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

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

EXECUTIVE SUMMARY

There are currently five Areas of Concern (AOCs) 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* (MDEQ, 2006), was used to determine whether sufficient data are available to remove the Wildlife BUI for these 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 (PCBs), and dioxin toxic equivalents (TEQs) on bald eagles, terns, and mink because impacts of these contaminants on these species was the primary reason for listing an AOC as having a Wildlife BUI. This update to a previous report (Bush and Bohr, 2012) includes more recent data from the MDEQ's bald eagle, herring gull, and fish contaminant monitoring programs; summarizes the MDEQ's analysis of contaminant data for forage fish from select AOCs; and includes the results of the analysis of mink livers from the St. Clair River AOC. This report also summarizes recent wildlife studies within the AOCs with a Wildlife BUI conducted by the Canadian Wildlife Service (frogs, turtles, and colonial nesting birds), the USFWS (colonial nesting birds), and the United States Geological Survey (USGS) (tree swallows). It also summarizes some recent articles published in the scientific literature.

After reviewing all of the data provided in the studies mentioned above, we have the following recommendations concerning the five 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 and mink/otters.

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

- 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 mink/otters.

- The Wildlife BUI for the St. Clair River AOC should be removed based on recent studies that found that frogs, turtles, and mink are not being adversely impacted. In addition, contaminant levels in carp and forage fish suggest that wildlife would not be impacted and that contaminants in this AOC are not higher than comparison populations.

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

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

- Continue to monitor wildlife productivity within the AOCs. It is particularly important to continue to study the impacts of contaminants on 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 AOC. Measure PCB levels in the livers of mink and assess whether there is still an increase in the incidence of jaw lesions.

- Continue to monitor contaminant levels and productivity of bald eagles in the Detroit River AOC. If a herring gull colony forms in the Detroit River AOC, analyze their eggs for contaminants.

- Continue to monitor productivity of bald eagles in the River Raisin AOC to determine whether it continues to be high even with elevated PCB levels in eaglet blood. Measure contaminant levels in forage fish from the River Raisin AOC.

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*, a BUI-specific team will be convened by the MDEQ 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 MDEQ 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*.

INTRODUCTION

At one time there were seven Michigan AOCs with a Wildlife BUI. The Wildlife BUI was removed from the Deer Lake and St. Marys River AOCs in 2011 and 2014, respectively. There are currently five AOCs in Michigan that have a Wildlife BUI (Table 1). The purpose of this project is to update the assessments made previously (Bush and Bohr, 2012) using more current contaminant and toxicity data and the results of studies conducted by the MDEQ based on recommendations made in the previous report. Specifically, the objectives of this assessment are to determine whether there are sufficient data available to remove the Wildlife BUI from the five 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
St. Clair River	Chironomids	Organic compounds
St. Marys River[2]	Terns	PCBs, Dioxins

[1]DDE = Dichlorodiphenyldichloroethane; HCB = Hexachlorobenzene; PCBs = Polychlorinated biphenyls; DDT = Dichlorodiphenyltrichloroethane
[2]Wildlife BUI removed in 2014

METHODOLOGY

The methodology provided in the document titled, *Guidance for Delisting Michigan's Great Lakes Areas of Concern* (MDEQ, 2006), was used to determine whether sufficient data are available to remove the Wildlife BUI for five 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 five AOCs because data from Michigan's wildlife and fish contaminant monitoring programs suggest that none of the five 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 five 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 the MDEQ 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 Grand River (similar nearby area) were selected as comparison populations for the Kalamazoo River AOC. 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)

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. The confidence in the fish tissue levels estimated to cause adverse effects in mink is high because mink were exposed to the contaminants in a controlled setting. 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 are 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:

Productivity-

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, productivity was based on a five-year average 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).

Blood Concentration-

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 *p,p'*-DDE concentration 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 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).

- Wiemeyer et al. (1984) estimated the concentration of mercury in eggs that would be protective of bald eagle populations to be < 0.5 mg/kg based on the concentration of mercury in eggs that caused adverse effects on pheasants (Fimreite, 1971). For this assessment, the egg concentration of 2.0 mg/kg that was associated with a dietary concentration of 0.3 mg/kg mercury that caused reproductive effects in American kestrels (Albers et al., 2007) was used because kestrels were considered better surrogates for bald eagles than pheasants.

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

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

* Based on data for pheasants.
** 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 used the field-derived Biomagnification Factors (BMFs) 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 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 = (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.

	PCBs	***p,p'*-DDE**	**TEQs**	**Mercury**
NOAEC (mg/kg egg)	4.0	3.5	0.00010	0.7
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	0.7
Fish Tissue LOAEC (mg/kg)	0.93	0.30	0.000011	2.0

Surrogate Species Approach

As part of the Great Lakes Initiative, surface water criteria protective of avian and mammalian wildlife 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 Test Dose (TD) was based on a No Observable Adverse Effect Level (NOAEL) or Lowest Observable 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 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 = [(TD/UF) x body weight]/fish consumption

Fish Tissue Level = [(TD/UF) x 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.

	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 et al., 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).

- It was not possible to derive effect levels for contaminants in herring gull eggs because few studies have identified adverse effects on herring gull populations (Weseloh et al., 1990 and 1994; Ewins et al., 1992). Decreased hatching success was found 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). This value was not added to Table 5 because it was an outlier relative to other values in the table.

- 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.

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

Fish Tissue Concentration-

Three approaches were used to determine the fish tissue concentrations of contaminants that could potentially cause adverse effects on colonial nesting birds. 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 the MDEQ 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 12). 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 16). 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 = (NOAEC or LOAEC in bird egg)/BMF

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

	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 or that could potentially cause adverse effects 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 = [(TD/UF) x body weight]/fish consumption

Fish Tissue Level = [(TD/UF) x 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.

	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 et al., 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 (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 defensible 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 the MDEQ 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 collected by the MDEQ 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:

- Herring gulls on Little Charity Island and the Saginaw Bay Confined Disposal Facility had suppressed immune systems, reduced growth rates in chicks, and elevated embryo lethality during a study conducted from 2010 to 2014. Caspian terns on the Saginaw Bay Confined Disposal Facility and on Charity Reef exhibited suppressed immune systems, reduced growth rates during several years, and reduced reproduction. Black-crowned night herons nesting on the Saginaw Bay Confined Disposal Facility also exhibited suppressed immune systems (Grasman, 2015). 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).

  Forage fish were collected from four areas of the Saginaw River/Bay AOC. 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 0.129 mg/kg, whereas, fish collected on the northwest shore and east shore of the bay had an average PCB concentration of 0.047 mg/kg. Forage fish from the three sites in Saginaw Bay had an average TEQ concentration of 4.54 nanograms per kilogram (ng/kg).

- 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 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 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 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	3.6	0.047 (outer bay) 0.13 (river, inner bay) **Average = 0.091**	Embryo-lethality, decreased growth, 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 recent study.				
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 Tables 8 and 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 Tables 8 and 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-tetrachlorodibenzofuran and our assessment was focused on studies that exposed mink to PCBs and TEQs in fish. All of the 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-

Sufficient 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).

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

NOAEC	LOAEC	Study Location (Reference)
3.1 mg/kg PCBs	3.1 mg/kg PCBs (kit survival at six weeks)	Housatonic River (Bursian et al., 2006a)
0.73 mg/kg PCBs	1.7 mg/kg PCBs (jaw lesions)	Housatonic River (Bursian et al., 2006b)
8.1 mg/kg PCBs	16 mg/kg PCBs (jaw lesions)	Saginaw River (Bursian et al., 2006c)
2.2 mg/kg PCBs	2.9 mg/kg PCBs (kit weight at six weeks)	Hudson River (Bursian et al., 2013a)
0.053 mg/kg PCBs	1.2 mg/kg PCBs (jaw lesions)	Hudson River (Bursian et al., 2013b)
Not Available	2.2 mg/kg PCBs (kit survival and weight at three and six weeks)	Saginaw Bay (Heaton et al., 1995)
6.0 mg/kg PCBs	7.3 mg/kg PCBs	Oak Ridge Reservation (Halbrook et al., 1999b)
0.05 µg/kg TEQs	0.189 µg/kg TEQs (kit survival at six weeks)	Housatonic River (Bursian et al., 2006a)
0.016 µg/kg TEQs	0.032 µg/kg TEQs (jaw lesions)	Housatonic River (Bursian et al., 2006b)
0.02 µg/kg TEQs	0.052 TEQs (jaw lesions)	Saginaw River (Bursian et al., 2006c)
0.018 µg/kg TEQs	0.061 µg/kg TEQs (kit weight at six weeks)	Hudson River (Bursian et al., 2013a)
0.0022 µg/kg TEQs	0.029 µg/kg TEQs (jaw lesions)	Hudson River (Bursian et al., 2013b
Not Available	0.226 µg/kg TEQs (kit survival and weight at three and six weeks)	Heaton et al., 1995 (Saginaw Bay)

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. All of the 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.

NOAEC	LOAEC	Reference
1.6 mg/kg PCBs	3.7 mg/kg PCBs (kit survival at six weeks)	Bursian et al., 2006a
0.61 mg/kg PCBs	0.96 mg/kg PCBs (jaw lesions)	Bursian et al., 2006b
0.83 mg/kg PCBs	1.1 mg/kg PCBs (jaw lesions)	Bursian et al., 2006c
0.72 mg/kg PCBs	1.5 mg/kg PCBs (kit weight at six weeks)	Bursian et al., 2013a
0.0074 mg/kg PCBs	0.72 mg/kg PCBs (jaw lesions)	Bursian et al., 2013b
0.015 mg/kg PCBs	0.72 mg/kg PCBs (kit survival and weight at three and six weeks)	Heaton et al., 1995
Not Available	0.25 mg/kg PCBs (whelping rate)	Restum et al., 1998
0.016 µg/kg TEQs	0.051 µg/kg TEQs (kit survival at six weeks)	Bursian et al., 2006a
0.0066 µg/kg TEQs	0.0042 µg/kg TEQs (jaw lesions)	Bursian et al., 2006b
0.022 µg/kg TEQs	0.036 µg/kg TEQs (jaw lesions)	Bursian et al., 2006c
0.0054 µg/kg TEQs	0.010 µg/kg TEQs (kit weight at six weeks)	Bursian et al., 2013a
0.00041 µg/kg TEQs	0.0048 µg/kg TEQs (jaw lesions)	Bursian et al., 2013b
0.00070 µg/kg TEQs	0.017 µg/kg TEQs (kit survival and weight at three and six weeks)	Heaton et al., 1995
0.40 mg/kg DDT*	2.0 mg/kg DDT* (survival)	Fitzhugh, 1948
Not Available	1.1 mg/kg Mercury (nervous system lesions)	Wobeser et al., 1976
Not Available	1.0 mg/kg Mercury (kit growth)	Wren et al., 1987
0.5 mg/kg Mercury	1.0 mg/kg Mercury (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 on 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 all of these values, the lowest of the most defensible values is provided in the last column of Table 12 as a screening tool. 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 particular wildlife species 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.

	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) requires the use of effect levels. Fish tissue NOAECs for the contaminants provided in Table 10 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 defensible 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 is 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 defensible as the bald eagle data. The value of 0.091 mg/kg determined by the MDEQ (Table 8) is defensible 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 defensible because they were derived using laboratory studies that fed mink contaminated fish under controlled conditions so the dose was accurately measured and potential adverse effects were assessed. 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 the MDEQ is defensible 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 defensible 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 very 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 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., 1994). 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 inches (1.7-17.4 cm) and 15.5 inches (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 the late May period, but were replaced by bluntnose minnows and spottail shiners 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., 1994). 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% (EPA, 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 2 to 50 cm (0.79 to 19.7 inches) or more in length. The three most commonly consumed fish (salmon, whitefish, and suckers) were larger than 30 cm (11.8 inches) in length (Melquist and Hornocker, 1983).

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 fish collected for this study are within the range of fish consumed by these species (Figure 1). Therefore, the forage fish data will be used to assess impacts to gulls, terns, and mink.

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 1). 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 the MDEQ's trend monitoring program will be used to assess the potential for contaminants to adversely impact these two larger species of piscivorous wildlife. 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. Use of contaminant levels in carp to assess impacts to bald eagles will only be done for the St. Clair River and Detroit River AOCs since the other AOCs with a Wildlife BUI have sufficient productivity and blood contaminant data to assess impacts to bald eagles directly.

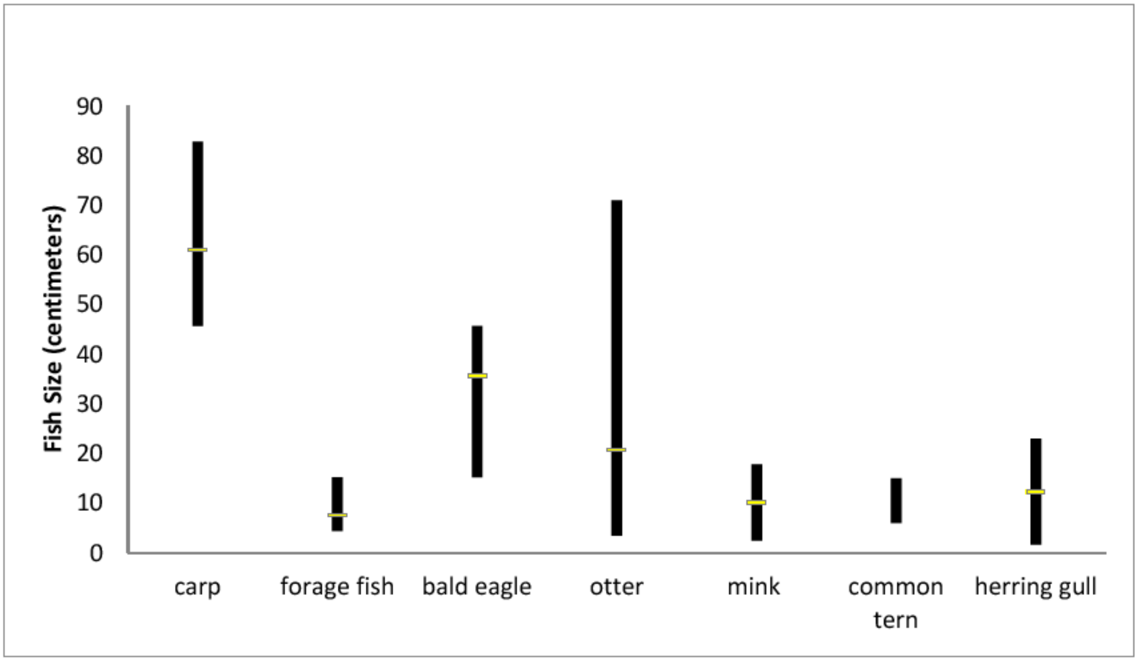

Figure 1. Size ranges (and means) of carp and forage fish collected by the MDEQ and the size of fish consumed by various piscivorous wildlife.

