MI/EGLE/WRD-20/002

Assessment of the Bird or Animal Deformities or Reproductive Problems Beneficial Use Impairment in Michigan's Great Lakes Areas of Concern 2020


Prepared by:
Dennis Bush, Toxicologist
Brandon Armstrong, Toxicologist
Sarah Bowman, Toxicologist
Joseph Bohr, Aquatic Biologist
Surface Water Assessment Section
Water Resources Division

January 2020

ACKNOWLEDGEMENTS

We would like to thank Dr. Lisa Williams and Mandy Annis of the United States Fish and Wildlife Service for providing Great Lakes Restoration Initiative funds for this project. Additional funding was also provided by the Clean Michigan Initiative. We would also like to thank University of Maryland staff (Dr. William Bowerman, Dr. Meredith Bohannon, and Hannah Evans) for providing the bald eagle and herring gull data and David Best for providing information regarding specific eagle territories. We would also like to thank Dr. Steven Bursian for facilitating the analysis of the mink jaws. We would like to thank Dr. Keith Grasman for providing information and data on herring gulls, Caspian terns, and black-crowned night herons. Lastly, we would like to thank Mr. Joe Medema for providing the mink and muskrats from the Kalamazoo River.

Cover photos: Common tern - Katherine Whittemore, United States Fish and Wildlife Service; Bald eagle - Dr. William Bowerman, University of Maryland; and Mink - Don Breneman, Great Lakes National Program Office.

Table of Contents_Toc26367018

EXECUTIVE SUMMARY

There are currently four Areas of Concern (AOC) in Michigan that have a Bird or Animal Deformities or Reproductive Problems Beneficial Use Impairment ("Wildlife BUI"). The methodology provided in the document titled, *Guidance for Delisting Michigan's Great Lakes Areas of Concern* (Michigan Department of Natural Resources [MDNR], 2018), was used to determine whether sufficient data are available to remove the Wildlife BUI for these AOCs. An earlier version of this guidance (Michigan Department of Environmental Quality [MDEQ], 2006) was used to remove the Wildlife BUI from the St. Marys and St. Clair River AOCs. To remove a Wildlife BUI there must either be evidence that the reproduction/development of wildlife species within the AOC is no longer being adversely affected, or there must be evidence that the incidence of the effects being observed do not exceed levels found in comparison populations.

This review assessed the impacts of *p,p*'-DDE, polychlorinated biphenyls (PCB), and dioxin toxic equivalents (TEQ) on bald eagles, herring gulls, terns, and mink because these contaminants are the primary reason for listing an AOC as having a Wildlife BUI. This update to previous reports (Bush and Bohr, 2012; Bush and Bohr, 2015) includes more recent data from the Michigan Department of Environment, Great Lakes, and Energy's (EGLE) bald eagle, herring gull, and fish contaminant monitoring programs; summarizes the analysis of more recent contaminant data in forage fish; and includes analytical results of livers from mink and muskrats collected from the Kalamazoo River AOC.

After reviewing the new monitoring data and data provided in the studies mentioned above, we have the following recommendations concerning the four AOCs with a Wildlife BUI:

- The Wildlife BUI for the Kalamazoo River AOC should be retained based on potential effects of contaminants on bald eagles.

- The Wildlife BUI for the Saginaw River/Bay AOC should be retained based on potential effects of contaminants on bald eagles and colonial nesting birds.

- The Wildlife BUI for the River Raisin AOC should be retained based on potential effects of contaminants on bald eagles and colonial nesting birds.

- The Wildlife BUI for the Detroit River AOC should be retained based on potential effects of contaminants on bald eagles and potential effects of contaminants on mink/otters based on levels of contaminants in their prey.

We have the following recommendations for future work related to the Wildlife BUI within the AOCs:

- Continue to measure contaminant levels in forage fish from the AOCs and comparison populations.

- Continue to study the impacts of contaminants on the reproduction/development of colonial nesting birds in the River Raisin and Saginaw River/Bay AOCs.

- Continue to monitor contaminant levels and productivity of bald eagles in the Kalamazoo River, Detroit River, Saginaw River/Bay, and River Raisin AOCs. Conduct eaglet genetic analysis using archived and new samples to determine relatedness of bald eagles among AOCs and inland areas of Michigan. Determine if the AOCs serve as a source or sink of eagles. Determine if fledglings from contaminated areas are successfully returning and creating new territories.

REPORT CONTEXT

This review and assessment of existing data for the Wildlife BUI is one in a series of statewide assessments for BUIs conducted in Michigan's Great Lakes AOCs. Review of existing data is the first step in the overall process of applying assessment criteria to a BUI in an affected AOC. The complete evaluation for any BUI is a public process, conducted by agency staff in partnership with the local Public Advisory Council and United States Environmental Protection Agency (USEPA) in each AOC. Per the *Guidance for Delisting Michigan's Great Lakes Areas of Concern* (MDNR, 2018), a BUI-specific team will be convened by the EGLE coordinator for each AOC to evaluate recommendations in this assessment and determine AOC-specific next steps. Outcomes of each team's deliberations on recommendations for BUI removal, further monitoring, or further remedial actions, as warranted by site-specific considerations, will be documented by the EGLE coordinator. If removal of the BUI is recommended by the team for any of the affected AOCs, documentation will be prepared and processed per procedures in the *Guidance for Delisting Michigan's Great Lakes Areas of Concern* (MDNR, 2018).

INTRODUCTION

At one time there were seven Michigan AOCs with a Wildlife BUI. The Wildlife BUI was removed from the Deer Lake, St. Marys River, and St. Clair River AOCs in 2011, 2014, and 2017, respectively. There are currently four AOCs in Michigan that have a Wildlife BUI (Table 1; Figure 1). The purpose of this project is to update the assessments made previously (Bush and Bohr, 2012; Bush and Bohr, 2015) using more current contaminant and toxicity data. Specifically, the objectives of this assessment are to determine whether there are enough data available to remove the Wildlife BUI from the four AOCs of interest and to identify additional studies that would assist with future assessments.

Table 1. AOCs with a Wildlife BUI, species impacted, and contaminants determined to be of concern according to the Remedial Action Plans.

AOC	Species	Contaminant[1]
Detroit River	Gulls, ducks	DDE, HCB, PCBs
Kalamazoo River	Mink, birds	PCBs
River Raisin	Eagles	DDT, PCBs
Saginaw River/Bay	Gulls, terns, herons, eagles	PCBs, Dioxins

[1]DDE = Dichlorodiphenyldichloroethane; HCB = Hexachlorobenzene; PCBs = Polychlorinated biphenyls; DDT = Dichlorodiphenyltrichloroethane

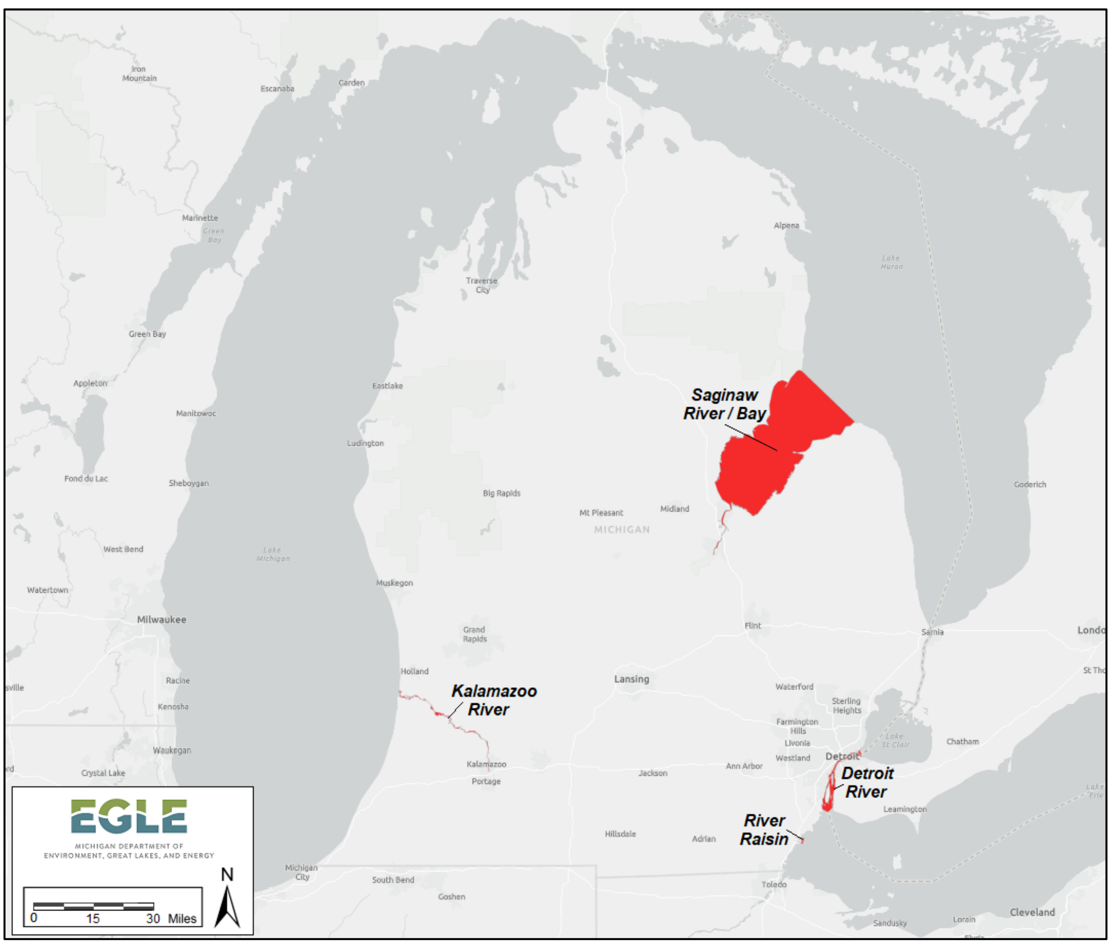

Figure 1. The four Michigan AOCs with a Wildlife BUI.

METHODOLOGY

The methodology provided in the document titled, *Guidance for Delisting Michigan's Great Lakes Areas of Concern* (MDNR, 2018), was used to determine whether sufficient data are available to remove the Wildlife BUI for four of the AOCs. To remove a Wildlife BUI there must be evidence that the reproduction or development of wildlife species within the AOC is no longer being adversely impacted; if adverse effects are evident the BUI may still be removed if the incidence of these effects does not exceed levels found in a comparison population. The following approaches (listed in order of importance) were used to determine whether wildlife within an AOC is being adversely impacted.

- Evaluate observational data on reproductive or developmental effects in wildlife living in the AOC.

- Compare tissue contaminant levels in egg, young, and/or adult wildlife to benchmarks for reproductive or developmental effects.

- Assess whether contaminant levels in fish are sufficiently high to cause reproductive or developmental effects in piscivorous wildlife.

Toxicity benchmarks were derived for total PCBs (referred to as "PCBs" throughout the remainder of this report); *p,p'*-DDE; 2,3,7,8-tetrachloro-*p*-dioxin TEQs; and mercury because studies have shown that these contaminants have adversely impacted Michigan wildlife. For the surrogate species approach, it was also necessary to derive benchmarks based on total DDT (the summation of the *para*, *para'* and *ortho*, *para'* forms of DDT, DDE, and DDD (1,1-bis(4-chlorophenyl)-2,2-dichloroethane) because this is what the animals were dosed with in the laboratory study. After further review, it was considered unnecessary to assess the impacts of mercury on wildlife within the four AOCs because data from Michigan's wildlife and fish contaminant monitoring programs suggest that none of the four AOCs are hotspots for mercury. Even though HCB is listed as being one of the potential causes of adverse effects on wildlife populations living along the Detroit River, it will not be assessed in this report because herring gull egg data (Weseloh et al., 2006) and fish contaminant data show that this contaminant is not elevated in the Detroit River compared to other areas of the state.

A thorough literature search was conducted to locate recent studies of wildlife within the four AOCs. All studies were reviewed even if they involved a wildlife species that was not the basis for the original BUI listing. This was considered a prudent approach since it would be illogical to remove the BUI based on data for one wildlife species when sufficient data are available to show impacts on another species. For this project, we relied heavily on the bald eagle and herring gull monitoring data that Michigan has collected since 1999 and 2002, respectively. Michigan's fish contaminant monitoring database and the recent forage fish data compiled by EGLE were the primary sources of contaminant data for fish within the AOCs. However, a literature search was conducted to locate any recent fish contaminant data available for the AOCs.

As mentioned earlier, Wildlife BUIs are recommended to be retained if there are sufficient data available to conclude that a reproduction or developmental benchmark is exceeded AND the incidence of these effects (or the concentration of the contaminant of interest in the AOC) exceeds levels found in the comparison populations. Comparison populations were selected from areas considered relatively pristine and areas near the AOC. For example, the Manistee River (relatively pristine area) and the Muskegon River (similar nearby area) were selected as comparison populations for the Kalamazoo River AOC. In addition, comparisons were also made to larger populations such as inland territories and territories along the Great Lakes. Based on this approach, it is possible that the removal of a Wildlife BUI will be recommended even if the reproduction or development of wildlife within the AOC is impacted if comparison populations within the state are exhibiting similar problems or have similar contaminant concentrations.

Whenever possible, multiple lines of evidence were used to make conclusions about the status of the Wildlife BUI. Based on the review of wildlife and fish data from the AOC and contaminant concentrations in comparison populations, one of the following conclusions was made: (1) sufficient data available to remove the BUI; (2) sufficient data available to retain the BUI; or (3) insufficient data available to make a determination. If insufficient data were available to determine whether the BUI should be removed, then recommendations for additional research were made.

TOXICITY REFERENCE VALUES (TRV)

TRVs can be defined as "point estimates of chemical doses or concentrations that are used in conjunction with exposure estimates of similar units to ascertain whether wildlife species may be adversely affected due to exposure to a chemical" (Allard et al., 2010). TRVs can be derived for concentrations of contaminants in biological matrices of the species of interest (e.g., eaglet blood, herring gull eggs, or mink liver), or concentrations of contaminants in the diet (e.g., fish tissue). TRVs can be derived using laboratory or field data for the species of interest or a surrogate species. This section describes the basis for bald eagle, colonial nesting bird, and mink TRVs used in this assessment.

Reviews by Bosveld and Van Den Berg (1994), USEPA (1995); Hoffman et al. (1996); Burger and Gochfeld (1997); Elliott and Harris (2001/2002); Fox and Bowerman (2005); Scheuhammer et al. (2007); and Blankenship et al. (2008) were used to determine the TRVs for *p,p'*-DDE, PCBs, TEQs, and mercury in wildlife species. No effort was made to update the TEQs reported in the original studies using the more current toxicity equivalence factors (TEF). Whenever possible, the TRVs were based on studies of bald eagles and/or colonial nesting birds since these types of birds have been shown to be sensitive to *p,p'*-DDE and PCBs and they are the basis for many of the Wildlife BUIs. TRVs for other bird species were used when limited data were available for bald eagles and/or colonial nesting birds. TRVs were also provided for mink since they are sensitive to the effects of PCBs, TEQs, and mercury. All concentrations presented in this document are reported as wet weight concentrations.

The concentrations of contaminants in fish that could cause adverse effects in bald eagles and colonial nesting birds were derived using two methods. The first method extrapolated from effect levels for contaminants in eggs of bald eagles and colonial nesting birds to fish tissue levels using relationships derived in the field. The second approach used dietary toxicity studies on surrogate bird species to extrapolate to a dietary concentration that could cause adverse effects in bald eagles and colonial nesting birds. Fish tissue concentrations that could adversely affect mink were derived using studies that either fed mink fish collected from a contaminated area or diets treated with the chemical of interest. Since the dietary concentrations were measured in these studies, the confidence in the fish tissue levels estimated to cause adverse effects in mink is high. Because surrogate bird species are normally needed to assess the effects of contaminants on bald eagles and colonial nesting birds, the protectiveness of the TRVs is less certain.

We updated the surrogate species approach used by Newell et al. (1987) by incorporating results from more recent laboratory and field studies. We also used fish consumption rates and body weights for wildlife based on the review conducted by the USEPA (1995). In addition, our assessment of laboratory studies focused on endpoints that would impact wildlife populations (i.e., growth, survival, and reproduction/development) and not just individual animals. Newell et al. (1987) also estimated the concentration of contaminants that would pose a cancer risk of 1 in 100. Cancer risk was not assessed for this project since the use of reproduction/developmental endpoints was considered more appropriate for the protection of wildlife populations than cancer risk and none of the Wildlife BUIs were based on an increased incidence of cancer in wildlife.

Bald Eagles:

<u>*Productivity-*</u>

The productivity of a bald eagle population can be quantified by dividing the total number of fledged young by the number of occupied nests (Postupalsky, 1974). Productivity of a bald eagle population must be at least 0.7 young per occupied nest for the population to be considered stable (Sprunt et al., 1973) and 1.0 young per occupied nest for a population to be considered healthy (Grier et al., 1983 based on data presented in Sprunt et al., 1973). For these endpoints, overall productivity was based on a five-year period (2014-2018) so that factors other than contaminants that may have an impact on productivity would not have as much influence on the resulting value (Wiemeyer et al., 1984). Observation flights were conducted statewide from 2014-2017. In 2018, monitoring was limited to the AOCs and reference areas; therefore, statewide productivity estimates are only based on territories that had five years of data.

<u>*Blood Concentration-*</u>

The concentration of *p,p'*-DDE and PCBs in the plasma of eaglets has been correlated with the productivity of bald eagles (Bowerman et al., 2003). This relationship can be used to determine mean concentrations of *p,p'*-DDE and PCBs in eaglet plasma that are associated with stable or healthy bald eagle populations. Using the productivity and contaminant data for various areas of the Great Lakes region provided in Bowerman et al. (2003), the following relationships between productivity and PCB and *p,p'*-DDE concentrations were determined:

Productivity = -0.00335 (µg PCBs/kg plasma concentration) + 1.11866 (R^2 = 0.65)
Productivity = -0.018 (µg *p,p'*-DDE/kg plasma concentration) + 1.2060 (R^2 = 0.75)

Using the equations presented above, eaglet plasma concentrations of 11 micrograms per kilogram (µg/kg) and 35 µg/kg for *p,p'*-DDE and PCBs, respectively, are associated with a productivity of 1.0 young per occupied nest. Concentrations of PCBs and *p,p'*-DDE in eaglet plasma at these levels and below are associated with healthy bald eagle populations. Eaglet plasma concentrations of 28 µg/kg and 125 µg/kg for *p,p'*-DDE and PCBs, respectively, are associated with a productivity of 0.7 young per occupied nest. Concentrations of PCBs and *p,p'*-DDE in eaglet plasma at these levels and below are associated with stable bald eagle populations. Elliott and Harris (2001/2002) determined threshold values associated with a productivity of 0.7 young per active nest for *p,p'*-DDE and PCBs in eaglet plasma of 28 µg/kg and 190 µg/kg, respectively, by extrapolating from egg concentrations to blood levels. Since the concentrations of *p,p'*-DDE and PCBs are correlated, it is not possible to determine the degree to which each contaminant affects the bald eagle population. The plasma concentration of TEQs in eaglets that would not adversely affect bald eagles is unknown.

No studies have related mercury exposure to a decrease in the productivity of bald eagles in the environment (Scheuhammer et al., 2007). It was therefore not possible to derive TRVs for mercury in eagle feathers.

Egg Concentration-

Contaminant concentrations in eggs have been associated with various effects on bald eagle populations. No Observable Adverse Effect Concentrations (NOAEC), Lowest Observable Adverse Effect Concentrations (LOAEC), and other effect levels in bald eagle eggs are provided in Table 2. A brief explanation of which values are considered most suitable for risk assessment purposes is provided below:

- The egg concentration associated with a productivity of 1.0 young/occupied nest was considered a NOAEC for this project since this is the recovery goal of the Northern States Bald Eagle Recovery Plan (Grier et al., 1983). The egg concentration associated with a productivity of 0.7 young/occupied nest was also used for this project since it is considered the concentration associated with a stable population by Sprunt et al. (1973).

- The egg *p,p'*-DDE concentrations of 3.5 milligrams per kilogram (mg/kg) (Wiemeyer et al., 1993) and 6.5 mg/kg (Best et al., 2010) associated with a productivity of 1.0 and 0.7 young/occupied nest, respectively, were used for risk assessment purposes. The results of the assessment conducted by Wiemeyer et al. (1993) was considered more suitable than Wiemeyer et al. (1984) because it was based on more data.

- The egg PCB concentration of 4.0 mg/kg (Wiemeyer, 1990) and 26 mg/kg (Best et al., 2010) associated with a productivity of 1.0 ("normal reproduction") and 0.7 young/occupied nest, respectively, were used for risk assessment purposes. The value of 4.0 mg/kg is higher than the concentration of < 3.0 mg/kg reported by Wiemeyer et al., (1993) because it has been corrected for some of the influence that *p,p'*-DDE has on bald eagle toxicity (Bowerman, 2012). This was considered a valid approach because the influence of *p,p'*-DDE on the effects of PCBs on bald eagle productivity has declined over the years. The NOAEC of 4.0 mg/kg has also been used for ecological risk assessments in the past (Giesy et al., 1995).

- It was necessary to use enzyme induction as the endpoint for TEQs because no adverse effects were observed on morphological, physiological, or histological parameters measured in the bald eagle study by Elliott et al. (1996).

- The NOAEC of 0.5 mg/kg mercury found in bald eagles (Anthony et al., 2007) was used in this assessment. A study of mercury on American kestrels found a similar NOAEC (Albers et al., 2007).

Table 2. Egg NOAEC and Effect Levels for *p,p'*-DDE, PCBs, TEQs, and mercury in bald eagles.

Chemical	Egg Concentration	Endpoint	Reference
p,p'-DDE (mg/kg)	< 3.0	1.0 Young/occupied nest	Wiemeyer et al., 1984
	3.5	1.0 Young/occupied nest	Wiemeyer et al., 1993
	16	15% Eggshell thinning	Wiemeyer et al., 1993
	6.5	0.7 Young/occupied nest	Best et al., 2010
PCBs (mg/kg)	< 4.5	1.0 Young/occupied nest	Wiemeyer et al., 1984
	< 3.0	1.0 Young/occupied nest	Wiemeyer et al., 1993
	4.0	Normal reproduction	Wiemeyer, 1990
	5.5	Successful nests	Wiemeyer et al., 1993
	8.7	Unsuccessful nests	Wiemeyer et al., 1993
	20	0.7 Young/occupied nest	Elliott and Harris 2001/2002
	26	0.7 Young/occupied nest	Best et al., 2010
	20	Increased probability of nest failure	Stratus Consulting Inc., 1999
TEQs (μg/kg)	0.10	Enzyme induction NOAEC	Elliott et al., 1996; Elliott and Harris, 2001/2002
	0.21	Enzyme induction	Elliott et al., 1996; Elliott and Harris, 2001/2002
Mercury (mg/kg)	0.5	Productivity NOAEC	Anthony et al., 2007
	0.7*	Reproductive NOAEC	Albers et al., 2007
	2.0*	Reproductive effects	Albers et al., 2007

*Based on data for American kestrels.

Fish Tissue Concentration-

Two approaches were used to estimate the fish tissue concentrations of various contaminants that may cause adverse effects on bald eagle populations. The first approach, the "BMF Approach," used the field-derived Biomagnification Factors (BMF) generated by Giesy et al. (1995) and Kubiak and Best (1991) to extrapolate from effect levels in eggs to fish tissue levels. The study by Giesy et al. (1995) derived BMFs using multiple species of fish (chinook, pike, walleye, sucker, steelhead, carp, and perch) from Great Lakes-influenced sections of the Au Sable, Manistee, and Muskegon Rivers, whereas the BMF reported for TEQs by Kubiak and Best (1991) was based on data for northern pike from Thunder Bay (northwestern Lake Huron). This approach should be used with caution since data provided by Kubiak and Best (1991) suggest that the BMF can vary based on the fish species. The second approach, the "Surrogate Species Approach," used toxicity studies in surrogate bird species to determine a dietary NOAEC and LOAEC in bald eagles.

