MI/DEQ/WRD-12/032

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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August 6, 2012

ACKNOWLEDGEMENTS

We would like to thank Julie Sims of the National Oceanic and Atmospheric Administration, Great Lakes Research Laboratory, for writing the proposal for the grant supporting this project. We would also like to thank the following Michigan Department of Environmental Quality (MDEQ) staff: Emily Weingartz for conducting the literature searches for this project, Sharon Baker for coordinating activities between the United States Fish and Wildlife Service (USFWS) and the MDEQ, and Denise Page for providing secretarial support. We thank Seth Wright of the Great Lakes Environmental Center for creating the report maps. We would also like to thank the Canadian Wildlife Service employees, Dr. Chip Weseloh and Daryl McGoldrick, for providing information related to colonial nesting birds and fish from Canada. We would also like to thank Dr. Christine Custer of the United States Geological Survey (USGS) for summarizing the results of her tree swallow work. We would like to thank Dr. Lisa Williams of the USFWS for obtaining the funds for this project and providing comments on a draft of the report, and David Best for providing information on the productivity of bald eagles in Michigan. The bald eagle and herring gull contaminant data, which were a vital part of this project, were provided by staff of Clemson University (Lindsay Moore and Latice Fuentes) and the University of Maryland (Dr. William Bowerman).

Partial funding for this project is supported by a Grant Agreement from the United States Department of the Interior, Fish and Wildlife Service with funding from the Great Lakes Restoration Initiative. Mention of trade names or commercial products does not constitute their endorsement by the United States Government.

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 six 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 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.

This review focused on assessing the impacts of *p,p*'-DDE, polychlorinated biphenyls (PCBs), and dioxin toxic equivalents (TEQs) in the AOCs on bald eagles, common terns, and mink since this was the basis for the original BUI for many of the AOCs. In addition, the results of the recent tree swallow studies conducted by the USGS in the AOCs were included in this review. Contaminant levels and productivity of bald eagles is currently being monitored by the MDEQ. Contaminant levels are also being monitored in herring gull eggs by the MDEQ. Since herring gulls are not very sensitive to the effects of environmental contaminants, it was necessary to compare concentrations of contaminants found in herring gull eggs to effect levels found in eggs of more sensitive species. Effect levels of contaminants in mink livers are available in the literature, but few mink studies have been conducted in the AOCs. Concentrations of contaminants in fish that would be protective of wildlife were also estimated for bald eagles, colonial nesting birds, mink, and otters because there are only limited wildlife studies available for some of the AOCs. The utility of this approach was limited because there were limited whole fish data available for the AOCs and most of the data that were available were for species and/or sizes of fish not normally consumed by the wildlife species that were the focus of this project. The limited forage fish contaminant data required us to base some of our assessments on rough extrapolations from contaminant levels in carp to levels in forage fish.

Provided below is a brief summary of our recommendations concerning the retention of the Wildlife BUI for the six AOCs of interest. It may be prudent to seek input from experts conducting wildlife studies within the AOCs to determine whether they agree with our recommendations.

- The Wildlife BUI for the Detroit River AOC should be retained based on potential effects of contaminants on terns, herons, and snapping turtles.

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

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

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

- Little scientific support was available for the retention of the Wildlife BUI for the St. Marys River AOC. However, since the Wildlife BUI for the St. Marys River AOC was originally based on effects of TEQs on terns, it is recommended that the Wildlife BUI be retained until the completion of a planned study of terns by the Canadian Wildlife Service.

- The Wildlife BUI for the St. Clair River AOC was based on an increased incidence of deformities in midges. If effects on midges are still considered to be wildlife impacts, then the Wildlife BUI for the St. Clair River AOC should be retained. However, we recommend that wildlife impacts be based on adverse effects found on vertebrates and deformities in midges be used in the assessment of the "Degradation of Benthos" BUI. If only vertebrate data are considered for the assessment, then the Wildlife BUI for the St. Clair River AOC should be removed.

We recommend that wildlife and fish contaminant monitoring continue so that informed decisions can be made regarding potential impacts to wildlife in the AOCs. The carp data collected by the MDEQ were very helpful for this project because they helped us to determine whether there were elevated contaminant levels in the AOCs and they provided insight into whether wildlife consuming fish from the AOC might be adversely impacted. It may be useful to also measure contaminant levels in forage fish from some of the AOCs so that a more accurate determination of exposure to wildlife can be determined.

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

There are currently six AOCs in Michigan that have a Bird or Animal Deformities or Reproductive Problems Beneficial Use Impairment (henceforth referred to as the "Wildlife BUI"). The purpose of this project is to assess the status of this impairment in the six AOCs listed in Table 1. Specifically, the objectives of this assessment were to determine whether there are sufficient data available to remove the Wildlife BUI and to identify additional study needs if insufficient data were available to make a determination.

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*
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	Terns	PCBs

*DDE = Dichlorodiphenyldichloroethane; HCB = Hexachlorobenzene; PCBs = Polychlorinated biphenyls; DDT = Dichlorodiphenyltrichloroethane

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 six 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 six AOCs because data from Michigan's wildlife and fish contaminant monitoring programs suggest that none of the six 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 six 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 was the primary source of contaminant data for fish within the AOC. 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

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 Toxicity Reference Values (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. 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 5-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 (NOAECs), Lowest Observable Adverse Effect Concentrations (LOAECs), 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 NOAEL 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 et al., 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 et al., 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.

<u>BMF Approach</u>

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 uncertainty factor 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. 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, test dose (mg/kg/d), total uncertainty factor (the uncertainty factor 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
Test Dose	1.8 (LOAEL)	0.027 (LOAEL)	0.000014 (NOAEL)*	0.078 (LOAEL)
Uncertainty Factors	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
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-

Two 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 concentration of contaminants in fish that might adversely impact herring gull populations.

<u>BMF Approach</u>

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). 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 following steps were used to generate a BMF for mercury:

- Vermeer et al. (1973) measured the concentration of mercury in perch (2.7 mg/kg) and merganser breast muscle (6.79 mg/kg) from Clay Lake, Ontario.

- The merganser breast muscle mercury concentration was multiplied by 7.13 to convert it to a liver concentration of 48.41 mg/kg using the relationship established by Fimreite (1974).

- Fimreite (1974) determined that common terns from Wabigoon Lake, Ontario, had 9.08 times more mercury in their livers than in their eggs. Dividing the estimated liver concentration of 48.41 mg/kg by 9.08 results in an estimated egg concentration of 5.33 mg/kg.

- The estimated BMF for common mergansers is therefore 2.0 (5.33 mg/kg divided by 2.7 mg/kg).

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)	2.0 (merganser)
Fish Tissue NOAEC	0.11	Not available	0.000010	0.5
Fish Tissue LOAEC	0.23	0.29	0.000017	1.8

*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).

<u>Surrogate Species Approach</u>

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 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, test dose (mg/kg/d), total uncertainty factor (uncertainty factor 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, 2004
Test Dose	1.8 (LOAEL)	0.027 (LOAEL)	0.000014 (NOAEL)*	0.078 (LOAEL)	Not available
Uncertainty Factors	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	0.15

*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. Since loons have been shown to be highly sensitive to the effects of 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.

In laboratory studies by Kenow et al. (2003, 2007a, 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 NOAEC of 0.05 mg/kg and LOAEC of 0.15 mg/kg for mercury determined by Evers (2004) were the most appropriate fish tissue level benchmarks for loons. If this NOAEC was used to determine a dietary concentration protective of colonial nesting birds, there would be no need to apply uncertainty factors to the assessment since the study was long-term in duration and loons are considered 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 these values is also more defensible because they are based on field data, which is a more realistic exposure scenario.

Mink:

The sensitivity of mink to various contaminants, its high trophic status, its ability to accumulate contaminants, and its 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 Housatonic River, Massachusetts (Bursian et al., 2006a and 2006b), Saginaw River, Michigan (Bursian et al., 2006c), Saginaw Bay, Michigan (Heaton et al., 1995; Restum et al., 1998), Poplar Creek/Clinch River, Tennessee (Halbrook et al., 1999), and Hudson River, New York (Bursian et al., 2012). 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 will contain contaminants other than just dioxin-like compounds that could influence the results of the toxicity studies.

Liver Concentration-

Table 8. Liver NOAECs and LOAECs for PCBs, TEQs, and Mercury in mink.

Liver concentration NOAEC	LOAEC	Reference
3.1 mg/kg PCBs	3.1 mg/kg PCBs	Bursian et al., 2006b
4.4 mg/kg PCBs	11 mg/kg PCBs	Bursian et al., 2006c
6.0 mg/kg PCBs	7.3 mg/kg PCBs	Halbrook et al., 1999
Not available	0.50 mg/kg PCBs	Heaton et al., 1995
0.056 µg/kg TEQs	0.22 µg/kg TEQs	Bursian et al., 2006b
0.073 µg/kg TEQs	0.15 µg/kg TEQs	Bursian et al., 2006c
28 mg/kg Mercury (n=3)	97 mg/kg (n=1)	Dansereau et al., 1999

Fish Tissue Concentration-

Sufficient toxicity studies on mink were available to derive dietary NOAECs and LOAECs for PCBs, TEQs, and mercury (Table 9). The use of a surrogate species was used to derive a fish tissue level for DDT because no suitable mink studies were available. The limitations of the mink studies conducted by Gilbert (1969) and Aulerich and Ringer (1970) are provided in USEPA (1995), and the study by Duby et al. (1971) was not used because it was an injection study and only examined the effects of DDT on uterine weights of immature mink. The studies by Bursian et al. (2006a; 2006c) were particularly suited for the derivation of fish tissue levels for PCBs and TEQs because mink were exposed to fish (carp and/or goldfish) collected from the environment.

Table 9. Dietary NOAECs and LOAECs for PCBs, TEQs, DDT, and Mercury in mink.

Fish tissue level NOAEC	LOAEC	Reference
1.6 mg/kg PCBs	3.7 mg/kg PCBs (kit survival at six weeks)	Bursian et al., 2006a
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., 2012 (unpublished)
Not available	0.25 mg/kg PCBs (whelping rate)	Restum et al., 1998
Not available	0.72 mg/kg PCBs (kit survival and weight at three and six weeks)	Heaton et al., 1995
0.016 µg/kg TEQs	0.069 µg/kg TEQs (kit survival at six weeks)	Bursian et al., 2006a
0.028 µg/kg TEQs	0.047 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., 2012 (unpublished)
Not available	0.019 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 an uncertainty factor 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 default body weights and fish consumption rates for mink and otters provided in the USEPA (1995) suggest that the dose received by mink and otters exposed to a dietary concentration of 1.1 mg/kg of mercury would be similar (0.20 mg/kg body weight/d for mink compared to 0.16 mg/kg body weight/d for otters). 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.

SIGNIFICANCE OF FISH CONTAMINANT LEVELS

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 10. The values considered to be the most scientifically defensible are highlighted in bold print. Based on a review of all of these values, a range of effect levels is provided in the last column of Table 10 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 10. Ranges of fish tissue concentrations (mg/kg) estimated to cause adverse effects in bald eagle, colonial nesting bird, and mink/otter populations (the most defensible values are shown in bold print).

	Bald Eagles	Colonial Nesting Birds	Mink/Otter	TRV
PCBs	**> 0.14-0.93**	0.23-1.4	**0.25-1.1**	> 0.14-1.1
TEQs	0.000011-0.00014	0.000017-0.000064	**0.000010-0.00024**	0.000010
p,p'-DDE	**> 0.16-0.30**	0.12*-**0.29**	2.0	> 0.16-0.30
Mercury	0.26-2.0	**0.15**-1.8	**1.0-1.1**	0.15-1.0

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

The concentrations provided in Table 10 are the concentrations of contaminants in fish estimated to adversely impact wildlife. A more conservative approach would be to develop fish tissue concentrations based on NOAELs instead of LOAELs. This approach was 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. The effects of a contaminant at concentrations between the NOAEC and LOAEC cannot be determined with certainty.

Justifications:

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. 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 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. 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. 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-

Bald eagles appear to be less sensitive to the effects of mercury than other birds studied such as 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. Since less uncertainty is associated with the loon data, it was considered appropriate to use the value of 0.15 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 0.15 to 1.0 mg/kg.

Data Used to Compare to Dietary TRVs:

There are many uncertainties associated with the use of fish tissue contaminant concentrations to assess whether there are reproductive or developmental impacts on wildlife living in an AOC. For example, the fish collected for contaminant analysis contain mixtures of chemicals that may differ from the exposure scenario used to derive the fish TRVs. Also, a significant proportion of the diets of mink and bald eagles may consist of things other than fish. In addition, the amount of a chemical ingested by wildlife via the consumption of fish depends on the size, species, and amount of each species of fish consumed. This information is not available for many species of wildlife and can vary depending on location. Even if specific information existed on the amount and size of each species of fish consumed, there are only limited fish contaminant data available.