WILDLIFE CONTAMINANT MONITORING DATA SUMMARY

Bald eagles:

The bald eagle monitoring program in Michigan includes measurements of concentrations of PCBs and *p,p'*-DDE in eaglet plasma in all five 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 regions presented 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. Bald eagle productivity in Michigan has been monitored regularly since 1961. Maps of the state showing active and inactive bald eagle breeding territories are presented in Appendix A.

Table 13. Median bald eagle plasma PCB and *p,p'*-DDE concentrations (µg/kg) for AOCs and comparison populations based on data collected from 2009 through 2013.

	Median Concentration (µg/kg)		
	N*	PCBs	*p,p'*-DDE
Lake Erie			
St. Clair River AOC	1	43	14
Detroit River AOC	3	92	16
River Raisin AOC	2	166	11
Overall Lake Erie (non-AOC)	2	55	18
Lake Huron			
Saginaw Bay/River AOC	36	39	15
St. Marys River AOC	12	30	17
Overall Lake Huron (non-AOC)	15	39	18
Lake Michigan			
Kalamazoo River AOC	2	301	42
Overall Lake Michigan (non-AOC)	38	38	23
Lake Superior			
Overall Lake Superior (non-AOC)	20	16	17
Overall Great Lakes (Excluding AOCs)	73	36	20
Overall Inland Lower Peninsula (Excluding AOCs)	97	6	11
Overall Inland Upper Peninsula (Excluding AOCs)	22	4	8

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

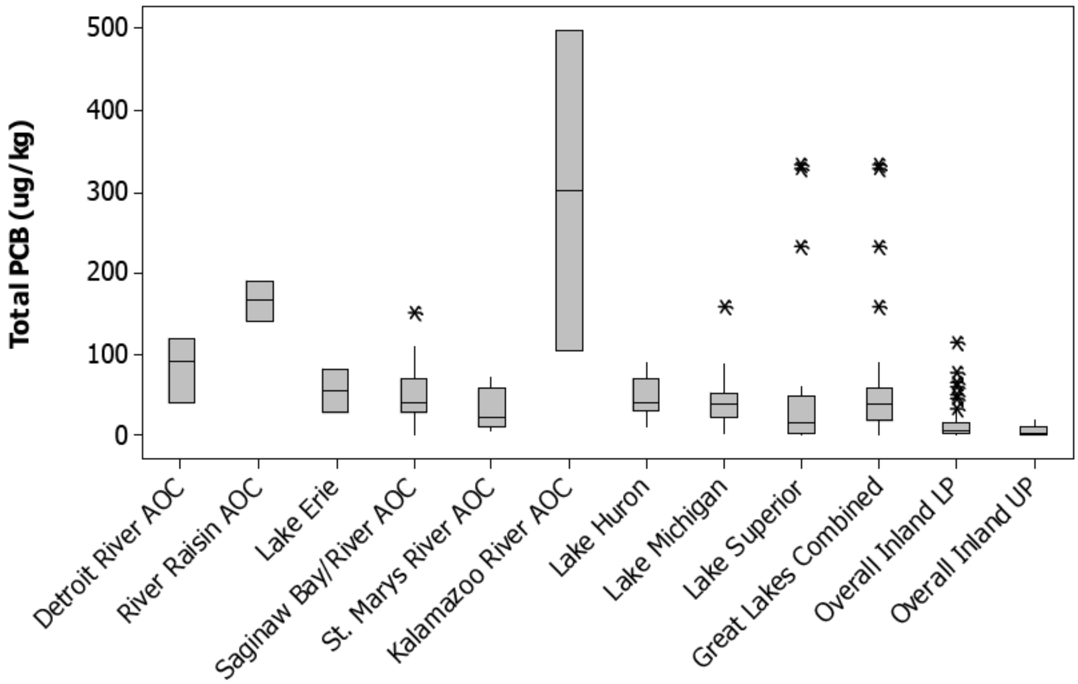

Figure 2. Boxplots of PCB concentrations measured in serum samples taken from nestling bald eagles between 2009 and 2013.

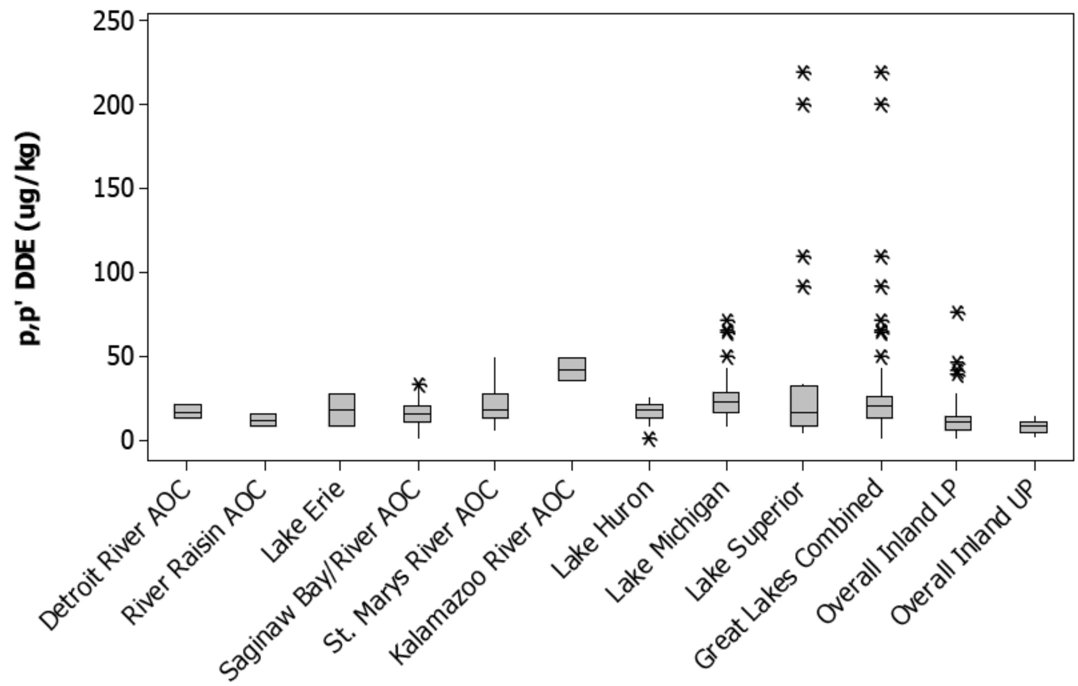

Figure 3. Boxplots of *p,p'*-DDE concentrations measured in serum samples taken from nestling bald eagles between 2009 and 2013.

Herring gulls:

In the past, the MDEQ monitored bioaccumulative compounds in herring gull eggs from ten colonies in Michigan waters. The MDEQ study, which currently monitors five colonies annually, complements similar work being conducted by the Canadian Wildlife Service across much of the Great Lakes. A map showing locations of colonies monitored by Michigan and Canada is presented in Appendix B. Table 14 presents a summary of contaminant concentrations measured in herring gull eggs and trends in contaminant levels from 2002 through 2012.

COMPARISON OF CONTAMINANT LEVELS AMONG COLONIAL BIRDS

Recent contaminant data are available for herring gulls in three 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 over time (Hebert et al., 2008 and 2009), only the most recent herring gull contaminant data 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 and black crowned night herons were similar to Caspian terns.

p,p'-DDE:

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

Table 14. Median concentrations of PCBs, p,p'-DDE, TEQ, and mercury in samples of herring gull eggs collected from colonies in Michigan.

	N		PCB (mg/kg)		*p,p'*- DDE (mg/kg)		TEQ (ng/kg)		Hg (mg/kg)	
	Median Concentration									
	2002 - 2006	2008 - 2012	2002 - 2006	2008 - 2012	2002 - 2006	2008 - 2012	2002 - 2006	2008- 2012	2002- 2006	2008- 2012
Lake Michigan										
Grand Traverse Bay (Bellow Island)	5	5	3.1	1.8*	2.2	0.8*	759	251†	0.69	0.41*
Lake Huron										
Saginaw Bay/River AOC‡ (Little Charity Island)	3	5	6.0	3.6*	1.3	0.7*	768	466	0.47	0.40
St. Marys River AOC‡ (5-Mile and West Twin Pipe Islands)	9	7	3.1	1.5*	1.0	0.4*	226	239	0.65	0.40*
Lake Superior	10	6	3.4	2.1**	1.5	0.7**	200	305	0.82	0.50*
Huron National Wildlife Refuge (Huron Island)	2	3	3	1.5†	1.5	0.5†	391	188	0.72	0.45
Lake Erie										
River Raisin AOC‡ (Detroit Edison)	5	5	10.8	7.8†	1.1	0.8*	719	511	0.42	0.32
All non-AOC Sites Combined	25	15	3.4	1.9†	1.6	0.7†	219	314	0.75	0.43†

* - Mann-Whitney test: significant at p <0.05

** - Mann-Whitney test: significant at p<0.001

† - Mann-Whitney test: significant at p=0.10

‡ - AOC with Wildlife BUI

Note: no significant differences in lipid content (Groups were compared using Kruskal-Wallis nonparametric test)

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)	1.8	0.77	NA	NA	NA
Hay Point (St. Marys River)	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)	0.376	0.099	NA	NA	NA
Hay Point (St. Marys River)	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:

The MDEQ 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). The means are grouped by AOC (in bold).

	Total PCB (mg/kg)	Total DDT (mg/kg)	Mercury (mg/kg)
Kalamazoo River (2011)	4.49	0.23	0.15
Grand River (2011)	0.21	0.17	0.11
Muskegon River (2012)	0.07	0.12	0.17
St. Joseph River (2012)	0.76	0.09	0.09
Detroit River (2011)	2.87	0.31	0.06
Lake St. Clair (2011)	0.69	0.08	0.09
Saginaw River and Bay (2012)	2.13	0.21	0.07
Lake Huron / Thunder Bay (2012)	1.33	0.24	0.10
Lake Michigan / Grand Traverse Bay (2011)	1.00	0.21	0.14
St. Clair River (2012)	0.90	0.10	0.09
Lake St. Clair (2011)	0.69	0.08	0.09
St. Marys River (2009)	1.76	0.27	0.16
Lake Michigan / L. Bay De Noc (2009)	1.45	0.38	0.28
Lake Michigan / Grand Traverse Bay (2008)	0.92	0.30	0.22
River Raisin (Lake Erie 2010)	3.31	0.11	0.08
River Raisin (upstream Waterloo Dam/Monroe, 2010)	0.14	0.05	0.11

*Either a dam or significant distances separate the populations being compared in all cases, except for comparisons of the St. Clair River/Lake St. Clair, and Saginaw Bay/Thunder Bay.

Forage Fish:

A recent study (Bush and Bohr, 2012) recommended that forage fish in the AOCs with a Wildlife BUI be analyzed for contaminants since the carp collected as part of the MDEQ's monitoring program are larger than fish normally consumed by mink, herring gulls, and terns. The results of this assessment for PCBs, *p,p'*-DDE, and mercury are shown in Table 18. A control site not expected to be impacted by contaminants was chosen near the Les Cheneaux Islands. Forage fish were collected from the St. Marys River AOC to provide additional information on contaminant levels that would not be expected to impact wildlife. Forage fish were not collected from the River Raisin AOC because there was concern that current dredging activities would influence the contaminant load in the fish from this site. The forage fish used for the assessment of the Detroit River AOC were collected just downstream of the AOC. The forage fish collected from Saginaw Bay were also analyzed for TEQs (Table 19) since the coplanar PCBs and dioxins/furans were the chemicals of concern when the Wildlife BUI was first established for the Saginaw River/Bay AOC. Maps showing the forage fish collection sites are provided in Appendix A.

Table 18. Contaminant concentrations in composite forage fish samples from selected Areas of Concern and a reference site (Mean concentrations are in bold).

Location		Species	N of Fish in Composite	Length (cm) Min	Mean	Max	Concentration (mg/kg) Total PCB	Total DDT	Hg
St. Clair River	Harsens Island	Bluegill	10	8.1	9.9	11.1	0.004	0.003	0.026
		Yellow perch	36	6.0	8.8	12.5	0.003	0.002	0.027
		Bluntnose minnow	38	4.7	6.7	8.6	0.019	0.006	0.02
							0.009	**0.004**	**0.024**
Saginaw River	Essexville	Yellow perch	3	5.3	9.7	12.1	0.17	0.045	0.038
		Gizzard shad	46	5.2	7.4	10.4	0.16	0.022	0.014
							0.165	**0.034**	**0.026**
Saginaw Bay	Wigwam Bay	Yellow perch	52	8.1	9.5	10.6	0.05	0.005	0.045
	(N.W. shore of Saginaw	Emerald shiner	66	4.9	5.4	5.9	0.04	0.004	0.029
	Bay)	Golden shiner	7	6.8	8.5	11.9	0.02	0.002	0.066
							0.037	**0.004**	**0.047**
Saginaw Bay	Sebawaing (east)	Bluntnose minnow	32	5.3	6.2	7.7	0.09	0.013	0.021
	(East shore of Saginaw	Emerald shiner	276	4.8	5.5	6.4	0.04	0.004	0.023
	Bay)	Yellow perch	37	8.0	8.8	9.8	0.04	0.005	0.027
							0.056	**0.007**	**0.024**
Saginaw Bay	Quanicassee	Bluntnose minnow	44	4.9	5.9	7.2	0.14	0.042	0.019
	(S. end of Saginaw	Emerald shiner	184	4.4	5.2	5.5	0.07	0.014	0.028
	Bay)	Yellow perch	51	8.8	10.0	11.2	0.11	0.025	0.021
							0.104	**0.027**	**0.023**

Table 18. (Continued) Contaminant concentrations in composite forage fish samples from selected Areas of Concern and a reference site (Mean concentrations are in bold).