BMF Approach-

The following equation was used to derive the fish tissue levels provided in Table 3:

$$Fish\ Tissue\ Level = \frac{NOAEC\ (or\ Effect\ Level)\ in\ Bird\ Egg}{BMF}$$

Table 3. Dietary NOAEC and Effect Levels (mg/kg) for PCBs, *p,p'*-DDE, TEQs, and Mercury.

Endpoint	PCBs	*p,p'*-DDE	TEQs	Mercury
NOAEC (mg/kg egg)	4.0	3.5	0.00010	0.5
Effect Level (mg/kg egg)	26	6.5	0.00021	2.0
BMF	28	22	19	1.0
Fish Tissue NOAEC (mg/kg)	0.14	0.16	0.0000053	0.5
Fish Tissue LOAEC (mg/kg)	0.93	0.30	0.000011	2.0

No field studies were found in the literature that determined the concentration of mercury in fish that could adversely impact bald eagles. However, a field study examining the effects of mercury on osprey at 21 sites in the James Bay and Hudson Bay regions of Canada was available (DesGranges et al., 1998). In this study, no effects were found on the fledging of osprey consuming fish with concentrations of mercury as high as 2.44 mg/kg. The mean for all sites examined in the study was 1.4 mg/kg (Fuchsman et al., 2016). This value provides support for the fish tissue NOAEC of 0.5 mg/kg calculated in the assessment provided above.

Surrogate Species Approach-

The surrogate species approach is based on the methodology used in the Great Lakes Initiative for deriving a wildlife value. As part of the Great Lakes Initiative, surface water criteria protective of avian and mammalian wildlife (wildlife values) were derived for PCBs; DDT; 2,3,7,8-TCDD; and mercury (USEPA, 1995). For the avian wildlife values, the geometric mean of the water concentration protective of kingfishers, herring gulls, and bald eagles were used to determine the concentration that would be protective of all avian wildlife. Since suitable toxicity tests were not available for these three bird species, the water concentrations were derived by using toxicity tests conducted on surrogate bird species. The tests conducted on surrogate species can be used to derive a fish tissue level that is estimated to cause no adverse effects (fish tissue NOAEC) or adverse effects (fish tissue LOAEC) on bald eagle populations.

The Test Dose (TD) was based on a no-observed-adverse-effect level (NOAEL) or lowest-observed-adverse-effect level (LOAEL) for growth, reproduction/development, or survival because these endpoints were considered most appropriate for the protection of wildlife populations. In some cases, the TD for the surrogate species was divided by uncertainty factors (UF) to account for LOAEL-to-NOAEL and/or subchronic-to-chronic extrapolations. An additional UF was used to account for possible differences in sensitivity between the species of interest and the surrogate species. The dose that was determined to be protective of bald eagles was then multiplied by the bald eagle's body weight and then divided by an appropriate fish consumption rate for bald eagles per USEPA (1995). No correction was made in the calculation of the fish tissue level to account for the percentage of trophic level 3 and 4 fish that were consumed.

The following equation was used to derive the fish tissue levels provided in Table 4:

$$Fish\ Tissue\ Level = \frac{\left(\frac{TD}{UF}\right) * Body\ Weight}{Fish\ Consumption} = \frac{\left(\frac{TD}{UF}\right) * 4.6\ kg}{0.4639\ kg/d}$$

Where: TD = test dose; UF = uncertainty factor

Table 4. Surrogate species, key study, TD (mg/kg/d), total UF (the UF for LOAEL-to-NOAEL extrapolation is provided in parentheses) and the resulting fish tissue levels (mg/kg) that are estimated to cause no adverse effects (NOAEC) or adverse effects (LOAEC) on bald eagle populations.

Chemical	PCBs	DDT	2,3,7,8-TCDD	Mercury
Surrogate Species	Pheasant	Pelican	Pheasant	Mallard
Key Study	Dahlgren et al., 1972	Anderson et al., 1975; 1977	Nosek et al., 1992	Heinz, 1974; 1975; 1976a; 1976b; and 1979
TD	1.8 (LOAEL)	0.027 (LOAEL)	0.000014 (NOAEL)*	0.078 (LOAEL)
UF	9 (3)	3 (3)	10 (1)	6 (2)
Fish Tissue NOAEC	2.0	0.089	0.000014	0.13
Fish Tissue LOAEC	3.0	0.27	0.00014	0.26

*LOAEL = 0.00014 mg/kg/d

Colonial Nesting Birds:

Productivity-

According to a review by Fox and Bowerman (2005), a herring gull population is stable if there are 0.8-1.0 young/nest, whereas, a common tern population is stable if there are 1.1 young/pair.

Egg Concentration-

Benchmarks in eggs for PCBs, *p,p'*-DDE, TEQs, and mercury derived from North American field studies conducted on colonial nesting birds are provided in Table 5. The following observations were considered noteworthy:

- The NOAEC of 0.22 µg/kg TEQs found by Elliott et al. (2001) in great blue herons exposed to contaminants from a pulp mill is much higher than the range of concentrations (> 0.005 to 0.020 µg/kg) found to adversely affect wood ducks exposed to contaminants from a chemical plant (White and Seginak,1994). This disparity could be due to differences in sensitivity between the two species, exposure to different dioxin congeners, or exposure to different chemicals (Elliott et al., 2001). The NOAEL of 4.6 µg/kg 2,3,7,8-TCDD found in a wood duck egg injection study (Augspurger et al., 2008) suggests that wood ducks are not as sensitive to TEQs as great blue herons. The wood duck data are not included in Table 5 because there are sufficient data available to determine effect levels for colonial nesting birds.

- Only *p,p'*-DDE concentrations expected to cause 20% eggshell thinning were included in the table since this is the amount of thinning expected to cause adverse effects on populations of colonial nesting birds (Pearce et al., 1979).

- Very few studies were found in the literature that identified contaminant levels that caused adverse effects on herring gull populations (Weseloh et al., 1990 and 1994;

Ewins et al., 1992). One of the few studies found in the literature showed decreased hatching success in herring gulls from Lake Ontario during the mid-1970s due most likely to very high PCB concentrations of 142 mg/kg in eggs (Gilman et al., 1977; Peakall and Fox, 1987). However, more recent studies (Grasman, 2015; 2018; 2019a, b) have determined that PCBs and TEQs may be causing adverse effects on the immune systems of herring gulls and other colonial nesting birds in the Saginaw River/Bay and River Raisin AOCs. These findings, in combination with herring gull egg contaminant data from EGLE's wildlife monitoring program, were used to identify LOAECs for PCBs and TEQs in herring gull eggs.

- A review of the results of laboratory and field studies on birds conducted by Stratus Consulting, Inc. (1999) concluded that the toxicity thresholds for reproductive malfunctions, embryo mortality, and embryo deformities in the eggs of sensitive bird species ranged from 5 to 10 mg/kg for PCBs and 0.2 to 10 µg/kg for TEQs.

Table 5. Egg NOAECs and Effect Levels for PCBs, *p,p'*-DDE, TEQs, and mercury for various species of colonial nesting birds.

Chemical	Species	NOAEC	Effect Level	Reference
Mercury	Herring gull	2-16 mg/kg	Not available	Vermeer et al., 1973
Mercury	Common tern	1.0 mg/kg	3.65 mg/kg (10% fledging success)	Fimreite, 1974
PCBs	Herring gull	Not available	1.8-4.9 mg/kg (immunotoxicity)	Grasman, 2018*
PCBs	Common tern	4.7 mg/kg	7.6 mg/kg (60% hatching success)	Hoffman et al., 1993
PCBs	Forster's tern	4.5 mg/kg	22.2 mg/kg (37% hatching success)	Kubiak et al., 1989
PCBs	Caspian tern	Not available	4.2 mg/kg (egg lethality and deformities)	Yamashita et al., 1993
PCBs	Double-crested cormorant	3.6 mg/kg (2% deformities)	7.3 mg/kg (6-7% deformities)	Yamashita et al., 1993
PCBs	Great blue heron	2.01 mg/kg	Not available	Halbrook et al., 1999a
TEQs	Herring gull	Not available	0.47-0.51 µg/kg (immunotoxicity)	Grasman, 2018*
TEQs	Forster's tern	0.22 µg/kg	2.18 µg/kg (hatching success)	Kubiak et al., 1989
TEQs	Double-crested cormorant	0.35 µg/kg (2% deformities)	1.20 µg/kg (6-7% deformities)	Yamashita et al., 1993
TEQs	Great blue heron	0.22 µg/kg	0.36 µg/kg (embryotoxicity)	Elliott et al., 2001
p,p'-DDE	Double-crested cormorant	Not available	10 mg/kg (20% eggshell thinning)	Pearce et al., 1979
p,p'-DDE	Great blue heron	Not available	19 mg/kg (20% eggshell thinning)	Blus, 1996

*Herring gull egg contaminant results from EGLE's monitoring program were used in combination with field studies conducted by Grasman (2018) to determine the LOAEC.

Fish Tissue Concentration-

Three approaches were used to determine the fish tissue concentrations of contaminants that could potentially cause adverse effects in colonial nesting birds: the BMF Approach, the Surrogate Species Approach, and the Field Data Approach. The first approach used BMFs to relate the contaminant concentration in eggs of colonial nesting birds shown to cause adverse effects to a contaminant concentration in fish; the second approach used toxicity studies in surrogate bird species to estimate the dietary concentration of contaminants that might adversely impact colonial nesting birds; and the third approach measured the concentration of contaminants in forage fish and then examined the results of field studies of colonial nesting birds.

BMF Approach-

The BMFs for PCBs, *p,p'*-DDE, and 2,3,7,8-TCDD were developed using the concentrations of contaminants measured in herring gull eggs from a colony in eastern Lake Ontario and alewives collected from three sites in western Lake Ontario (Braune and Norstrom, 1989). Even though changes have occurred in the foraging behavior of herring gulls over time (Hebert et al., 2008 and 2009), the BMFs reported for PCBs and *p,p'*-DDE in Table 6 are consistent with BMFs of 40 and 39 determined for PCBs and *p,p'*-DDE, respectively, by EGLE for the Saginaw River/Bay AOC. Another approach was needed to determine the BMF for mercury since the study by Braune and Norstrom (1989) did not analyze for this substance.

The median concentration of mercury in herring gull eggs collected from 2008-2012 for Little Charity Island (Saginaw River/Bay AOC) and Five-Mile Island and West Twin Pipe Island (St. Marys River AOC) combined were both 0.40 mg/kg (Table 14). The average concentration of mercury in forage fish from the Saginaw River/Bay AOC and the St. Marys River AOC were 0.03 and 0.052 mg/kg, respectively (Table 18). The BMF for the Saginaw River/Bay AOC and the St. Marys River AOC are therefore 7.7 and 13, respectively, resulting in an average BMF of 10.

The following equation was used to derive the fish tissue levels provided in Table 6:

$$Fish\ Tissue\ Level = \frac{NOAEC\ (or\ Effect\ Level)\ in\ Bird\ Egg}{BMF}$$

Table 6. Dietary NOAECs and LOAECs (mg/kg) for PCBs, *p,p'*-DDE, TEQs, and mercury.

Endpoint	PCBs	*p,p'*-DDE	TEQs	Mercury
NOAEC (mg/kg egg)	3.6 (cormorant)	Not available	0.00022 (heron)	1.0 (tern)
LOAEC (mg/kg egg)	7.3 (cormorant)	10 (cormorant)	0.00036 (heron)	3.65 (tern)
BMF	32 (gull)	34 (gull)	21* (gull)	10 (gull)
Fish Tissue NOAEC	0.11	Not available	0.000010	0.10
Fish Tissue LOAEC	0.23	0.29	0.000017	0.37

*This is the BMF for 2,3,7,8-TCDD. Using this value results in a conservative value for TEQs since the BMF reported for other dioxin congeners ranged from 4.5 to 9.7 (Braune and Norstrom, 1989).

Surrogate Species Approach-

The second approach uses toxicity studies in surrogate bird species to determine dietary concentrations that would either be protective (fish tissue NOAEC) or that could potentially cause adverse effects (fish tissue LOAEC) on colonial nesting bird populations. The fish tissue level was derived using the body weight and fish consumption rate of herring gulls (USEPA, 1995) since this species was the only one of the three avian species used in the Great Lakes Initiative that was a colonial nesting bird.

The following equation was used to derive the fish tissue levels provided in Table 7:

$$Fish\ Tissue\ Level = \frac{\left(\frac{TD}{UF}\right) * Body\ Weight}{Fish\ Consumption} = \frac{\left(\frac{TD}{UF}\right) * 1.1\ kg}{0.24\ kg/d}$$

Table 7. Surrogate species, key study, TD (mg/kg/d), total UF (UF for LOAEL-to-NOAEL extrapolation in parentheses) and the resulting fish tissue levels (mg/kg) estimated to be protective (NOAEC) or cause adverse effects (LOAEC) in herring gull populations.

Chemical	PCBs	DDT	2,3,7,8-TCDD	Mercury	Mercury
Surrogate Species	Pheasant	Pelican	Pheasant	Mallard	Loon
Key Study	Dahlgren et al., 1972	Anderson et al., 1975; 1977	Nosek et al., 1992	Heinz, 1974; 1975; 1976a; 1976b; and 1979	Evers et al., 2004; Depew et al., 2012
TD	1.8 (LOAEL)	0.027 (LOAEL)	0.000014 (NOAEL)*	0.078 (LOAEL)	Not available
UF	9 (3)	3 (3)	10 (1)	6 (2)	Not available
Fish Tissue NOAEC	0.92	0.041	0.0000064	0.06	0.05
Fish Tissue LOAEC	1.4	0.12	0.000064	0.12	0.18

*LOAEL = 0.00014 mg/kg.

Since many recent studies have shown that loons are very sensitive to the effects of mercury, it was considered reasonable to determine a fish tissue benchmark based on these new data. Given loon sensitivity to mercury, this fish tissue level would be expected to be protective of colonial nesting birds.

A field study by Barr (1986) found adverse effects (fewer nests, clutches of one egg instead of two, and no progeny) on loons that consumed fish with mercury concentrations ranging from 0.3 to 0.4 mg/kg, whereas, Burgess and Meyer (2008) determined that loon productivity dropped 50% when fish mercury levels were 0.21 mg/kg and failed completely when fish mercury concentrations were 0.41 mg/kg. Based on field data, Evers et al. (2004) considered a fish tissue concentration of 0.15 mg/kg mercury to be a LOAEC and a concentration of 0.05 mg/kg to be a NOAEC. A recent evaluation of studies on loons derived dietary benchmarks for loons of 0.1, 0.18, and 0.4 mg/kg (Depew et al., 2012). The lowest benchmark is the threshold for adverse behavioral impacts, the next higher benchmark is associated with reproductive impairment, and the highest benchmark is associated with reproductive failure in adult loons.

In laboratory studies by Kenow et al. (2003, 2007a, and 2007b), juvenile loons were fed diets containing 0.08, 0.4, and 1.2 mg/kg mercury for 105 days. No overt toxicity or reduction in growth was found in any treatment group. However, decreased immune function and demyelinization of central nervous system tissue occurred in loons consuming the 0.4 mg/kg dietary concentration. No effects were observed in loons consuming dietary concentrations of 0.08 mg/kg. Since Kenow et al. (2008) found that blood mercury levels were still increasing at the end of their study, the dietary concentration of 0.08 mg/kg food is considered a dietary NOAEC for a less than lifetime exposure.

The dietary LOAEC of 0.18 mg/kg determined by Depew et al. (2012) will be used for the assessment because it is the most recent and thorough assessment of impacts of mercury on loons. The dietary benchmark of 0.1 mg/kg was not used because the authors had little confidence in the value. Instead, the dietary NOAEC of 0.05 mg/kg identified by Evers et al. (2004) will continue to be used. If these data were used to determine a dietary concentration protective of colonial nesting birds, there would be no need to apply UFs to the assessment since studies examined a sensitive endpoint over a long period of time and loons are highly sensitive to the effects of mercury. These values are consistent with the fish tissue NOAEC of 0.06 mg/kg and LOAEC of 0.12 mg/kg determined using a TD for mallards. The use of the loon data is also more appropriate because they are based on field data, which is a more realistic exposure scenario.

Field Data Approach-

The results of three recent studies in combination with the forage fish data collected by EGLE can be used to determine levels of contaminants in forage fish associated with effect and no effect levels in colonial nesting birds. The validity of this approach depends on how accurately the forage fish replicate the species/size of fish routinely consumed by colonial nesting birds and whether the contaminant levels found in fish from the sampling sites are similar to levels found at sites within the AOCs where the colonial nesting birds are feeding. The following three studies were used in this assessment:

- Consistent with past studies (Grasman, 2015), herring gulls on Little Charity Island and the Saginaw Confined Disposal Facility had suppressed immune systems, elevated embryonic infertility, and increased frequency of failed development during a study conducted from 2014 to 2019 (Grasman et al., 2019a). Caspian terns had lower productivity (with complete reproductive failure in 2015 and 2016) and suppressed immune systems in the Saginaw Bay AOC compared to reference sites. Black-crowned night herons nesting on the Saginaw Bay Confined Disposal Facility also exhibited suppressed immune systems (Grasman et al., 2019a). An earlier study by the same researcher found a strong correlation between effects on the immune system of herring gulls and the concentration of PCBs and TEQs in their livers (Grasman et al., 2013).

  Evidence that PCBs and TEQs can adversely impact the immune system of birds has also been reported in laboratory studies. For example, plasma total triiodothyronine was decreased in mallards exposed to 20 mg/kg Aroclor 1254 for five weeks (Fowles et al., 1997). Thyroid weight in these birds was significantly increased at dietary exposures ≥ 100 mg/kg. Additionally, male American kestrels exposed to a mixture of PCBs in their diet had increased total white blood cell counts and depressed plasma total triiodothyronine levels in both sexes (Smits et al., 2002). Furthermore, female American kestrels fed a mixture of PCBs at 7 mg/kg/d for 120 days had significantly higher antibody production, whereas, its production was suppressed in males (Smits and Bortolotti, 2001). Moreover, chicken eggs injected with PCB 126 resulted in reduced thymus mass, lymphoid cell numbers, and bursa mass (Fox and Grasman, 1999). Similarly, chicken eggs injected with PCB 126 or PCB 77 resulted in a two-fold suppression of antibody titers in 28-day old chicks and decreased thymus and bursa cellularity in 14-day old chicks (Lavoie and Grasman, 2007). *In ovo* exposure of chicken eggs to PCB 126 (1.2 nanograms [ng] TEQ/egg) resulted in similar elevated antibody titers that were observed in Caspian tern chicks from the Saginaw River/Bay AOC (Lavoie et al., 2007, Grasman and Fox, 2001).

Forage fish were collected from the Saginaw River/Bay AOC in 2014 and 2016. The concentrations of PCBs in the forage fish collected from the east and west sides of the bay differed from the analytical results of fish collected from the river and in the southern part of the bay. The fish collected from the Saginaw River and the southern part of the bay had an average PCB concentration of 0.149 mg/kg, whereas, fish collected on the northwest shore and east shore of the bay had an average PCB concentration of 0.035 mg/kg. Forage fish from the three sites in Saginaw Bay had an average TEQ concentration of 4.54 ng/kg (Bush and Bohr, 2015).

- Herring gulls and common terns breeding within the St. Marys River AOC were examined for reproductive and developmental effects in 2011 and 2012. Freshly laid eggs were collected, artificially incubated, and then assessed for embryonic viability, embryonic deformities, and contaminant levels. The study concluded that the concentrations of PCBs and other contaminants were not at levels that would impact the reproduction and development of herring gulls and common terns nesting in the St. Marys River AOC (Hughes et al., 2014c).

  The forage fish collected in 2013 by EGLE from the St. Marys River had an average PCB concentration of 0.007 mg/kg.

- Black-crowned night herons breeding on Turkey Island in the Detroit River AOC were examined for reproductive and developmental effects in 2009 and 2011 (Hughes et al., 2013). A decrease in the number of fledged young occurred on Turkey Island in both years of the study compared to the control colony on Nottawasaga Island in Georgian Bay. Higher levels of contaminants were found in eggs from birds living on Turkey Island compared to the control population. The researchers surmised that decreased reproduction on Turkey Island may be due to stressors other than contaminants such as predation, weather, and disturbance.

  The forage fish (bluntnose minnow, spottail shiner, and emerald shiner) collected from the Canadian side of the Detroit River near Fighting Island in 2011 and 2012 by the University of Windsor had an average PCB concentration of 0.012 and 0.087 mg/kg, respectively (the fish collected in 2012 were larger than those collected in 2011). The average concentration for both years combined was 0.049 mg/kg (McLeod et al., 2014; McLeod - personal communication, 2015).

  The forage fish collected from the American side of the Detroit River in 2013 by EGLE had an average PCB concentration of 0.573 mg/kg, whereas, the forage fish from the Canadian side had an average concentration of 0.049 mg/kg suggesting that there may be a difference in contaminant levels from the two sides of the river. Since the forage fish collected from near Fighting Island are closest to Turkey Island, they were used in the assessment provided below.

Table 8 relates the findings of the studies on colonial nesting birds in the St. Marys River AOC, Detroit River AOC, and Saginaw River/Bay AOC to the concentrations of PCBs in eggs and forage fish.

Table 9 relates the effects found on colonial nesting birds in the Saginaw River/Bay AOC to concentrations of TEQs in herring gull eggs and forage fish.

Table 8. Concentrations of PCBs in colonial nesting bird eggs and forage fish in select AOCs from recent studies.

Species	Location	Egg Concentration (mg/kg)	Forage Fish Concentration (mg/kg)	Effect
Herring gull	St. Marys River AOC	1.6, 1.5	**0.007**	No effect
Common tern	St. Marys River AOC	0.83	**0.007**	No effect
Black-crowned night heron	Detroit River AOC	1.2	0.012 (2011) 0.087 (2012) **Average = 0.049**	Decreased fledged young*
Herring gull (Caspian terns and black-crowned night herons also impacted)	Saginaw River/Bay AOC	1.8	0.035 (outer bay) 0.149 (river, inner bay) **Average = 0.073**	Embryo-lethality, suppressed immune system

*Researchers concluded that effects were not related to contaminants

Table 9. Concentrations of TEQs in colonial nesting bird eggs and forage fish from Saginaw Bay from Bush and Bohr (2015).

Species	Location	Egg Concentration (ng/kg)	Forage Fish Concentration (ng/kg)	Effect
Herring gull (Caspian terns and black-crowned night herons also impacted)	Saginaw River/Bay AOC	466	4.54	Embryo-lethality, decreased growth, suppressed immune system

The data provided in Table 8 and Table 9 suggest that colonial nesting birds feeding on forage fish with average PCB and TEQ concentrations of 0.091 and 0.0000045 mg/kg, respectively, may exhibit adverse effects. Both the PCB and TEQ concentrations in forage fish estimated to cause adverse effects to colonial nesting birds are lower than concentrations estimated using other approaches.

Mink:

The sensitivity of mink to various contaminants, its high trophic status, ability to accumulate contaminants, and relatively small home range make it a good indicator species of environmental health (Basu et al., 2007). Many toxicity studies have examined the reproductive effects of feeding mink fish collected from sites contaminated with PCBs, dioxins, and/or furans. For example, mink have been fed fish from the Hudson River, New York (Bursian et al., 2013a; 2013b), the Housatonic River, Massachusetts (Bursian et al., 2006a; 2006b), the Saginaw River, Michigan (Bursian et al., 2006c), the Saginaw Bay, Michigan (Heaton et al., 1995; Restum et al., 1998), and the Poplar Creek/Clinch River, Tennessee (Halbrook et al., 1999b). The few studies that examined the toxicity of mercury and *p,p'*-DDE on mink are based on laboratory studies. The results of these studies are provided in Table 8 and Table 9.