The size and species of fish consumed by bald eagles, common terns, mink, and otter were evaluated below to help determine how to best use the available fish contaminant data provided later in this assessment. The diets of common terns were examined to assess the fish consumed by colonial nesting birds because terns appear to be more sensitive to the effects of contaminants than herring gulls. The diets of mink and otters were assessed because they have been shown to be sensitive to the effects of environmental contaminants. Otters may also have a greater potential than mink to be exposed to higher contaminant levels since they tend to eat larger fish and a greater percentage of their diets consist of fish.

Bald Eagles-

The food remains were examined at bald eagle nest 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. 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 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.

Common Terns-

The diet of common terns at Lake Ontario, Niagara River, and Lake Erie colonies were evaluated 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. Alewives were the primary species of fish consumed by common terns at a southern Lake Michigan colony, followed by spottail shiners (Ward et al., 2010). Based on an isotope analysis, nest observation, and foraging behavior, gobies were determined to not be a significant component of a common tern's diet (Ward et al., 2010). Common terns typically feed on fish that are 2.4 to 5.9 inches in length (Cuthbert et al., 2003).

Mink and Otter-

An examination was made of the stomach contents of 41 mink collected along the North Branch of the Au Sable River and along 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 (the highest numbers of fish were collected in the 4-inch size range).

The stomach contents of otters from the study sites mentioned above were also examined (Alexander, 1977). He found that the otter stomachs contained brook trout (n=3), brown trout (n=1), rainbow trout (n=1), blacknose dace (n=16), creek chub (n=7), common shiners (n=2), suckers (n=7), and darters (n=5). Based on a limited dataset, it was determined that otters consume fish that are 3 to 11 inches in length (Alexander, 1977). Studies suggest that otters tend to feed on slow moving fish like suckers, carp, chubs, dace, shiners, squawfish, bullhead, and catfish because they are easier to catch (Toweill and Tabor, 1982). Otters consume fish ranging in size from 1 to 20 inches (Melquist and Dronkert, 1987). A study of the feeding behavior of captive otters determined that otters normally catch fish ranging in length from 6 to 7 inches because they are the easiest to catch (Erlinge, 1968).

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 five of six AOCs with a Wildlife BUI as well as for other Great Lakes and inland territories that may be used as references (Table 11). Figures 1 and 2 provide a comparison of the ranges of PCBs and *p,p*'-DDE concentrations, respectively, measured in each of the regions presented in Table 11. Data for more specific comparison populations will be provided in the write-ups for the individual AOC assessments. 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 11. Median bald eagle plasma PCB and *p,p'*-DDE concentrations (µg/kg) for AOCs and comparison populations. All medians except for the River Raisin are based on data collected from 2004 through 2008; River Raisin data were collected in 1999 and 2001.

		Median Concentration (µg/kg)	
	N*	**PCBs**	***p,p*'-DDE**
Lake Erie			
St. Clair River AOC	0	No data	
Detroit River AOC	2	7.9	< 1
River Raisin AOC (1999-2001)	2	191.8	8.9
Overall Lake Erie (non-AOC)	2	59.1	7.8
Lake Huron			
Saginaw Bay/River AOC	18	38.8	10.8
St. Marys River AOC	11	25.0	12.0
Overall Lake Huron (non-AOC)	24	26.9	11.3
Lake Michigan			
Kalamazoo River AOC	2	142.6	9.0
Overall Lake Michigan (non-AOC)	45	25.7	13.6
Lake Superior			
Overall Lake Superior (non-AOC)	37	10.1	3.1
Overall Great Lakes (Excluding AOCs)	112	20.7	10.0
Overall Inland Lower Peninsula (Excl AOCs)	114	1.9	3.4
Overall Inland Upper Peninsula (Excl AOCs)	67	< 1	0.5

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

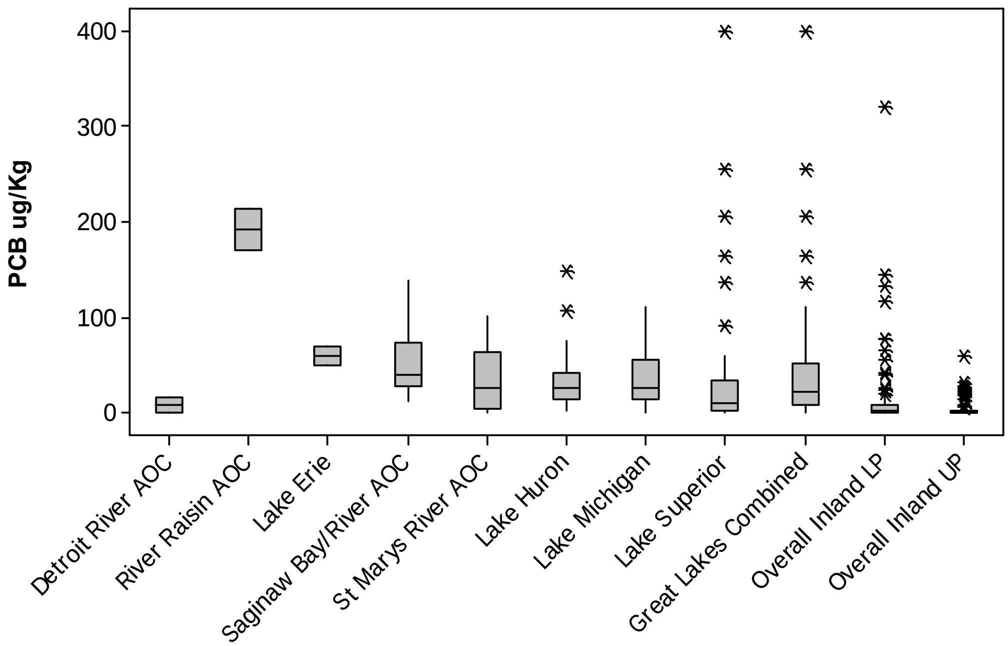

Figure 1. Boxplots of PCB concentrations measured in serum samples taken from nestling bald eagles. River Raisin samples were collected between 1999 and 2001, all other samples were collected between 2004 and 2008.

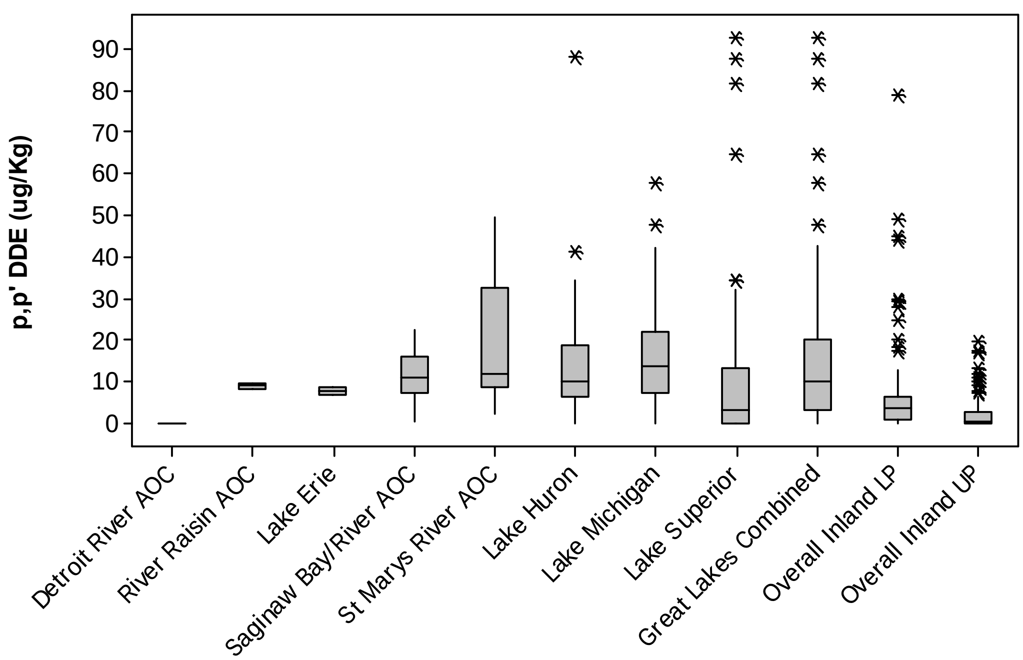

Figure 2. Boxplots of *p,p*'-DDE concentrations measured in serum samples taken from nestling bald eagles. River Raisin samples were collected between 1999 and 2001, all other samples were collected between 2004 and 2008.

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 12 presents a summary of contaminant concentrations measured in herring gull eggs from 2002 through 2006 as part of the Michigan study.

Table 12. Median concentrations of PCBs, *p,p*'-DDE, and TEQs in composite samples of herring gull eggs collected from colonies in Michigan from 2002 to 2006.

		Median Concentration		
	N†	**PCB (mg/kg)**	***p,p*'- DDE (mg/kg)**	**TEQ (ng/kg)**
Lake Michigan				
Grand Traverse Bay (Bellows I.)	5	3.1	2.2	739
Straits of Mackinac (Green I.)	5	3.0	1.6	228
Lake Huron				
Thunder Bay (Scarecrow I.)	5	4.1	1.5	183
Saginaw Bay/River AOC* (L. Charity I.)	3	6.0	1.3	739
St. Marys River AOC* (5-Mile I. and W. Twin Pipe I.)	9	3.1	1.0	222
Lake Superior				
Whitefish Bay (Tahquamenon I.)	4	3.3	1.5	185
Huron National Wildlife Refuge (Huron I.)	2	3.0	1.5	397
Isle Royale (Net I.)	4	3.6	1.9	217
Lake Erie				
River Raisin AOC* (Detroit Edison)	5	10.8	1.1	686
All non-AOC Sites Combined	25	3.4	1.6	210

† - Number of composite samples analyzed over the five-year period; a composite consisted of 1 egg from each of 13 separate nests from each colony

*- AOC with Wildlife BUI

Monitoring data are available for herring gulls, but only limited data are available for other colonial nesting birds that are more sensitive to the effects of various contaminants. Since effect levels are not available for PCBs, *p,p'*-DDE, and TEQ in herring gull eggs (Table 5), a method was needed to estimate concentrations of contaminants in the eggs of terns, cormorants, and herons nesting in the same general area as herring gulls. A cursory review of the literature was undertaken to find studies that compared the concentrations of contaminants in herring gull eggs to concentrations measured in the eggs of other birds nesting in the same general area. The results of this assessment showed that the concentration of contaminants in herring gull eggs is often higher than the concentration of contaminants in other colonial nesting birds. This assessment provided factors that can be used to extrapolate from herring gull eggs to the eggs of other species of colonial nesting birds. The results of this assessment are provided below:

PCBs-

The concentrations of PCBs measured in herring gull eggs were compared to levels found in common tern and double-crested cormorant eggs (Table 13) since effect levels are available for these two sensitive species. Since the effect level for Forster's terns is higher than the effect levels for common terns and double-crested cormorants, it was not necessary to compare egg concentrations of herring gulls and Forster's terns.

Table 13. The ratios of the concentrations of PCBs (mg/kg) in herring gull eggs to concentrations measured in common tern and/or double-crested cormorant eggs collected from the same location.

Location	A. Herring Gulls	B. Common Terns	Ratio (A/B)	C. Cormorants	Ratio (A/C)
Severn Sound	4.8	2.1	2.3	NA	NA
Hamilton Harbor	16	5.3	3.0	9.4	1.7
Fighting Island	115	31	3.7	NA	NA
Fighting Island	137	34	4.0	NA	NA
Lake Erie	42	NA	NA	33	1.3
Lake Erie	29	NA	NA	24	1.2
Lake Ontario	53	NA	NA	14	3.8
Lake Ontario	17	NA	NA	13	1.3

References: Severn Sound (Martin et al.,1995); Hamilton Harbor (Weseloh et al.,1995); Fighting Island (Bishop et al.,1992); and Lakes Erie and Ontario (Haffner et al.,1997)

p,p'-DDE-

The concentrations of *p,p*'-DDE found in herring gull eggs were compared to levels found in double-crested cormorant eggs since cormorants had the lowest effect level for *p,p*'-DDE (Table 5). The ratio of the concentration of *p,p*'-DDE in herring gull and cormorant eggs collected from Hamilton Harbor, Pigeon Island, and Little Galloo Island in Lake Ontario were 0.67, 3.7, and 1.5, respectively (Bishop et al., 1992; Weseloh et al., 1995).

TEQs-

Effect levels for TEQs are available for great blue herons, Forster's terns, and double-crested cormorants (Table 5). No studies were found that compared the concentration of TEQs in herring gull eggs to concentrations in great blue heron eggs. The concentrations of TEQs in herring gull eggs were compared to concentrations in double-crested cormorant eggs because the effect level for cormorant eggs is lower than for Forster's terns. Since the majority of TEQs in eggs is due to coplanar PCBs, the TEQs calculated by Haffner et al. (1997) based on PCBs was used to compare the TEQs in herring gull eggs to cormorant eggs. In this study, the ratios of TEQs in herring gull eggs to cormorant eggs were 2.2 and 1.9 for Lake Erie and 3.2 and 1.3 for Lake Ontario.

