LAKE ERIE LAKEWIDE MANAGEMENT PLAN

Lake Erie Lakewide Management Plan (LaMP) Technical Report Series

Executive Summary
Animal Deformities or Reproduction Problems

Keith Grasman, Christine Bishop, William Bowerman
James Ludwig and Pamela Martin

April 2000

Lake Erie LaMP Technical Report No. 7

Technical Report 7

Animal Deformities or Reproduction Problems

Prepared for the Lake Erie LaMP
Preliminary Beneficial Use Impairment Assessment

Keith A. Grasman, Lead Author

Co-Authors: Christine A. Bishop, William W. Bowerman, James P. Ludwig,
Pamela A. Martin

April 2000

NOTE TO THE READER:

This technical report was prepared as one component of Stage 1, or "Problem Definition," for the Lake Erie LaMP. This report provides detailed technical and background information that provides the basis for the impairment conclusions recorded in the LaMP 2000.

This document has been extensively reviewed by the government agencies that are partnering to produce the LaMP, outside experts, and the Lake Erie LaMP Public Forum, a group of citizen volunteers. This review was designed to answer two questions:

- Is the document technically sound and defensible?
- Do the reviewers agree with the document conclusions regarding impairment?

In its present form, this report has been revised to address the comments received during that review process, and there is majority agreement with the impairment conclusions presented.

List of Abbreviations

AOC	Area of Concern
DDE	1,1-dichloro-2,2-bis(*p*-chlorophenyl)ethylene
DDT	1,1,1-trichloro-2,2-bis(*p*-chlorophenyl)ethane
IJC	International Joint Commission
LaMP	Lakewide Management Plan
LC_{50}	lethal concentration for 50% of the population
96h LC_{50}	lethal concentration required to kill 50 percent of the test population within 96 hours
LOEC	lowest observed effect concentration
NOEC	no observed effect concentration
PAH	polycyclic aromatic hydrocarbons
PCB	polychlorinated biphenyl
TFM	3-trifluoromethyl-4-nitrophenol

7.1 Introduction

Industrial activity, agriculture, and development have led to many changes in the Lake Erie ecosystem. During the 1960s and 70s, pollution was associated with reproductive failures and population declines in many species of fish-eating wildlife. Since the 1970s, many problem pollutants have been restricted or banned, but additional chemicals have been introduced into Lake Erie. Furthermore, significant changes in the aquatic community, such as the introduction of the zebra mussel (*Dreissena polymorpha*) and other exotic species, have changed how energy, and potentially pollutants, move through the food web. As part of the Lake Erie Lakewide Management Plan, it is important to:

- assess the current reproductive status of Lake Erie wildlife to determine whether impairments continue,
- assess the causes of these impairments whenever possible, and
- identify important data gaps concerning reproduction and deformities in Lake Erie wildlife.

For each species addressed in this assessment, the primary questions to be answered are "is the reproductive health of this species impaired, and what is the extent of the impairment?" Whenever possible, current reproductive status is compared to species-specific criteria for reproductive success.

Reproductive impairments cannot be understood clearly without considering the factors that cause them. Determining the cause(s) of the impairments, whenever possible, is a secondary purpose of this assessment. However, most of the data describing impairments has been collected in toxicological studies directed at determining the causes of the problems, especially pollutants. Ideally, large monitoring studies of reproduction or population status would be used to determine impairment first. Subsequently, additional investigations would then look for the factors causing the impairment. However, in some cases, much (but not all) of the evidence for impairment comes from a risk assessment (e.g., comparing egg or diet residues to a reference dose), which by its definition includes a potential causal factor.

If such a risk assessment suggests impairment, then that is one part of the weight of evidence for impairment. It does not rule out other factors (non-chemical or other chemicals) that might contribute to the impairment. This assessment also addresses the level of confidence that can be ascribed to the status and potential cause(s) of the impairment. This includes evaluation of the quality of the data and identification of data gaps and research needs.