Location		Species	N of Fish in Composite	Min	Mean	Max	Total PCB	Total DDT	Hg
St. Marys River	Munuscong Bay	Trout-perch	15	6.8	8.8	10.4	ND	0.001	0.037
		Spottail shiner	26	5.5	7.6	9.8	0.018	0.003	0.043
		Yellow perch	4	7.6	12.3	15.2	ND	0.001	0.075
							0.007	**0.002**	**0.052**
Kalamazoo River	Lake Allegan	Bluntnose minnow	11	4.7	5.7	7.5	0.91	0.043	0.041
		Spottail shiner	10	7.2	7.9	8.9	2.10	0.093	0.06
		Spottail shiner	9	6.7	8.2	11.0	1.66	0.07	0.096
							1.557	**0.069**	**0.066**
Detroit River	Pte Mouillee	Gizzard shad	6	6.1	9.9	11.5	1.16	0.054	0.013
		Brook silverside	96	6.0	6.9	7.7	0.35	0.026	0.041
		Shiners (Notropis)	25	4.5	5.75	6.8	0.21	0.013	0.042
							0.573	**0.031**	**0.032**
Lake Huron	Les Cheneaux (reference site)	Bluegill	12	5.2	6.0	7.0	0.004	0.002	0.034
		Yellow perch	92	5.2	6.4	7.5	0.006	0.003	0.029
		Common shiner	4	8.6	9.6	10.5	0.016	0.006	ND
							0.009	**0.004**	**0.021**

Table 19. TEQ concentrations in composite forage fish samples collected from three areas in the Saginaw Bay (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-

Recent productivity and contaminant data (2009-2013) for bald eagles nesting in the Kalamazoo River AOC are provided in Tables 20 and 21, respectively. A map depicting locations of active bald eagle territories and PCB contaminant levels is provided in Appendix C-1. Productivity and success rates of bald eagles nesting in the Kalamazoo River AOC are lower than all of the comparison populations. The productivity of 0.8 for the Kalamazoo River AOC is below the level of 1.0 required for a healthy population. The concentration of PCBs in bald eagle nestlings from the Kalamazoo River AOC are greater than those from all of the comparison populations, whereas, *p,p'*-DDE concentrations in bald eagles from the Kalamazoo River AOC are higher than all but one of the comparison populations.

The findings of this study are consistent with the findings of an older study of the Kalamazoo River AOC. In this study, contaminant levels and productivity were examined in bald eagles in the Kalamazoo River AOC from 2000 to 2004 (Strause, 2007). The study found elevated concentrations of PCBs in bald eagle eggs and nestling plasma from the

Kalamazoo River AOC. The annual bald eagle productivity rate for the Kalamazoo River AOC was 0.4 fledglings per active nest compared to productivities of 0.9 and 1.0 fledglings per active nest found in the riverine and lacustrine control sites, respectively. The study concluded that bald eagle productivity was adversely impacted in the Kalamazoo River AOC.

Herring gulls-

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

Mink-

The risk of PCBs to mink residing along the Kalamazoo River was assessed using two approaches (Millsap et al., 2004). The concentration of PCBs and TEQs in mink liver collected at the site and the estimated concentration of PCBs and TEQs in the diets of mink were compared to benchmarks determined in toxicity studies conducted on mink. Both approaches suggested that PCBs and TEQs are near the threshold for effects on reproduction in mink living along the Kalamazoo River. This study also found that the mean liver concentrations of PCBs were 2.7 and 2.3 mg/kg wet weight in mink captured in the Kalamazoo River AOC and the upstream control site, respectively.

Four of nine mink trapped in the Kalamazoo River AOC during the period 2000 to 2002 exhibited histological evidence of a jaw lesion (Beckett et al., 2005). Mink trapped from an upstream reference area did not exhibit this lesion. Significant correlations were found between the severity of the lesion and hepatic concentrations of PCBs and TEQs.

Tree swallows-

The concentration of PCBs in tree swallow eggs was monitored by the 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).

The findings of the Custer study are consistent with the finding of an older study, which examined the productivity of tree swallows in the Kalamazoo River AOC from 2000 to 2002 (Neigh et al., 2006a). In this study, tree swallows in the Kalamazoo River AOC had a lower clutch size in the contaminated downstream location compared to the upstream location in two of the three years of the study. However, no significant differences were found between the two sites with respect to fledging success, brood size, number of fledglings, or fledgling growth. The study concluded that PCBs were not adversely affecting tree swallow populations living in the Kalamazoo River AOC.

Other birds-

The contaminant levels and productivity in great horned owls in the Kalamazoo River AOC were examined from 2000 to 2004 (Strause, 2007). No effects on great horned owl productivity were found.

The effects of PCBs on bluebirds and house wrens living in the Kalamazoo River AOC were assessed during the 2001 to 2003 nesting seasons (Neigh et al., 2007). Productivity of bluebirds was significantly less at the more contaminated downstream location of the Kalamazoo River than at the upstream reference location. The house wrens exhibited a decrease in hatching success, clutch size, and brood size in the Kalamazoo River AOC compared to the control site. However, fledging success was significantly greater at the contaminated site than at the reference site. The estimated daily dose of PCBs and TEQs in the diets of the birds were 6- to 29-fold and 16- to 35-fold greater, respectively, at the contaminated sites than at a reference location (Neigh et al., 2006b). The researchers concluded that other factors in addition to PCB exposure such as habitat, prey availability, small sample size, and co-contaminants were likely the causes of the differences that were observed at the two locations.

A Peer Review Panel identified problems with the study design and the method used to analyze the reproductive parameters in the studies summarized above (Dickson et al., 2008). For example, the panel recalculated the overall reproductive success using a different methodology and found a 47% lower estimate of fledglings per nest initiated for bluebirds and 18% lower for house wrens at the contaminated site compared to the reference area. The Peer Review Panel concluded that the studies should not be used to reach risk conclusions on their own and that a thorough reanalysis of the data is needed.

Table 20. Bald eagle productivity, brood size, and success rates in the Kalamazoo River AOC territories compared to territories in the Grand, Manistee, and Pere Marquette Rivers watersheds, all territories with access to Lake Michigan fish, and all territories statewide. Estimates are averages over the five-year period from 2009 to 2013.

Population Metric[1]	KR AOC	Manistee River (d/s Tippy Dam)	Pere Marquette River	Lake Michigan[2]	Great Lakes Statewide[3]	Inland Statewide[3]
Productivity	0.8	1.0	1.1	1.1	1.1	1.0
Brood Size	1.5	1.7	1.4	1.6	1.6	1.5
Success Rate	0.5	0.6	0.8	0.7	0.7	0.7
Mean # Territories	4.2	3	7.4	111	238.8	348.2

[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 the lower peninsula with access to Lake Michigan fish, excluding Kalamazoo River AOC

[3] - excluding all AOCs

Table 21. A comparison of median PCB and *p,p*'-DDE concentrations in the serum of bald eagle nestlings from the Kalamazoo River 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 2009 through 2013.

	Healthy / Stable Population TRV[1]	KR AOC	Manistee River (d/s Tippy Dam)	Pere Marquette River	Lake Michigan[2]	Great Lakes Statewide[3]	Inland Statewide[3]
PCB (µg/Kg)	35 / 125	301	38	159	38	37	5
p,p'-DDE (µg/Kg)	11 / 28	42	25	66	23	20	10
Number of Samples		2	7	1	41	77	123

[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

Fish data:

Spatial comparison-

The concentrations of PCBs in carp are higher in the Kalamazoo River AOC than in the Grand, Muskegon, and St. Joseph Rivers (Table 17). Total DDT concentrations were not elevated compared to the Grand and Muskegon Rivers, but were elevated compared to the St. Joseph River. Mercury concentrations were not elevated in carp from the Kalamazoo River compared to the three comparison sites.

The concentrations of PCBs in forage fish are higher in the Kalamazoo River AOC than in fish collected in the Detroit River, Saginaw River/Bay, the St. Marys River, and near the Les Cheneaux Islands.

Comparison to wildlife benchmark value-

The concentration of 1.56 mg/kg PCBs in forage fish from the Kalamazoo River (Table 18) is above the TRV for the protection of mink. Even though the carp collected for the trend monitoring program are probably larger than would normally be consumed by bald eagles and otters, it is noteworthy that the average PCB concentration of 2.44 mg/kg for 2009 exceeds the fish TRV.

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.

- Bald eagle productivity in territories within the Kalamazoo River AOC is lower than the productivity of the comparison populations.

- PCB concentrations in eaglet plasma (median = 301 µg/kg) are above levels associated with a stable population (125 µg/kg).

- Mink collected in 2000 and 2002 within the Kalamazoo River AOC exhibited an increase in jaw lesions due to PCBs and TEQs. Liver concentrations of PCBs were also near levels associated with effects on reproduction. No more recent data were available for this assessment.

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

- PCB concentrations in forage fish and carp exceed the fish tissue TRV.

Recommendation:

Existing data are sufficient to conclude that the Wildlife BUI should be retained for the Kalamazoo River AOC.

Monitoring of productivity and contaminant levels in bald eagles in the Kalamazoo River AOC and contaminant concentrations in Kalamazoo River fish should continue while ongoing river sediment remediation work progresses. The frequency of jaw lesions in mink from the Kalamazoo River AOC and the levels of PCBs in the livers of mink should be determined.

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 recent productivity of bald eagles nesting in the Saginaw River/Bay AOC is similar to the productivity of bald eagles nesting in the comparison populations (Table 22). The plasma concentrations of PCBs are greater in birds from the Saginaw River/Bay AOC compared to three of the four comparison populations. The plasma concentrations of *p,p'*-DDE in birds from the Saginaw River/Bay AOC is similar to the comparison populations. The median 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 23).

Since the Saginaw River/Bay AOC encompasses a very large area, it was considered reasonable to look at productivity and contaminant data for individual territories to assess whether there are specific areas where bald eagles are being impacted. Appendices C-2 and D-1 show that eagles from breeding areas near the lower Saginaw River have levels of PCBs (territories BY-02, BY-07, and BY-08) that are greater than levels associated with stable bald eagle populations. Some breeding areas in Saginaw River/Bay AOC are also exhibiting very low productivity and success rates (Appendix D-1). For at least one of these nests (BY-02), low productivity may be due to human disruption of the nesting bald eagles (Dave Best, personal communication, 2015). Within this dataset, PCB and *p,p'*-DDE concentrations and productivity were not correlated during the 2009 to 2013 time period (Figures 4 and 5).

Table 22. Bald eagle productivity, brood size, and success rates in the Saginaw River/Bay AOC territories compared to territories with access to Lake Huron fish, and all territories statewide. Estimates are averages over the five-year period from 2009 to 2013.

Population Metric[1]	SRB AOC	Lake Huron Lower Peninsula[2]	Great Lakes Statewide[3]	Inland Lower Peninsula[3]	Inland Statewide[3]
Productivity	1.1	1.2	1.1	1.0	1.0
Brood Size	1.6	1.7	1.6	1.5	1.5
Success Rate	0.7	0.7	0.7	0.7	0.7
Mean # Territories	33	37	238.8	231.2	348.2

[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 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

Table 23. A comparison of median PCB and *p,p'*-DDE concentrations in the serum of bald eagle nestlings from the Saginaw River/Bay AOC with other bald eagle populations in Michigan. Medians are the overall values based on median concentrations per nest per year observed over the 5-year period from 2009 through 2013.

	Healthy / Stable Population TRV[1]	SRB AOC	Lake Huron Lower Peninsula[2]	Great Lakes Statewide[3]	Inland Lower Peninsula[3]	Inland Statewide[3]
PCB (µg/Kg)	35 / 125	39	39	37	6	5
p,p'-DDE (µg/Kg)	11 / 28	15	18	20	11	10
Number of Samples		35	15	77	100	123

[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

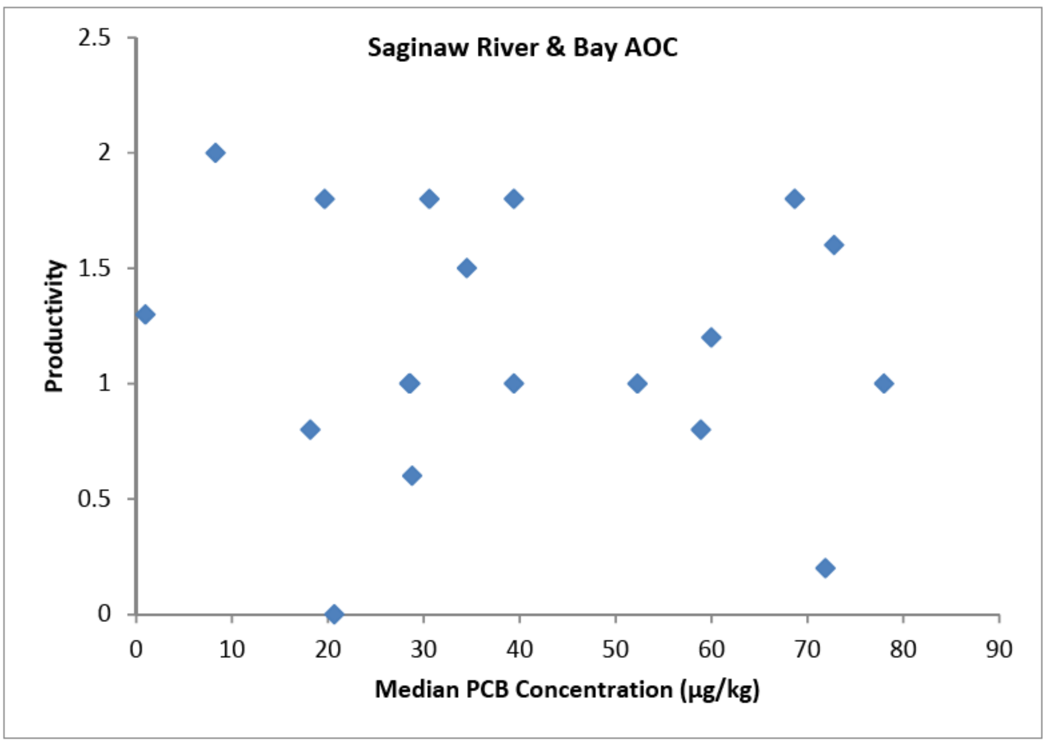

Figure 4. Productivity of bald eagles nesting in the Saginaw River/Bay AOC versus median PCB concentration (2009-2013).