A recent review (Blankenship et al., 2008) of the more than 30 studies that examined the effects of dioxin-like compounds on mink concluded that Bursian et al. (2006a; 2006b; and 2006c) and Zwiernik et al. (2009) were the best studies available for the derivation of liver and dietary TRVs for TEQs. The review recommended that the studies that exposed mink to fish from Saginaw Bay (Heaton et al., 1995; Restum et al., 1998) should not be used because of "confounding impacts of other co-contaminants." For this project, the Heaton et al. (1995) and Restum et al. (1998) studies will be included in the assessment since they examined the reproductive effects of mink that were fed fish collected from one of the areas of focus of this project, they provided a lower bound for reproductive effects in mink, and one of the studies examined the toxicity of PCBs to mink over multiple generations. The study conducted by Zwiernik et al. (2009) was not used because it only exposed mink to 2,3,7,8-tetrachloro-dibenzofuran and our assessment was focused on studies that exposed mink to PCBs and TEQs in fish. All studies that exposed mink to fish collected from contaminated sites should be used with caution since the fish contained contaminants other than just dioxin-like compounds that could influence the results of the toxicity studies.

Liver Concentration-

Toxicity studies were available to relate the concentrations of PCBs and TEQs in the livers of mink to reproductive and developmental effects. The NOAEC and LOAEC values provided below for the Housatonic River, Saginaw River, Hudson River, and the Saginaw Bay were taken from Bursian et al. (2013a and 2013b). It is important to note that the jaw lesion LOAECs provided in Table 10 do not take into account the severity of the lesions. For example, the lesions found in mink from the Hudson River were considered mild at PCB and TEQ concentrations ≤ 2.9 mg/kg and 0.000061 mg/kg, respectively (Bursian et al., 2013b). Jaw lesions can impact the survival of mink since lesions can eventually result in loose and displaced teeth (Beckett et al., 2005).

Table 10. Liver concentrations of PCBs and TEQs associated with reproductive/developmental effects in mink fed contaminated fish.

Chemical	NOAEC	LOAEC	Endpoint	Study Location	Reference
PCBs (mg/kg)	3.08	3.13	kit survival at six weeks	Housatonic River	Bursian et al., 2006a,b
	0.73	1.7	jaw lesions	Housatonic River	Bursian et al., 2006b
	8.1	16	jaw lesions	Saginaw River	Bursian et al., 2006c
	2.2	2.9	kit weight at six weeks	Hudson River	Bursian et al., 2013a
	0.053	1.2	jaw lesions	Hudson River	Bursian et al., 2013b
	NA	2.2	kit survival and weight at three and six weeks	Saginaw Bay	Heaton et al., 1995
	6.0	7.3	kit weight at six weeks	Oak Ridge Reservation	Halbrook et al., 1999b
TEQs (µg/kg)	0.05	0.189	kit survival at six weeks	Housatonic River	Bursian et al., 2006a
	0.016	0.032	jaw lesions	Housatonic River	Bursian et al., 2006b
	0.02	0.052	jaw lesions	Saginaw River	Bursian et al., 2006c
	0.018	0.061	kit weight at six weeks	Hudson River	Bursian et al., 2013a
	0.0022	0.029	jaw lesions	Hudson River	Bursian et al., 2013b
	NA	0.226	kit survival and weight at three and six weeks	Saginaw Bay	Heaton et al., 1995

Fish Tissue Concentration-

Sufficient toxicity studies on mink were available to derive dietary NOAECs and LOAECs for PCBs, TEQs, and mercury (Table 11). The use of a surrogate species was used to derive a fish tissue level for DDT because the studies that did examine the effects of DDT on mink (Gilbert, 1969, Aulerich and Ringer, 1970, and Duby et al., 1971) were considered to be of insufficient design for use in the derivation of a fish tissue level. Studies used to establish values for PCBs and TEQs were well-suited for the derivation of fish tissue levels because the mink in the studies were exposed to fish collected from areas with elevated contaminant levels. The NOAEC and LOAEC values provided below for the Housatonic River, Saginaw River, Hudson River, and the Saginaw Bay studies were taken from Bursian et al. (2013a and 2013b). It is important to note that the jaw lesion LOAECs provided in Table 11 do not take into account the severity of the lesions. For example, the lesions found in mink from the Hudson River were considered mild at PCB and TEQ concentrations ≤ 1.5 mg/kg and 0.0001 mg/kg, respectively (Bursian et al., 2013b).

Table 11. Dietary NOAECs and LOAECs for PCBs, TEQs, DDT, and mercury in mink.

Chemical	NOAEC	LOAEC	Endpoint	Reference
PCBs (mg/kg)	1.6	3.7	kit survival at six weeks	Bursian et al., 2006a
	0.61	0.96	jaw lesions	Bursian et al., 2006b
	0.83	1.1	jaw lesions	Bursian et al., 2006c
	0.72	1.5	kit weight at six weeks	Bursian et al., 2013a
	0.0074	0.72	jaw lesions	Bursian et al., 2013b
	0.015	0.72	kit survival and weight at three and six weeks	Heaton et al., 1995
	Not Available	0.25	whelping rate	Restum et al., 1998
TEQs (µg/kg)	0.016	0.051	kit survival at six weeks	Bursian et al., 2006a
	0.0066	0.0042	jaw lesions	Bursian et al., 2006b
	0.022	0.036	jaw lesions	Bursian et al., 2006c
	0.0054	0.010	kit weight at six weeks	Bursian et al., 2013a
	0.00041	0.0048	jaw lesions	Bursian et al., 2013b
	0.00070	0.017	kit survival and weight at three and six weeks	Heaton et al., 1995
DDT (mg/kg)	0.40*	2.0*	survival	Fitzhugh, 1948
Mercury (mg/kg)	Not Available	1.1	nervous system lesions	Wobeser et al., 1976
	Not Available	1.0	kit growth	Wren et al., 1987
	0.5	1.0	survival	Dansereau et al., 1999

*Value based on a two-year study in rats. The dose was modified using the mink fish consumption rate, mink body weight, and a UF of 10x to extrapolate from rats to mink.

Since mink and otters are closely related, the same dietary concentrations determined to cause adverse effects in mink were used for otters. The amount of fish consumed per kg body weight by mink and otters can be calculated using the default body weights and fish consumption rates provided in USEPA (1995). Mink weigh 0.8 kg and consume 0.159 kg fish per day, whereas, otters weigh 7.4 kg and consume 1.221 kg fish/day. The amount of fish consumed per kg body weight for mink and otters would be 0.20 and 0.17, respectively. This calculation suggests that the dose received by mink and otters per kg body weight is similar. The use of otters has some advantages over the use of mink because otters tend to consume larger fish than mink and a greater percentage of their diets consist of fish so they would be expected to have a higher exposure to bioaccumulative compounds.

APPLICATION OF FISH TRVs

Fish TRV Summaries:

The concentrations of contaminants in fish estimated to cause adverse effects in bald eagles, colonial nesting birds, and mink/otter are provided in Table 12. Based on a review of these values, a range of the most defensible values to be used as a screening tool is provided in the last column of Table 12. However, it should be kept in mind that a TRV can be species-specific and should be applied to sizes and species of fish that a species of wildlife would consume. Since the recovery goal for a healthy bald eagle population is 1.0 young/occupied nest, it can be argued that any fish tissue concentration resulting in a lower productivity would be considered adverse. The lowest end of the range of TRVs for PCBs and *p,p'*-DDE in bald eagles is therefore set as greater than the fish tissue concentration associated with a productivity of 1.0 young/occupied nest.

Table 12. Ranges of fish tissue concentrations (mg/kg) estimated to cause adverse effects on reproduction and/or development in bald eagle, colonial nesting bird, and mink/otter populations.

Chemical	Bald Eagles	Colonial Nesting Birds	Mink/Otter	TRV
PCBs	> 0.14 - 0.93	0.091 - 1.4	0.25 - 3.7	0.091 - 0.25
TEQs	0.000011 - 0.00014	0.0000045 - 0.000064	0.000010 - 0.000069	0.0000045 - 0.000010
p,p'-DDE	> 0.16 - 0.30	0.12* - 0.29	2.0	> 0.16 - 0.30
Mercury	0.26 - 2.0	0.12 - 1.8	1.0 - 1.1	0.18 - 1.0

*This value was based on the results of a study that exposed pelicans to anchovies contaminated with DDT (69% DDE).

The concentrations of contaminants in fish estimated to adversely impact wildlife are provided in Table 12. A more conservative approach would be to develop fish tissue concentrations based on NOAELs instead of LOAELs. NOAELs were not used for this project because the delisting methodology (MDEQ, 2006; MDNR, 2018) requires the use of effect levels. Fish tissue NOAECs for the contaminants provided in Table 6 can be found in tables provided in previous sections of this report. Effects could occur between the NOAEC and LOAEC.

The following is the justification for the final TRVs provided in Table 12.

PCBs-

The fish tissue concentrations of > 0.14 and 0.93 mg/kg PCBs estimated to result in a healthy and stable bald eagle population, respectively, are appropriate to use because they are based on comparisons of contaminant data in bald eagle eggs to productivity measures. In addition, the BMF used to extrapolate from egg concentrations to fish concentrations is based on bald eagle field data. The value of 0.93 mg/kg PCBs is based on more recent data so may be less influenced by other contaminants such as *p,p'*-DDE than the value associated with a productivity of 1.0 young/occupied nest (Table 2).

With respect to colonial nesting birds, the cormorant toxicity data used to generate the fish tissue concentration are defensible. However, the BMF used to extrapolate from the egg concentration in cormorants to a fish tissue concentration is based on a relationship found for herring gull eggs and alewife so the resulting value is not considered as appropriate as the bald eagle data. The value of 0.091 mg/kg determined by EGLE (Table 8) is valid because it related the analysis of forage fish to effects observed on colonial nesting birds.

The quality of the mink data was considered high because mink were fed contaminated fish under controlled conditions so the dose was accurately measured and potential adverse effects were assessed. The upper end of the range used for the fish tissue TRV is 1.1 mg/kg, which is the effect level found in more recent studies on mink. Even though the study by Restum et al. (1998) found effects at lower concentrations than many of the other mink studies, it was not set as the upper end of the TRV range because it may have been more affected by co-contaminants than more recent studies. However, since it was a well conducted multi-generation study it is scientifically defensible and is included within the TRV range.

TEQs-

The fish tissue concentrations estimated to cause adverse effects on mink populations are the most appropriate to use because they were derived using laboratory studies that fed mink contaminated fish, measured the doses, and examined many adverse effects. The fish tissue concentration estimated to be protective of bald eagles using the BMF approach is a conservative value because it is based on enzyme induction (not reproduction or development) and it relied solely on a BMF for 2,3,7,8-TCDD (many of the dioxin congeners would be expected to have lower BMFs than 2,3,7,8-TCDD). Since the BMF used in the calculation of a fish tissue level protective of colonial nesting birds was also based solely on 2,3,7,8-TCDD, the resulting value was considered conservative. The value of 0.0000045 mg/kg determined by EGLE is valid because it related the analysis of forage fish to effects observed on colonial nesting birds. Since the lowest dietary concentration of 0.010 µg/kg found to cause adverse effects in mink is at the low end of the range of fish tissue values found to be protective of bald eagles and colonial nesting birds, it will be considered the final TRV.

p,p'-DDE-

The fish tissue concentrations of > 0.16 and 3.0 mg/kg *p,p'*-DDE estimated to result in a healthy and stable bald eagle population, respectively, are valid because they are based on comparisons of contaminant data in bald eagle eggs to productivity measures. However, these values have some limitations since they were derived using older data so the eagles were exposed to elevated levels of a variety of contaminants. Limited data suggest that bald eagles and colonial nesting birds are more sensitive to the effects of *p,p'*-DDE than mink. Since the fish tissue level estimated to adversely impact mink was based on rat data, it was not used to derive the final TRV.

Mercury-

The productivity of bald eagles appears to be less sensitive to the effects of mercury than other birds such as loons, pheasants, and mallards. Since the fish tissue levels estimated to impact bald eagles were based on either American kestrels (BMF approach) or mallard (surrogate species approach) data, the results are considered conservative. Less uncertainty is associated with the loon data, and it was considered appropriate to use the value of 0.18 mg/kg as the low end of the effect range. The range of mink values are considered defensible because the studies exposed mink in a laboratory setting to diets contaminated with mercury. Since the sensitivity of colonial nesting birds to the effects of mercury relative to loons is unknown and the value based on the loon data is significantly lower than the value based on the mink data, it was considered reasonable to present the final fish tissue TRV as a range of 0.18 to 1.0 mg/kg.

Fish Consumed by Wildlife:

There are many uncertainties associated with the use of fish tissue contaminant concentrations to assess whether reproductive or developmental impacts are occurring on piscivorous wildlife. For example, the amount of a chemical ingested by wildlife depends on the size, species, and amount of each species of fish consumed. The contaminant levels in fish may also vary depending on where in the AOC they were collected. Also, the mixtures of contaminants in fish collected for this study would most likely differ from the mixtures of contaminants used to derive the fish TRVs.

The fish consumed by bald eagles, herring gulls, common terns, Caspian terns, mink, and otters were evaluated below to help determine the potential for these species to consume the size and species of fish that were collected as part of this study. These species were selected because they are either routinely monitored in Michigan or they have been shown to be sensitive to the effects of environmental contamination.

Bald Eagles-

Food remains were examined at bald eagle nests and perch trees near the Wisconsin shoreline of Lake Superior (Kozie and Anderson, 1991). Suckers (55%), burbot (27%), and whitefish (8.0%) were the most frequently observed fish remains. The average length of fish estimated from bones found at the nests was 14 inches (35.6 centimeters [cm]). Prey delivery was examined at six bald eagle nests along the Au Sable and Manistee Rivers in Michigan (Bowerman, 1993). Suckers (47%), bullhead (3.9%), bass (14%), northern pike (3.9%), and bowfin (2.9%) were the most frequently observed fish brought to the nests. Most of the fish were between 6.0 and 18 inches (15.2 and 45.7 cm) in length. Prey delivery was also monitored at seven bald eagle nests along Green Bay (Dykstra et al., 2001). Suckers (28%), northern pike (17%), yellow perch/walleye (16%), bass (11%), bullheads (9%), and carp (8%) were the most frequently observed fish brought to the nests.

Herring Gulls-

Fish were found in 58% of the pellets collected from four herring gull colonies in Lake Ontario (Fox et al., 1990). Alewife (56.8%), sunfish (15.8%), smelt (13.0%), rock bass (8.0%), and yellow perch (5.6%) were the most frequently found fish in the pellets. Fish were found in 56% of the pellets collected from nine herring gull colonies in Lakes Huron, Erie, and Ontario (Ewins et al., 1994a). Alewife (35%), freshwater drum (23%), rainbow smelt (13%), sunfishes (11%), and perch (11%) were the most frequently found fish in the pellets. The average length of smelt and alewife were 9.0 cm (1.7-17.4 cm) and 15.5 cm (7.5-19.9 cm), respectively. The length of the drum consumed by the gulls ranged from 16 to 23 cm.

Common Terns-

The diet of common terns was examined at Lake Ontario, Niagara River, and Lake Erie colonies by direct observation of the delivery of fish to nests and by examining fish remains at the nest (Courtney and Blokpoel, 1980). At the Lake Ontario colony, alewives were the most frequent species of fish consumed followed by smelt and then emerald shiners. At the Niagara River colony, smelt was the principal species of fish consumed. Emerald and common shiners were next in importance during late May with bluntnose minnows and spottail shiners being more important later in the season. At the Lake Erie colony, smelt and emerald shiners were the principal species of fish consumed during the early season, whereas, smelt was the principal fish species consumed later in the season. Trout perch and emerald shiners were also occasional food items at this colony. At a southern Lake Michigan colony, alewives were the primary species of fish consumed by common terns, followed by spottail shiners (Ward et al., 2010).

Common terns typically feed on fish that are 6-15 cm (2.4 to 5.9 inches) in length (Cuthbert et al., 2003). The length of prey fed to chicks is typically 3.0 to 9.0 cm (1.2 to 3.5 inches) (Galbraith et al., 1999).

Caspian Terns-

Caspian terns typically feed on fish that are 5-15 cm in length. Of 1,219 prey items brought to young in Lake Michigan Caspian tern colonies in 1977 and 1978, 57% were alewives and 34% were smelt (Shugart et al., 1978). The percent frequency of occurrence of fish in pellets from two Lake Michigan colonies in 1991 were alewife (90 and 100%), yellow perch (0 and 25%), Centarchidae (3 and 20%), and rainbow smelt (10 and 15%) (Ewins et al., 1994b). The percent frequency of occurrence of fish in pellets from four colonies in Lake Huron ranged from 65% to 96% for Centrarchidae, 12% to 63% for alewife, 0% to 39% for yellow perch, and 0% to 6% for rainbow smelt.

Mink-

Studies have found that 55% (Alexander, 1977) to 90% (USEPA, 1995) of a mink's diet consists of fish or aquatic prey. An examination was made of the stomach contents of 41 mink collected from the North Branch of the Au Sable River and Hunt Creek Area streams in Michigan (Alexander, 1977). The stomach contents of mink collected along the Au Sable River contained brook trout (n=5), sculpin (n=3), darters (n=3), blacknose dace (n=2), creek chub (n=2), brown trout (n=1), and suckers (n=1), whereas, the stomach contents of mink collected along Hunt Creek Area streams contained brook trout (n=10), creek chub (n=3), sculpin (n=1), and redbelly dace (n=1). The mink consumed fish ranging in size from 1 to 7 inches (2.5 to 17.8 cm) (the highest numbers of fish were collected in the 4-inch [10.2 cm] size group). Examination of mink scats collected along two rivers in Spain found that the most common size of fish consumed were in the 10-15 cm size range, followed by fish in the 5-10 cm size range. The remaining fish consumed by one population was in the < 5 cm category, whereas, the remaining fish consumed by the other mink population was in the 15 to 20 cm and > 20 cm categories (Bueno, 1996).

Otter-

About 100% of an otter's diet consists of fish or aquatic prey (USEPA, 1995; Melquist and Hornocker, 1983). Studies suggest that otters tend to feed on slow moving fish like suckers, carp, chubs, dace, shiners, squawfish, bullhead, and catfish because they are the easiest to catch (Toweill and Tabor, 1982). For instance, the stomach contents of otters from the north branch of the Au Sable River and Hunt Creek area streams in Michigan contained blacknose dace (n=16), creek chub (n=7), suckers (n=7), darters (n=5), brook trout (n=3), common shiners (n=2), and rainbow trout (n=1). Based on this limited dataset, it was determined that otters consume fish that are 3 to 11 inches (approximately 7.6 to 27.9 cm) in length (Alexander, 1977).

Otter scats collected along three rivers in North Dakota were examined to determine the species and sizes of fish consumed (Stearns and Serfass, 2011). Carp/minnows, catfish, suckers, and sunfish occurred in 64.7%, 17.4%, 13.0%, and 11.2%, respectively, of the scats examined. These fish ranged in length from 3.5 to 71.0 cm) (1.4 to 28.0 inches) with a mean of 20.7 cm (8.2 inches). The percentage of fish in the ≤10 cm, 10.1-20.0 cm, 20.1-30.0 cm, 30.1-40.0 cm, and 40.1-50.0 cm size range was 24.6%, 36.5%, 14.1%, 14.0%, and 8.2%, respectively.

Otter scats collected from west central Idaho showed that prey species consumed were generally in direct proportion to their relative abundance. Otters consumed prey ranging in size from 0.79 to 19.7 inches (2 to 50 cm) or more in length. The three most commonly consumed fish (salmon, whitefish, and suckers) were larger than 11.8 inches (30 cm) in length (Melquist and Hornocker, 1983).

The five most common fish species found in otter scats collected from a site along the California coast had average lengths of 2.00, 3.54, 3.17, 1.90, and 3.41 inches (5.09, 8.99, 8.04, 4.82, and 8.67 cm, respectively) (Cosby, 2013).

Fish Collected Versus Fish Consumed:

The assessment of the diets of wildlife discussed previously show that the species of forage fish collected for this study are consumed by gulls, terns, and mink. The sizes of the forage fish collected are within the range of fish consumed by these species (Figure 2).

The data discussed previously suggest that the forage fish collected for this study are smaller than the average size fish consumed by bald eagles and otters (Figure 2). Since carp are consumed by bald eagles (Dykstra et al., 2001), and otters (Stearns and Serfass, 2011; Toweill and Tabor, 1982), the carp data collected as part of EGLE's trend monitoring program will be used to assess the potential for contaminants to adversely impact bald eagles. This is a conservative approach since these fish are larger than fish normally consumed by eagles and otters, and carp consistently have the highest concentrations of chlorinated organic contaminants compared to other fish species inhabiting the same water body. Since otters eat such a wide range of sizes of fish (including very small fish), both forage fish and carp will be used to assess whether fish consumed by otters are a potential concern.

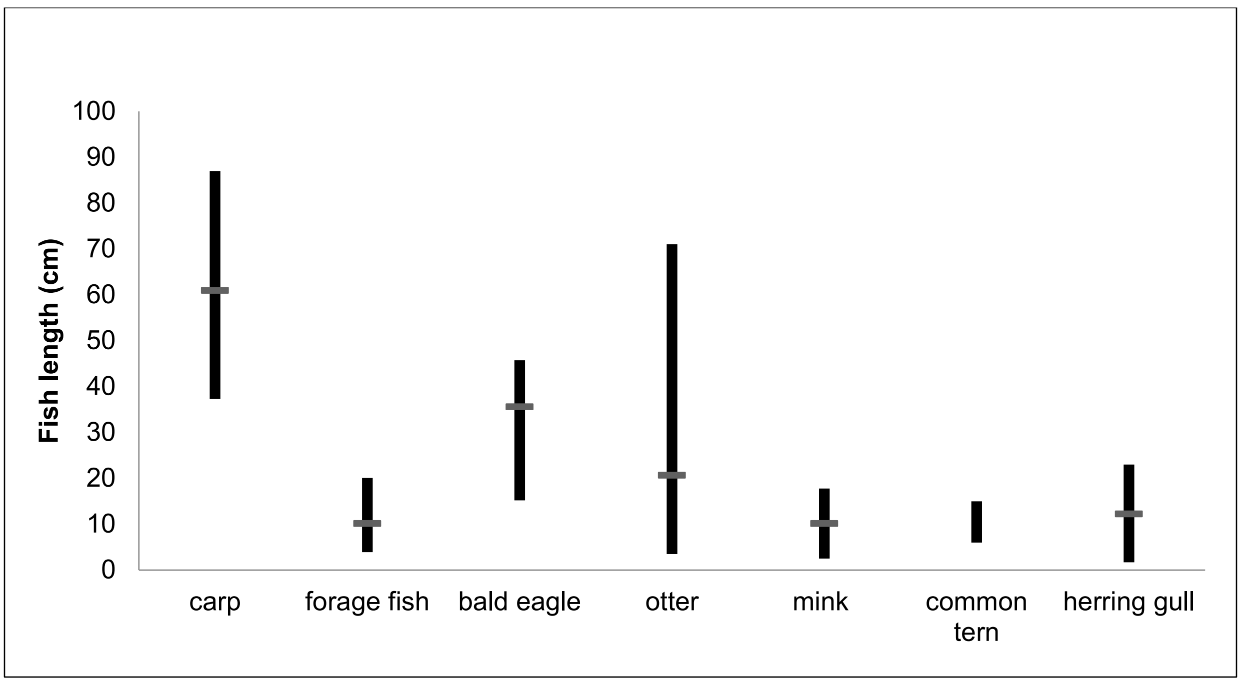

Figure 2. Size ranges (and means) of whole carp (collected 2010-2017; corresponds to carp used in Table 17) and forage fish (2014 and 2016) collected by EGLE and the size of fish consumed by various piscivorous wildlife reported in the literature (Alexander, 1977; Sterns and Serfass, 2011; Cuthbert et al., 2003; Ewins et al., 1994; Shugart et al., 1978).