Synopsis-

These comparisons suggest that the concentrations of *p,p*'-DDE, PCBs, and TEQs are normally greater in herring gull eggs compared with concentrations measured in common tern and double-crested cormorant eggs. Therefore, assuming that the egg concentrations in common terns and cormorants are equivalent to concentrations in herring gull eggs collected from the same area would be a conservative assumption. The data for concentrations in Caspian terns relative to those in herring gulls are mixed. At Severn Sound, Caspian tern eggs had greater concentrations of PCBs and *p,p*'-DDE than herring gull eggs (Martin et al., 1995), whereas concentrations of PCBs, *p,p'*-DDE, and TEQs in Caspian tern eggs were less than in herring gull eggs from Hamilton Harbor (Weseloh et al., 1995). If Caspian terns are as sensitive as common terns and cormorants to the effects of PCBs, *p,p'*-DDE, and TEQs, then comparing concentrations of contaminants in herring gull eggs directly to concentrations shown to cause adverse effects in other species of birds may not be overly conservative.

Fish:

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 14. Insufficient data were available to make this assessment for TEQs.

Table 14. 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) and relevant reference areas.*

	PCBs (mg/kg)	Total DDT (mg/kg)	Mercury (mg/kg)
Kalamazoo River (2009)	2.44	0.14	0.14
Grand River (2009)	0.20	0.16	0.15
Muskegon River (2009)	0.07	0.12	0.20
St. Joseph River (2009)	0.30	0.02	0.13
Detroit River (2009)	1.39	0.16	0.10
Lake St. Clair (2009)	0.81	0.13	0.09
Saginaw River and Bay (2009)	1.39	0.14	0.08
Lake Huron / Thunder Bay (2008)	1.37	0.35	0.15
Lake Michigan / Grand Traverse Bay (2008)	0.91	0.30	0.22
St. Clair River (2009)	0.79	0.11	0.13
Lake St. Clair (2009)	0.81	0.13	0.09
St. Marys River (2004)	0.39	0.06	0.23
Lake Michigan / L. Bay De Noc (2005)	2.51	0.38	0.28
Lake Michigan / Grand Traverse Bay (2003)	1.64	0.30	0.22
River Raisin (Lake Erie 2008)	2.77	0.15	0.11
River Raisin (upstream Monroe, 2008)	0.13	0.04	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.

The data presented in Table 14 were not used to assess impacts on common terns or mink because carp are not a significant component of their diets. Since carp are a potential prey species of eagles (Dykstra et al., 2001) and otters (Toweill and Tabor, 1982), it was considered reasonable to compare the contaminant data for carp in Table 14 to the fish TRVs protective of these two species. However, this would be a conservative comparison since the carp used in the trend monitoring program 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.

After analysis of all of the MDEQ fish contaminant data and data reported in the literature, it was concluded that insufficient forage fish data are available from the Kalamazoo River, Detroit River, River Raisin, St. Clair River, and St. Marys River AOCs to make firm conclusions about wildlife impacts based solely on contaminant levels in fish. However, the MDEQ does have unpublished whole body contaminant analysis results for several species of forage fish collected from Lake Huron that can be compared to results for carp collected from the same areas over the same time period. Alewife were collected from Saginaw Bay in 2003 and 2007, spottail shiners were collected from Saginaw Bay in 2003, and rainbow smelt and ninespine stickleback were collected from Thunder Bay (Lake Huron) in 2005. PCB concentrations in those forage fish species ranged from 0.01 to 0.27 mg/kg (mean = 0.14 mg/kg), *p,p'*-DDE concentrations ranged from 0.01 to 0.04 mg/kg (mean = 0.02 mg/kg), and mercury concentrations ranged from 0.01 to 0.11 mg/kg (mean = 0.03 mg/kg). Carp collected from Thunder Bay and Saginaw Bay in 2003, 2004, 2005, and 2006 had mean PCB, *p,p'*-DDE, and mercury concentrations of 1.51, 0.43, and 0.14 mg/kg. Based on these data the ratio of contaminant concentrations in forage fish to carp in Lake Huron is 0.09 for PCB, 0.05 for *p,p'*-DDE, and 0.21 for mercury. These ratios were applied to the mean contaminant concentrations measured in carp from each AOC (Table 14) where forage fish data were not available.

Limited fish contaminant data for the Saginaw Bay/River AOC were found in the literature to assess impacts of PCBs on bald eagles, common terns, mink, and otters. These data are discussed in the section of the report that addresses this specific AOC.

WILDLIFE BUI ASSESSMENTS

Kalamazoo River AOC (KR AOC):

Wildlife studies:

Bald eagles-

Contaminant levels and productivity were examined in bald eagles in the KR AOC from 2000 to 2004 (Strause, 2007). The study found elevated concentrations of PCBs in bald eagle eggs and nestling plasma from the KR AOC. The annual bald eagle productivity rate for the KR 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 KR AOC.

More recent productivity (2006-2010) and contaminant (2005-2009) data for bald eagles nesting in the KR AOC are provided in Tables 15 and 16, respectively. A map depicting locations of active bald eagle territories is presented in Appendix C-1. Productivity, brood size, and success rates of bald eagles nesting in the KR AOC are lower than all of the comparison populations. Furthermore, the KR AOC productivity of 0.53 is below the TRV of 0.7 required for a stable population. Concentration of PCBs in bald eagle nestlings from the KR AOC are greater than those from all of the comparison populations and *p,p'*-DDE concentrations in bald eagles from the KR AOC are less than concentrations found in bald eagles from most of the comparison populations (Table 16).

Herring gulls-

No herring gull colonies are present in the KR AOC.

Tree swallows-

The productivity of tree swallows in the KR AOC was examined from 2000 to 2002 (Neigh et al., 2006a). Tree swallows in the KR 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 KR AOC. Tree swallow data (both egg concentrations and reproductive success measurements) from other locations in the AOC will be collected beginning in spring of 2012 (Custer, 2012).

Other wildlife studies-

The contaminant levels and productivity in great horned owls in the KR 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 KR 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 KR 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.

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 KR AOC and the upstream control site, respectively.

Four of nine mink trapped in the KR 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.

Table 15. Bald eagle productivity, brood size, and success rates in the KR 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 2006 to 2010.

Population Metric[1]	KR AOC	Grand River (Ottawa County)	Manistee River (d/s Tippy Dam)	Pere Marquette River	Lake Michigan[2]	Great Lakes Statewide[3]	Inland Statewide[3]
Productivity	0.53	1.45	1.07	1.61	1.14	1.09	1.03
Brood Size	1.30	1.81	1.59	1.68	1.60	1.59	1.51
Success Rate	0.41	0.80	0.68	0.96	0.71	0.69	0.68
Mean # Territories	3.4	4.0	5.6	4.6	80.4	172.8	306.2

[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 KR AOC
[3] - excluding all AOCs

Table 16. A comparison of median PCB and *p,p*'-DDE concentrations in the serum of bald eagle nestlings from the KR AOC with other bald eagle populations in Michigan. Medians are the overall values based on median concentrations per nest per year observed over the five-year period from 2004 to 2008.

	Healthy / Stable Population TRV[1]	KR AOC	Grand River (Ottawa County)	Manistee River (d/s Tippy Dam)	Pere Marquette River	Lake Michigan*	Great Lakes Statewide†	Inland Statewide†
PCB (µg/Kg)	35 / 125	142.6	16.7	53.3	23.8	25.7	20.7	0.2
p,p'-DDE (µg/Kg)	11 / 28	9.0	<1	23.1	12.3	13.6	10.0	2.2
Number of Nests		2	1	11	8	45	112	180

[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 KR AOC
[3] - excluding all AOCs

Fish data:

Spatial comparison-

The concentrations of PCBs in carp are higher in the KR AOC than in the Grand, Muskegon, and St. Joseph Rivers (Table 14). Total DDT concentrations were not elevated compared to the 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.

Comparison to wildlife benchmark value-

There are insufficient contaminant data available for fish inhabiting the KR AOC to adequately assess wildlife impacts. 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. If the ratio of PCB concentrations in forage fish to the concentrations in carp in the KR AOC is equivalent to the same ratio in Lake Huron then the estimated PCB concentration in KR AOC forage fish is 0.22 mg/kg (0.09 x 2.44 mg/kg). This concentration is above the low end of the range of fish TRVs.

Conclusions:

- Based on bald eagle, mink, and carp data, it was concluded that piscivorous wildlife within the KR AOC are exposed to greater concentrations of PCBs than wildlife from the comparison populations.
- Bald eagle productivity in territories within the KR AOC is lower than the productivity of the comparison populations.
- PCB concentrations in eaglet plasma (median = 143 μg/kg; geometric mean = 138 μg/kg) are above levels associated with a stable population (125 μg/kg).
- Mink within the KR AOC may be exhibiting an increase in jaw lesions due to PCBs and TEQs. Liver concentrations of PCBs are near levels associated with effects on reproduction.
- The reproduction of tree swallows nesting along the KR AOC does not appear to be adversely impacted.
- PCB concentrations in carp exceed the fish tissue TRV. 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 KR AOC.

Monitoring of productivity and contaminant levels in bald eagles in the KR AOC and contaminant concentrations in Kalamazoo River fish should continue while ongoing river sediment remediation work progresses. PCB concentrations in KR AOC forage fish should be measured.

Saginaw River/Bay AOC (SRB AOC):

Wildlife studies:

Bald eagles-

The recent productivity of bald eagles nesting in the SRB AOC is similar to the productivity of bald eagles nesting along the Great Lakes Statewide, Inland Lower Peninsula, and Inland Statewide, but lower than the Lake Huron Lower Peninsula comparison population (Table 17). The plasma concentrations of PCBs are greater in birds from the SRB AOC compared to the other populations. The plasma concentrations of *p,p'*-DDE are greater in birds from the SRB AOC compared to all but one of the comparison populations. The median PCB concentration in eaglet plasma exceeds the concentration associated with a healthy population, but is below the level associated with a stable population (Table 18).

Since the SRB 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 high levels of PCBs (BY-01 and BY-02). Eaglets from three other territories (AR-03, AR-09, and AR-10) also exhibited PCB concentrations greater than eaglets sampled from other areas in the SRB AOC. Concentrations of PCBs for some nestlings are much greater than levels associated with healthy bald eagle populations. Some breeding areas in SRB AOC are also exhibiting very low productivity and success rates (Appendix D-1). However, within this small dataset, contaminant concentrations and productivity were not correlated in the 2006 to 2010 time period.

Table 17. Bald eagle productivity, brood size, and success rates in the SRB AOC territories compared to territories with access to Lake Huron fish, and all territories statewide. Estimates are averages over the five-year period from 2006 to 2010.

Population Metric[1]	SRB AOC	Lake Huron Lower Peninsula[2]	Great Lakes Statewide[3]	Inland Lower Peninsula[3]	Inland Statewide[3]
Productivity	1.01	1.26	1.09	1.06	1.03
Brood Size	1.56	1.72	1.59	1.53	1.51
Success Rate	0.65	0.73	0.69	0.69	0.68
Mean # Territories	25.8	17.0	172.8	184.2	306.2

[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 SRB AOC

[3] - excluding all AOCs

Table 18. A comparison of median PCB and *p,p'*-DDE concentrations in the serum of bald eagle nestlings from the Saginaw River/Bay AOC (SRB AOC) with other bald eagle populations in Michigan. Medians are the overall values based on median concentrations per nest per year observed over the 5-year period from 2004 to 2008.

	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	38.8	31.9	20.7	2.0	0.2
p,p'-DDE (µg/Kg)	11 / 28	10.8	14.8	10.0	3.5	2.2
Number of Nests		18	12	112	114	181

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 SRB AOC
3 - excluding all AOCs

Herring gulls-

The concentration of contaminants in herring gull eggs are monitored at Channel Shelter Island by the Canadian Wildlife Service and at Little Charity Island by the State of Michigan. The five-year median concentrations (2002-2006) of PCBs in eggs from the two colonies are 10.6 and 6.0 mg/kg, respectively (Bowerman et al., 2011). The five-year median concentration (2002-2006) of TEQs at Little Charity Island is 739 nanograms per kilogram (ng/kg). Little Charity Island is ranked number two in PCB concentrations and tied for the highest TEQ concentrations for the ten monitored Michigan colonies. The concentration of *p,p*'-DDE is not elevated compared to concentrations found in the non-AOC Michigan colonies (Table 12). Herring gull eggs from Channel Shelter Island have the greatest concentration of PCBs of the 15 colonies monitored by the Canadian Wildlife Service (Weseloh, 2003; Weseloh et al., 2006). The concentrations of PCBs in the eggs of herring gulls in the SRB AOC are near the levels shown to cause adverse effects in common terns, Caspian terns, and cormorants.