7.2 Assessment Criteria and Approach

According to the International Joint Commission (IJC), an animal reproductive or deformity impairment occurs when "wildlife survey data confirm the presence of deformities (e.g., cross-bill syndrome) or other reproductive problems (e.g., eggshell thinning) in sentinel wildlife species (IJC 1989)." Sentinel wildlife species are indicators of environmental conditions, especially pollutants. Fish-eating wildlife and other species that spend a significant part of their life in or near the water often make good sentinel species.

Using the IJC listing criteria, the LaMP needed to determine the types of survey data that would confirm impairments for Lake Erie. Great Lakes Areas of Concern (AOCs) have used two benchmarks to define wildlife deformity and reproductive impairments:

- when the incidence rates of cross-bill syndrome, reproductive failure, etc. are significantly (95% probability level) higher than incidence rates at control sites, or
- when bald eagle (*Haliaeetus leucocephalus*) reproduction is less than one eaglet per active nest.

While these impairment benchmarks are appropriate for the Lake Erie LaMP, they are not comprehensive enough. Data and evaluation criteria are available for sentinel species other than the bald eagle. Species-specific criteria may be based on biological or chemical assessments. These species-specific criteria are based on benchmark concentrations that must not be exceeded in order to maintain normal reproduction or a healthy or stable population, or on reproductive values measured at reference sites not impacted by pollutants. Typical measures of reproductive success include rates of embryonic survival or fledging success (i.e., in birds, survival to flying). For example, the above-mentioned productivity standard of 1.0 young per occupied nest has been used as the recovery goal for healthy populations within the Northern States Bald Eagle Recovery Plan (Grier et al. 1983). Other biological criteria are discussed in the sections on each species.

Lowest Observable Effects Concentrations (LOECs; concentrations at which reproductive effects are statistically different from reference sites) or No Observed Effect Concentrations (NOECs; highest observed concentrations at which reproduction is not statistically different from reference sites), measured in field and laboratory studies, can be used to derive chemical criteria that must not be exceeded in order maintain normal reproduction or a healthy population. For example, reproductive NOEC criteria for bald eagle eggs are 4.0 mg/kg for total PCBs, 3.5 mg/kg for p,p'-DDE, and 1 mg/kg for dieldrin (all expressed as fresh, wet-weight; Wiemeyer et al. 1984; Wiemeyer et al. 1993; Giesy et al. 1995). If chemical concentrations above these criteria are known to be present in fish and wildlife tissues in the Lake Erie ecosystem, we can conclude that impairment is likely, even if a particular population has not been monitored for reproductive effects and deformities. Such a finding is a good tool to focus future reproduction and population studies. A risk assessment based on field-derived exposure levels and species-specific effect levels avoids the uncertainties of interspecies extrapolations and estimated exposure (by modeling).

There are also important effects not mentioned in the IJC listing criteria, but which can nevertheless be used to indicate whether impairment is occurring or is likely to occur. As the fields of biochemistry, molecular biology, and physiology have advanced during the last 25 years, biologists have gained additional tools for investigating the effects of pollutants on wildlife. Often these physiological variables are called biomarkers--biochemical, cellular, or physiological changes that indicate exposure to and toxic effects of pollutants (e.g., immune function, histology, vitamin A stores, porphyria, liver enzyme activity, reproductive hormones). Measurement of impairments within the body helps to explain deformities and reproductive problems seen on the organismal level. The application of these state-of-the-art techniques is similar to laboratory tests performed by a physician to elucidate the causes and severity of particular diseases. Environmental toxicologists have successfully used biochemical and cellular biomarkers to investigate contaminant-associated impairments in fish and wildlife species, including many Great Lakes studies. Measurement of these characteristics in sentinel species can provide important supplemental information to more traditional assessments of reproductive performance and deformities.

Therefore, the LaMP has adopted a weight of the evidence approach to this particular assessment where information related to all of the above-mentioned criteria are considered, where available, to draw impairment conclusions for a particular species.