WILDLIFE CONTAMINANT MONITORING DATA SUMMARY

Bald Eagles:

Michigan's bald eagle monitoring program includes measurements of concentrations of PCBs and *p,p*'-DDE in eaglet plasma in all four of the AOCs with a Wildlife BUI as well as for other Great Lakes and inland territories that may be used as references (Table 13). Figures 2 and 3 provide a comparison of the ranges of PCBs and *p,p*'-DDE concentrations, respectively, measured in each of the categories listed in Table 13. Data for more specific comparison populations will be provided in the assessments of the individual AOCs. The concentrations of PCBs and *p,p'*-DDE in the plasma can be compared directly to benchmarks associated with stable and healthy bald eagle populations. Maps of the state showing 2014-2018 active bald eagle breeding territories are presented in Appendices A-1 and A-2.

Table 13. Median bald eagle plasma PCB and *p,p'*-DDE concentrations (µg/kg) for AOCs and comparison populations based on data collected from 2014 through 2018.

Location	N*	Median Concentration (µg/kg)	
		PCBs	*p.p'*-DDE
Lake Erie			
Detroit River AOC	2	40	6
River Raisin AOC	3	84	4
Overall Lake Erie (non-AOC)	13	47	4
Lake Huron			
Saginaw Bay/River AOC	19	40	6
Overall Lake Huron (non-AOC; Lower Peninsula)	16	31	7
Lake Michigan			
Kalamazoo River AOC	2	108	11
Overall Lake Michigan (non-AOC)	34	38	12
Lake Superior			
Overall Lake Superior	18	10	3
Overall Great Lakes (Excluding AOCs)	83	31	7
Overall Inland Lower Peninsula (Excluding AOCs)	62	19	3
Overall Inland Upper Peninsula (Excluding AOCs)	17	11	3

* Number of nests sampled; overall medians are based on median concentrations per nest per year

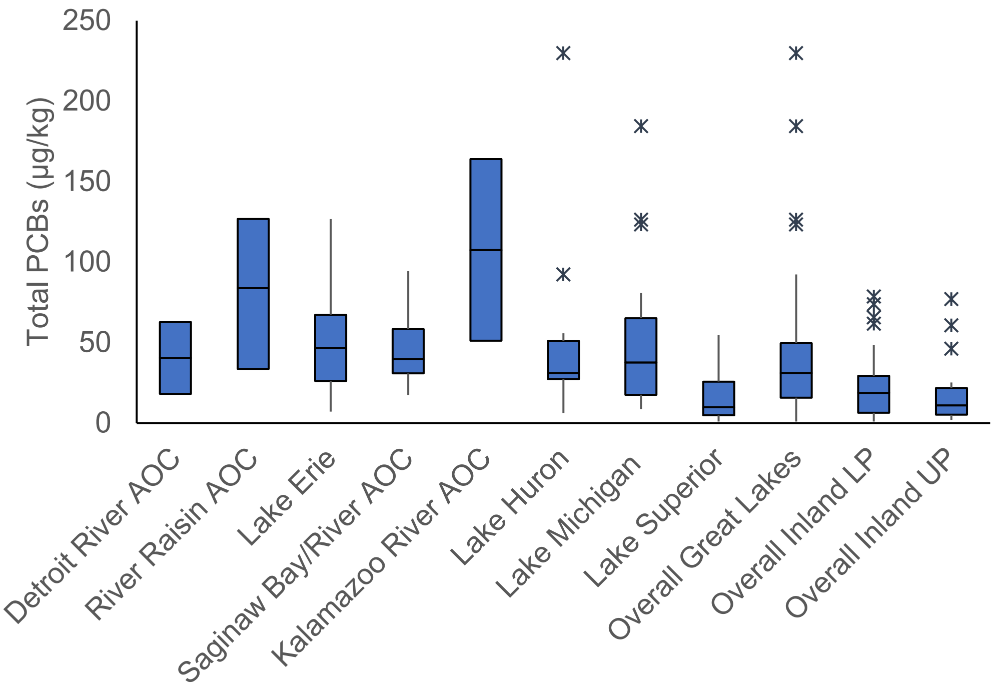

Figure 3. Boxplots of PCB concentrations measured in serum samples taken from nestling bald eagles between 2014 and 2018.

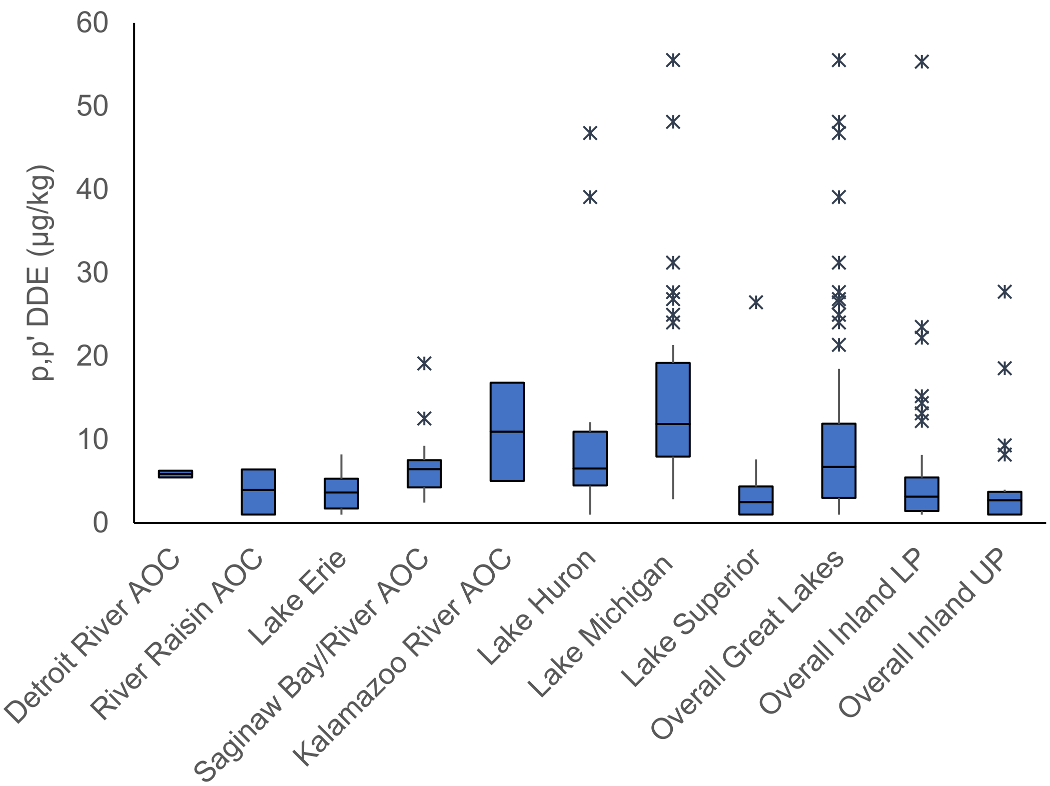

Figure 4. Boxplots of *p,p*'-DDE concentrations measured in serum samples taken from nestling bald eagles between 2014 and 2018.

Herring gulls:

From 2002 to 2009, EGLE monitored contaminant levels in herring gull eggs from ten Michigan colonies. Currently, only five colonies are monitored annually. A map showing locations of colonies monitored by Michigan is presented in Appendix B. Table 14 provides a summary of contaminant concentrations measured in herring gull eggs from 2002 through 2017.

Recent contaminant data are available for herring gull eggs from two of the AOCs with a Wildlife BUI. However, only limited data are available for other colonial nesting birds. Since other species are often more sensitive to contaminants than herring gulls (Table 5), a method was needed to estimate concentrations of contaminants in the eggs of other birds nesting in the same general area as herring gulls. Below are results of studies that compared the concentrations of contaminants in eggs of different species of birds nesting in the same area. Due to changes in the foraging behavior of herring gulls in the past (Hebert et al., 2008 and 2009), only the recent herring gull contaminant data reported by Hughes et al. (2014c) were used for these comparisons.

PCBs-

The data provided in Table 15 suggests that the concentration of PCBs in herring gull and Caspian tern eggs are approximately twice the concentration found in common tern eggs. PCB levels in double-crested cormorants, black crowned night herons, and Caspian tern eggs were similar.

p,p'-DDE-

The data provided in
Table 16 suggest that the concentration of *p,p'*-DDE in herring gull and Caspian tern eggs are about three times the concentration found in common tern eggs. *p,p'*-DDE levels in double-crested cormorants, black crowned night herons, and Caspian tern eggs were similar.

Table 14. Median concentrations of PCBs, *p,p′*-DDE, TEQ, and mercury in samples of herring gull eggs collected from Michigan colonies from 2002 to 2017.

Location	N			PCB (mg/kg)			*p,p'*- DDE (mg/kg)			TEQ (ng/kg)			Mercury (mg/kg)		
	2002-2006	2008-2012	2013-2017	2002-2006	2008-2012	2013-2017	2002-2006	2008-2012	2013-2017	2002-2006	2008-2012	2013-2017	2002-2006	2008-2012	2013-2017
Lake Michigan															
Grand Traverse Bay (Bellows I.)	5	5	5	3.1	1.8	1.2	2.2	0.8	0.5	759	251	NA	0.69	0.41	NA
Lake Huron															
Saginaw Bay/River AOC‡ (L. Charity I.)	3	5	5	6.0	3.6	1.8	1.3	0.7	0.3	768	466	NA	0.47	0.40	NA
St. Marys River AOC (5-Mile I. and W. Twin Pipe I.)	9	7	5	3.1	1.5	0.8	1.0	0.4	0.2	226	239	NA	0.65	0.40	NA
Lake Superior	10	6		3.4	2.1		1.5	0.7		200	305	NA	0.82	0.50	NA
Huron National Wildlife Refuge (Huron I./Gull I.)	2	3	3	3	1.5	1.0	1.5	0.5	0.4	391	188	NA	0.72	0.45	NA
Lake Erie															
River Raisin AOC‡ (Detroit Edison)	5	5	5	10.8	7.8	4.9	1.1	0.8	0.4	719	511	NA	0.42	0.32	NA

‡ - AOC with Wildlife BUI

Table 15. Comparison of the concentrations of PCBs (mg/kg) in eggs of colonial birds nesting in the same locations.

Location	Herring Gulls	Common Terns	Caspian Terns	Double-Crested Cormorants	Black Crowned Night Herons
Hay Point* (St. Marys River) (2011)	1.8	0.77	NA	NA	NA
Hay Point* (St. Marys River) (2012)	1.4	0.89	NA	NA	NA
Severn Sound* (L. Ontario)	NA	2.1	5.5	NA	NA
Hamilton Harbor* (L. Ontario)	NA	5.3	10.1	9.4	12.2
Pigeon Island* (L. Ontario)	NA	NA	31.6	17.8	22.0

*References: Hay Point (Hughes et al., 2014c); Severn Sound (Martin et al.,1995); Hamilton Harbor (Weseloh et al.,1995); Pigeon Island (Bishop et al.,1992)

Table 16. Comparison of the concentrations of *p,p'*-DDE (mg/kg) in eggs of colonial birds nesting in the same locations.

Location	Herring Gulls	Common Terns	Caspian Terns	Double-Crested Cormorants	Black Crowned Night Herons
Hay Point* (St. Marys River) (2011)	0.376	0.099	NA	NA	NA
Hay Point* (St. Marys River) (2012)	0.248	0.146	NA	NA	NA
Severn Sound* (L. Ontario)	NA	0.83	3.12	NA	NA
Hamilton Harbor* (L. Ontario)	NA	1.8	3.8	3.9	2.6
Pigeon Island* (L. Ontario)	NA	NA	5.23	3.75	4.83

*References: Hay Point (Hughes et al., 2014c); Severn Sound (Martin et al.,1995); Hamilton Harbor (Weseloh et al.,1995); Pigeon Island (Bishop et al.,1992)

FISH CONTAMINANT MONITORING DATA SUMMARY

Carp:

EGLE routinely analyzes whole fish from 26 locations in the state as part of an effort to measure spatial and temporal trends in contaminant concentrations in Michigan. The carp data from the trend monitoring program were used for this project to assess whether concentrations of PCBs, total DDT, and mercury levels are higher within the AOCs than in other areas of the state. Although contaminant concentrations are often correlated with fish length, this is generally not the case for carp in the range of sizes normally sampled; therefore, the effect can be ignored for these comparisons. The results of this assessment are shown in Table 17. Insufficient data were available to make this assessment for TEQs.

Table 17. Mean concentrations of PCBs, total DDT, and mercury in whole carp collected from Michigan waters. Means are based on results from the most recent samples (year in parenthesis). AOC means are bold.

Water body Location (Collection year)	Total PCB (mg/kg)	Total DDT (mg/kg)	Mercury (mg/kg)
Kalamazoo River / Lake Allegan (2015)	3.01	0.17	0.20
Grand River / Grand Rapids upstream 6th St. dam (2017)	0.10	0.33	0.09
Muskegon River / Croton Dam Pond (2017)	0.05	0.08	0.13
St. Joseph River / Chapin Lake (2016)	0.60	0.07	0.10
Detroit River / Grassy Island (2017)	2.57	0.19	0.07
St. Clair River / Algonac (2015)	0.41	0.06	0.09
Lake St. Clair / L'Anse Creuse Bay (2014)	0.94	0.12	0.13
Saginaw River and Bay / Saginaw Bay (2015)	2.09	0.28	0.09
St. Marys River / Munuscong Bay (2014)	1.08	0.11	0.13
Lake Huron / Thunder Bay (2015)	1.41	0.17	0.14
Lake Michigan / Grand Traverse Bay (2015)	1.54	0.28	0.15
River Raisin / Lake Erie; Brest Bay (2017)	2.17	0.13	0.09
River Raisin / Monroe upstream Waterloo Dam (2010)	0.14	0.05	0.11

Forage Fish:

A recent study (Bush and Bohr, 2015) examined the contaminant levels in forage fish collected in the AOCs with a Wildlife BUI to determine whether mink and colonial nesting birds feeding on these fish could be adversely affected. The use of forage fish to assess impacts to wildlife is consistent with the delisting methodology (MDNR, 2018). The analysis of smaller fish was considered important because the fish collected as part of EGLE's monitoring program are larger than fish normally consumed by mink, herring gulls, and terns. The analysis of additional forage fish was conducted as part of this study so that the most current data could be used to assess whether wildlife still may be adversely impacted in select AOCs. The results of the analysis of forage fish for PCBs, *p,p'*-DDE, and mercury are shown in Table 18. Portage Creek was selected as a reference site for the Kalamazoo River AOC, a site on the River Raisin near Raisinville Road was selected as a reference site for the River Raisin AOC and a site near the Les Cheneaux Islands was selected as a reference site for the other AOCs. Since the forage fish collected from Saginaw Bay were not analyzed for TEQs as part of this study, the TEQ results reported in 2015 (Bush and Bohr, 2015) are included in Table 19.

Table 18. Contaminant concentrations in composite forage fish samples from selected AOCs and reference sites (Arithmetic mean concentrations are italicized and in bold). NA indicates that the analysis was not conducted. Sites are listed in order from downstream to upstream.

Water Body	Location	Collection Year	Species	Total PCB (mg/kg)	Total DDT (mg/kg)	Mercury (mg/kg)
Saginaw Bay	Near Saginaw River mouth	2016	Gizzard Shad	0.4509	0.021	0.048
			Yellow Perch	0.0528	0.003	0.039
			Lepomis sp.	0.0713	0.003	0.034
				0.1917	***0.009***	***0.040***
	Quanicassee SWA (S. end of Saginaw Bay)	2014	Bluntnose Minnow	0.1422	0.043	0.019
			Emerald Shiner	0.0659	0.014	0.028
			Yellow Perch	0.1066	0.025	0.021
				0.1049	***0.027***	***0.023***
	Sebewaing (E. Shore of Saginaw Bay)	2014	Bluntnose Minnow	0.0933	0.013	0.021
			Emerald Shiner	0.0381	0.005	0.023
			Yellow Perch	0.0408	0.005	0.027
				0.0574	***0.008***	***0.024***
	Wigwam Bay (NW shore of Saginaw Bay)	2014	Yellow Perch	0.0513	0.005	0.045
			Emerald Shiner	0.0373	0.005	0.029
			Golden Shiner	0.0158	0.002	0.066
		2016	Emerald Shiner	0.092	0.008	0.056
			White Sucker	0.0012	0.001	0.019
			Yellow Perch	0.0162	0.002	0.048
		2014-2016		***0.0356***	***0.004***	***0.044***
	Wildfowl Bay (NE shore of Saginaw Bay)	2016	Gizzard Shad	0.0269	0.004	0.025
			Brook Silverside	0.0026	0.001	0.045
			Yellow Perch	0.002	0.001	0.051
				0.0105	***0.002***	***0.040***
Detroit River	Trenton Channel	2016	Emerald Shiner	0.193	0.019	0.058
			Bluntnose Minnow	0.4251	0.025	0.029
			Yellow Perch	0.1133	0.009	0.051
				0.2438	***0.018***	***0.046***

Water Body	Location	Collection Year	Species	Total PCB (mg/kg)	Total DDT (mg/kg)	Mercury (mg/kg)
Kalamazoo River	d/s Lake Allegan	2016	Bluegill	0.5073	0.023	0.041
				0.5073	***0.023***	***0.041***
	D-Avenue	2016	*Lepomis* sp.	0.6413	0.030	0.083
				0.6413	***0.030***	***0.083***
	Lake Allegan	2016	*Lepomis* sp.	0.6675	0.030	0.026
				0.6675	***0.030***	***0.026***
	Morrow Pond	2016	*Lepomis* sp.	0.1735	0.020	0.018
			Common Shiner	0.4190	0.044	0.020
			Yellow Perch	0.1155	0.011	0.018
				0.2360	***0.025***	***0.019***
	Trowbridge Area	2019	Bluegill	0.2696	NA	NA
			Yellow Perch	0.1740	NA	NA
			Common Shiner	0.4762	NA	NA
				0.3066	***-***	***-***
Portage Creek	u/s Hampton Lake (Reference site 1)	2019	Blacknose Dace	0.0010	NA	NA
			Mottled Sculpin	0.0010	NA	NA
				0.0010	***-***	***-***
River Raisin	Monroe (Below Winchester Bridge)	2016	*Lepomis* sp.	0.1929	0.015	0.015
			Gizzard Shad	0.3253	0.017	0.018
			Rock Bass	0.0261	0.009	0.038
				0.1814	***0.014***	***0.024***
	Raisinville Road (Reference site 1)	2016	Rock Bass	0.0038	0.003	0.047
			River Chub	0.0213	0.008	0.029
			Common Shiner	0.0543	0.011	0.083
				0.0265	***0.007***	***0.053***
Lake Huron	Les Cheneaux Islands (Reference site 2)	2016	*Lepomis* sp.	0.0029	0.002	0.038
			Bluntnose Minnow	0.0046	0.003	0.05
			Yellow Perch	0.0010	0.001	0.038
				0.0028	***0.002***	***0.042***

Table 19. TEQ concentrations (Bush and Bohr, 2015) in composite forage fish samples collected from three areas in the Saginaw Bay (Arithmetic mean concentrations are in bold). The mammalian TEFs used for the TEQ calculation are from Van den Berg et al. (2006), whereas, the avian TEFs are from Van den Berg et al. (1998).

Location	Species	Mammalian TEQ (ng/kg)	Avian TEQ (ng/kg)
Saginaw Bay, Wigwam Bay	Yellow Perch	2.82	2.3
Saginaw Bay, Wigwam Bay	Emerald Shiner	2.42	3.31
Saginaw Bay, Wigwam Bay	Golden Shiner	1.97	3.28
	Location Mean	**2.40**	**2.96**
Saginaw Bay, Sebewaing	Bluntnose Minnow	4.08	3.65
Saginaw Bay, Sebewaing	Emerald Shiner	3.22	2.23
Saginaw Bay, Sebewaing	Yellow Perch	3.49	2.43
	Location Mean	**3.60**	**2.77**
Saginaw Bay, Quanicassee SWA	Bluntnose Minnow	4.53	6.75
Saginaw Bay, Quanicassee SWA	Emerald Shiner	3.59	10.3
Saginaw Bay, Quanicassee SWA	Yellow Perch	5.03	6.62
	Location Mean	**4.38**	**7.89**

WILDLIFE BUI ASSESSMENTS

Kalamazoo River AOC:

Wildlife studies-

Bald eagles

Productivity and contaminant data (2014-2018) for bald eagles nesting in the Kalamazoo River AOC are provided in Table 20 and Table 21, respectively. A map depicting locations of active bald eagle territories and PCB contaminant levels in the Kalamazoo River watershed during this time period is provided in Appendix C-1a.

Productivity and success rates of bald eagles nesting in the Kalamazoo River AOC are lower than the other eagles nesting in the watershed. The overall productivity for the entire Kalamazoo River AOC (0.9) was the same as the statewide inland productivity, but lower than all but one of the comparison populations. The productivity of 0.9 for the Kalamazoo River AOC is below the level of 1.0 required for a healthy population. The overall productivity of the three territories below the Lake Allegan Dam (Calkins Dam) (0.4) is lower than all the comparison populations and is below the levels associated with stable and healthy populations.

Table 20. Bald eagle productivity, brood size, and success rates in the Kalamazoo River AOC (KR AOC) territories compared to territories in the Manistee and Muskegon River watersheds, all territories with access to Lake Michigan fish, and all territories statewide. Overall metrics are presented for the five-year period from 2014 to 2018.

Population Metric[1]	KR AOC d/s Calkins dam	KR AOC u/s Calkins dam	KR non-AOC	Manistee River (d/s Tippy Dam)	Muskegon (d/s Croton Dam)	Lake Michigan[2]	Great Lakes Statewide[3]	Inland Statewide[4]
Productivity	0.4	1.2	1.4	1.2	0.7	1.1	1.1	0.9
Brood Size	1.3	1.8	1.7	1.4	1.6	1.5	1.6	1.5
Success Rate	0.3	0.7	0.8	0.9	0.4	0.7	0.7	0.6
Mean # Territories	2.0	2.6	5.4	6.6	3.4	50.0[5]	99.8[6]	192.2[7]

[1] Definitions or population metrics:

- Productivity equals the number of fledged young per occupied nest.
- Brood Size equals the number of fledged young per successful nest.
- Success Rate equals the ratio of the number of nesting attempts producing at least one fledged young to the number of nesting attempts.
- Mean # Territories equals the average number of active nests per year over the five-year period.

[2] Territories in the lower peninsula with access to Lake Michigan fish, excluding Kalamazoo River AOC.

[3] Excluding all AOCs with BUI for bird or animal deformities (Detroit River, Kalamazoo River, River Raisin, and Saginaw River/Bay); Most territories were not monitored in 2018 (so these numbers are largely based on four-year estimates)

[4] Excluding all AOCs with BUI for bird or animal deformities (Detroit River, Kalamazoo River, River Raisin, and Saginaw River/Bay)

[5] This number only includes 69 Lake Michigan territories that were monitored by two flights from 2014-2018 (excludes 145 territories in areas where flights were not conducted in 2018).

[6] This number only includes 135 Great Lakes territories that were monitored by two flights from 2014-2018 (excludes 414 territories where flights were not conducted in 2018).

[7] This number only includes 231 Inland territories that were monitored by two flights from 2014-2018 (excludes 465 territories in areas where flights were not conducted in 2018).

Table 21. A comparison of median PCB and *p,p*'-DDE concentrations in the serum of bald eagle nestlings from the Kalamazoo River AOC (KR AOC) with other bald eagle populations in Michigan. Medians are the overall values based on median concentrations per nest per year observed over the five-year period from 2014 through 2018.

Chemical	Healthy / Stable Population TRV[1] (μg/Kg)	KR AOC		Manistee River (d/s Tippy Dam)	Pere Marquette River	Lake Michigan[2]	Great Lakes Statewide[3]	Inland Statewide[3]
		d/s Calkins dam	u/s Calkins dam					
PCB	35 / 125	51.2	164.0	61	13	38	31	14
p,p'-DDE	11 / 28	5.1	16.8	14	4	12	7	3
Nests Sampled	-	1	1	2	1	34	83	92

[1] Concentration associated with a productivity of 1.0 (healthy) or 0.7 (stable) young per occupied nest.
[2] Territories in the lower peninsula with access to Lake Michigan fish, excluding Kalamazoo River AOC.
[3] Excluding all AOCs.