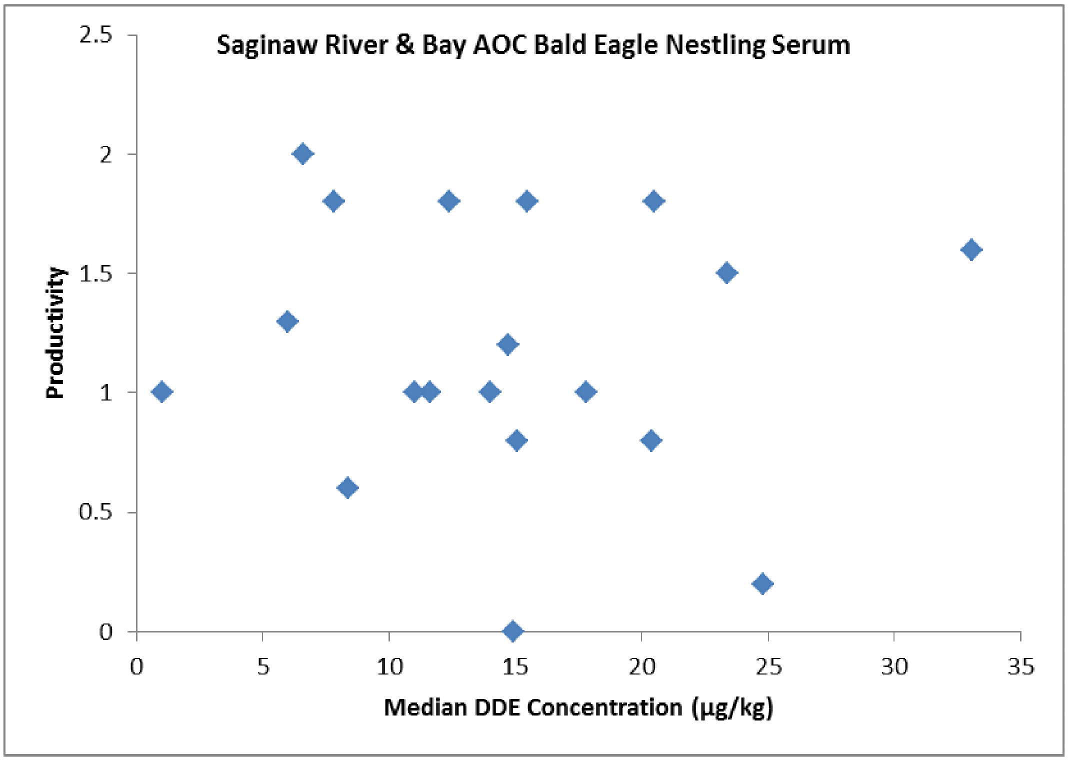

Figure 5. Productivity of bald eagles nesting in the Saginaw River/Bay AOC versus median *p,p'*-DDE concentration (2009-2013).

Herring gulls-

A study of herring gulls on Little Charity Island and the Saginaw Bay Confined Disposal Facility from 2010 to 2014 found suppressed immune systems, reduced growth rates in chicks during 3 out of the 4 years of the study, and elevated embryo-lethality. Caspian terns exhibited suppressed immune systems, reduced growth rates during several years, and reduced reproduction. Black-crowned night herons nesting on the Saginaw Bay Confined Disposal Facility also exhibited suppressed immune systems (Grasman, 2015). 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).

Herring gull eggs collected from Little Charity Island had a median PCB concentration of 3.6 mg/kg and a median TEQ concentration of 466 ng/kg for the period 2008-2012. Both of these values are the second highest found in the five colonies currently being monitored by the state of Michigan.

Mink-

Mink were fed diets containing 0, 10, 20, or 30% carp collected from the Saginaw River in 2000 prior to breeding and throughout gestation and lactation. The six-week old kits from adults that were fed diets containing 10% carp had significant increases in total and free thyroxine (T4) levels, while kits fed the 20% and 30% carp diet had decreased levels relative to control mink (Martin et al., 2006). The adults had maxillary and mandibular squamous epithelial proliferation in the jaws when exposed to diets containing 20% and 30% carp (Bursian et al., 2006c). No effects were found on mink reproduction and kit survivability.

Mink were fed diets containing 0, 10, 20, or 40% carp collected from the Saginaw Bay in 1988 prior to and throughout the reproductive period (Heaton et al., 1995). Kit body weights at birth were significantly reduced in the 20 and 40% groups, whereas, kit body weights and survival in the 10 and 20% groups were significantly reduced at three and six weeks of age. In a two-generation study (Restum et al., 1998), mink fed carp from Saginaw Bay at levels resulting in dietary PCB concentrations of 0.25 mg/kg had a delayed onset of estrus and a lower whelping rate. The mink also had decreased organ weights and there were variable effects on serum triiodothyronine and T4 levels.

Tree swallows and house wrens-

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).

Greater concentrations of dioxins and furans were found in house wren eggs, house wren nestlings, and tree swallow nestlings living along the Saginaw River compared to reference sites located along the Chippewa River and the Tittabawassee River upstream from Midland. However, contaminant concentrations in eggs of tree swallows from the Saginaw River were similar to the concentrations in eggs from the reference site upstream of Midland (Fredricks et al. (2010).

Fish data:

Spatial comparison-

PCB concentrations in carp from the Saginaw River/Bay AOC were higher than concentrations found in Thunder Bay and the Grand Traverse Bay (Table 17). Concentrations of total DDT and mercury were lower in the Saginaw River/Bay AOC compared to the two comparison sites. 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). However, the concentrations were lower than levels found in the Detroit River and the Kalamazoo River AOC.

Comparison to wildlife benchmark value-

In addition to the carp data reported in Table 17, contaminant data are available in the literature for walleye. PCB concentrations in walleye collected from Saginaw Bay in 2007 were 1.9 for very large (average length = 24 inches) and 1.2 mg/kg for extremely large walleye (average length = 27 inches). PCB concentrations of 0.46, 0.87, and 1.1 mg/kg were reported for small (average length = 14 inches), medium (average length = 18 inches), and large (average length = 21 inches) walleyes, respectively, collected from the Saginaw and Tittabawassee Rivers (Jude et al., 2010). PCB concentrations of 1.58 and 0.55 mg/kg were reported in male (average length = 21 inches) and female (average length = 22 inches) walleyes, respectively, collected in 2007 from the Tittabawassee River during the spawning run (Madenjian et al., 2009).

Forage fish recently collected by the MDEQ from the Saginaw River, the northwest shore of Saginaw Bay, the east shore of Saginaw Bay, and the south end of Saginaw Bay contained 0.165, 0.037, 0.056, and 0.104 mg/kg PCBs, respectively (Table 18). The TEQ concentrations in forage fish collected by the MDEQ averaged 0.0000045 mg/kg (Table 19). Since reproductive/developmental effects have been observed in various colonial nesting birds within the Saginaw River/Bay AOC that have been related to PCBs, it can be assumed that the concentration 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.

The concentrations for medium and large walleye collected from Saginaw Bay in 2007 are near (or above) the fish TRV that may adversely impact otters. Even though the carp collected for Michigan's trend monitoring program are most likely larger than would normally be consumed by otters, it is noteworthy that the average PCB concentration of 2.13 mg/kg for 2012 exceeds the range of fish TRVs.

<u>Conclusions</u>:

- 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. Caspian terns, herring gulls, and black-crown night herons in the Saginaw River/Bay AOC have also been exhibiting low growth rates and immune suppression.

- Productivity of bald eagles nesting in the Saginaw River/Bay AOC from 2009 to 2013 is above levels associated with a healthy population. Productivity was similar to the productivity of the comparison populations. There may be specific areas within the AOC where bald eagles are being adversely impacted.

- PCB concentrations in eaglet plasma (median = 39 µg/kg; geometric mean = 41 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.

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

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

<u>Recommendation</u>:

Existing data are sufficient to conclude that the Wildlife BUI should be retained for the Saginaw River/Bay AOC.

Monitoring of productivity and contaminant levels in the bald eagles in the Saginaw River/Bay AOC and contaminant concentrations in Saginaw Bay herring gulls and fish should continue. In addition, the immune suppression and variable productivity of the colonial nesting birds in colonies in the Saginaw Bay should continue to be monitored until they are similar to reference colonies.

River Raisin AOC:

Wildlife studies:

Bald eagles-

Active nesting territories within the River Raisin AOC are depicted in Appendix C-3. The productivity and brood size of birds nesting in the River Raisin AOC from 2009 to 2013 is higher than the comparison populations (Table 24) even though these eaglets have much greater levels of PCBs in their plasma than birds in the comparison populations (Table 25). The median plasma PCB concentration of 166 µg/kg is higher than the TRV associated with a healthy bald eagle population. The concentrations of *p,p*'-DDE in bald eagles inhabiting the River Raisin AOC were similar to the median levels found for the comparison populations. In addition, two deformed nestlings were collected in 1993 and 1995 from this breeding area (Bowerman et al., 1994 and 1998). However, no deformities in bald eagles have been found in this area since this period.

Table 24. Bald eagle productivity, brood size, and success rates in the River Raisin AOC territories compared to territories with access to Lake Erie fish, and all territories statewide. Estimates are averages over the five-year period from 2009 to 2013.

Population Metric[1]	RR AOC	Lake Erie (Michigan Waters)[2]	Great Lakes Statewide[3]	Inland Lower Peninsula[3]	Inland Statewide[3]
Productivity	1.4	1.2	1.1	1.0	1.0
Brood Size	1.6	1.6	1.6	1.5	1.5
Success Rate	0.9	0.8	0.7	0.7	0.7
Mean # Territories	1.8	6.6	238.8	231.2	348.2

[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

Table 25. A comparison of median PCB and *p,p'*-DDE concentrations in the serum of bald eagle nestlings from the River Raisin AOC with other bald eagle populations in Michigan. Medians are the overall values based on median concentrations per nest per year observed over the 5-year period from 2009 through 2013.

	Healthy / Stable Population TRV[1]	RR AOC	Lake Erie[2]	Great Lakes Statewide[3]	Inland Lower Peninsula[3]	Inland Statewide[3]
PCB (µg/Kg)	35 / 125	166	55	37	6	5
p,p'-DDE (µg/Kg)	11 / 28	11	18	20	11	10
Number of Samples		2	2	77	100	123

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

Herring gulls-

A study conducted on the Detroit Edison herring gull colony from 2010 to 2014 found suppressed immune systems; reduced growth rates in chicks during 3 out of the 4 years of the study; elevated embryo-lethality (including two cross-billed chicks); and reproductive failure during 2010 and decreased productivity during 2012 (Grasman, 2015). 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 7.8 mg/kg and a median TEQ concentration of 511 ng/kg for the period 2008-2012. Both of these values are the highest found in the five colonies currently being monitored by the state of Michigan. In addition, two herring gulls with crossed bills were found during the 2012-2013 monitoring season.

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).

<u>Fish data</u>:

Spatial comparison-

Concentrations of PCBs and total DDT in carp were greater in the River Raisin downstream of the Waterloo Dam in Monroe compared to upstream (Table 17). The total DDT concentrations in carp from the River Raisin AOC were similar to those found in the St. Joseph, St. Clair, and Muskegon Rivers. Mercury concentrations in fish collected upstream and downstream of the Waterloo Dam were similar.

Comparison to wildlife benchmark value-

There are insufficient contaminant data available for fish inhabiting the River Raisin AOC to adequately assess wildlife impacts. Even though the carp used in the contaminant analysis are probably larger than those normally consumed by otters, the average PCB concentration of 3.31 mg/kg for 2010 exceeds the fish TRVs.

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

It is presumed that the concentration of PCBs in forage fish from the River Raisin AOC will be higher than the levels of PCBs (0.57 mg/kg) found in forage fish from the Detroit River AOC. This concentration is above the low end of the range of fish TRVs protective of mink.

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 the comparison populations.
- Based on the herring gull data, piscivorous wildlife within the River Raisin AOC are exposed to greater concentrations of TEQs than gulls from the comparison populations.
- Data for 2009-2013 show that the productivity of bald eagles nesting in the River Raisin AOC is higher than levels associated with a healthy population.
- Data for 2009-2013 show that blood levels of PCBs (median = 166 µg/kg) exceed levels associated with a stable population. Based on the magnitude of these concentrations, it is unclear why the productivity for the River Raisin AOC is currently high.
- Herring gulls in the River Raisin AOC are exhibiting low growth rates, immune suppression, and low growth rates relative to a comparison population.
- The concentrations of PCBs and TEQs present in herring gull eggs from the River Raisin AOC suggest that other species of colonial nesting birds could be adversely impacted.
- Two herring gulls with crossed bills were found during the 2012-2013 monitoring season.
- Reproduction of tree swallows nesting along the River Raisin AOC does not appear to be adversely impacted.
- PCB concentrations in carp from the River Raisin AOC exceed the fish tissue TRVs. The estimated concentration of PCBs in forage fish is above the low end of the fish TRV range of concentrations estimated to adversely impact wildlife.

Recommendation:

Existing data are sufficient to conclude that the Wildlife BUI should be retained for the River Raisin AOC.

The monitoring of productivity in bald eagles should continue in the River Raisin AOC to determine if the bald eagles continue to exceed the benchmark associated with a healthy population. Measurement of contaminant concentrations in bald eagles, herring gull eggs, and fish (including forage fish) should be conducted to evaluate the effects of ongoing river sediment remediation work.

Detroit River AOC:

Wildlife studies:

Bald eagles-

Active nesting territories within the Detroit River AOC are depicted in Appendix C-3. There are only two territories within the Detroit River AOC. Bald eagles in one of these territories (Humbug Marsh; WA-07) fledged no young in 2010, but fledged one young each year from 2011 to 2013. The other territory within the Detroit River AOC (Stony Island; WA-06) fledged a total of two young from 2009 to 2013. A territory adjacent to the AOC (near the Huron River upstream of Lake Erie; WA-03) was active every year fledging a total of eight young from 2009 to 2013. The productivity of bald eagles in these three territories from 2009-2013 is provided in Table 23.

The overall productivity and success rate for the Detroit River AOC was lower than in all other comparison populations (Table 26). Contaminant data are available for one bald eagle territory within the Detroit River AOC (Table 27). The median PCB and *p,p'*-DDE concentrations for three samples from territory WA-07 were 92 and 16 ug/kg, respectively. The PCB levels were higher than the comparison populations, whereas, the *p,p'*-DDE levels were lower than two of the four comparison populations.

Table 26. Bald eagle productivity, brood size, and success rates in the Detroit River AOC territories compared to territories with access to Lake Erie fish, and all territories statewide. Estimates are averages over the five-year period from 2009 to 2013.

Population Metric[1]	DR AOC	Lake Erie (Michigan Waters)[2]	Great Lakes Statewide[3]	Inland Lower Peninsula[3]	Inland Statewide[3]
Productivity	0.9	1.2	1.1	1.0	1.0
Brood Size	1.6	1.6	1.6	1.5	1.5
Success Rate	0.6	0.8	0.7	0.7	0.7
Mean # Territories	2.8	6.6	238.8	231.2	348.2

[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 the Michigan with access to Lake Erie fish, excluding AOCs

[3] - excluding all AOCs

Table 27. A comparison of median PCB and *p,p*'-DDE concentrations in the serum of bald eagle nestlings from the Detroit River AOC with other bald eagle populations in Michigan. Medians are the overall values based on median concentrations per nest per year observed over the 5-year period from 2009 through 2013.

	Healthy / Stable Population TRV[1]	DR AOC	Lake Erie[2]	Great Lakes Statewide[3]	Inland Lower Peninsula[3]	Inland Statewide[3]
PCB (µg/Kg)	35 / 125	92	55	37	6	5
p,p'-DDE (µg/Kg)	11 / 28	16	18	20	11	10
Number of Samples		3	2	77	100	123

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

Herring gulls-

There has not been a herring gull colony nesting in the Detroit River for many years. 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 greatest PCB concentration and the ninth greatest TEQ concentration of the 15 colonies routinely monitored by the Canadian Wildlife Service (Weseloh, 2003; Weseloh et al., 2006). This PCB concentration is greater than any of the PCB concentrations found in the ten colonies monitored by the state of Michigan in 2002.