7.3 Scope of the Assessment

It should be noted that contaminant studies tend to look at **effects on a particular organism in a particular location** versus population-wide effects. Per the IJC listing criteria, this assessment is not required or intended to determine whether basin-wide or sub-population effects are occurring due to the identified deformities or reproductive problems. The purpose of this assessment is to identify whether reproduction or deformity problems are occurring due to chemical contaminants. Population-level impairments are covered in the degradation of wildlife populations assessment.

Reproductive effects do not immediately or always translate into population effects. For example, if a population is near its carrying capacity (point at which species is in equilibrium with its environment), then there may not be enough resources (food, nesting habitat, etc.) for all young to survive to reproductive age. Hence, up to a point, a decrease in production of young due to a contaminant may not affect adult population size because many young would have died anyway. However, if the population is below its carrying capacity, a decrease in production of young may prevent the population from reaching carrying capacity. In this situation, the impairments summarized in Table 7.1 can become more significant when all stressors to a particular species group are summed (contaminants, habitat loss, exotics, etc.).

The geographic boundary of the area where impairments are identified includes the open waters of Lake Erie, the nearshore areas, embayments, river mouths, and the lake effect zone of tributaries. The Lake Saint Clair watershed is not included in the scope of the Lake Erie LaMP beneficial use impairment assessment. However, the source and/or cause of impairment may fall outside the above-mentioned geographic boundary.

Deformity and (or) reproductive impairments have been assessed for:

- aquatic birds, including bald eagles, colonial waterbirds, and tree swallows,
- fish-eating mammals, including mink (*Mustela vison*) and river otter (*Lutra canadensis*), and
- amphibians and reptiles, including snapping turtles (*Chelydra serpentina serpentina*) and eastern spiny softshell turtles (*Apalone spiniferus*), frogs and toads in general, and mudpuppies (*Necturus maculosus*).

Findings for each group are presented in Table 7.1 and following text in section 7.4.

7.4 Impairment Conclusions

Table 7.1 Summary of Animal Deformity or Reproduction Impairment Conclusions

Species/ Species Group	Reproduction		Deformities		Physiology			Notes
	Impaired?	Likely Cause	Impaired?	Likely Cause	Impaired?	Likely Cause	Type of Impairment	
Bald Eagle	**Yes**; observed; exposure above effect levels	PCBs, dieldrin, DDE	**Yes**; observed	PCBs	No data			* Extent of impairment is probably obscured by hacking/fostering and immigration from less contaminated inland territories
Colonial Waterbirds	**Yes**; observed in herring gull; exposure above effect levels in herring gull, cormorant, and common tern eggs	PCBs, possibly other chemicals	**Yes**; observed; exposure above effect levels	PCBs	**Yes**; observed; exposure above effect levels	PCBs, other organochlorines (OCs)	Immune system, reproductive organs, thyroids, liver enzymes, vitamin A and porphyrins*	* Most data from W. basin and herring gulls * Tree nesting cormorants hard to study, but contaminant concentrations are among highest in Great Lakes and are likely associated with embryonic mortality and deformities * Cause of recent reproductive failures of herring gulls on W. Sister Is. may include PCBs, microcystin, and (or) other factors * Although Caspian terns have attempted to colonize LE as recently as 1996, they are still too rare in the basin for field study.
Tree Swallow	No		No data		No			* Significant OC exposure; resistance to effects may make swallow a poor indicator species for other insect-eating songbirds
Mink	Likely; PCB levels in food above effect levels	PCBs	No data		No data; likely, based on PCB levels in food			
Otter	Insufficient data, but likely based on predicted high exposure	PCBs	No data		No data			* Too rare in Erie basin for study, as they were re-introduced in 1986.
Snapping Turtle	Not observed, but exposure at some Ohio sites above effect levels	PCBs, other OCs	Not observed, but exposure at some Ohio sites above effect levels	PCBs, other OCs	Likely	organochlorines	Endocrine /reproductive	

Table 7.1 Summary of Animal Deformity or Reproduction Impairment Conclusions (continued)