The concentrations of PCBs and *p,p'*-DDE in eaglets from the Kalamazoo River AOC upstream of the Calkins Dam are greater than those from all of the comparison populations. The concentration of PCBs downstream of the dam are higher than all but one of the comparison populations. The PCB concentration in eaglets above the dam (164 µg/kg) is above levels associated with stable and healthy populations, whereas, the concentration of PCBs downstream of the dam are above levels associated with a healthy population.

Table 22 shows the productivity of the territories within the Kalamazoo River AOC. The concentration of total PCBs is also provided when available. The Cooper Center nest has been successful since 2005 even though levels of total PCBs are elevated. The productivity of the New Richmond nest is only 0.8 even though the concentration of PCBs is below levels found in the Cooper Center nest. It is unknown why the eagles at Swan Creek-Highbanks territory continue to be active, yet unsuccessful. Territories AN02 and AN03 (data not displayed) are both located within the Allegan State Game Area, both have an abundance of habitat, competition with other eagles is minimal, and human disturbance is unlikely (although foot traffic could be a potential issue; personal communication with D. Best December 5, 2018). Territory AN06 is also located within the Allegan State Game area with other land use including a tree farm and agriculture. Competition with other eagles is unlikely; however, predation and disturbance at this nest is unknown (personal communication with D. Best December 5, 2018).

Table 22. Productivity (P) and total PCB concentration of four bald eagle territories located within the Kalamazoo River AOC. Note: The AN03 territory was located downstream of the Calkins Dam; however, this nest has been inactive since 2010; therefore, the data are not shown.

Year	Territory											
	Downstream						Upstream					
	AN08		AN04		AN02		AN05		AN06		KZ01	
	Saugatuck		New Richmond		Swan Creek – Highbanks		Allegan		Trowbridge		Cooper Center	
	P	ΣPCBs	P	ΣPCBs	P	ΣPCBs	P	ΣPCBs	P	ΣPCBs	P	ΣPCBs
2018	1		2	51	0		3		0		2	92
2017			1		0		1		0		2	249
2016			0		0		1		2		2	164
2015			0		0		0				2	
2014					0		0				1	
2013			1		0						2	
2012			2	104	0						2	
2011			0		0						1	
2010			0		0						2	
2009			1	498	0						1	
2008					0						1	
2007			1		0						1	
2006			0		0						2	
2005					0						1	
2004			2	107	0							
2003			1		0							
2002			0		0							
2001					0							
2000					0							
1999					2	77						
1998					0							
1997					0							
1996					0							
1995					0							
1994					0							
1993					0							

Herring gulls

No herring gull colonies are present in the Kalamazoo River AOC.

Mink

The impact of PCBs on mink residing in the Trowbridge area of the Kalamazoo River AOC from 2000 to 2002 was assessed by comparing the concentrations of PCBs and TEQs in the livers of nine mink and in their prey (fish, crayfish, muskrats, and small mammals) to benchmarks determined in toxicity studies conducted using ranch mink (Millsap et al., 2004). Both comparisons suggested that PCBs and TEQs were near the thresholds for effects on reproduction/development for mink living along the Kalamazoo River.

In a companion study, the jaws of the mink collected for the study summarized above were examined for lesions. Four of the nine mink exhibited jaw lesions (hyperplasia of squamous epithelium in the mandible and maxilla) with the severity of these lesions being correlated to the concentrations of PCBs and TEQs in the mink livers (Beckett et al., 2005). Table 23 provides the concentration of PCBs found in the mink livers with their associated jaw lesion rating.

Table 23. Concentrations of total PCBs in mink livers collected within the Kalamazoo AOC and nearby control site during the 2000-2002 trapping season and jaw lesion rating (Beckett et al., 2005).

Location	Sex	PCBs (mg/kg wet weight)	Lesion Rating
Kalamazoo River (below Trowbridge Dam)	M	6.0	Moderate
	M	5.0	Mild-moderate
	M	2.9	Mild
	M	3.3	Mild
	Arithmetic mean	**4.3**	
	M	3.4	No lesion
	M	1.0	No lesion
	M	0.05	No lesion
	M	1.6	No lesion
	M	1.1	No lesion
	Arithmetic mean	**1.4**	
Fort Custer Recreation Area	M	3.68	No lesion
	M	1.55	No lesion
	F	1.59	No lesion
	Arithmetic mean	**2.3**	

Mink were collected from the same area of the Kalamazoo River AOC as the studies mentioned above to determine whether mink still have jaw lesions associated with elevated levels of PCBs in their livers. Five mink were collected from the Kalamazoo River AOC and one mink was collected from a nearby control site on Portage Creek, upstream of the AOC (see map in Appendix C-1b). Table 24 provides the concentration of PCBs found in the mink livers with their associated jaw lesion rating (see Appendix C-1b for map of mink collection sites).

Table 24. Concentrations of total PCBs in mink livers collected within the Kalamazoo River AOC and nearby control site during the 2017-2019 trapping season and jaw lesion rating.

Location	Sex	PCBs (mg/kg wet weight)	Lesion Rating*
Kalamazoo River (below Trowbridge Dam)	M	0.660	No lesion
	M	0.301	No lesion
	M	0.025	No lesion
	M	0.624	No lesion
	M	0.044	No lesion
	Arithmetic mean	**0.331**	
Portage Creek (upstream of Hampton Lake)	M	0.006	No lesion

*Fitzgerald, 2019.

The average concentration of PCBs in the livers of mink collected from the Kalamazoo River AOC from 2017-2019 (0.331 mg/kg) is lower than the average concentration found in 2000-2002 (2.8 mg/kg) and lower than one sample collected in 1994 (2.40 mg/kg; MDEQ, 2003). This decrease in PCBs during this time period is supported by the carp and bass fillet data shown in Figure 5 and Figure 6. No lesions were found in the jaws of any of the mink collected from 2017-2019. The lack of lesions is not surprising since the highest concentration of PCBs measured in the livers of mink collected in this study (0.660 mg/kg) is lower than the lowest concentration that was associated with lesions in the previous study (2.9 mg/kg). The concentration of PCBs in the mink livers were also below the benchmarks listed in Table 10 of this report suggesting that PCBs are not causing adverse effects on the reproduction or development of mink in this segment of the Kalamazoo River.

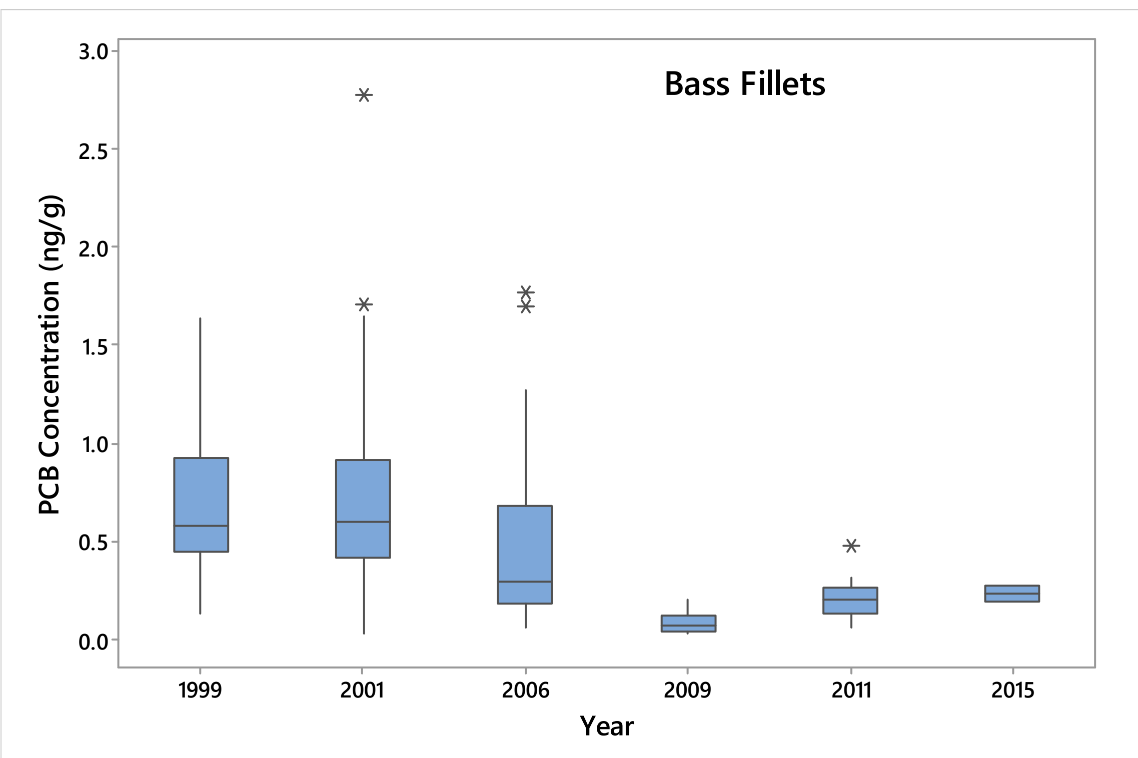

Figure 5. The concentration of PCBs in smallmouth bass fillets collected from the Kalamazoo River between the city of Otsego and the city of Allegan dams (includes the Trowbridge area).

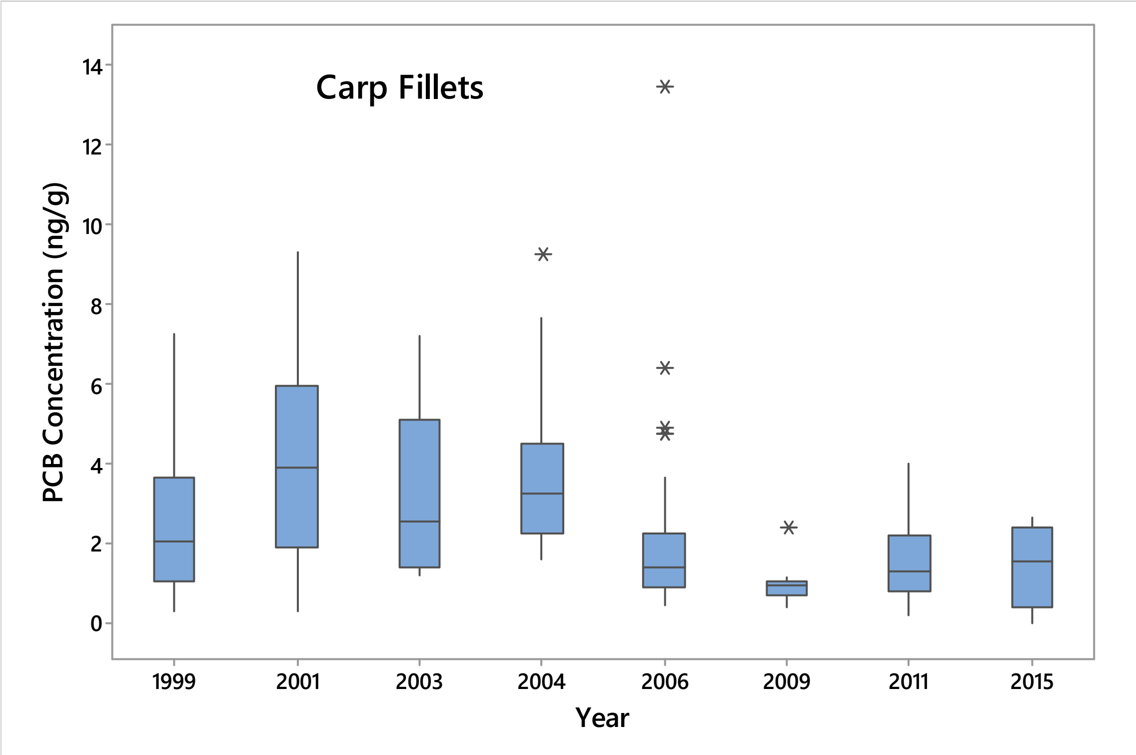

Figure 6. The concentration of PCBs in carp fillets collected from the Kalamazoo River between the city of Otsego and the city of Allegan dams (includes the Trowbridge area).

The average concentration of PCBs found in the livers of mink from the Kalamazoo River (0.331 mg/kg) are much higher than levels found in a tributary to the Kalamazoo River (Portage Creek; upstream of the AOC) (0.006 mg/kg). The average concentration was also higher than the average concentration found in the livers of mink collected in 2013 from Harsens Island in the St. Clair River (0.021 mg/kg) (Bush and Bohr, 2015).

Muskrats

Contaminant levels in the livers of muskrats living in the same area as the mink that were collected from 2017-2019 were also examined. Table 25 provides the results of this analysis (see Appendix C-1b for map of muskrat collection sites).

Table 25. Concentrations of PCBs in muskrat livers collected within the Kalamazoo River AOC and nearby control site.

Location	Sex	PCBs (mg/kg)
Kalamazoo River (below Trowbridge Dam)	M	0.003
	M	0.001
	F	0.005
	M	0.002
	F	0.002
	F	0.004
	Arithmetic mean	**0.003**
Portage Creek (upstream of Hampton Lake)	M	0.001
	M	0.001
	M	0.001
	Arithmetic mean	**0.001**

The average concentration of PCBs found in the livers of muskrats from the Kalamazoo River AOC (0.003 mg/kg) is higher than levels found in a tributary to the Kalamazoo River (Portage Creek) (0.001 mg/kg). The average concentration of PCBs found in the livers of muskrats from the Trowbridge area of the Kalamazoo River AOC in 2019 (0.003 mg/kg; Table 25) is lower than the average concentration of PCBs found in the livers of muskrats collected from the same area in 1994 (0.44 mg/kg, n=5; MDEQ, 2003). The low levels of PCBs in the livers of the muskrats suggest that they are not being adversely impacted by PCBs.

Tree swallows

The concentration of PCBs in tree swallow eggs was monitored by the United States Geological Survey (USGS) in nest boxes located near Douglas in the Kalamazoo River AOC. The median concentration of PCBs was 2.16 mg/kg, which is lower than the concentration of 20 mg/kg associated with reproductive effects. The median PCB concentration for this AOC ranked number 2 out of the 27 AOCs studied. The median dioxin and furan concentration of 251 ng/kg ranked 8 out of 27 AOCs studied (Custer, 2015).

<u>*Fish data-*</u>

Spatial comparison

The concentrations of PCBs in forage fish collected from the Kalamazoo River AOC are higher than the concentrations in fish collected from the Detroit River, Saginaw River/Bay, River Raisin, and near the Les Cheneaux Islands (Table 18).

The concentrations of PCBs in carp collected from the Kalamazoo River AOC are higher than levels found in fish collected from the Grand, Muskegon, and St. Joseph Rivers (Table 17). Total DDT concentrations were higher in fish collected from the Kalamazoo River AOC than in fish collected from the Muskegon and St. Joseph Rivers. Mercury concentrations were higher in carp collected from the Kalamazoo River compared to the three comparison sites.

Comparison to wildlife benchmark values

The concentration of 0.51 mg/kg PCBs in forage fish from the Kalamazoo River AOC (Table 18; Appendix C-1b) is above the lower limit of the range of TRVs (0.25-3.7 mg/kg) estimated to be protective of mink and otters. The average concentration of PCBs in forage fish is lower than the concentration measured in forage fish from the Kalamazoo River by Bush and Bohr (2015; 1.557 mg/kg) and lower than the average concentration (3.2 mg/kg) reported in Millsap et al. (2004). The differences may be due to the species of the forage fish collected for this study compared to the previous studies. The forage fish collected by Millsap et al. (2004) were less than 23 cm in length and comprised of species from the Cyprinidae, Catastomidae, and Centrarchidae families. In comparison, the forage fish collected by Bush and Bohr (2015) were less than 11 cm in length and comprised only of Cyprinidae species. The forage fish collected from the Kalamazoo River for this study were less than 10 cm in length and comprised of species in the Cyprinidae, Centrarchidae, and Percidae families. The data in Table 18 suggest that forage fish from the Cyprinidae family typically have greater PCB levels than Centrarchidae and Percidae species. Differences in lipid content between species may be a reason for the higher PCB concentration in Cyprinids due to the lipophilic nature of PCBs. Common shiners (*Luxilus cornutus;* Cyprindae) from Morrow Pond of the Kalamazoo River had an average fat content of 6.5% whereas forage fish sized *Lepomis* (Centrarchidae) and yellow perch from the same area were only 2.2% and 0.6% fat in 2016 (EGLE, 2019). Age could also play a factor when comparing contaminant concentrations in forage fish between studies. For example, a 10 cm-long common shiner may be 3-years old (Trial et al., 1983) whereas a 10 cm-long bluegill

(*Lepomis macrochirus;* Centrarchidae) may be less than 2 years old and a 23 cm-long bluegill may be 9 years old or older (Schneider et al., 2000). Therefore, the data indicate a reduction of PCBs in the river since the Millsap et al. (2004) study; however, it is likely that the differences in forage fish PCB levels between Bush and Bohr (2015) and this study are due to the species collected for analysis.

Even though the carp used in this assessment are probably larger than would normally be consumed by bald eagles and otters, it is noteworthy that the average PCB concentration of 3.01 mg/kg for 2009 is near the upper limit of the fish TRV range estimated to cause adverse effects on reproduction and/or development in bald eagles and otters.

Food Web Analysis-

The trophic transfer of PCBs in an abbreviated food web for the Kalamazoo River is shown in Figure 7. The following inputs were used in the figure:

- Forage fish: Whole fish composites (~100 grams) of common shiners, young-of-the-year bluegill (*Lepomis macrochirus*), and young-of-the-year yellow perch (*Perca flavescens*) collected from the Trowbridge impoundment in 2019.

- Sportfish: Fillets from smallmouth bass (*Micropterus dolomieu*) (N=10) and common carp (*Cyprinus carpio*) (N=20) collected in 2015 and 2016 between Morrow Dam and Calkins Dam (includes the Trowbridge Impoundment). Total PCB concentrations measured in fillets were converted to a whole fish concentration by assuming that the concentration of total PCBs in fillets is 65% of the total PCB concentration found in whole fish (Exponent, 2003).

$$Whole\ fish\ \Sigma PCB\ \left(\frac{ug}{kg}\right) = \frac{Fillet\ \Sigma PCB\ (\frac{ug}{kg})}{0.65}$$

- Mammals: Livers from muskrats (*Ondatra zibethicus*) (N=6) and mink (*Neovison vison*) (N=5) trapped near the Trowbridge Impoundment in 2018 and 2019.

- Bald eagles: Plasma (N=4) from eaglets nesting in territory KZ-01 from 2014-2018.

PCB concentrations were not available for the following key components of the food web: aquatic plants (an important diet of muskrat) and aquatic invertebrates (an important diet of fish, muskrat, and mink).

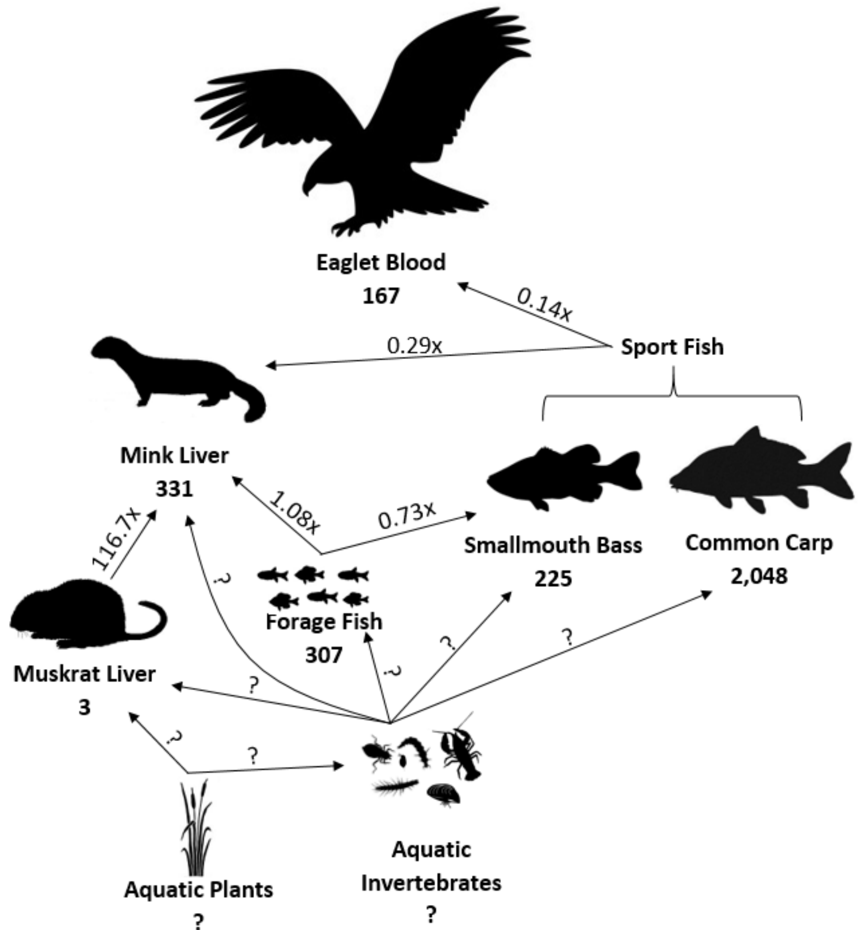

Figure 7. Schematic diagram showing average PCB concentrations (parts per billion) for various components of the Kalamazoo River food web. Biomagnification factors are provided on the arrows between components of the food web.

Conclusions-

- Based on bald eagle, forage fish, and carp data, it was concluded that piscivorous wildlife within the Kalamazoo River AOC are exposed to greater concentrations of PCBs than wildlife from the comparison populations.

- Overall bald eagle productivity within the Kalamazoo River AOC is below the level associated with a healthy population. The productivity of bald eagles nesting below the Lake Allegan Dam (Calkins Dam) is below levels associated with stable and healthy populations.

- PCB concentrations in eaglet plasma (108 µg/kg) are above levels associated with a healthy population (35 µg/kg). The PCB concentrations in eaglets from one territory (164 µg/kg) are above levels associated with healthy and stable populations. Based on the magnitude of this concentration, it is unclear why the productivity of eagles in this territory continues to be high.

- Mink collected from 2017-2019 within the Kalamazoo River AOC did not exhibit an increase in jaw lesions. Liver concentrations of PCBs were below the levels associated with adverse effects on reproduction/development.

- PCB concentrations in forage fish and carp are within the range of fish tissue TRVs estimated to cause adverse effects on reproduction and/or development in bald eagles mink and otters.

- The reproduction of tree swallows nesting along the Kalamazoo River AOC does not appear to be adversely impacted.

Recommendation-

Bald eagle productivity data and fish (forage fish and carp) concentration data support the retention of the Wildlife BUI for the Kalamazoo River AOC.

Since contaminant levels in bald eagles are above levels associated with a healthy population, yet productivity is below the level associated with a healthy population, continued monitoring is recommended. Monitoring of productivity and contaminant levels in bald eagles and contaminant concentrations in fish from the Kalamazoo River AOC should continue while ongoing river sediment remediation work progresses. Additionally, genetic analyses should be conducted to determine if Kalamazoo eagles are a source or sink of eagles within Michigan. It is unclear why eagles (especially in the lower Kalamazoo) have low contaminant levels yet are not productive. Also, territories with some of the higher contaminant levels within the Kalamazoo AOC are successful. Are fledging young successfully returning to the Michigan population and contributing to future success of the population? Genetic analyses could help answer some of these questions.

Saginaw River/Bay AOC:

Wildlife studies-

Bald eagles

Active nesting territories and PCB contaminant levels within the Saginaw River/Bay AOC are depicted in Appendix C-2. The productivity of bald eagles nesting in the Saginaw River/Bay AOC is higher than the productivity of the comparison population (Table 26). The plasma concentration of PCBs in birds from the Saginaw River/Bay AOC is higher than the comparison populations, whereas, the plasma concentrations of *p,p'*-DDE in birds from the Saginaw River/Bay AOC is similar to the comparison populations. The PCB concentration in eaglet plasma is slightly above the concentration associated with a healthy population, but is below the level associated with a stable population (Table 27). For this time period, the PCB and *p,p'*-DDE concentrations were not correlated with productivity (Figures 8 and 9).

