs diver) rather than individual species. Collecting waterfowl based on feeding habit, rather than specific species, should be more representative of local exposure of waterfowl to contaminants. In addition, we also collected samples from resident Canada geese within the Milwaukee AOC.

Department staff attempted to trap ducks at different locations within the AOC. Ducks were also obtained from the Milwaukee County Humane Society. Canada geese were obtained from USDA-Wildlife Services goose control operations.

All carcasses were processed in an identical manner. Briefly, an area (approximately 10 x 12 cm) was plucked from each carcass and a 20 g sample of breast muscle with skin on was dissected. Samples were placed into a labeled plastic bag and submitted to the WI State Lab of Hygiene (WSLH) for analysis. Samples were analyzed for legacy contaminants (PCBs, lead (Pb), mercury (Hg), DDT/DDE, and organochlorine pesticides). In addition to the legacy contaminants, samples collected in 2014 were also analyzed for emerging contaminants such as polybrominated diphenyl ethers (PBDEs), and perfluorinated compounds (PFCs).

Advisories for human consumption (Table 1) were obtained from the Protocol for a Uniform Great Lakes Fish Consumption Advisory (GLSFATF 1993), the Health Guide for People Who Eat Sport Fish from Wisconsin Waters (WDNR and WDH 1994), and Action Levels for Poisonous or Deleterious Substances in Human Food and Animal Feed (USFDA 1994).

Table 1. Human Health Consumption Advisory Critical Concentrations in Fish or Meat Products.

CONTAMINANT	MINIMUM DETECTION LIMIT (µg/g)	ADVISORY CONCENTRATION (µg/g)		
		Unlimited consumption	No more than 1 meal/Week	Do Not Eat
PCB	0.04	<0.05	0.06 - 0.22	>2.0
Mercury (Children under age 15, pregnant women and women of childbearing age)	0.004	<0.05	0.06 - 0.22	>0.95
Lead	0.005	<0.05	n/a	n/a
Cadmium	0.0045	<0.3*	n/a	n/a
PFOS (perfluorooctane sulfonate)	0.12 (ng/g)	<40 (ng/g)	40 - 200 (ng/g)	> 800 (ng/g)

*Level of concern rather than advisory concentration

Wildlife Health staff evaluated and interpreted sample results from the WSLH. Results for each contaminant was compared with the associated critical advisory concentration in food to determine if consumption advisories could be repealed or new advisories are warranted. This process included consultation with the Department of Health Services (DHS) on the interpretation of results.

RESULTS and DISCUSSION

We realize the difficulty regarding the issuance of consumption advisories for waterfowl. Because they are mobile and migratory, it is difficult to pinpoint whether waterfowl have accumulated contaminants from outside WI or the United States or from a location in the state other than the area where they are

harvested. To address this issue, we focused on collecting adult mallards and Canada geese known to be members of a resident flock and/or juvenile birds known to have been hatched in Wisconsin. In addition, diving ducks often overwinter on Lake Michigan and collecting them in the late winter/early spring would allow for the collection of ducks which have been in the area for 3-5 months, therefore better reflecting local contamination.

Efforts to collect mallards within the AOC were unsuccessful, so we were unable to re-evaluate current contaminant levels and potential advisories on mallards within the AOC. The diving ducks were obtained during the winters of 2013-2014 and 2014-2015 primarily from the Milwaukee County Humane Society from ducks either found dead or euthanized at the facility.

PCBs

Detectable levels of PCBs were observed in 7 of the 19 samples from resident Canada geese (range ND – 0.17 µg/g), but the mean concentration (0.05 µg/g) was below any advisory concentration (Table 2). A total of 19 diving ducks were collected (10 scaup, 4 common goldeneye, 2 red-breasted mergansers, 1 common mergansers, and 2 long-tailed duck). PCBs were also detected in every sample collected from diving ducks (range 0.31 – 13.0), and the mean concentration (3.88) was above advisory concentrations (Table 2). The observed mean concentration remains in the advisory range of "do not eat". Based on these results, we recommend the current advisory of "do not eat" remain in effect. Furthermore, we recommend the advisory be changed to include the "do not eat" advisory for all diving ducks.

METALS

There is no single standard for permissible amounts of lead in food. Furthermore, FDA regulatory standards and guidelines for Pb in food are complicated by the relatively recent recognition (ATSDR 2007, EPA 2007) of Pb as a probable human carcinogen. However, for meat and fat products, an international consensus standard of 0.05 ppm is under discussion (FDA 2000).

Lead was detected in 15 of the 19 samples collected from resident Canada geese (range ND – 0.12 µg/g) (Table 3). However, the mean Pb concentration (0.015 µg/g) was below the advisory concentration of 0.05 µg/g, therefore, an advisory due to Pb contamination is not necessary. Lead was also detected in 16 of 19 samples from diving ducks, but 10 of these 16 samples failed quality control standards (Table 3). However, the observed levels in the diving ducks were very low and below the advisory concentration.

Mercury was detected in only 6 of the 19 samples from resident Canada geese (range ND – 0.009 µg/g) and the mean concentration (0.005 µg/g) was below the advisory concentration (Table 3). Mercury was detected in every sample collected from diving ducks (range 0.04 – 1.36 µg/g) (Table 3). The mean Hg concentration in diving ducks (0.33 µg/g) is high enough to warrant a limited consumption advisory of "no more than 1 meal/week" for men and older women and "no more than 1 meal/month" for children and for women of childbearing years. However, due to the results of the PCB analysis and the current advisory based on PCB results, we recommend the "do not eat" advisory for diving ducks remain in place.