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).

Snapping turtles-

The concentrations of PCBs, dioxins/furans, and organochlorine pesticides were measured in the eggs and plasma of snapping turtles from three AOCs (Wheatley Harbor, Detroit River, and St. Clair River) and two reference sites (Algonquin Provincial Park and Tiny Marsh) (De Solla and Fernie, 2004). The eggs collected from the Wheatley Harbor AOC and the Canadian side of the Detroit River AOC had much higher concentrations of *p,p*'-DDE and PCBs in 2001-2002 than the other sites. Dioxins were highest in the Detroit River AOC. De Solla et al. (2008) examined the hatching success, deformity rates, and contaminant concentrations (PCBs, PBDEs, and pesticides) in snapping turtles at 14 sites in the Canadian lower Great Lakes, including 8 AOCs between 2001 and 2004. These researchers found a decrease in hatching success and a lower deformity rate in snapping turtles from Turkey Creek in the Detroit River AOC for the 2002 to 2004 period. They did not find a relationship between contaminant concentrations and hatching success.

Common terns-

According to Szczechowski and Bull (2007), nesting populations of common terns have decreased in the Detroit River AOC due to environmental factors, contamination, and predation primarily by black-crowned night heron. It has been estimated that only about 20% of the chicks are surviving to the fledgling stage. PCB 1260 concentrations of 5.0 and 5.1 mg/kg wet weight were measured in eggs of common terns collected at the Grosse Ile Free Bridge in 2003 and 2004, respectively (Szczechowski, 2007; Szczechowski and Bull, 2007). These concentrations are above the concentration determined by Hoffman et al. (1993) to cause a decrease in hatching success of common terns.

Black-crowned night herons-

The Canadian Wildlife Service assessed the reproductive viability of black-crowned night herons living on Turkey Island in the Detroit River AOC 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 like PCBs and *p,p'*-DDE were found in eggs from birds living on Turkey Island compared to birds living on Nottawasaga Island. The researchers concluded that decreased reproduction on Turkey Island may be due to stressors other than contaminants such as predation, weather, and disturbance.

<u>Fish data</u>:

Spatial comparison-

The concentration of PCBs in carp from the Detroit River AOC were higher than levels found in carp from Lake St. Clair and the Grand, Muskegon, and St. Joseph Rivers (Table 17). The concentrations of total DDT and mercury in carp from the Detroit River AOC were similar to levels found in Lake St. Clair carp.

Comparison to wildlife benchmark value-

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 2.87 mg/kg for 2011 exceeds the fish TRVs. 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.

<u>Conclusions</u>:

- Based on the herring gull, snapping turtle, 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.

- PCB concentrations measured in common tern eggs from the Detroit River AOC are above levels associated with decreased hatching success.

- Snapping turtles and black-crowned night herons living in the Detroit River AOC may be adversely impacted.

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

- PCB concentrations in carp from the Detroit River AOC exceed the fish tissue TRV. The concentration of PCBs in forage fish are above concentrations that may adversely impact wildlife.

Recommendation:

Existing data are sufficient to conclude that the Wildlife BUI should be retained for the Detroit River AOC.

Monitoring of the bald eagle and other wildlife populations in the Detroit River AOC and contaminant concentrations in Detroit River fish should continue.

St. Marys River AOC:

Wildlife studies:

Bald eagles-

Active nesting territories within the St. Marys River AOC are depicted in Appendix C-4. Both the overall productivity and the overall success rate for bald eagles nesting in the St. Marys River AOC were higher than observed in all of the comparison populations (Table 28). Bald eagle nestlings from the St. Marys River AOC for 2009-2013 had PCB and *p,p*'-DDE blood levels that were slightly elevated relative to the concentrations of these contaminants in eaglets from the Great Lakes (excluding the AOCs) (Table 29).

Table 28. Bald eagle productivity, brood size, and success rates in the St. Marys River AOC territories compared to territories with access to Lake Huron fish, Lake Superior fish, and all territories statewide. Estimates are averages over the five-year period from 2009 to 2013.

Population Metric[1]	SMR AOC	Lake Huron[2]	Lake Superior[3]	Great Lakes Statewide[3]	Inland Upper Peninsula[3]	Inland Statewide[3]
Productivity	1.4	0.9	1.0	1.1	0.9	1.0
Brood Size	1.7	1.5	1.6	1.6	1.4	1.5
Success Rate	0.8	0.6	0.6	0.7	0.6	0.7
Mean # Territories	17.4	17	64.6	238.8	115	348.2

[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 percent of nesting attempts producing at least one fledged young
- Mean # Territories equals the average number of active nests per year over the 5-year period

[2] - territories in the upper peninsula (Chippewa and Mackinac Counties) with access to Lake Huron fish, excluding the St. Marys River AOC

[3] - excluding all AOCs

Table 29. A comparison of median PCB and *p,p*'-DDE concentrations in the serum of bald eagle nestlings from the St. Marys River 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 2009 to 2013.

	Healthy / Stable Population TRV[1]	SMR AOC	Lake Huron[2]	Lake Superior[2]	Great Lakes Statewide[2]	Inland Upper Peninsula[3]	Inland Statewide[3]
PCB (µg/Kg)	35 / 125	53	39	16	37	4	5
p,p'-DDE (µg/Kg)	11 / 28	34	18	17	20	8	10
Number of Samples		2	15	19	77	21	123

[1] - concentration associated with a productivity of 1.0 (healthy) or 0.7 (stable) young per occupied nest
[2] - territories with access to Great Lakes fish, excluding territories in AOCs
[3] - excluding all AOCs

Herring gulls and common terns-

Michigan is currently monitoring contaminant levels in two herring gull colonies from the St. Marys River AOC (Five Mile Island and West Twin Pipe). The Five Mile Island and West Twin Pipe colonies had 2008-2012 median PCB egg concentrations of 1.5 mg/kg (Table 14). The five-year median TEQ concentration for these two colonies was 239 ng/kg. The PCBs and the TEQs are relatively low compared to results for the other colonies monitored in Michigan. The PCB and TEQ concentrations are less than the effect levels found for common tern and double-crested cormorant eggs.

The St. Marys River AOC was originally listed as having a Wildlife BUI due to a study that found adverse effects on common terns. The study determined that the common tern colony on Lime Island in the St. Marys River collapsed in 1999 due, in part, to the presence of dioxin and dioxin-like PCBs (Senthilkumar et al., 2004). Bill defects were also found in two hatchlings. The researchers concluded that the TEQ concentrations in the tern eggs were above concentrations that have been shown to be toxic to other species of birds and within the range of concentrations that have been shown to be toxic to common tern embryos in egg injection studies.

The reproduction and development of herring gulls and common terns breeding within the St. Marys River AOC were examined in 2011 and 2012. Freshly laid eggs were collected, artificially incubated, and then assessed for embryonic viability, embryonic deformities, and contaminant levels. The researchers concluded that the concentrations of PCBs and other contaminants were not adversely impacting the reproductive success and development of herring gulls and common terns foraging in the St. Marys River AOC (Hughes et al., 2014).

Tree swallows-

The concentration of PCBs in tree swallow eggs was monitored by the USGS in nest boxes located near Ashmun Bay and Back Bay in the St. Marys River AOC. The median PCB concentration for the individual sites was 0.17 and 0.09 mg/kg, respectively, with a median for the two sites combined of 0.12 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 26 out of 27 AOCs studied. The median dioxin and furan concentration of 73.1ng/kg ranked 26 out of 27 AOCs studied (Custer, 2015).

Fish data:

Spatial comparison-

The PCB and total DDT concentrations in carp from the St. Marys River AOC were lower than levels found in carp from Little Bay De Noc and Grand Traverse Bay (Table 17). Mercury levels in carp from the St. Marys River AOC were similar to those found in carp from Little Bay De Noc and Grand Traverse Bay. The concentration of PCBs in forage fish collected from the St. Marys River AOC were lower than all the comparison populations (Table 18).

Comparison to wildlife benchmark value-

The concentration of PCBs in forage fish collected from the St. Marys River AOC are below levels that would be expected to impact mink and colonial nesting birds (Table 18). Even though the carp used in the contaminant analysis are probably larger than would normally be consumed by otters, it is noteworthy that the average PCB concentration of 1.76 mg/kg for 2009 exceeds the fish TRV.

Conclusions:

- The productivity data for bald eagles living along the St. Marys River AOC indicate a healthy population.
- PCB and *p,p*'-DDE concentrations in eaglet plasma are below NOAEC levels associated with a healthy population.
- Based on bald eagle, herring gull, forage fish, and carp data, it was concluded that piscivorous wildlife within the St. Marys River AOC are not exposed to higher concentrations of contaminants than surrounding areas.
- The Canadian Wildlife Service determined that contaminants were not affecting reproductive success of herring gulls and common terns nesting in the St. Marys River AOC.
- PCB concentrations in carp from the St. Marys River AOC slightly exceed the low end of the fish tissue TRV range of concentrations estimated to adversely impact wildlife. The estimated concentration of PCBs in forage fish is well below the fish TRV.

Recommendation:

Bush and Bohr (2012) recommended that the Wildlife BUI for the St. Marys River AOC be removed. The Wildlife BUI was officially removed for the St. Marys River AOC in 2014. Monitoring data for the St. Marys River AOC is still valuable since this area serves as a very good reference site.

St. Clair River AOC:

Wildlife studies:

Bald eagles-

There is currently only one active bald eagle territory in the St. Clair River AOC (Appendix C-3). The eagles using this territory have fledged 1, 0, and 1 eaglet in 2011, 2012, and 2013, respectively. A comparison of the productivity in this territory relative to comparison populations is shown in Table 30.

A comparison of contaminant levels in eaglets from the one territory in the St. Clair River AOC to other eagle populations are shown in Table 31.

Table 30. Bald eagle productivity, brood size, and success rates in the St. Clair River AOC territories compared to territories with access to Lake Huron fish, and all territories statewide. Estimates are averages over the five-year period from 2009 to 2013.

Population Metric[1]	SCR AOC	Lake Huron Lower Peninsula[2]	Great Lakes Statewide[3]	Inland Lower Peninsula[3]	Inland Statewide[3]
Productivity	0.7	1.2	1.1	1.0	1.0
Brood Size	1.0	1.4	1.5	1.5	1.0
Success Rate	0.7	0.7	0.7	0.7	0.7
Mean # Territories	0.6	37	238.8	231.2	348.2

[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 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

Table 31. A comparison of median PCB and *p,p'*-DDE concentrations in the serum of bald eagle nestlings from the St. Clair River AOC with other bald eagle populations in Michigan. Medians are the overall values based on median concentrations per nest per year observed over the 5-year period from 2009 through 2013.

	Healthy / Stable Population TRV[1]	SCR AOC	Lake Huron Lower Peninsula[2]	Great Lakes Statewide[3]	Inland Lower Peninsula[3]	Inland Statewide[3]
PCB (μg/Kg)	35 / 125	43	39	37	6	5
p,p'-DDE (μg/Kg)	11 / 28	14	18	20	11	10
Number of Samples		1	15	77	100	123

[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

The productivity data for the one bald eagle territory in the St. Clair River AOC is below the productivity associated with both a stable and a healthy population. According to Dave Best (personal communication, 2015) the cause of the low productivity is most likely predation by great-horned owls, raccoons, or other predator. The levels of PCBs and *p,p'*-DDE are similar to levels found in territories along Lake Huron.

Herring gulls-

No herring gull colonies are located in the St. Clair River AOC.

Mink-

Mink livers were collected in 2013 from Harsens Island, Michigan, in the St. Clair River AOC and analyzed for PCBs. The island was divided into three zones based on potential for exposure. A total of 15 samples were collected from the island with composites of 2, 7, and 6 livers being analyzed in each of the 3 zones (Table 32).

Table 32. The concentration of PCBs measured in the livers of mink collected from Harsens Island in 2013.

ZONE	# Samples in Composite	Percent Lipid	Total PCBs (mg/kg)
A	2	2.76	0.020
B	7	3.67	0.026
C	6	2.96	0.016

The total PCBs in all three composite samples were well below the LOAECs of 2.2, 3.1, 7.3, 16, and 2.9 mg/kg found for effects on kit survival and weights by Heaton et al. (1995), Bursian et al. (2006a), Halbrook et al. (1999b), Bursian et al., (2006c), and Bursian et al., (2013a) respectively. These concentrations are also well-below concentrations shown to cause deformities in mink jaws.

Tree swallows-

The concentration of PCBs in tree swallow eggs was monitored by the USGS in nest boxes located in Michigan at Marysville (north end of the St. Clair River AOC) and Algonac State Park (south end of the St. Clair River AOC). The median PCB concentration for the individual sites was 0.23 and 0.17 mg/kg, respectively, with a median for the two sites combined of 0.20 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 24 out of 27 AOCs studied. The median dioxin and furan concentration of 112 ng/kg ranked 23 out of 27 AOCs studied (Custer, 2015).

Snapping turtles-

The concentrations of PCBs, dioxins/furans, and organochlorine pesticides were measured in the eggs and plasma of snapping turtles from three AOCs (Wheatley Harbor, Detroit River, and St. Clair River) and two reference sites (Algonquin Provincial Park and Tiny Marsh) (De Solla and Fernie, 2004). The eggs from the St. Clair River AOC had much lower concentrations of *p,p*'-DDE and PCBs in 2001-2002 than the Wheatley Harbor and the Detroit River AOCs.

Contaminant levels in eggs from the St. Clair River AOC were generally higher than those from Algonquin Park, but similar to those from Tiny Marsh (De Solla and Fernie, 2004).

The Canadian Wildlife Service collected snapping turtle eggs in 2011 from Walpole Delta in the St. Clair River AOC (Hughes et al., 2014a). Hatching success of the artificially incubated eggs was high (93.5%) and the frequency of hatching deformities was low (7.7%) and were similar to the reference site (Tiny Marsh). The contaminant levels were high relative to the eggs from the inland reference site, but were low compared to other Great Lakes sites. The researchers concluded that there was no evidence of impairment of reproduction and development for snapping turtles.

Leopard frogs-

The Canadian Wildlife Service collected leopard frog eggs and raised them in water (2007) and sediment and water (2011) from various locations on the Canadian side of the St. Clair River AOC (Hughes et al., 2014b). Hatching success was high (>98%) and embryo deformities were low to moderate (<7%). These incidences were statistically similar to non-AOC Great Lakes reference sites. The researchers concluded that contaminants in the St. Clair River AOC are not adversely impacting the reproduction and development.of leopard frogs.