Tree swallows-

The concentrations of contaminants in tree swallow eggs were 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 and ranked 22 out of 26 sites located in AOCs. The median concentration of PCBs is approximately 10 times lower than levels shown to cause adverse effects in tree swallows and other wild bird species (Custer, 2012).

Other wildlife studies-

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.

Caspian terns and herring gulls on Channel Shelter Island (Confined Disposal Facility) in the Saginaw Bay had suppressed T cell function and enhanced antibody production during the period 1997-1999 (Grasman and Fox, 2001). Caspian tern and herring gull reproduction at Channel Shelter Island is poor in some years and successful in others (Grasman, 2007). During 2006, reproductive success was poor in Caspian terns, but good in herring gulls nesting at Channel Shelter Island. Both herring gulls and Caspian terns also demonstrated significant T cell suppression (Grasman, 2007). In 2010, Caspian terns at Charity Reef had an extremely low productivity rate. Caspian terns, herring gulls, and black-crown night herons in the SRB AOC exhibited low growth rates and immune suppression during the study period (Grasman et al., 2011). These effects are consistent with previous studies that examined the effects of persistent pollutants such as PCBs on Great Lakes birds, although other stressors may be contributing (Grasman et al., 2011).

Fredricks et al. (2010) found greater concentrations of dioxins and furans 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.

<u>Fish data</u>:

Spatial comparison-

PCB concentrations in carp from the SRB AOC and Thunder Bay were similar, whereas, concentrations in both areas were greater than levels found in the Grand Traverse Bay (Table 14). Concentrations of total DDT and mercury were lower in the SRB AOC compared to the two comparison sites.

Comparison to wildlife benchmark value-

In addition to the carp data reported in Table 14, contaminant data are available for walleye, bluntnose minnows, and spottail shiners inhabiting the SRB AOC. PCB concentrations in walleye collected from Saginaw Bay in 2007 were 1.9 and 1.2 mg/kg for very large (average length = 24 inches) and extremely large walleye (average length = 27 inches), respectively. 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. PCB concentrations in bluntnose minnows and spottail shiners from Saginaw Bay (average length ranged from 1.5 to 2.4 inches) collected in 2005 ranged from 0.022 to 0.095 mg/kg (Jude et al., 2010). PCB concentrations in alewife and spottail shiners collected from Saginaw Bay in 2003 averaged 0.26 and 0.18 mg/kg, respectively (MDEQ, unpublished data). 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).

The concentrations for medium and large walleye collected from Saginaw Bay in 2007 are near (or above) the fish TRV that may adversely impact bald eagles and otters. The walleye data were not used to assess potential effects on common terns and mink because the fish were much larger than the size normally consumed by these animals. The concentration of PCBs in bluntnose minnows, spottail shiners, and alewives from Saginaw Bay (Jude et al., 2010; MDEQ unpublished data) are below concentrations expected to cause effects in colonial nesting birds and mink. Even though the carp collected by Michigan for the trend monitoring program are most likely larger than would normally be consumed by bald eagles and otters, it is noteworthy that the average PCB concentration of 1.39 mg/kg for 2009 exceeds the range of fish TRVs.

Conclusions:

- Based on bald eagle, herring gull, and carp data, it was concluded that piscivorous wildlife within the SRB 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 SRB AOC is exposed to higher levels of TEQs than at other areas of the state.

- Caspian terns in the SRB are exhibiting low productivity. Caspian terns, herring gulls, and black-crown night herons in the SRB AOC have also been exhibiting low growth rates and immune suppression.

- Productivity of bald eagles nesting in the SRB AOC from 2006 to 2010 was slightly above levels associated with a healthy population, but productivity was lower than 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).

- PCB and TEQ concentrations in SRB AOC herring gull eggs are near concentrations shown to cause adverse effects in other species of colonial nesting birds.

- Reproduction in tree swallows nesting in one area adjacent to the SRB AOC does not appear to be adversely impacted.

- PCB concentrations in SRB AOC walleye and carp exceed the fish tissue TRV. The concentration of PCBs in forage fish is below 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 SRB AOC.

Monitoring of productivity and contaminant levels in the bald eagles in the SRB 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 on Channel Shelter Island should continue to be monitored until they are similar to reference colonies. Lastly, additional measurements of PCB concentrations in SRB AOC forage fish should be made.

River Raisin AOC (RR AOC):

Wildlife studies:

Bald eagles-

Active nesting territories within the RR AOC are depicted in Appendix C-3. The productivity and brood size of birds nesting in the RR AOC from 2006 to 2010 is lower than the comparison populations (Table 19) and the eaglets from these territories have greater levels of PCBs in their plasma than birds in the comparison populations (Table 20). The median plasma PCB concentration of 192 µg/kg is also higher than the TRV associated with a healthy bald eagle population. The concentrations of *p,p*'-DDE in bald eagles inhabiting the RR AOC were equivalent to the median level found for all of the Great Lakes populations. More recent contaminant data are not available for bald eagles nesting in this area. In addition, two deformed nestlings were collected in 1993 and 1995 from this breeding area (Bowerman et al., 1994; Bowerman et al., 1998). However, no deformities have been found in this area since this period.

Table 19. Bald eagle productivity, brood size, and success rates in the RR AOC territories compared to territories with access to Lake Erie fish, and all territories statewide. Estimates are averages over the five-year period from 2006 to 2010.

Population Metric[1]	RR AOC	Lake Erie (Michigan Waters)[2]	Great Lakes Statewide[3]	Inland Lower Peninsula[3]	Inland Statewide[3]
Productivity	0.67	0.93	1.09	1.06	1.03
Brood Size	1.0	1.44	1.59	1.53	1.51
Success Rate	0.67	0.64	0.69	0.69	0.68
Mean # Territories	1.2	2.8	172.8	184.2	306.2

[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 20. A comparison of median PCB and *p,p'*-DDE concentrations in the serum of bald eagle nestlings from the RR AOC with other bald eagle populations in Michigan. Medians are the overall values based on median concentrations per nest per year. The River Raisin samples were taken between 1999 and 2001; comparison concentrations were measured over the five-year period from 2004 to 2008.

	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	191.8	59.1	20.7	1.9	0.2
p,p'-DDE (µg/Kg)	11 / 28	8.9	7.8	10.0	3.4	2.2
Number of Nests		2	2	112	114	181

[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-

Herring gull eggs from the colony at Detroit Edison had a median PCB concentration of 10.8 mg/kg for the period 2002-2006. This was the highest concentration of PCBs found in the ten colonies monitored by the State of Michigan. This concentration is above effect levels for common terns and double-crested cormorants. The TEQ concentration of 686 ng/kg was the third highest of the ten colonies monitored in Michigan. This concentration is above the effect level for great blue herons, but below effect levels for Forster's terns and double-crested cormorants.

Tree swallows-

The concentrations of contaminants in tree swallow eggs were 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 of 1.81 mg/kg ranked 21 out of 26 sites located in AOCs. The median PCB concentration is approximately 10 times lower than levels shown to cause adverse reproductive effects in tree swallows and other wild bird species (Custer, 2012).

Other wildlife studies-

In 2010, herring gulls at the Detroit Edison colony failed to produce fledglings. Herring gulls in the RR AOC exhibited low growth rates (29% of chicks lost weight from three to four weeks of age) and immune suppression during the study period (Grasman et al., 2011). No other studies examining the impacts of contaminants on wildlife in the RR AOC were found in the literature.

<u>Fish data</u>:

Spatial comparison-

Concentrations of PCBs and total DDT in carp were greater in the River Raisin downstream of Monroe compared to upstream data (Table 14). However, the total DDT concentrations in carp from the RR AOC were similar to those found in the Kalamazoo, Grand, and Muskegon Rivers. Mercury concentrations in fish collected upstream and downstream of Monroe were identical.

Comparison to wildlife benchmark value-

There are insufficient contaminant data available for fish inhabiting the RR AOC to adequately assess wildlife impacts. 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 2.77 mg/kg for 2008 exceeds the range of fish TRVs. If the ratio of PCB concentrations in forage fish to the concentrations in carp in the RR AOC is equivalent to the same ratio in Lake Huron then the estimated PCB concentration in RR AOC forage fish is 0.25 mg/kg (0.09 x 2.77 mg/kg). This concentration is above the low end of the range of fish TRVs.

<u>Conclusions</u>:

- Based on bald eagle, herring gull, and carp data, it is apparent that piscivorous wildlife within the RR AOC is exposed to greater concentrations of PCBs than wildlife from the comparison populations.

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

- Data for 2006-2010 suggest that the productivity of bald eagles nesting in the RR AOC is lower than levels associated with stable populations.

- Data for 1999-2001 show that blood levels of PCBs (median = 192 µg/kg; geometric mean = 190 µg/kg) exceed levels associated with a stable population. More recent contaminant data are not available.

- Herring gulls in the RR AOC during 2010 and 2011 exhibited lower productivity than the comparison population. Herring gulls in the RR AOC have also been exhibiting low growth rates and immune suppression.

- The concentrations of PCBs and TEQs present in herring gull eggs from the RR AOC suggest that other species of colonial nesting birds could be adversely impacted.

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

- PCB concentrations in carp from the RR 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.

<u>Recommendation</u>:

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

Monitoring of productivity and contaminant levels in bald eagles in the RR AOC and contaminant concentrations in River Raisin fish and Lake Erie fish and herring gulls should continue in order to evaluate the effects of ongoing river sediment remediation work. PCB concentrations in RR AOC forage fish should be measured.

Detroit River AOC (DR AOC):

Wildlife studies:

Bald eagles-

The DR AOC has only two bald eagle territories associated with it. One nesting territory adjacent to the AOC (near the Huron River upstream of Lake Erie; WA-03, Appendix C-3) was active every year from 2006 to 2010. A second territory in the DR AOC (Humbug Marsh; WA-07, Appendix C-3) had an active pair of bald eagles in 2010, but no young were fledged. The productivity of bald eagles in these two territories from 2006-2010 is provided in Table 21.

Contaminant data are available for one bald eagle territory adjacent to the DR AOC (Table 22). The median PCB concentration in two eaglet blood samples collected in 2006 and 2007 was 7.9 µg/kg and the *p,p'*-DDE concentration was below the detection level. Despite relatively low contaminant levels, the overall productivity and success rate for the DR AOC was lower than in all other comparison populations (Table 21). These data suggest that bald eagles in this territory may be adversely impacted by factors other than PCBs and *p,p*'-DDE. It is possible that these eagles were feeding on fish primarily from the Huron River instead of the Detroit River and thus do not represent conditions in the DR AOC.

Table 21. Bald eagle productivity, brood size, and success rates in the DR AOC territories compared to territories with access to Lake Erie fish, and all territories statewide. Estimates are averages over the five-year period from 2006 to 2010.

Population Metric[1]	DR AOC	Lake Erie (Michigan Waters)[2]	Great Lakes Statewide[3]	Inland Lower Peninsula[3]	Inland Statewide[3]
Productivity	0.83	0.93	1.09	1.06	1.03
Brood Size	1.67	1.44	1.59	1.53	1.51
Success Rate	0.5	0.64	0.69	0.69	0.68
Mean # Territories	1.2	2.8	172.8	184.2	306.2

[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 22. A comparison of median PCB and *p,p'*-DDE concentrations in the serum of bald eagle nestlings from the DR AOC with other bald eagle populations in Michigan. Medians are the overall values based on median concentrations per nest per year observed over the five-year period from 2004 to 2008.

	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	7.9	59.1	20.7	1.9	0.2
p,p'-DDE (µg/Kg)	11 / 28	<1	7.8	10.0	3.4	2.2
Number of Nests		2	2	112	114	181

[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-

The Canadian Wildlife Service routinely monitors 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 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.

Tree swallows-

The concentrations of contaminants in tree swallow eggs were monitored by the USGS in nest boxes located at the following four sites arranged from north to south: Detroit Edison's plant at Connor Creek, Wyandotte Golf Course, Trenton Channel, and Lake Erie MetroPark. The median concentrations of PCBs for these sites were 0.48, 0.96, 1.79, and 1.94 mg/kg, respectively, and ranked 5, 13, 20, and 23 of the 26 sites located in AOCs. The PCB concentrations were between 10 and 40 times lower than levels shown to cause adverse reproductive effects in tree swallows and other wild bird species (Custer, 2012).

Other wildlife studies-

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 Wheatley Harbor AOC and the DR AOC had much higher concentrations of *p,p'*-DDE and PCBs in 2001-2002 than the other sites. Dioxins were highest in the DR 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 DR AOC for the 2002 to 2004 period. They did not find a relationship between contaminant concentrations and hatching success.

According to Szczechowski and Bull (2007), nesting populations of common terns have decreased in the DR 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 in 2004 and 2005, 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.