Species/ Species Group	Reproduction		Deformities		Physiology			Notes
	Impaired?	Likely Cause	Impaired?	Likely Cause	Impaired?	Likely Cause	Type of Impairment	
Frogs/Toads	Likely	High DDE and nitrates	No data		No data			* Nitrate concentrations in Lake Erie watershed often exceed lethal and sublethal concentrations for amphibians in laboratory experiments (see section 7.4.1.6)
Mudpuppies	Considered likely by the authors; determined to be inconclusive by the LaMP (see sections 7.4.1.6 and 7.5)		**Yes**; observed	PAHs and OCs	No data			* Data from the Grand River in Ohio and elsewhere in the Great Lakes indicate acute mortality following TFM application for sea lamprey control (see section 7.4.1.6)

*porphyrins - the liver synthesizes heme, which is important for hemoglobin and some enzymes. PCBs and other organochlorines block this process and cause the accumulation of intermediate products called highly carboxylated porphyrins.

7.4.1 Reproductive Impairments

7.4.1.1 Bald Eagle

Bald eagles nesting within 8 km of Lake Erie have impaired reproduction. Although bald eagle productivity, the number of fledglings (survival to age of flying) per nest, has increased since 1980, the Ohio Lake Erie eagles remain below the recovery goal of 1.0 young fledged/occupied nest. Increases in the reproductive success of the Lake Erie basin bald eagle sub-population may have been influenced by several factors that potentially confound linkages between exposure to contaminants in Lake Erie and biological effects. A large number of uncontaminated nestlings were introduced to the sub-population through hacking and fostering projects along the Ontario and Ohio shorelines during the mid-1980s. There appears to have been a great increase in nesting success within the time period associated with the sexual maturation of these introduced birds. The recovery of the bald eagle throughout North America, including inland areas near the Great Lakes, has created a pool of young eagles dispersing to find available and unclaimed breeding territories. The high turnover of adults along the Ohio and Michigan shorelines of Lake Erie suggests the possibility of colonization of these territories by eagles raised elsewhere. Reproductive success tends to increase following replacement of an older adult in a shoreline territory.

Because human interventions and natural immigration have potentially led to the introduction of adult eagles that were not exposed developmentally (i.e., *in ovo*) to Lake Erie contaminants, a risk assessment based on comparison of contaminant concentrations in eagle eggs to known adverse effect concentrations is particularly insightful. Eagle eggs from the Ohio and Ontario shorelines of Lake Erie consistently exceed PCB and dieldrin criteria, and often exceed the p,p'-DDE criterion for adverse effects. These Lake Erie data, when interpreted in the context of studies showing effects of organochlorines on eagle reproduction elsewhere in North America, strongly suggest that current concentrations of organochlorines in Lake Erie are causing reproductive impairment of bald eagle reproduction.

7.4.1.2 Colonial Waterbirds

DDE-induced eggshell thinning does not appear to be important at current levels of contamination for any of the species examined.

There are significant reproductive and physiological impairments in herring gulls from western Lake Erie. The cause of the reproductive impairment requires further investigation. Potential causes include contaminants, cyanobacterial toxin (microcystins), and infectious diseases. Many but not necessarily all of the physiological impacts, including immunosuppression and altered thyroid function and vitamin A status, are associated with PCB exposure. Current PCB concentrations in Lake Erie herring gull eggs, especially in the western basin (20 ug/g), are sufficient to cause some embryonic mortality (LOEC 5.0 ug/g).

While the tree nesting habits of Lake Erie cormorants make reproductive assessments difficult, measurement of PCB concentrations in Lake Erie cormorant eggs suggests the strong probability of reduced hatching success and increased rates of deformities.

Recent data for common terns in the western basin indicates reproductive impairment caused primarily by predation. However, organochlorine concentrations in eggs are high enough to contribute to reproductive impairment.

Overall, PCB concentrations in Lake Erie, primarily in sediments but also the water column, are high enough to present a significant risk of reproductive and physiological effects in fish-eating colonial waterbirds, especially in the western basin.

7.4.1.3 Tree Swallows

There does not appear to be reproductive impairment in Lake Erie tree swallows. Tree swallows are good indicators of exposure to contaminants via aquatic insects, but they tend to be resistant to the reproductive impacts (measured in terms of embryonic survival and fledging success) of organochlorine exposure. Other species of insectivorous passerine birds in Lake Erie may be more sensitive to the reproductive effects of contaminants.