Table 26. Bald eagle productivity, brood size, and success rates in the Saginaw River/Bay AOC (SRB AOC) territories compared to territories with access to Lake Huron fish, and all territories statewide. Overall metrics are presented for the five-year period from 2014 to 2018.

Population Metric	SRB AOC			SRB Non-AOC	Lake Huron Lower Peninsula[1]	Great Lakes Statewide[2]	Inland Lower Peninsula[2]	Inland Statewide[2]
	River	**Bay**	**Entire AOC**					
Productivity	1.5	1.3	1.3	1.1	1.0	1.1	0.9	0.9
Brood Size	1.8	1.6	1.6	1.6	1.6	1.6	1.5	1.5
Success Rate	0.8	0.8	0.8	0.7	0.6	0.7	0.6	0.6
Mean # Territories	5.8	26.4	32.2	73.6	39.2[3]	99.8[4]	202[5]	192.2[6]

[1] Territories in the lower peninsula (Cheboygan, Presque Isle, Alpena, Alcona, and Iosco Counties) with access to Lake Huron fish, excluding Saginaw River/Bay AOC.

[2] Excluding all AOCs with BUI for bird or animal deformities (Detroit River, Kalamazoo River, River Raisin, and Saginaw River/Bay); most territories were not monitored in 2018 (so these numbers are largely based on four-year estimates).

[3] This number only includes 51 Lake Huron Lower Peninsula territories that were monitored by two flights from 2014-2018 (excludes 109 territories in areas where flights were not conducted in 2018).

[4] This number only includes 135 Great Lakes territories that were monitored by two flights from 2014-2018 (excludes 414 territories in areas where flights were not conducted in 2018).

[5] This number only includes 247 inland lower peninsula territories that were monitored by two flights from 2014-2018 (excludes 168 territories where flights were not conducted in 2018).

[6] This number only includes 231 Inland territories that were monitored by two flights from 2014-2018 (excludes 465 territories in areas where flights were not conducted in 2018).

Table 27. A comparison of median PCB and *p,p'*-DDE concentrations in the serum of bald eagle nestlings from the Saginaw River/Bay AOC (SRB AOC) with other bald eagle populations in Michigan. Medians are the overall values based on median concentrations per nest per year observed over the five-year period from 2014 through 2018.

Chemical	Healthy / Stable Population TRV[1] (µg/Kg)	SRB AOC			SRB Non-AOC	Lake Huron Lower Peninsula[2]	Great Lakes Statewide[3]	Inland Lower Peninsula[3]	Inland Statewide[3]
		River	**Bay**	**Entire AOC**					
PCB	35 / 125	57	38	40	26	31	31	19	14
p,p'-DDE	11 / 28	7	6	6	5	7	7	3	3
Nests Sampled		6	13	19	21	16	83	62	92

[1] Concentration associated with a productivity of 1.0 (healthy) or 0.7 (stable) young per occupied nest.
[2] Territories in the lower peninsula (Cheboygan, Presque Isle, Alpena, Alcona, and Iosco Counties) with access to Lake Huron fish, excluding Saginaw River/Bay AOC.
[3] Excluding all AOCs.

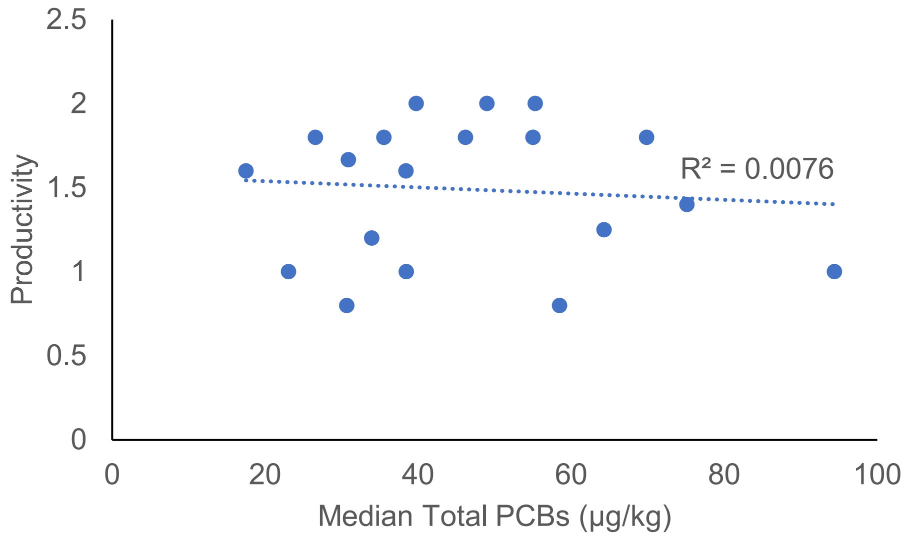

Figure 8. Average productivity of all bald eagle territories within the Saginaw River/Bay AOC versus median PCB concentration (2014-2018).

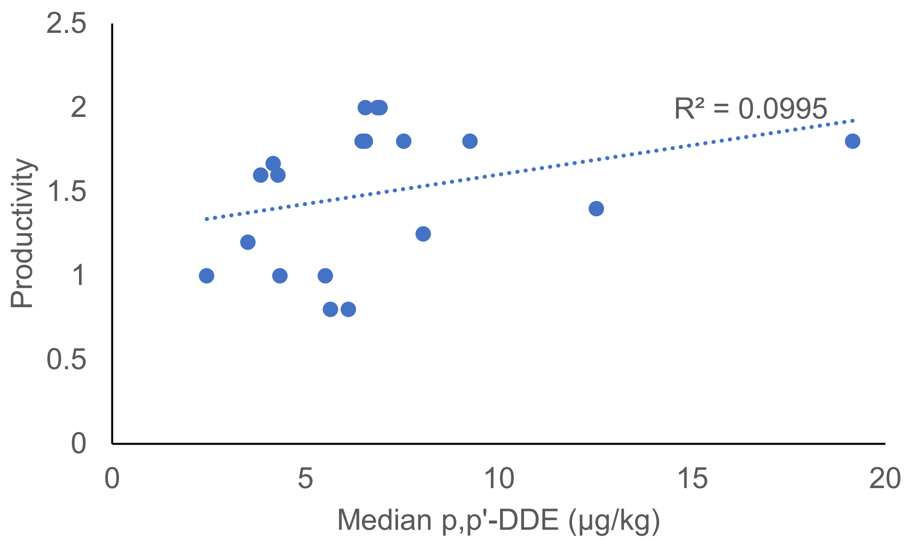

Figure 9. Average productivity of all bald eagle territories in the Saginaw River/Bay AOC versus median *p,p'*-DDE concentration (2014-2018).

Colonial nesting birds

Grasman et al. (2019a) found that herring gulls nesting on Little Charity Island and the Saginaw Bay Confined Disposal Facility had elevated embryonic infertility, failed development, and suppressed immune function. This is consistent with previous studies in the Saginaw Bay/River AOC (Grasman, 2015). Caspian terns had lower overall productivity in the AOC (with complete reproductive failure in 2015 and 2016) and tern chick growth was significantly lower on the Saginaw Bay Confined Disposal Facility compared to a reference colony. Terns from the AOC also had suppressed immune systems (Grasman et al., 2019a).

Grasman et al. (2019b) also reported that the breeding population of Caspian terns in the Saginaw River AOC declined from 2007 to 2019. Black-crowned night herons nesting on the Saginaw Bay Confined Disposal Facility also exhibited suppressed immune systems (Grasman et al., 2019a). A previous study by the same researcher found a strong correlation between effects on the immune system of herring gulls from the Hudson-Raritan estuary and the concentration of PCBs and TEQs in their livers (Grasman et al., 2013). In addition, the following were found with crossed bills: a Caspian tern on Little Charity Island (2016), herring gull embryos on the Saginaw Bay Confined Disposal Facility (2016) and Little Charity Island (2017), and a cormorant on Little Charity Island (2017) (Grasman, 2018).

Herring gull eggs collected from Little Charity Island had a median PCB concentration of 1.8 mg/kg for the period 2013-2017 (Table 14) and a median TEQ concentration of 466 ng/kg for the period 2008-2012 (Table 15). These are the second highest concentrations found in the five Michigan colonies currently being monitored. Concentrations of PCBs (Figure 10) and DDE (Figure 11) decreased from 2002-2017.

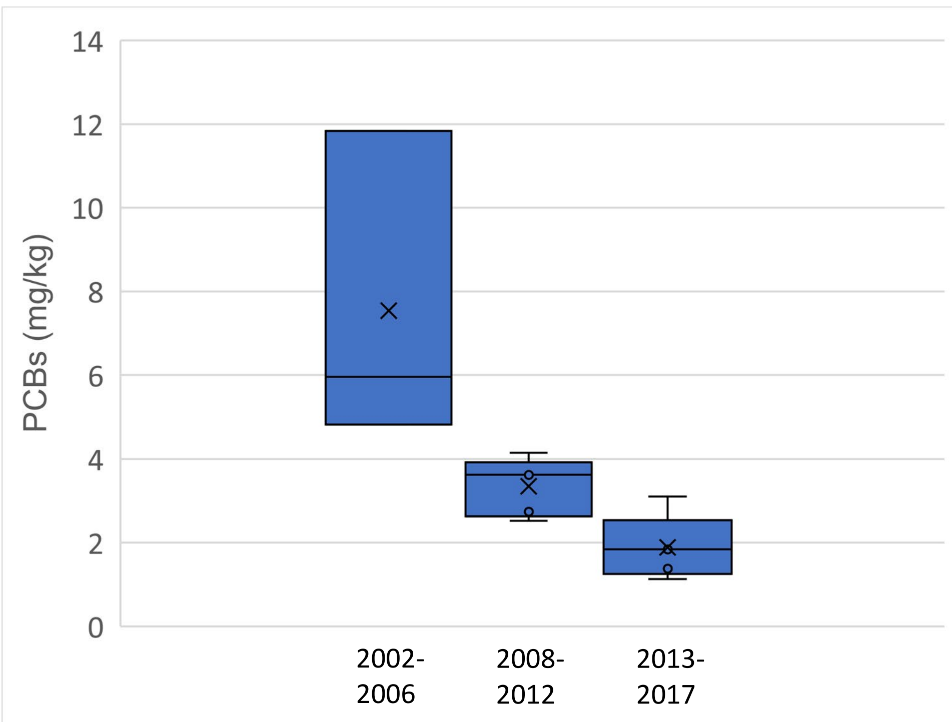

Figure 10. The concentration of PCBs in herring gull eggs collected from Saginaw Bay/River AOC (Little Charity Island).

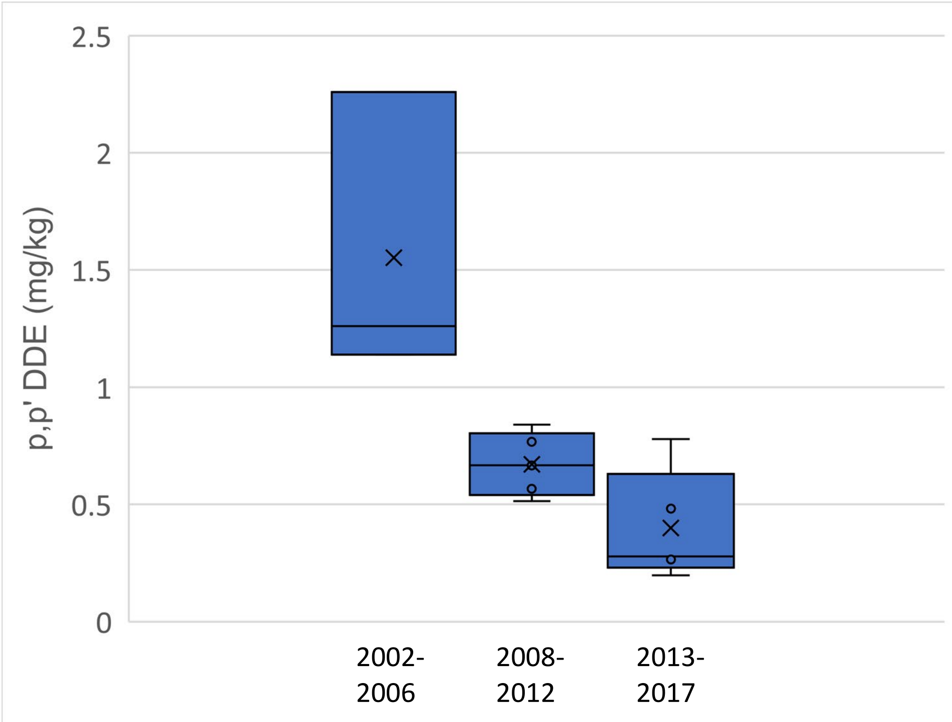

Figure 11. The concentration of *p,p'*-DDE in herring gull eggs collected from Saginaw Bay/River AOC (Little Charity Island).

Tree swallows

The concentration of PCBs in tree swallow eggs was monitored by the USGS in nest boxes located at the Bay City sewer treatment facility. The median concentration of PCBs was 1.88 mg/kg, which is lower than the concentration of 20 mg/kg associated with reproductive effects. The median PCB concentration for this AOC ranked number 5 out of 27 AOCs studied. The median dioxin and furan concentration of 579 ng/kg ranked 3 out of 27 AOCs studied (Custer, 2015).

Fish data-

Spatial comparison

The concentration of PCBs in forage fish from the Saginaw River/Bay AOC were higher than those found in the St. Marys River AOC and the Les Cheneaux Islands reference site (Table 18; see Appendix C-2 for a map of collection locations). However, the concentrations were lower than levels found in the Detroit River and the Kalamazoo River AOC.

PCB concentrations in whole carp from the Saginaw River/Bay AOC were higher than concentrations found in the St. Marys River, Thunder Bay, and the Grand Traverse Bay (Table 17). Concentrations of mercury were lower in the Saginaw River/Bay AOC compared to these sites, whereas, total DDT in Saginaw River/Bay were identical to levels found in Grand Traverse Bay.

Comparison to wildlife benchmark value

Forage fish collected near the mouth of the Saginaw River, the south end of Saginaw Bay, the east shore of Saginaw Bay, the north west shore of Saginaw Bay, and the northeast shore of

Saginaw Bay contained 0.11, 0.10, 0.053, 0.019, and 0.0052 mg/kg PCBs, respectively (Table 18). The TEQ concentrations in forage fish collected averaged 3.46 ng/kg (using mammalian TEFs) and 4.54 ng/kg (using avian TEFs) (Table 19). Since reproductive/developmental effects have been observed in various colonial nesting birds within the Saginaw River/Bay AOC due to PCBs and TEQs (Grasman, 2015) and the concentrations of PCBs measured in this study are similar to levels found previously (Bush and Bohr, 2015), it can be assumed that the current concentrations of PCBs and TEQs in these fish are sufficiently high to pose a risk to colonial nesting birds. These concentrations are below dietary levels shown to adversely impact mink and otters.

Even though the carp collected for Michigan's trend monitoring program are most likely larger than would normally be consumed by bald eagles and otters, it is noteworthy that the average PCB concentration of 2.09 mg/kg for 2015 exceeds the range of fish TRVs.

Conclusions-

- Based on herring gull and carp data, it was concluded that piscivorous wildlife within the Saginaw River/Bay AOC are exposed to greater concentrations of PCBs than wildlife from most of the comparison populations. The herring gull data also suggest that wildlife within the Saginaw River/Bay AOC is exposed to higher levels of TEQs than at other areas of the state.

- Caspian terns in the Saginaw River/Bay AOC are exhibiting low productivity and low growth rates (on the Confined Disposal Facility). Herring gull embryonic infertility and failed development were both elevated at the Saginaw Bay colonies compared to a reference colony. Caspian terns, herring gulls, and black-crown night herons in the Saginaw River/Bay AOC have also been exhibiting immune suppression, which may be attributed to PCB and TEQ exposure (Fowles et al., 1997; Fox and Grasman, 1999; Smits and Bortolotti, 2001; Smits et al., 2002; Lavoie and Grasman, 2007).

- Productivity of bald eagles nesting in the Saginaw River/Bay AOC from 2014 to 2018 is above levels associated with a healthy population. The productivities of bald eagles within the Saginaw River/Bay AOC and comparison populations were similar.

- PCB concentrations in eaglet plasma (40 µg/kg) are above levels associated with a healthy population (35 µg/kg). Comparison of PCBs and *p,p'*-DDE levels in bald eagles do not suggest a strong relationship between productivity and PCB or *p,p'*-DDE concentrations.

- PCB concentrations in Saginaw River/Bay AOC whole carp exceed the fish tissue TRV. The concentration of PCBs and TEQs in forage fish are at levels shown to impact colonial nesting birds.

- Reproduction in tree swallows nesting in one area adjacent to the Saginaw River/Bay AOC does not appear to be adversely impacted.

Recommendation-

Colonial nesting bird data, fish (forage fish and carp) concentration data, and eaglet plasma data support the retention of the Wildlife BUI for the Saginaw River/Bay AOC.

Monitoring of productivity and contaminant levels in bald eagles nesting in the Saginaw River/Bay AOC should continue. Eaglet genetic analysis should be conducted using archived and new samples to determine relatedness of bald eagles among AOCs and inland areas of Michigan to determine if the Saginaw River/Bay AOC serves as a source or sink for new bald eagle territories. This work would also determine if fledglings from the contaminated area are successfully returning and creating new territories.

Continue to measure contaminant concentrations in Saginaw Bay herring gulls and fish. In addition, the immune suppression and variable productivity of the colonial nesting birds in colonies in the Saginaw Bay should continue to be monitored.

River Raisin AOC:

Wildlife studies-

Bald eagles

Active nesting territories within the River Raisin AOC are depicted in Appendix C-3. The overall productivity of birds nesting in the River Raisin AOC from 2014-2018 is higher than the comparison populations (Table 28) even though these eaglets have higher levels of PCBs in their plasma (

Table 29). The median plasma PCB concentration of 84 µg/kg is higher than the concentration associated with a healthy bald eagle population. The concentrations of *p,p*'-DDE in bald eagles inhabiting the River Raisin AOC are similar to the median levels found for the comparison populations. No deformities in eaglets have been found in this area since the two deformed nestlings found in 1993 and 1995 (Bowerman et al., 1994; 1998).

Table 28. Bald eagle productivity, brood size, and success rates in the River Raisin AOC (RR AOC) territories compared to territories with access to Lake Erie fish, and all territories statewide. Overall metrics are presented for the five-year period from 2014 to 2018.

Population Metric[1]	RR AOC	RR non-AOC	Lake Erie (Michigan waters)[2]	Great Lakes Statewide[3]	Inland Lower Peninsula[3]	Inland Statewide[3]
Productivity	1.7	1.5	1.4	1.1	0.9	0.9
Brood Size	1.9	1.6	1.8	1.6	1.5	1.5
Success Rate	0.9	0.9	0.8	0.7	0.6	0.6
Mean # Territories	2.2	3.0[4]	15.0[5]	99.8[6]	202[7]	192.2[8]

[1] Definitions for population metrics
- Productivity equals the number of fledged young per occupied nest.
- Brood Size equals the number of fledged young per successful nest.
- Success Rate equals the ratio of the number of nesting attempts producing at least one fledged young to the number of nesting attempts.
- Mean # Territories equals the average number of active nests per year over the 5-year period.

[2] Territories in Michigan with access to Lake Erie fish, excluding AOCs.
[3] Excluding all AOCs with BUI for bird or animal deformities (Detroit River, Kalamazoo River, River Raisin, and Saginaw River/Bay); Most territories were not monitored in 2018 so these numbers are largely based on four-year estimates.
[4] This number includes 4 territories that were monitored by two flights from 2014-2018 (excludes 3 territories in areas where flights were not conducted/data not available for 2018).
[5] This number includes 23 territories that were monitored by two flights from 2014-2018 (excludes 5 territories in areas where flights were not conducted/data not available for 2018).

[6] This number only includes 135 Great Lakes territories that were monitored by two flights from 2014-2018 (excludes 414 territories in areas where flights were not conducted in 2018).
[7] This number only includes 247 inland lower peninsula territories that were monitored by two flights from 2014-2018 (excludes 168 territories where flights were not conducted in 2018).
[8] This number only includes 231 Inland territories that were monitored by two flights from 2014-2018 (excludes 465 territories in areas where flights were not conducted in 2018).

Table 29. A comparison of median PCB and *p,p*'-DDE concentrations in the serum of bald eagle nestlings from the River Raisin AOC (RR AOC) with other bald eagle populations in Michigan. Medians are the overall values based on median concentrations per nest per year observed over the five-year period from 2014 to 2018.

Chemical	Healthy / Stable Population TRV[1] (µg/Kg)	RR AOC	RR Non-AOC	Lake Erie[2]	Great Lakes Statewide[3]	Inland Lower Peninsula[3]	Inland Statewide[3]
PCB	35 / 125	84	17	47	31	19	14
p,p'-DDE	11 / 28	4	1	4	7	3	3
Nests Sampled		3	1	3	83	62	92

[1] Concentration associated with a productivity of 1.0 (healthy) or 0.7 (stable) young per occupied nest.
[2] Territories in Michigan with access to Lake Erie fish, excluding AOCs.
[3] Excluding all AOCs.

Table 30 shows the productivity of the Monroe territory eaglets within the River Raisin AOC and the three other territories that are associated with the AOC. The concentration of total PCBs is also provided when available. The Monroe 03 nest was not consistently successful from 1992 to around 2009. It was successful from 2010 to 2016 even though levels of total PCBs remained high. This territory was vacant from 2017 to 2018, but there are currently two successful nearby territories with the eaglets having elevated levels of total PCBs.

Table 30. Productivity (P) and total PCB concentration of four bald eagle territories located within the River Raisin AOC and comparison to a non-AOC territory.

Year	AOC Territory								Non-AOC Territory	
	MO03		MO09		MO18		MO24		MO14	
	River Raisin Monroe		Plum Creek West		Plum Creek East		Dormitory		Dundee North	
	P	ΣPCBs	P	ΣPCBs	P	ΣPCBs	P	ΣPCBs	P	ΣPCBs
2018			2	83.8	2	124.6	0		1	
2017					3	129.0			2	
2016	1		2	93.9	1				2	5.9
2015	3	91.2 33.8 28.5	2	20.6 36.7					3	27.4
2014	1		2						2	
2013	2	191.0	2						2	
2012	2		2							
2011	1	141.2	2							
2010	1		0							
2009			1							
2008	1									
2007	0									
2006	1									
2005	0									
2004	2									
2003	1									
2002	0									
2001	2	152.8 188.5								
2000	0									
1999	1	213.0								
1998	0									
1997	0									
1996	1									
1995	1									
1994	2									
1993	0									
1992	0									

Herring gulls

Consistent with previous studies, Grasman et al. (2019a) found that the Detroit Edison herring gull colony continues to show impairments in immune response and reproduction. Embryonic nonviability (including infertility and failed development) was elevated in gulls from the AOC colony and chick productivity was below the 10-year average in 2015 and 2016 (Grasman et al., 2019a). Grasman et al. (2019b) also reported that from 1995-2019, the breeding population of herring gulls at the Detroit Edison herring gull colony has significantly declined. In addition, two herring gulls with crossed bills were found in 2012, 2013, and 2016 (Grasman et al., 2019b). A previous study by the same researcher found a strong correlation between effects on the immune system of herring gulls and the concentration of PCBs and TEQs in the liver (Grasman et al., 2013).

Herring gull eggs from the Detroit Edison colony had a median PCB concentration of 4.9 mg/kg for the period 2013-2017 (Table 14) and a median TEQ concentration of 511 ng/kg for the period 2008-2012 (Table 15). Concentrations of PCBs (Figure 12) and DDE (Figure 13) decreased from 2002-2017. These values are higher than concentrations found in the other four colonies currently being monitored by the state of Michigan.