<u>Fish data</u>:

Spatial comparison-

The concentrations of PCBs, total DDT, and mercury in carp from the St. Clair River AOC were similar to concentrations found in Lake St. Clair (Table 17). The concentrations of PCBs, total DDT, and mercury in forage fish from the St. Clair River were similar to concentrations found in forage fish collected from the St. Marys River and near the Les Cheneaux Islands (Table 18).

Comparison to wildlife benchmark value-

The concentration of PCBs in forage fish collected from the St. Clair River AOC are below levels that would be expected to impact 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 0.90 mg/kg for 2011 exceeds the low end of the range of fish tissue TRVs. Large carp would also be expected to have higher concentrations of PCBs than many of the fish consumed by wildlife.

<u>Conclusions</u>:

- The productivity of bald eagles nesting in the only territory within the St. Clair River AOC is below levels associated with a healthy population. This low productivity is most likely due to predation.

- PCBs are not elevated in mink livers collected from Harsens Island. These levels are well below levels shown to adversely impact reproduction/development in mink.

- The carp and forage fish data suggest that PCB, total DDT, and mercury concentrations are not elevated in the St. Clair River AOC.

- Reproduction and developmental effects were not observed in turtles nesting in the Walpole Delta of the St. Clair River AOC. Turtle plasma and egg data suggest that PCB, *p,p*'-DDE, and TEQ concentrations are not elevated in the St. Clair River AOC.

- PCB concentrations in carp from the St. Clair River AOC slightly exceed the low end of the fish tissue TRV range of concentrations estimated to adversely impact wildlife. The estimated concentration of PCBs in forage fish is well below the fish TRV.

<u>Recommendation</u>:

The Wildlife BUI for the St. Clair River AOC should be removed based on recent studies that found that frogs, turtles, and mink are not being adversely impacted. In addition, contaminant levels in carp and forage fish suggest that wildlife would not be impacted and that contaminants in this AOC are not higher than comparison populations.

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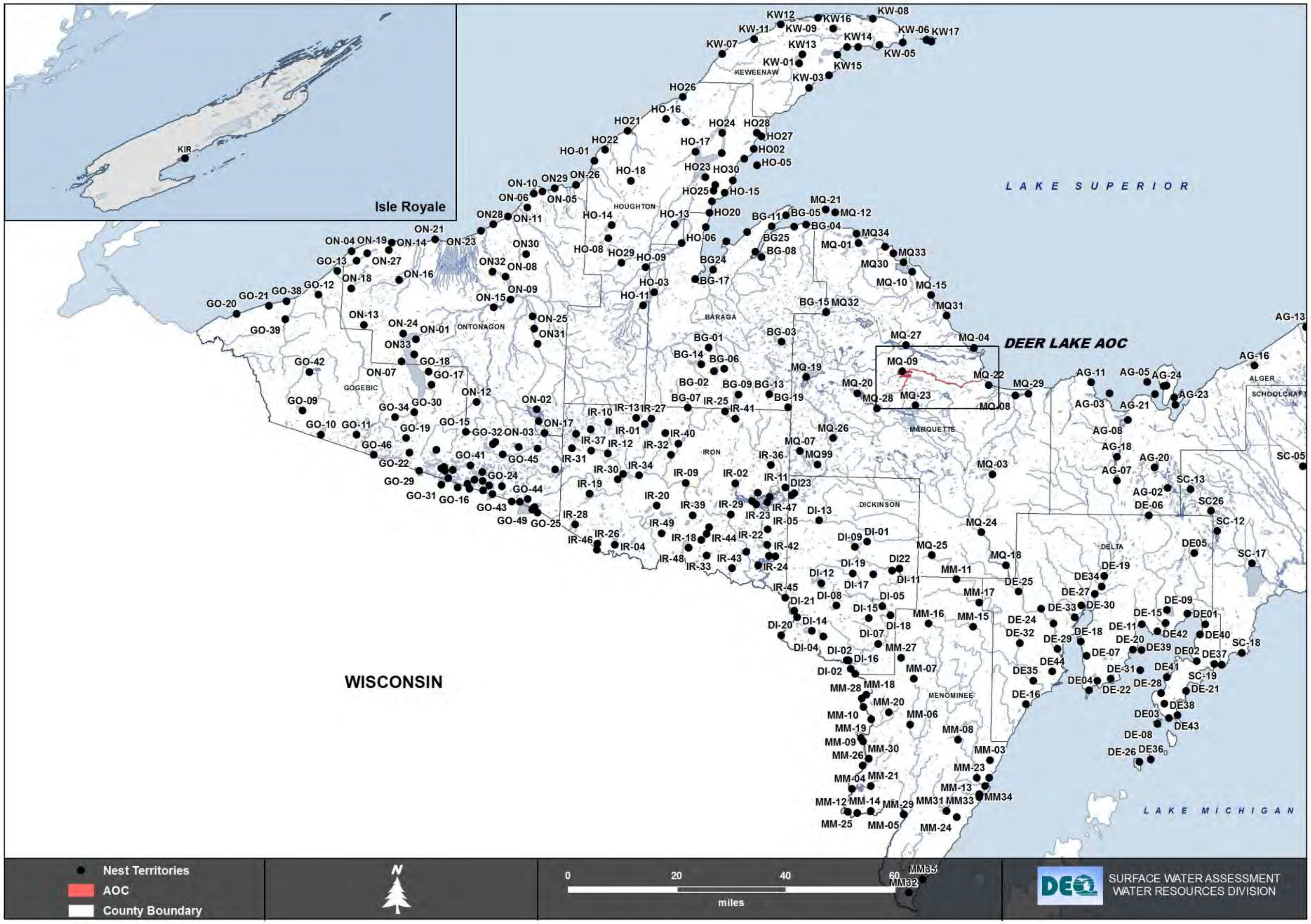
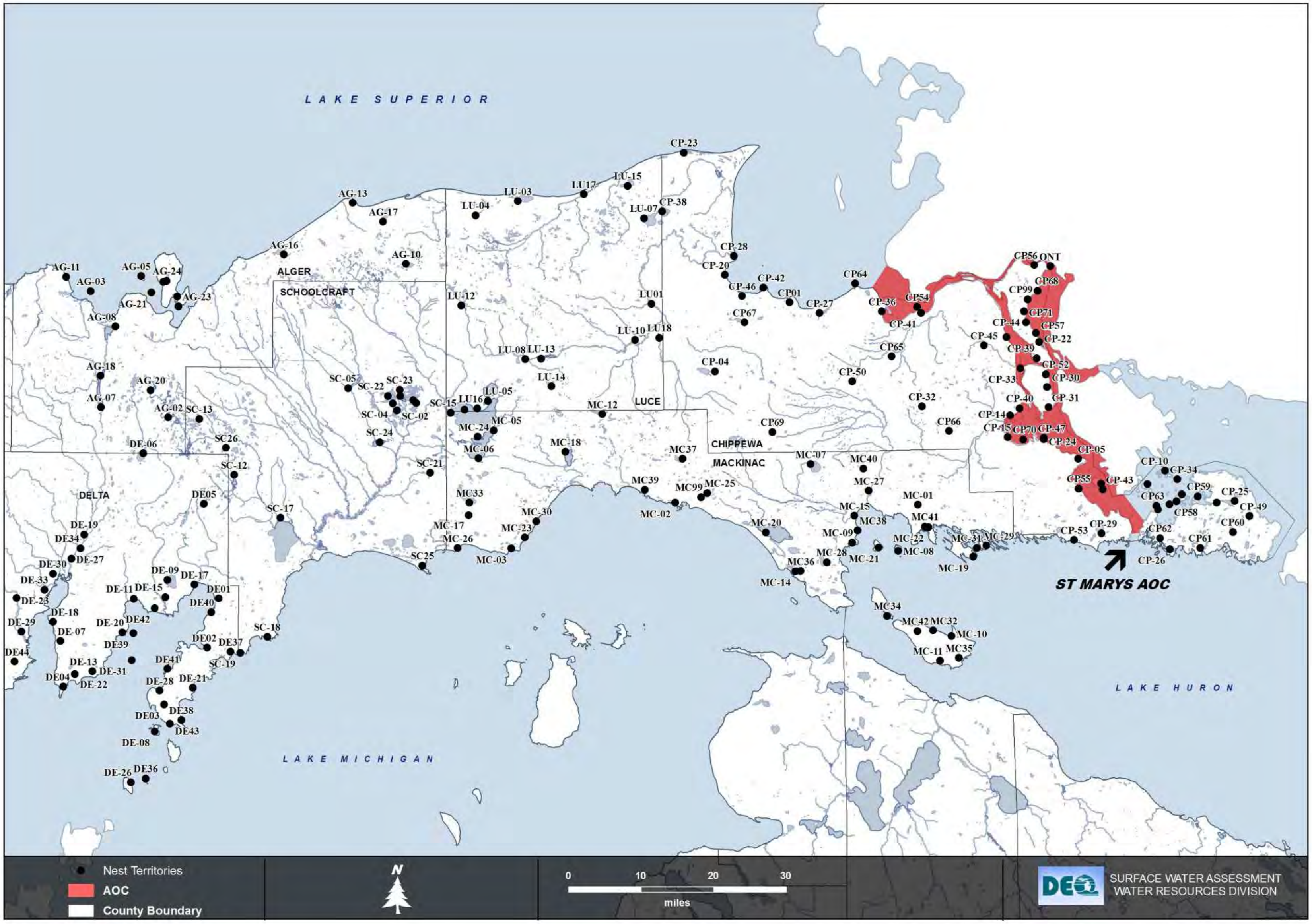
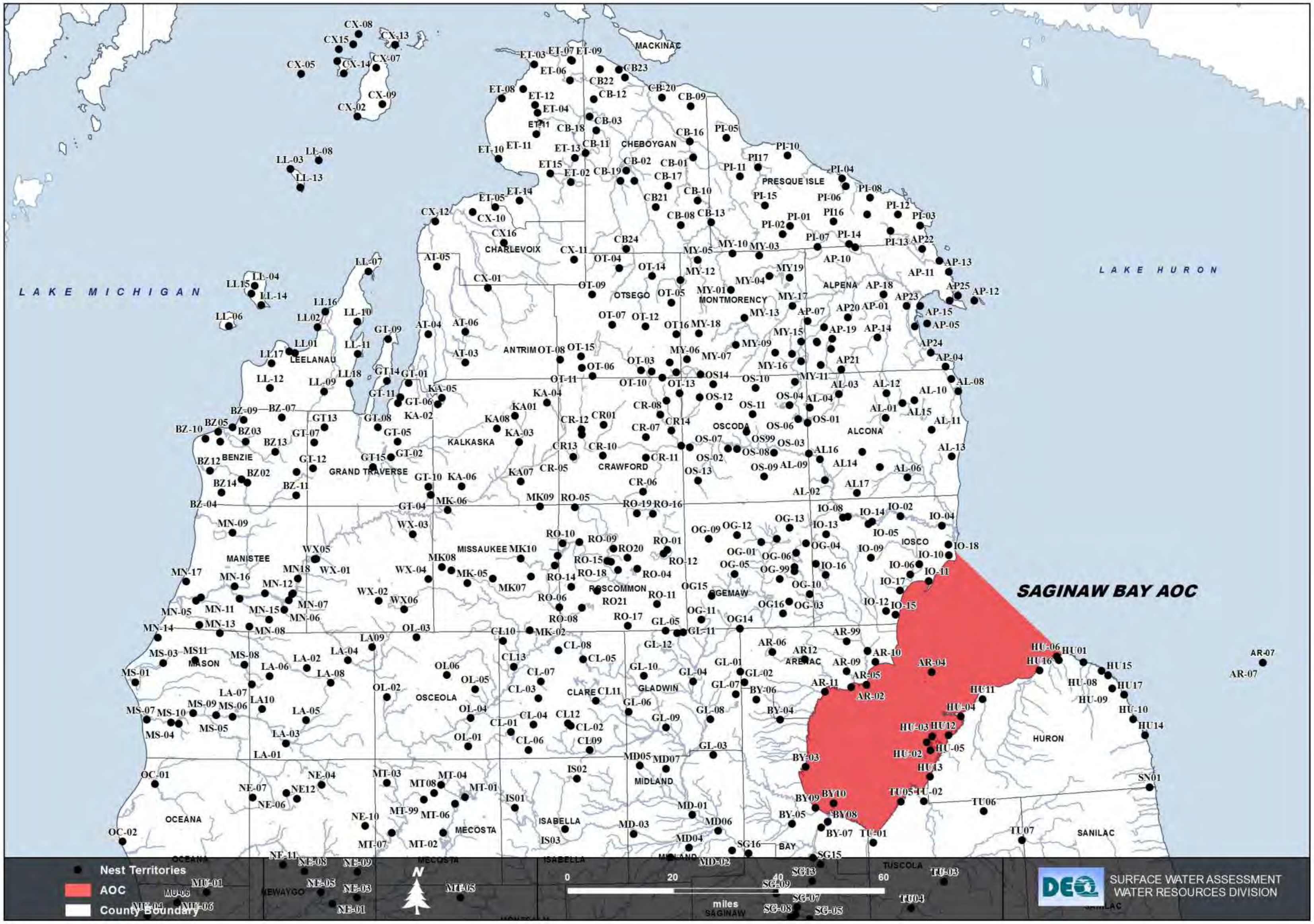