A study conducted in 2004 and 2005 indicates that the incidence of deformities in some chironomid (midge) species inhabiting the Detroit River around Belle Isle on the United States side are elevated (Zhang, 2008). Zhang (2008) found that two genera of midges (*Dicrotendipes* and *Procladius*) had deformity rates of 25%, which is much higher than other areas in the Lake Huron-Lake Erie corridor. Furthermore, midges of the genus *Procladius*, inhabiting the Detroit River near Belle Isle had significantly higher deformity rates than the baseline rate of 2.27 found for this genus by Burt et al. (2003). The incidence of deformities in midges in the lower portion of the Detroit River could not be assessed because there were insufficient chironomids present (Zhang, 2008). The researchers could not determine the cause of the deformities.

The Canadian Wildlife Service assessed the reproductive viability of black-crowned night herons living on Turkey Island in the DR AOC in 2009 and 2011 (Weseloh and Moore, 2011). The researchers concluded that there was lower breeding success in the DR AOC in both years of the study compared to the control populations. The researchers also found higher levels of many contaminants (i.e., PCBs, *p,p*'-DDE, dieldrin, heptachlor epoxide, hexachlorobenzene, and PBDEs) in eggs from birds living in the DR AOC compared to birds living on Nottawasaga Island in Georgian Bay. The researchers concluded that there was lower breeding success in the DR AOC in both years of the study compared to the control population.

<u>Fish data</u>:

Spatial comparison-

The concentration of PCBs in carp from the DR AOC were higher than levels found in carp from Lake St. Clair and the Grand, Muskegon, and St. Joseph Rivers (Table 14). The concentrations of total DDT and mercury in carp from the DR AOC were similar to levels found in Lake St. Clair carp.

Comparison to wildlife benchmark value-

There are insufficient contaminant data available for fish within the DR AOC to adequately assess wildlife impacts. 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 1.39 mg/kg for 2009 exceeds the fish TRVs. If the ratio of PCB concentrations in forage fish to the concentrations in carp in the DR AOC is equivalent to the same ratio in Lake Huron then the estimated PCB concentration in DR AOC forage fish is 0.12 mg/kg (0.09 x 1.39 mg/kg). This concentration is below the range of fish TRVs.

<u>Conclusions</u>:

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

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

- Snapping turtles, black-crowned night herons, and midges living in the DR AOC may be adversely impacted.

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

- PCB concentrations in carp from the DR AOC exceed the fish tissue TRV. The estimated concentration of PCBs in forage fish is below 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 DR AOC.

Monitoring of the bald eagle and other wildlife populations in the DR AOC and contaminant concentrations in Detroit River fish should continue. PCB concentrations in DR AOC forage fish should be measured.

St. Marys River AOC (SMR AOC):

Wildlife studies:

Bald eagles-

A map and table presenting productivity and nestling eagle serum PCB concentrations for individual bald eagle territories active between 2006 and 2010 is presented in Appendices C-4 and D-2, respectively. Both the overall productivity and the overall success rate for bald eagles nesting in the SMR AOC were higher than observed in all of the comparison populations (Table 23). Bald eagle nestlings from the SMR AOC 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 24).

Table 23. Bald eagle productivity, brood size, and success rates in the SMR 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 2006 to 2010.

Population Metric[1]	SMR AOC	Lake Huron[2]	Lake Superior[3]	Great Lakes Statewide[3]	Inland Upper Peninsula[3]	Inland Statewide[3]
Productivity	1.20	0.90	0.99	1.09	0.98	1.03
Brood Size	1.54	1.38	1.56	1.59	1.49	1.51
Success Rate	0.78	0.65	0.64	0.69	0.66	0.68
Mean # Territories	15.2	13.8	48.0	172.8	120.4	306.2

[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 SMR AOC

[3] - excluding all AOCs

Table 24. A comparison of median PCB and *p,p'*-DDE concentrations in the serum of bald eagle nestlings from the SMR 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 2004 to 2008.

	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	25.0	26.9	10.1	20.7	< 1	0.2
p,p'-DDE (µg/Kg)	11 / 28	12.0	10.3	3.1	10.0	0.5	2.2
Number of Nests		11	26	37	112	67	181

[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-

Michigan is currently monitoring contaminant levels in two herring gull colonies from the SMR AOC (Five Mile Island and West Twin Pipe). The Five Mile Island and West Twin Pipe colonies had 2002-2006 median PCB egg concentrations of 3.1 mg/kg (Table 12). The five-year median TEQ concentration for these two colonies was 222 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.

Tree swallows-

Tree swallow data (both egg concentrations and reproductive success) from two locations on the St. Marys River AOC will be collected beginning in spring of 2012 (Custer, 2012).

Other wildlife studies-

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.

It is not possible to determine whether terns are still adversely impacted on Lime Island because they no longer inhabit the island. However, the Canadian Wildlife Service is currently working on a two-year study of common terns in the St. Marys River, which will determine whether terns are being adversely impacted.

<u>Fish data</u>:

Spatial comparison-

The PCB and total DDT concentrations in carp from the SMR AOC were lower than levels found in carp from Little Bay De Noc and Grand Traverse Bay (Table 14). Mercury levels in carp from the SMR AOC were similar to those found in carp from Little Bay De Noc and Grand Traverse Bay.

Comparison to wildlife benchmark value-

There are insufficient contaminant data available for fish inhabiting the SMR AOC to adequately assess wildlife impacts. 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 0.39 mg/kg for 2004 exceeds the low end of the range of fish TRVs. Large carp would also be expected to have higher concentrations of PCBs than many of the potential fish consumed by wildlife. If the ratio of PCB concentrations in forage fish to the concentrations in carp in the SMR AOC is equivalent to the same ratio in Lake Huron then the estimated PCB concentration in SMR AOC forage fish is 0.04 mg/kg (0.09 x 0.39 mg/kg). This concentration is well below the fish TRV.

Conclusions:

- The productivity data for bald eagles living along the SMR 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, and carp data, it was concluded that piscivorous wildlife within the SMR AOC are not exposed to higher concentrations of contaminants than surrounding areas.
- At this time, it is unknown whether terns are adversely impacted in the SMR AOC. The two-year study planned by the Canadian Wildlife Service should be able to answer this question.
- PCB concentrations in carp from the SMR 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:

Existing data suggest that the Wildlife BUI could be removed for the St. Marys River AOC; however, actions to remove the BUI should be deferred pending results of the Canadian Wildlife Service's study of common terns in the AOC.

St. Clair River AOC (SCR AOC):

Wildlife studies:

Bald eagles-

No bald eagle territories are located in the SCR AOC.

Herring gulls-

No herring gull colonies are located in the SCR AOC.

Tree swallows-

Tree swallow data (both egg concentrations and reproductive success measurements) from two locations on the St. Clair River AOC (at Marysville at the north end and at Algonac State Park at the south end of the river) will be collected beginning in spring of 2012 (Custer, 2012).

Other wildlife studies-

The Bird or Animal Deformities or Reproductive Problems beneficial use was listed as impaired in the 1992 Stage 1 Remedial Action Plan due to observations of an abnormally high number of mouth-part deformities in some chironomid (midge) species collected along the Ontario side of the river downstream of Sarnia (Ontario Ministry of the Environment and Michigan Department of Natural Resources, 1991). A study conducted in 2004 and 2005 indicates that the incidence of these deformities in parts of the St. Clair River remains elevated compared to other areas in the Lake Huron to Lake Erie corridor (Zhang, 2008). In addition, the rate of deformities in several genera of midges from the river was higher than the baseline rate observed in other waters of the Great Lakes (Burt et al., 2003). Specifically, midges of the genus *Chironomus* from the Canadian side of the St. Clair River near Sarnia and from the Walpole Island region had rates of mouth-part deformities of 16.00% and 12.24%, respectively, which is significantly higher than the baseline rate of 2.15% found by Burt et al. (2003). The researchers could not determine the cause of the deformities.

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 SCR 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 SCR AOC were generally higher than those from Algonquin Park, but similar to those from Tiny Marsh (De Solla and Fernie, 2004).

<u>Fish data</u>:

Spatial comparison-

The concentrations of PCBs, total DDT, and mercury in carp from the SCR AOC were similar to concentrations found in Lake St. Clair (Table 14).

Comparison to wildlife benchmark value-

There are insufficient contaminant data available for fish inhabiting the SCR AOC to adequately assess wildlife impacts. 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 0.79 mg/kg for 2009 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. If the ratio of PCB concentrations in forage fish to the concentrations in carp in the SCR AOC is equivalent to the same ratio in Lake Huron then the estimated PCB concentration in DR AOC forage fish is 0.07 mg/kg (0.09 x 0.79 mg/kg). This concentration is well below the fish TRV.

<u>Conclusions</u>:

- Few wildlife studies are available for the SCR AOC.

- The carp data suggest that PCB, total DDT, and mercury concentrations are not elevated in the SCR AOC.

- Turtle plasma and egg data suggest that PCB, *p,p*'-DDE, and TEQ concentrations are not elevated in the SCR AOC.

- The incidences of deformities in midges in some areas of the SCR AOC are higher than comparison populations.

- PCB concentrations in carp from the SCR 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>:

If an increased incidence of deformities in midges is still considered a legitimate basis for considering that wildlife within an AOC is impaired, then the Wildlife BUI for the SCR AOC should be retained. However, an alternative approach would be to remove the Wildlife BUI for the SCR AOC and consider the deformities in midges under the "Degradation of Benthos" BUI.