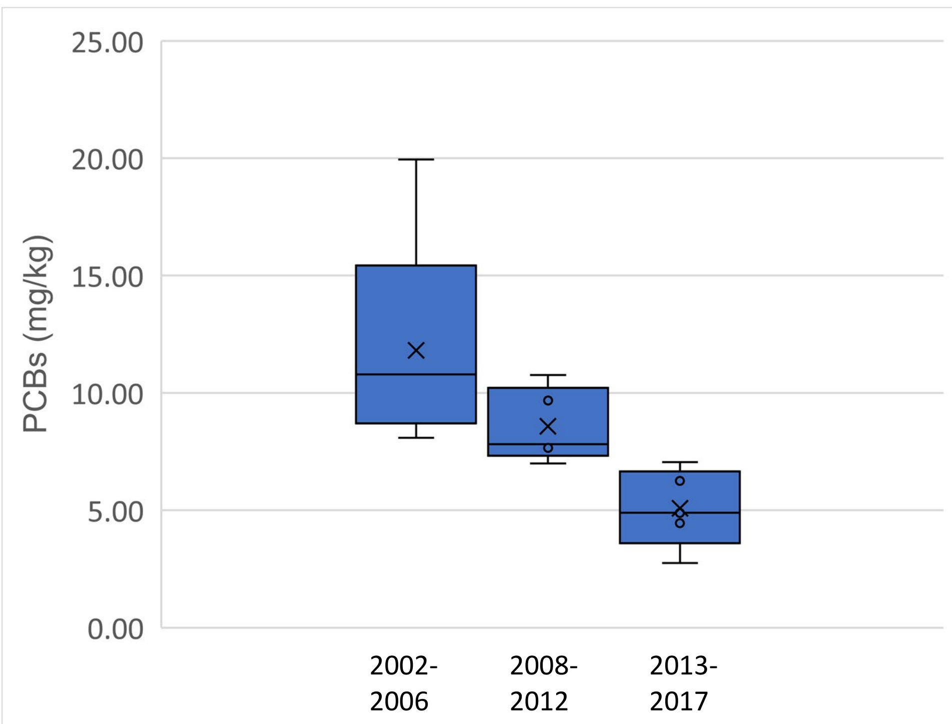

Figure 12. The concentration of PCBs in herring gull eggs collected from the River Raisin AOC (Detroit Edison) colony.

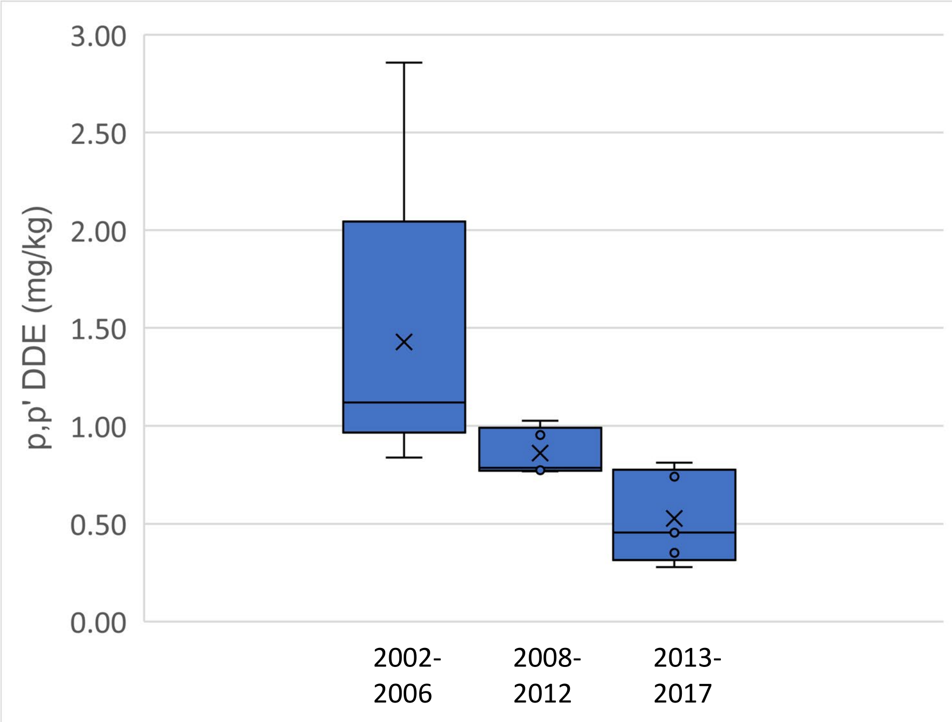

Figure 13. The concentration of *p,p'*-DDE in herring gull eggs collected from the River Raisin AOC (Detroit Edison colony).

Tree swallows

The concentration of PCBs in tree swallow eggs was monitored by the USGS in nest boxes located adjacent to the Monroe sewer treatment facility and at the Port of Monroe. The median PCB concentration for the individual sites was 1.88 and 2.16 mg/kg, respectively, with a median for the two sites combined of 2.05 mg/kg. This median concentration is much lower than the concentration of 20 mg/kg associated with reproductive effects in tree swallows. The median PCB concentration for the River Raisin AOC ranked number 13 out of 27 AOCs studied. The median dioxin and furan concentration of 201 ng/kg ranked 13 out of 27 AOCs studied (Custer, 2015).

Fish data-

Spatial comparison

Concentrations of PCBs and total DDT in whole carp were higher in fish collected from Brest Bay in Lake Erie than from an area upstream of the Waterloo Dam in Monroe (Table 17). However, the concentrations of PCBs and total DDT in carp collected from Brest Bay were lower than those found in the Detroit and Kalamazoo Rivers. Mercury concentrations in fish collected from Brest Bay and upstream of the Waterloo Dam were similar. The concentration of PCBs and DDT in forage fish collected in 2016 from the River Raisin AOC (see Appendix C-3 for collection locations) were elevated in comparison to the reference site on the River Raisin upstream of the AOC. Mercury concentrations in forage fish from the River Raisin AOC were lower than the reference site.

Comparison to wildlife benchmark value

The average PCB concentration of 2.17 mg/kg found in carp collected from Brest Bay is within the range of fish TRVs associated with adverse effects in piscivorous wildlife. The concentrations of PCBs found in forage fish collected from the River Raisin AOC (0.18 mg/kg) are below levels expected to cause adverse effects to mink and otters. The concentration of PCBs in forage fish collected from the River Raisin AOC are below concentrations found in forage fish collected from the area of the Kalamazoo River AOC where no effects were observed on mink.

Since reproductive/developmental effects related to PCBs have been observed in herring gulls within the River Raisin AOC during the 2010-2014 time period, it can be assumed that the concentrations of PCBs and TEQs in the fish in this area are sufficiently high to pose a concern to colonial nesting birds.

Conclusions-

- Bald eagle, herring gull, and carp data show that piscivorous wildlife within the River Raisin AOC are exposed to greater concentrations of PCBs than wildlife from a site upstream of the AOC.

- The productivity of bald eagles nesting in the River Raisin AOC (1.7) is higher than levels associated with a healthy population (1.0).

- The eaglet blood levels of PCBs (84 μg/kg) exceed levels associated with a healthy population. Based on the magnitude of these concentrations, it is unclear why the productivity of eagles associated with the River Raisin AOC is currently high.

- Based on the herring gull egg data, piscivorous wildlife within the River Raisin AOC are exposed to greater concentrations of TEQs than gulls from the comparison populations.

- Herring gulls in the River Raisin AOC are exhibiting immune suppression, which may be attributed to PCB and TEQ exposure (Fowles et al., 1997; Fox and Grasman, 1999; Smits and Bortolotti, 2001; Smits et al., 2002; Lavoie and Grasman, 2007) and reproductive impairments relative to a comparison population.

- PCB concentrations in whole carp from the River Raisin AOC exceed the fish tissue TRVs. The estimated concentration of PCBs in forage fish is below the range of fish TRVs that may adversely impact wildlife.

- Reproduction of tree swallows nesting along the River Raisin AOC does not appear to be adversely impacted.

Recommendation-

Fish tissue (forage fish and carp) data, eaglet blood concentrations, and herring gull data support the retention of the Wildlife BUI for the River Raisin AOC.

The measurement of contaminant concentrations in bald eagles, herring gull eggs, and fish (including forage fish) should continue.

The monitoring of productivity of bald eagles in the River Raisin AOC to determine if birds exceeding the benchmark associated with a healthy population continue to successfully fledge young. Genetic work should be conducted on eagles inhabiting territories near the River Raisin AOC to determine whether they are related to birds inhabiting the original territory (i.e., if the River Raisin population is a source or sink for eagles in Michigan). If they are related, this would provide evidence that fledged young from a territory adjacent to the Great Lakes with elevated levels of contaminants successfully returned and fledged young. Archived blood samples from eaglets in the Monroe territory should be examined to determine whether the transition from an unsuccessful nest to a successful one around 2010 was due to nest turnover (i.e., a new pair inhabiting the territory).

The study of the reproduction/development of colonial nesting birds in the River Raisin AOC should continue.

Detroit River AOC:

Wildlife studies-

Bald eagles

Active nesting territories within the Detroit River AOC are depicted in Appendix C-4. The overall productivity and success rate for the Detroit River AOC and the comparison populations were similar (Table 31). Contaminant data are available for two bald eagle territories within the Detroit River AOC (Table 32). The median PCB and *p,p'*-DDE concentrations were 40 and 6 µg/kg, respectively. PCB concentrations were higher than all of the comparison populations except one, whereas, the *p,p'*-DDE levels were lower than all but one of the comparison populations.

Table 31. Bald eagle productivity, brood size, and success rates in the Detroit River AOC (DR AOC) territories compared to territories with access to Lake Erie fish, and all territories statewide. Estimates are averages over the five-year period from 2014 to 2018.

Population Metric[1]	DR AOC	Lake Erie[2]	Great Lakes Statewide[3]	Inland Lower Peninsula[3]	Inland Statewide[3]
Productivity	1.3	1.4	1.1	0.9	0.9
Brood Size	1.8	1.8	1.6	1.5	1.5
Success Rate	0.8	0.8	0.7	0.6	0.6
Mean # Territories	3.2	15.0[4]	99.8[5]	202[6]	192.2[7]

[1] Definitions for population metrics

- Productivity equals the number of fledged young per occupied nest.
- Brood Size equals the number of fledged young per successful nest.
- Success Rate equals the ratio of the number of nesting attempts producing at least one fledged young to the number of nesting attempts.
- Mean # of territories equals the average number of active nests per year over the 5-year period.

[2] Territories in Michigan with access to Lake Erie fish, excluding AOCs.

[3] Excluding all AOCs with BUI for bird or animal deformities (Detroit River, Kalamazoo River, River Raisin, and Saginaw River/Bay); most territories were not monitored in 2018 (so these numbers are largely based on four-year estimates.

[4] This number includes 23 territories that were monitored by two flights from 2014-2018 (excludes 5 territories in areas where flights were not conducted/data not available for 2018).

[5] This number only includes 135 Great Lakes territories that were monitored by two flights from 2014-2018 (excludes 414 territories in areas where flights were not conducted in 2018).

[6] This number only includes 247 inland lower peninsula territories that were monitored by two flights from 2014 2018 (excludes 168 territories where flights were not conducted in 2018).

[7] This number only includes 231 Inland territories that were monitored by two flights from 2014-2018 (excludes 465 territories in areas where flights were not conducted in 2018).

Table 32. A comparison of median PCB and *p,p*'-DDE concentrations in the serum of bald eagle nestlings from the Detroit River AOC (DR AOC) with other bald eagle populations in Michigan. Medians are the overall values based on median concentrations per nest per year observed over the five-year period from 2014 through 2018.

Chemical	Healthy / Stable Population TRV[1] (µg/Kg)	DR AOC	Lake Erie[2]	Great Lakes Statewide[3]	Inland Lower Peninsula[3]	Inland Statewide[3]
PCB	35 / 125	40	47	31	19	14
p,p'-DDE	11 / 28	6	4	7	3	3
Nests Sampled		2	3	83	62	92

[1] Concentration associated with a productivity of 1.0 (healthy) or 0.7 (stable) young per occupied nest.

[2] Territories in Michigan with access to Lake Erie fish, excluding AOCs.

[3] Excluding all AOCs.

Herring gulls

There are currently no herring gull colonies in the Detroit River. In the past, the Canadian Wildlife Service routinely monitored contaminant levels in herring gull eggs from Fighting Island in the Detroit River. Based on 1998-2002 data, herring gull eggs from Fighting Island had a PCB concentration of 12.79 mg/kg and TEQ concentration of 221.1 ng/kg. This colony had the second highest PCB concentration and the ninth highest TEQ concentration of the 15 colonies routinely monitored by the Canadian Wildlife Service (Weseloh, 2003; Weseloh et al., 2006).

Tree swallows

The concentration of PCBs in tree swallow eggs was monitored by the USGS in nest boxes located at the following four Michigan sites arranged from north to south: Detroit Edison's plant at Connor Creek, Wyandotte Golf Course, Trenton Channel, and Lake Erie MetroPark. The median PCB concentrations for these sites were 0.48, 0.96, 1.79, and 1.94 mg/kg, respectively, with a median for the four sites combined of 1.12 mg/kg. This median concentration is much lower than the concentration of 20 mg/kg associated with reproductive effects in tree swallows. The median PCB concentration for this AOC ranked number 9 out of 27 AOCs studied. The median dioxin and furan concentration of 239 ng/kg ranked 9 out of 27 AOCs studied (Custer, 2015).

Fish data-

Spatial comparison

The concentration of PCBs in whole carp from the Detroit River AOC were higher than levels found in carp from Lake St. Clair and the St. Clair River (Table 17). The concentrations of total DDT in carp from the Detroit River AOC and Lake St. Clair were similar. The concentration of mercury in carp from the Detroit River AOC, Lake St. Clair, and the St. Clair River were similar. The concentration of PCBs in forage fish collected in 2016 from the Detroit River AOC were much lower than levels found in the reference site near the Les Cheneaux Islands in Lake Huron.

Comparison to wildlife benchmark value

The concentration of 0.573 mg/kg PCBs in forage fish collected from the Detroit River (Table 18) is above the TRV for the protection of mink and colonial nesting birds. Even though the carp used in the contaminant analysis are probably larger than would normally be consumed by bald eagles and otters, it is noteworthy that the average PCB concentration of 2.57 mg/kg for 2017 exceeds the fish TRVs.

Conclusions-

- Based on the herring gull, forage fish, and carp data, it was concluded that piscivorous wildlife within the Detroit River AOC are exposed to higher concentrations of PCBs than wildlife from comparison populations.

- The productivity of bald eagles nesting in the Detroit River AOC (1.3) is higher than levels associated with a healthy population (1.0).

- The blood levels of PCBs (40 µg/kg) exceed levels associated with a healthy population.

- PCB concentrations in whole carp and forage fish from the Detroit River AOC are above concentrations that may adversely impact wildlife.

- Reproduction of tree swallows nesting along the Detroit River AOC does not appear to be adversely impacted.

Recommendation-

Existing data support the retention of the Wildlife BUI for the Detroit River AOC.

Monitoring of productivity and contaminant levels in the bald eagles nesting in the Detroit River AOC should continue. Eaglet genetic analysis using archived and new samples should be conducted to determine relatedness of bald eagles among AOCs and inland areas of Michigan. This information will help to determine if the Detroit River AOC serves as a source or sink for new bald eagle territories. It should also be determined if fledglings from the contaminated area are successfully returning and creating new territories.

The measurement of contaminant concentrations in forage fish to determine potential effects on other piscivorous wildlife should continue.

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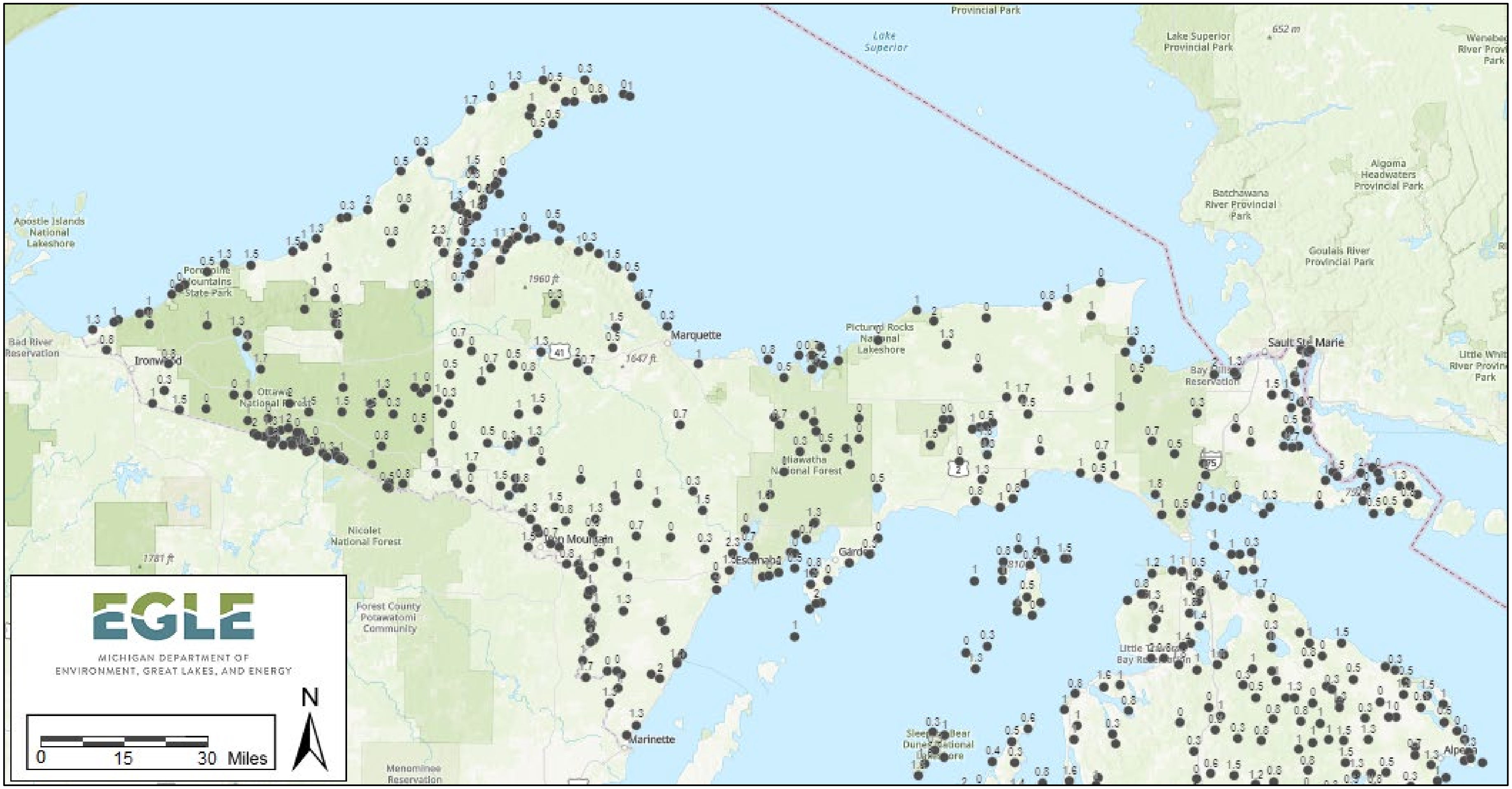
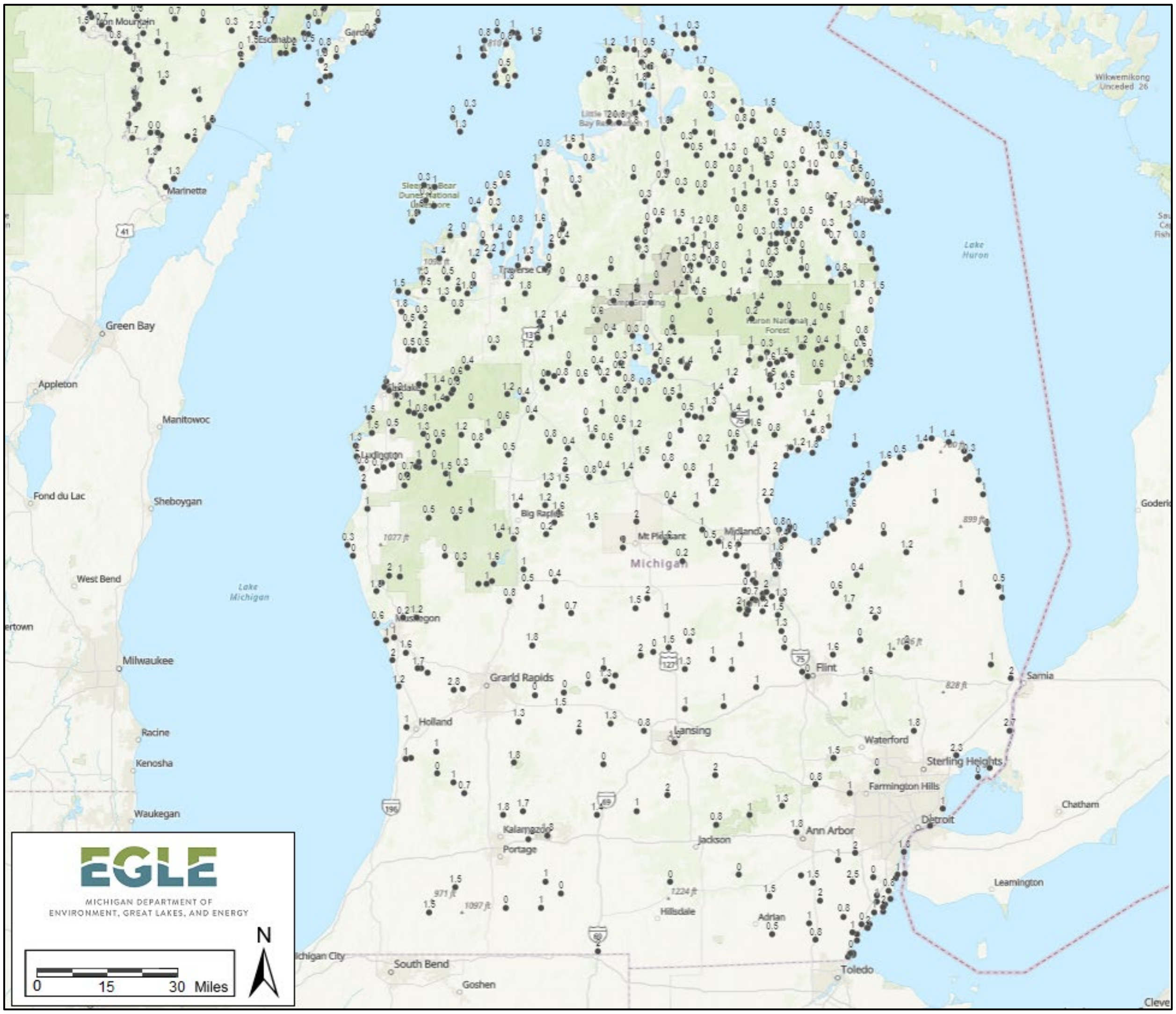
APPENDIX A

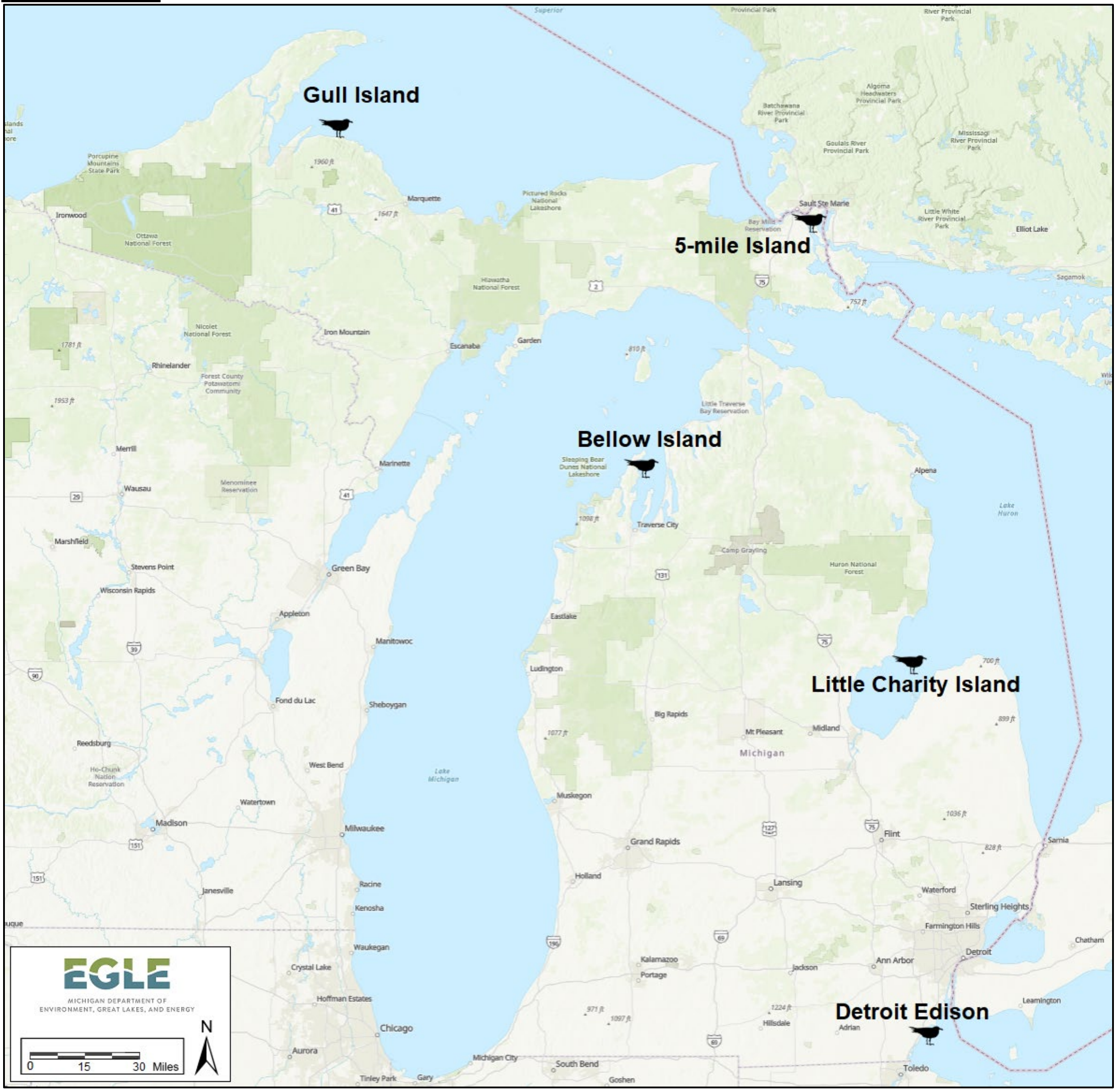


Appendix A-1. 2014-2018 Bald eagle nesting locations in Michigan's Upper Peninsula. Active nests and associated productivity numbers are displayed.