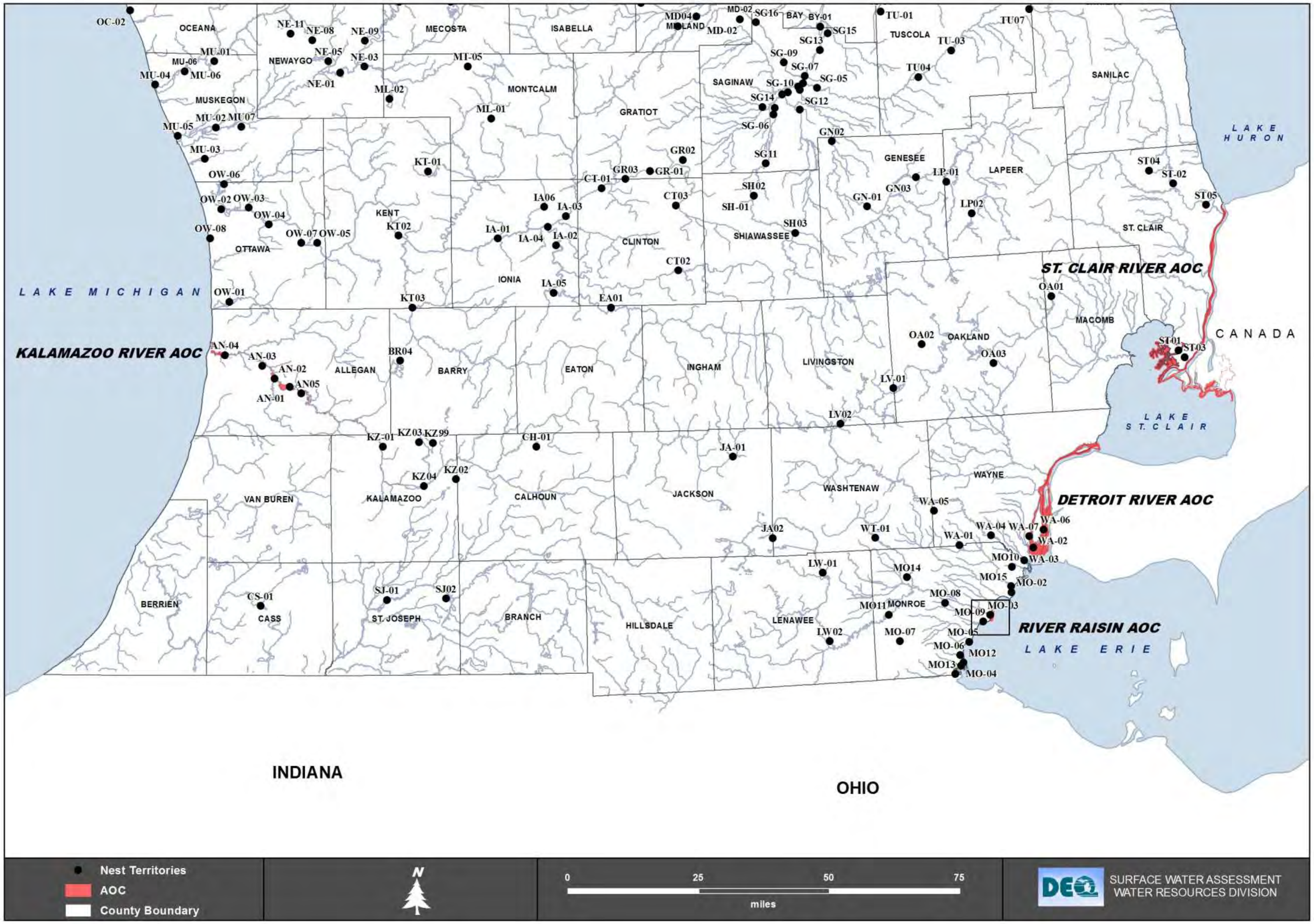
Appendix A-1. Active and inactive bald eagle nests in the western Upper Peninsula of Michigan.



Appendix A-2. Active and inactive bald eagle nests in the eastern Upper Peninsula of Michigan



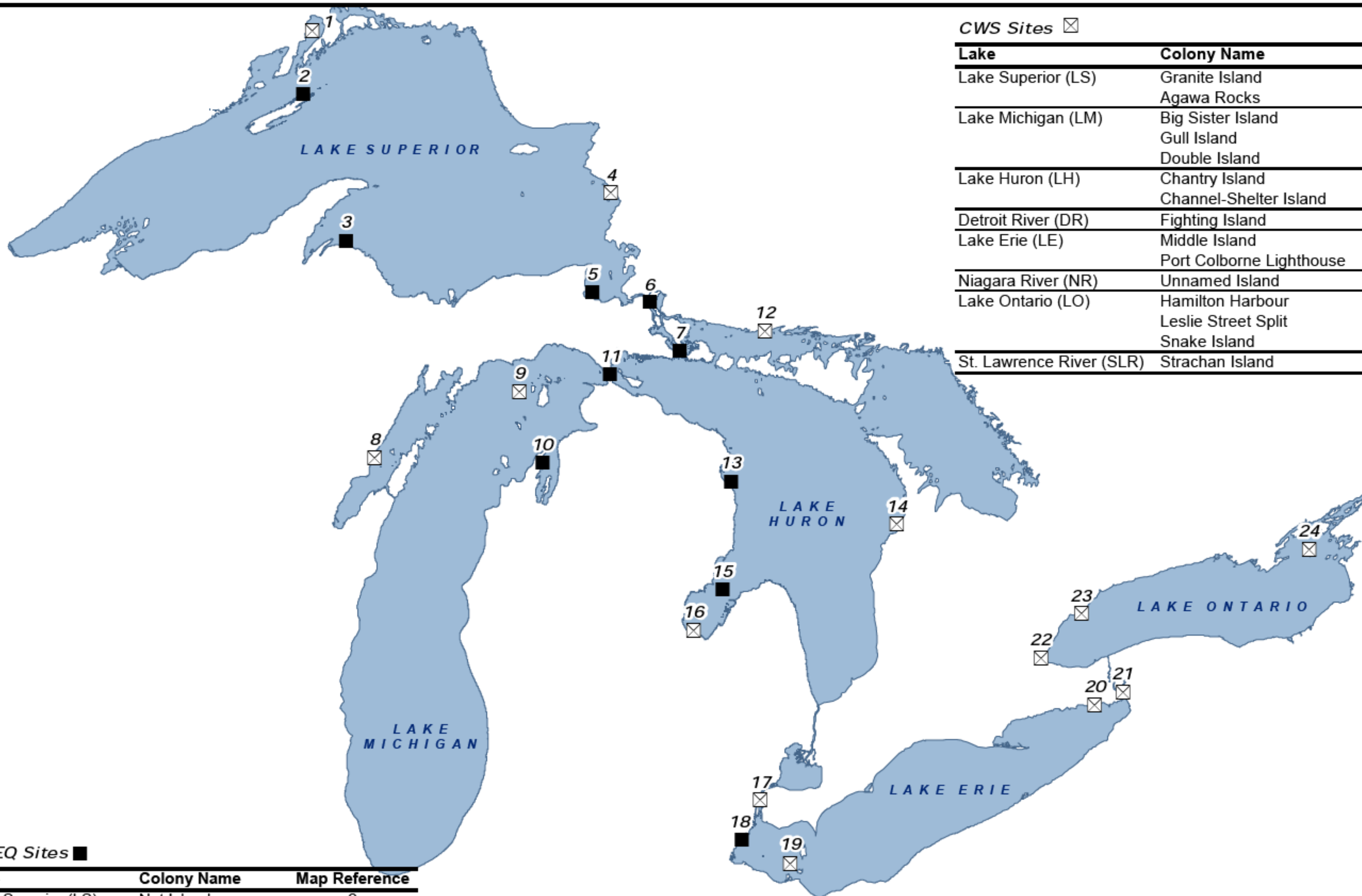
Appendix A-3. Active and inactive bald eagle nests in the northern Lower Peninsula of Michigan.



Appendix A-4. Active and inactive bald eagle nests in the southern Lower Peninsula of Michigan.

CWS Sites ☒

Lake	Colony Name	Map Reference
Lake Superior (LS)	Granite Island	1
	Agawa Rocks	4
Lake Michigan (LM)	Big Sister Island	8
	Gull Island	9
	Double Island	12
Lake Huron (LH)	Chantry Island	14
	Channel-Shelter Island	16
Detroit River (DR)	Fighting Island	17
Lake Erie (LE)	Middle Island	19
	Port Colborne Lighthouse	20
Niagara River (NR)	Unnamed Island	21
Lake Ontario (LO)	Hamilton Harbour	22
	Leslie Street Split	23
	Snake Island	24
St. Lawrence River (SLR)	Strachan Island	25



MDEQ Sites ■

Lake	Colony Name	Map Reference
Lake Superior (LS)	Net Island	2
	Huron Island	3
	Tahquamenon	5
St. Marys River (SMR)	Five Mile Island	6
	West Twin Pipe	7
Lake Michigan (LM)	Bellows Island	10
	Green Island	11
Lake Huron (LH)	Scarecrow Island	13
	Little Charity Island	15
Lake Erie (LE)	Detroit Edison	18