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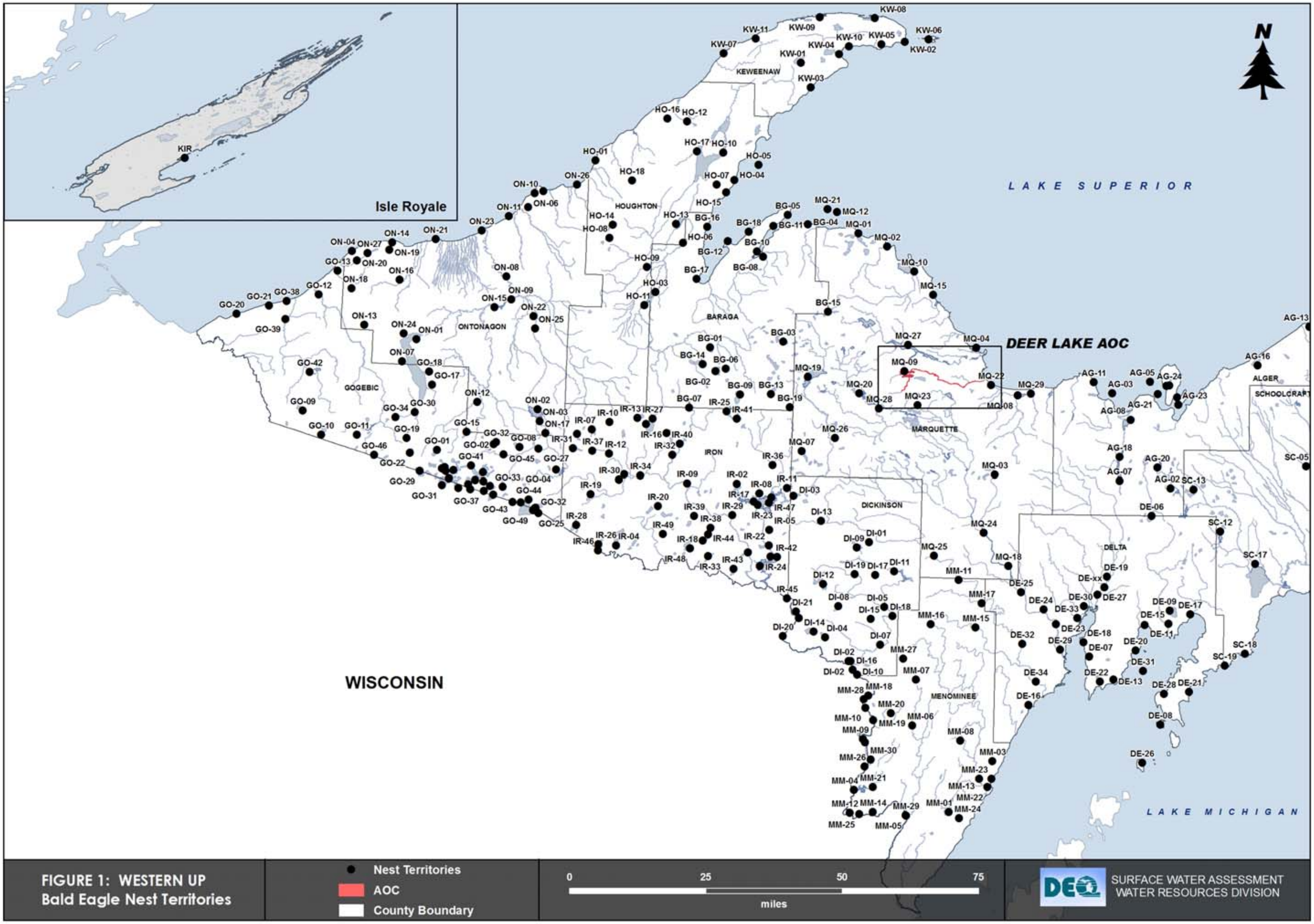
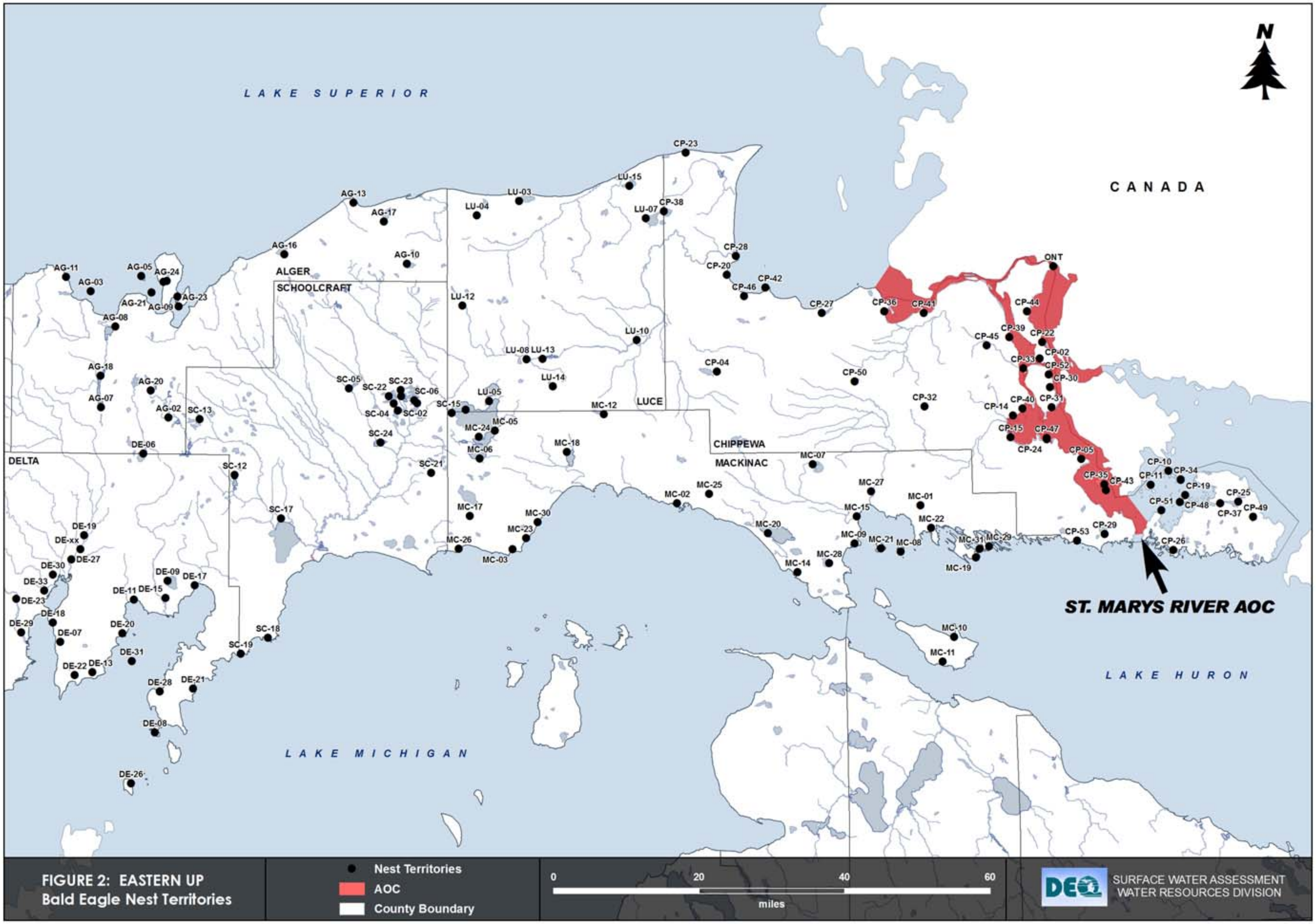
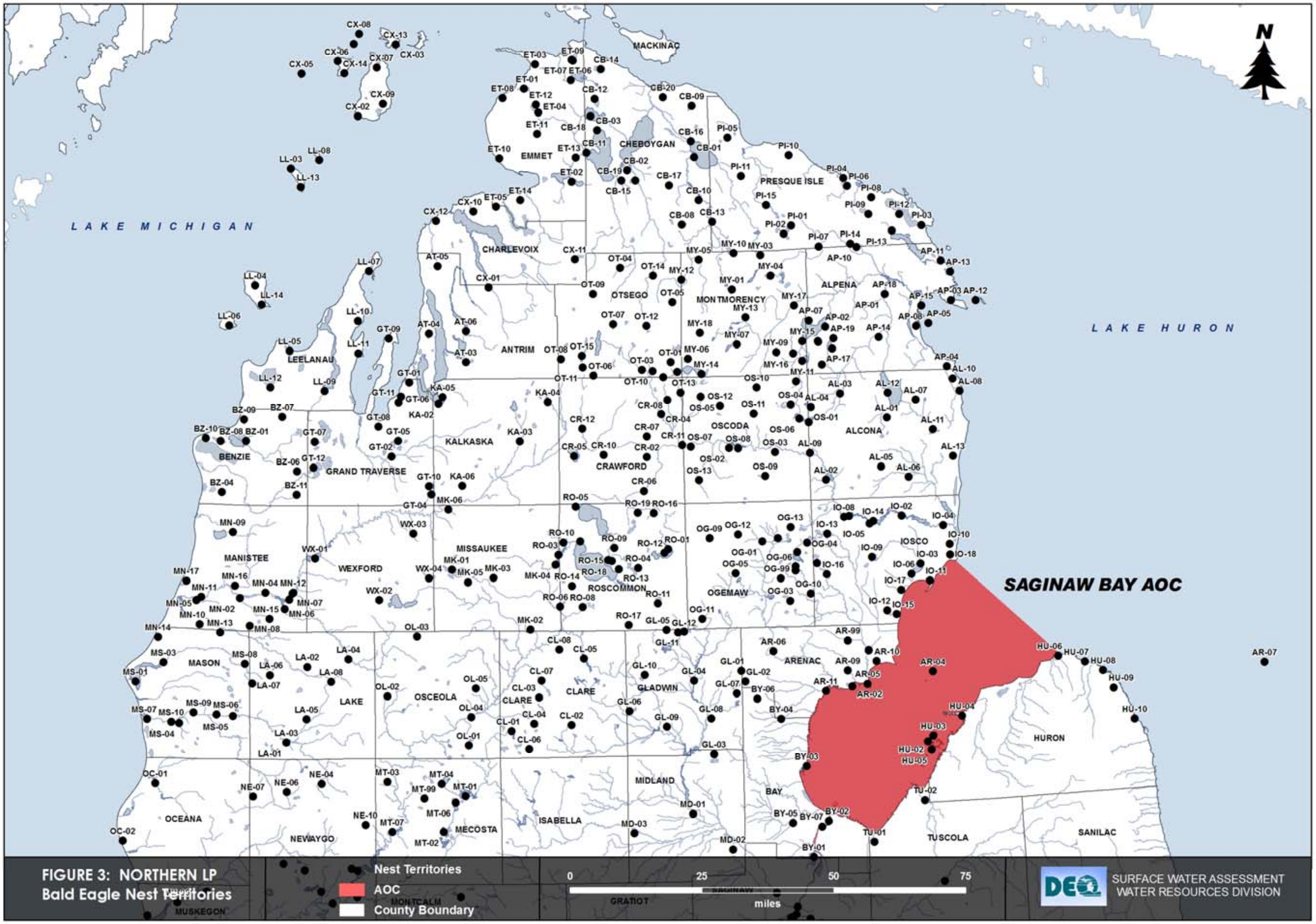
List of Appendices



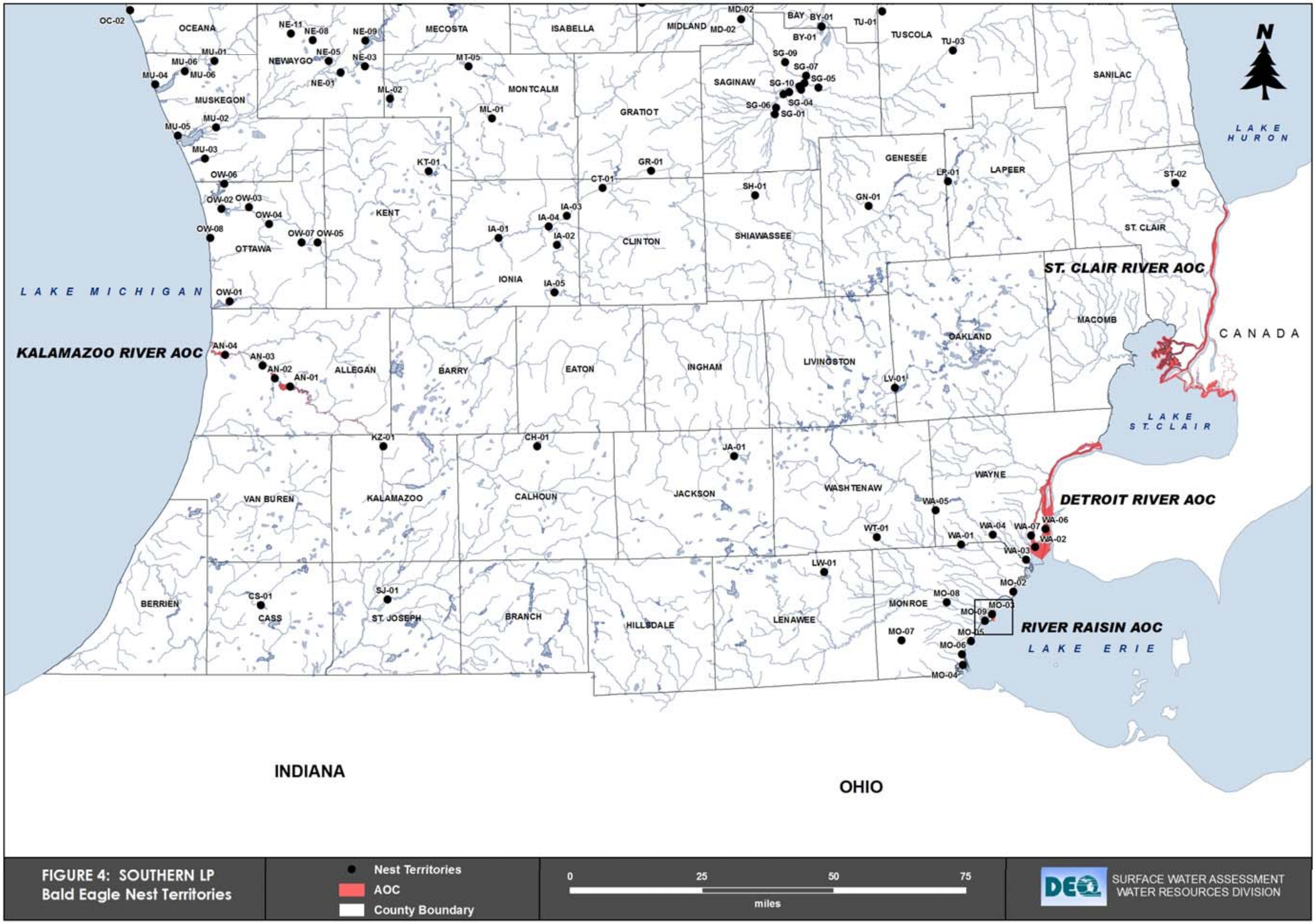
Appendix A-1. Active and inactive bald eagle nesting territories in the western Upper Peninsula of Michigan.