7.4.1.4 Mink and River Otter

Trapping data provide our only estimates of mink population abundance. However, factors such as trapping effort and correlation with muskrat abundance confound the analysis of trapping data as an indicator of reproductive success. Some assessments of numbers of trapped mink suggest lower mink populations along Lake Erie, but other assessments show little difference from inland areas.

Although strong population data do not exist, laboratory studies clearly show that mink are highly sensitive to the lethal, reproductive, and immunosupressive effects of PCBs. The few existing data on Lake Erie mink tissue residues indicate that wild mink are exposed to potentially harmful concentrations of PCBs. Analysis of important prey species for mink suggests high concentrations of PCBs above dietary concentrations known to adversely affect mink in the laboratory, strongly indicating potential reproductive impairments.

Otters were extirpated from the Lake Erie watershed by 1900, and there is no data to support or refute an association between PCBs and reproduction and population impairments in Lake Erie, although data from other locations indicates a cause-effect relationship. Exposure to PCBs is often greater for otters than mink, and otters may be equally sensitive to the effects of PCBs. Recovery of otter populations are still impaired in the Lake Erie basin, as evidenced by the need for introduction programs in the Lake Erie region, and the relatively rare observations of otter families in the Lake Erie watershed despite reintroduction programs.

7.4.1.5 Reptiles

The few available studies on turtles have shown that contaminant concentrations in snapping turtle eggs from Big Creek Marsh and Rondeau Provincial Park, Lake Erie (Canada) are not associated with elevated rates of embryotoxicity or deformities. Concentrations of PCBs detected in eggs from two sites in Ohio are similar to those from Hamilton Harbour where reproductive anomalies have been correlated with PCB exposure in snapping turtle eggs. Feminization effects noted in a correlational study between organochlorine concentrations in plasma and effects in adult male snapping turtles from Long Point (Canada) indicate subtle endocrine disrupting effects may be occurring.

Contaminant concentrations in Lake Erie water snakes from Pelee Island are high enough to justify a study of health and reproductive effects.

Contaminant concentrations in the eastern spiny softshell turtle and the corresponding low rates of hatching in eggs in the Lake Erie basin suggest further investigation of contaminant effects is warranted. This species is considered threatened by the Province of Ontario.

7.4.1.6 Amphibians

Contaminant concentrations, including organochlorine and polycyclic aromatic hydrocarbons, have been measured in amphibians at various locations in the Canadian Lake Erie basin. Studies of biological effects are sparse. The presence of p,p'-DDE in some amphibians from Point Pelee suggests that further study is required to determine the sensitivity to p,p'-DDE of amphibian species native to Lake Erie. Deformity rates of mudpuppies at Long Point and in the Detroit River are elevated well above the background rates reported for inland areas of the Great Lakes and St. Lawrence River basin. However, a contaminant-associated etiology has not been confirmed at this time.

Emerging Issues

Nitrates and 3-trifluoromethyl-4-nitrophenol (TFM) are two chemicals that do not bioaccumulate. Nevertheless, they are pollutants that have been shown to cause biological impacts to amphibians. Because less research and monitoring data is generally available for amphibian populations as a group, the mechanisms for the observed biological effects of these chemicals are not as clearly defined as those for other organisms. A short summary of what is known is provided below.

A review by Rouse et al. (1999) evaluated the risk of direct and indirect effects of nitrate on amphibian populations. This review used a simple comparison of known environmental nitrate concentrations in North American waters to nitrate concentrations known to cause toxicity in a laboratory setting to amphibian larvae and other species that play an important role in amphibian ecology. Lethal and sublethal effects in amphibians are detected in laboratory tests at nitrate concentrations between 2.5 and 385 mg/L Amphibian food sources such as insects and predators such as fish are also affected by elevated levels of ammonia and nitrate in surface waters.