Wisconsin does not routinely test for Cd in fish as part of the fish consumption advisory program and therefore, Wisconsin does not have an advisory concentration for Cd. However, Iowa uses a Cd concentration of 0.3 µg/g as a level of concern. Although, this concentration is not used as an advisory guideline, it does serve as a point of comparison. Cadmium was detected in 9 of the 19 samples from Canada geese, but the concentrations were very low and below the level of concern (Table 3). Cadmium was also detected in 18 of the 19 samples collected from diving ducks (Table 3). Although the

concentrations in diving ducks were greater compared to Canada geese, the mean concentration (0.14 µg/g) was well below the level of concern.

PERFLUORINATED COMPOUNDS (PFCs)

Perfluorinated compounds were only analyzed in Canada geese and diving ducks collected in 2013 - 2014. Advisory concentrations only exist for one PFC compound (perfluorooctane sulfonate). As such, only concentrations of this specific compound were able to be interpreted for the purpose of consumption advisories. Perfluorooctane sulfonate (PFOS) was detected in 6 of 10 samples collected from resident Canada geese (range ND – 1.6 ng/g) (Table 2). The average concentration of PFOS in resident geese was below the advisory concentration. PFOS was detected in all 10 samples collected from diving ducks in 2014 (range 8.5 – 520 ng/g) (Table 2). The mean PFOS concentration in diving ducks (134.9 ng/g) falls within the "no more than 1 meal/week" guidelines. However, due to the results of the PCB analysis and the current advisory based on PCB results, we recommend the "do not eat" advisory for diving ducks remain in place.

CONCLUSIONS

Based on levels of PCBs observed in diving ducks collected from the Milwaukee AOC, it is our recommendation that the "do not eat" advisory which is currently in place for ruddy ducks and scaup from the Milwaukee Harbor remain in effect. In addition, we recommend re-vising this advisory to include all diving ducks – based on the similar feeding habits of several species. Comparing results from the current sample collection with samples collected in the late-1980s for scaup indicate PCB levels have changed little over the last 25 years.

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Table 2: Concentrations of total PCBs, PFOS, and total PFCs (average ± standard deviation) in waterfowl collected from the Milwaukee Estuary AOC.

Species	Sample Size	Total PCBs (µg/g)	PFOS (ng/g)*	Total PFCs (ng/g)*
Canada	19	0.052 ± 0.053	0.79 ± 0.57	6.21 ± 3.29
Diving Ducks	18	3.88 ± 3.48	134.9 ± 195.6	187.3 ± 247.9

*PFCs only analyzed in samples collected in 2013 – 2014.

Table 3: Cadmium, mercury, and lead concentrations (average ± standard deviation) in waterfowl collected from the Milwaukee Estuary AOC

Species	Sample Size	Cd (µg/g)	Hg (µg/g)	Pb (µg/g)
Canada Geese	19	0.006 ± 0.005	0.005 ± 0.001	0.015 ± 0.026
Diving Ducks	19	0.14 ± 0.0.22	0.33 ± 0.37	0.014* ± 0.008

*Sample results failed QC

Appendix G

Aesthetics BUI Target Adjustment Comparison

***Proposed* Delisting Target**

This delisting target is consistent with Chapter NR 102, Wisconsin Administrative Code, Water Quality Standards for Surface Waters. Delisting shall occur when monitoring data within the AOC and/or surveys collected by multiple observers for any two consecutive year period indicates that water bodies in the AOC do not exhibit unacceptable levels of the following properties in quantities which interfere with the Water Quality Standards for Surface Waters:

(a) Substances that will cause objectionable deposits on the shore or in the bed of a body of water shall not be present in such amounts as to interfere with public rights in waters of the state.
(b) Floating or submerged debris, oil, scum, or other material shall not be present in such amounts as to interfere with public rights in waters of the state.
(c) Materials producing color, odor, taste, or unsightliness shall not be present in such amounts as to interfere with public rights in waters of the state.

The following target will also be met to determine when restoration has occurred:

- Corrective action plans are in-place and being implemented for significant, persistent issues contributing to the degradation of aesthetics within the AOC identified via aesthetics monitoring/surveys.

***Current* Delisting Targets and Actions Needed**

This delisting target is consistent with Chapter NR 102, Wisconsin Administrative Code, Water Quality Standards for Surface Waters. Delisting shall occur when monitoring data within the AOC and/or surveys for any five year period indicates that water bodies in the AOC do not exhibit unacceptable levels of the following properties in quantities which interfere with the Water Quality Standards for Surface Waters:

(a) Substances that will cause objectionable deposits on the shore or in the bed of a body of water shall not be present in such amounts as to interfere with public rights in waters of the state.
(b) Floating or submerged debris, oil, scum, or other material shall not be present in such amounts as to interfere with public rights in waters of the state.
(c) Materials producing color, odor, taste, or unsightliness shall not be present in such amounts as to interfere with public rights in waters of the state.

The following target will also be met to determine when restoration has occurred:

- Corrective action plans are in-place and being implemented for all known sources of materials contributing to the degradation of aesthetics within the AOC.

Additional Information from Delisting Targets Report (March 2008)

Rationale

The Degradation of Aesthetics BUI is subjective compared to most impairments. Milwaukee AOC utilizes existing Wisconsin standards as they apply to all surface waters of the state. If any of the properties are persistent, then the beneficial use has not been restored. Any single occurrence due to such instances as an accident, line break, or equipment breakdown would not be considered an impairment.