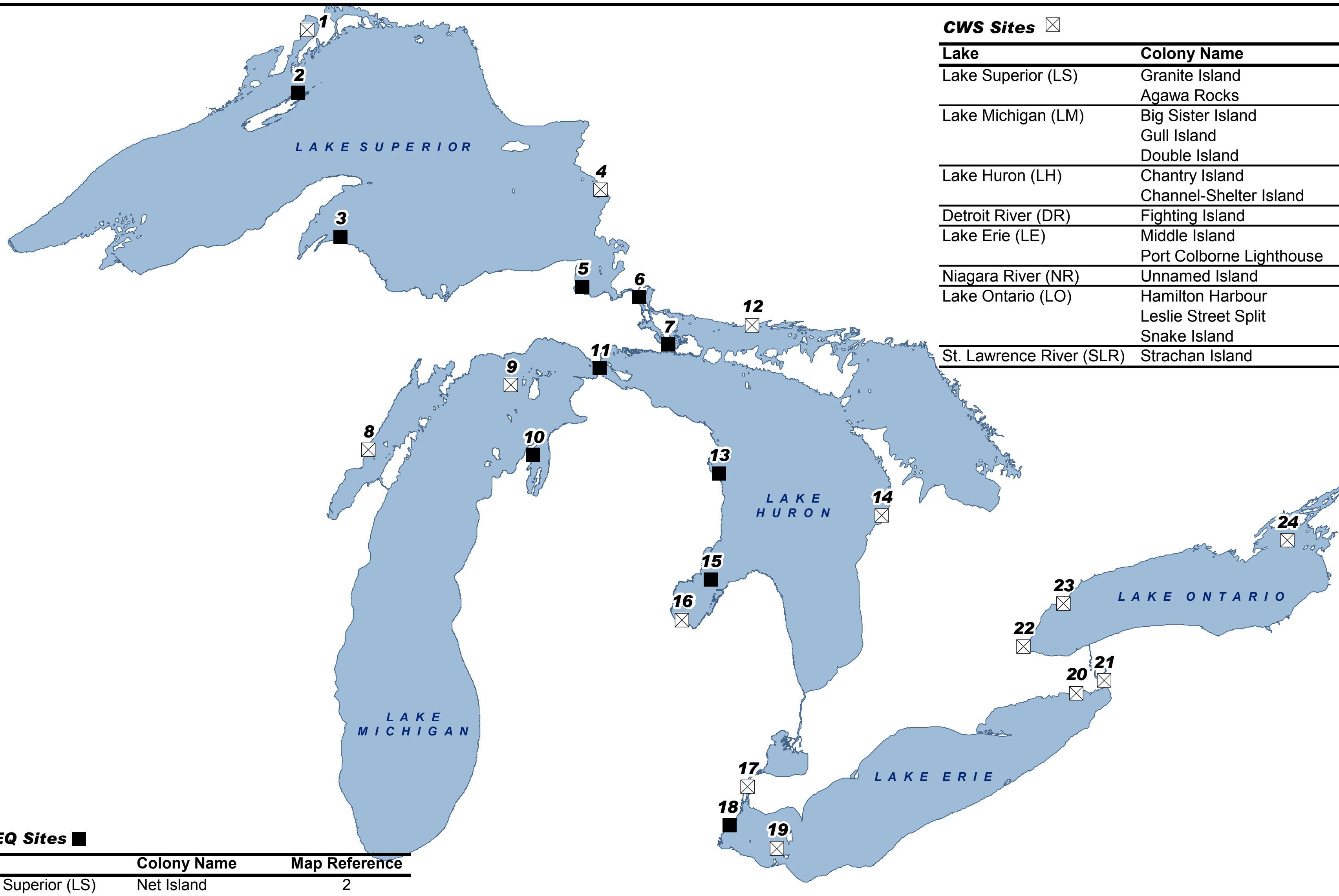
Appendix A-2. Active and inactive bald eagle nesting territories in the eastern Upper Peninsula of Michigan.



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



Appendix A-4. Active and inactive bald eagle nesting territories 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

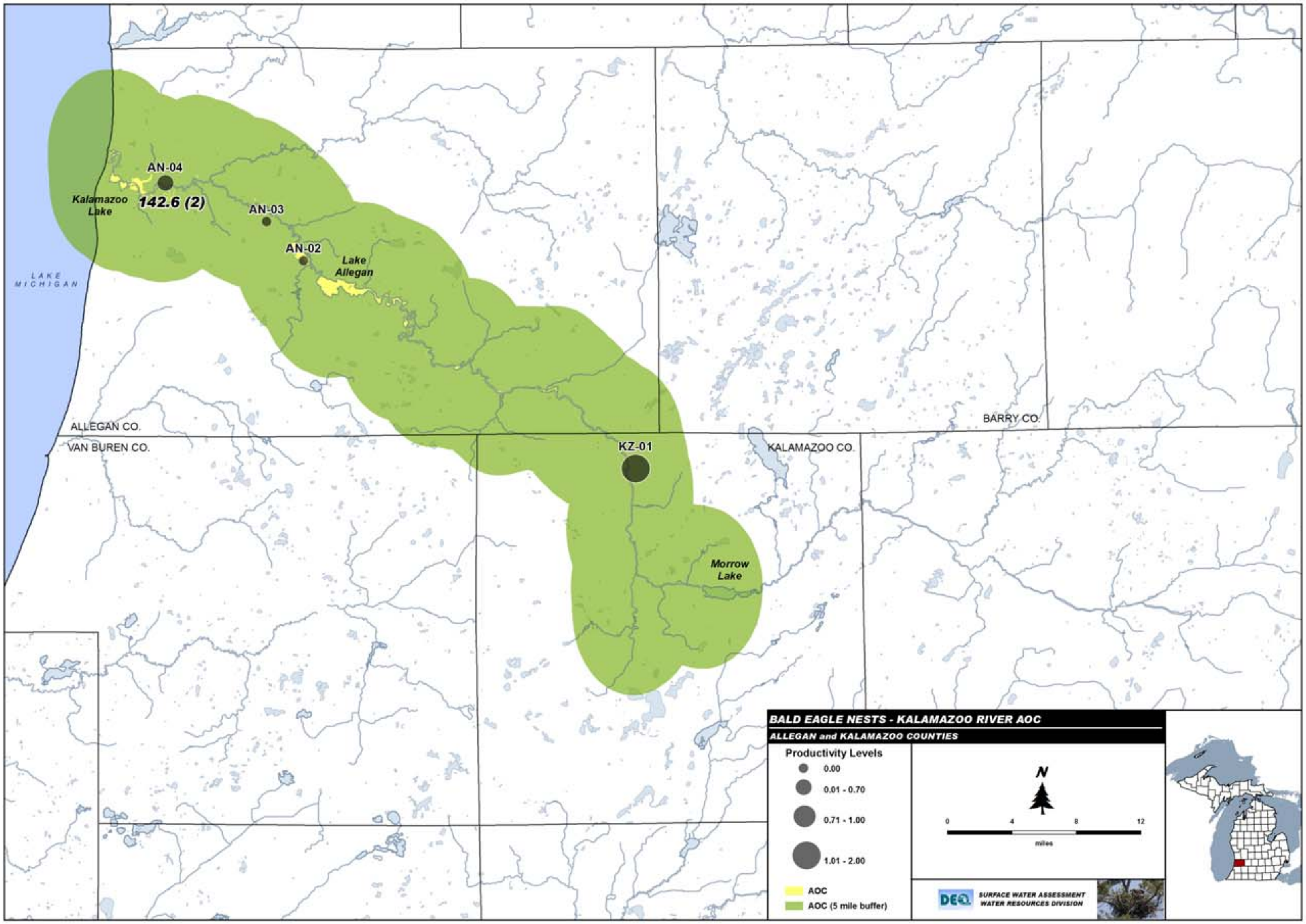
Great Lakes Region

0 80 160 240

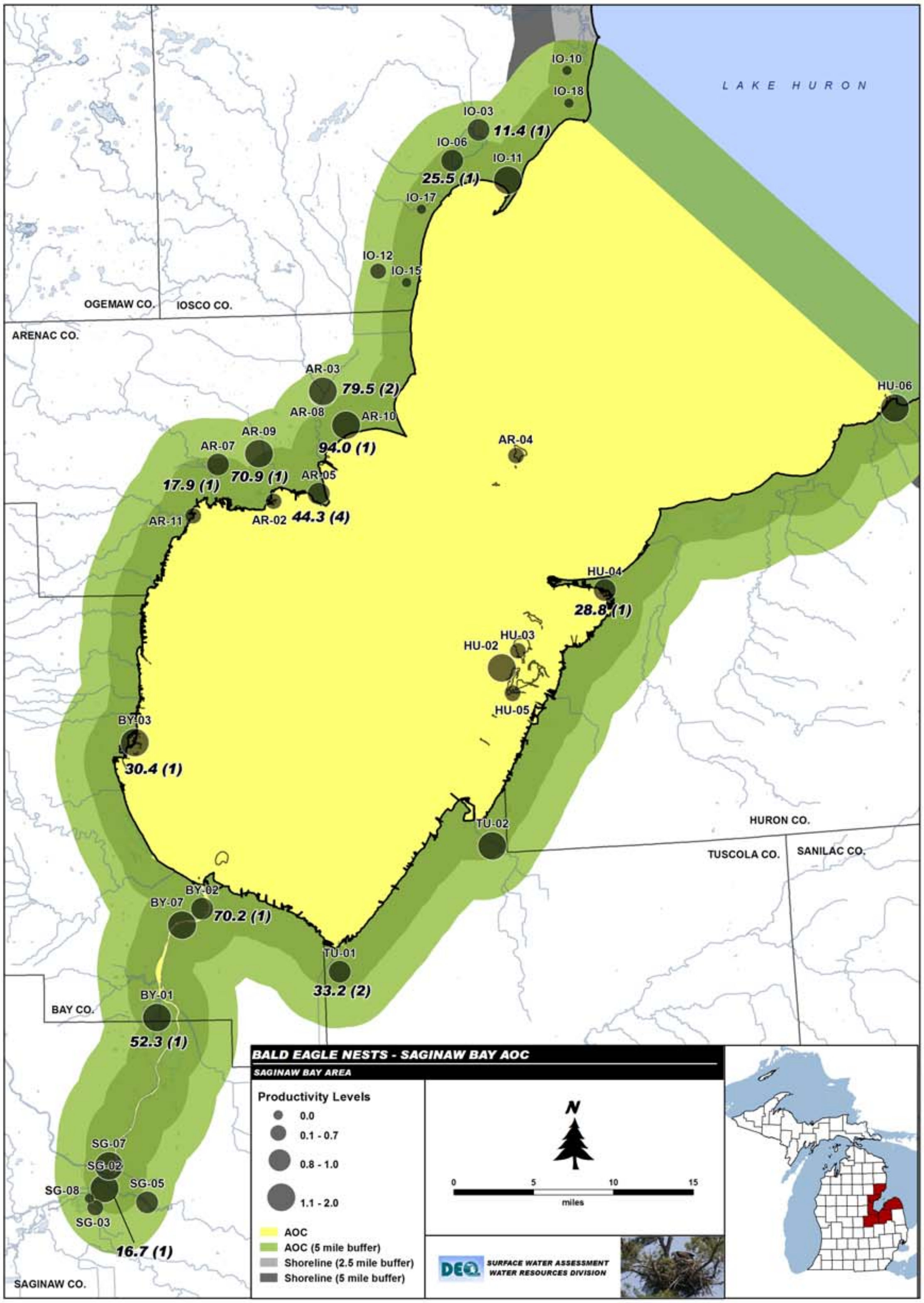
miles

DEQ SURFACE WATER ASSESSMENT
WATER RESOURCES DIVISION

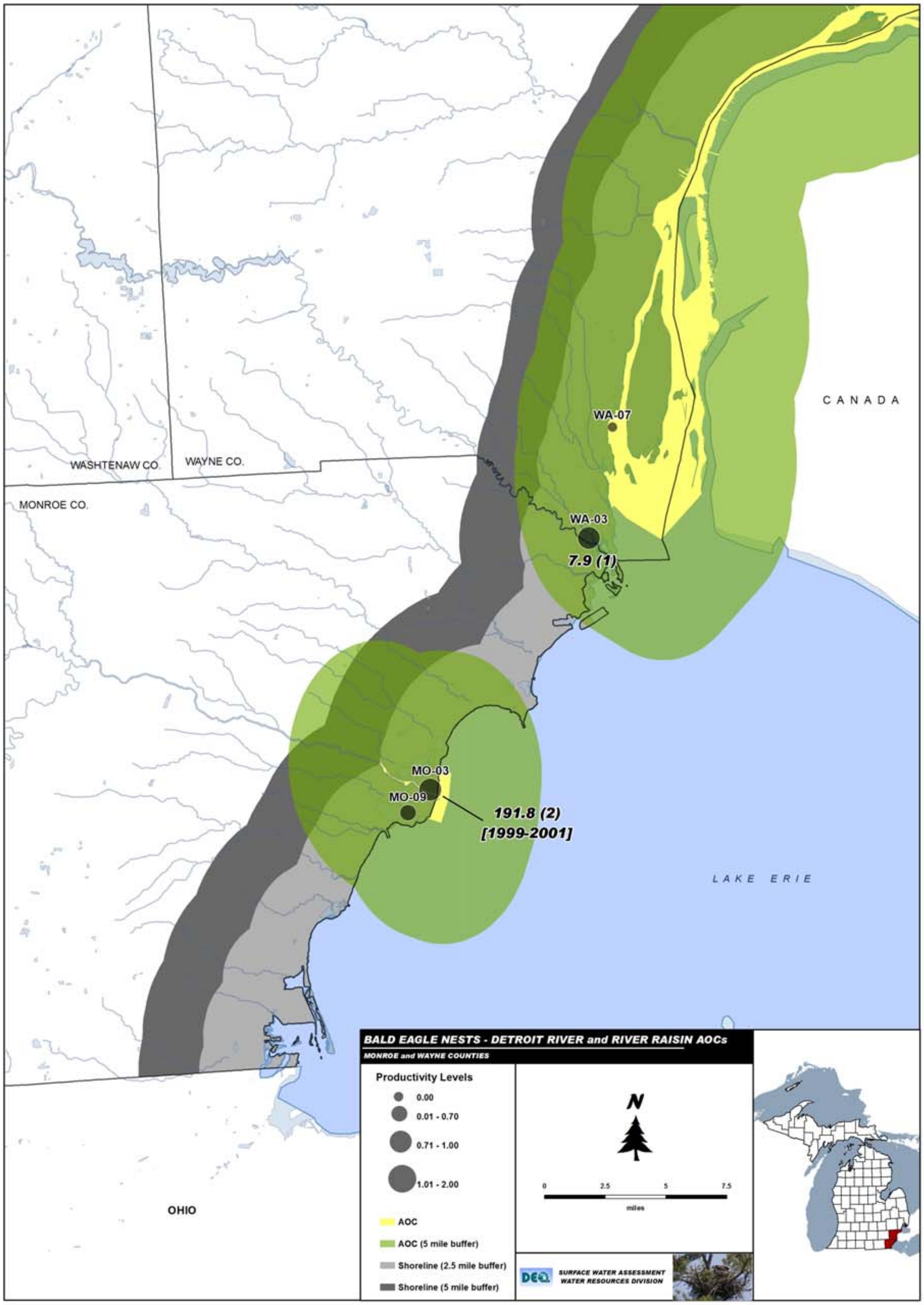
Appendix B. Great Lakes herring gull colonies monitored by Michigan DEQ and the Canadian Wildlife Service (CWS).