Of 8000 water samples from rivers in the watersheds of Lake Erie and St. Clair in the Canadian Great Lakes and in U.S. states in the Lake Erie watershed, 19.8% had nitrate levels above 3 mg/L. This concentration was known to cause physical and behavioral abnormalities in some amphibian species in the laboratory. A total of 3.1% samples contained nitrate levels that would be high enough to kill tadpoles of native amphibian species in laboratory. This may have important implications for the survival of amphibian populations and the health of food webs in general. However, these predictions are based on laboratory-based studies and need to be tested in the wild.

The sensitivity of mudpuppies, frog tadpoles and adult frogs to TFM use in the Great Lakes has been noted (Gilderhus and Johnson, 1980). TFM is intended to control larval sea lamprey and has been used historically in 19 (8 in U.S./11 in Canada) of the 842 tributaries to Lake Erie for sea lamprey (*Petromyzon marinus*) control. Since 1995, TFM has been applied in Conneaut Creek and the Grand River in Ohio and Big Creek and Big Otter Creek in Ontario. Only four Lake Erie tributaries (Big Creek Ontario, and 3 U.S. tributaries) are currently scheduled for future regular treatments every 4 to 6 years.

When TFM is used, amphibians have regularly been found dead in creeks immediately after treatment in Lake Erie watersheds and elsewhere in the Great Lakes (Gilderhus and Johnson, 1980; Matson, 1990). Laboratory tests have confirmed that species native to the Great Lakes basin such as gray tree frog, leopard frog, and bullfrog are sensitive to field applied rates of TFM (Chandler and Marking, 1975). In the Grand River, Ohio, Matson (1990) found that in the year following TFM application (1997), mudpuppy population size decreased by a minimum of 29% in the segment treated. In 1999, the Grand River was treated with TFM and dead mudpuppies were found downstream of the application zone within twenty-fours hours.

Because TFM is not bioaccumulative and is only applied periodically in closely controlled and monitored conditions, the associated mudpuppy mortality is often perceived to be insignificant. However, mudpuppies do not become sexually mature until 4 to 6 years of age. Given the past and projected future schedule for TFM applications, there is the potential for the TFM applications to match periods when large numbers of mudpuppy are reaching an age when they can reproduce. In addition, TFM is generally applied in the spring when stream flows are higher. Therefore, TFM has the potential to kill a portion of the existing females before they lay their eggs in May and June. For these reasons, future study is needed to determine the significance of the mortality and the life stages most affected (see section 7.5).

7.4.2 Deformity Impairments

The weight of evidence from field and laboratory studies shows a causal association between dioxin-like chemicals and developmental deformities such as crossed bills. In the Great Lakes, the largest proportion of dioxin-like activity is attributable to PCBs. Deformities, which are an impairment per the IJC listing criteria, have been observed in Lake Erie eagles, and are suspected in herring gulls (based on anecdotal observations) and in cormorants (based on comparing PCB concentrations in Lake Erie eggs to concentrations at other Great Lakes sites where elevated deformities have been documented). The rate of deformities in Lake Erie eagles is greatly above the background rate for birds and is similar to the rate in cormorants in Green Bay, which isamong the highest reported rates. The observation of two deformed herring gulls in western Lake Erie, which has high PCB contamination, provides further evidence for an impairment. The tree-nesting habits of Lake Erie cormorants precludes the examination of large numbers of chicks, but PCB concentrations in these eggs are similar to or greater than the concentrations in Green Bay cormorant eggs, so a high deformity rate is predicted for Lake Erie cormorants.

7.5 Potential Research Issues and Priority Information Gaps

Programs and funding for monitoring contaminant concentrations and assessing their biological effects have declined in recent years. Maintenance of these programs is essential for assessing recovery from impairment, detecting the emergence of new problems, and filling the information gaps described in this section.

- Most of the major contaminants considered in this report are organochlorines, because research shows that they have caused past and current reproductive impairments and population-level effects. More environmental data are available for this class of chemicals than others. However, other newer industrial chemicals and pesticides are released into the Lake Erie ecosystem in large quantities. Few biomonitoring studies have examined the concentrations and biological effects of these chemicals in Lake Erie wildlife. Recent advances in laboratory and field toxicology have shown that some of these chemicals (e.g., nonylphenol, bisphenol A, atrazine, aldicarb) are able to disrupt the function of the endocrine, immune, and nervous systems, often following low level exposure during development.