HERRING GULL - COLONY LOCATIONS

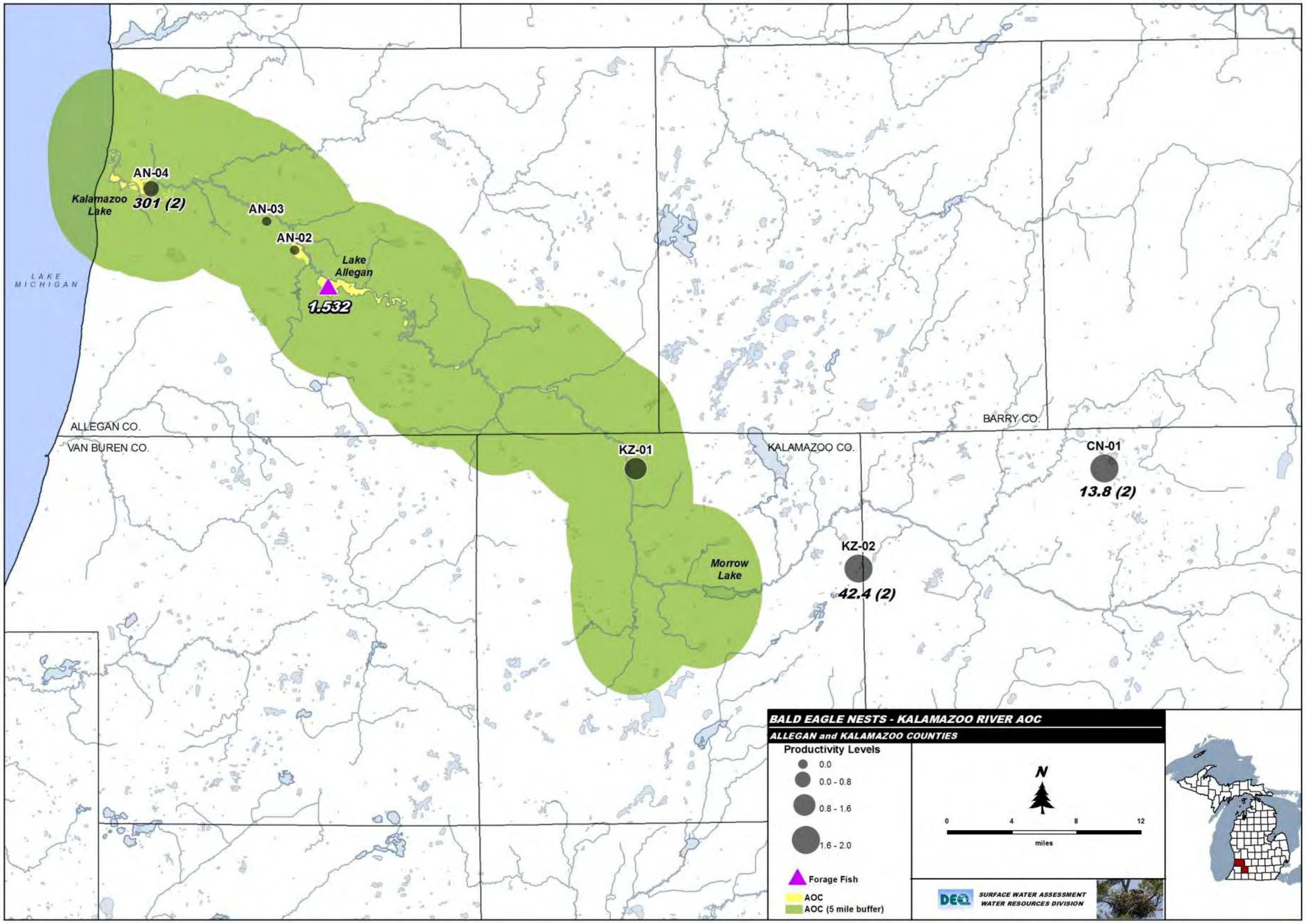
Great Lakes Region

0 80 160 240

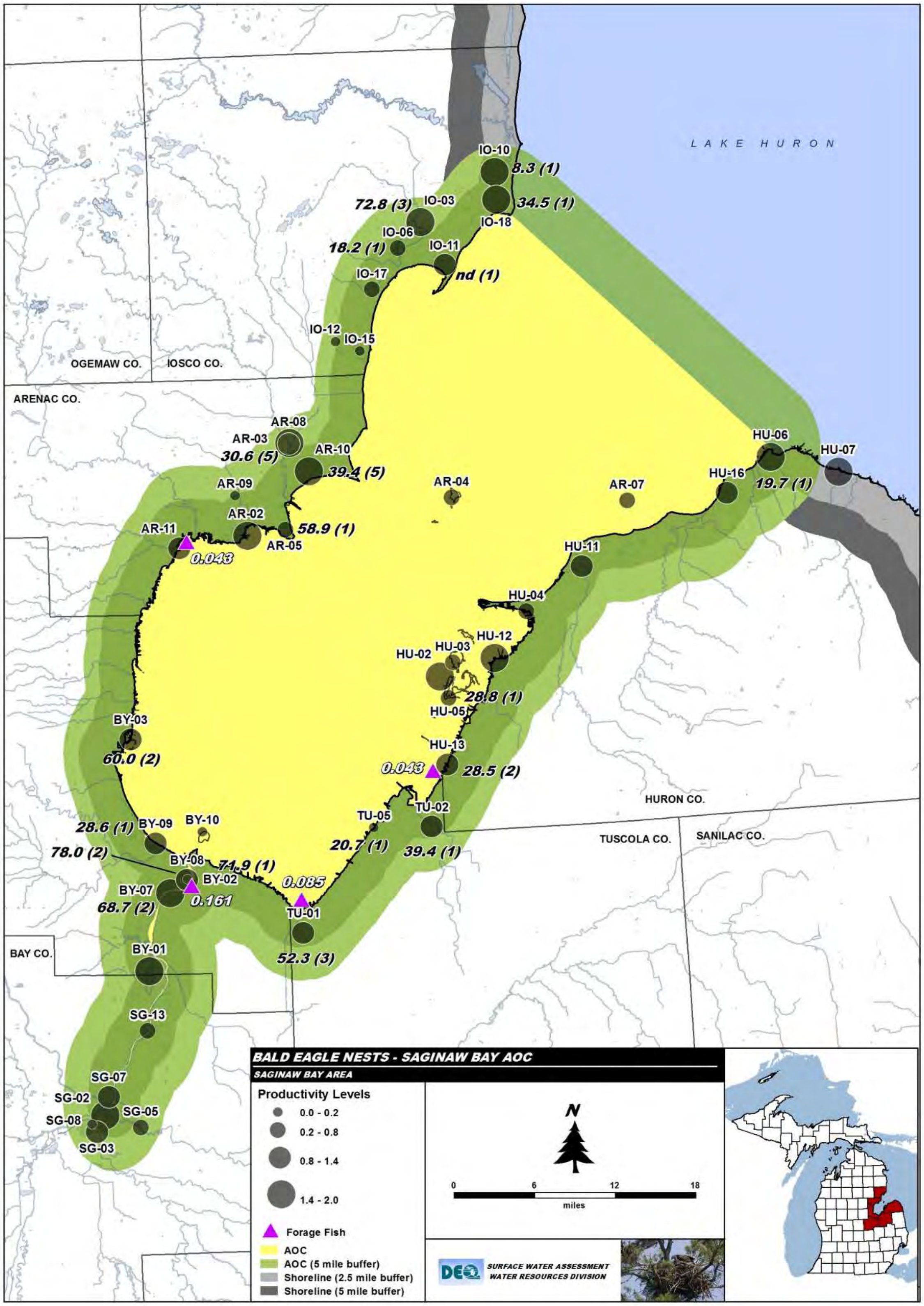
miles

DEQ SURFACE WATER ASSESSMENT
WATER RESOURCES DIVISION

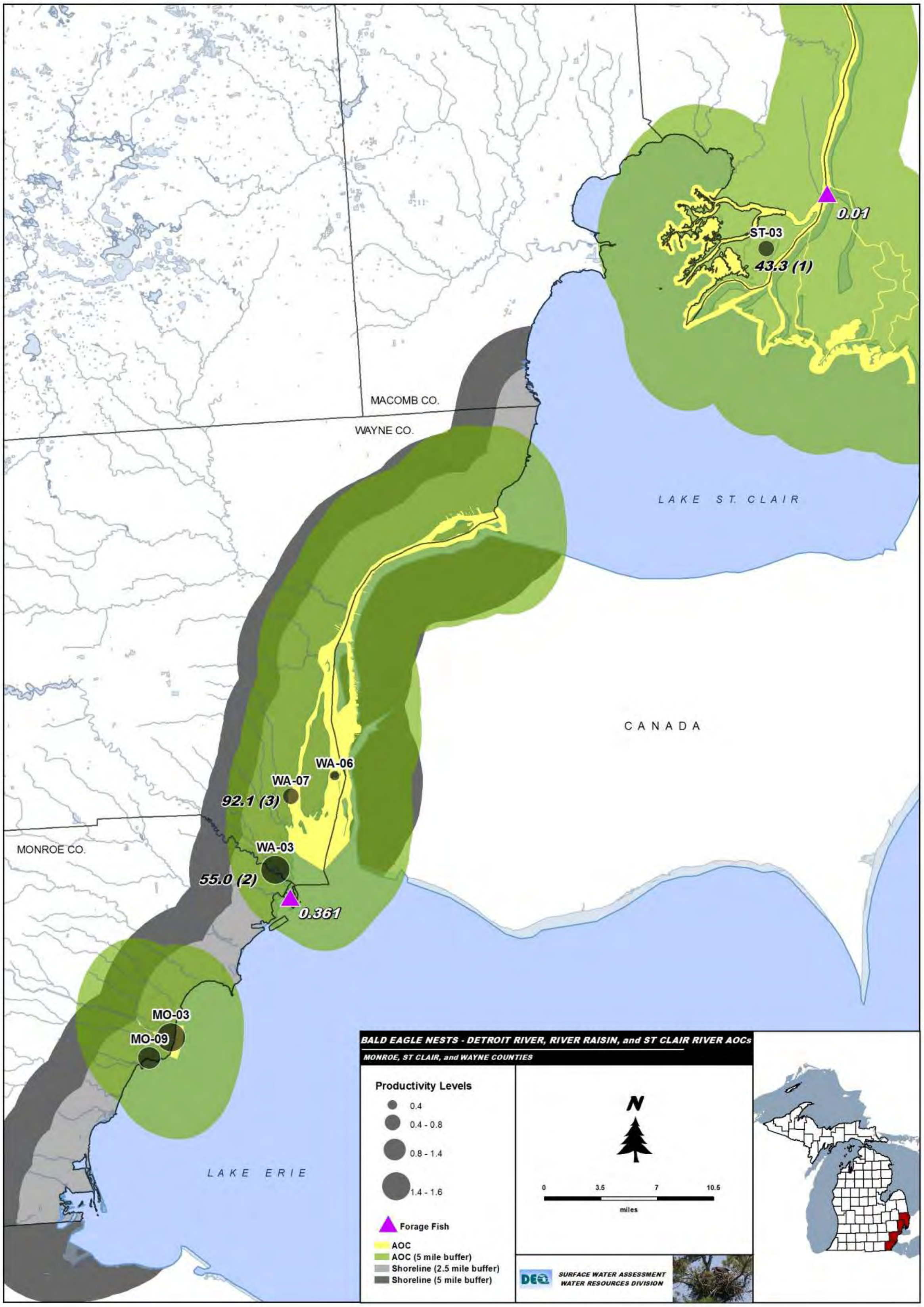
Appendix B. Great Lakes herring gull colonies monitored by Michigan DEQ and the Canadian Wildlife Service (CWS).



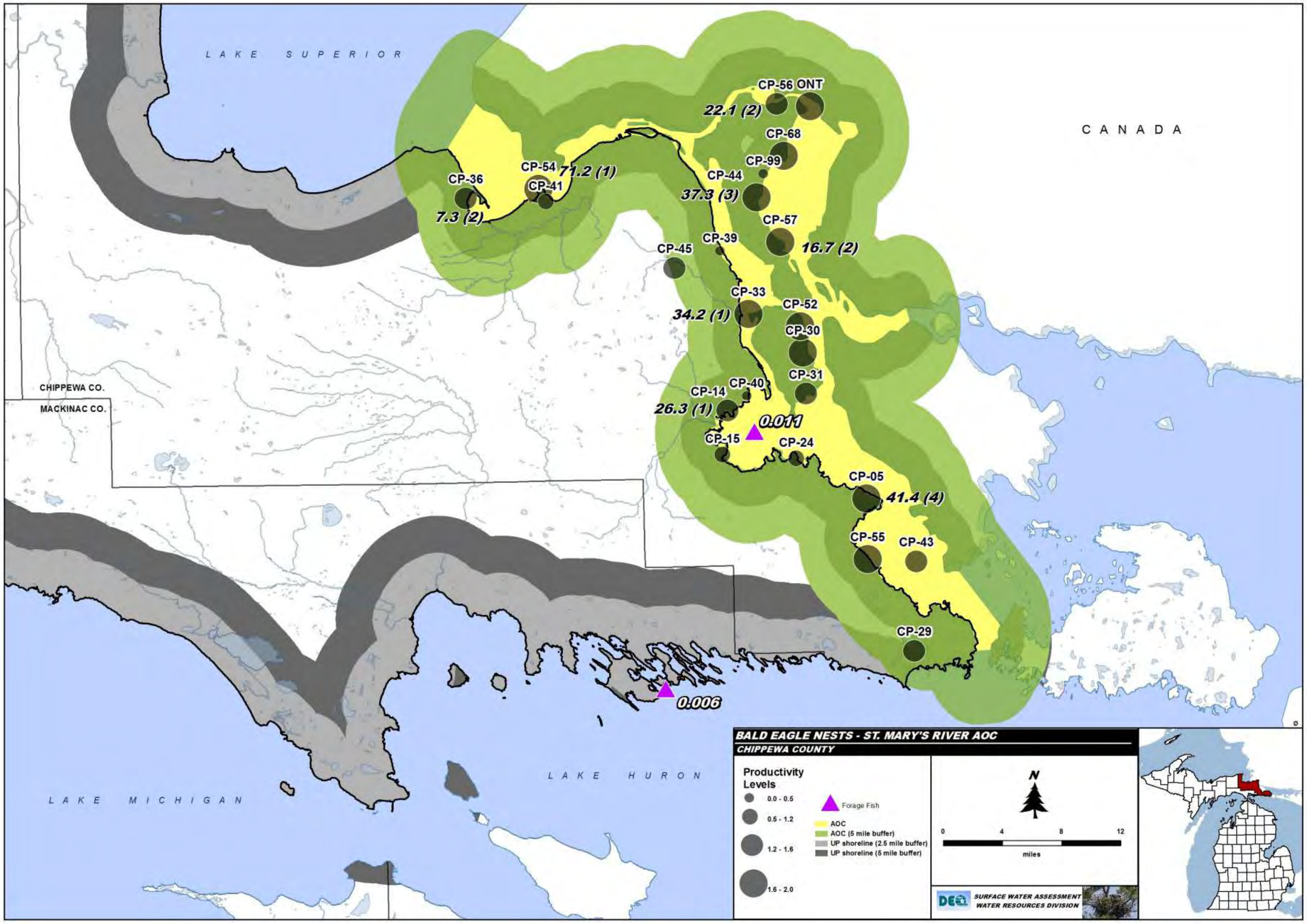
Appendix C1. Active bald eagle territories in the Kalamazoo River AOC with productivity estimates and median total PCB concentrations (ug/kg) in eaglet serum from independent nests sampled between 2009 and 2013 (N in parentheses).



Appendix C2. Active bald eagle territories in the Saginaw River/Bay AOC with productivity estimates and median total PCB concentrations (ug/kg) in eaglet serum from independent nests sampled between 2009 and 2013 (N in parentheses).



Appendix C3. Active bald eagle territories in the River Raisin, Detroit River, and St. Clair River AOCs with productivity estimates and median total PCB concentrations (ug/kg) in eaglet serum from independent nests sampled between 2009 and 2013 (N in parentheses).



Appendix C4. Active bald eagle territories in the St. Marys River AOC with productivity estimates and median total PCB concentrations (ug/kg) in eaglet serum from independent nests sampled between 2009 and 2013 (N in parentheses).

Appendix D-1. Bald eagle productivity and nestling serum contaminant concentration detail for individual active territories in the Saginaw River and Bay AOC, 2009 through 2013. (N = number of independent nests sampled)

AOC	Site	Name	Fledged Young	Attempts	Productivity	Success Rate	Brood Size	Median PCB (µg/Kg)	Median DDE (µg/Kg)	N
Saginaw Bay/River	AR02	AuGres-Wigwam-Rifle R	8	5	1.6	1.0	1.6			
Saginaw Bay/River	AR03	Santiago	9	5	1.8	1.0	1.8	30.6	12.4	5
Saginaw Bay/River	AR04	Big Charity Isd	4	5	0.8	0.6	1.3			
Saginaw Bay/River	AR05	Pt AuGres S	3	4	0.8	0.8	1.0	58.9	20.4	1
Saginaw Bay/River	AR07	Hickory Isd	4	5	0.8	0.6	1.3			
Saginaw Bay/River	AR08	Delano	5	5	1.0	0.6	1.7			
Saginaw Bay/River	AR10	Pt AuGres N	9	5	1.8	1.0	1.8	39.4	15.5	5
Saginaw Bay/River	AR11	Wigwam Bay	7	5	1.4	0.8	1.8			
Saginaw Bay/River	BY01	Skull/Stoney Isd	8	5	1.6	1.0	1.6			
Saginaw Bay/River	BY02	Quanicassee	1	5	0.2	0.2	1.0	71.9	24.8	1
Saginaw Bay/River	BY03	Nayanquing Pt	6	5	1.2	0.6	2.0	60.0	14.7	2
Saginaw Bay/River	BY07	Golson Park	7	4	1.8	1.0	1.8	68.7	20.5	2
Saginaw Bay/River	BY08	Marina	3	3	1.0	0.7	1.5	78.0	11.6	2
Saginaw Bay/River	BY09	Tobico Marsh	1	1	1.0	1.0	1.0	28.6	11.0	1
Saginaw Bay/River	BY10	Spoil Isd	0	2	0.0	0.0	--			
Saginaw Bay/River	HU02	Maisou/Katechay Isd/N Isd	8	5	1.6	1.0	1.6			
Saginaw Bay/River	HU03	Heisterman Isd	3	4	0.8	0.8	1.0			
Saginaw Bay/River	HU04	Sand Pt	4	5	0.8	0.6	1.3			
Saginaw Bay/River	HU05	Wildfowl Bay	3	5	0.6	0.4	1.5	28.8	8.4	1
Saginaw Bay/River	HU06	Port Austin New	9	5	1.8	1.0	1.8	19.7	7.8	1
Saginaw Bay/River	HU-07	Grindstone City	9	5	1.8	1.0	1.8			
Saginaw Bay/River	HU11	Caseville	4	3	1.3	1.0	1.3			
Saginaw Bay/River	HU12	Bay Port	7	4	1.8	1.0	1.8			
Saginaw Bay/River	HU13	Sebewaing	3	3	1.0	0.7	1.5	28.5	14.0	2
Saginaw Bay/River	HU16	Crescent City	1	1	1.0	1.0	1.0			
Saginaw Bay/River	IO03	Tawas L N	8	5	1.6	1.0	1.6	72.8	33.1	3
Saginaw Bay/River	IO06	Tawas L SW	4	5	0.8	0.4	2.0	18.2	15.1	1

Appendix D-1 (continued). Bald eagle productivity and nestling serum contaminant concentration detail for individual active territories in the Saginaw River and Bay AOC, 2009 through 2013. (N = number of independent nests sampled)

AOC	Site	Name	Fledged Young	Attempts	Productivity	Success Rate	Brood Size	Median PCB (µg/Kg)	Median DDE (µg/Kg)	N
Saginaw Bay/River	IO11	L Solitude	5	4	1.3	0.8	1.7	nd	6.0	1
Saginaw Bay/River	IO12	Alabaster	1	5	0.2	0.2	1.0			
Saginaw Bay/River	IO15	US Gypsum	0	1	0.0	0.0	--			
Saginaw Bay/River	IO17	Dead Ck	3	4	0.8	0.5	1.5			
Saginaw Bay/River	IO18	Spencer L	6	4	1.5	0.8	2.0	34.5	23.4	1
Saginaw Bay/River	SG02	Shiawassee NWR #1	8	5	1.6	0.8	2.0			
Saginaw Bay/River	SG03	Shiawassee NWR #2-Spaulding	5	5	1.0	0.6	1.7			
Saginaw Bay/River	SG05	Bridgeport	4	5	0.8	0.6	1.3			
Saginaw Bay/River	SG07	Ojibway Isd	7	5	1.4	0.8	1.8			
Saginaw Bay/River	SG08	Shiawassee NWR-Pool 1A	0	1	0.0	0.0	--			
Saginaw Bay/River	SG10	Shiawassee NWR-Eastwood Drain	4	5	0.8	0.6	1.3			
Saginaw Bay/River	SG13	Zilwaukee Bridge	1	2	0.5	0.5	1.0			
Saginaw Bay/River	TU01	Dinsmoore	4	4	1.0	0.8	1.3	52.3	17.8	3
Saginaw Bay/River	TU02	New Fish Pt SWA	4	4	1.0	0.8	1.3	39.4	nd	1
Saginaw Bay/River	TU05	Gotham-Old Fish Pt SWA	0	2	0.0	0.0	--	20.7	14.9	1