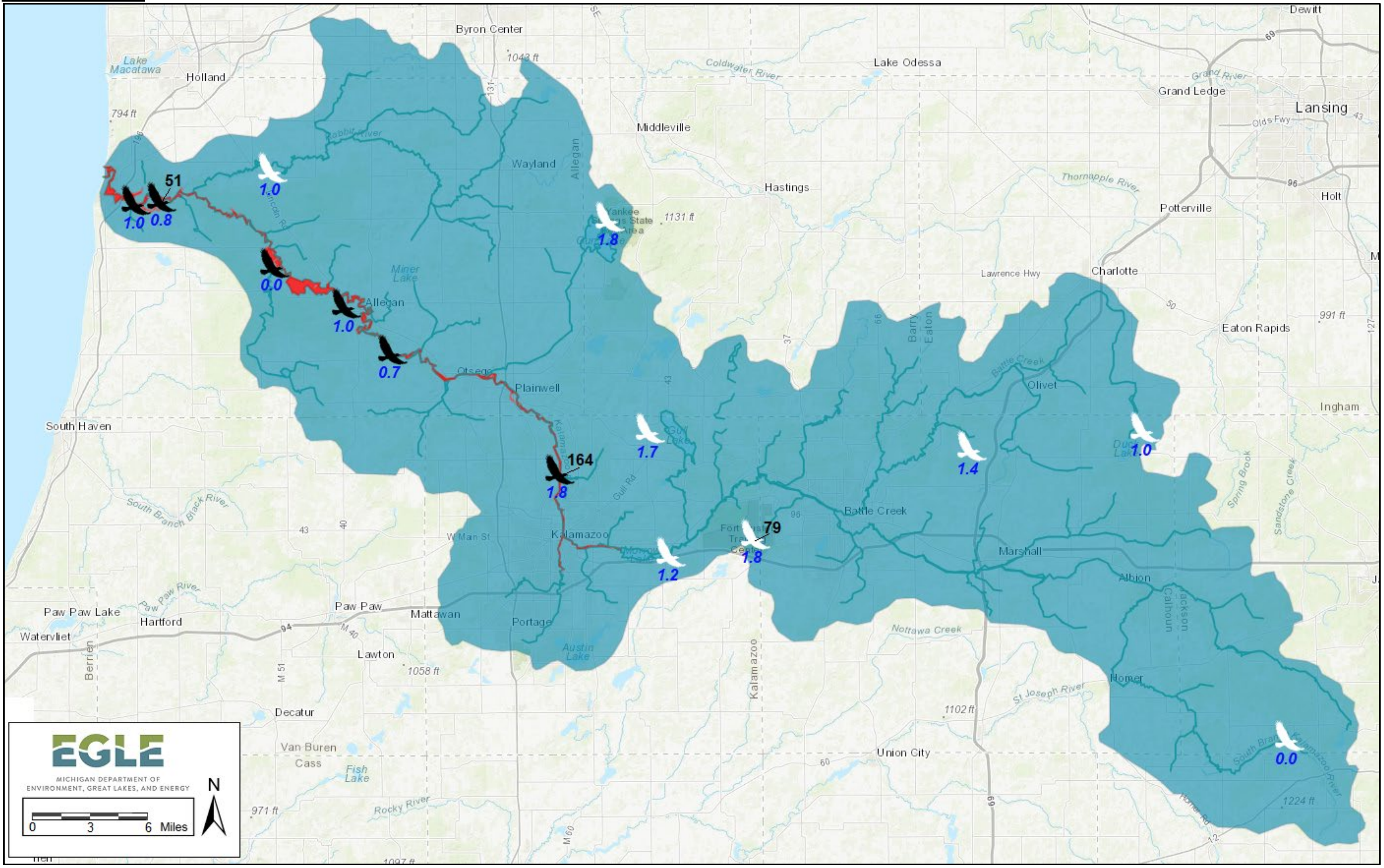
Appendix A-2. 2014-2018 Bald eagle nesting locations in Michigan's Lower Peninsula. Active nests and associated productivity numbers are displayed.

APPENDIX B

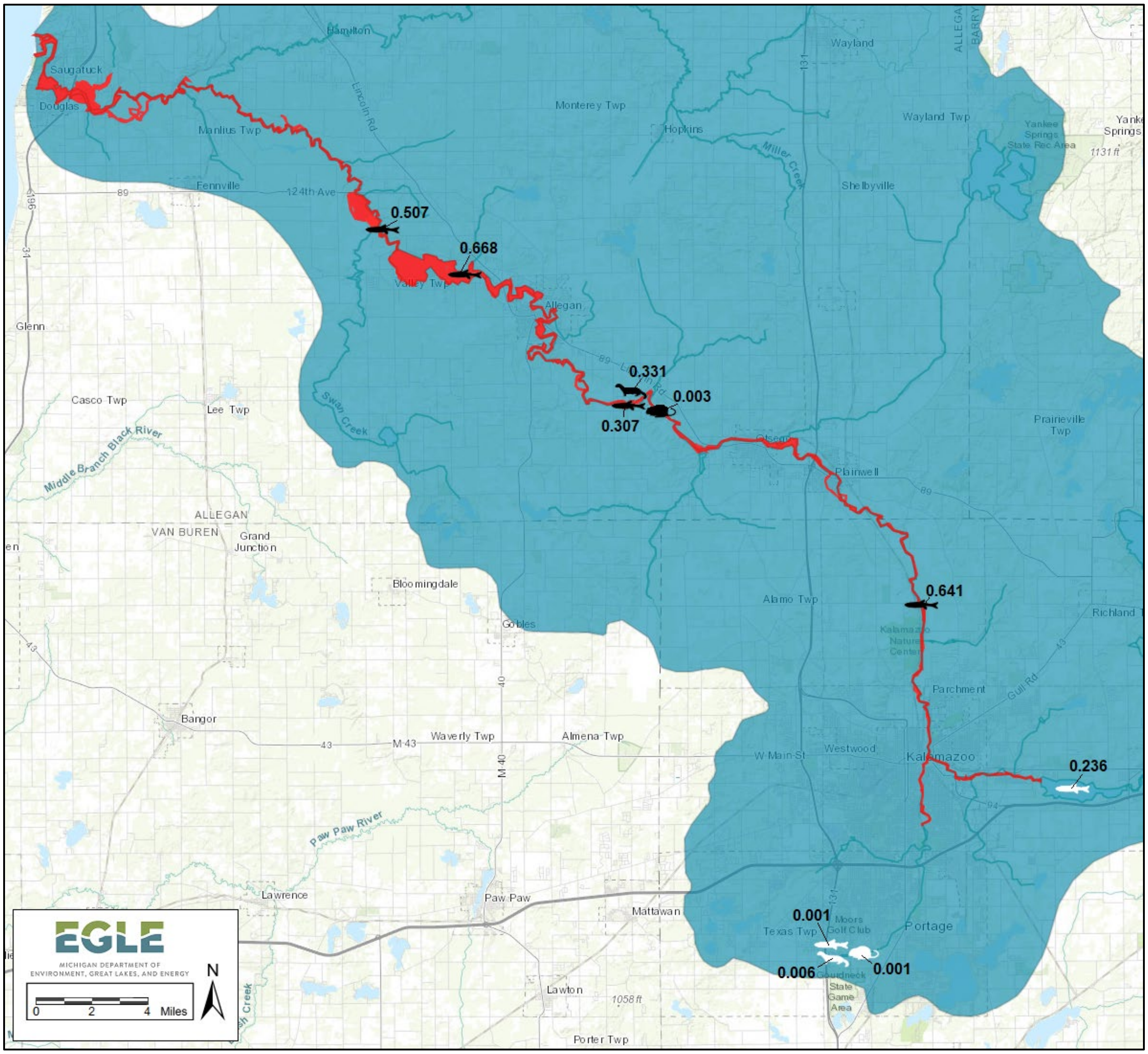


Appendix B. Great Lakes herring gull colonies monitored by EGLE.

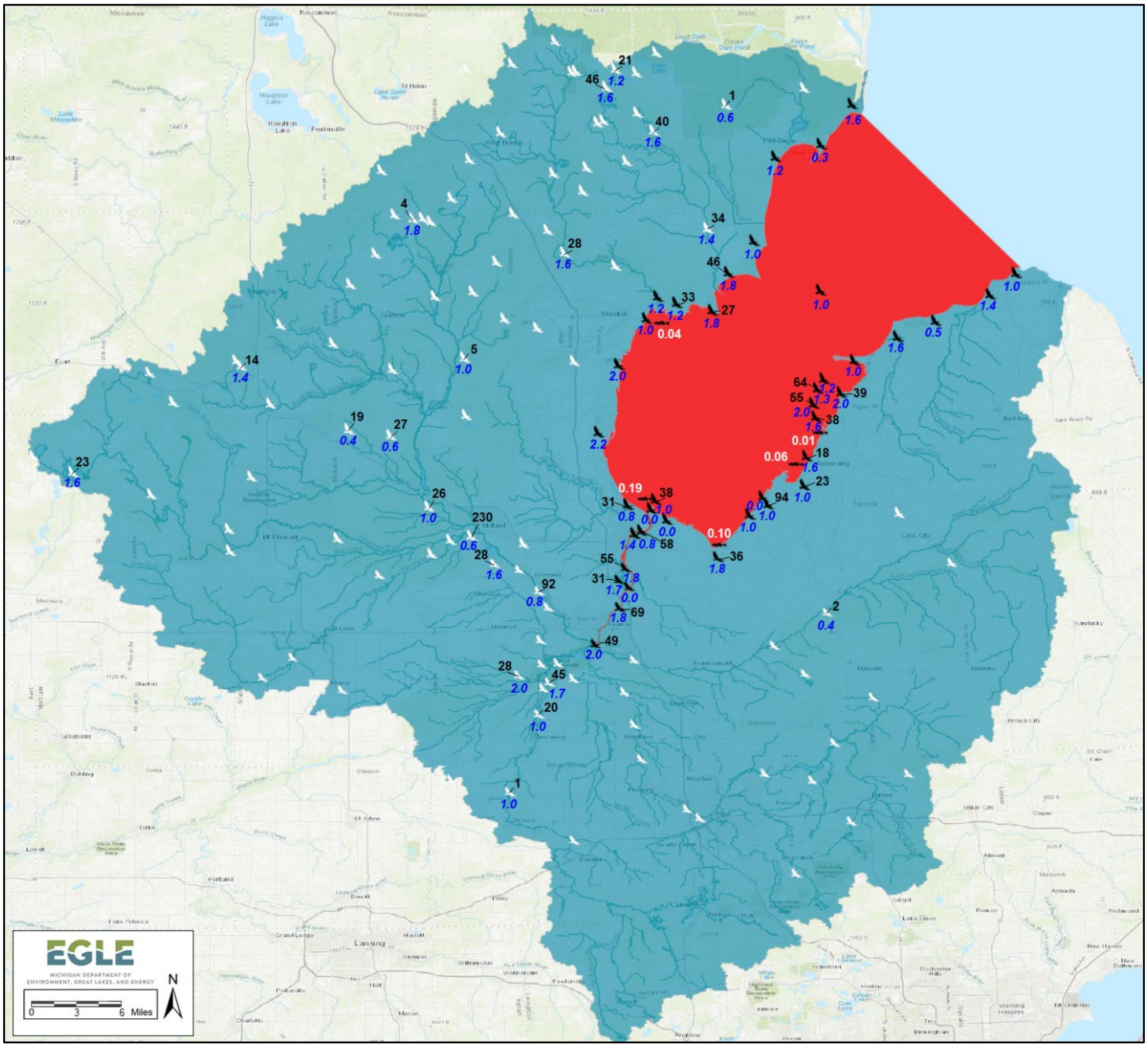
APPENDIX C



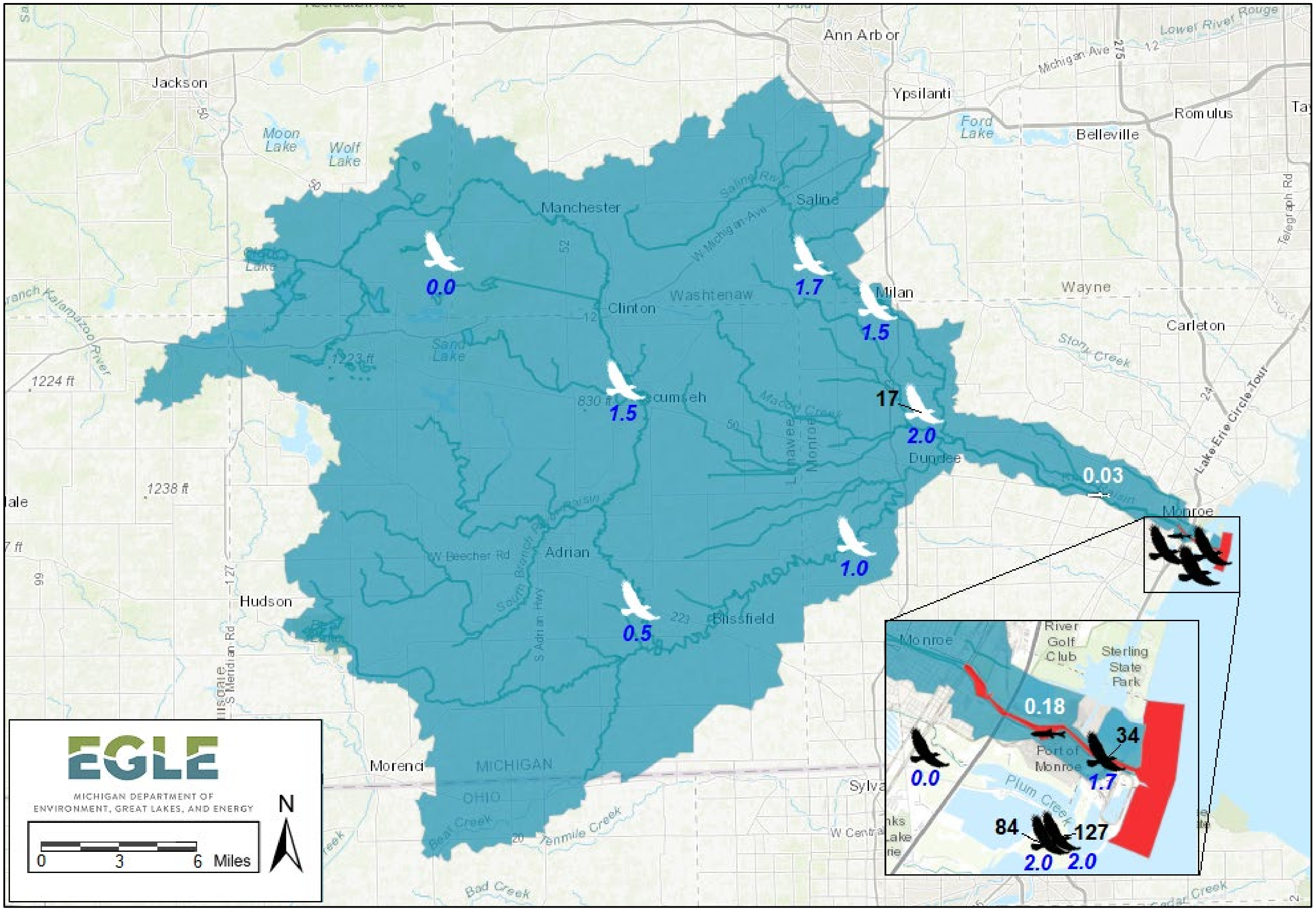
Appendix C-1a. Productivity of bald eagles within the Kalamazoo River watershed (italicized numbers in blue) between 2014 and 2018. Median eaglet blood ΣPCB concentrations (µg/kg) are shown in black font where available. is a territory within the Kalamazoo River AOC (red area). is a territory located outside of the AOC.



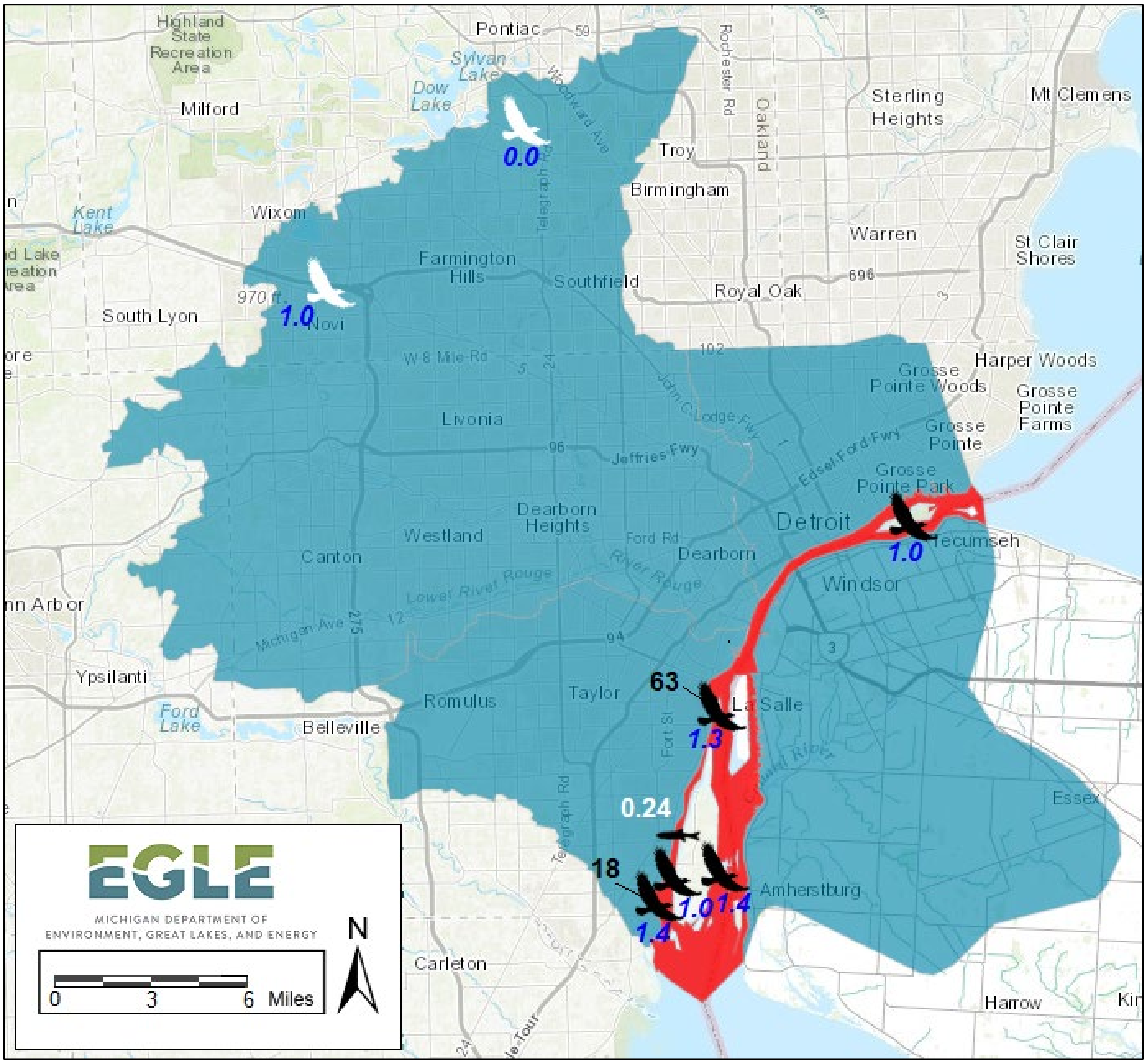
Appendix C-1b. Mink ( ) and muskrat ( ) trapping (2017-2018) and forage fish ( ) collection (2016-2019) locations in the Kalamazoo River watershed. Animal icons in black are located within the AOC (red area) whereas white icons are located outside of the AOC. Arithmetic mean ΣPCB concentrations (mg/kg) are displayed.



Appendix C-2. Productivity of bald eagles associated with the Saginaw River/Bay AOC (red area) between 2014 and 2018 (italicized numbers in blue). Median eaglet blood ΣPCB concentrations (µg/kg) are shown in black font where available. For clarity purposes, the non-AOC bird productivity is displayed for only those territories where contaminant concentrations were measured. is a territory within the Saginaw River/Bay AOC. is a territory located outside of the AOC. indicates a forage fish collection location in 2014 or 2016. Arithmetic mean forage fish ΣPCB concentrations (mg/kg) are displayed in white text.



Appendix C-3. Productivity of bald eagles associated with the River Raisin watershed (italicized numbers in blue) between 2014 and 2018. Median eaglet blood ΣPCB concentrations (µg/kg) are shown in black font where available. is a territory where eagles may forage within the River Raisin AOC (red area). is a territory located outside of the AOC. indicates a forage fish collection location in 2016. Arithmetic mean forage fish ΣPCB concentrations (mg/kg) are displayed in white text.



Appendix C-4. Bald eagle productivity in the Detroit River watershed between 2014 and 2018 (italicized numbers in blue). Median eaglet blood ΣPCB concentrations (µg/kg) are shown in black font where available. is a territory within the Detroit River AOC (red area). is a territory located outside of the AOC. indicates a forage fish collection location in 2016. Arithmetic mean forage fish ΣPCB concentrations (mg/kg) are displayed in white text.