- Due to improvements in the health of national populations of bald eagles in both the U.S. and Canada, the level of effort to monitor or band Lake Erie bald eagles has decreased in recent years. However, contaminant impacts are still affecting the recovery of the Lake Erie sub-population. Therefore, it is important to continue studies of reproductive success, deformities, and contaminant concentrations in blood and eggs. It is also important to consider continuing banding/color marking studies to allow tracking of individual eagles from the territories where they are raised to the territories where they breed. Until about 2 years ago, this was done across the entire lake. Today this type of more intensive monitoring is more spotty and declining due to reduced funding. Studies of recruitment patterns will be essential for answering questions about the high turnover rate of adult eagles breeding on the Lake Erie shoreline, the survival and reproductive success of eagles exposed developmentally to contaminants from Lake Erie, and the rate of immigration from inland areas to the Lake Erie shoreline.

- The cause of the reproductive impairment in herring gulls on West Sister Island requires further investigation. Toxicologically significant concentrations of microcystin toxin have been found in the livers of one herring gull from West Sister Island and a number of Caspian tern chicks from Saginaw Bay, which bears some similarity to western Lake Erie in terms of primary productivity and PCB concentrations. The accumulation of microcystin toxin in colonial waterbirds is an emerging issue that deserves further study. Other potential causes of the reproductive failure include PCB-induced wasting syndrome, infectious disease, or some interaction among these factors.

- A formal deformity survey in herring gulls should be initiated to better estimate the rate of deformities. A deformity survey should be conducted in cormorants if significant numbers (i.e., hundreds) nest on the ground in the future.

- Birds, such as tree swallows, that eat emergent aquatic insects can accumulate high concentrations of organochlorines and other contaminants. Although studies of Lake Erie tree swallows from the eastern and central basins have shown only a few biochemical effects and no reproductive effects, biologically significant impacts are possible in more sensitive species, especially in the western basin where organochlorine concentrations are higher. Such studies should be initiated.

- Little is known about the potential exposure of wild diving ducks to contaminants through consumption of zebra mussels. A significant proportion (52%) of diving ducks (scaup, goldeneye, bufflehead, scoter, and oldsquaw) had zebra mussels in their gizzards at the time of collection (Hamilton and Ankney 1994). The potential for physiological effects following consumption of contaminated zebra mussels has not been studied.

- Better information is needed for mink and otter in the following areas: population surveys, tissue residues, and contaminant concentrations in food. The Canadian Wildlife Service has initiated a mink carcass collection to take place from 1999-2001 within the Canadian Lake Erie watershed. Trapper-caught carcasses from Lake Erie marshes and inland tributaries will be analyzed for contaminants, and examined histopathologically and morphologically. Measurements of reproductive organs will be made to determine possible contaminant effects on reproductive development. Collections of mink carcasses and potential food items from two Lake Erie Marshes were made in 1998, and will be analyzed for carbon and nitrogen stable isotope ratios, a technique that provides information on the diet of marsh-living mink. Ongoing monitoring of mink populations in shoreline marshes using track censuses is planned.

- Few studies exist that examine both the levels and associated effects of contaminants on reptiles living in the Lake Erie watershed. The few studies that exist for Lake Erie have primarily examined contaminant concentrations in tissues and eggs. Contaminant concentrations in Lake Erie water snakes from Pelee Island are high enough to justify a study of health and reproductive effects. The Canadian Wildlife Service, World Wildlife Fund and Upper Thames River Conservation Authority recently initiated such a study.

- Contaminant concentrations in the threatened eastern spiny softshell and the corresponding low rates of egg hatching in the Lake Erie basin suggest that further investigation of contaminant effects is warranted. The Canadian Wildlife Service, World Wildlife Fund and Upper Thames River Conservation Authority recently initiated such a study.