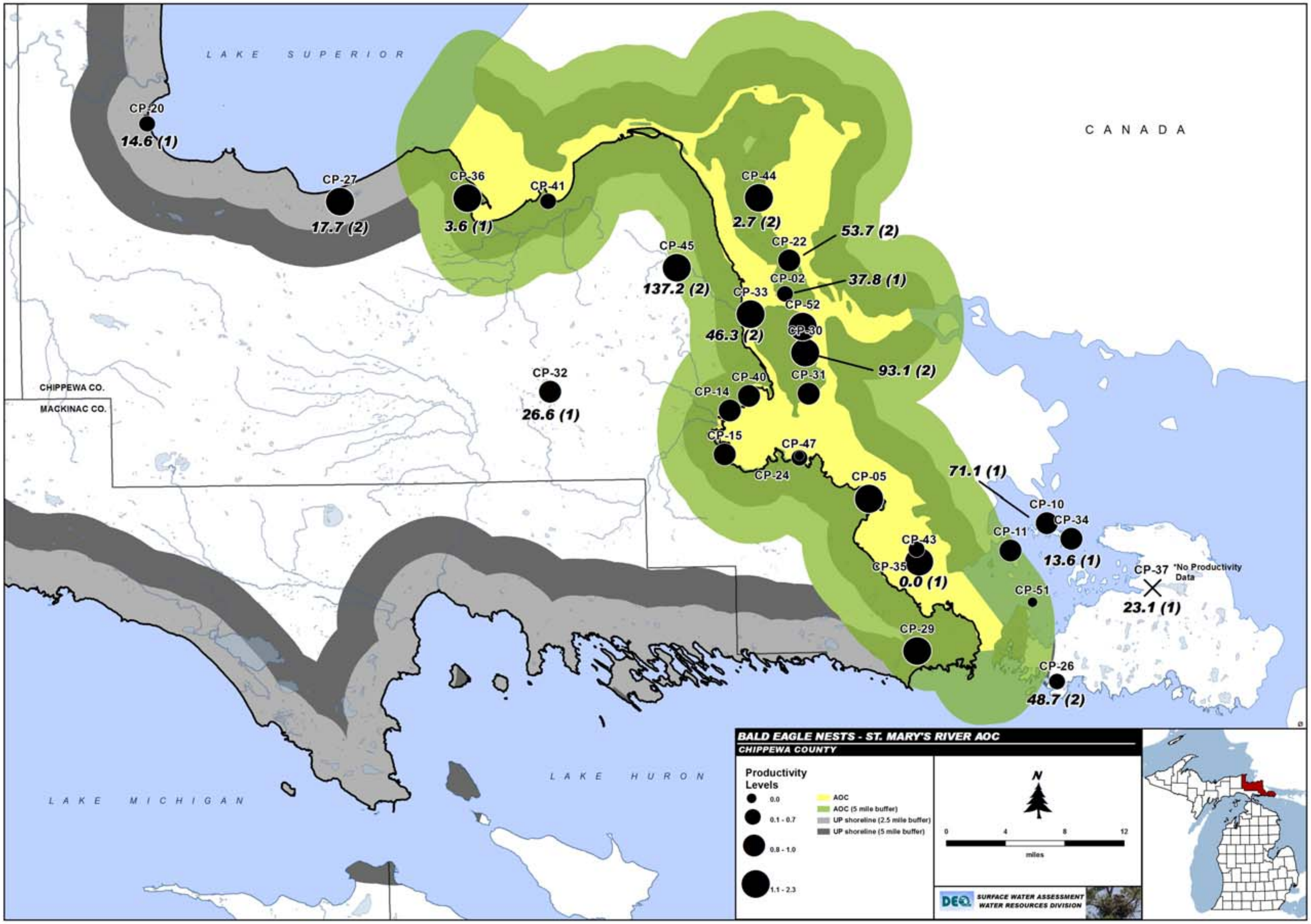
Appendix C1. Active bald eagle territories in the Kalamazoo River AOC with median total PCB concentrations (ug/Kg) in eaglet serum from independent nests sampled between 2004 and 2008 (N in parentheses). Productivity estimates are averages for the 5-year period from 2006 through 2010.



Appendix C2. Active bald eagle territories in the Saginaw River/Bay AOC with median total PCB concentrations (ug/Kg) in eaglet serum from independent nests sampled between 2004 and 2008 (N in parentheses). Productivity estimates are averages for the 5-year period from 2006 through 2010.



Appendix C3. Active bald eagle territories in the River Raisin and Detroit River AOCs with median total PCB concentrations (ug/Kg) in eaglet serum from independent nests. The River Raisin nest was sampled between 1999 and 2001; the Detroit River nest was sampled between 2004 and 2008 (N in parentheses). Productivity estimates are averages for the 5-year period from 2006 through 2010.



Appendix C4. Active bald eagle territories in the St. Marys River AOC with median total PCB concentrations (ug/Kg) in eaglet serum from independent nests sampled between 2004 and 2008 (N in parentheses). Productivity estimates are averages for the 5-year period from 2006 through 2010.

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

AOC	Site	Name	Fledged Young	Attempts	Productivity	Success Rate	Brood Size	Median PCB (µg/Kg)	Median DDE (µg/Kg)	N
Saginaw Bay/River	AR-02	AuGres-Wigwam-Rifle R	3	5	0.6	0.6	1.0			
Saginaw Bay/River	AR-03	Santiago	6	5	1.2	0.6	2.0	79.5	16.1	2
Saginaw Bay/River	AR-04	Big Charity Isd	3	5	0.6	0.6	1.0			
Saginaw Bay/River	AR-05	Pt AuGres S	4	5	0.8	0.6	1.3	44.3	10.8	4
Saginaw Bay/River	AR-07	Hickory Isd	4	5	0.8	0.4	2.0	17.9	5.1	1
Saginaw Bay/River	AR-08	Delano	7	5	1.4	0.8	1.8			
Saginaw Bay/River	AR-09	Knoll View	5	3	1.7	1.0	1.7	70.9	1.0	1
Saginaw Bay/River	AR-10	Pt AuGres N	6	3	2.0	1.0	2.0	94.0	22.5	1
Saginaw Bay/River	AR-11	Wigwam Bay	2	3	0.7	0.3	2.0			
Saginaw Bay/River	BY-01	Skull/Stoney Isd	8	5	1.6	1.0	1.6	52.3	21.1	1
Saginaw Bay/River	BY-02	Quanicassee	5	5	1.0	0.6	1.7	70.2	8.0	1
Saginaw Bay/River	BY-03	Nayanquing Pt	7	5	1.4	0.8	1.8	30.4	13.0	1
Saginaw Bay/River	BY-07	Golson Park	2	1	2.0	1.0	2.0			
Saginaw Bay/River	HU-02	Maisou/Katechay/N Isd	6	5	1.2	1.0	1.2			
Saginaw Bay/River	HU-03	Heisterman Isd	1	2	0.5	0.5	1.0			
Saginaw Bay/River	HU-04	Sand Pt	3	4	0.8	0.5	1.5	28.8	14.9	1
Saginaw Bay/River	HU-05	Wildfowl Bay	2	5	0.4	0.4	1.0			
Saginaw Bay/River	HU-06	Port Austin	7	4	1.8	1.0	1.8			
Saginaw Bay/River	IO-03	Tawas L N	5	5	1.0	0.8	1.3	11.4	6.6	1
Saginaw Bay/River	IO-06	Tawas L SW	5	5	1.0	0.6	1.7	25.5	8.8	1
Saginaw Bay/River	IO-10	Grass L-Oscoda	0	1	0.0	0.0	---			
Saginaw Bay/River	IO-11	L Solitude	7	5	1.4	0.8	1.8			
Saginaw Bay/River	IO-12	Alabaster	2	5	0.4	0.4	1.0			
Saginaw Bay/River	IO-15	US Gypsum	0	2	0.0	0.0	---			
Saginaw Bay/River	IO-17	Dead Ck	0	1	0.0	0.0	---			
Saginaw Bay/River	IO-18	Spencer L	0	1	0.0	0.0	---			
Saginaw Bay/River	SG-02	Shiawassee NWR #1	7	5	1.4	0.8	1.8	16.7	0.5	1
Saginaw Bay/River	SG-03	Shiawassee NWR #2-Spaulding	1	5	0.2	0.2	1.0			
Saginaw Bay/River	SG-05	Bridgeport	5	5	1.0	0.6	1.7			
Saginaw Bay/River	SG-07	Ojibway Isd	7	5	1.4	0.8	1.8			
Saginaw Bay/River	SG-08	Shiawassee NWR-Pool 1A	0	2	0.0	0.0	---			
Saginaw Bay/River	TU-01	Dinsmoore	5	5	1.0	0.6	1.7	33.2	11.0	2
Saginaw Bay/River	TU-02	Fish Pt SWA	8	5	1.6	1.0	1.6			

Definitions for population metrics
- Productivity equals the number of fledged young per occupied nest
- Success Rate equals the number of nesting attempts producing at least one fledged young
- Brood Size equals the number of fledged young per successful nest

Appendix D-2. Bald eagle productivity and nestling serum contaminant concentration detail for individual active territories in the St. Marys River AOC.
(N = number of independent nests sampled for eaglet serum contaminant levels)

AOC	Site	Name	Fledged Young	Attempts	Productivity	Success Rate	Brood Size	Median PCB (μg/Kg)	Median DDE (μg/Kg)	N
St Marys River	CP-02	Sugar Isd S	1	2	0.5	0.5	1.0	37.8	17.5	1
St Marys River	CP-05	Pt Aux Frenes	4	3	1.3	1.0	1.3			
St Marys River	CP-11	Butterfield Isd	4	4	1.0	0.8	1.3			
St Marys River	CP-14	Munscong Bay NW	5	5	1.0	0.8	1.3			
St Marys River	CP-15	Barbeau Pt	1	1	1.0	1.0	1.0			
St Marys River	CP-22	Duck Bay-Sugar Isd	2	2	1.0	0.5	2.0	53.7	24.3	2
St Marys River	CP-24	Roach Pt	3	5	0.6	0.4	1.5			
St Marys River	CP-29	Caribou L	7	4	1.8	1.0	1.8			
St Marys River	CP-30	Neebish Isd E	9	4	2.3	1.0	2.3	93.1	32.6	2
St Marys River	CP-31	Neebish Isd S-Perrys Bay	5	5	1.0	0.8	1.3			
St Marys River	CP-33	Sand Isd-Dunbar	10	5	2.0	1.0	2.0	46.3	27.5	2
St Marys River	CP-35	Lime Isd N	1	3	0.3	0.3	1.0			
St Marys River	CP-36	Back Bay	9	5	1.8	1.0	1.8	3.6	12.0	1
St Marys River	CP-40	Fowlers Bay	4	5	0.8	0.6	1.3			
St Marys River	CP-41	Izaak Walton Bay	2	5	0.4	0.4	1.0			
St Marys River	CP-43	Lime Isd S	4	3	1.3	1.0	1.3	< 1	8.6	1
St Marys River	CP-44	Whipple Pt-Sugar Isd NE	8	5	1.6	1.0	1.6	2.7	5.6	2
St Marys River	CP-45	Rosedale	7	5	1.4	1.0	1.4			
St Marys River	CP-47	Birch Pt	0	1	0.0	0.0	---			
St Marys River	CP-51	Surveyors Isd	0	1	0.0	0.0	---			
St Marys River	CP-52	Neebish Isd NE	5	3	1.7	1.0	1.7			

Definitions for population metrics
- Productivity equals the number of fledged young per occupied nest
- Success Rate equals the number of nesting attempts producing at least one fledged young
- Brood Size equals the number of fledged young per successful nest