- Further investigation of contaminant levels and effects in the common snapping turtle is warranted in coastal wetlands of Lake Erie, especially the western basin and marshes in the U.S. Hatching success and deformity rates should be examined. The University of Guelph and the Canadian Wildlife Service are studying other endpoints, such as differential effects on males versus females and behavioral effects in snapping turtles from Lake Ontario and the St. Lawrence River. These endpoints could be examined in Lake Erie populations in the future.

- Data are needed about the sensitivity of amphibian eggs, larvae, and adults to DDT concentrations presently occurring in water and the food web of coastal wetlands, especially in Point Pelee National Park.

- There are conflicting opinions about the significance of non-target species sensitivity, particularly mudpuppy, to TFM (when used for sea lamprey eradication), and its implications for potential impairment. Therefore, the impact of TFM on amphibian populations needs to be assessed by monitoring populations of mudpuppies and other amphibians pre- and post-application. From a reproductive standpoint, it is particularly important to determine if TFM has greater impacts on certain age classes and/or egg-bearing females.

- Based on laboratory studies, nitrate concentrations in agricultural watersheds of Lake Erie are high enough (3.1 % of water samples) to exceed the LC_{50} or sublethally affect (19.8% of water samples) amphibian tadpoles of various species. The results of these laboratory studies need to be verified in wild populations.

7.5 References

Chandler, J.H. and L.L. Marking. 1975. Toxicity of the lampricide 3-trifluoromethyl-4-nitrophenol (TFM) to selected aquatic invertebrates and frog larvae. Invest. Fish Control 62:1-7.

Giesy, J.P., Bowerman, W.W., M.A. Mora, P.D. Jones, D.A. Verbrugge, R.A. Othout, J.L. Newsted, C. Vandervoort, C.L. Summer, R.J. Aulerich, S.J. Bursian, J.P. Ludwig, M. Ludwig, G.A. Dawson, T.J. Kubiak, D.A. Best, and D.E. Tillitt. 1995. Contaminants in fishes from Great Lakes-influenced sections and above dams of three Michigan rivers: III. Implications for health of birds of prey. Arch. Environ. Contamn. Toxicol. 29:309-321.

Gilderhus, P.A. and B.G.H Johnson. 1980. Effects of sea lamprey (*Petromyzon marinus*) control in the Great Lakes on aquatic plants, invertebrates, and amphibians. Can. J. Fish. Aquat. Sci. 37:1895-1905.

Grier, J.W., J.B. Elder, F.J. Gramlich, N.F. Green, J.B. Kussman, J.E. Mathisen, and J.P. Mattsson. 1983. Northern States Bald Eagle Recovery Plan. USDI-Fish and Wildlife Service, Washington, DC, 105 pp.

Hamilton, D.J., and C.D. Ankney. 1994. Consumption of zebra mussels *Dreisenna polymorpha* by diving ducks in Lakes Erie and St. Clair. Wildfowl 45:159-166.

IJC. 1989. Proposed Listing/Delisting Criteria for Great Lakes Areas of Concern. Focus on International Joint Commission Activities. Volume 14, Issue 1, insert.

Matson, T.O. 1990. Estimation of numbers for a riverine *Necturus* population before and after TFM lampricide exposure. Kirtlandia 45:33-38

Rouse, J.D., C.A. Bishop, and J. Struger. 1999. Nitrogen Pollution: An assessment of the impact on amphibians. Env. Health Persp. 107:1-6.

Wiemeyer, S.N., T.J. Lamont, C.M. Bunck, C.R. Sindelar, F.J. Gramlich, J.D. Fraser, and M.A. Byrd. 1984. Organochlorine pesticide, polychlorobiphenyl, and mercury residues in bald eagle eggs--1969-1979--and their relationships to shell thinning and reproduction. Arch. Environ. Contam. Toxicol. 13:529-549.

Wiemeyer, S.N., C.M. Bunck, and C.J. Stafford, 1993. Environmental contaminants in bald eagle eggs--1980-84--and further interpretations of relationships to productivity and shell thickness. Archiv. Environ. Contam. Toxicol. 24:213-227.